Temporary Investment Tax Incentives: Theory with Evidence from Bonus Depreciation

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First draft: September 28, 2004

Revised: January 13, 2005

We gratefully acknowledge the comments of Alan Auerbach, William Gale, Austan Goolsbee, James Hines, Peter Orszag, Samara Potter, Dan Silverman, and Joel Slemrod.

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ABSTRACT

This paper considers the economy's reaction to a temporary investment tax subsidy. Because the eventual payoff from acquiring a long-lived capital good is unrelated to the date of purchase or installation, there are powerful incentives to delay or accelerate investment to take advantage of predictable intertemporal variations in cost. For these goods, the elasticity of investment demand is nearly infinite. Consequently, for a temporary tax change, the price of long-lived capital goods fully reflects the tax subsidy regardless of the elasticity of investment supply. This result is very general and relies only on an arbitrage argument. Thus, contrary to conventional wisdom, price data provide no information on the elasticity of supply. Instead, because the price of investment goods shifts by exactly the amount of the subsidy, the elasticity of investment supply can be inferred from quantity data alone.

The bonus depreciation allowance passed in 2002 and increased in 2003 provides a sharp test of the 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 capital that qualified for the subsidy was substantially higher than capital that did not. The adjustment cost parameters implied by the data are in line with estimates from earlier studies. Market prices do not react to the subsidy, which suggests that internal adjustment costs not reflected in market prices are important for investment decisions.

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I. Introduction

The U.S. economy is now in the wake of three major tax changes: the *Economic Growth and Tax Relief Reconciliation Act* of 2001 (*EGTRRA*), the *Job Creation and Worker Assistance Act* of 2002 (*JCWAA*), and the *Jobs and Growth Tax Relief Reconciliation Act* of 2003 (*JGTRRA*). In academic journals, in policy briefs, and in the popular press, there has been and continues to be much more emphasis on the 2001 and 2003 laws. This is no accident. The 2001 and 2003 laws have much bigger price tags than the 2002 law. The cumulative loss in revenue attributed to *EGTRRA* in the ten years after its passage is roughly $1.3 trillion. The ten-year revenue shortfall attributed to *JGTRRA* is $350 billion. In comparison, the 2002 tax bill reduces revenue by only about $40 billion over ten years.

Another reason that the 2001 and 2003 laws got so much public attention is that these laws made tax changes that were easily understood—reductions in tax rates, the increased child tax credit, reductions in the estate tax, and so on. The main provision of the 2002 tax bill was an accelerated depreciation allowance for businesses. In 2003, *JGTRRA* further accelerated depreciation allowances.

Yet, even though *JCWAA* offered a relatively small tax cut to businesses, the tax cut applies to something that is potentially very sensitive to such changes: the timing of investment. There are good reasons to believe that the decision to invest should respond sharply to even modest changes in after-tax costs, especially those that are temporary.

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. Several 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 variations 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 variations in short-run 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, regardless of the elasticity of the flow supply of investment goods, the pre-tax shadow price of investment goods must move one-for-one with the tax subsidy. Firms are indifferent over small changes in the timing of installation of long-lived capital. Investment will increase in response to a temporary subsidy so that the net cost of purchasing an investment good is equal before and after the subsidy. This result relies only on an arbitrage argument and thus is extremely general. In particular, it is independent of functional form or other details of the model.

Because prices increase by the same amount regardless of the elasticity of supply, observing price increases following a temporary tax incentive is not evidence that the supply of investment is relatively inelastic. 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 effective elasticity of supply can be inferred from data on quantity alone.

Goolsbee [1998] shows that investment goods prices rise almost one-for-one with the Investment Tax Credit. He argues that this finding implies that the supply of investment goods is inelastic. Our analysis shows that one-for-one movement in investment goods prices is a general prediction of the standard model of investment. The prediction is independent of the supply elasticity. Therefore, our results confirm Goolsbee's point that price effects of tax subsidies are important. Yet, our theory shows that price effects in response to temporary tax subsidies have no implications for the supply elasticity of investment goods.

To complicate matters, observed market prices may only partially reflect the subsidy. Because the shadow price of capital includes costs that are both internal and external to the firm, the observed increases in market prices are bounded above by the size of the tax incentive. Thus, while price data are not informative about the elasticity of supply, price data can provide information about the composition of internal versus external costs of investment. If pre-tax prices only partially reflect the subsidy then a significant part of the cost of investment must be internal.

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*, which allowed firms to deduct immediately an increased fraction of their investment. Specifically, under the 2002 bill firms could deduct immediately 30% of investment and then depreciate the remaining 70% under the existing accelerated depreciation schedule. Under the 2003 bill, the immediate deduction increased to 50%. Only investments made through 2004 qualified for this tax treatment.

Features of the legislation allow for a sharp test of the theory because investment goods with different tax lifetimes are affected quite differently. First, the model predicts that there should be a sharp difference in the tax induced change in investment spending between goods with recovery periods of 20 years, which qualify for bonus depreciation, and goods with more than a 20-year recovery period, which do not. Second, for goods that do qualify, the bonus depreciation deduction is relatively more valuable for longer tax depreciation lives. If a good already has a short tax lifetime, bonus depreciation does not have a large effect on its after-tax cost.

Using cross-section data on investment expenditures, we confirm both of these predictions. The policy clearly had a stimulative impact on investment in capital that qualified for the bonus depreciation. Prices, on the other hand, show little if any tendency to increase in the short run. Thus, the data suggest that internal adjustment costs are at least as important in restraining investment as external adjustment costs. The data imply investment adjustment costs that are in line with previous estimates from other researchers.

Our findings 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. Investment spending should drop in early 2005 when the bonus depreciation expires.

In Section II we present a general equilibrium model that allows for a general investment tax incentive. Section III presents some general results for temporary investment tax incentives and discusses their econometric implications. Section IV briefly describes the *Modified Accelerated Cost Recovery System* (MACRS), under which firms depreciate investment expenditures. This section also briefly describes the tax changes called for by the 2002 and 2003 laws. Section V uses the model to analyze the provisions in the 2002 and 2003 laws. Section VI presents an empirical analysis of actual investment behavior following these policies. Section VII offers our conclusions.

II. MODEL

In this section we present a general equilibrium model that we use to analyze temporary investment tax subsidies. Later we modify the model to consider bonus depreciation allowances like those included in the 2002 and 2003 tax bills. 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 experience disutility from labor (N_t). Their utility functions are additively separable and 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.

We assume that the households own the entire capital stock. Because the tax policies we eventually analyze provide different incentives across different types of capital, we include several different types of capital. Let $m = 1...M$ be an index of capital types. For each type of capital m, δ^m is the economic rate of depreciation, and K^m is the physical stock of capital. Output cannot be costlessly transformed into capital because of either internal adjustment costs or external costs which include, among other things, increasing marginal costs of producing capital goods. We model all of these costs with one adjustment cost function. The adjustment cost functions may differ across capital types. We assume that each cost function is a simple quadratic form

$$K_t^m \frac{\xi^m}{2}\left[\frac{I_t^m}{K_t^m}-\delta^m\right]^2 .$$

The parameter ξ^m indexes the slope of the investment supply curve for type *m* capital. Specifically, ξ^m is the percent change in the marginal cost of adjustment for a change in investment necessary to increase the type *m* capital stock by 1%. The elasticity of the marginal cost of adjustment with respect to investment itself is $\delta^m \xi^m$.

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 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 (for instance the corporate income tax), and τ^d is the tax rate on the distribution of capital income (dividends and capital gains taxes). Our formulation embraces the "old view" of dividend taxation. Later we consider a financing structure that adheres to the "new view" in which the marginal source of finance for investment is retained earnings and is therefore not affected by dividend taxation.[1]

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

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

$$= C_t + S_t + \sum_{m=1}^{M}\left\{\left(K_t^m \frac{\xi^m}{2}\left[\frac{I_t^m}{K_t^m}-\delta^m\right]^2 + I_t^m\right)\left[1-\zeta_t^m\right]\right\} \qquad (2)$$

and

$$K_{t+1}^m = K_t^m\left(1-\delta^m\right) + I_t^m \text{, for all } m \qquad (3)$$

[1] The discussion of the "new view" versus the "old view" of corporate finance originates with King [1977], Auerbach [1979], Bradford [1981], and Poterba and Summers [1985]. More recently see Auerbach [2002], Auerbach and Hassett [2003] and McGrattan and Prescott [2003].

Here ζ_t^m is the total effective subsidy on new purchases of type *m* capital.[2] The variable ζ_t^m includes the value of depreciation deductions and any investment tax credits. 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 their yield.

The household's optimization requires the first-order conditions

$$\phi N_t^{\frac{1}{\eta}} = W_t\left(1-\tau_t^N\right)C_t^{-\frac{1}{\sigma}}, \tag{4}$$

$$C_t^{-\frac{1}{\sigma}} = \beta\left(1+r_t\right)C_{t+1}^{-\frac{1}{\sigma}}, \tag{5}$$

$$q_t^m = \beta C_{t+1}^{-\frac{1}{\sigma}}\left[(1-\tau_{t+1}^{\pi})(1-\tau_{t+1}^{d})R_{t+1}^m + \frac{\xi^m}{2}\left\{\left(\frac{I_{t+1}^m}{K_{t+1}^m}\right)^2 - \left(\delta^m\right)^2\right\}\left(1-\zeta_{t+1}^m\right)\right] + \beta\left(1-\delta^m\right)q_{t+1}^m, \tag{6}$$

and

$$q_t^m = C_t^{-\frac{1}{\sigma}}\left\{1+\xi^m\left[\frac{I_t^m}{K_t^m}-\delta^m\right]\right\}\left[1-\zeta_t^m\right], \tag{7}$$

where (6) and (7) hold for all *m*. q_t^m, the Lagrange multiplier on constraint (3), is the shadow value of an additional unit of type *m* capital. Equation (6) is the first-order condition for the choice of K_{t+1}^m and equation (7) is the first-order condition for the choice of I_t^m.

Let φ_t^m be the pre-tax shadow price of type *m* capital

$$\varphi_t^m \equiv 1+\xi^m\left[\frac{I_t^m}{K_t^m}-\delta^m\right]. \tag{8}$$

Then we can rewrite (7) as

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[2] We assume that adjustment costs are treated just like direct investment expenditures for the purpose of the tax subsidy. If adjustment costs are external (included in the market price), then this is correct. The specification is less justifiable if adjustment costs are internal. Depreciation deductions are allowed for internal adjustment costs that are paid out of pocket by the firm. Payments to ship or install equipment are supposed to be depreciated together with the purchase price (though in fact firms may expense these costs more often than not). If the adjustment costs are in the form of foregone output – say due to confusion or disruption of some sort – then the adjustment costs reduce current taxable earnings.

$$q_t^m = C_t^{-\frac{1}{\sigma}} \varphi_t^m \left[1 - \zeta_t^m\right]. \tag{9}$$

Equation (9) relates the shadow value of capital q_t^m to the pre-tax shadow price of capital φ_t^m. The variable q_t^m is in units of utility per capital good, while the variable φ_t^m is in units of consumption goods (real dollars) per capital good. Though not the focus of our analysis, it is worth noting the relationship of these variables to Brainard-Tobin's *Q*,

$$Q_t^m \equiv \frac{q_t^m}{C_t^{-\frac{1}{\sigma}} \varphi_t^m}$$

which is a unit-free variable. Below, we show that in response to temporary tax policies, movements in q_t^m are negligible. Because φ_t^m and $C_t^{-\frac{1}{\sigma}}$ can jump in response to such policies, Q_t^m can jump even though q_t^m does not.

2.2 Firms

Firms produce output according to a constant returns to scale production function. For simplicity we take the production function to be a generalized Cobb-Douglas form:

$$Y_t = A \cdot \left[\prod_{m=1}^{M} \left(K_t^m\right)^{\gamma_m}\right]^{\alpha} \cdot \left(N_t\right)^{1-\alpha} \tag{10}$$

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.

$$R_t^m = \alpha \gamma_m \frac{Y_t}{K_t^m}, \text{ for all } m \tag{11}$$

$$W_t = \left(1 - \alpha\right) \frac{Y_t}{N_t} \tag{12}$$

2.3 Government Spending and Market Clearing

The government levies taxes and consumes output. Government spending is G_t each period. The government's intertemporal budget constraint must hold in equilibrium. This budget constraint is

$$\sum_{t=0}^{\infty}\left\{\frac{\tau_t^N N_t W_t + \left(\tau_t^\pi + \left(1-\tau_t^\pi\right)\tau_t^d\right)\sum_{m=1}^{M} R_t^m K_t^m - T_t - G_t - \tau_t^\pi\left(1-\tau_t^d\right)\sum_{m=1}^{M}\varphi_t^m I_t^m \zeta_t^m}{\prod_{s=0}^{t-1}\left(1+r_s\right)}\right\} = 0 \quad (13)$$

Recall that adjustment costs are included in φ_t^m. Like most tax changes, the policies we consider will typically 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

$$Y_t = C_t + \sum_{m=1}^{M}\left[I_t^m + K_t^m \frac{\xi^m}{2}\left(\frac{I_t^m}{K_t^m} - \delta^m\right)^2\right] + G_t. \quad (14)$$

III. TEMPORARY INVESTMENT TAX INCENTIVES

In this section we present some basic results for temporary tax incentives. These results shed light on the basic economic incentives involved in such policies and also inform econometric studies of investment behavior. The economy begins with capital stocks for each type in steady state equilibrium. (See Appendix A.1 for the details of the steady state calculation.) The government then credibly announces that it will enact a temporary investment tax subsidy, which it will finance through variations in the lump-sum transfer T. The tax subsidy temporarily increases ζ_t^m for certain (perhaps all) investment goods. The precise form of the subsidy is not important at this point; it could be in the form of an investment tax credit, a bonus depreciation allowance, and so on. We analyze perfect foresight equilibria.

3.1 Short-Run Approximations for Long-Lived Investment Goods

While the model above is complicated, we can gain insight into its behavior by appealing to two "short run" approximations. The accuracy of these approximations rests on two conditions: First, as we have assumed, the policy under consideration must be temporary. The approximations will be misleading for permanent or long lasting changes in policy. Second, the approximations are most accurate for long-lived investment goods, that is, goods with low economic rates of depreciation. The approximation will be less accurate for capital that depreciates rapidly.

The solution to the model is complicated because it has both backward- and forward-looking variables. We show that for 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 analyses. For capital with low depreciation rates, the stock is much bigger than the flow. To a first order approximation, the percent change in the capital stock is δ^m times the percentage change in investment . (With balanced growth the percent change would be δ^m plus the growth rate.) For example, residential investment could be twice its normal level for a year and still only result in a 2 or 3% increase in the total stock of housing. Clearly, this approximation is most accurate for capital with low rates of economic depreciation.

The justification for approximating q_t^m with its steady state value is more subtle. Expanding equation (6), we can write q_t^m as

$$q_t^m = \beta \sum_{j=0}^{\infty} \left\{ C_{t+j+1}^{-\frac{1}{\sigma}} \left[\beta\left(1-\delta^m\right)\right]^j \left[(1-\tau_{t+j+1}^{\pi})(1-\tau_{t+j+1}^{d}) R_{t+j+1}^m + \frac{\xi^m}{2} \left\{ \left(\frac{I_{t+j+1}^m}{K_{t+j+1}^m} \right)^2 - \left(\delta^m\right)^2 \right\} \left(1-\zeta_{t+j+1}^m\right) \right] \right\}.$$

Because the policy is temporary, the system will eventually return to its steady state. While this may take some time, many of the terms in the brackets, particularly those in the future, will remain close to their steady state values. Put differently, the difference between q_t^m and its steady state level q^m come entirely from the first few terms in the expansion – the "short-run" terms. Provided that the agents are sufficiently patient (i.e., that β is close to 1) and that depreciation is sufficiently slow (i.e., δ^m and $\hat{\delta}^m$ are low), the future terms will dominate these expressions and the short-run deviations of the system will have 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 economic policies, the benefit to any given investment is independent of the short run. This is particularly true for long-lived capital: capital for which the economic rate of depreciation is low.[3] To evaluate these approximations, we later compare a truly instantaneous change in policy with one where the change matches the duration of changes in the 2002 and 2003 legislation.

3.2 Response of Investment to Temporary Tax Subsidies

In this section, we examine 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], or 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 the flow supply of investment. This result has important implications for econometric tests of the effects of changes in tax policy.

In our model, equation (8) gives the real pre-tax price of new type *m* capital, φ_t^m, which includes all of the costs of investment. Specifically, 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

[3] These results are identical to what one would find in standard *q*-theoretical investment models, which are typically partial equilibrium (Abel [1982], Hayashi [1982], Summers [1981, 1985], and Auerbach and Hines [1987]). In these models, even though *q* is a jump variable, it will not jump in response to a policy change that only changes tax rates for an instant.

equation for a single type of capital. The total pre-tax price of investment φ is on the vertical axis and the quantity of investment, *I*, is on the horizontal axis. Using our short run approximation $K_t \approx K$, equation (8) describes a simple upward sloping relation between φ and *I*. The slope of this curve is governed by the adjustment cost parameter ξ. Higher values of ξ mean that this curve is steeper while lower values of ξ imply a shallow curve.

Equation (9) relates the shadow price of capital φ to its shadow value *q*, the marginal utility of resources $C_t^{-\frac{1}{\sigma}}$, and the tax subsidy $(1-\zeta)$. Using our second 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 (9) gives a horizontal line with shift variables *C* and ζ.

The equilibrium price and the equilibrium rate of investment for each *m* is determined by the intersection of (7) and (9). Combining (7) and (9) gives

$$\varphi_t^m = \frac{q^m C_t^{\frac{1}{\sigma}}}{1-\zeta_t^m}, \tag{15}$$

which is independent of elasticity of supply of type *m* investment (ξ^m) and also independent of the quantity of investment. 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. If the policy does not move aggregate consumption (e.g., if it is focused on a small segment of investment or if there is an offsetting tax increase elsewhere), then the subsidy moves the shadow price of capital one-for-one. If the policy does have aggregate effects (e.g., increasing aggregate investment so that consumption falls in equilibrium), then all investment goods shadow prices move by the multiple of the change in consumption. In this case, the relative after-tax shadow prices of various types of capital remain constant in the wake of temporary tax subsidies, but changes in the pre-tax relative shadow prices precisely reflect the differences in the tax subsidy. Price increases are a necessary consequence of investment tax subsidies and are not direct evidence of relatively inelastic supply curves. Again, this finding arises because a temporary change in a tax subsidy does not change the shadow value of capital. Equation (9) links the shadow value and the after-tax shadow price in equilibrium. Thus, relative differences in tax subsidies translate directly into relative differences in pre-tax shadow prices.[4]

3.3 Implications for Empirical and Policy Analysis

Price increases are a necessary accompaniment of a temporary investment subsidy. Thus, observing increased investment goods prices following a temporary tax subsidy is not direct evidence of a relatively inelastic supply curve. In fact, the theory suggests that the pre-tax price should rise roughly one-for-one with the investment subsidy. At the same time, because the rate of investment is determined by the supply elasticity, observing only modest increases in investment purchases is evidence of an inelastic supply.

Because theory has such sharp implications for the equilibrium determination of prices, it is useful to consider what conclusions, if any, can be drawn from price data. Recall that the shadow price of investment goods reflects both external and internal costs. In the model, this distinction does not matter. It does matter for relating the predictions of the model to observations in the data, which only capture market (i.e., external) prices. Let p_t^m be the market price of type *m* investment goods. We assume that the direct purchase of the investment good plus a fraction θ of the adjustment costs are external. The remaining fraction of the adjustment costs are internal, i.e., not mediated by a market transaction. That is,

$$p_t^m = 1 + \theta \xi^m \left[\frac{I_t^m}{K_t^m} - \delta^m \right] = 1 + \theta \left(\varphi_t^m - 1 \right). \tag{16}$$

Hence, movements in the shadow price of investment goods only affect market price to the extent that adjustment cost are external.

Without knowledge of θ, the elasticity of supply cannot be inferred from market price data. It can be inferred, however, from the response of quantities to a temporary tax subsidy. Let $\tilde{v}_t$ be the percent deviation of a variable *v* from its steady state value,

[4] This finding has antecedents in the *q*-theoretical investment literature. 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.

$\tilde{v}_t \equiv \frac{dv_t}{v}$. Then, using the constancy of q_t^m under a temporary tax subsidy and evaluating at the steady state $\frac{I^m}{K^m} = \delta^m$, condition (7) implies

$$\tilde{I}_t^m = \frac{1}{\sigma \delta^m \xi^m} \tilde{C}_t - \frac{1}{\delta^m \xi^m \left(1-\zeta^m\right)} d\zeta_t^m, \tag{17}$$

where $d\zeta_t^m$ is the change in the investment subsidy. In the case where the tax subsidy has no aggregate effects (e.g., it applies to a small fraction of investment or there is an offsetting tax increase), $\tilde{C}_t = 0$ so the elasticity of investment supply $\left(\delta^m \xi^m\right)^{-1}$ can be inferred directly from the change in investment. If there are aggregate effects, one must also control for the change in aggregate consumption to make this inference.

Our work reinterprets 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. In some cases, the price increases are nearly one-for-one. His findings are consistent with our analysis of investment tax incentives provided that the ITC was temporary. Goolsbee suggests that the price increases are indicative of a relatively inelastic supply of investment. Our analysis leads to a different interpretation. Because the price elasticity of investment demand is essentially infinite for long-lived capital, the elasticity of supply is essentially irrelevant for the equilibrium determination of price in response to temporary investment incentives. That is, price is determined by investment demand alone. Then, given the equilibrium price, the elasticity of supply determines the response of investment to a temporary tax incentive. Hence, Goolsbee's finding of one-for-one increases in prices is consistent with any positive elasticity of supply. It does not suggest that supply is inelastic. To learn about supply elasticity, one must look at the response of quantity.

Often, the analysis of tax policy focuses on the user cost of capital. Cohen, Hansen, and Hassett [2002] use this approach to analyze the potential impact of the bonus depreciation policies that we consider in this paper. Naturally, the Jorgensonian user cost relationships hold in our model. For simplicity, assume that capital stocks do not enter the adjustment cost functions. Then, using (5), (6) and (9), we can write the standard user cost expression as

$$(1-\tau^{\pi}_{t+1})(1-\tau^{d}_{t+1})R^{m}_{t+1} = \left\{ r_t + \delta - \left(1-\delta^m\right)\frac{\Delta\left(\varphi^m_{t+1}\left[1-\zeta^m_{t+1}\right]\right)}{\varphi^m_t\left[1-\zeta^m_t\right]} \right\} \varphi^m_t\left[1-\zeta^m_t\right] \qquad (18)$$

where $\Delta\left(x_{t+1}\right) \equiv x_{t+1} - x_t$. This expression says simply that the after-tax marginal product of capital equals the user cost of capital.

In certain instances expression (18) can be used directly to analyze the effects of a policy change. For instance, *ceteris paribus*, an increase in ζ^m_t 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 temporarily. Notice, however, that many assumptions are required to read the effect of the policy from expression (18). The real interest rate r_t, and the real price of new capital φ^m_t 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. To use equation (18) for policy analysis requires that the policy in question have 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, $q^m_t \approx q^m$, which implies that φ^m_t fully reflects the tax subsidy ζ^m_t. Hence, $\varphi^m_t\left[1-\zeta^m_t\right]$ is constant, so the user cost of capital does not change.

This finding is an equilibrium implication of the standard neoclassical model. Equation (18) determines the demand for capital. Temporary investment tax subsidies do not change the demand for capital. Instead, they change investment, that is, the timing of when capital is acquired. For long-lived capital goods, the user cost formula gives no guidance for analyzing temporary subsidies.

IV. Depreciation and Current Tax Policy

We use the temporary bonus depreciation allowances provided in the 2002 and 2003 tax bills as a test of the model's predictions. In this section we briefly describe the deduction of depreciation in the U.S. Tax Code as well as the form of the depreciation deductions in the 2002 and 2003 laws.

4.1 The Modified Accelerated Cost Recovery System

Under the U.S. tax code, depreciation deductions 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% declining balance, 150% declining balance, or straight-line depreciation, see Appendix A.4 for more details on MACRS). The recovery period specifies how long it takes to fully deduct the cost of investment. By the end of the recovery period, the total nominal value of the investment will have been deducted. Recovery periods differ substantially across investments and are supposed to correspond roughly with the productive life of the property. Table 1 lists selected types of property and their associated 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. Certain other structures are depreciated over shorter horizons.

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% of the costs of investment from their taxable income in the first year of the recovery period. The remaining 70% would then be depreciated over the standard recovery period in accordance with MACRS. The 2003 *Jobs and Growth Tax Relief Reconciliation Act* (*JGTRRA*) increased the first-year bonus depreciation to 50%. 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. The property must have been placed in service after September 11, 2001 and prior to January 1, 2005.[5,6]

For example, suppose that a business buys a car and depreciates it according to MACRS. The recovery period for cars is five years. The normal MACRS depreciation for a vehicle in the first year is 20% (see Table A.1). The 2002 law allows the firm to first deduct 30% and then depreciate the remaining 70% according to MACRS. Thus, the deduction in the first year is 44% ($30\% + .2(70\%)$) rather than 20%.

4.3. Quantifying Accelerated Depreciation

Hall and Jorgenson [1967] analyzed alternative depreciation policies by focusing on the present discounted value of depreciation deductions. Essentially, they modeled depreciation as if, when the firm invests, it immediately recovers the present discounted value of its depreciation deductions. This approach is common in the public finance literature. If nominal interest rates and tax rates were constant, then, for any path of depreciation deductions D_j, the present discounted value of these deductions would be

$$z = \sum_{j=1}^{R} \frac{D_j}{(1+i)^j}. \quad (19)$$

In this case, the cost of investment is reduced by an amount $X = \tau^{\pi}\left(1-\tau^{d}\right)z$.[7] In terms of the model in Section III, X would be included as part of the total subsidy ζ. If the only investment subsidy were the regular depreciation deduction, then $\zeta = X$ and the cost of acquiring one dollar of capital would be $1-X$.

[5] *JCWAA* requires that the property be *acquired* (but not necessarily placed in service) prior to September 11, 2004. *JGTRRA* eliminated this requirement. Additionally, property with a production period greater than two years or property with a production period more than one year and a cost exceeding one million dollars is allowed an extension to January 1, 2006.

[6] The laws also changed investment incentives for small investments. Prior to *JCWAA*, the U.S. tax system allowed firms to fully expense investment up to $24,000 annually. In 2002, this limit was raised $25,000. The 2003 law increased the exemption further to $100,000. Like the bonus depreciation allocation, this exemption only applies to property with a recovery period of no more than 20 years. The bills also featured other provisions. The 2002 law included a five-year carryback of net operating losses for businesses, extended unemployment assistance to states in financial distress, and tax benefits for New York City. The 2003 law accelerated tax rate cuts originally scheduled to occur in 2004 and 2006. It also provided substantial reductions in capital gains and dividend tax rates. Because they do not have strong effects across different types of capital, we do not analyze these additional provisions in this paper. For an analysis of the 2001 and 2003 tax policies see House and Shapiro [2004].

[7] The discounted value is calculated with the nominal interest rate because tax depreciation allowances are not indexed for inflation. Note also that this approach assumes that firms are never in a loss position.

Table 2.A shows our calculations of the present discounted value of depreciation deductions z for various MACRS recovery periods. We use the actual MACRS depreciation schedules to make these calculations. The table also shows the effects of changing the nominal interest rate and the bonus depreciation allowance on the present value.

Table 2.B shows the effects of the bonus depreciation policy on the cost of investment. In the table, we assume that the effective tax subsidy due to the bonus depreciation under the assumption that the applicable tax rate on capital income is 35% (the statutory tax rate on corporate profits). For property with very short recovery periods, the investment subsidy is small. For five-year property (which includes vehicles) the 50% bonus depreciation reduces the cost of investment by at most 2.88%. In contrast, 20-year properties would get a subsidy of 8% to 10% with a 50% bonus depreciation allowance. For longer recovery periods, z is substantially less than one and the bonus depreciation is worth more. Obviously, the higher the nominal interest rate is, the greater the value of the bonus depreciation.

V. ANALYZING THE EFFECTS OF BONUS DEPRECIATION

In this section we specialize the model to permit an explicit analysis of the 2002 and 2003 bonus depreciation provisions. We use the model to assess the policies' impact on aggregate investment, employment and production.

5.1 Modeling Bonus Depreciation

Because doing so would entail tracking the vintage structure of investment in each capital type and thus require many state variables, we abstract from the details of the various MACRS depreciation schedules. Instead, we approximate the tax depreciation rate for each type of investment m with a geometric rate $\hat{\delta}^m$. In this case, MACRS, without the bonus depreciation, reduces the cost of investment by X_t^m where X_t^m obeys the recursion

$$X_t^m = \frac{(1-\tau_{t+1}^d)\tau_{t+1}^{\pi}\hat{\delta}^m}{(1+\pi)(1+r_t)} + \frac{1-\hat{\delta}^m}{(1+\pi)(1+r_t)} X_{t+1}^m \tag{20}$$

with $(1+i_t) = (1+\pi)(1+r_t)$. Note that we can write (20) 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

$$X_t^m C_t^{-\frac{1}{\sigma}} \approx C^{\frac{1}{\sigma}} \tau^\pi (1-\tau^d) z^m. \tag{21}$$

The 2002 and 2003 laws increased X_t^m by providing the bonus depreciation deduction allowances. 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

$$\zeta_t^m = \lambda_t^m \tau_t^\pi \left(1-\tau_t^d\right) + \left(1-\lambda_t^m\right) X_t^m. \tag{22}$$

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

Using (21) and approximating *q* and *K* with their steady state values, we can write (7) as

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

This is equation (17) for an incremental bonus depreciation allowance $d\lambda_t^m$. Again, the first term captures the extent to which the policy has aggregate effects. The second term is the direct change in investment due to the bonus depreciation allowance.

To illustrate the force of the bonus depreciation policy, we contrast two types of capital: agricultural equipment and structures for use in electric power generation and transmission. For agricultural equipment, $\delta = 0.097$ and $z = 0.863$ (see Table 1 and

Table 2.A). For electric power structures, $\delta = 0.03$ and $z = 0.667$. Both qualify for the bonus depreciation since they both have recovery periods less than or equal to 20 years. For illustration, we set the tax rates to $\tau^{\pi} = 0.35$ and $\tau^{d} = 0.25$ which are roughly in line with statutory rates. We set $\xi = 4$ which is in line with typical estimates of this parameter and corresponds to moderate adjustment costs. Assuming a 30% bonus depreciation allowance ($d\lambda_t = 0.30$), the second term in (23) is 0.036 for agricultural equipment and 0.265 for electric power structures. Thus, the bonus depreciation provides very little extra incentive to invest in agricultural equipment (which has a recovery period of seven years) but it does provide a strong incentive to invest in electrical power structures (which has a 20-year recovery period). Investment in power structures should increase by more than 26% relative to trend while the tax policy is in effect.

If the bonus depreciation policy applies broadly, it will have aggregate effects. In particular, employment will increase. Using the labor supply condition (4), the production function (10) and the goods market clearing condition (14), one can show that the equilibrium change in employment is approximately

$$\tilde{N}_t = \frac{\sum_{m=1}^{M}\left\{\frac{I^m}{Y}\frac{\tau^{\pi}(1-\tau^{d})(1-z^{m})}{\xi^{m}\delta^{m}\left[1-z^{m}\tau^{\pi}(1-\tau^{d})\right]}d\lambda_t^{m}\right\}}{(1-\alpha)+\left(\frac{1}{\eta}+\alpha\right)\left(\frac{C}{Y}\sigma+\sum_{m=1}^{M}\left\{\frac{I^m}{Y}\frac{1}{\xi^{m}\delta^{m}\left[1-z^{m}\tau^{\pi}(1-\tau^{d})\right]}\right\}\right)} \geq 0 \qquad (24)$$

The inequality is strict as long as $\tau^{\pi} < 1$, $\sigma < \infty$, $\eta > 0$ and as long as some types of qualified capital have $z^{m} < 1$. Employment increases because the bonus depreciation allowance increases the after-tax real wage. In general increases in the real wage 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 (permanent) income effect is negligible (in fact this is embodied in our approximations $q_t^{m} \approx q^{m}$). Essentially, the policy has only substitution effects and employment rises.

The labor supply condition (4) relates employment and consumption. The first-order approximation of this condition is

$$\tilde{C}_t = -\left(\eta^{-1}+\alpha\right)\sigma\tilde{N}_t \leq 0 .$$

Like the substitution effect on employment, bonus depreciation gives an incentive to substitute away from consumption and toward subsidized investment. Thus, in equilibrium, employment and output rise and consumption falls.

Since consumption decreases, equation (23) implies that, for capital that is ineligible for the bonus depreciation allowance, investment must fall. These types receive no direct investment subsidy and aggregate resources are redirected towards subsidized investment goods. It should be emphasized that even if the change in aggregate employment and aggregate consumption were small (or zero), perhaps due to a low labor supply elasticity or a low intertemporal elasticity of substitution, equation (23) still implies that the change in investment should vary dramatically across capital goods.

The real relative prices of investment goods are also affected by the special depreciation allowance. To a first-order approximation, the real pre-tax shadow price of type *m* capital is $\tilde{\varphi}_t^m = \xi \delta^m \tilde{I}_t^m$. Using (23) we can write this as

$$\tilde{\varphi}_t^m = \frac{\tilde{C}_t}{\sigma\left[1 - z^m \tau^\pi (1-\tau^d)\right]} + \frac{\tau^\pi (1-\tau^d)(1-z^m)}{1 - z^m \tau^\pi (1-\tau^d)} d\lambda_t^m \qquad (25)$$

As we saw in Section III, this equation is independent of the elasticity of the supply of investment goods. Instead, equation (25) says the relative price of investment goods depends only on z^m. It is easy to show that the second term is decreasing in z^m. Again, high z^m indicates that most of the cost of investment is already recovered under the existing system. Using the 30% bonus depreciation allowance from 2002, the shadow price of power structures should rise by 3.2% relative to trend; the price of agricultural equipment should rise by 1.4%. For the 50% bonus depreciation in the 2003 law, the relative shadow price should rise by 3.5%. As discussed above, market prices will reflect these changes in shadow prices only to the extent that adjustment costs are external.

5.3 The 2002 and 2003 Tax Laws: Simulations

In this section we simulate the effects of the bonus depreciation policy using numerical methods. The numerical solution provides quantitative results that do not rely on the approximations $q_t^m \approx q^m$ and $K_t^m \approx K^m$. We calibrate the model to match features of the U.S. economy. The parameter values used in the simulations are summarized in Table 3.

The parameters are set as follows: The discount factor is 0.97, which gives a 3% annual real interest rate. We use 0.5 as our baseline value for the Frisch labor supply elasticity (η). This is in line with recent estimates (see Farber [2003] and Kimball and Shapiro [2003]). Most empirical evidence indicates that the elasticity of intertemporal substitution (σ) is substantially less than 1. Our baseline setting for σ is 0.2, which is roughly the average estimate in Hall [1988], Campbell and Mankiw [1989] and Barsky, *et al.* [1997]. The annual rate of inflation is 3%.

Empirical evidence on adjustment costs varies considerably. The early empirical literature on the *q*-theory of investment often gives implausibly large point estimates for these parameters (see Summers [1981] and Tobin [1981]). Erickson and Whited [2000] argue that measurement error in *q* is considerable and is partially to blame for the large estimates. Shapiro [1986] and Hall [2004] present evidence consistent with smaller adjustment costs; they estimate ξ to be roughly between 2 and 4. We set ξ^m to 4 (annually) in each sector which corresponds to moderate adjustment costs.

To calibrate labor's share, we take total employee compensation as a fraction of total GDP less proprietors' income. This share has been roughly constant in the post war period and its average is $1-\alpha = 0.62$. We then split proprietors' income into labor income ($0.62\times$ proprietors' income) and capital income ($0.38\times$ proprietors' income).

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]. These rates are updated depreciation figures estimated using techniques established by Hulten and Wykoff [1981a], [1981b]. The approximate MACRS depreciation rates are defined to be broadly consistent with IRS publication 946 and with Brazell and Mackie [2000]. Table 4 lists the capital types included in the model together with their associated rates of economic and tax depreciation.

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 $\tau^{\pi} = 0.2235$ and $\tau^{d} = 0.2975$. These calibrations account for differences in forms of ownership (corporate versus proprietors), and for differences in financial structure (debt versus equity). Later, as a robustness check, we consider alternative tax rates.

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. The appendix provides more discussion of the calibration of tax rates and capital shares.

The 2002 law was signed on March 9, 2002. For the simulations, we assume that it goes into effect in the second quarter of 2002 and that the policy change was unanticipated. The 2003 law was signed on May 28, 2003. In the simulation, it goes into effect in the third quarter of 2003. Again the firms and workers do not anticipate the change in policy prior to that date. We assume that in 2002 and again in 2003, the private sector expects the bonus depreciation policy to expire December 31, 2004.

Figure 2 shows the simulated reaction to the bonus depreciation allowances called for in the 2002 and 2003 tax bills. The top two panels show the responses of GDP, total employment, aggregate investment and aggregate consumption. The lower panels show the response of investment for each type of capital.

Employment, output, and investment increase after each policy change. Naturally the biggest effects come after the 2003 law. In the quarter after *JGTRRA* passes, GDP is 0.09% above trend. Employment and aggregate investment are 0.10 and 0.89% above trend. Consumption decreases mildly as people substitute towards saving and investment. Following the 2003 law, aggregate consumption falls by 0.04%.

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 the bonus depreciation. Furthermore, some qualified investments are not substantially affected by the policy. Five-year property, vehicles and computer equipment for instance, experience only small reductions in cost. For the U.S., the investments that are significantly affected account for at most 30% 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,[8] rail structures, and electric power structures which increase by more than 28.0% after *JGTRRA*. Telephone structures and other power and utility structures increase by 15.8%. At the other extreme, residential investment and commercial structures both contract slightly. Residential investment falls by 2.8% and investment in offices, warehouses and other industrial structures falls by 1.9%.

Two factors explain the dramatic differences in these groups' responses to the policy. First, we are comparing investments that get the most stimulus with investments that get none. Farm, rail, and electric power structures have 20-year recovery periods; telephone and other power and utility structures have 15-year recovery periods. For these groups, the 30%, and the subsequent 50% bonus depreciation allowances substantially change the real cost of investment. In contrast, residential investment and investment in commercial structures are not directly affected by the policy.

Second, investment goods with more than a 15-year recovery period have low economic rates of depreciation and consequently have high intertemporal elasticities of substitution for investment purchases; investment spending for this group is extremely sensitive to temporary price changes. Since one group gets a large temporary tax subsidy while the other does not, it is not surprising to see big differences in production following the policy.

Figure 3 graphs simulated changes in investment and relative prices against the tax depreciation rate of each type of capital. In the figure, each point represents the percentage deviation from steady state of a particular type of capital. Solid circles indicate capital types that qualify for the bonus depreciation. Empty circles indicate capital types that do not qualify. To evaluate our analysis from Section III, we have included the changes predicted by approximations (23) and (25). In the figure, diamonds indicate approximate responses. The approximations underlying our analytical solution are exact only when tax policy changes for an instant. Yet, the figure shows that the

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

numerical solutions for the 2-1/2 year policy change (the circles) are quite close to the analytic solutions (the diamonds).

The top panels show the changes in real investment spending six months after both the 2002 law and the 2003 law. Recall that the tax subsidy is increasing in the MACRS recovery period. Thus, as the tax depreciation rate gets lower and lower, we see investment rise steadily until the tax depreciation rate reaches 0.08. This is the tax depreciation rate for 20-year property. Again, property that does not qualify for the depreciation allowance exhibits either no change or a slight negative change.[9] The lower panels graph the changes in real shadow prices against the associated tax depreciation rates. As the tax depreciation rate falls, the real shadow prices rise. This continues until the tax depreciation rate reaches 0.08 at which point there is a sudden drop.

It is important to emphasize that while the shape of the responses in the upper panel could change if adjustment costs varied across sector, the pattern observed in the lower panel is not affected by such variations. The effect of the tax policy on prices only depends on the tax depreciation rates and the effective tax rates on capital income. However, because internal adjustment costs may be an important part of the total cost of investment and reported investment goods prices only reflect external costs, it is not guaranteed that we will observe the pattern above in the data.

To summarize, standard neoclassical analysis suggests that the bonus depreciation allowances in the 2002 and 2003 laws should have had modest positive effects on aggregate economic activity. Aggregate consumption should have fallen slightly and investment should have increased by perhaps as much as 1%. Moreover, there should be clear differences in the responses of investment and prices for different types of capital goods. For qualified properties, we should observe a negative relationship between tax depreciation rates and real investment and real relative prices. For unqualified properties, investment and prices should be low in comparison with qualified property. Finally, 20-year property should experience *much* larger increases in real investment than general commercial structures and residential investment.

[9] In the figure, residential investment is assigned a tax depreciation rate of 0.

5.4 Aggregate Effects of the 2002 and 2003 Legislation under Alternative Parameter Values

The simulation presented above suggests that the aggregate effects of the legislation were modest. To an extent, this conclusion relies on the particular parameterization of the model. Table 5 considers several modifications to our baseline parameterization. For each specification we document the percent change in GDP and total employment in 2003 predicted by the model. We also report the approximate increase in output in current dollars (based on actual GDP in 2003 ($11 trillion)) and the approximate increase in jobs (based on total employment in 2003 (130 million workers)). The jobs figure assumes that all of the adjustment in employment is at the extensive margin. The different specifications are described in the table. Parameters not explicitly stated in the table are set at their baseline values.

The baseline model predicts that GDP in 2003 increases by .075% relative to trend. This corresponds to approximately $8.3 billion in additional output. The predicted total change in output for 2002:2 – 2004:1 is $24.24 billion. The baseline model predicts that employment will increase in 2003 by .079%, which corresponds to roughly 100,000 jobs. The peak effect on employment (occurring in the months immediately following the 2003 policy) is almost 130,000 jobs.

Naturally, as we increase the elasticity of supply for the investment goods the aggregate effects on output and employment increase. Dropping ξ to 2 implies that GDP in 2003 would increase by .095% relative to trend; employment in 2003 would increase by 118,000 jobs.

Changing the tax structure of the model has strong effects on the equilibrium. One possibility is to assume that all investment is financed directly from retained earnings rather than requiring the firm to raise more funds directly from the households. This is equivalent to assuming that, for investment decisions, $\tau^d = 0$. In this case, the increase in GDP in 2003 is .129% and roughly 200,000 jobs are created (the peak increase in employment is almost 250,000 jobs). Naturally, more elastic labor supply causes the economy to expand more. A higher intertemporal elasticity of substitution for consumption ($\sigma = 1$) implies that consumption can fall more to finance the increase in aggregate investment without resulting in a sharp increase in marginal utility. Thus, employment and production react less when σ is higher. When $\sigma = .2$ (the baseline setting) the marginal utility of consumption rises rapidly with reductions in consumption spending. In that case, increases in investment require a greater increase in total production. Variations in the nominal interest rate also affect the value of the bonus depreciation policy. With a 7% annual nominal interest rate, the increase in GDP is slightly higher than the baseline – .084%; when the nominal interest rate is 5%, the increase in GDP is only .066% in 2003.

In accordance with our baseline calibration, the effects of the policy are modest. For the most part, the predicted increase in 2003 GDP lies between .07 and .14% of GDP. This is roughly between \$7.7 and \$15.4 billion in that year and between \$24 and \$41 billion over the entire life of the policy. Employment increases by roughly 100,000 to 200,000 jobs.

The simulations in this section and the theory of temporary tax incentives in general depend critically on the public's belief that the policies will expire. A National Association of Business Economics (NABE) survey in January 2004 finds that 62% of business economists indeed expect the policy to be extended. If firms knew for certain that bonus depreciation would be extended, then the incentive to invest in 2004 instead of 2005 would be eliminated. Since the intertemporal elasticity of substitution is nearly infinite, however, the theory implies that as long as there is some probability that the policy will expire, firms still have a powerful incentive to invest prior to 2005. Even if there is a substantial likelihood of the policy being extended, firms lose little by investing in 2004 instead of 2005.[10]

VI. CROSS-SECTIONAL EVIDENCE ON THE EFFECTS OF BONUS DEPRECIATION

In this section, we compare the predictions of the model with actual U.S. data. At the aggregate level, the model predicts that the 30% bonus depreciation allowance in *JCWAA*

[10] The 2004 *Working Families Tax Relief Act*, which was approved by Congress in September 2004, extends several provisions that were scheduled to sunset. The bonus depreciation allowance was not among the extensions. Thus, bonus depreciation may indeed sunset as scheduled. The provisions extended include the child tax credit, the 10% tax bracket, marriage penalty relief and AMT relief, all of which were set to expire under existing law.

and the 50% allowance in *JGTRRA* should cause modest increases in GDP, employment, and investment beginning in the summer of 2002, and again in late 2003. The predicted effects of the policy, however, are relatively small. As a result, in all likelihood, it would be impossible to disentangle the subtle aggregate effects of the policy from other more important aggregate shocks. Instead, we test the model's predictions at a disaggregate level. Specifically, we examine changes in real purchases and real relative prices of different types of investment goods following the tax policy.

The model's predictions are stark: Investment and prices should increase for any type of capital that qualifies for bonus depreciation. These effects should be smaller for capital goods with rapid tax depreciation rates. Thus, we should see relatively more of an increase in investment for 20 and 15-year property compared to 7 and 5-year property. More importantly, there should be a sharp difference between investment in 20-year properties, the properties qualifying for bonus depreciation with longest tax lifetimes and investment in properties with longer tax lifetimes that do not qualify for bonus depreciation.

Note that the effects we estimate are identified by variation across types of investment goods. Data by industry or by firm would not be a good vehicle for this estimation because most firms and industries buy many types of investment goods.

Of course, focusing on "micro" data is not a silver bullet. The aggregate shocks and policy changes mentioned earlier may have effects that vary systematically by capital type. It is easy to imagine shocks that cause relatively more investment in capital with low economic rates of depreciation. On the other hand, it is unlikely that such a shock would also suddenly disappear for property with tax recovery periods in excess of 20 years. This discontinuity provides a sharp test of the effectiveness of bonus depreciation as a temporary investment incentive.[11]

Our basic econometric approach is to first forecast real investment spending and relative prices for a panel of industries for the period when the policy was in effect.

[11] The investment data are collected based on the production of the goods, and thus reflect actual investment regardless of how firms report it on their tax returns. Although firms have an incentive to misclassify longer-lived property to qualify for bonus depreciation, it is not clear whether they can easily do so. Such misclassification biases against finding an effect of the policy.

Then, we examine the cross-sectional forecast errors to see if they vary systematically with the variation in tax treatment implied by the bonus depreciation policies.

Our data consists of quarterly observations on the quantity and price of investment of capital goods by type from the Bureau of Economic Analysis (BEA). In 1997, the BEA made changes to its series on private domestic investment. We use investment categories that were consistent pre and post-1997. We eliminate several BEA types of capital goods that we could not readily match with IRS depreciation schedules. There are 37 types of capital goods that meet both requirements. Table 6 lists the capital goods we examine with their tax depreciation rates. Table 6 lists residential investment as a type 38. Since much of residential capital is not subject to Federal taxation, we do not include it in the statistical analysis. We show it in some of the figures for comparison with nonresidential investment. Appendix A.3 provides more information on the data.

The details of our procedure are as follows. In the first stage we estimate univariate forecasting equations for each type of capital (m) for each horizon (h). These are reduced-form forecasts which control for heterogeneity across industry and are not a structural part of the test for the effects of the tax policy. In the second stage, we use the forecasting equations to predict investment and relative prices for each quarter from 2002:1 to 2002:4. We then regress the forecast errors on the tax rate of depreciation.

If the policy is having an effect, two relationships should be readily apparent after 2002:2. First, there should be a negative relationship between forecast errors and tax depreciation rates for properties with recovery periods less than or equal to 20 years. Second, 20-year property should have much higher forecast errors than longer-lived property that does not qualify for the bonus depreciation allowance. In other words, we want to see a clear pattern like that in Figure 3.

We examine multiple periods to study the effect of the policy changes through time. It is important to compare behavior before and after the policy went into effect. Although the bill was signed into law in the second quarter of 2002, there may have been effects due to anticipation of the legislation, which was introduced in early 2002 and retroactive to September 11, 2001. Moreover, although not included in the model, planning and preparation horizons may be important for investment decisions. Having multiple horizons allows for either anticipation effects or delays in the effects of the policies. In mid-2003, with the enhancement of bonus depreciation in *JGTRRA*, the effects should strengthen.[12]

We examine the behavior of the natural logarithms of real investment, $\ln(I_t^m)$, and relative price, $\ln(p_t^m)$, for each type of capital *m*. 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 first stage forecasting equations predict $\ln(I_{t+h}^m)$ and $\ln(p_{t+h}^m)$ given information at date *t*; that is, they predict investment purchases and prices *h* periods in the future. The forecasting equations are

$$\ln\left(I_{t+h}^m\right) = \alpha_{i,0}^{h,m} + \alpha_{i,1}^{h,m} t + \alpha_{i,2}^{h,m} t^2 + A_i^{h,m}(L) \begin{bmatrix} \ln\left(p_t^m\right) \\ \ln\left(I_t^m\right) \\ \mathrm{ITC}_t^m \end{bmatrix} + B_i^{h,m}(L) Z_t + \varepsilon_{i,t}^{h,m} \tag{26}$$

and

$$\ln\left(p_{t+h}^m\right) = \alpha_{p,0}^{h,m} + \alpha_{p,1}^{h,m} t + \alpha_{p,2}^{h,m} t^2 + A_p^{h,m}(L) \begin{bmatrix} \ln\left(p_t^m\right) \\ \ln\left(I_t^m\right) \\ \mathrm{ITC}_t^m \end{bmatrix} + B_p^{h,m}(L) Z_t + \varepsilon_{p,t}^{h,m}. \tag{27}$$

Equations (26) and (27) are estimated across time $t=1,...,T$ for each horizon *h* and type of capital *m*. *A* and *B* are matrices of polynomials in the lag operator *L*. ITC_t^m is the investment tax credit at time *t* for type *m* capital.[13] We allow investment and prices to have linear and quadratic time trends. Z_t is a vector of aggregate covariates. Z_t in the baseline specification include real GDP and real corporate earnings. In the baseline specification, we allow for current and one lag in all the polynomials.[14] Estimation is by OLS. The sample period $t=1,...,T$ is 1965:1 to 2000:4.[15]

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[12] The effects should strengthen as the expiration of bonus depreciation at the end of 2004 approaches. In 2005, if bonus depreciation sunsets as under current law, the effects should reverse as the excess accumulation of capital with tax incentives is allowed to depreciate.

[13] 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].

[14] We considered several alternate specifications of the forecasting equations. In particular, we considered selecting the lag length using the Schwartz Information Criteria as well as adding additional variables (the real interest rate on ten-year treasury bonds, the federal funds rate, the unemployment rate and the real value of the S&P500). These alternative specifications gave qualitatively similar results, and are therefore

In the second stage of the econometric procedure, we use data up to 2001:4 to form forecasts for 2002:1 to 2004:1. Conditioning on information as of 2001:4 allows us to analyze changes in investment and relative prices that take place subsequent to the policy.[16] Denote the forecast errors from 2001:4 to periods h equal to 2001: to 2004:1 as $\hat{\varepsilon}_i^{h,m}$ and $\hat{\varepsilon}_p^{h,m}$. We graph the forecast errors against the tax depreciation rate to look for the effects discussed above.

We also estimate and test for these effects using the following specification

$$\hat{\varepsilon}_i^{h,m} = \beta_{i0} + \beta_{i1}\left[\hat{\delta}^m - \hat{\delta}^{39}\right] + \beta_{i2} D^m + e_i^{h,m} \tag{28}$$

and

$$\hat{\varepsilon}_p^{h,m} = \beta_{p0} + \beta_{p1}\left[\hat{\delta}^m - \hat{\delta}^{39}\right] + \beta_{p2} D^m + e_p^{h,m} \tag{29}$$

These relationships are estimated across types of capital m=1,..,M and for each horizon h = 2002:1 to 2004:1. (In a slight abuse of notation, we use h here to denote the particular horizons for the forecasts rather than the number of steps ahead.) They relate the forecast error to the tax depreciation rates $\hat{\delta}^m$ and a dummy D^m that takes on the value of 1 for industries that do not receive bonus deprecation because they have service lives in excess of 20 years. All of these industries have recovery periods of 39 years (corresponding to a tax depreciation rate of $\hat{\delta}^{39}$), so the coefficients β_{i1} and β_{p1} are the effect of the policy on industries receiving the treatment and the coefficients β_{i2} and β_{p2} are shifts for not receiving the treated.

We estimate (28) and (29) by both ordinary least squares and by generalized least squares (GLS). The GLS estimates take into account both heteroskedasticity across industries and contemporary correlation across industries. For the GLS estimates, we estimate the M x M covariance matrices Ω_i^h and Ω_p^h for each horizon h using the

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not reported. The most noticeable effects came from including the stock market index, which exhibited dramatic changes during the forecast period. Recall that the forecasting equations are not structural and thus there is no "correct" specification *per se*. Instead, they are used to construct reduced form estimates of investment from which equilibrium realizations might deviate due to the change in tax policy. The relatively parsimonious specification that we adopt avoids factors, such as the stock market, that moved idiosyncratically during the interval we examine.

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

[16] We chose a later date to begin forecasting to avoid having the latest recession at the very end of our sample. We also wanted to avoid fitting the forecasts to data that was too close to the policy. If there were anticipation effects, this could bias our results.

residuals from the time series estimate of (26) and (27). Because we have *T* observations from the time series estimation period, we can estimate the entire covariance structure of the forecasts errors precisely. This situation differs from the usual feasible GLS estimation where the covariance matrix is estimated over the same sample as the parameters.[17] Moreover, unlike feasible GLS, we do not need to make structural assumptions about the parametric form of the covariance matrix.

Table 7 shows the estimates of the second stage regressions for quantity (28) and Table 8 shows the estimates for price (29) for the various forecast horizons. Figures 4 and 5 plot the data underlying these regressions. In each panel, the horizontal axis is the tax rate of depreciation $\hat{\delta}^m$; the vertical axis is for the forecast errors for investment, $\hat{\varepsilon}_i^{h,m}$ (Figure 4) or the forecast error of relative price, $\hat{\varepsilon}_p^{h,m}$ (Figure 5). Each panel corresponds to a forecast horizon *h*. Each circle corresponds to a type of investment good *m.* The size of the circles is inverse proportional to the square root of the forecast error variance, i.e., the diagonal element of the Ω matrix. Solid dots are types of investment goods that are eligible for the bonus depreciation; the open circles are investment goods that are not treated. The solid diamond-shaped marker is the forecast error for residential investment. For the graphs, we assign it a tax depreciation rate of zero. It does not enter the regressions. The solid line is the OLS estimate of the second-stage regression line and the dotted line is the GLS estimate.

Table 7 and Figure 4 show consistent and robust findings concerning the effect of the temporary investment incentives in 2003 and 2004 on real investment across types of capital. Prior to the implementation of bonus depreciation in mid-2002, there is no discernable pattern of investment across industries. With the implementation of the policy in mid-2002, the quantity of investment responds in the manner the theory predicts. That investment forecast errors in Figure 4 are negative on average does not say anything about the effectiveness of the policy, but instead indicates that other aggregate shocks were negative for investment over this period.

[17] It would be possible to do our two step procedure in one step by stacking the time series equations (26) and (27) then using dummy variables for the forecast periods to estimate the parameters of equations (28) and (29). This procedure would be numerically identical.

Capital goods that are ineligible for the bonus depreciation have below average rates of investment. In Figure 4, these types of capital, shown by the open circles, lie uniformly below the regression line after 2002:2. In Table 7, the coefficient on the dummy variable for not receiving bonus depreciation becomes negative and significant after 2002:2. The discontinuity in investment between types of ineligible capital and eligible capital with slightly higher tax depreciation rates is clearly evident in Figure 4. Finally, among the investment goods that are eligible for the bonus depreciation allowance, the negative relationship between the tax rate of depreciation and investment is evident in Figure 4 and confirmed by the regressions in Table 7.

These effects – the below-average investment for types of capital that is ineligible for bonus depreciation, the discontinuity in investment at the eligibility cut-off, and the negative relationship between investment forecast errors and tax depreciation rates among eligible types – get stronger as time moves forward. There are good reasons for this. First, bonus depreciation was increased from 30% to 50% with the passage of *JGTRRA* in mid-2003. Second, bonus depreciation expires at the end of 2004, so investment should increase as the expiration approaches.

The OLS parameter estimates for equation (28) differ somewhat from the GLS parameter estimates. The GLS estimator of β_{i2}, the effect of not receiving bonus depreciation, shows a substantial and significant downward shift as the policy goes into effect in mid-2002. Similarly, the GLS estimate of the slope coefficient β_{i1}, the effect of variations in tax depreciation among the eligible types of capital, becomes negative and significant in mid-2002. In contrast, the OLS point estimates change only slightly as the policy goes into effect. Inspection of Figure 4 shows why these differences occur. The small outlying circle at tax depreciation rate 0.1 in the 2002:1 panel is the forecast error for investment in steam engines. This point pulls the OLS regression line up because it is such an outlier. The GLS regression gives this point little weight because the forecast error for this type of capital is so variable. The forecast error for steam engines is an outlier in all of the panels – initially very positive and then later very negative. Absent this outlier, OLS and GLS would tell very similar stories.[18]

[18] We also considered weighted least squares (WLS) estimates that take into account heteroskedasticity, but not correlation across industries. For the investment regressions, WLS give results similar to GLS.

The reaction of investment spending to the tax policy provides evidence about the elasticity of investment supply. Using equation (23), we can compare two hypothetical types of capital that are identical in all respects (same depreciation rates, same supply elasticities, etc.) except that one qualifies for the bonus depreciation while the other does not. Suppose that type *m* gets the bonus depreciation allowance and type *j* is ineligible. Then, the difference in investment should satisfy

$$\tilde{I}_t^m - \tilde{I}_t^j = \frac{\tau^\pi(1-\tau^d)}{\xi\delta\left[1 - z\tau^\pi(1-\tau^d)\right]}(1-z)\lambda_t^m .$$

The estimated coefficient on the dummy variable for being unqualified (β_{i2}) is a measure of $\tilde{I}_t^j - \tilde{I}_t^m$. Then,

$$\xi = -\frac{\tau^\pi(1-\tau^d)}{\delta\left[1 - z\tau^\pi(1-\tau^d)\right]}\frac{(1-z)}{\beta_{i2}}\lambda_t^m$$

is an analog estimate of the adjustment cost parameter.

Calculating ξ requires knowledge of the tax rates, the appropriate *z*, and the economic rate of depreciation. The investment goods that do not qualify for the bonus depreciation all have the same MACRS tax depreciation schedule (they are all 39-year property). Assuming an annual interest rate of 6% gives $z = 0.373$. The depreciation rate for these structures is similar across types (see Table 6). We set $\delta = 0.03$ (annual). For illustration, we set τ^π and τ^d to the calibrated rates from Section 5.3. The implied values of ξ are reported in Table 7; because the tax policy went into effect late in 2002:2, we only report estimates of ξ for 2002:3 – 2004:1. Our estimates of the adjustment cost parameter fall in the conventional range between 2 and 4. The adjustment costs implied by the GLS regression are centered at 2.8 while the OLS regression has noisier estimates with an average value of roughly 4.

Table 8 and Figure 5 show the results for the relative prices of investment goods. Unlike the findings for the real quantity of investment, the results for relative prices of investment goods are not as clear. The scatter plots in Figure 5 do not suggest a clear relationship between the tax rate of depreciation and price. In addition, there is no noticeable difference between the prices of investment goods that qualified for the bonus depreciation and those that did not. On the whole, the parameter estimates confirm this finding. None of the OLS estimates is statistically significantly different from zero. The point estimates reveal no discernable effect of bonus depreciation on investment prices. The GLS estimates, while statistically significant, have the wrong sign.

Broadly speaking, the data suggest that the temporary investment incentives in 2002 and 2003 had little systematic effect on the price of investment goods. The model guides our interpretation of this finding. First, the price results provide no evidence on the flow elasticity of supply. For durable capital, the shadow price of capital should move one-for-one with the temporary investment incentive regardless of the supply elasticity. Second, to the extent that adjustment costs are internal to the firm (θ is close to zero), the effect of flow demand for investment on the shadow price of capital goods may not be reflected in transactions prices.

We find that prices did not respond to the bonus depreciation allowance, but that investment spending did. This finding contrasts with Goolsbee's [1998] that investment tax subsidies typically bid up the price of equipment without sharp increases in real investment. 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, the bonus depreciation allowance was explicitly temporary, while the ITC (the focus of Goolsbee's paper) was typically more persistent. On the one hand this suggests that investment spending should respond more for the explicitly temporary policy. On the other hand, it also means that prices should respond more. Second, while the ITC applied evenly to a broad class of equipment, the value of the bonus depreciation allowance was to a large extent concentrated on a narrow portion of total investment. The finding that prices do not react to the tax policy suggests that there are significant costs of investment that are internal to the firm and thus not revealed in the price data. Indeed, one possible explanation for the difference of our findings with Goolsbee's is that goods benefiting from the bonus depreciation had mainly internal adjustment costs while the more aggregative ITCs of the 1970s and 1980s increased external costs.[19]

[19] 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

Finally, our finding that bonus depreciation does have the predicted effect on investment suggests that firms did take into account the temporary feature of the policy. If the policy expires as scheduled, there will be a further sharp test of the theory. The effects of tax depreciation on investment shown in Figure 4 should disappear beginning in 2005.

VII. CONCLUSION

Our findings stem from a fundamental implication of the neoclassical model of capital accumulation. Temporary tax incentives do not change the demand for capital. Rather, they change the timing of when capital is acquired. The value of a long-lived capital good is dictated by long-run considerations and is not sensitive to small changes in the date of purchase or installation. As such, there are strong incentives to alter the timing of investment in response to temporary tax subsidies. These incentives are so strong that for a temporary tax change, the shadow price of long-lived investment goods fully reflects the tax subsidy regardless of the elasticity of investment supply. Thus, observing that prices of long-lived capital goods rise following explicitly temporary tax incentives does not imply that the supply of such investment goods is inelastic. On the other hand, in response to a temporary tax cut, the elasticity of supply can be inferred from quantity data alone.

While prices do not reveal the elasticity of investment supply, price data can reveal the composition of internal versus external costs of investment. If pre-tax prices only partially reflect the subsidy then a significant fraction of the cost of investment is internal to the firm.

The bonus depreciation allowance passed in 2002 and then increased in 2003 provides an excellent test of the theory. Only investment goods with a tax recovery period less than or equal to 20 years qualify for the bonus depreciation. Moreover, among the qualified types, the magnitude of the tax subsidy is higher for longer recovery periods. Because investment goods with recovery periods of 20 years or more are highly durable, the intertemporal elasticity of substitution for purchases of these goods is

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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.

extremely high. The theory suggests that there should be a sharp difference in the response of investment spending between the 20-year goods and investment goods with more than a 20-year recovery period. In addition, among the qualified types, we should observe higher investment spending for goods with higher tax recovery periods. The data support both of these predictions. We use these data to estimate investment adjustment cost parameters. Our estimates of adjustment costs are in line with estimates from earlier studies.

In summary, we find that bonus depreciation 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 spite of the sizeable effects on investment, the policy had only modest effects on aggregate employment and output. Finally, there should be a noticeable drop in investment and a modest decline in production and employment in 2005 when the bonus depreciation allowance expires.

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. 1979. "Share Valuation and Corporate Equity Policy." *Journal of Public Economics*, 11(3), June, pp. 291-305.

Auerbach, Alan J. 2002. "Taxation and Corporate Financial Policy." In *The Handbook of Public Economics*, vol. 3, Alan J. Auerbach and Martin S. Feldstein, eds., pp. 1251-1292.

Auerbach, Alan J., and Hassett, Kevin A. 2003. "On the Marginal Source of Investment Funds." *Journal of Public Economics*, January, pp. 205-232.

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.

Bradford, David. 1981. "The Incidence and Allocation Effects of a Tax on Corporate Distributions." *Journal of Public Economics*, 15(1), April, pp. 1-22.

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.; 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. 2004. "Phased-In Tax Cuts and Economic Activity." *NBER* working paper # 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*. Vol. 15, No. 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, *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.

King, Mervyn. 1977. *Public Policy and the Corporation* (London: Chapman and Hall).

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

McGrattan, Ellen R., and Prescott, Edward C. 2003 "Taxes, Regulations, and the Value of U.S. and U.K. Corporations." Federal Reserve Bank of Minneapolis Staff Report 309.

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

Poterba, James M. and Summers, Lawrence H. 1985. "The Economic Effects of Dividend Taxation," in *Recent Advances in Corporate Finance*, Altman and Subrahmanyam eds., pp. 227-284.

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 $K_t^m = K^m, I^m = \delta^m K^m \ \forall m$. The real and nominal interest rates are

$$1+r=\frac{1}{\beta}$$

$$1+i=(1+r)(1+\pi)$$

Equation (7) implies $q^m = C^{-\frac{1}{\sigma}}\left[1-\zeta^m\right]$. The Euler equations (6) give the real rental prices for each type of capital:

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

Using 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, (11) implies that that any other capital stock is given by

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

with $\psi_{m,1}\equiv\frac{R^m}{R^1}\frac{\gamma_1}{\gamma_m}$. Together with the production function (10), we have total output as

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

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

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

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

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

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

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

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

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.[20] 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% and 150% 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% declining balance rate is $\frac{200\%}{R}$; the 150% rate is $\frac{150\%}{R}$. Only non-farm property with recovery periods of 10 years or less may use the 200% declining balance method. All farm property and all 15 and 20-year property uses the 150% declining balance rate. Non-residential real property (business structures) and rental property use the straight-line method.

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.[21] Firms deduct half of a year's depreciation in the year the property was purchased. Thus, even though five-year properties have a 40% annual MACRS depreciation rate, the firm only deducts 20% 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.

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[20] 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.

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

Table 1: Recovery Periods and Deprecation Methods by Type of Capital

Type of Capital	Recovery Period (R)	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 2. 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 3. Baseline Parameters

Parameter	Baseline Value
Discount factor, annual rate (β)	0.96
Capital share (α)	0.38
Labor supply elasticity (η)	0.5
Elasticity of intertemporal substitution of consumption (σ)	0.2
Average Inflation Rate (π)	0.03
Curvature of adjustment cost functions (ξ)	4
Elasticity of Capital Substitution (ρ)	1
Tax Rate on Capital Earnings (τ^{π})	0.2235
Tax Rate on Earnings Distribution (τ^{d})	0.2975

Table 4. Annual Economic and Tax Depreciation Rates by Type of Capital

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 5. Simulated Effects of a 30 Percent Bonus Depreciation Allowance: Alternative Parameters

Parameters	GDP		Employment	
	Change from Trend (percent)	Change (billions of dollars)	Change from Trend (percent)	Number (1000s)
Baseline	0.075	8.3	0.079	103
Low Adjustment Costs, $\xi = 2$	0.095	10.4	0.091	118
Estimated (GLS) Adj. Costs, $\xi = 2.8$	0.085	9.4	0.086	112
Full internal finance, $\tau^d = 0$	0.129	14.2	0.153	199
Internal finance with high profit tax, $\tau^d = 0$, $\tau^\pi = 0.35$	0.210	23.1	0.250	325
High Labor Supply Elasticity, $\eta = 1$	0.101	11.0	0.116	151
Log preferences (High IES), $\sigma = 1$	0.071	7.8	0.062	81
High nominal interest rates, $\pi = 4$	0.084	9.2	0.089	114
Low nominal interest rates, $\pi = 2$	0.066	7.2	0.070	91

Note: This table shows the results of simulating the effect of the 30% bonus depreciation provisions of *Job Creation and Worker Assistance Act* of 2002 (*JCWAA*) on 2003 GDP and employment. Parameters other than those specified in the table are set at their baseline values in Table 3.

Table 6. 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
Steam engines	0.052	15	150	0.100
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
Single-family structures	0.015	---	---	---

Table 7. Investment Quantity: Regression on Forecast Errors Across Types of Investment Good, Baseline Specification

	2002:1	2002:2	2002:3	2002:4	2003:1	2003:2	2003:3	2003:4	2004:1
					A. OLS				
Constant (β_{i0})	0.168	0.146	0.138	0.097	0.195	0.084	0.038	0.064	0.122
	(0.067)	(0.073)	(0.099)	(0.106)	(0.109)	(0.143)	(0.144)	(0.147)	(0.159)
Not treated (β_{i2})	-0.222	-0.231	-0.294	-0.285	-0.422	-0.305	-0.293	-0.363	-0.472
	(0.099)	(0.107)	(0.145)	(0.156)	(0.161)	(0.210)	(0.212)	(0.216)	(0.234)
Treated x Treatment (β_{i1})	-0.473	-0.412	-0.483	-0.442	-0.843	-0.554	-0.412	-0.441	-0.675
	(0.255)	(0.277)	(0.374)	(0.403)	(0.414)	(0.543)	(0.546)	(0.557)	(0.603)
Implied ξ	--	--	3.560	3.662	2.477	3.425	5.950	4.802	3.688
SEE	0.16	0.18	0.24	0.26	0.26	0.34	0.35	0.35	0.38
R^2	0.14	0.12	0.11	0.09	0.17	0.06	0.05	0.08	0.11
					B. GLS				
Constant (β_{i0})	0.025	-0.012	0.085	0.129	0.196	0.202	0.191	0.137	0.209
	(0.030)	(0.053)	(0.080)	(0.081)	(0.102)	(0.121)	(0.128)	(0.123)	(0.138)
Not treated (β_{i2})	-0.088	-0.088	-0.264	-0.425	-0.464	-0.491	-0.579	-0.505	-0.769
	(0.053)	(0.086)	(0.122)	(0.135)	(0.163)	(0.179)	(0.202)	(0.198)	(0.214)
Treated x Treatment (β_{i1})	-0.214	-0.255	-0.716	-1.055	-1.323	-1.491	-1.364	-1.247	-1.708
	(0.097)	(0.169)	(0.252)	(0.249)	(0.293)	(0.328)	(0.371)	(0.387)	(0.424)
Implied ξ	--	--	3.962	2.456	2.250	2.130	3.008	3.452	2.265
SEE	0.18	0.21	0.26	0.29	0.29	0.37	0.37	0.38	0.44

Note: Dependent variable is the forecast error from equation (25) for the quantity of investment good conditional on information as of 2001:4 for the quarter indicated for each column. The explanatory variables are a constant, a dummy for types of investment good not receiving bonus depreciation, and an interaction between a dummy for types of good receiving the bonus depreciation and their tax rate of depreciation $\hat{\delta}^m$. See equation (27) and text for details. The top panel contains OLS estimates; the bottom panel contains GLS estimates taking into account heteroscedasticity and correlation across types of capital.

Table 8. Investment Price: Regression on Forecast Errors Across Types of Investment Good, Baseline Specification

	2002:1	2002:2	2002:3	2002:4	2003:1	2003:2	2003:3	2003:4	2004:1
					A. OLS				
Constant (β_{i0})	0.002	0.005	0.009	0.002	0.006	0.003	-0.006	-0.018	-0.019
	(0.004)	(0.008)	(0.013)	(0.016)	(0.017)	(0.020)	(0.023)	(0.028)	(0.032)
Not treated (β_{i2})	0.009	0.005	0.000	0.008	0.008	0.009	0.017	0.037	0.045
	(0.006)	(0.012)	(0.019)	(0.024)	(0.025)	(0.029)	(0.034)	(0.041)	(0.047)
Treated x Treatment (β_{i1})	-0.009	-0.032	-0.051	-0.026	-0.037	-0.032	0.009	0.063	0.060
	(0.015)	(0.031)	(0.050)	(0.061)	(0.065)	(0.075)	(0.089)	(0.106)	(0.121)
SEE	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.08
R^2	0.15	0.08	0.05	0.02	0.03	0.02	0.01	0.02	0.03
					B. GLS				
Constant (β_{i0})	-0.001	-0.007	-0.002	-0.003	-0.005	-0.010	-0.024	-0.029	-0.021
	(0.006)	(0.008)	(0.011)	(0.011)	(0.012)	(0.014)	(0.017)	(0.019)	(0.018)
Not treated (β_{i2})	0.010	0.017	0.016	0.020	0.027	0.030	0.037	0.042	0.038
	(0.002)	(0.004)	(0.005)	(0.006)	(0.007)	(0.008)	(0.009)	(0.011)	(0.011)
Treated x Treatment (β_{i1})	0.042	0.083	0.070	0.086	0.096	0.128	0.195	0.196	0.208
	(0.016)	(0.024)	(0.036)	(0.037)	(0.040)	(0.050)	(0.060)	(0.063)	(0.066)
SEE	0.01	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0.08

Note: Dependent variable is the forecast error from equation (26) for the relative price of investment good conditional on information as of 2001:4 for the quarter indicated for each column. The explanatory variables are a constant, a dummy for types of investment good not receiving bonus depreciation, and an interaction between a dummy for types of good receiving the bonus depreciation and their tax rate of depreciation $\hat{\delta}^m$. See equation (28) and text for details. The top panel contains OLS estimates; the bottom panel contains GLS estimates taking into account heteroscedasticity and correlation across types of capital.

Table A.1: MACRS Recovery Schedules by Recovery period, Percent per Year of Life

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	1.390
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								0.963

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 mid-month dating convention. Source: IRS Publication 946, *How to Depreciate Property*.

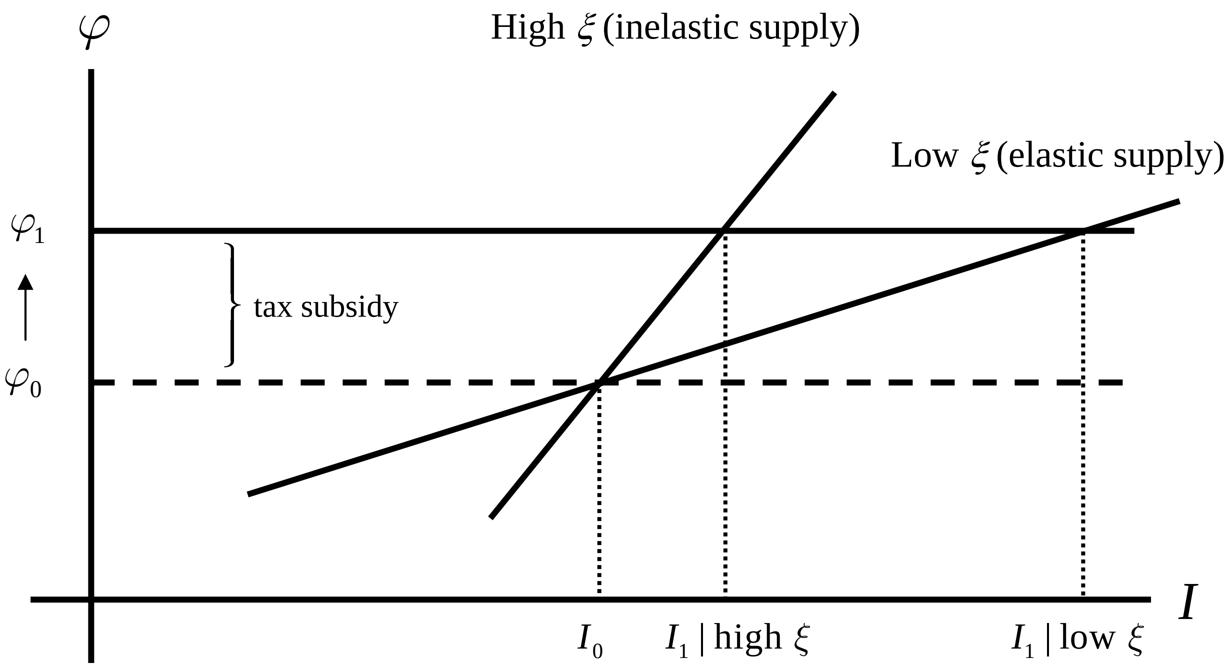


Figure 1: Price Reactions to Temporary Investment Subsidies.

Figure 2: Simulated Response to the 2002 and 2003 Depreciation Provisions

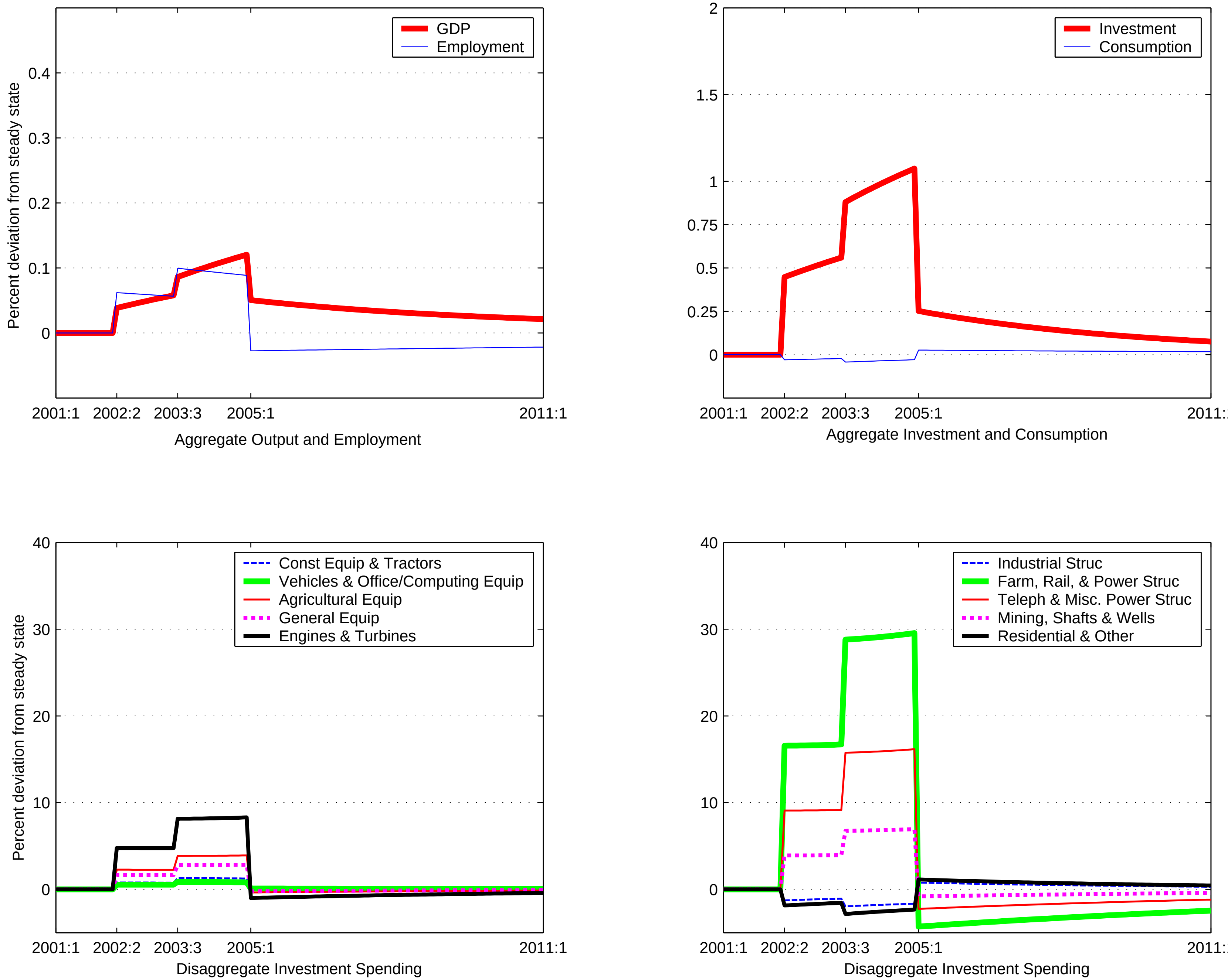
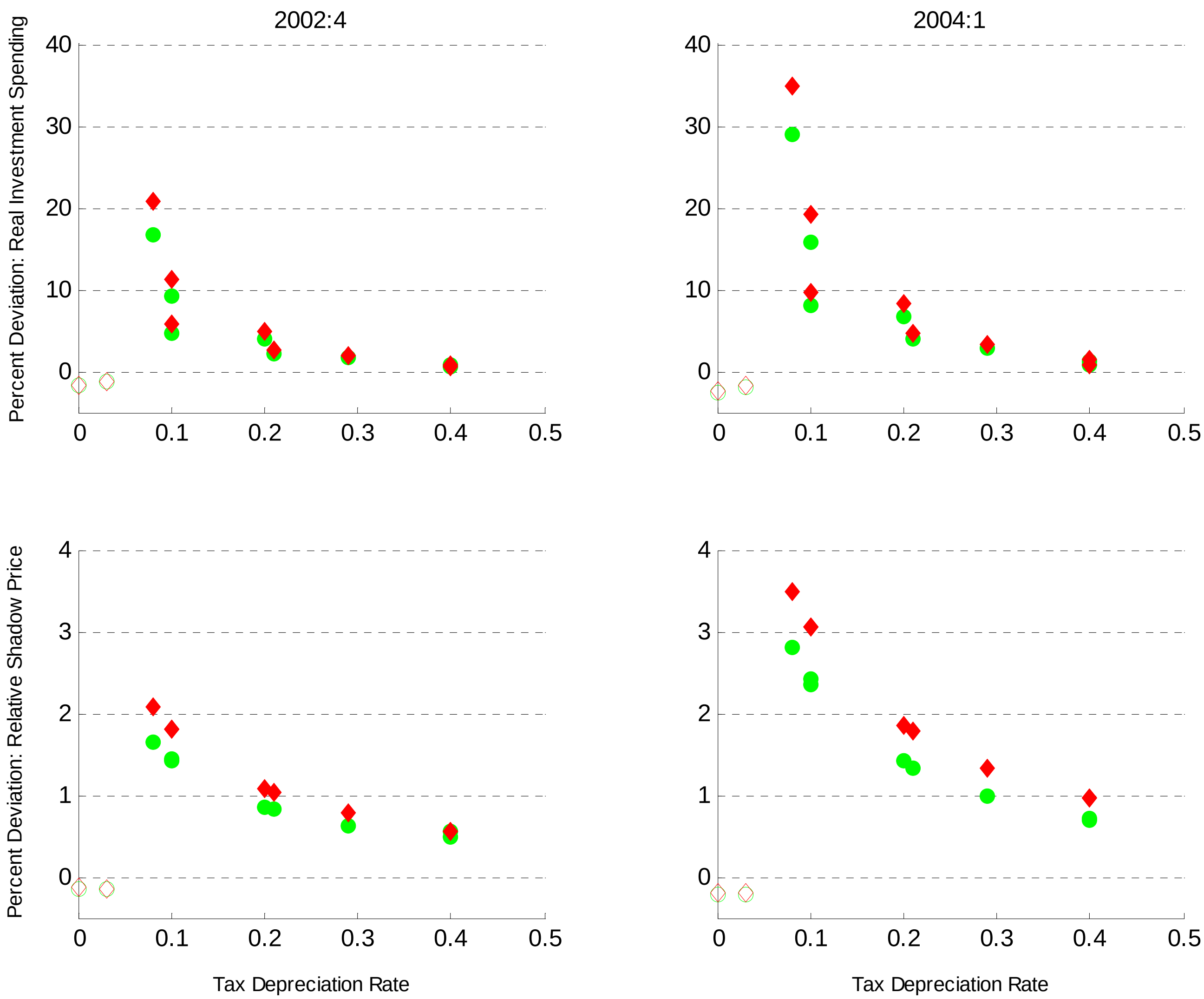


Figure 3: Simulated Changes in Investment and Relative Prices by Type of Capital



Note: Simulated response of investment and shadow prices for various types of capital to the 2002 and 2003 bonus depreciation policy as of 2002:4 and 2004:1. The tax depreciation rate ($\hat{\delta}^m$) is on the horizontal axis. Percent deviation from steady state is on the vertical axis. Circles are numerical calculations; diamonds are approximate calculations based on equations (22) and (24). Solid markers are for capital that qualifies for bonus depreciation. Empty markers are for capital that does not qualify.

Figure 4: Investment Forecast Errors 2002:1 - 2004:1

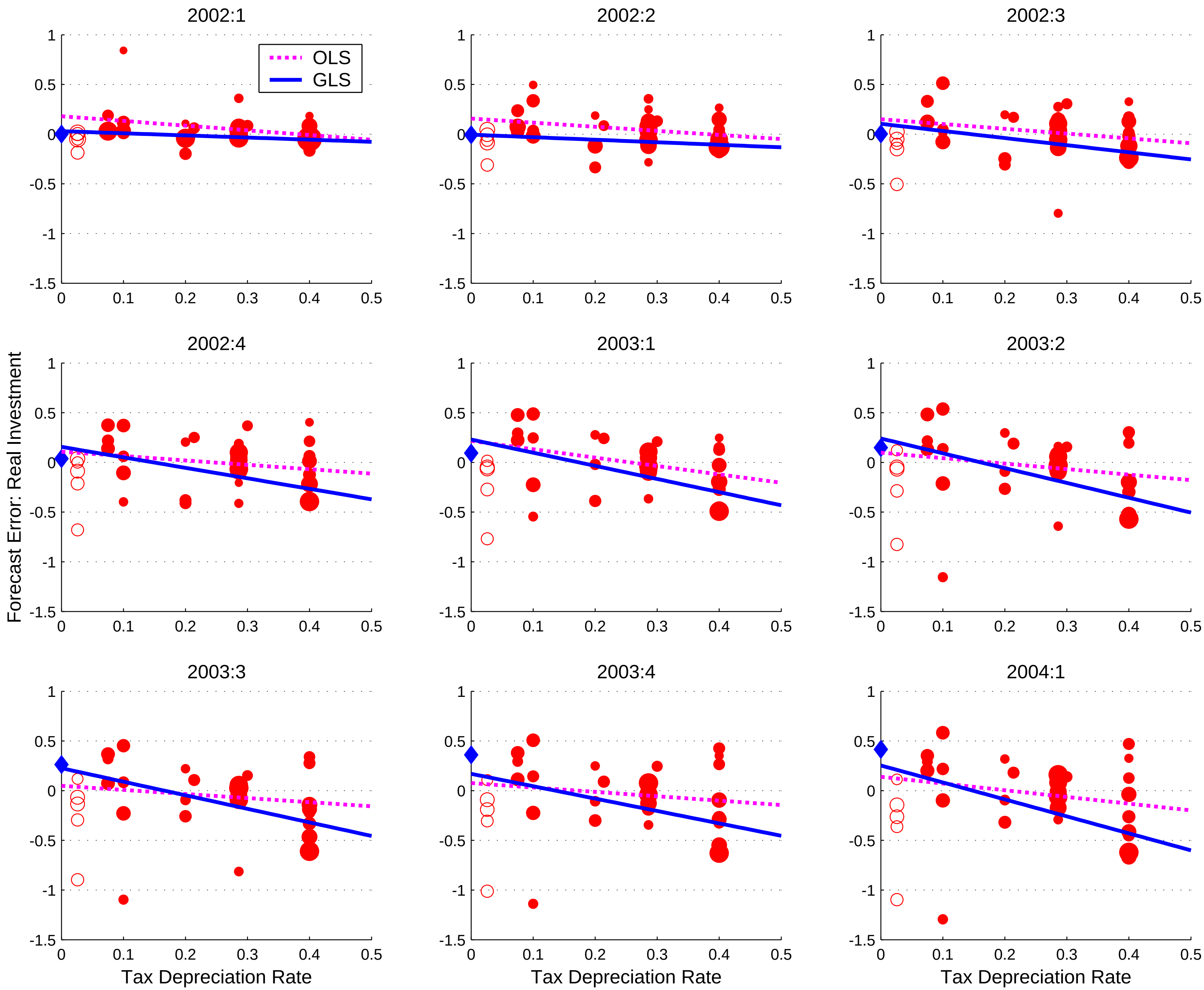


Figure 5: Price Forecast Errors 2002:1 - 2004:1