The Effects of Taxation on Business Investment: New Evidence from Used Equipment

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Abstract

This paper uses data on transaction prices of used farm machinery, aircraft, and construction machinery to examine the impact and incidence of tax incentives for investment. Theory predicts that incentives applying only to new investment should drive a wedge equal to the value of the incentives between the prices of new equipment and equally productive used equipment. Evidence from the repeal of the investment tax credit in the Tax Reform Act of 1986 produces a large and significant estimated effect of the ITC on the relative price of used farm machinery, with similar, but less robust results for aircraft. The estimated effect of recent bonus depreciation incentives on the price of used construction machinery is close to zero, however, suggesting that bonus depreciation had little value to machinery buyers.

JEL Codes: H25, H32, G31, E22
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1 Introduction

The effects of taxation on business investment have long been a focus of research in economics and finance. In the long run, the taxation of income from capital can provide the revenues needed to fund government, but may depress capital formation, output, and consumption. The optimal long-run level of capital income taxation remains the subject of vigorous debate in both the theoretical economics literature and in public political discourse. In the short run, policymakers frequently use tax policy in attempts to stimulate business investment. Recent examples include the "bonus depreciation" provisions in place in the U.S. from 2002 to 2004 and 2008 to 2009, and the allowance for full expensing of equipment investment in 2011. At the time of this writing, further efforts towards reforming the corporate income tax to encourage investment appear likely.

Although the effects of taxation on investment have inspired a voluminous theoretical literature and frequent tax policy changes, empirical evidence on the size of such effects remains mixed. To briefly summarize a large literature, early results like Eisner [1969], Summers [1981], Bernanke, Bohn, and Reiss [1988], and Chirinko, Fazzari, and Meyer [1999] implied small effects of tax variables on business investment. A more recent literature, including Auerbach and Hassett [1991], Cummins, Hassett, and Hubbard [1994], and Desai and Goolsbee [2004] has estimated larger effects. Regarding the bonus depreciation policy of the early 2000s, House and Shapiro [2008] find significant differences in investment across asset types that were differentially affected by the policy. *Using the same data*, Cohen and Cummins [2006] find no evidence for such effects. Overall, it seems that the effects of tax policy found in the investment data are quite sensitive to the choice of estimation method.

This paper measures the effects of tax policy in the market for investment goods using new data and an original methodology. Both the investment tax credit (in place prior to 1986) and more recent bonus depreciation incentives applied only to investment in new capital equipment. Theory predicts that incentives like these should drive a wedge between the price of new equipment and equally productive used equipment, where the size of this wedge

measures the implied value of the incentives to marginal investors. If the wedge is present and large, we can be more confident that the impact of taxation on investment comports with theoretical predictions. This paper estimates the size of this wedge for the first time using data on sales of used farm machinery, aircraft, and construction machinery.

This exercise also provides information on the incidence of tax incentives for investment, that is, to the distribution across agents of welfare gains or losses from incentives. Since the influential work of Summers [1981], it has been widely understood that tax policy changes can affect owners of existing assets through their impact on asset prices. A large literature based on this "asset price approach to incidence" provides theoretical and simulation results on the welfare impacts of various proposed tax changes. See, for example, Poterba [1984], Auerbach and Hines [1987], Goulder and Summers [1989], Bradford [1996], Hall [1996], Gentry and Hubbard [1997], Altig, Auerbach, Kotlikoff, Smetters, and Walliser [2001], and Judd [2001]. All of these papers assume that,

> "[s]ince equally productive units of new and old capital must sell for the same
> price, tax provisions favoring new capital imply a lower price for existing capital,"

as stated by Kotlikoff [1983].

There is surprisingly little empirical work examining this statement. In the absence of data on transaction prices of used assets, papers by Downs and Tehranian [1988], Cutler [1988], and Lyon [1989] tested for effects consistent with the asset price approach in stock market returns around the passage of tax legislation. Results from these papers are mixed. Cutler [1988], for example, finds no evidence for effects at the industry level. At the firm level, he finds evidence supporting the asset price approach in only one of several subsets of results. Noting the weakness of these results, Cutler concludes that the stock market may fail to price news about tax changes efficiently. His conclusion suggests that a more powerful test of the asset price approach might look for effects of tax changes through a direct comparison of prices of new and used assets, rather than in stock prices of firms that own them. To my knowledge, this is the first paper to conduct such a test.

The lack of prior evidence on this question likely stems from a paucity of relevant data on sales prices of used assets.[1] Although the Bureau of Labor Statistics tracks the prices of thousands of goods in order to construct various price indices, the only used goods prices they measure are for cars and other vehicles, for whom the marginal buyer is most likely a consumer. Seminal papers related to used asset prices like Hulten and Wykoff [1981] and Gordon [1990] relied primarily on values from published price guides to used equipment, in which the source of price estimates is unclear. In this paper, I use datasets on sales of aircraft and farm machinery that were first used by researchers studying questions unrelated to taxation. I also assemble a new dataset of more than one million sales of used construction machines using data available on the internet.

To summarize results, I find some evidence that the investment tax credit held down the relative price of used farm equipment, with similar, but less robust, results for aircraft. However, the estimated effect of recent bonus depreciation incentives on the relative price of used construction machinery is close to zero, and I can reject many plausible values in the range predicted by a neoclassical investment model. These estimates suggest that bonus depreciation had less value to machinery buyers than the neoclassical model would predict.

The following section of the paper models the expected effects of bonus depreciation on the relative prices of new and used machinery. Section 3 describes the data, Section 4 presents results, and Section 5 concludes.

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[1]A related literature tests for effects of property and other taxes in house prices. Results in this literature are mixed. Poterba [1990], Agell, Englund, and Sodersten [1996], and Boelhouwer, Haffner, Neuteboom, and Vries [2004] discuss the annual time series of housing prices surrounding changes in the income tax treatment of housing in the United States, Sweden, and several European countries, respectively. All three suggest that the time series are, at best, partially consistent with any affect of these tax changes on house prices. Another literature, dating at least to Oates [1969], attempts to measure the extent to which property taxes are capitalized into house prices, and finds a wide range of estimates. Neither literature makes use of the distinction between old and new capital, as the tax provisions under study typically apply to both old and new houses.

While an early version of this paper was circulating, Smith [2009] presented estimates of the change in used aircraft prices after the Tax Reform Act of 1986. He does not, however, compare movements in used and new prices, as I do here.

2   Theory

This section of the paper discusses theoretical predictions of the effects of tax incentives on the relative prices of used and new equipment. The empirical work to follow will be simple and transparent, but the model presented here shows that it is firmly grounded in a theoretical framework that has long been used to study taxation and investment. Subsection 2.1 presents a neoclassical model of the demand for machinery, and subsection 2.2 discusses the effects of tax incentives for investment in the context of the model. Subsection 2.3 extends the model the possibility that used machines are imperfect substitutes for new machines.

2.1   A Basic Model of Investment

I first introduce a relatively standard neoclassical model of investment, resembling that of Hall and Jorgenson [1967], to provide context for discussion of relevant tax legislation. A firm chooses its current investment in new machinery, I_t, and its stock of machinery, K_t, to maximize the present discounted value of after-tax cash flows. It solves,

$$\max \int_0^\infty e^{-rt}[(1-\tau)(F(K_t) - rD_t) - (1 - \tau z)p_t I_t + p_t I_t ITC_t + B_t]dt, \tag{1}$$

subject to,

$$\dot{K}_t = I_t - \delta K_t$$

$$\dot{D}_t = B_t$$

$$B_t \leq \phi p_t I_t.$$

Units of machinery can be purchased at price p_t and depreciate at a geometric rate of δ. Borrowing B_t increases the stock of debt D_t, which requires interest payments at the discount rate r. New borrowing is limited by the parameter ϕ, which is the debt capacity of

machines, or the maximum fraction of their purchase price that can be borrowed.[2] Modeling the determination of of optimal risky debt levels and interest rates is beyond the scope of this paper. The tax rate is τ, the present value of the depreciation deductions available on newly purchased machines is z, and the investment tax credit available from a dollar of investment is ITC. The solution to this problem requires that firms set,

$$F'(K_t) = p_t(r + \delta - \pi_t)\frac{1 - \tau(\phi + z) - ITC}{1 - \tau},$$
(2)

where $\pi_t = (\partial \Gamma_t / \partial t)/\Gamma_t$ for $\Gamma_t = p_t(1 - \tau(\phi + z) + ITC)$. This expression is quite similar to the seminal user cost of capital result in Hall and Jorgenson [1967].

2.2   The Value of Tax Incentives

The investment tax credit (ITC) was first introduced in 1962 at a rate of up to 7%. That is, firms could deduct an amount up to 7% of their investment spending from their tax bill. It was briefly repealed in 1969 and 1970 and then increased to 10% in 1975, before it was repealed by the Tax Reform Act of 1986. TRA86 was signed on October 22, 1986, but the repeal of the ITC was retroactive to equipment placed in service after December 31, 1985. This legislation was first introduced in the House of Representatives on December 3, 1985, so throughout 1986 firms may have known that the ITC had some probability of being repealed. At the time of its repeal, only a firm's first $125,000 of spending on used equipment could qualify for the ITC. Thus, the ITC was essentially limited to investment in new equipment.

More recent tax provisions have changed the timing of the depreciation deductions that businesses are allowed on purchases of new equipment; in the model, these provisions raise z. Table 1 summarizes the "bonus depreciation" tax incentives included in recent legislation.

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[2]The role of ϕ in the user cost of capital is determined by the formulation of this constraint. Other authors have sometimes limited the stock of debt D_t by the value of the capital stock $p_t K_t$, with or without some adjustment for tax variables. The formulation here provides a simple expression for the user cost with the possibility that ϕ substantially reduces the after-tax price of capital and amplifies the relative effects of tax incentives.

Table 1: Bonus Depreciation Provisions in Recent Legislation

Legislation	Proposed	Signed	Bonus Amt	Until
Job Creation and Worker Assistance Act	10/11/2001	03/09/2002	30%	09/10/2004
Jobs and Growth Tax Relief Reconciliation Act	01/07/2003	05/28/2003	50%	12/31/2004
Economic Stimulus Act	01/24/2008	02/13/2008	50%	12/31/2008
American Recovery and Reinvestment Act	01/26/2009	02/17/2009	50%	12/31/2009
Small Business Jobs Act	08/05/2010	09/27/2010	50%	12/31/2010
Tax Relief Act	12/01/2010	12/17/2010	100%	12/31/2011
			50%	12/31/2012

The Job Creation and Worker Assistance Act of 2002 included a 30% bonus depreciation provision, which allowed firms to deduct 30% of the purchase price of new equipment from taxable income in the year the equipment was placed in service. The remaining 70% was deducted under the standard schedules of the Modified Accelerated Cost Recovery System (MACRS). Bonus depreciation applies only to new equipment. Newly purchased used equipment continues to be depreciable under the standard MACRS schedules.

The provisions were signed into law on March 9, 2002, and applied retroactively to equipment placed in service after September 10, 2001. They were to remain in effect for equipment placed in service prior to September 11, 2004. On May 28, 2003, however, new legislation increased the deductible percentage to 50% and extended the provisions through December 31, 2004. On February 13, 2008, similar 50% bonus depreciation was enacted for equipment placed in service in 2008, and this incentive was later extended through 2009.[3] In early 2010, one might have thought there was some chance of bonus depreciation being extended again, but no legislation was enacted, and it began to seem less likely. Then, rather suddenly in September 2010, the Small Business Jobs Act reinstated 50% bonus depreciation retroactively on all investments made during 2010 (even those by large businesses). Later, the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010 enacted 100% bonus depreciation (expensing) for 2011, plus 50% bonus depreciation for

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[3]The JGTRRA and ESA also altered rules related to Section 179 expensing of equipment for small businesses. It is feasible that eligibility for Section 179 expensing could make bonus depreciation irrelevant for marginal equipment buyers. Were this the case, however, we should observe differential movements in prices for equipment likely to be eligible and ineligible for Section 179 expensing. In results not reported, I found no evidence of such price movements.

Table 2: Predicted Value of 10% Investment Tax Credit from Neoclassical Model

	$\tau = 0.25$ $\phi = 0$	$\tau = 0.46$ $\phi = 0$	$\tau = 0.46$ $\phi = 0.5$	$\tau = 0.46$ $\phi = 0.8$
$r = 0.05$	0.138	0.188	0.332	0.621
$r = 0.10$	0.135	0.176	0.296	0.504
$r = 0.15$	0.132	0.167	0.271	0.436

Figures in the table are values of $\ln(1-\tau(\phi+z))/(1-\tau(\phi+z)-ITC)$ under the indicated configurations of parameters, where τ is the marginal tax rate, z is the present value of depreciation deductions, r is the rate used to discount depreciation allowances, and ϕ is the fraction of a machine's purchase price that may be borrowed. These approximate the value of the 10% ITC as a percentage of the after-tax price for five-year property under the Accelerated Cost Recovery System.

2012. It is not clear which depreciation schedule machinery buyers believed would apply to their purchases during most of 2010, but results are not sensitive to including or excluding these observations.

Table 2 summarizes the value of a 10% investment tax credit by displaying the value of $\ln(1 - \tau(\phi + z))/(1 - \tau(\phi + z) - ITC)$ under different configurations of parameter values. All figures are for five-year property under the Accelerated Cost Recovery System (ACRS), the set of depreciation rules in place prior to TRA86, and the pre-TRA86 corporate tax rate of 46%. Essentially, these figures summarizes the value of the ITC as a fraction of the after-tax price of investment goods. As I describe below, I will estimate the magnitude of this quantity implied by the wedge between new and used machine prices.

The first thing to note about Table 2 is that the figures in it are all larger than 10%. When depreciation is accelerated such that z is close to 1, then the effective after-tax price of investment $(1 - \tau z)$ is far less than 1, even if $\phi = 0$. Thus an investment tax credit of 10% of the pre-tax price can be much more than 10% of this effective after-tax price. If $\phi > 0$ and investment provides additional debt shields as well, then the after-tax price can be lower still and the ITC even larger in percentage terms.

Table 3 presents similar figures summarizing the value of 50% bonus depreciation under

Table 3: Predicted Value of 50% Bonus Depreciation from Neoclassical Model

	$\tau = 0.25$ $\phi = 0$	$\tau = 0.35$ $\phi = 0$	$\tau = 0.35$ $\phi = 0.5$	$\tau = 0.35$ $\phi = 0.8$
$r = 0.05$	0.013	0.021	0.029	0.037
$r = 0.10$	0.024	0.038	0.051	0.064
$r = 0.15$	0.033	0.051	0.068	0.085

Figures in the table are values of $\ln(1-\tau(\phi+z))/(1-\tau(\phi+z^B))$ under the indicated configurations of parameters, where τ is the marginal tax rate, z is the present value of depreciation deductions, r is the rate used to discount depreciation allowances, and ϕ is the fraction of a machine's purchase price that may be borrowed. These approximate the value of bonus depreciation as a percentage of the after-tax price for five-year property under the Modified Accelerated Cost Recovery System.

the Modified Accelerated Cost Recovery System (MACRS) and 35% tax rate in place after the Tax Reform Act of 1986. These figures are far smaller than those for the ITC in Table 2, but still potentially economically important. This potential is rather sensitive to parameter values, however. If a buyer is taxed at 25% on marginal income, has no ability to borrow against the value of a newly-purchased machine, and discounts future tax savings at a rate of 5%, then bonus depreciation would be worth only 1.3% of the after-tax price of a new machine. On the other hand, if a buyer is taxed at the top corporate or individual rate of 35%, can borrow 80% of the cost of a machine, and discounts future tax savings at 15%, then she would value bonus depreciation at 8.5% of the after-tax price.

The predicted value of bonus depreciation is particularly sensitive to the rate at which future depreciation deductions are discounted. Summers [1987] argues that firms should discount depreciation deductions at a rate close to the risk-free Treasury rate, since they are essentially obligations of the U.S. government. However, he reports results from a survey of firms suggesting that few, if any, firms followed this practice. At least 93% of respondent firms indicated that they discounted depreciation deductions at the same rate as all other cash flows associated with their investment projects. The median reported nominal discount rate was 15%. Meier and Tarhan [2006] report results from a similar survey conducted during

the first bonus depreciation episode in October 2003. The median reported nominal discount rate in their sample was 14%.

In light of this evidence it would seem quite reasonable to assume that marginal buyers of construction machinery discount depreciation deductions at 15% or more. Even if one were to assume that marginal buyers discount deductions at a 10% rate, Table 3 suggests that the value of bonus depreciation could easily exceed 5% of the after-tax price.

2.3 New versus Used Machines

In the model just discussed, new and used machinery were perfect substitutes. Output depended only on the total machinery stock, which consisted of a mix of machinery of various vintages. To match features of the data which will soon be discussed, I extend the model to allow new and used machinery to enter the production function as imperfect substitutes. Firms solve,

$$\max \int_0^\infty e^{-rt}[(1-\tau)(F(K_t^N, K_t^U) - rD_t) - (1-\tau z^N - ITC)p_t^N I_t^N - (1-\tau z^U)p_t^U I_t^U + B_t]dt, \quad (3)$$

subject to,

$$\dot{K}_t^N = I_t^N - \delta K_t^N - e^{-\delta T^N} I_{t-T^N}^N$$

$$\dot{K}_t^U = I_t^U - \delta K_t^U + e^{-\delta T^N} I_{t-T^N}^N$$

$$\dot{D}_t = B_t$$

$$B_{it} \le \phi(p_t^N I_t^N + p_t^U I_t^U).$$

The prices of equivalent units of new and used machines are p_t^N and p_t^U.[4] The stocks of new and used machines are K_t^N and K_t^U. I_t^N and I_t^U are investments in new and used

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[4]One might think of p_t^N and p_t^U as the prices of machines that can provide the same (discounted) number of hours of service over their remaining lifetimes. Hours of service of new and used machines enter the production function as imperfect substitutes. Physical depreciation reduces the number of hours of service that a machine can provide per year.

machines. That is, I_t^U represents new acquisitions of previously-owned machines for an individual firm, or imports of used machines for the aggregate economy. The present values of the depreciation deductions available on newly purchased new and used machines are z^N and z^U. Other variables are as above.

The dynamics of the new and used capital stocks embed the assumption that newly manufactured machines remain "new" for a period of T^N years, at which point they become "used." This somewhat crude formulation captures the notion that used machines may become less substitutable for new machines as they age, in addition to physically depreciating. This imperfect substitutability could come from a variety of sources. For example, perhaps old and new machines require operators with somewhat different skillsets, making them imperfect substitutes in production. Or perhaps old machines are more often used for parts or as backups for newer machines.

The solution to (3) requires,

$$F_U(K_t^N, K_t^U) = p_t^U(r + \delta - \pi_t^U)\frac{1 - \tau(\phi + z^U)}{1 - \tau}, \tag{4}$$

where F_U denotes the first derivative of the production function with respect to the used capital stock. This expression is quite similar to the one derived in the previous section. A similar expression applies for the new capital stock,

$$F_N(K_t^N, K_t^U) = p_t^N(r + \delta + \tilde{\lambda}_t - \pi_t^N)\frac{1 - \tau(\phi + z^N) - ITC}{1 - \tau}, \tag{5}$$

where the term $\tilde{\lambda}_t$ captures the shadow cost or benefit incurred by buyers of new machines that is associated with their eventual transformation into used machines. These results are derived in an appendix, which also discusses the case where firms face explicit costs of adjusting their machinery stock.[5]

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[5]In previous versions of the paper, I explicitly modeled the possibilities that contractors lease machines from third-party lessors and that buyers may resell machines prior to the end of their useful lives, triggering recapture of tax benefits. Both possibilities results in modifications to the user cost expressions in equations

I will study substitution between new and used machines by considering the ratio of these equations. In the case where new and used machines are, in fact, perfect substitutes, then $F_U = F_N$ and $\pi_t^U = \pi_t^N - \tilde{\lambda}_t$. Taking logs of the ratio of (4) and (5) then produces,

$$\ln \frac{p_t^U}{p_t^N} = \ln \frac{1 - \tau(\phi + z^N) - ITC}{1 - \tau(\phi + z^U)}. \tag{6}$$

When new and used machines are perfect substitutes and both are used in production, their prices must be equal, unless taxes drive a wedge between them. These assumptions underlie the large literature based on the asset price approach to incidence cited previously.[6]

Suppose instead that new and used machines are combined to create a composite stock of machines such that,

$$F_t(K_t^N, K_t^U) = A_t[G_t(K_t^N, K_t^U)]^\alpha,$$

with $G_t(K_t^N, K_t^U)$ taking the familiar constant elasticity of substitution form,

$$G_t(K_t^N, K_t^U) = \left[(A_t^N K_t^N)^{\frac{\sigma-1}{\sigma}} + (A_t^U K_t^U)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}.$$

This formulation would allow, for example, production to take a Cobb-Douglas form in labor, materials, and the CES composite capital stock. Shocks to output prices, labor supply, labor productivity, total factor productivity, and the like are all captured as changes in A_t.

In this more general case, taking logs of the ratio of the marginal products of new and used capital produces,

$$\ln \frac{p_t^U}{p_t^N} = \ln \frac{1 - \tau(\phi + z^N) - ITC}{1 - \tau(\phi + z^U)} + \frac{1}{\sigma} \ln \frac{K_t^N}{K_t^U} - \frac{\sigma-1}{\sigma} \ln \frac{A_t^U}{A_t^N} - \ln \frac{r + \delta - \pi_t^U}{r + \delta + \tilde{\lambda}_t - \pi_t^n}. \tag{7}$$

(4) and (5). If contractors lease machines from competitive lessors, it is the lessors' tax variables that determine the user cost. If contractors or lessors sell machines before their useful lives end, triggering recapture of tax savings, then, essentially, z^N and z^U must be modified to reflect the value of recapture. Neither modification affects the empirical approach I take in this paper, so I omit them.

[6]Eisfeldt and Rampini [2007] study a model where new and used capital are perfect substitutes in production, but used capital requires the payment of maintenance costs. Credit constraints can then create an additional wedge between their prices.

From the last three terms we see that the log ratio of used and new prices is related to the log ratio of new and used capital and affected by time variation in relative productivity (A_t^U/A_t^N) and forecasted price changes $(\pi_t^U, \pi_t^N,$ and $\tilde{\lambda}_t)$. Note that when new and used capital are perfect substitutes, $A_t^U = A_t^N$, $\sigma \to \infty$, and (7) reduces to (6). Most importantly, any difference in the tax treatment of new and used machines continues to drive a wedge between new and used prices, now conditionally on the chosen ratio of new and used capital.

The movements in relative used prices induced by tax incentives in equation (7) reflect the impact of investment in new machines on the marginal product of used machines. When new and used machines are imperfect CES substitutes, an increase in new investment may either increase or decrease the marginal product of used machines. In the model above, the marginal product of used capital is decreasing in new capital if and only if $\sigma(1 - \alpha) > 1$.[7] The existing literature on the asset price approach to incidence assumes that new and used capital are perfect substitutes ($\sigma \to \infty$), and thus that increased investment in new capital sharply decreases the marginal product of used capital. I will estimate σ and assess the validity of this assumption.

Subsume the last two terms in (7) into a single error term ϵ_t,

$$\ln \frac{p_t^U}{p_t^N} = \ln \frac{1 - \tau(\phi + z^N) - ITC}{1 - \tau(\phi + z^U)} + \frac{1}{\sigma} \ln \frac{K_t^N}{K_t^U} + \epsilon_t. \tag{8}$$

When the ITC and bonus depreciation are not in effect, the first term on the right-hand side

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[7]The derivative of the marginal product of used capital with respect to new capital is,

$$\frac{\partial^2 F(K^N, K^U)}{\partial K^U \partial K^N} = \alpha A_t A_t^U A_t^N \frac{\sigma(\alpha - 1) + 1}{\sigma} (K_t^U K_t^N)^{\frac{-1}{\sigma}} \left[(A_t^N K_t^N)^{\frac{\sigma-1}{\sigma}} + (A_t^U K_t^U)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma(\alpha-2)+2}{\sigma-1}}.$$

This quantity is negative if and only if $\sigma(1 - \alpha) > 1$.

is equal to zero.[8] I will thus estimate equations of the form,

$$\ln \frac{p_t^U}{p_t^N} = \eta_0 \mathrm{ITC}_t + \eta_1 \ln \frac{K_t^N}{K_t^U} + \epsilon_t$$

$$\ln \frac{p_t^U}{p_t^N} = \eta_0 \mathrm{BONUS}_t + \eta_1 \ln \frac{K_t^N}{K_t^U} + \epsilon_t.$$

The dummy variables ITC_t and BONUS_t will take the value of 1 when the ITC and bonus depreciation provisions were in effect. The coefficient η_0 on these variables will measure $\ln(1 - \tau(\phi + z^N) - ITC)/(1 - \tau(\phi + z^U))$, the value of these incentives implied by market prices.[9]

Credible identification of these equations might appear challenging, as they have price variables on the left-hand-side and quantity variables on the right. However, the fact that they are *relative* prices and quantities solves the problem. Once could formally write a system of four structural equations that determines the four price and quantity variables,

$$p_t^U (r + \delta - \pi_t^U) \frac{1 - \tau(\phi + z^U)}{1 - \tau} = A_t \alpha \sigma \left[(A_t^N K_t^N)^{\frac{\sigma-1}{\sigma}} + (A_t^U K_t^U)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} A_t^U K_t^U$$

$$p_t^N (r + \delta + \tilde{\lambda}_t - \pi_t^N) \frac{1 - \tau(\phi + z^N) - ITC}{1 - \tau} = A_t \alpha \sigma \left[(A_t^N K_t^N)^{\frac{\sigma-1}{\sigma}} + (A_t^U K_t^U)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} A_t^N K_t^N$$

$$K_t^U = f_s^U(p_t^U, \theta^U, \nu_t^u)$$

$$K_t^N = f_s^N(p_t^N, \theta^N, \nu_t^N).$$

The first two of these are the demand equations for used and new capital formally derived in the text. The second are unspecified supply equations for used and new capital, where θ^U and θ^N are parameters and ν^U and ν^N are supply shocks. The solution (p^N, p^U, K^N, K^U) to

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[8]Even if ϕ or r vary across new and used assets when bonus depreciation is not in effect, this value will be absorbed by a constant. The BONUS and ITC dummies will still pick up the percentage change in the value of depreciation deductions for new equipment.

[9]That the end of bonus depreciation, presumably anticipated by market participants, would induce an increase in used machinery prices requires the assumption that all buyers intend to hold machinery for some time before selling it. Otherwise arbitrageurs could make money by purchasing used machinery cheaply while bonus depreciation is in place and selling it soon after expiration. In fact, reselling of individual machines is quite rare in the data, suggesting that transactions costs may prevent such arbitrage. Less than 0.5% of the construction machinery sales observations are repeat sales of machines with the same serial number.

Figure 1: New/Used Price and Quantity Ratios with Shocks to Aggregate Demand
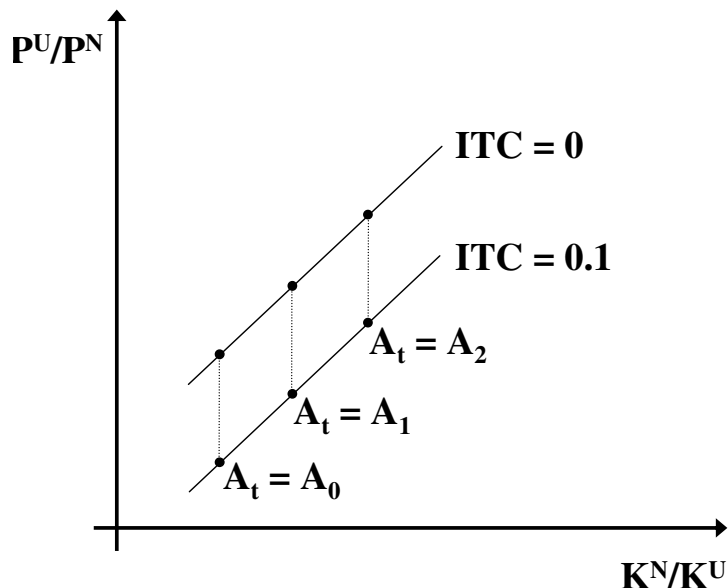
This figure illustrates how schocks to output demand (for example, the demand for construction) or machinery supply affect the relative prices and quantities of new and used machinery when the supply of used machinery is inelastic relative to that of new machinery. As construction demand increases, ($A_0 < A_1 < A_2$), the relative price of used machinery and the quantity of new machinery both rise together, tracing out the line in the figure. The presence of the investment tax credit or bonus depreciation would shift this line. The empirical work to follow estimates the slope of the line along with the shift induced by tax changes.

these four equations, will in general depend on the aggregate demand shock A_t, which can represent, for example, shocks to demand for construction, along with the supply shocks ν_t^U and ν_t^N. Changes to A_t will thus create changes in p^N/p^U and K^N/K^U. A_t, however, does not appear in the relative demand equation in (7). Thus if relative price and quantity changes are driven primarily by changes in aggregate demand for output and not by idiosyncratic shocks to new or used capital (i.e. A_t^U/A_t^N), then OLS estimates of (8) will not be badly biased. One could also use variables that proxy for output demand as instruments in estimation of (8).

Intuitively, the case for identification is also clear. It will be quite apparent in the data that relative prices and quantities covary strongly, and that these comovements are driven by shifts in demand for output. For example, when demand for construction is high, used construction machinery prices and investment in new construction machinery are both high.

As long as one is willing to assume that these aggregate shifts in demand for construction are uncorrelated with shocks that differentially affect the productivity of new and used machinery (whatever such shocks might be), then estimates of equation (8) will be unbiased. For example, the last several years in the United States have seen wild swings in construction activity associated with a boom and bust in housing markets that many believe was caused by a speculative bubble and not by economic fundamentals.[10] It will be clear in the data that these swings in demand for construction created large swings in both used construction machinery prices and investment in new construction machinery. As long as these swings were not correlated with large productivity shocks that were specific to either new or used machinery, then OLS estimates of equation (8) will not be badly biased.

Figure 1 illustrates this scenario. Shocks to A_t change p^N, p^U, K^N, K^U through the relationships in the four-equation system above, tracing out the relationship in equation (8). Changes in the ITC or bonus depreciation can shift this relationship.

3   Data

I use three sources of data on prices of used equipment. For farm machinery, I use a dataset of 1,669 auction sales of used farm machinery that took place from 1984 to 1990. These were gathered from printed issues of the Hot Line Farm Equipment Guide and originally used by Perry, Bayaner, and Nixon [1990], Cross and Perry [1995], and Wu and Perry [2004] to study farm equipment depreciation patterns. For aircraft, I use a dataset of 3,333 sales of used airplanes from 1978 to 1991 assembled by Avmark Inc. from Department of Tansportation and Federal Aviation Administration filings. These data were first used by Pulvino [1998] to study asset "fire sales." Finally, I assembled a dataset of over a million auction sales of used construction machines from 1994 to the present using data available on equipmentwatch.com

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[10]For example, Robert Solow wrote in the *New York Review of Books*, "The word "bubble" is often misused; but there was a housing bubble. Rising house prices induced many people to buy houses simply because they expected prices to rise; those purchases drove prices still higher, and confirmed the expectation. Prices rose because they had been rising."

and machinerytrader.com.

For all three equipment types, I estimate regressions of log price on a set of dummies for assets (e.g. the Caterpillar 416C backhoe loader), age (e.g. 6 years old), and time (e.g. 1987Q3). The time dummies are first transformed using the method of Deaton [1997], which ensures that the time dummy coefficients have zero mean. The series of estimated coefficients on the time dummies is a quality-adjusted, age-adjusted, detrended price index for used equipment. I work with price indices estimated at a quarterly frequency.

For prices of new equipment, I use the Producer Price Indices for agricultural machinery, aircraft, and construction machinery. These are quality-adjusted price indices for new equipment based on surveys of U.S. manufacturers conducted by the Bureau of Labor Statistics. The PPI intends to measure the price received by the manufacturer, and thus it does not include things like excise taxes or dealer markups. The PPI does, however, capture the effects of manufacturer-to-customer price incentives like rebates and low-interest financing plans.[11]

It is possible, unfortunately, that price changes relevant to the results of this paper may appear in dealer markups as well as in manufacturer-to-dealer prices and manufacturer-to-customer incentives. It is also possible that the PPI surveys simply fail to capture some relevant movements in new machinery prices. I am not aware of any data that would permit systematic analysis of prices for new machinery in transactions between dealers and customers. Data from markets for new and used cars, however, can arguably bear on the likely importance of dealer markups and systematic measurement error for interpreting the results in this paper. The BLS collects PPI data on manufacturer-level new car prices and CPI data

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[11]According to the BLS Handbook of Methods, "Because the PPI is meant to measure changes in net revenues received by producers, changes in excise taxes—revenues collected on behalf of the government—are not reflected in the index. But changes in rebate programs, low-interest financing plans, and other sales promotion techniques are reflected to the extent that these policies affect the net proceeds ultimately realized by the producer for a unit sale. If an auto manufacturer offers retail customers a rebate of $500, the manufacturer's net proceeds are reduced by $500 and the PPI for new cars would reflect a lower price. . . .The statistical accuracy of producer price indexes depends heavily on the quality of the information voluntarily provided by respondents. BLS emphasizes to cooperating businesses the need for reports of realistic transaction prices, including all discounts, premiums, rebates, allowances, and so forth, rather than list or book prices (Bureau of Labor Statistics [2008])".

on retail-level new car prices. The CPI measure of new car prices includes dealer markups and manufacturer rebates, but excludes manufacturer financing incentives. The PPI measure includes manufacturer rebates and financing incentives, but excludes dealer markups. The PPI series fluctuates far more over the course of the model year cycle than does the CPI, suggesting that most price changes appear at the producer price level. Further, the declines in PPI prices over each model year are comparable to the declines in customer-level prices net of rebates and financing incentives that are documented by Copeland, Dunn, and Hall [2005] using detailed data on transactions between dealers and customers. Thus, if the data on cars are relevant for interpreting data on the kinds of equipment studied here, it appears that the PPI should capture the majority of movements in the prices faced by potential buyers of new equipment.

To create indices that are comparable to the used price indices just described, I detrend the PPIs by regressing their logarithms on a linear trend and taking the residuals. Note that I do not observe the absolute level of the prices of new and used machinery, but I can observe their relative changes over time by comparing changes in these indices. For data on new investment and the stock of used capital, I use data from the Fixed Assets tables of the Bureau of Economic Analysis.

4   Results

Figure 2 graphs the new and used price series for construction machinery. It is immediately clear from the figure that used prices fluctuate far more than new prices. For example, used prices fell by about 15% (relative to trend) between 1998 and 2003, while new prices fell by only 6%. Used prices fell by more than 30% from the peak of the housing boom in 2006 to their trough in 2009.

It is also clear from the figure that simply regressing the ratio of used to new prices on a dummy for the presence of bonus depreciation would give a misleading impression of

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Figure 2: New and Used Prices: Construction Machinery
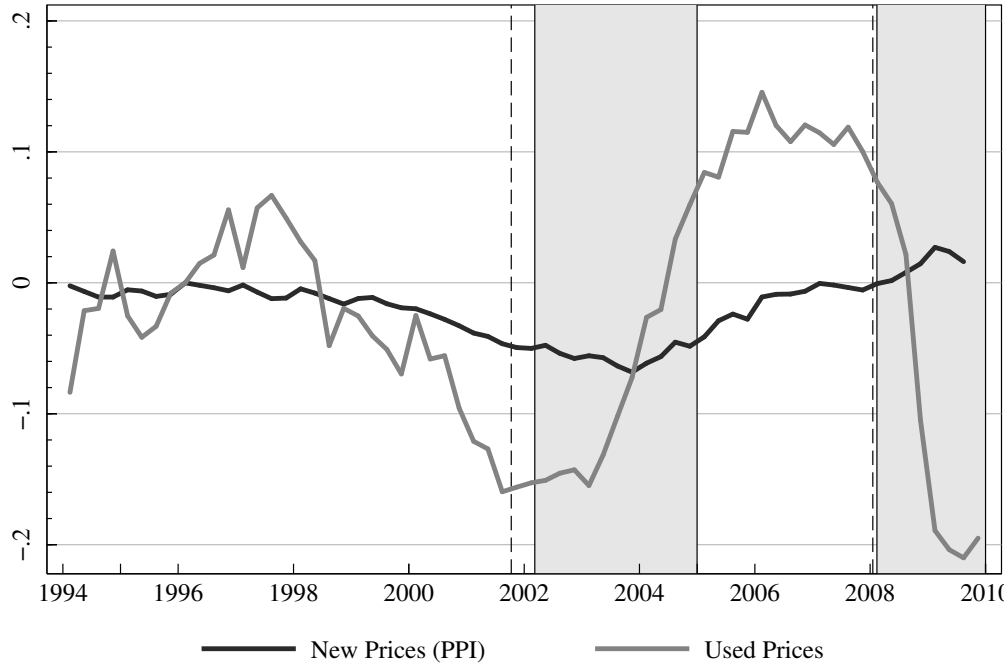
Both series in logarithms, detrended and indexed to 1996Q1.
Bonus depreciation was first proposed at the dashed lines and was in place during the shaded periods.

the impact of bonus depreciation on relative prices. Used prices began falling far before the first episode of bonus depreciation began in 2002, and they actually rose throughout the episode. Used prices plummeted during the second bonus depreciation episode in 2008 and 2009, but one suspects that this movement was driven primarily by the collapse of the housing market and not by bonus depreciation. It is thus clear that correctly controlling for other events contemporaneous with tax changes will be crucial for estimating any effects of the tax changes on relative prices. The model developed above suggests that any other factors affecting the equipment market are effectively summarized in the ratio of new to used equipment. This notion is intuitively appealing as well—any factors affecting demand for equipment should appear in quantities as well as prices.

Figure 3 graphs the ratio of used to new prices against the ratio of new investment to used capital for all three equipment types. Looking first at the construction machinery data in the third panel, it is immediately clear that the used to new price ratio and the investment

ratio move together quite closely. They both reached a trough in 2002, peaked during the housing boom in 2006, and crashed in 2008 and 2009. Bonus depreciation, in place during the shaded periods in the graph, should have driven the investment ratio up relative to the used to new price ratio. It is difficult to see any effect of bonus depreciation in the graph.

The top panels of Figure 3 present similar data for farm machinery and aircraft. The price series are considerably noisier than the construction machinery series due to the far smaller numbers of observations available for these other equipment types. The dashed vertical lines in the figures represent the introduction of the Tax Reform Act of 1986 in the House of Representatives on December 3, 1985, and the solid lines represent its signing by President Reagan on October 22, 1986. The investment ratio and used to new price ratio series are both indexed to 1987Q1, just after the enactment of TRA86.
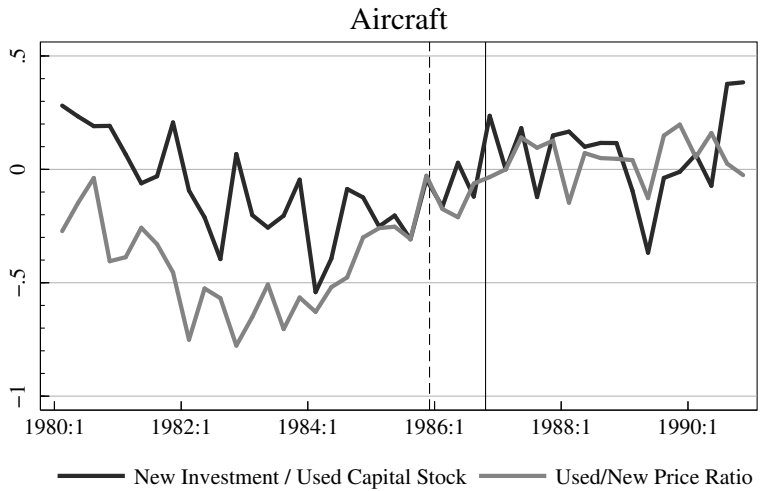
The presence of the investment tax credit should have held down relative used prices prior to TRA86, and the data in the top panels of Figure 3 are consistent with this story. New investment and used prices for farm machinery were both falling prior to TRA86, but used prices jumped and remained high following passage of the Act. New investment and used prices for aircraft were falling together from 1980 to 1982, and rising together from 1982 to 1985. Between 1983 and 1987, used prices rose considerably relative to new investment. This fact alone is consistent with a role for TRA86, but it also appears in the figure that the gap was already narrowing in 1984 and 1985. Thus it may be harder to conclude that TRA86 was responsible for the change.

Table 4 presents regression results for farm machinery in Panel A and for aircraft in Panel B. All regressions use price indices at a quarterly frequency and are weighted using the number of used sales observations in each quarter. Unweighted estimates are very similar. Column 1 presents a simple regression of the used to new price ratio on a dummy for the presence of the investment tax credit. The sample in this column includes all available data from 1984 to 1990, excluding quarters 1, 2, and 3 of 1986, when passage of TRA86 was possible, but not assured. On average, relative used prices were 8.9% lower when the

Figure 3: New Investment and Used/New Price Ratios
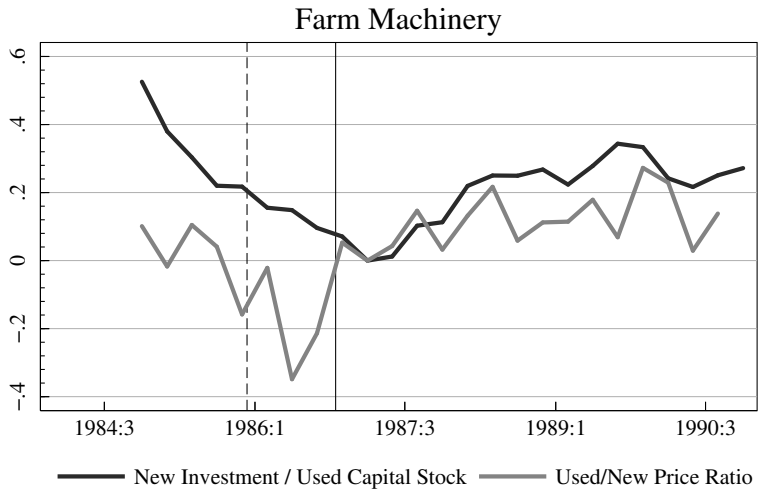
Farm Machinery

New Investment / Used Capital Stock —— Used/New Price Ratio

Both series in logarithms, detrended and indexed to 1987q1.
TRA86 was first introduced at the dotted line and enacted at the solid line.

Aircraft

New Investment / Used Capital Stock —— Used/New Price Ratio

Both series in logarithms, detrended and indexed to 1987q1.
TRA86 was first introduced at the dotted line and enacted at the solid line.

Construction Machinery

New Investment / Used Capital Stock —— Used/New Price Ratio

Both series in logarithms, detrended and indexed to 1996Q1.
Bonus depreciation was first proposed at the dashed lines and was in place during the shaded periods.

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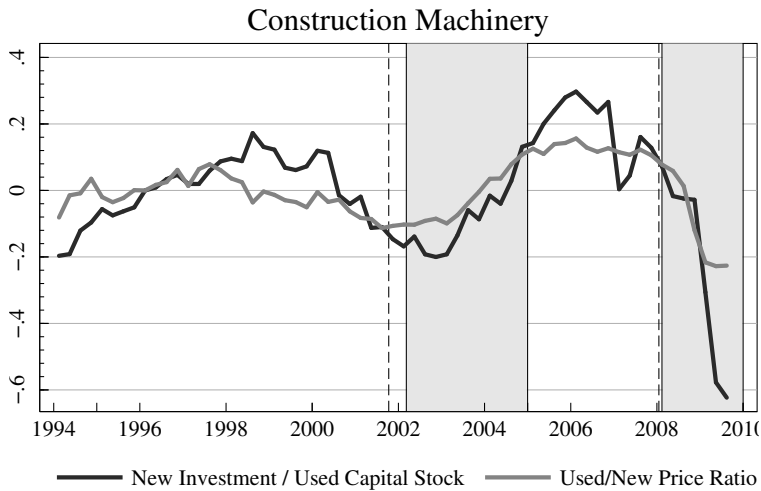
ITC was in effect. Column 2 includes the logarithm of the ratio of new investment to the used capital stock as a regressor, as suggested by equation (7) above. Column 2 suggests that the ITC caused a 14.9% reduction in relative used prices. Columns 3 and 4 include quarters 1, 2, and 3 of 1986 in the regression with ITC = 1 during this time, thus assuming that market participants correctly anticipated the passage of TRA86. Estimates in column 4 use Newey-West standard error with a lag length of four, and are thus robust to serial correlation with residuals up to four quarters away. Standard errors actually fall somewhat in this specification. Columns 5 through 7 limit the "post-period" sample to 1987 and 1988, and the estimated ITC effect rises a bit in magnitude. Columns 8 and 9 introduce linear and quadratic time trends. Point estimates change little, although the ITC dummy loses statistical significance in column 9. The median point estimate from columns 2 through 9 suggests that the investment tax credit lowered the relative price of used farm machinery by about 17%. This estimate is right in line with the predicted values of the ITC in column 2 of Table 2.

Table 4: Regressions of Log Used/New Price Ratio on ITC and I/K

Panel A: Farm Machinery

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ITC	-.089	-.149	-.164	-.164	-.159	-.177	-.177	-.199	-.174
	(.044)**	(.037)***	(.035)***	(.028)***	(.049)***	(.045)***	(.033)***	(.090)**	(.133)
Log I/K		.501	.539	.539	.528	.581	.581	.583	.588
		(.134)***	(.136)***	(.060)***	(.177)***	(.176)***	(.088)***	(.191)***	(.198)***
Observations	21	21	24	24	14	17	17	21	21
R^2	.179	.538	.577	.577	.519	.551	.551	.548	.55
Start Year	1984	1984	1984	1984	1984	1984	1984	1984	1984
End Year	1990	1990	1990	1990	1988	1988	1988	1990	1990
Exclude Q1-Q3 1986	Yes	Yes	No	No	Yes	No	No	Yes	Yes
Time Trend	None	None	None	None	None	None	None	Linear	Quadr.

Panel B: Aircraft

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ITC	-.489	-.465	-.423	-.423	-.202	-.161	-.161	-.165	-.070
	(.056)***	(.067)***	(.067)***	(.120)***	(.107)*	(.095)*	(.122)	(.112)	(.094)
Log I/K		.095	.124	.124	.492	.543	.543	.104	.146
		(.148)	(.152)	(.143)	(.246)**	(.228)**	(.268)**	(.130)	(.105)
Observations	33	33	36	36	17	20	20	33	33
R^2	.712	.716	.665	.665	.732	.697	.697	.788	.867
Start Year	1982	1982	1982	1982	1984	1984	1984	1982	1982
End Year	1990	1990	1990	1990	1988	1988	1988	1990	1990
Exclude Q1-Q3 1986	Yes	Yes	No	No	Yes	No	No	Yes	Yes
Time Trend	None	None	None	None	None	None	None	Linear	Quadr.

This table presents regressions of the form:

$$\ln \frac{p_t^U}{p_t^N} = \eta_0 \text{ITC}_t + \eta_1 \ln \frac{I_t^N}{K_{t-1}^U} + \epsilon_t,$$

where ITC is a dummy variable indicating the presence of a 10% investment tax credit. Standard errors in Columns 4 and 7 are Newey-West with a lag length of 4.

*** indicates statistical significance at the 1% level, ** at 5%, and * at 10%.

Panel B of Table 4 presents similar results for aircraft. Results are far less consistent across specifications than results for farm machinery. Columns 1 though 4 use data from 1982 to 1990, and estimate that relative used prices were more than 40% lower when the ITC was in place. Columns 5 through 7 limit the sample to 1984 to 1988, thus narrowing the pre- and post-periods to two years each. This cuts the estimate to 16%, which is very similar to estimates from Panel A for farm machinery. Adding linear and quadratic trends in columns 8 and 9 lowers the estimate to as little as 7%, and results are no longer statistically different from zero. As was clear from Figure 3, the used prices began rising relative to new investment well before TRA86, so results are sensitive to changes in the sample period and including trend controls. It may thus be harder to be certain that the Act played any role in these price changes.

Table 5 presents similar results for construction machinery over the period from 2000 to 2009. The first column, with no controls, shows that relative used prices were 8.8% lower when bonus depreciation was in effect. Adding controls for the investment ratio and for linear and quadratic trends in columns 2 through 5 makes the estimated effect of bonus depreciation change sign and lose significance. The lower bound on the 95% confidence interval for the effect of bonus depreciation ranges from -0.8% in column 2 to -4.9% in column 5. Thus, there is little evidence that bonus depreciation had a negative effect on the relative prices of used construction machinery, and we can often reject many plausible values from the neoclassical investment model displayed in Table 3.

Another conclusion that emerges from these results is that new and used equipment are far from perfect substitutes. In fact, this is immediately apparent from Figure 3. If new and used equipment were perfect substitutes, we would see demand for new equipment fall to zero as soon as the price of used equipment falls relative to new equipment. Instead, firms continue to purchase new equipment even when the price of used equipment has fallen dramatically.

In the model developed above, the reciprocals of the coefficients on the investment ratio

Table 5: Regressions of Log Used/New Price Ratio on BONUS and I/K

	Construction Machinery				
	(1)	(2)	(3)	(4)	(5)
BONUS	-.088	.034	.034	.010	-.012
	(.038)**	(.021)	(.029)	(.020)	(.019)
Log I/K		.524	.524	.501	.415
		(.046)***	(.054)***	(.042)***	(.043)***
Observations	39	39	39	39	39
R^2	.129	.811	.811	.852	.892
Time Trend	None	None	None	Linear	Quadr.

This table presents regressions of the form:

$$\ln \frac{p_t^U}{p_t^N} = \eta_0 \text{BONUS}_t + \eta_1 \ln \frac{I_t^N}{K_{t-1}^U} + \epsilon_t,$$

where bonus is a dummy variable indicating the presence of 50% bonus depreciation.
Standard error in Column 3 is Newey-West with a lag length of 4.
*** indicates statistical significance at the 1% level, ** at 5%, and * at 10%.

in Tables 4 and 5 are estimates of σ, the elasticity of substitution between new and used equipment. These estimates range between 1.7 and 2.0 for farm machinery, between 1.8 and 10.5 for aircraft, and between 1.9 and 2.4 for construction machinery. These estimates suggest that the assumption of perfect substitution ($\sigma = \infty$) maintained in the literature on the asset price approach to tax incidence may not be very realistic. Were tax changes to induce a proliferation of new capital, these estimates suggest there would be only a modest impact on the marginal product of used capital. This may explain the weak evidence for any effects consistent with the asset price approach to incidence presented by Cutler [1988] and others.

5   Conclusions

This paper has presented evidence consistent with a model where the investment tax credit held down the relative price of used farm machinery. There is less robust evidence for similar effects of the ITC on used aircraft. There is no evidence, however, that recent bonus

depreciation investment incentives had any effect on the relative price of used construction machinery, and we can reject many plausible values for the value of bonus depreciation from a calibrated neoclassical investment model. Thus it seems that machinery buyers placed little value on bonus depreciation.

These results beg the question of why the investment tax credit would shift the demand curve for investment, while bonus depreciation would not. In other work, I have studied two potential reasons behind these results. In Edgerton [2010], I investigate the role of recent corporate losses in mitigating the effects of bonus depreciation, and in Edgerton [2009], the role of the accounting treatment of depreciation deductions. Each of these appears to have played some role, but puzzles remain. Knittel [2007], for example, documents that the firms making 40% of the investments eligible for bonus depreciation neglected to claim the benefits to which they were entitled. More research directed towards understanding this behavior would be welcome.

6   Appendix

The firm solves,

$$\max \int_0^\infty e^{-rt}[(1-\tau)(F(K_t^N, K_t^U) - rD_t - \psi(I_t^N, I_t^U, K_t^N, K_t^U)) - (1-\tau z^N)p_t^N I_t^N - (1-\tau z^U)p_t^U I_t^U + B_t]dt,$$

subject to,

$$\dot{K}_t^N = I_t^N - \delta K_t^N - e^{-\delta T^N} I_{t-T^N}^N$$

$$\dot{K}_t^U = I_t^U - \delta K_t^U + e^{-\delta T^N} I_{t-T^N}^N$$

$$\dot{D}_t = B_t$$

$$B_t \le \phi(p_t^N I_t^N + p_t^U I_t^U).$$

The Hamiltonian is,

$$H = e^{-rt}[(1-\tau)(F(K_t^N, K_t^U) - rD_t - \psi(I_t^N, I_t^U, K_t^N, K_t^U)) - (1-\tau z^N)p_t^N I_t^N - (1-\tau z^U)p_t^U I_t^U + B_t]$$

$$+ \lambda_t^N[I_t^N - \delta K_t^N - e^{-\delta T^N} I_{t-T}^N] + \lambda_t^U[I_t^U - \delta K_t^U + e^{-\delta T^N} I_{t-T}^N] + \mu_t B_t + \gamma_t[\phi(p_t^N I_t^N + p_t^U I_t^U) - B_t],$$

where $\lambda_t^N, \lambda_t^U, \mu_t$, and γ_t are Lagrange multipliers on the four constraints above. The first order conditions for I_t^N, I_t^U, and B_t are,

$$0 = -e^{-rt}[(1-\tau)\psi_{I_t^N} + p_t^N(1-\tau z^N)] + \lambda_t^N + e^{-\delta T^N}(\lambda_{t+T^N}^U - \lambda_{t+T^N}^N) + \gamma_t \phi p_t^N \tag{9}$$

$$0 = -e^{-rt}[(1-\tau)\psi_{I_t^U} + p_t^U(1-\tau z^U)] + \lambda_t^U + \gamma_t \phi p_t^U \tag{10}$$

$$0 = e^{-rt} + \mu_t - \gamma_t, \tag{11}$$

where $\psi_X = \partial \psi / \partial X$. The costate equations for K_t^N, K_t^U, and D_t are,

$$\dot{\lambda}_t^N = -e^{-rt}(1-\tau)[F_{K_t^N} - \psi_{K_t^N}] + \delta \lambda_t^N \tag{12}$$

$$\dot{\lambda}_t^U = -e^{-rt}(1-\tau)[F_{K_t^U} - \psi_{K_t^U}] + \delta \lambda_t^U \tag{13}$$

$$\dot{\mu}_t = e^{-rt}(1-\tau)r \tag{14}$$

From (14) and (11), we see $\gamma_t = e^{-rt}\tau$.

We see from (10),

$$\lambda_t^U = e^{-rt}[p_t^U(1 - \tau(z^U + \phi)) + \psi_{I_t^U}(1 - \tau)]$$

$$\dot{\lambda}_t^U = -r\lambda_t^U + e^{-rt}[\dot{\Gamma}_t^U + \dot{\psi}_{I_t^U}(1 - \tau)],$$

for $\dot{\Gamma}_t^U = \partial(p_t^U(1 - \tau(z^U + \phi)))/\partial t$. Combining with (13) and assuming no adjustment costs ($\psi = 0$) produces equation (4) in the text, and similar steps produce equation (5).

With nonzero adjustment costs, further manipulation produces,

$$F_{K_t^U} - \psi_{K_t^U} - \psi_{I_t^U}(r + \delta) + \dot{\psi}_{I_t^U} = p_t^U(r + \delta - \pi_t^U)\frac{1 - \tau(z^U + \phi)}{1 - \tau}.$$

The equivalent of equation (7) is then,

$$\ln\frac{p_t^N}{p_t^U} = \ln\frac{1 - \tau(z^U + \phi)}{1 - \tau(z^N + \phi)} + \ln\frac{r + \delta - \pi_t^U}{r + \delta + \tilde{\lambda}_t - \pi_t^N} + \ln\frac{F_{K_t^N} - \psi_{K_t^N} - \psi_{I_t^N}(r + \delta) + \dot{\psi}_{I_t^N}}{F_{K_t^U} - \psi_{K_t^U} - \psi_{I_t^U}(r + \delta) + \dot{\psi}_{I_t^U}}.$$

In the case of perfect substitution in both the production and adjustment cost functions, the final two terms vanish, and we are again left with a price wedge determined solely by the tax wedge.

References

Jonas Agell, Peter Englund, and Jan Sodersten. Tax reform of the century–the Swedish experiment. *National Tax Journal*, 49(4):643–64, December 1996.

David Altig, Alan J. Auerbach, Laurence J. Kotlikoff, Kent A. Smetters, and Jan Walliser. Simulating fundamental tax reform in the United States. *The American Economic Review*, 91(3):574–595, 2001.

Alan J. Auerbach and Kevin Hassett. Recent U.S. investment behavior and the tax reform act of 1986: A disaggregate view. *Carnegie-Rochester Conference Series on Public Policy*, 35:185–215, 1991.

Alan J. Auerbach and James R. Hines. Anticipated tax changes and the timing of investment. In Martin Feldstein, editor, *The Effects of Taxation on Capital Accumulation*, pages 163–96. University of Chicago Press, Chicago, 1987.

Benjamin Bernanke, Henning Bohn, and Peter Reiss. Alternative non-nested specification tests of time series investment models. *Journal of Econometrics*, 37(2):293–326, 1988.

Peter Boelhouwer, Marietta Haffner, Peter Neuteboom, and Paul De Vries. House prices and income tax in the Netherlands: an international perspective. *Housing Studies*, 19(3):415–432, May 2004.

David F. Bradford. Consumption taxes: Some fundamental transition issues. In Michael J. Boskin, editor, *Frontiers of Tax Reform*, pages 123–150. Stanford, CA, 1996.

Bureau of Labor Statistics. *BLS Handbook of Methods*. 2008. URL `http://www.bls.gov/opub/hom/`.

Robert S. Chirinko, Steven M. Fazzari, and Andrew P. Meyer. How responsive is business capital formation to its user cost?: An exploration with micro data. *Journal of Public Economics*, 74(1):53 – 80, 1999.

Darrel S. Cohen and Jason G. Cummins. A Retrospective Evaluation of the Effects of Temporary Partial Expensing. *FEDS Working Paper Series*, 2006(19), 2006.

Adam M. Copeland, Wendy E. Dunn, and George J. Hall. Prices, Production, and Inventories over the Automotive Model Year. *SSRN eLibrary*, 2005.

Timothy L. Cross and Gregory M. Perry. Depreciation patterns for agricultural machinery. *American Journal of Agricultural Economics*, 77(1):194–204, 1995.

Jason G. Cummins, Kevin Hassett, and Glenn Hubbard. A reconsideration of investment behavior using tax reforms as natural experiments. *Brookings Papers on Economic Activity*, 1994(2):1–74, 1994.

David M. Cutler. Tax reform and the stock market: An asset price approach. *The American Economic Review*, 78(5):1107–1117, 1988.

Angus Deaton. *The analysis of household surveys: a microeconometric approach to development policy.* World Bank Publications, 1997.

Mihir A. Desai and Austan D. Goolsbee. Investment, overhang, and tax policy. *Brookings Papers on Economic Activity*, 2004(2):285–355, 2004.

Thomas W. Downs and Hassan Tehranian. Predicting stock price responses to tax policy changes. *The American Economic Review*, 78(5):1118–1130, 1988.

Jesse Edgerton. Investment, accounting, and the salience of the corporate income tax. Unpublished Working Paper, 2009.

Jesse Edgerton. Investment incentives and corporate tax asymmetries. *Journal of Public Economics*, 94 (11-12):936–952, 2010.

Andrea L. Eisfeldt and Adriano A. Rampini. New or used? investment with credit constraints. *Journal of Monetary Economics*, 54(8):2656 – 2681, 2007.

Robert Eisner. Tax policy and investment behavior: Comment. *The American Economic Review*, 59(3): 379–388, 1969.

William M. Gentry and R. Glenn Hubbard. Distributional implications of introducing a broad-based consumption tax. In James Poterba, editor, *Tax Policy and the Economy*, volume 11, page 1. The MIT Press, Cambridge, MA, 1997.

Robert James Gordon. *The Measurement of Durable Goods Prices.* University of Chicago Press, Chicago, IL, 1990.

Lawrence H. Goulder and Lawrence H. Summers. Tax policy, asset prices, and growth : A general equilibrium analysis. *Journal of Public Economics*, 38(3):265–296, April 1989.

Robert E. Hall. The effect of tax reform on prices and asset values. In James Poterba, editor, *Tax Policy and the Economy*, volume 10, pages 71–88. The MIT Press, Cambridge, MA, 1996.

Robert E. Hall and Dale W. Jorgenson. Tax policy and investment behavior. *The American Economic Review*, 57(3):391–414, June 1967.

Christopher L. House and Matthew D. Shapiro. Temporary investment tax incentives: Theory with evidence from bonus depreciation. *The American Economic Review*, 98:737–768(32), 2008.

Charles R. Hulten and Frank C. Wykoff. The estimation of economic depreciation using vintage asset prices : An application of the Box-Cox power transformation. *Journal of Econometrics*, 15(3):367–396, 1981.

Kenneth L. Judd. The impact of tax reform in modern dynamic economies. In Kevin A. Hassett and R. Glenn Hubbard, editors, *Transition Costs of Fundamental Tax Reform*. The AEI Press, Washington DC, 2001.

Matthew Knittel. Corporate response to accelerated tax depreciation: Bonus depreciation for tax years 2002-2004. *Office of Tax Analysis Papers*, 98, 2007.

Laurence J. Kotlikoff. National savings and economic policy: The efficacy of investment vs. savings incentives. *American Economic Review*, 73(2):82–88, 1983.

Andrew B. Lyon. The effect of the investment tax credit on the value of the firm. *Journal of Public Economics*, 38(2):227 – 247, 1989.

Iwan Meier and Vefa Tarhan. Corporate investment decision practices and the hurdle rate premium puzzle. Mimeo, 2006.

Wallace E. Oates. The effects of property taxes and local public spending on property values: An empirical study of tax capitalization and the Tiebout hypothesis. *The Journal of Political Economy*, 77(6):957–971, 1969.

Gregory M. Perry, Ahmet Bayaner, and Clair J. Nixon. The effect of usage and size on tractor depreciation. *American Journal of Agricultural Economics*, 72(2):317–325, 1990.

James Poterba. Tax subsidies to owner-occupied housing: An asset-market approach. *The Quarterly Journal of Economics*, 99(4):729–752, 1984.

James Poterba. Taxation and housing markets: Preliminary evidence on the effects of recent tax reforms. In Joel Slemrod, editor, *Do Taxes Matter? The Impact of the Tax Reform Act of 1986*, pages 141–160. MIT Press, Cambridge, MA, 1990.

Todd C. Pulvino. Do asset fire sales exist? an empirical investigation of commercial aircraft transactions. *The Journal of Finance*, 53(3):939–978, 1998.

Loren K. Smith. New market policy effects on used markets: Theory and evidence. *The B.E. Journal of Economic Analysis and Policy: Topics*, 9(1), 2009.

Lawrence Summers. Taxation and corporate investment: A Q-theory approach. *Brookings Papers on Economic Activity*, 1981(1):67–140, 1981.

Lawrence H. Summers. Investment incentives and the discounting of depreciation allowances. In Martin Feldstein, editor, *The Effects of Taxation on Capital Accumulation*. University of Chicago Press, Chicago, 1987.

Jing Wu and Gregory M. Perry. Estimating farm equipment depreciation: Which functional form is best? *American Journal of Agricultural Economics*, 86(2):483–491, 2004.