JASON G. CUMMINS
Columbia University

KEVIN A. HASSETT
Board of Governors of the Federal Reserve System

R. GLENN HUBBARD
Columbia University

A Reconsideration of Investment Behavior Using Tax Reforms as Natural Experiments

ECONOMISTS and policymakers have long been interested in measuring the effects of changes in the returns to and costs of business fixed investment. That interest reflects both theoretical and practical concerns, which have stimulated a large body of empirical research using aggregate and micro-level data. This literature has reached few unambiguous conclusions.[1]

We thank Alan Auerbach, Ricardo Caballero, Bill Gentry, Bronwyn Hall, Robert Hall, Charles Himmelberg, Anil Kashyap, Steve Oliner, Kristen Willard, and seminar participants at the Brookings Panel on Economic Activity, Board of Governors of the Federal Reserve System, University of Chicago, Columbia University, Duke University, Federal Reserve Bank of New York, University of Kentucky, University of Maryland, Miami University, Massachusetts Institute of Technology, National Bureau of Economic Research, Princeton University, and C.V. Starr Center Conference on Finance, Productivity, and Real Activity for helpful comments. Cummins thanks the Board of Governors of the Federal Reserve System for their hospitality during an internship. Hubbard is grateful for support from the John M. Olin Foundation to the Center for the Study of the Economy and State at the University of Chicago and from the Federal Reserve Bank of New York. The views expressed in this paper are those of the authors and do not reflect those of the Board of Governors of the Federal Reserve System.

1. For reviews of existing studies, see Jorgenson (1971), Auerbach (1983b), and Chirinko (1993).

The theoretical concerns are clear. Because firm demand for fixed capital is a derived demand, changes in the value of installed capital or in the cost of purchasing or using capital should, all else equal, be fundamental determinants of investing. However, specific applications of this general proposition, including the user cost of capital and q model approaches, have not proved empirically successful.[2] By the late 1960s, the neoclassical model developed by Dale Jorgenson and his collaborators had become the standard model for studying investment decisions.[3] The neoclassical approach offers a structural link between tax policy parameters—the corporate tax rate, the present value of depreciation allowances, and the investment tax credit—and investment through the user cost of capital.[4] Robert Eisner, both in solo work and in work with M. Ishaq Nadiri and Robert Chirinko, and other authors have noted, however, that the empirical link between investment and the user cost of capital is tenuous.[5] By the 1980s, models based on the q representations had largely replaced those based on the user cost of capital for analyzing investment.[6] However, the q models have also explained investment poorly using aggregate time-series data or firm-level data. Very small estimated effects of q on investment, implying implausibly high estimates of the cost of adjusting the capital stock, make it difficult to infer effects of changes in market valuation or tax parameters on investment.

One forceful empirical criticism of the user cost of capital and q approaches has been that they fail to explain investment as well as ad hoc models emphasizing sales or profits with no proxies for the net return to investing.[7] Recent research on the consequences of asymmetric information in financial markets has offered an interpretation of this finding:

2. Appendix A derives both approaches in a common framework.

3. See Jorgenson (1963) and the application to tax policy in Hall and Jorgenson (1967).

4. Alternatively, Feldstein (1982) explored the effects of effective tax rates on investment in reduced-form models; for a critique of this approach, see Chirinko (1987).

5. Eisner (1969, 1970), Eisner and Nadiri (1968), and Chirinko and Eisner (1983).

6. Hayashi (1982) provided the conditions required to equate marginal q with average q, which is observable since it depends on the market valuation of the firm's assets. In an important extension, Summers (1981) incorporated additional tax parameters in the q model. An alternative to using financial variables as proxies for marginal q is to use a forecasting approach, as in Abel and Blanchard (1986) on aggregate data and more recently in Gilchrist and Himmelberg (1991, 1992) on firm-level panel data.

7. See, for example, Clark (1979, 1993), Bernanke, Bohn, and Reiss (1988), and Oliner, Rudebusch, and Sichel (forthcoming-a).

when a firm's net worth improves, lenders become more willing to lend, holding constant "true" investment opportunities, allowing additional capital spending to be financed.[8] With few exceptions, however, empirical studies have not offered structural models that permit evaluation of policy changes.[9]

The practical concerns about investment models are also clear. Business fixed investment accounts for only about 10 percent of GDP in the United States but is much more volatile than consumption or government purchases. Policymakers have responded to this volatility by trying to manipulate tax policy to smooth investment spending. Sixteen shifts in business taxation in the postwar period have resulted, roughly one every three years.

This manipulation of tax policy suggests that policymakers perceive some responsiveness of business fixed investment to tax changes. However, the empirical evidence is far from conclusive.[10] That is, not only have models emphasizing the net return to investing been defeated in forecasting "horse races" by ad hoc models, but, more important, structural variables are frequently found to be economically or statistically insignificant.

A general difficulty with existing empirical studies is their failure to identify *exogenous* shifts in the marginal profitability of investment or in the user cost of capital. As a result, analyses rely on very imprecise measures of q or the user cost of capital. Studies using the user cost of capital confront a significant measurement error problem, in that investment depends upon observed current and expected future values of many fundamentals. Given the discreteness of tax changes, future val-

8. See Fazzari, Hubbard, and Petersen (1988), Gertler and Hubbard (1988), Calomiris and Hubbard (1990), and Oliner and Rudebusch (1994).

9. Exceptions include Cummins, Harris, and Hassett (1994), Cummins and Hubbard (1994), Hubbard and Kashyap (1992), Hubbard, Kashyap, and Whited (forthcoming), and Sakellaris (forthcoming).

10. See Bosworth (1985), Bosworth and Burtless (1992), and the survey in Chirinko (1993). The often poor empirical performance of q models has led some researchers to abandon the assumptions of reversible investment and convex adjustment costs used in testing neoclassical models in favor of approaches based on lumpy and "irreversible" investment. See the discussions and reviews of studies in Pindyck (1991), Dixit and Pindyck (1994), and Hubbard (1994); for some empirical applications, see Bertola and Caballero (1990), Bizer and Sichel (1991), Caballero and Engel (1994), Caballero and Pindyck (1992), Leahy and Whited (1994), and Pindyck and Solimano (1993); for a synthesis of alternative modeling approaches, see Abel and Eberly (1994).

ues of the user cost of capital are difficult to project linearly.[11] The q formulation confronts a slightly different, but equally troublesome, measurement error problem if fluctuations in firm value cannot be explained by fluctuations in expected future profitability.[12] Studies focusing on internal funds as an explanatory variable for investment, holding investment opportunities or observable measures of the user cost of capital constant, face the problem that changes in internal finance may simply measure fundamentals better than financial market prices.

This paper focuses on the effects of changes in fundamentals on business fixed investment using adaptations of the tax-adjusted q and the user cost of capital models. We stay within the framework of those models because of their widespread use among economists, practitioners, and policymakers. We attempt to improve upon existing approaches by using *tax reforms* to identify determinants of investment decisions. Major tax reforms offer natural experiments for evaluating the responsiveness of investment to fundamentals affecting the net return to investing.[13] Each such tax reform represents a discrete event with a large and discernible effect on the return to investment. Below we present estimates for the period between 1962 and 1988, which encompasses several business tax reforms.[14]

Although we are interested in macroeconomic policy issues, our analysis relies on firm-level panel data rather than aggregate time-series data for two reasons. First, panel data allow us to exploit the significant *cross-sectional* variation in investment opportunities and in the cost of investing. Second, for our use of tax reform episodes to be revealing,

11. The Brookings panel discussion of the poor results for the neoclassical model in Clark (1979) stressed many of the issues addressed here. Martin Feldstein, for example, argued that the user cost variable used in that study might be severely mismeasured. Robert Hall suggested that there might be a simultaneity problem: higher investment might cause a rise in interest rates. We address both of these issues.

12. Such problems could be accounted for by noise trading (as in De Long and others, 1990) or by differences in information available to internal managers and financial markets (as explored in Gilchrist and Himmelberg, 1991, 1992).

13. We expand on Auerbach and Hassett (1991), Calomiris and Hubbard (1993), and Cummins and Hassett (1992). Romer and Romer (1989) use a similar approach to analyze the effects of monetary policy surprises on economic activity.

14. Steigerwald and Stuart (1993) present evidence that major reforms are largely unanticipated until the year before enactment and that firms behave as if the current tax code, including known future changes, is permanent; Givoly and others (1992) present similar results in their study of the Tax Reform Act of 1986.

reforms should be exogenous to investment decisions. In addition to interest rate endogeneity, it is also unlikely that the taxation of investment is exogenous at the aggregate level.[15] Even a casual examination of aggregate time series for detrended equipment investment and the investment tax credit for equipment reveals this endogeneity. Policymakers have introduced an investment tax credit when investment was perceived to be "low" and removed the investment tax credit when investment was perceived to be "high."[16] However, because the composition of the capital stock varies across firms, tax policy designed to alter aggregate investment affects individual firms differently, and this variation is less likely to be endogenous in disaggregated data. We use this insight, combined with the firm-level panel data to control for dynamic aspects of the investment decision, to estimate structural models of investment.

Tax Reforms and Incentives for Investment

Before describing our technique for exploiting tax reforms as periods in which we can identify structural determinants of firms' investment decisions, we describe below the tax reforms that occurred during our sample period, the cross-sectional variation (by asset type) in tax incentives during reforms, and the cross-sectional relationship (across asset types) between changes in investment and in its tax treatment.

Business Tax Reforms

There were 13 arguably significant changes in the corporate tax code during the 1962–88 period, beginning with the Kennedy tax cut in 1962 and ending with the Tax Reform Act of 1986.[17] Before explaining the details of each change, it is useful to provide an overview of the trend in the corporate tax burden.

The statutory corporate tax rate was reduced steadily from 52 percent in 1962 to 34 percent in 1988, except between 1968 and 1970 when a sur-

15. Hall in the general discussion of Clark (1979).

16. The estimated coefficient from an ordinary least squares regression using the aggregate investment tax credit to predict aggregate equipment investment-to-capital ratio is significant but *negative*.

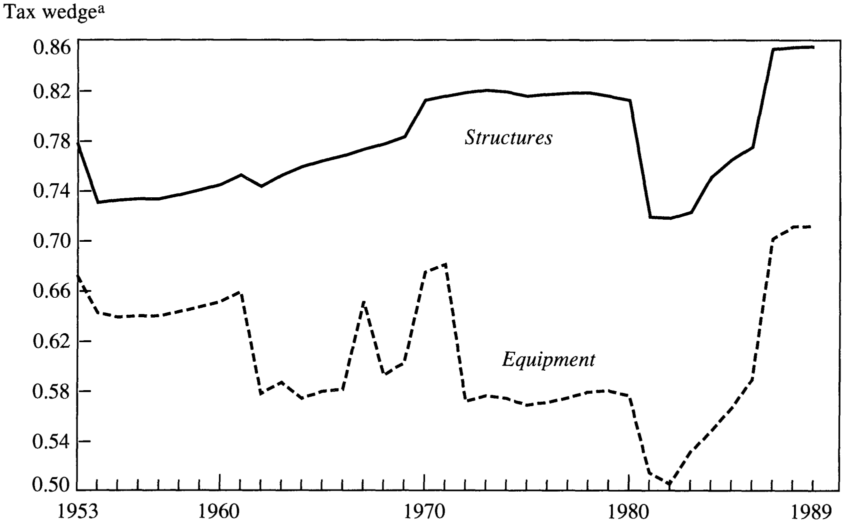
17. For discussions and historical reviews of the changes, see Auerbach (1982, 1983a), Pechman (1987), and U.S. Senate Committee on the Budget (1986, 1992).

charge was imposed. The investment tax credit was first enacted January 1, 1962, and was in effect through 1986, except for two periods from October 10, 1966, to March 9, 1967, and from April 19, 1969, to August 15, 1971. The credit was increased three times, and the number of assets eligible for the credit has expanded. Depreciation allowances became more generous, culminating in the Accelerated Cost Recovery System introduced by the Economic Recovery Tax Act of 1981, but were subsequently limited by the Tax Equity and Fiscal Responsibility Act of 1982, which introduced the Modified Accelerated Cost Recovery System.

The Kennedy tax cut introduced an investment tax credit for most types of equipment. The effective rate was generally 4 percent. The Revenue Act of 1964 lowered the corporate tax rate from 52 percent to 50 percent for 1964 and from 50 percent to 48 percent for 1965. The 1964 act also modified the investment tax credit so that the credit was no longer deducted from the cost of the asset before computing depreciation for tax purposes, effectively doubling the benefit of the investment tax credit. The credit was then suspended in 1966. The Revenue and Expenditure Control Act of 1968 introduced a corporate income tax surcharge of 10 percent. The investment tax credit was reinstated in 1967. For 1970, the surcharge was reduced to 2.5 percent, and the investment tax credit was eliminated. The surcharge was removed for 1971. For 1972, the investment tax credit was reintroduced, and the first major liberalization of depreciation allowances was enacted. Asset lives were shortened through the asset depreciation range system. Taking these changes together, the effective credit rate was generally about 7 percent. The credit was temporarily increased to 10 percent in 1975. In 1979, the corporate tax rate was lowered from 48 percent to 46 percent, and the temporary increase in the investment tax credit was made permanent.

The Economic Recovery Tax Act of 1981 provided the second major liberalization of depreciation allowances. It replaced the numerous asset depreciation classes with three capital recovery classes. Light equipment was written off over 3 years, other equipment over 5 years, and structures over 15 years. The reduction was modified one year later by repealing the accelerations in the write-off that were to occur in 1985 and 1986 and by instituting a basis adjustment of 50 percent for the credit. As a result, the effective rate was generally about 8 percent. The Tax Reform Act of 1986 reduced the corporate tax rate to 40 percent in 1987 and to 34 percent in 1988 and eliminated the investment tax credit.

Figure 1. After-Tax Cost of One Dollar of Investment: Equipment and Structures, 1953–89



Source: Authors' calculations from Auerbach (1982, 1983a), Pechman (1987), and U.S. Senate Committee on the Budget (1986, 1992).

a. The tax wedge is calculated from Γ, which is the sum of the present value of tax savings from depreciation allowances and the investment tax credit. Higher values for the tax wedge $(1 - \Gamma)$ correspond to higher after-tax costs of investing.

To summarize this information, figure 1 plots typical values of the tax wedge for equipment and structures investment for each year between 1953 and 1989. (The samples differ because the first year for which we can estimate our model using Compustat data is 1962, but we use a longer sample from the Bureau of Economic Analysis, BEA, for descriptive purposes.) The tax wedge plotted—described more formally below—equals $(1 - \Gamma)$, where Γ is the sum of the present value of tax savings from depreciation allowances and the investment tax credit.[18] An increase in the value of $(1 - \Gamma)$, as, for example, following the 1986 change, corresponds to an increase in the after-tax cost of investing; a decrease in the value of $(1 - \Gamma)$, as, for example, following the 1962 change, corresponds to a fall in the after-tax cost of investing. Table 1 presents the average values of the corporate tax rate, the investment tax

18. The plot is of $(1 - \Gamma)$ for a representative equipment asset (special industrial machinery) and a representative structures asset (industrial buildings).

Table 1. Average Tax Parameters for Manufacturing Equipment and Structures, 1953–88

		Equipment		Structures	
Year	Corporate tax rate	Investment tax credit	Present value of depreciation allowances	Investment tax credit	Present value of depreciation allowances
1953	0.520	0.0000	0.3107	0.0	0.1981
1954	0.520	0.0000	0.3451	0.0	0.2475
1955	0.520	0.0000	0.3461	0.0	0.2476
1956	0.520	0.0000	0.3471	0.0	0.2475
1957	0.520	0.0000	0.3487	0.0	0.2475
1958	0.520	0.0000	0.3453	0.0	0.2436
1959	0.520	0.0000	0.3425	0.0	0.2406
1960	0.520	0.0000	0.3366	0.0	0.2358
1961	0.520	0.0000	0.3273	0.0	0.2279
1962	0.520	0.0399	0.3781	0.0	0.2339
1963	0.520	0.0390	0.3688	0.0	0.2253
1964	0.500	0.0657	0.3544	0.0	0.2175
1965	0.480	0.0657	0.3484	0.0	0.2127
1966	0.480	0.0657	0.3462	0.0	0.2098
1967	0.480	0.0000	0.3404	0.0	0.2040
1968	0.528	0.0658	0.3366	0.0	0.2001
1969	0.528	0.0658	0.3272	0.0	0.1954
1970	0.492	0.0000	0.3190	0.0	0.1628
1971	0.480	0.0000	0.3150	0.0	0.1608
1972	0.480	0.0675	0.3351	0.0	0.1568
1973	0.480	0.0674	0.3302	0.0	0.1548
1974	0.480	0.0674	0.3323	0.0	0.1565
1975	0.480	0.0962	0.3385	0.0	0.1593
1976	0.480	0.0962	0.3354	0.0	0.1582
1977	0.480	0.0961	0.3312	0.0	0.1570
1978	0.480	0.0962	0.3260	0.0	0.1561
1979	0.460	0.0962	0.3262	0.0	0.1589
1980	0.460	0.0962	0.3304	0.0	0.1619
1981	0.460	0.0987	0.3890	0.0	0.2710
1982	0.460	0.0789	0.3980	0.0	0.2720
1983	0.460	0.0789	0.3913	0.0	0.2670
1984	0.460	0.0789	0.3749	0.0	0.2380
1985	0.460	0.0789	0.3540	0.0	0.2230
1986	0.460	0.0789	0.3294	0.0	0.2110
1987	0.400	0.0000	0.2918	0.0	0.1280
1988	0.340	0.0000	0.2814	0.0	0.1260

Source: Authors' calculations using data from Auerbach (1982, 1983a), Pechman (1987), and U.S. Senate Committee on the Budget (1986, 1992).

credit, and the present value of depreciation allowances for representative classes of equipment and structures.

Our criteria for identifying key tax reforms are as follows: (i) the value of the tax wedge must have changed in absolute value by at least 10 percent; (ii) no tax shift of that magnitude occurred in the preceding or succeeding year; and (iii) the reforms are unanticipated in the year before the reform. By these criteria, we identify "major reforms" as those tax changes occurring in legislation enacted in 1962, 1971, 1981, and 1986.[19]

Cross-Sectional Variation in Tax Treatment during Reforms

In addition to changing the tax treatment of investment on average, tax reforms are also associated with changes in the relative tax treatment of different assets. This *cross-sectional* variation—stemming mostly from differences in depreciation across assets—is critical for the formal experiments we derive in the next section.

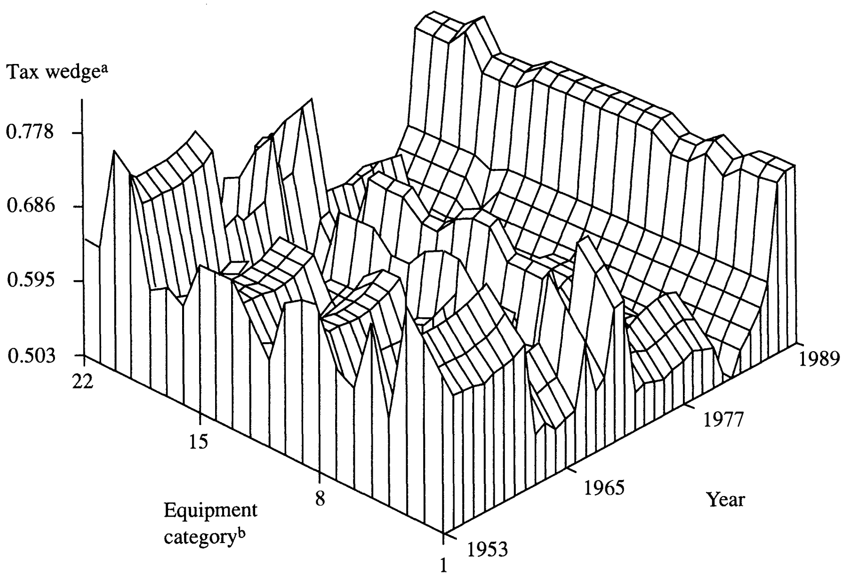
Many previous researchers have constructed aggregate measures of the marginal tax on investment by using tax rules for particular asset types and capital stock data that document the relative importance of the different assets.[20] Industry measures for tax depreciation can be easily constructed, for example, by taking weighted averages of the marginal value of tax depreciation, with the share of each asset in the total capital stock of that industry as weights.

Since the key variation in the tax treatment occurs at the asset level, we begin at that level. Figure 2 plots the annual values of the tax component used in our study, $(1 - \Gamma)$, for the 22 classes of equipment capital classified by the Bureau of Economic Analysis. Figure 3 provides the same description of the variation for the 14 different types of structures classified by the BEA. Table 2 details the type of assets in each asset category. In both figures 2 and 3, the peaks and valleys along the "year" axis for a given asset reveal the time-series variation in the tax parameters, and those along the "asset" axis for a given year reveal the cross-

19. Legislation passed in 1954 met these criteria, but, owing to data constraints, we did not analyze this reform.

20. See, for example, Hulten and Robertson (1982), King and Fullerton (1984), and Auerbach (1983b). Our estimates for corporate tax rates and depreciation rules are taken from Auerbach and Hassett (1992) and are discussed in more detail below.

Figure 2. After-Tax Cost of One Dollar of Equipment Investment, 1953–89



Source: Authors' calculations based upon data from the Bureau of Economic Analysis.
a. The tax wedge is calculated from Γ, which is the sum of the present value of tax savings from depreciation allowances and the investment tax credit. Higher values for (1 – Γ) correspond to higher after-tax costs of investing.
b. See table 2 for BEA classifications.

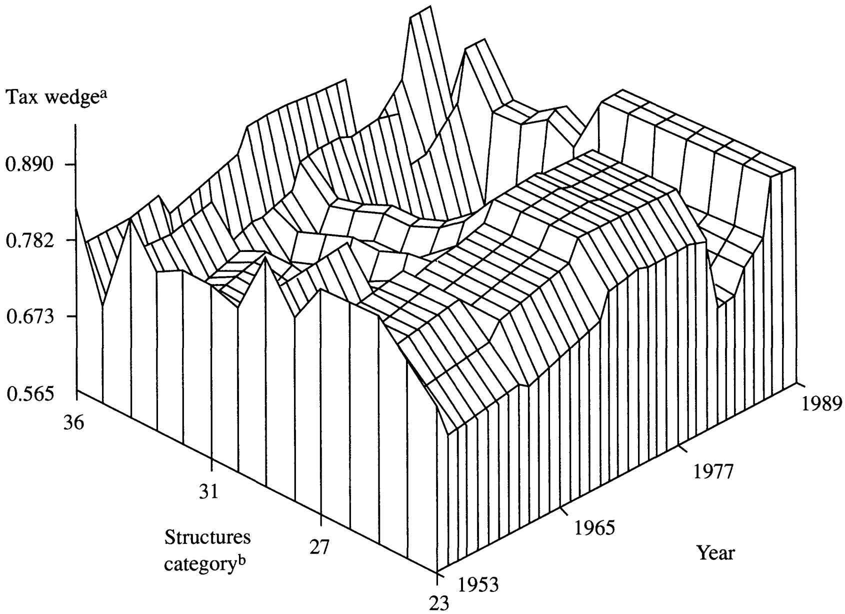
sectional variation. For asset eight (metalworking machinery), for example, the after-tax cost of investing falls in 1962, 1972, and 1981, and rises in 1986.

The figures reveal that the variation across assets is large within most years in our samples, as is the time-series variation. In addition, the positions of the peaks and valleys change somewhat over time. For example, following the removal of the investment tax credit and the reduction of the corporate tax rate by the Tax Reform Act of 1986, the cross-sectional variation across assets fell, consistent with the act's stated goal to "level the playing field."

Cross-Sectional Relationship between Investment and Its Tax Treatment

For our purposes, the important question is whether this cross-sectional variation is significant. Below, we argue that tax reforms allow us

Figure 3. After-Tax Cost of One Dollar of Structures Investment, 1953–89



Source: Authors' calculations based upon data from the Bureau of Economic Analysis.
a. The tax wedge is calculated from Γ, which is the sum of the present value of tax savings from depreciation allowances and the investment tax credit. Higher values for $(1 - \Gamma)$ correspond to higher after-tax costs of investing.
b. See table 2 for BEA classifications.

to identify investment models when they provide large and enduring shifts in the cost of or net return to investment. We examine whether simple forecast errors for types of investment and their user costs of capital exhibit a systematic negative correlation during the tax reforms. If the cross-sectional variation in tax parameters is economically significant, we should see that a positive "surprise" in the user cost of capital for a particular asset is associated with a negative "surprise" in the quantity of investment in that asset. In figures 4–7, we plot autoregressive forecast errors for each of the disaggregated investment series against a similar forecast error for a simplified user cost variable.[21] Each figure plots one of the four years in which a "major" tax reform took effect. The assets are the same as those used in the three-dimensional illustrations in

21. We construct the user cost here under the assumptions that the relative price of the capital good is unity and that the real interest rate is 0.04. As elsewhere in this paper, the asset depreciation rates are from Jorgensen and Sullivan (1981).

Table 2. Asset Classifications in BEA Data

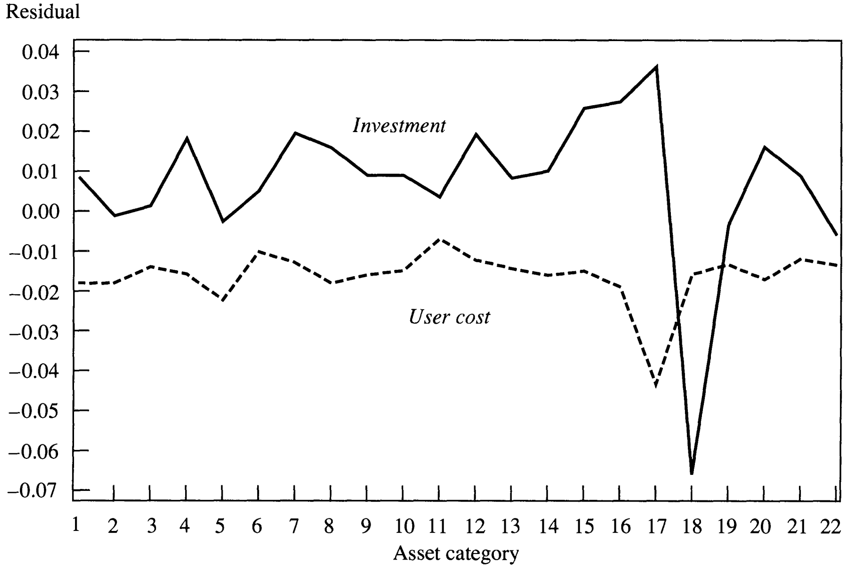
Equipment	
1.	Furniture and fixtures
2.	Fabricated metal products
3.	Engines and turbines
4.	Tractors
5.	Agricultural machinery, except tractors
6.	Construction machinery, except tractors
7.	Mining and oilfield machinery
8.	Metalworking machinery
9.	Special industrial machinery
10.	General industrial machinery
11.	Office and computing machinery
12.	Service industry machinery
13.	Electrical transmission, distribution, and industrial apparatus
14.	Communications equipment
15.	Electrical equipment
16.	Trucks, buses, and trailers
17.	Autos
18.	Aircraft
19.	Ships and boats
20.	Railroad equipment
21.	Instruments
22.	Other equipment
Structures	
23.	Industrial buildings
24.	Commercial buildings
25.	Religious buildings
26.	Educational buildings
27.	Hospital and institutional buildings
28.	Other nonresidential buildings, excluding farm
29.	Railroads
30.	Telephone and telegraph
31.	Electric light and power
32.	Gas
33.	Petroleum pipelines
34.	Farm nonresidential structures
35.	Mining exploration shafts and wells
36.	Other nonresidential nonbuilding structures

Source: Bureau of Economic Analysis.

figures 2 and 3, with those numbers above 22 representing structure assets. The figures illustrate a negative correlation between the forecast errors, consistent with the neoclassical theory.[22]

22. For illustrative purposes, we have plotted the data for the years that the major changes took effect, using simple AR(1) forecasting equations. Timing around reforms is complicated, and below, when constructing our estimators, we are very conservative when constructing the forecast errors, starting the forecast well before the reform and forecasting the variables' values for the year following the reform.

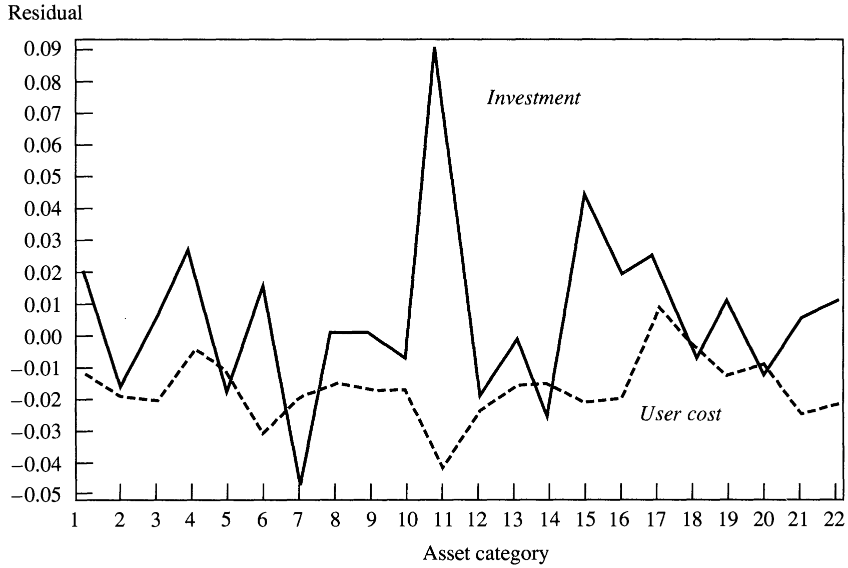
Figure 4. Forecast Errors for Equipment Investment and Equipment Price, 1962 Reform[a]



Source: Authors' calculations from BEA data.

a. Autoregressive forecast errors for each disaggregated investment series are plotted against forecast errors for a simplified user cost variable.

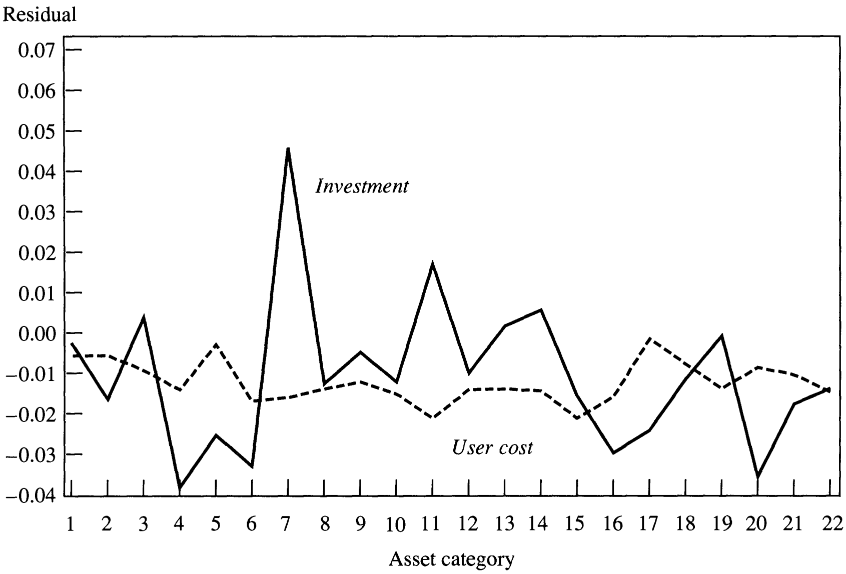
Figure 5. Forecast Errors for Equipment Investment and Equipment Price, 1971 Reform[a]



Source: Authors' calculations from BEA data.

a. Autoregressive forecast errors for each disaggregated investment series are plotted against forecast errors for a simplified user cost variable.

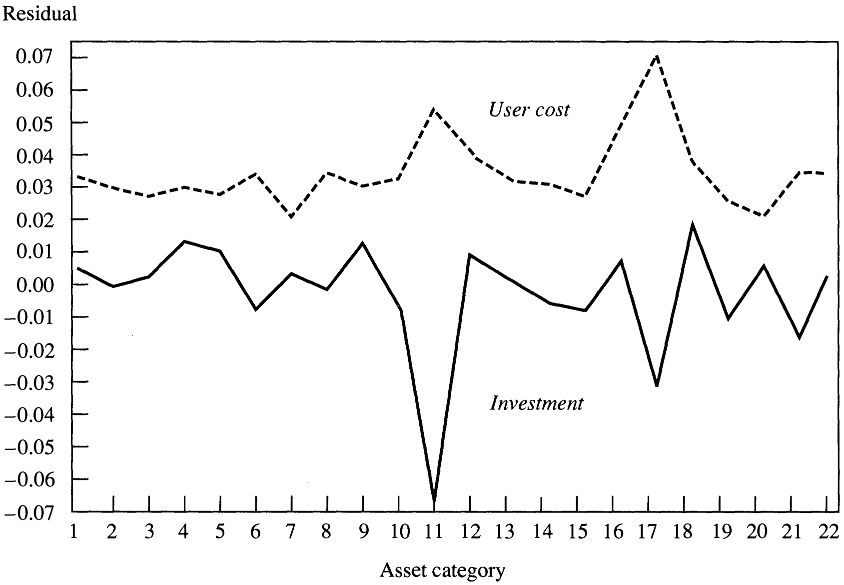
Figure 6. Forecast Errors for Equipment Investment and Equipment Price, 1981 Reform[a]



Source: Authors' calculations from BEA data.

a. Autoregressive forecast errors for each disaggregated investment series are plotted against forecast errors for a simplified user cost variable.

Figure 7. Forecast Errors for Equipment Investment and Equipment Price, 1986 Reform[a]



Source: Authors' calculations from BEA data.

a. Autoregressive forecast errors for each disaggregated investment series are plotted against forecast errors for a simplified user cost variable.

Modeling the Effects of Tax Reforms on Investment

In this section, we describe the techniques we use to study the effects of tax reforms on investment.

The Approach

We now describe the technique used to estimate the determinants of firm investment. Consider the following general model of investment, which here is related to models based on tax-adjusted q, the user cost of capital, and internal funds models:

$$I_{i,t}/K_{i,t-1} = E_{i,t-1}(S_{i,t}\gamma) + \epsilon_{i,t}, \tag{1}$$

where I and K denote investment and the capital stock, respectively; i and t are the firm and time indexes, respectively; S is an underlying structural variable (either tax-adjusted q or user cost of capital) or set of variables; $E_{i,t-1}$ is the expectations operator for firm i conditional on information available at time $t - 1$; γ is a coefficient whose structural interpretation relates to assumptions about convex adjustment costs;[23] and ϵ is a white-noise error term that reflects optimization error by firms.[24]

Traditionally, such models have been estimated using either ordinary least squares or generalized method of moments techniques with instrumental variables, and linear projections have been used to form the expectation on the right-hand side of equation 1. The introduction suggested that this approach might not be promising for studying tax changes, since tax reforms are infrequent and difficult to predict. Our approach is (i) to assume that major changes in S are infrequent and not easily predictable with standard projection techniques and (ii) to design an empirical experiment that will nonetheless allow us to isolate the effects of changes in S.

23. Studies have typically assumed convex costs of adjusting the capital stock in order to obtain empirical investment equations based on Jorgenson's (1963) or Tobin's (1969) approaches. The basic idea is that it is more costly to implement a given increment to the capital stock quickly rather than gradually. Following the initial formalization by Eisner and Strotz (1963), key applications include Lucas (1967), Gould (1968), Abel (1980), and Hayashi (1982).

24. Incorporation of more complex error structures is possible. For ease of exposition, we make the simplifying assumption above.

The first observation is that the expectations employed by firms to construct their investment plans may well be formed from information beyond that reflected in linear projection techniques. This might be the case, for example, if the firm has access to information (such as a newspaper or a trade newsletter) that announces the true value of the structural variable S. For example, firms knew with certainty what the key tax variables for 1987 would be in September 1986; they could read them in the newspaper. Just after the reform, it is likely that firms expected future tax policy to reflect the current tax code, because, at the very least, it takes some time to legislate changes in the tax code. When a tax reform year is distant, however, it is difficult to determine a firm's expectations concerning both the likelihood of future tax changes and their direction. Under these assumptions, the econometrician can accurately measure the relevant expected tax variables only immediately following the tax reform, and, further, there is no need to construct forecasts of future tax variables using instruments at these times because the key structural variable (expected S) is observable. Hence, we treat S as known immediately following reforms and rewrite equation 1 as

$$I_{i,t}/K_{i,t-1} = S_{i,t}\gamma + \epsilon_{i,t}. \tag{2}$$

If equation 2 holds, the deviation of true (I/K) from the value that is linearly predictable using information available at time $t - 1$ is

$$I_{i,t}/K_{i,t-1} - P_{i,t-1}(I_{i,t}/K_{i,t-1}) = (S_{i,t} - P_{i,t-1}S_{i,t})\gamma + \epsilon_{i,t}, \tag{3}$$

where P is a projection operator constructed from a nontax subset of the firm's information set. More conveniently,

$$\omega_{i,t} = \gamma\psi_{i,t} + \epsilon_{i,t}, \tag{4}$$

where ω measures the deviation of investment from what it would have been without the exogenous shock to the structural variable, and ψ measures that shock.

Equation 4 states that the econometric "surprise" to investment will be proportional to the "surprise" to the structural variable if firms are aware of changes in S that cannot be predicted using a linear projection onto the beginning-of-period information set. If we isolate periods in which firms observe the true value of S, then we can estimate γ by constructing a cross-section of observations of the variables in equation 4. To implement this approach, we use first-stage regressions to construct estimates of $\omega_{i,t}$ and $\psi_{i,t}$ and then pool a cross-section of these to estimate γ.

Alternatively, one could use this cross-section to estimate equation 1 directly, but the former approach is likely to be more powerful. By expressing the variables in terms of their deviations from conditional expectations, we control for important cross-sectional heterogeneity. In fact, this estimator can be thought of as the "difference from own means" estimator, in which individual firm means are replaced by individual conditional expectations.[25] If firms indeed observe the true tax variable, then this approach sidesteps the errors-in-variables problem with respect to the underlying structural variables. Finally, this approach mitigates the problem of endogenous tax policy faced by time-series models. If the surprises are tax policy surprises, then we can treat the variation of the tax variables in the right-hand side of equation 4 as exogenous.

In order to construct our estimator, we make the identifying assumption that around tax reforms we can observe the S used by firms when formulating their investment decisions. In principle, this includes the nontax elements as well. To avoid the introduction of contemporaneous values of the nontax components of S, which might introduce simultaneity bias into the second-stage regression, we assume that the firm's expected value for each nontax component of S is equal to that variable's value at the beginning of the previous period. That is, we construct S_t by combining the tax components for period t and the nontax components for period $t - 2$. It is this variable that we forecast in the first stage and this variable that we use to construct the "surprise." Tax information is the only information dated ahead of year $t - 2$ that is included on the right-hand side of our second-stage regression. For example, the expected interest rate in 1987 is assumed to be the year-end rate for 1985. This assumption has received empirical support from Douglas Steigerwald and Charles Stuart.[26]

25. If one uses only a constant term in the first-stage projection, then the estimator is exactly a difference-in-own-means estimator, applied only in the year of the tax reform. The substitution of firm-specific conditional expectations for firm means adds power: firm means may be a poor measure of what investment would have been at time t had there been no tax-induced shift in the net return to investing.

26. Steigerwald and Stuart (1993). Violation of our assumption concerning the observability of S would introduce into the second-stage regression the deviation of "true" expected S from our assumed S. It is straightforward to show that our estimate of the structural parameters will be unbiased if this is a white-noise error. As a further specification check, we investigate whether the inclusion of variables that should be correlated with this potential omitted variable alters our estimate of γ.

When a tax reform year is distant, the identifying assumption that the true value of S is observable is clearly tenuous. In years following substantial changes in the tax code, γ should be of the expected sign and precisely estimated if our identifying assumption is correct. In periods during which there were no changes in the tax code, γ should be imprecisely estimated and, to the extent that we are measuring the structural variable with significant error, biased toward zero. In periods during which there were changes that were part of a previous tax reform (such as the reduction in the corporate tax rate from 40 percent in 1987 to 34 percent in 1988), the value of γ depends on whether linear projection techniques adequately describe firms' expectations following an initial tax reform. If they do adequately capture expectations, γ is unidentified.[27]

Care in choosing the timing of the experiment is crucial. For example, the Tax Reform Act of 1986 was passed late in that year, and it is unclear whether investment decisions during 1986 could possibly have anticipated these changes. To avoid confounding timing issues, we sidestep tax change years. For example, we estimate a first-stage projection equation for each firm, using data available for that firm through 1985 and then construct forecasts for 1987, the first postreform year. Generally it is the year following a reform in which we expect to see the first effects of reform. To the extent that information about future retroactive changes alters firm behavior, we might observe significant responses in reform years as well. If the underlying model is correct, those firms for which our forecast error in S is smallest will be the firms whose investment we predict best.[28] We pay the same attention to timing for each tax change we study, forecasting postreform investment with information available in the year before the reform and examining effects of changes in the structural variable on investment in the first postreform year.

27. The identification occurs *only* when we encounter a period in which the firm observes a change in S that can not be predicted with the information in P (as, for example, during a tax reform in our setup). If the projection measures expected S perfectly, γ would be unidentified given the definition of ψ in equation 4.

28. Pagan (1984) has shown that the second-stage parameter estimates and their standard errors are consistent and asymptotically efficient, respectively, when the second-stage regressors are innovations. We require numerous assumptions to map our problem to that result, and, for generality, one would prefer maximum likelihood. The likelihood function for this two-stage estimator is not difficult to write, but estimation would be extremely cumbersome because of the large number of nuisance parameters.

The years in which there were no tax changes act as our "control." The "treatment" is the tax reform. If the experiment is well designed, and our characterization of the shortcomings of previous empirical work is accurate, we should observe a strong response in the periods during which there has been a "treatment." The effects on investment of changes in the net return to investing should be difficult to measure in nonreform years. The finding of little effect in the "control" years is an important link between our paper and the literature, since it helps explain why empirical results are often inconclusive.

Tax-Adjusted q, the Cost of Capital, and Investment

There are four standard ways of obtaining empirical representations of investment models emphasizing the net return to investment. Each begins with the firm maximizing its net present value. The first-order conditions lead to an Euler equation describing the period-to-period optimal path of investment. Andrew Abel and Olivier Blanchard have solved the difference equation that relates investment to its expected current and future marginal revenue products.[29] Alternatively, the Euler equation itself may be estimated.[30] As in work by both Alan Auerbach and Abel, investment can be expressed in terms of current and future values of the user cost of capital and, under some conditions, expressed in terms of average q.[31] This final approach was first suggested by James Tobin, with the necessary conditions supplied by Fumio Hayashi.[32] We relate the q and user cost of capital models of investment to the approach discussed above.

We estimate both of these models, because we feel that this is a robust test of whether we are estimating the true "structural" coefficients. While the estimation equations differ significantly depending upon the path taken in solving the model, the basic structural setup is the same, so comparing coefficient estimates across specifications is a useful specification check. Since the investment specifications we test are largely familiar, we refrain from repeating derivations presented elsewhere and

29. Abel and Blanchard (1986).

30. See Abel (1980), Pindyck and Rotemberg (1983), Shapiro (1986), and Hubbard and Kashyap (1992).

31. Auerbach (1983b) and Abel (1990).

32. Tobin (1969) and Hayashi (1982).

focus on the estimation equations. Appendix A provides a formal derivation of the models.

Following both Hayashi and Lawrence Summers, who derive the relationship between q and investment in the presence of quadratic adjustment costs, we represent the tax-adjusted q approach as follows:[33]

$$(5) \qquad I_{i,t}K_{i,t-1} = \mu_i + \Omega Q_{i,t} + \epsilon_{i,t},$$

where μ is a firm-specific constant, Ω is a coefficient whose value is inversely related to adjustment costs, ϵ is an error term (as in equation 1 above), and Q is the tax-adjusted value of q.[34] In other words,

$$(6) \qquad Q_{i,t} = \frac{q_{i,t} - p_t(1 - \Gamma_{i,t})}{(1 - \tau_t)},$$

where τ is the corporate tax rate, p is the price of capital goods relative to output, and Γ is the present value of tax savings from depreciation allowances and other investment incentives. For example, with an investment tax credit at rate k, Γ is

$$(7) \qquad \Gamma_{i,t} = k_{i,t} + \sum_{s=t}^{\infty} (1 + r_s + \pi_s^e)^{-t}\tau_s DEP_{i,s}(s-t),$$

where r is the default risk-free real rate of interest, and $DEP_{i,s}(a)$ is the depreciation allowance permitted an asset of age a discounted at a nominal rate that includes the expected inflation rate π^e.

In the user cost of capital formulation, the firm equates the marginal product of capital and the user cost of capital, c:[35]

$$(8) \qquad c_{i,t} = \frac{p_t(1 - \Gamma_{i,t})\left[\rho_{i,t} + \delta_i - \left(\frac{\Delta p_{t+1}(1-\Gamma_{i,t+1})}{p_t(1-\Gamma_{i,t})}\right)\right]}{(1 - \tau_t)},$$

where ρ is the firm's required rate of return, δ is the rate of economic depreciation, and Δ is the differencing operator.

33. Hayashi (1982) and Summers (1981).

34. This presentation assumes that new equity issues are the firm's marginal source of finance; see, for example, Hayashi (1985) for alternatives. In both the Q and user cost of capital models we derive, we assume that firms face the statutory tax parameters. We are thus abstracting from complications introduced by asymmetries, such as those arising from tax-loss carryforwards and the alternative minimum tax.

35. See Hall and Jorgenson (1967) and Auerbach (1983b).

When quadratic adjustment costs and multiplicative shocks to the firm's production function are incorporated, the firm determines current investment based on current and expected future values of a term similar to equation 8. Firm i's investment rule is given by

$$(9) \qquad I_{i,t}/K_{i,t-1} = \mu_i + \xi E_{i,t} \sum_{s=t}^{\infty} \omega_i^s c_{i,s} + \epsilon_{i,t},$$

where ξ and ω are technology parameters depending on adjustment costs and the long-run average of the user cost term, and c is defined as in equation 8; the subscripts i and s recognize that components of c may vary across firms and time.[36] We proceed with the variables defined in equations 5 and 9 substituted for S in equation 4.

Using equations 5 and 9 to estimate equation 4, we assume for simplicity that firms believe that the tax reform in the year it is enacted is permanent.[37] Prior to a tax reform, S will depend on firms' beliefs about the likelihood and significance of tax reforms. These beliefs are unobservable, and we have little confidence that the tax code per se is an accurate description of firms' beliefs in these periods. Immediately following a reform, however, we have argued that it is more reasonable to assume that firms place a much greater weight on the existing tax code (because, at the very least, initiating another significant reform requires a lengthy legislative process). Thus, another identifying assumption implicit in our approach is that any expected changes in the code are sufficiently far away that they receive no weight in current decisions. If this assumption is not accurate, our estimates of the effects of tax changes will be biased toward zero.

Finally, for the estimation of both the tax-adjusted q and user cost of capital models, we allow only contemporaneous tax surprises to enter into our second-stage estimation. Other variables, such as interest rates, whose exogeneity is otherwise questionable, are fixed at their prereform values.[38]

36. To simplify, we have assumed that the productivity term in the derivation in Auerbach (1989) equals unity and that the long-run average of the user cost can be factored out into ξ.

37. This assumption is not strictly necessary. For reasonable values of the discount rate, a three-year horizon (which closely matches the mean time between tax reforms) is a first-order approximation to "permanent."

38. This is the same as in Steigerwald and Stuart (1993).

Internal Funds and Investment

A significant body of research has emerged relating investment to the availability of internal funds, holding constant investment opportunities. To the extent that we find that tax policy is an important determinant of investment, one might argue that our results depend on the omission of "internal funds," which may be correlated with other structural variables. If our estimates are truly structural, they will not be altered if we include other explanatory variables. To check the robustness of our results in this context, we include cash flow surprises in the second stage.

Empirical work in this literature has sometimes been criticized because current cash flow may be correlated with future profitability, and thus might well be a proxy for unobserved indicators of profitability (such as the true marginal q).[39] Shocks to firms' internal funds that result from tax policy, for a given pretax income, are an obvious candidate for an exogenous shift in the availability of internal finance.[40] To explore this line of inquiry, one could develop an analogous tax reform–based natural experiment as follows. Suppose that the firm forms an expectation of its pretax net income (as a ratio to its beginning-of-period capital stock), $E_{i,t-1} y_{i,t}$. As long as this expectation is determined using the same lagged information available to financial markets (used in determining tax-adjusted q), $E_{i,t-1} y_{i,t}$ should have no predictive power for investment. The tax surprise in this case equals the change in the average effective corporate tax rate multiplied by $E_{i,t-1} y_{i,t}$—that is, the unexpected after-tax income. By design, this additional term in the tax-adjusted q model described earlier does not capture unexpected changes in pretax income, which might convey information about investment op-

39. Gilchrist and Himmelberg (1991, 1992) argue, however, that cash flow appears to be an important explanatory variable for investment, holding constant a number of plausible empirical proxies for marginal q. The Euler equation approaches cited earlier are also immune to this criticism.

40. In this vein, Calomiris and Hubbard (1993) use firm-level data to explore firms' reaction to the undistributed profits tax of 1936–37, which levied a graduated surtax on retained earnings. They find that investment decisions of firms that simply increased dividend payouts to avoid the tax could be adequately represented by conventional neoclassical models. Cash flow effects on investment, holding constant investment opportunities measured by q, are attributable only to the set of firms that incurred significant surtax payments. Calomiris and Hubbard argue that these firms traded off the cost of the surtax payments with the (likely high) shadow cost of external finance.

portunities not captured in beginning-of-period tax-adjusted q; it captures only the surprise in after-tax net income (as a consequence of the tax reform) for a given anticipated pretax net income. We leave this latter test for future research, however, as the correct tax rate for this experiment is the firm-specific expected average tax rate, and construction of this rate is beyond the scope of this paper.

Data and Estimation: Firm-Level Data

The data set we use in the remainder of our empirical work is a 36-year (1953–88) unbalanced panel of firms from the Compustat Industrial data base.[41] Compustat data are reported in 20-year waves, so the 1989 file is combined with the 1973 file to make a continuous panel. Variable definitions are standard except for our measures of tax-adjusted q and the user cost of capital. We exploit additional firm-level information in Compustat to construct more precise estimates of q and the user cost of capital and to add to the cross-sectional variation in the panels.

The variables we use are defined as follows. Gross investment is the sum of the changes in the net stock of property, plant and equipment, and depreciation. Gross equipment investment (used to estimate the user cost of capital model) is the change in the net stock of machinery and equipment plus the firm-specific depreciation rate multiplied by the beginning-of-period capital stock.[42] The investment variables are divided by the values of their own beginning-of-period capital stocks. Cash flow is defined as pretax income, before extraordinary items, plus depreciation and amortization. This variable is also divided by the beginning-of-period capital stock. Where appropriate, variables are deflated by the implicit price deflator for gross domestic product.

We experimented with additional macroeconomic variables as first-stage instruments. These included the price of investment goods, oil prices, and various interest rates. We found that including additional variables had little effect on the results. For the reported results, we use

41. Compustat data tapes are compiled from company annual data by Standard and Poor's.

42. Compustat does not separately report equipment depreciation; we estimate it using the procedure outlined in appendix B. The level of SIC disaggregation changes because of data availability.

the most parsimonious specification, including only lags of investment, cash flow, and a time trend.

There are several data construction issues that merit attention. The number of firms in the panel decreases in 1971. The Compustat Industrial file reports data only for those firms still in existence at the end of the 20-year reporting period. As a result, in 1971, the year in which the 1989 file begins, there are firms included in the old wave but not in the new one. We chose to retain those firms to avoid deleting data from our relatively small beginning-of-period panels.[43]

Additional difficulties arise in using equipment data. Data on the gross stock of equipment capital are first reported in 1969. In order to construct the gross stock of equipment capital before 1969, we multiply the firm's gross stock of property, plant, and equipment by the annual share of equipment in gross capital stock for the firm's two-digit industry (according to the standard industrial classifications, SIC), as reported by the BEA. Thus, the equipment share is never missing before 1969. After 1969, the number of firms in our sample drops because the equipment share in Compustat is missing for many firms.

We make two significant improvements in the construction of the user cost of capital.[44] First, we construct firm-specific depreciation rates, using the method outlined in appendix B, rather than using the depreciation rates for one-digit SIC codes that were constructed with data from Charles Hulten and Frank Wykoff's 1981 study combined with aggregate capital stock weights.[45] Second, for our user cost of capital experiments, we construct a firm-specific required rate of return using Compustat data on firms' interest expense and total long-term and short-term debt.[46] These changes necessarily introduce measurement error. Despite this problem, we believe that the benefits of better capturing firm-specific investment incentives outweigh the cost of increased mea-

43. Excluding those firms did not significantly affect the results.

44. For a summary of the standard construction, see Auerbach and Hassett (1991) and Cummins and Hassett (1992).

45. Hulten and Wykoff (1981).

46. We experimented with using Compustat data on the firms' S&P debt rating and bond rating as measures of the real interest rate firms face. We opted to use the method above because Compustat reports the debt and bond ratings only from 1978 onward. We believe the class of debt and bond rating may provide a better measure of a firm's real interest rate but did not find that using either measure in our sample after 1978 significantly improved our results.

surement error. The relatively precise estimates reported below appear to justify this conclusion.[47]

The construction of tax-adjusted *q* incorporates the same improvements in calculating firm-specific depreciation. Otherwise, the construction generally follows the work of Michael Salinger and Summers.[48] The market value of equity is the sum of the market value of a firm's equity (defined as the common stock outstanding multiplied by the end-of-year common stock price) and the market value of preferred stock (defined as the firm's preferred dividend payout divided by Standard and Poor's, S&P's, preferred dividend yield).[49] The value of firm debt is the sum of short-term debt and long-term debt, both measured by their book values. Replacement values of inventories and the capital stock are calculated using the standard perpetual inventory method reported in appendix B. Data on expected inflation are taken from the Livingston Survey and are available from 1947 on.[50] The value of the firm's required rate of return is calculated as the difference between the firm's interest rate and expected inflation.[51] Price deflators are obtained from Citibase. Tax parameters are updated and corrected from those used by Auerbach and Hassett; we construct asset-specific investment tax credits to reflect the firm's two-digit SIC code asset composition.[52]

Firm data were deleted or modified according to the following rules. If the estimated firm depreciation rate is negative or greater than unity, we set it equal to the mean for firms in the same four-digit SIC code. If the estimated interest rate is above 25 percent, we also set it equal to the mean for firms in the same four-digit SIC code.[53] If the replacement value of the capital stock or inventory is estimated to be negative, we set

47. The empirical results for the user cost experiments presented in tables 8 and 9 include firm-specific required rates of return. Estimates of models with a fixed required rate of return of 4 percent produced virtually identical results.

48. Salinger and Summers (1983).

49. S&P's preferred dividend yield is obtained from Citibase.

50. The Livingston Survey data were provided by the Federal Reserve Board, which maintains a data base of numerous macroeconomic variables culled from many sources, including data on inflationary expectations (as provided by the Livingston Survey).

51. When available, we use Compustat's S&P bond rating for the interest rate, and the associated interest rate is obtained from Citibase; before 1978, the firm-specific interest rate is used.

52. Auerbach and Hassett (1991).

53. Alternatively, the observations were deleted without significantly affecting the empirical results.

it equal to book value. If dividend payouts on preferred stock are reported as missing, we set them equal to zero. If no inventory valuation method is specified, we assume the firm used the first in, first out (FIFO) system. If multiple valuation methods are reported, our calculations assume that the primary method is used.

We delete observations if the ratio of investment to the beginning-of-period capital stock is greater than unity. We also delete observations if the ratio of cash flow (or net income) to the beginning-of-period capital stock is greater than ten in absolute value. These two rules are intended to eliminate those observations that represent especially large mergers, extraordinary firm shocks, or Compustat coding errors. The rules delete less than 5 percent of the firms used in first-stage estimation. Finally, we delete observations whose forecast errors from the first stage are more than 20 times higher than the mean forecast error. These large forecast errors typically occur when there are very few observations for the firm, so that forecasting is very imprecise. Again, these rules eliminate a very small fraction of the data (usually about 1 percent of the firms and never more than 5 percent) of each year's sample. The results are not sensitive to which specific cutoff values are used.

Results from Conventional Estimation Approaches

Before presenting our findings focusing on tax reforms, we begin by reporting results from conventional techniques used to estimate neoclassical investment models with convex costs of adjustment. These estimates provide a baseline against which to later compare estimates using our technique. Table 3 provides different sets of estimates for the tax-adjusted q model. In the first column, ordinary least squares (OLS) is used to estimate equation 5 with fixed firm and year effects. Although statistically significant, the estimated coefficient of 0.025 on Q is small and, as in previous studies, implies very high costs of adjustment.[54] The specification in the second column follows work by Steven Fazzari, Hubbard, and Bruce Petersen, as well as others, adding cash flow relative to the beginning-of-period capital stock (CF/K), where K is the beginning-of-period capital stock and CF denotes before-tax cash flow.[55] Both estimated coefficients are positive and precisely estimated, but again the small Q coefficient implies large costs of adjustment.

54. See Summers (1981).
55. Fazzari, Hubbard, and Petersen (1988).

Table 3. Basic Investment Equations: Tax-Adjusted *q* Model[a]

Model feature	*OLS*		*GMM*		*OLS*[b]		*GMM*[b]	
Independent variable								
$Q_{i,t}$	0.025 (0.001)	0.019 (0.001)	0.019 (0.003)	0.015 (0.003)	0.040 (0.001)	0.028 (0.001)	0.057 (0.002)	0.044 (0.002)
Cash flow $(CF/K)_{i,t}$	. . .	0.164 (0.005)	. . .	0.154 (0.026)	. . .	0.193 (0.006)	. . .	0.344 (0.013)
Instrumental variables	. . .	. . .	$Q_{i,t-2,\ t-3}$ $(I/K)_{i,t-2,\ t-3}$ $(CF/K)_{i,t-2,\ t-3}$		. . .	. . .	$QT_{i,t}$, $Q_{i,t-2,\ t-3}$ $(I/K)_{i,t-2,\ t-3}$ $(CF/K)_{i,t-2,\ t-3}$	
Fixed firm effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\bar{R}^2$	0.039	0.049	. . .	. . .	0.068	0.127	. . .	. . .
$\chi^2_{(n-p)}$ (p-value)	. . .	. . .	13.18 (0.022)	11.75 (0.019)	. . .	. . .	500.46 (7×10^{-105})	448.98 (8×10^{-95})
Number of observations	19,855	19,855	18,729	18,399	18,168	18,168	18,129	17,973

Source: Authors' calculations using Compustat data.

a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Variables are defined in the text. Standard errors on coefficients, in parentheses, are computed from a heteroscedastic-consistent correlation matrix. The regression follows equation 5 in the text, with the cash flow variable added.

b. Regressions are based on a differenced version of equation 5 as described in the text.

We report exercises using generalized method of moments (GMM) estimates in the third and fourth columns, respectively. Instrumental variables for $Q_{i,t}$ are time $t - 2$ and $t - 3$ values of Q, I/K, and CF/K.[56] The tests of the model's overidentifying restrictions are also reported; each test is asymptotically distributed as $\chi^2_{(n-p)}$, where n represents the number of instruments and p the number of parameters estimated. The estimated coefficients are similar to those reported in the first two columns. The fifth and sixth columns report results using a "two-period" differenced version of the models reported in the first two columns, respectively, following work by Zvi Griliches and Jerry Hausman.[57] Although the estimated coefficients increase somewhat relative to the fixed-effects OLS base case, as one might expect if measurement error is important, they still imply large costs of adjustment. The seventh and eighth columns report GMM estimates using second differences.

To link the conventional estimation strategy to our approach, we report in table 4 differenced estimates of a modified q model. Specifically,

56. We choose a parsimonious instrument list. Expansion of the instrument set to include lags of other variables tended to increase power but had little effect on the point estimates.

57. Griliches and Hausman (1986). By "two-period" differenced, we mean the difference between the period t and period $t - 2$ values of the variable. All of the differences reported in the text are for two periods.

Table 4. Basic Investment Equations: Tax-Adjusted *q* Model (Focusing on Tax Variation)[a]

	OLS					GMM				
Model feature	*All years*	*1962*	*1972*	*1981*	*1986*	*All years*	*1962*	*1972*	*1981*	*1986*
Independent variable										
$QT_{i,t}$	0.083 (0.006)	0.554 (0.165)	0.198 (0.067)	0.299 (0.091)	0.178 (0.083)	0.063 (0.006)	0.585 (0.161)	0.136 (0.065)	0.262 (0.090)	0.245 (0.085)
Instrumental variables	. . .	. . .	. . .	. . .	. . .			$QT_{i,t}$ $Q_{i,t-2,\,t-3}$ $(I/K)_{i,t-2,\,t-3}$ $(CF/K)_{i,t-2,\,t-3}$		
Second differences	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\bar{R}^2$	0.011	0.041	0.015	0.012	0.010	. . .	. . .	. . .	. . .	. . .
χ^2_6 (p-value)	. . .	. . .	. . .	. . .	. . .	523.32 (8×10^{-110})	6.31 (0.390)	13.40 (0.037)	32.60 (1×10^{-5})	27.63 (1×10^{-4})
Number of observations	18,168	267	572	861	892	17,632	266	555	860	890

Source: Authors' calculations using Compustat data.

a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Variables are defined in the text. Standard errors on coefficients, in parentheses, are computed from a heteroscedastic-consistent correlation matrix. The regressions follow a differenced version of equation 5.

we equate the nontax components of $Q_{i,t}$ with their $t - 2$ values, thereby forcing variation to reflect principally that variation arising from tax parameters. We denote this new variable as QT. The first column reports OLS estimates with fixed firm and year effects. The estimated QT coefficient increases substantially over the Q coefficient in the earlier regressions. More dramatic differences emerge when we estimate the model using cross-sectional variation in the "major" tax reform years, with estimated QT coefficients ranging from 0.178 to 0.554, as shown in the second through fifth columns. The remaining five columns repeat the exercises just described using GMM estimates of the differenced tax-adjusted q model. The results are qualitatively similar to the OLS estimates.

The results of the exercises reported in tables 3 and 4 illustrate the potential significance of attempts to estimate investment models during periods in which major tax reforms provide a discrete change in the cross-sectional distribution of net returns to investment.

Empirical Results in the Modified Estimation Approach

In this section, we provide empirical estimates for tax-adjusted q and user cost of capital specifications with and without proxies for internal net worth—that is, before-tax cash flow. We present, in turn, the results from estimating investment equations that isolate the effects of tax surprises on investment through the tax-adjusted q and user cost of capital models.

Tax-Adjusted q Results

Following equations 4 and 5, we estimate a model for each year:[58]

$$(10) \qquad (I_{i,t}/K_{i,t-1}) - (\widehat{I_{i,t}/K_{i,t-1}}) = \mu_i + \Omega\,(Q_{i,t} - \widehat{Q_{i,t}}) + \epsilon_{i,t},$$

58. Note that we are ignoring the change in the nontax part of tax-adjusted q—that is, in the financial market valuations embodied in q and in the price of investment goods, p. We do this to focus on the cross-sectionally exogenous information from tax changes. This abstraction does not lead our estimated coefficients on tax-adjusted q to be biased upward. One concern might be that the introduction of an investment incentive would reduce the value of old capital in stock market valuations so that tax-adjusted q would move in a direction opposite to Γ; marginal q would not be affected, however. Another concern might be that the price of investment goods p would rise following the introduction of investment incentives. In this case, our estimated coefficient on tax-adjusted q is biased downward. We return to this point below.

where the variables with caret marks are firm-specific projections using period $t - 2$ information. To focus on the tax surprise, we set

$$Q_{i,t} = \frac{q_{i,t-2} - p_{t-2}(1 - \Gamma_{i,t})}{(1 - \tau_t)}. \tag{11}$$

Table 5 presents the estimation results for equation 10. We include years in which there was no tax reform as a control. By construction the coefficient on tax-adjusted q should be imprecisely estimated unless there has been a tax reform. Years following a "major" tax reform are denoted in the table by Δ; other tax reform years are denoted by κ. In each of the tax reform years, we find that tax-adjusted q has a positive and significant effect on investment. In the nonreform years, we find no significant effect of tax-adjusted q on firm behavior.

We argued in the introduction that we believe prior results presented point estimates of structural variables that were biased toward zero. The small coefficients reported in previous studies implied unreasonably large adjustment costs; Summers' preferred estimate (which summed the coefficients on Q and lagged Q) implied that a one-dollar increase in investment leads to between one and five dollars of adjustment costs.[59] For most of the other results reported by Summers, the scale of the adjustment cost is substantially larger than that of the purchase cost of the machine. Our estimates of the coefficient on Q in table 5, which range from 0.874 to 0.470 following the major reform years, are an order of magnitude larger than those reported in previous studies.[60] If one accepts the assumptions underlying the Hayashi-Summers approach, our estimates suggest that an extra dollar of investment will add between 0.05 and 0.12 dollar of adjustment costs.[61]

59. Summers (1981).

60. See Salinger and Summers (1983), Fazzari, Hubbard, and Petersen (1988), and Blundell and others (1992).

61. Interpretation of the size of the adjustment costs depends on the proximity of I/K to its steady-state value. Near the steady state, most of investment is replacement investment, which does not incur any adjustment costs in the model. For the first few units of investment over and above depreciation, marginal adjustment costs are low, by the convexity assumption. Far away from the steady state, marginal adjustment costs can be very high, even given our parameter estimates. For the comparison reported in the text, we applied the sample means of the investment to capital and depreciation to capital ratios (0.18 and 0.13, respectively) in order to gauge the relative adjustment costs.

Table 5. Investment Equations: Tax-Adjusted *q* Model for the Full Sample[a]

Year	*Number of firms*	$\overline{R}^2$	*Intercept*	*Q*
1963 Δ	251	0.056	−0.028 (2.74)	0.874 (3.86)
1964	362	0.000	0.044 (3.13)	0.011 (0.06)
1965 κ	457	0.033	−0.020 (1.27)	0.742 (3.95)
1966	606	0.001	0.031 (3.38)	0.109 (0.73)
1967	636	0.000	0.030 (2.83)	0.002 (0.02)
1968 κ	665	0.018	0.026 (1.11)	0.554 (3.46)
1969 κ	682	0.028	0.028 (1.12)	0.607 (4.44)
1970 κ	722	0.049	−0.030 (4.14)	0.533 (6.10)
1971 κ	707	0.046	−0.085 (9.09)	0.494 (5.81)
1972 κ	735	0.037	−0.056 (8.84)	0.446 (5.29)
1973 Δ	828	0.029	−0.046 (6.64)	0.470 (4.97)
1974	874	0.000	−0.025 (3.46)	0.054 (0.50)
1975	959	0.002	−0.068 (10.87)	−0.119 (1.28)
1976 κ	1007	0.037	−0.003 (0.61)	0.515 (6.23)
1977	1046	0.001	0.055 (9.96)	0.074 (0.79)
1978	1063	0.001	0.065 (10.22)	0.080 (0.81)
1979	1077	0.002	0.026 (3.37)	0.138 (1.41)
1980 κ	1081	0.024	−0.003 (0.51)	0.491 (5.15)

(*continued*)

Table 5 (*continued*)

Year	*Number of firms*	$\bar{R}^2$	*Intercept*	*Q*
1981	1103	0.001	−0.022	0.088
			(3.77)	(0.83)
1982 Δ	1114	0.030	−0.026	0.599
			(5.07)	(5.84)
1983 κ	1130	0.023	−0.004	0.609
			(0.74)	(5.85)
1984	1136	0.000	0.028	−0.020
			(3.43)	(0.20)
1985	1160	0.001	0.032	0.085
			(4.15)	(0.83)
1986	1188	0.001	0.021	0.105
			(2.50)	(1.14)
1987 Δ	1250	0.034	−0.026	0.613
			(3.18)	(6.66)
1988	1294	0.001	−0.030	0.127
			(1.15)	(1.32)

Source: Authors' calculations using Compustat data.
a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Heteroscedastic-consistent t-statistics in parentheses. Δ and κ denote years following major and minor tax changes, respectively. See text for descriptions.

Table 6 reports coefficient estimates for the same model for sample firms in the manufacturing sector (SIC codes 20–39). We provide this decomposition both to evaluate whether our results are merely reflecting variation across one-digit industries and to compare our results to other studies that focus on the manufacturing sector. Again, we find the coefficient on tax-adjusted q is statistically and economically significant in years immediately following a major tax reform. For the manufacturing sector, estimated adjustment costs are even smaller than for the sample as a whole, which is entirely plausible since the manufacturing capital stock is relatively more equipment intensive than other sectors.

Table 7 provides two sets of results for each year. The first augments the tax-adjusted q model to include a twice-lagged ratio of cash flow to capital.[62] The inclusion of this variable allows us to check the sensitivity

62. This follows Fazzari, Hubbard, and Petersen (1988), Gilchrist and Himmelberg (1991, 1992), and Blundell and others (1992).

Table 6. Investment Equations: Tax-Adjusted *q* Model for the Manufacturing Sector[a]

Year	*Number of firms*	$\bar{R}^2$	*Intercept*	*Q*
1963 Δ	225	0.088	0.017 (1.41)	1.190 (4.62)
1964	298	0.001	0.051 (3.28)	0.085 (0.42)
1965 κ	317	0.036	−0.002 (0.08)	0.868 (3.42)
1966	354	0.003	0.037 (2.72)	0.251 (1.07)
1967	371	0.001	0.037 (2.39)	0.181 (0.62)
1968 κ	378	0.032	0.027 (0.90)	0.651 (3.51)
1969 κ	388	0.030	0.008 (0.28)	0.604 (3.45)
1970 κ	416	0.034	−0.031 (2.39)	0.555 (3.84)
1971 κ	394	0.053	−0.058 (5.50)	0.650 (4.66)
1972 κ	436	0.040	−0.038 (4.61)	0.639 (4.24)
1973 Δ	493	0.031	−0.023 (2.83)	0.537 (3.93)
1974	506	0.002	−0.001 (1.27)	0.170 (1.00)
1975	527	0.001	−0.070 (6.71)	0.125 (0.72)
1976 κ	549	0.042	−0.015 (2.11)	0.588 (4.80)
1977	565	0.003	0.035 (5.09)	0.155 (1.20)
1978	590	0.001	0.065 (7.81)	0.133 (0.92)
1979	597	0.002	0.035 (2.86)	0.168 (0.93)
1980 κ	606	0.027	0.015 (2.10)	0.577 (4.07)

(*continued*)

Table 6 (*continued*)

Year	*Number of firms*	$\bar{R}^2$	*Intercept*	*Q*
1981	610	0.001	−0.021 (2.48)	0.118 (0.72)
1982 Δ	628	0.023	−0.034 (4.35)	0.593 (3.79)
1983 κ	634	0.028	−0.016 (1.92)	0.645 (4.23)
1984	644	0.001	0.030 (2.60)	0.072 (0.49)
1985	660	0.001	0.038 (3.42)	0.139 (0.94)
1986	680	0.002	0.010 (0.69)	0.196 (1.23)
1987 Δ	706	0.027	−0.030 (3.26)	0.661 (4.39)
1988	722	0.001	−0.038 (0.80)	0.160 (0.91)

Source: Authors' calculations using Compustat data.
a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Heteroscedastic-consistent *t*-statistics in parentheses. Δ and κ denote years following major and minor tax changes, respectively. See text for descriptions.

of the tax-adjusted q coefficients against our assumption that cross-sectional variation in internal funds does not materially affect the ability to estimate policy changes through tax-adjusted q. Although the estimated cash flow coefficient is positive and statistically significant (as in the studies cited above), it does not qualitatively change the point estimates on tax-adjusted q. This coefficient implies that the cash flow innovation in the period prior to the reform helps predict today's investment over and above beginning-of-period tax-adjusted q.

The second equation reported for each year includes an interaction term, denoted ND, between a dummy variable for paying zero dividends and the cash flow term. The dummy variable is one if the firm paid no dividends in period $t - 2$ and zero if the firm paid a dividend in period $t - 2$. As noted previously by Fazzari, Hubbard, and Petersen, the variation across firms of the sensitivity of investment to tax-adjusted q, combined with ex ante information as to which firms are most likely to be financially constrained, can arguably allow one to isolate the effects of

Table 7. Investment Equations: Tax-Adjusted *q* and Cash Flow for the Full Sample[a]

Year	$\bar{R}^2$	*Intercept*	*Q*	*CF/K*[b]	*ND*[c]
1963 Δ	0.117	−0.030 (1.99)	0.717 (3.13)	0.143 (4.14)	. . .
	0.117	−0.030 (1.98)	0.717 (3.11)	0.143 (4.02)	−0.004 (0.03)
1964	0.058	0.016 (0.84)	0.115 (0.65)	0.150 (4.47)	. . .
	0.060	0.019 (0.98)	0.097 (0.54)	0.137 (3.68)	0.071 (0.81)
1965 κ	0.073	−0.018 (0.91)	0.661 (3.37)	0.122 (4.56)	. . .
	0.075	−0.020 (0.99)	0.663 (3.38)	0.137 (4.33)	−0.053 (0.88)
1966	0.068	0.022 (2.61)	0.042 (0.32)	0.151 (6.55)	. . .
	0.071	0.021 (2.47)	0.049 (0.37)	0.167 (6.30)	−0.064 (1.19)
1967	0.160	0.028 (1.38)	−0.034 (0.22)	0.243 (11.11)	. . .
	0.167	0.029 (1.44)	−0.027 (0.18)	0.221 (9.30)	0.140 (2.35)
1968 κ	0.118	0.022 (0.94)	0.391 (3.12)	0.200 (8.26)	. . .
	0.120	0.019 (0.82)	0.380 (3.03)	0.183 (7.10)	0.074 (1.38)
1969 κ	0.141	−0.034 (2.70)	0.335 (4.07)	0.166 (9.23)	. . .
	0.142	−0.034 (2.67)	0.339 (4.12)	0.174 (8.86)	−0.045 (1.04)
1970 κ	0.128	−0.014 (1.49)	0.417 (5.87)	0.135 (7.87)	. . .
	0.131	−0.014 (1.52)	0.413 (5.83)	0.155 (7.10)	−0.052 (1.47)
1971 κ	0.224	−0.040 (5.07)	0.337 (4.70)	0.168 (12.54)	. . .
	0.235	−0.039 (4.92)	0.350 (4.91)	0.137 (8.31)	0.087 (3.22)

(*continued*)

Table 7 (*continued*)

Year	$\overline{R}^2$	*Intercept*	*Q*	*CF/K*[b]	*ND*[c]
1972 κ	0.147	−0.044	0.340	0.155	. . .
		(6.39)	(5.33)	(9.36)	
	0.147	−0.044	0.338	0.158	−0.012
		(6.36)	(5.27)	(8.09)	(0.35)
1973 Δ	0.134	−0.050	0.325	0.111	. . .
		(6.48)	(4.62)	(10.25)	
	0.136	−0.051	0.326	0.121	−0.027
		(6.52)	(4.64)	(8.88)	(1.19)
1974	0.163	−0.028	−0.068	0.180	. . .
		(3.96)	(0.85)	(13.08)	
	0.178	−0.024	−0.057	0.151	0.138
		(3.45)	(0.71)	(9.87)	(4.00)
1975	0.121	−0.070	0.083	0.147	. . .
		(13.06)	(1.15)	(11.37)	
	0.117	−0.068	0.065	0.131	0.139
		(12.81)	(0.90)	(9.57)	(3.46)
1976 κ	0.136	−0.014	0.359	0.146	. . .
		(2.68)	(5.34)	(10.77)	
	0.137	−0.014	0.359	0.158	−0.031
		(2.72)	(5.34)	(9.09)	(1.12)
1977	0.102	0.041	−0.016	0.137	. . .
		(6.90)	(0.21)	(10.80)	
	0.102	0.041	−0.015	0.135	0.006
		(6.90)	(0.20)	(8.88)	(0.23)
1978	0.105	0.054	−0.071	0.158	. . .
		(8.39)	(0.82)	(11.11)	
	0.105	0.053	0.070	0.165	−0.025
		(8.26)	(0.82)	(9.89)	(0.80)
1979	0.089	0.035	−0.042	0.130	. . .
		(4.25)	(0.39)	(10.20)	
	0.090	0.034	−0.040	0.141	−0.036
		(4.14)	(0.37)	(9.21)	(1.30)
1980 κ	0.108	−0.001	0.404	0.124	. . .
		(1.07)	(4.63)	(9.88)	
	0.108	−0.001	0.404	0.123	0.004
		(1.07)	(4.63)	(8.40)	(0.15)

(*continued*)

Table 7 **(*continued*)**

Year	$\bar{R}^2$	*Intercept*	*Q*	*CF/K*[b]	*ND*[c]
1981	0.091	−0.013	−0.137	0.139	. . .
		(2.27)	(1.38)	(10.44)	
	0.098	−0.015	−0.122	0.128	0.151
		(2.53)	(1.23)	(9.32)	(2.82)
1982 Δ	0.158	−0.000	0.327	0.187	. . .
		(0.041)	(3.61)	(13.67)	
	0.164	−0.001	0.321	0.163	0.081
		(0.11)	(3.55)	(9.98)	(2.79)
1983 κ	0.107	0.021	0.418	0.129	. . .
		(3.94)	(4.42)	(10.25)	
	0.108	0.022	0.425	0.141	−0.032
		(4.06)	(4.49)	(9.00)	(1.26)
1984	0.099	0.037	0.052	0.147	. . .
		(6.09)	(0.54)	(11.09)	
	0.101	0.037	0.053	0.164	−0.043
		(6.09)	(0.54)	(9.85)	(1.54)
1985	0.113	0.036	−0.029	0.151	. . .
		(6.17)	(0.32)	(12.03)	
	0.115	0.035	−0.028	0.167	−0.037
		(5.98)	(0.31)	(10.05)	(1.48)
1986	0.085	0.032	0.062	0.119	. . .
		(4.95)	(0.70)	(10.31)	
	0.085	0.032	0.060	0.116	0.005
		(4.95)	(0.68)	(7.57)	(0.24)
1987 Δ	0.107	−0.014	0.461	0.111	. . .
		(1.73)	(6.01)	(9.80)	
	0.107	−0.014	0.457	0.107	0.010
		(1.69)	(5.93)	(7.11)	(0.46)
1988	0.053	0.011	0.017	0.087	. . .
		(0.73)	(0.20)	(8.28)	
	0.053	0.011	0.016	0.091	−0.006
		(0.74)	(0.19)	(5.86)	(0.31)

Source: Authors' calculations using Compustat data.

a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Heteroscedastic-consistent t-statistics in parentheses. Δ and κ denote years following major and minor tax changes, respectively. See text for descriptions.

b. Cash flow variable.

c. *ND* denotes the no-dividend interaction term, $nodivdum_{i,t-2} \times CF/K$, where *nodivdum* equals 0 if firm pays a dividend and 1 if firm pays no dividend.

firms' net worth on investment.[63] If the availability of internal funds is not important, and the cash coefficient is just capturing misspecification, then the coefficient on the interaction term should be zero. In fact, the coefficient on this term is not always zero but follows a clearly discernible pattern: investment by non–dividend paying firms is much more sensitive to cash flow during recessions.[64] This cyclical sensitivity is consistent with the models of Gertler and Hubbard and of Stephen Oliner and Glenn Rudebusch, in which net worth constrains investment in downturns, but not in booms.[65]

Finally, table 8 reports coefficient estimates for the same model as in table 7 for a sample restricted to manufacturing firms. As with the basic Q model, the results closely match those for the sample as a whole.

User Cost of Capital Results

The user cost of capital and tax-adjusted q formulations are derived from the same model of firm investment, and one should expect that estimation of either model would imply similar adjustment costs. In fact, estimated coefficients on q have tended to be uniformly small, while estimated coefficients on the user cost of capital have varied significantly across studies. As a further check of our approach, we report in this section our estimates of the user cost of capital model (equation 4). If we are indeed measuring the "true" structural explanatory variables of investment, then our estimated adjustment costs using the user cost of capital model should be consistent with those reported for the tax-adjusted q representation in the previous section. In theory, the coefficient on the user cost of capital is equal to that on tax-adjusted q, divided by the expected value of the user cost term.[66]

Table 9 reports our estimates of equation 9 (using the full sample) for the basic user cost of capital model for equipment investment described earlier. The estimated coefficient on the fundamental variable is large and statistically significant in the years just following a major tax reform

63. Fazzari, Hubbard, and Petersen (1988).

64. The only year that contradicts this statement is 1967, but this was the year of the post–Regulation Q "credit crunch." See Gertler and Hubbard (1988).

65. Gertler and Hubbard (1988) and Oliner and Rudebusch (1994).

66. Under constant returns to scale and perfect competition, the coefficient is equal to the inverse of the proportional adjustment cost term, as in the conventional q specification.

Table 8. Investment Equations: Tax-Adjusted *q* and Cash Flow for the Manufacturing Sector[a]

Year	$\bar{R}^2$	*Intercept*	*Q*	*CF/K*[b]	*ND*[c]
1963 Δ	0.237	−0.020	0.927	0.170	. . .
		(1.16)	(3.67)	(6.27)	
	0.237	−0.021	0.929	0.173	−0.022
		(1.17)	(3.67)	(6.02)	(0.26)
1964	0.123	0.029	0.074	0.180	. . .
		(1.41)	(0.40)	(6.29)	
	0.124	0.030	0.072	0.171	0.038
		(1.46)	(0.39)	(5.20)	(0.56)
1965 κ	0.064	−0.004	0.764	0.093	. . .
		(0.21)	(3.10)	(2.96)	
	0.067	−0.003	0.768	0.079	0.086
		(0.11)	(3.12)	(2.29)	(0.95)
1966	0.103	0.034	0.102	0.178	. . .
		(2.75)	(0.50)	(6.25)	
	0.104	0.032	0.118	0.187	−0.043
		(2.57)	(0.58)	(5.83)	(0.61)
1967	0.191	0.046	0.143	0.225	. . .
		(1.64)	(0.66)	(9.29)	
	0.208	0.049	0.153	0.193	0.178
		(1.74)	(0.71)	(7.30)	(2.85)
1968 κ	0.150	0.008	0.488	0.159	. . .
		(0.22)	(3.04)	(7.43)	
	0.155	0.002	0.477	0.137	0.072
		(0.11)	(2.98)	(5.30)	(1.55)
1969 κ	0.113	−0.046	0.472	0.120	. . .
		(2.51)	(4.31)	(5.35)	
	0.114	−0.045	0.474	0.129	−0.037
		(2.48)	(4.31)	(5.04)	(0.76)
1970 κ	0.132	−0.019	0.409	0.137	. . .
		(1.00)	(3.31)	(7.03)	
	0.132	−0.019	0.409	0.135	0.005
		(1.00)	(3.30)	(5.47)	(0.14)
1971 κ	0.201	−0.052	0.323	0.149	. . .
		(3.82)	(3.12)	(9.08)	
	0.213	−0.049	0.345	0.122	0.086
		(3.61)	(3.34)	(6.28)	(2.52)

(*continued*)

Table 8 (*continued*)

Year	$\bar{R}^2$	Intercept	Q	CF/K[b]	ND[c]
1972 κ	0.127	−0.043	0.460	0.143	. . .
		(5.20)	(3.92)	(6.86)	
	0.128	−0.043	0.454	0.149	−0.025
		(5.19)	(3.83)	(6.32)	(0.54)
1973 Δ	0.169	−0.039	0.545	0.111	. . .
		(4.25)	(4.88)	(8.45)	
	0.169	−0.039	0.545	0.115	−0.011
		(4.27)	(4.88)	(6.72)	(0.43)
1974	0.274	−0.037	0.111	0.229	. . .
		(4.62)	(0.88)	(13.71)	
	0.292	−0.032	0.101	0.198	0.148
		(3.87)	(0.81)	(10.60)	(3.51)
1975	0.206	−0.092	0.018	0.204	. . .
		(12.43)	(0.17)	(11.63)	
	0.228	−0.092	0.007	0.185	0.249
		(12.42)	(0.06)	(10.25)	(3.81)
1976 κ	0.161	−0.018	0.467	0.152	. . .
		(2.89)	(4.08)	(9.16)	
	0.162	−0.018	0.465	0.162	−0.028
		(2.91)	(4.06)	(7.95)	(0.81)
1977	0.080	0.020	−0.007	0.113	. . .
		(2.77)	(0.06)	(6.95)	
	0.081	0.020	−0.017	0.121	−0.025
		(2.73)	(0.14)	(6.24)	(0.71)
1978	0.127	0.037	0.068	0.149	. . .
		(4.18)	(0.53)	(9.13)	
	0.130	0.036	0.049	0.165	−0.049
		(4.12)	(0.38)	(8.39)	(1.44)
1979	0.089	0.038	−0.010	0.134	. . .
		(3.42)	(0.06)	(7.55)	
	0.089	0.038	−0.010	0.135	−0.006
		(3.37)	(0.06)	(6.34)	(0.16)
1980 κ	0.092	0.008	0.471	0.111	. . .
		(1.18)	(3.62)	(6.55)	
	0.094	0.008	0.466	0.122	−0.039
		(1.16)	(3.58)	(6.13)	(1.03)

(*continued*)

Table 8 (*continued*)

Year	$\bar{R}^2$	*Intercept*	*Q*	*CF/K*[b]	*ND*[c]
1981	0.145	−0.013	−0.126	0.172	. . .
		(1.65)	(0.82)	(10.14)	
	0.154	−0.011	−0.086	0.150	0.097
		(1.46)	(0.56)	(7.89)	(2.44)
1982 Δ	0.181	−0.012	0.439	0.182	. . .
		(1.32)	(3.11)	(10.87)	
	0.196	−0.011	0.443	0.150	0.131
		(1.30)	(3.17)	(7.91)	(3.50)
1983 κ	0.107	0.008	0.453	0.148	. . .
		(1.05)	(3.14)	(8.37)	
	0.125	0.009	0.462	0.157	−0.025
		(1.13)	(3.19)	(7.21)	(0.71)
1984	0.139	0.046	0.095	0.167	. . .
		(5.19)	(0.70)	(10.05)	
	0.139	0.046	0.093	0.174	−0.016
		(5.19)	(0.68)	(8.27)	(0.45)
1985	0.153	0.042	0.064	0.158	. . .
		(5.25)	(0.48)	(10.66)	
	0.154	0.040	0.070	0.173	−0.031
		(5.02)	(0.52)	(8.53)	(1.05)
1986	0.076	0.036	0.020	0.131	. . .
		(2.94)	(0.12)	(7.40)	
	0.080	0.036	0.015	0.111	0.054
		(2.95)	(0.10)	(5.04)	(1.47)
1987 Δ	0.117	−0.015	0.543	0.133	. . .
		(0.96)	(3.51)	(8.61)	
	0.119	−0.016	0.547	0.120	0.028
		(0.98)	(3.53)	(5.81)	(0.93)
1988	0.059	0.016	0.007	0.096	. . .
		(0.52)	(0.04)	(6.69)	
	0.059	0.015	0.006	0.097	−0.002
		(0.52)	(0.04)	(4.54)	(0.08)

Source: Authors' calculations using Compustat data.

a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Heteroscedastic-consistent t-statistics in parentheses. Δ and κ denote years following major and minor tax changes, respectively. See text for descriptions.

b. Cash flow variable.

c. *ND* denotes the no-dividend interaction term, $nodivdum_{i,t-2} \times CF/K$, where *nodivdum* equals 0 if firm pays a dividend and 1 if firm pays no dividend.

Table 9. Equipment Investment Equations: Cost of Capital Model for the Full Sample[a]

Year	Number of observations	$\bar{R}^2$	Intercept	User cost
1963 Δ	107	0.145	−0.078	−0.605
			(2.72)	(4.21)
1964	136	0.001	0.041	0.024
			(3.78)	(0.33)
1965 κ	150	0.087	0.010	−0.691
			(0.58)	(3.74)
1966	294	0.000	0.057	0.044
			(2.34)	(0.26)
1967	305	0.002	0.046	−0.129
			(1.91)	(0.72)
1968 κ	335	0.044	−0.000	−0.506
			(0.02)	(3.93)
1969 κ	144	0.067	−0.254	−0.711
			(5.17)	(3.21)
1970 κ	197	0.058	−0.053	−0.499
			(3.21)	(3.47)
1971 κ	138	0.064	−0.037	−0.632
			(0.58)	(3.05)
1972 κ	241	0.043	0.004	−0.654
			(0.28)	(3.29)
1973 Δ	267	0.057	0.024	−0.546
			(1.32)	(4.00)
1974	291	0.005	−0.019	0.188
			(1.20)	(1.19)
1975	441	0.001	−0.055	0.104
			(5.05)	(0.66)
1976 κ	574	0.050	−0.045	−0.680
			(3.89)	(5.51)
1977	641	0.000	0.076	0.040
			(7.77)	(0.29)
1978	670	0.004	0.065	0.219
			(6.82)	(1.60)
1979	682	0.002	0.032	0.167
			(3.53)	(1.14)

(continued)

Table 9 (***continued***)

Year	*Number of observations*	$\bar{R}^2$	*Intercept*	*User cost*
1980 κ	687	0.040	0.039 (2.92)	−0.610 (5.33)
1981	452	0.002	−0.010 (0.90)	0.205 (1.05)
1982 Δ	469	0.032	−0.047 (5.06)	−0.757 (3.89)
1983 κ	512	0.019	−0.047 (4.21)	−0.829 (3.18)
1984	520	0.000	0.017 (1.76)	−0.066 (0.35)
1985	524	0.000	0.056 (5.53)	−0.015 (0.08)
1986	532	0.004	0.023 (0.74)	0.286 (1.43)
1987 Δ	549	0.022	0.012 (0.74)	−0.747 (3.32)
1988	573	0.004	−0.068 (3.58)	0.296 (1.52)

Source: Authors' calculations using Compustat data.
a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Heteroscedastic-consistent t-statistics in parentheses. Δ and κ denote years following major and minor tax changes, respectively. See text for descriptions.

and insignificant in nonreform years. The mean of the coefficients over the 13 tax reform years is about −0.65. Since the mean of our user cost of capital is about 0.25, these results roughly correspond to a coefficient on tax-adjusted q of 0.16. In terms of the structural parameters, this implies that an extra dollar of investment will lead to about 0.30 dollar of additional adjustment costs. Because we study equipment investment in this case—as opposed to total investment in the tax-adjusted q setup—the coefficient estimates are not strictly comparable.[67] Nonetheless, the coefficient estimates on tax-adjusted q and the user cost of capital are

67. Also at issue may well be the assumption of perfect competition required to make the comparison. In the case of monopolistic competition, for example, the estimated value of ξ should fall relative to the perfectly competitive case. As a result, it may appear that estimated adjustment costs are larger in the user cost specification than in the q specification when perfect competition is assumed.

much larger than those reported by previous studies, and both are in an intuitively reasonable range.[68]

As we did for the tax-adjusted q model, we also investigate whether the inclusion of cash flow variables significantly alters the estimated effect of the user cost of capital on investment. The result of this experiment is reported in table 10. As we found in the tax-adjusted q model, lagged cash flow is positively correlated with investment, and this effect is most pronounced for non–dividend paying firms during economic downturns. The inclusion of this additional variable does not qualitatively alter the coefficients on the user cost of capital, however.

Some Additional Considerations

In this section, we discuss other related evidence. We then proceed to relate our results to past empirical work and to the recently developed models of irreversible investment.

Evidence from International Data

An additional check on the usefulness of our approach of using tax reforms as natural experiments is to estimate investment models similar to equations 5 and 10 for other countries. We believe it is important to compare the robustness of our results based on U.S. micro data to those based on micro data from other industrial countries (members of the Organization for Economic Cooperation and Development, or OECD). In addition, however, OECD countries provide a more varied laboratory for analyzing business fixed investment. The institutional environment, capital market imperfections, and tax changes that firms face vary across countries, potentially allowing richer conclusions to be drawn.

In previous work, we conducted such tests for the tax-adjusted q model using panel data from the Global Vantage data base.[69] We provided results for a group of industrial countries—Australia, Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands,

68. Similar results were obtained using the manufacturing sample but are not reported here.

69. See Cummins, Hassett, and Hubbard (1994). Global Vantage is a Compustat-like data set for firms from many countries compiled by Standard and Poor's.

Table 10. Equipment Investment Equations: Cost of Capital and Cash Flow for the Full Sample[a]

Year	$\bar{R}^2$	*Intercept*	*User cost*	*CF/K*[b]	*ND*[c]
1963 Δ	0.267	−0.074	−0.503	0.104	. . .
		(2.75)	(3.70)	(4.17)	
	0.274	−0.073	−0.494	0.101	0.152
		(2.73)	(3.63)	(4.02)	(0.96)
1964	0.160	0.020	−0.029	0.098	. . .
		(2.41)	(0.43)	(5.01)	
	0.166	0.026	−0.030	0.101	−0.135
		(2.46)	(0.44)	(5.10)	(1.00)
1965 κ	0.197	0.001	−0.702	0.100	. . .
		(0.07)	(4.04)	(4.49)	
	0.197	0.002	−0.694	0.096	0.017
		(0.141)	(3.95)	(3.69)	(0.33)
1966	0.114	0.028	−0.104	0.131	. . .
		(1.15)	(0.66)	(6.11)	
	0.115	0.028	−0.103	0.127	0.019
		(1.15)	(0.65)	(5.42)	(0.35)
1967	0.164	0.048	−0.122	0.156	. . .
		(2.18)	(0.75)	(7.66)	
	0.206	0.043	−0.106	0.118	0.203
		(1.97)	(0.66)	(5.34)	(3.97)
1968 κ	0.077	0.004	−0.484	0.074	. . .
		(0.21)	(3.82)	(3.43)	
	0.077	0.004	−0.484	0.075	−0.003
		(0.21)	(3.81)	(2.84)	(0.06)
1969 κ	0.104	−0.217	−0.612	0.102	. . .
		(4.27)	(2.76)	(2.39)	
	0.104	−0.217	−0.610	0.110	−0.023
		(4.62)	(2.74)	(2.12)	(0.27)
1970 κ	0.139	−0.048	−0.422	0.096	. . .
		(2.98)	(3.04)	(4.26)	
	0.139	−0.047	−0.421	0.091	0.016
		(2.92)	(3.03)	(3.27)	(0.33)
1971 κ	0.340	0.069	−0.505	0.124	. . .
		(1.29)	(2.87)	(7.51)	
	0.359	0.065	−0.484	0.097	0.060
		(1.23)	(2.78)	(4.58)	(2.04)

(*continued*)

Table 10 (*continued*)

Year	$\bar{R}^2$	*Intercept*	*User cost*	*CF/K*[b]	*ND*[c]
1972 κ	0.195	0.010	−0.555	0.100	. . .
		(0.77)	(3.03)	(6.69)	
	0.203	0.011	−0.571	0.084	0.048
		(0.90)	(3.12)	(4.64)	(1.42)
1973 Δ	0.091	−0.030	−0.540	0.073	. . .
		(1.72)	(4.03)	(3.16)	
	0.092	−0.030	−0.538	0.070	0.008
		(1.70)	(3.99)	(2.40)	(0.16)
1974	0.196	−0.018	0.042	0.118	. . .
		(1.27)	(0.29)	(8.26)	
	0.232	−0.014	0.043	0.079	0.107
		(0.98)	(0.31)	(4.50)	(3.71)
1975	0.114	−0.072	0.030	0.101	. . .
		(6.80)	(0.20)	(7.47)	
	0.135	−0.072	−0.018	0.074	0.095
		(6.92)	(0.20)	(4.72)	(3.27)
1976 κ	0.159	−0.027	−0.591	0.075	. . .
		(2.42)	(5.06)	(8.57)	
	0.159	−0.026	−0.583	0.080	−0.011
		(2.37)	(4.96)	(6.82)	(0.63)
1977	0.057	0.060	−0.048	0.058	. . .
		(6.09)	(0.36)	(6.19)	
	0.059	0.059	−0.053	0.066	−0.023
		(5.98)	(0.39)	(5.75)	(1.23)
1978	0.102	0.042	0.124	0.085	. . .
		(4.51)	(0.96)	(8.52)	
	0.102	0.043	0.126	0.083	0.006
		(4.51)	(0.97)	(7.14)	(0.27)
1979	0.105	0.026	0.187	0.086	. . .
		(2.94)	(1.34)	(8.82)	
	0.105	0.026	0.189	0.088	−0.007
		(2.93)	(1.35)	(7.55)	(0.33)
1980 κ	0.109	0.037	−0.570	0.069	. . .
		(2.87)	(5.16)	(7.30)	
	0.110	0.037	−0.572	0.064	0.019
		(2.89)	(5.17)	(5.93)	(0.84)

(*continued*)

Table 10 (*continued*)

Year	$\bar{R}^2$	*Intercept*	*User cost*	*CF/K*[b]	*ND*[c]
1981	0.143	−0.001	0.290	0.136	. . .
		(0.11)	(1.59)	(8.56)	
	0.152	−0.004	0.290	0.112	0.076
		(0.37)	(1.60)	(5.81)	(2.22)
1982 Δ	0.155	−0.026	−0.632	0.111	. . .
		(2.87)	(3.46)	(8.18)	
	0.170	−0.029	−0.643	0.079	0.078
		(3.24)	(3.55)	(4.51)	(3.00)
1983 κ	0.098	−0.018	−0.620	0.088	. . .
		(1.58)	(2.46)	(6.66)	
	0.103	−0.016	−0.587	0.103	−0.044
		(1.41)	(2.32)	(6.44)	(1.61)
1984	0.105	0.027	−0.063	0.086	. . .
		(2.94)	(0.36)	(7.77)	
	0.105	0.027	−0.065	0.084	0.007
		(2.94)	(0.37)	(6.24)	(0.32)
1985	0.097	0.051	−0.009	0.083	. . .
		(5.22)	(0.05)	(7.49)	
	0.097	0.051	−0.009	0.081	0.005
		(5.18)	(0.05)	(5.48)	(0.22)
1986	0.095	0.006	0.089	0.083	. . .
		(0.20)	(0.46)	(7.31)	
	0.096	0.006	0.086	0.077	0.017
		(0.20)	(0.45)	(5.48)	(0.74)
1987 Δ	0.081	0.023	−0.722	0.071	. . .
		(1.52)	(3.30)	(5.58)	
	0.084	0.025	−0.729	0.085	−0.034
		(1.61)	(3.34)	(5.22)	(1.35)
1988	0.113	−0.059	0.240	0.094	. . .
		(3.29)	(1.31)	(8.33)	
	0.113	−0.059	0.249	0.098	−0.011
		(3.30)	(1.35)	(6.70)	(0.46)

Source: Authors' calculations using Compustat data.

a. The dependent variable is $I_{i,t}/K_{i,t-1}$. Heteroscedastic-consistent t-statistics in parentheses. Δ and κ denote years following major and minor tax changes, respectively. See text for descriptions.

b. Cash flow variable.

c. *ND* denotes the no-dividend interaction term, $nodivdum_{i,t-2} \times CF/K$, where *nodivdum* equals 0 if firm pays a dividend and 1 if firm pays no dividend.

Norway, Spain, Sweden, and the United Kingdom—analogous to those we present here for the United States. For each country, we found implausibly large adjustment costs using traditional techniques. Estimated coefficients on tax-adjusted q averaged about 0.05 when we used OLS or GMM with fixed firm and year effects. Focusing on the years in which there were significant tax reforms, we estimated much larger coefficients on tax-adjusted q, implying smaller adjustment costs than those conventionally estimated. For most countries these coefficients were similar to those reported here for the United States, averaging about 0.7 for the many countries in our sample.

Comparison with Euler Equation Estimates

The argument that we are estimating structural parameters depends crucially on one's judgment about the validity of our identifying assumption that there are times when we can observe the relevant expected structural variable. If our assumption is accurate, and our estimates are capturing adjustment cost parameters, those estimates should not vary significantly over time and specification. Oliner, Rudebusch, and Sichel have shown that Euler equation estimates of the adjustment cost parameters presented here can vary over time by a factor of ten.[70] By contrast, our estimates vary over a much smaller range and are economically similar across different econometric specifications of the same basic model over a 27-year period.

Consideration of Changes in the Price of Capital Goods

Our technique for analyzing the responsiveness of investment to changes in the net return to investing relies on contemporaneous tax information, holding nontax components of structural variables constant at their pretax reform values. As a result, the estimated effect of changes in tax-adjusted q and the user cost of capital do not incorporate additional contemporaneous effects of a tax-induced shock to investment demand on the prices of investment goods (if the marginal cost for supplying investment were increasing, for example). The response of the value of investment expenditures to a change in the net return to in-

70. Oliner, Rudebusch, and Sichel (forthcoming-b).

vesting will be larger than our implied effects if there are significant short-term price effects of an increase in investment demand. Analyzing this channel is a topic for future research.[71]

Comparison with Irreversible Investment Models

According to our setup, firms always respond to fundamentals in a manner consistent with the neoclassical model; the problem for the econometrician is that recovering "reasonable" estimates is possible only during periods in which large exogenous changes in the cross-sectional distribution of the structural determinants occur, as during tax reforms. Given our results, some might argue that we have documented that firms respond only to changes in fundamentals when these changes are large—that is, our results are consistent with the predictions of a model of irreversible investment.[72] Under this line of argument, the problem is not that the neoclassical optimizing behavior cannot be estimated using conventional techniques but that the neoclassical model with convex adjustment costs is not a reasonable description of firm's decisions. At an intuitive level, it is not difficult to suggest examples of nonconvex adjustment costs (such as retooling in automobile plants or the adoption of more energy-efficient kilns in cement plants). Mark Doms and Timothy Dunne examine more systematically changes in capital stocks at the plant level using a large data set drawn from the Longitudinal Research data base maintained by the Bureau of the Census.[73] Doms and Dunne find that 25 percent of expenditures on new equipment and structures is made by (generally small) plants that increase real capital stocks by more than 30 percent in a given year. However, they report that 80 percent of plants, accounting for 45 percent of total investment, change their real capital stocks by less than 10 percent in a given year.

Using our firm-level data from Compustat, we examine whether firms concentrate investment spending in periods of significant shifts in the

71. For one attempt at so doing, see Goolsbee (1994), who studies the investment tax credit in isolation.

72. Models of irreversible investment under uncertainty stress the importance of the option value of delaying investment in order to obtain new information about a project's cost or value. Because investment is assumed to be reversible in the conventional neoclassical model, and firms cannot delay exercising their option to invest, this complication does not arise.

73. Doms and Dunne (1993).

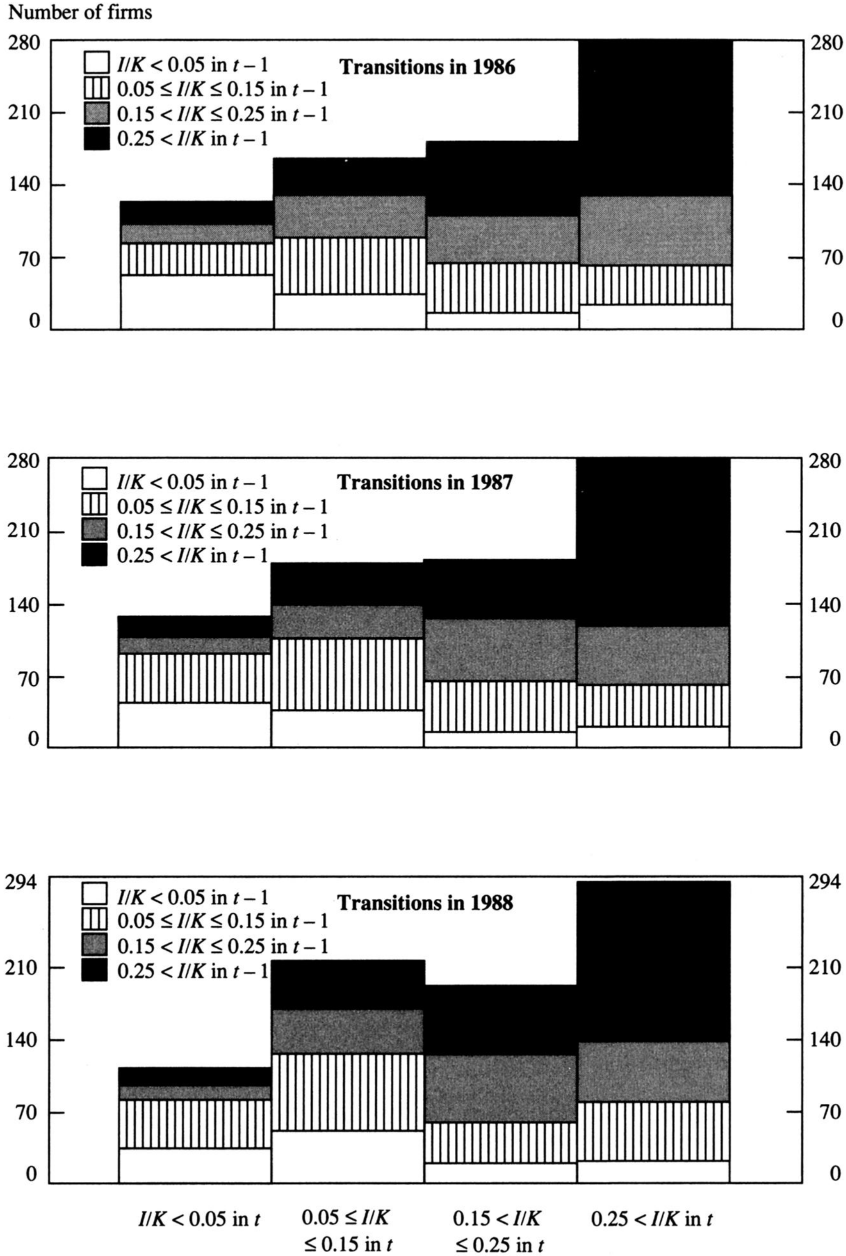
net return to investing. Figure 8 illustrates changes in investment to beginning-of-period capital stock ratios (I/K) in 1986, 1987, and 1988 (the year the Tax Reform Act of 1986 was enacted and the subsequent two years). The four column blocks represent firms' values of I/K in the given year: less than 0.05, between 0.05 and 0.15, between 0.15 and 0.25, and greater than 0.25. The height of each block indicates the number of firms falling into that range. Each block is decomposed into cells according to the firms' I/K in the preceding year. These cells illustrate the movement of firms across cells. While the figures for 1986, 1987, and 1988 indicate that firms change their investment rates, they do not appear to reflect any discernible bunching. If the change in the Tax Reform Act of 1986 was anticipated, firms could have shifted investment from 1987 to 1986, before the investment tax credit was eliminated. The transitions in figure 8 do not show a significant shift from higher investment rates into lower investment rates in 1987 and 1988. Figures for years surrounding the other major tax reforms reveal similar patterns and are available from the authors on request.

"Bunching" is not the only implication of irreversibility. In addition, the estimated coefficients on tax variables should vary in a well-defined way across the different reform years. Avinash Dixit and Robert Pindyck develop an example of tax policy uncertainty in which policy switches between regimes.[74] There are different threshold criteria for investment in the two regimes, and in each year there is some given probability of enactment of the "generous" or "stingy" regime. If the stingy regime is currently in place, the greater the probability of enactment of the generous regime in the next year, and the greater the incentive to delay investing today. When the generous regime is in place, the prospect of a subsequent switch to the stingy regime causes firms to increase current investment. Since irreversibility can lead to long periods of inaction, these forces cause a bunching of investment in the years during which the generous regime is in place. Dixit and Pindyck present simulation results that suggest that there is asymmetry associated with this story.[75] The value of bunching investment is much greater when firms expect the stingy regime to be followed by a generous one than when they expect a generous regime to be followed by a stingy one. This result

74. Dixit and Pindyck (1994, chap. 9). This example is based on Hassett and Metcalf (1994).

75. Dixit and Pindyck (1994).

Figure 8. Investment Transitions around Tax Reforms



Source: Authors' calculations from Compustat data.

suggests that we should see a difference in the estimated effects of the user cost or Q in years when the tax treatment of investment is made more or less generous.[76] In fact, as shown in tables 5–10, there is very little difference in coefficients across the tax reform years. Compare, for example, the coefficients estimated in 1982 and 1987. In the tables, the coefficients are quite similar in these two years, even though investment tax policy moved in opposite directions.

Hence, while models of policy uncertainty and irreversibility provide insights into the determinants of business investment, we do not believe that our results necessarily favor these models. Developing testable differences between neoclassical models and models based on irreversibility is an important task for future research.

Further Macroeconomic Implications

Our results strongly suggest that shifts in the cross-sectional distribution of the net return to investing have significant effects on the composition of investment. If one accepts the assumptions required to interpret our estimates as "structural," then one can—with great caution—make inferences about the likely effects of tax reform on the aggregate level of investment. For example, we can calculate the elasticity of aggregate investment with respect to the user cost of capital. Given that the mean values of equipment (I/K) and the user cost of capital in our sample are similar (about 0.25), our average estimated user cost coefficient of -0.66 translates into an elasticity of about -0.66.

We can use this elasticity to gauge the responsiveness of equipment investment to the tax reforms. For example, in response to the 1962 reform, the changes in the user cost of capital and in our estimated coefficient imply that the aggregate equipment investment–capital ratio should have risen by about 0.01, or about 7 percent. (The investment capital ratio actually rose by 0.017, or about 11 percent.) Our predicted change corresponds to about \$7 billion in 1987 prices. The absolute

76. In the neoclassical model, bunching can occur if reforms are anticipated (see Nickell, 1978). Auerbach (1989) illustrates this mechanism: the change in the relative price of capital used to calculate the real interest rate includes Γ, so the user cost can increase significantly just before an investment tax credit is introduced. This effect is not, however, asymmetric, since the adjustment cost function that connects behavior in different periods is symmetric. The asymmetries of the sort described in the text arise because irreversibility constrains firms in periods where they would like to reduce their capital stocks.

value of the predicted change of major tax reforms in our sample is also about 0.01.

How important have the tax changes been? Many other fundamentals—for example, interest rates, productivity, and capital goods prices—contribute to fluctuations in investment. Although we have provided evidence that tax parameters may contribute to movements in investment, other things being equal, it is certainly true that tax parameters are seldom the only thing changing. Indeed, the predicted effects of large permanent tax reforms must only be a single piece of the puzzle. The standard deviation of I/K over our sample period is 0.038. That is, the standard deviation of investment is roughly four times the mean predicted effect of the major tax reforms in our sample. We argue here that changes in tax parameters are the easiest of the fundamentals affecting investment to measure, and we are reassured that, in the end, a strong case can be made that they are important. However, explaining the remaining variation in investment is likely to prove far more challenging, as the measurement error and simultaneity problems that provided the initial motivation for our work are probably more difficult to overcome when attempting to evaluate the contributions of other nontax investment fundamentals.

We do not estimate here a structural model of links between internal funds and investment. Our estimated coefficients on "cash flow" in tables 7, 8, and 10 suggest that changes in average tax rates might also affect investment by changing the internal funds available to financially constrained firms. To the extent that the investment spending of such firms is quantitatively important, tax reforms may have an effect on investment over and above that contained in the neoclassical model.[77] An application of our technique to models of investment decisions under imperfect capital markets is a important task for future research, one that might well explain a significant portion of the variation left unexplained by this study.

Conclusions

We use tax reforms as natural experiments in order to estimate the responsiveness of business fixed investment to underlying determinants

77. See, for example, Bernanke, Gertler, and Gilchrist (forthcoming).

suggested by models stressing the net return to investing. We argue that this approach significantly reduces measurement error problems that have plagued previous attempts at estimation. The estimates of the effects of tax-adjusted q or the user cost of capital on investment are much more economically significant than those obtained in many previous studies with more traditional techniques and imply reasonable adjustment costs in both the tax-adjusted q and user cost of capital frameworks. We find that subsequent to every major business tax reform since 1962, the cross-sectional pattern of investment has changed significantly. Investment spending in those firms facing the greatest change in tax incentives responded the most. In periods without tax reforms, we find no unusual response in investment. We also explore the sensitivity of our results to the inclusion of internal funds. Their inclusion does not qualitatively alter our estimates of the effects of tax-adjusted q or the user cost of capital, although their importance suggests the desirability of studying "tax surprises" in internal funds.

If one accepts the assumptions required to derive neoclassical investment models, our estimated coefficients on fundamental variables in those models may be interpreted as structural. In that case, our findings suggest that long-lasting changes in corporate taxation can have significant effects on the level of business fixed investment. At a minimum, our results suggest that the investment models based on tax-adjusted q and the user cost of capital, well understood by business people and policymakers, may be useful for forecasting purposes.

APPENDIX A

Model Derivations

To DERIVE the tax-adjusted q model, we begin with an expression for the value of the firm, which in turn stems from the arbitrage condition governing the valuation of shares.[78] The after-tax return to the owners of the firm at time t reflects capital appreciation and current dividends.

78. See Poterba and Summers (1985) and Abel (1990).

In equilibrium, if the owners are to be content holding their shares, this return must equal their required return ρ:

$$\text{(A1)} \qquad [(1 - z_t)(E_{i,t}(V_{i,t+1} - S_{i,t+1}) - V_{i,t}) + (1 - m_t)E_{i,t}D_{i,t+1}]/V_{i,t} = \rho_{i,t},$$

where i and t are the firm and time indexes, respectively; $E_{i,t}$ is the expectations operator of firm i conditional on information available at time t; V is the value of the firm's equity; S is the value of new shares issued; D represents the dividends the firm pays; z is an accrual-equivalent capital gains tax rate; and m is the personal tax rate on dividends.

In the absence of any speculative bubbles, solving equation A1 forward yields the following expression for the market value of the firm's equity at time t:

$$\text{(A2)} \qquad V_{i,t} = E_{i,t} \sum_{s=t}^{\infty} \left(\prod_{j=t}^{s} \right) \beta_{i,j}(\eta_s D_{i,s} - S_{i,s}),$$

where $\beta_{i,j}$ is the time j discount factor for firm i and η_s equals $(1 - m_s)/(1 - z_s)$.

The firm maximizes equation A2 subject to five constraints. The first is the capital stock accounting identity:

$$K_{i,t} = (1 - \delta_i)K_{i,t-1} + I_{i,t},$$

where I denotes investment and K denotes the capital stock, and δ is the rate of economic depreciation. The second constraint defines firm "dividends" (net cash flow). Cash inflows consist of sales, new share issues, and net borrowing, while cash outflows consist of dividends, factor and interest payments, and investment expenditures:

$$D_{i,t} = (1 - \tau_t)[F(K_{i,t-1}, \mathbf{N}_{i,t}) - \mathbf{w}_t\mathbf{N}_{i,t} - C(I_{i,t}, K_{i,t-1}) - i_{t-1}B_{i,t-1}] + S_{i,t} + B_{i,t} - (1 - \pi^e) B_{t-1} - p_t(1 - \Gamma_{i,t})I_{i,t},$$

where τ is the corporate tax rate; $F(K,\mathbf{N})$ is the firm's production function ($F_K > 0$, $F_{KK} < 0$); $C(I,K)$ is the real cost of adjusting the capital stock ($C_I > 0$, $C_{II} > 0$, $C_K < 0$, $C_{KK} < 0$); $\mathbf{N}$ is a vector of variable factors of production; $\mathbf{w}$ is a vector of real factor prices; B is the market value of outstanding debt; i is the nominal interest rate paid on corporate bonds; π^e is expected inflation; p is the price of capital goods relative to the price of output; and Γ is the tax benefit of investing. For example, with an investment tax credit at rate k, Γ is

$$\Gamma_{i,t} = k_{i,t} + \sum_{s=t}^{\infty} (1 + r_s + \pi_s^e)^{-t} \tau_s DEP_{i,s}(s - t),$$

where r is the default risk–free real interest rate (assumed to equal 4 percent), and $DEP_{i,s}(a)$ is the depreciation allowance permitted an asset of age a discounted at a nominal rate that includes the expected inflation rate π^e.

The third constraint restricts dividends to be nonnegative:

$$D_{i,t} \geq 0.$$

The fourth constraint limits share repurchases:

$$S_{i,t} \geq \overline{S}.$$

The fifth constraint is a transversality condition that prevents the firm from borrowing an infinite amount to pay out dividends:

$$\lim_{T \to \infty} \left(\prod_{j=t}^{T-1} \beta_{i,j} \right) B_{i,T} = 0, \quad \text{for all } t.$$

Turning first to the equilibrium value of marginal q, the solution for the case in which internal funds exceed desired investment is familiar. If the dividend tax rate exceeds the accrual-equivalent tax rate on capital gains ($m > z$), it is never optimal to issue new shares and pay dividends simultaneously. When we abstract from corporate tax considerations and adjustment costs, the equilibrium value of marginal q is η. At that value of q, shareholders are indifferent between a dollar of retentions reinvested in the firm taxed at rate z and a dollar of dividends taxed at rate m. New shares are issued only when internal funds are exhausted and the marginal q on additional projects exceeds one.

From the first-order condition for investment, we obtain a relationship among the shadow price of additional capital, adjustment costs, and tax parameters:

$$\text{(A3)} \qquad (1 - \tau_t) \left[p_t \left(\frac{1 - \Gamma_{i,t}}{1 - \tau_t} \right) + C_I \right] = q_{i,t},$$

where q is the shadow value of an increase in the capital stock (that is, marginal q). Equation A3 states that, after adjusting for tax considerations, the firm selects an investment rate at which the marginal cost of investment—including the after-tax cost of the investment good and the marginal cost of adjustment—equals the value of an incremental unit of installed capital, marginal q.

To derive the equation we estimate, we posit a quadratic adjustment cost function:

$$C(I_{i,t}, K_{i,t-1}) = \frac{\alpha}{2}\left(\frac{I_{i,t}}{K_{i,t-1}} - \mu_i\right)^2 K_{i,t-1}, \tag{A4}$$

where μ is steady-state rate of investment and α is the adjustment cost parameter. Using equation A4 and rearranging terms in equation A3 yield

$$\frac{I_{i,t}}{K_{i,t-1}} = \mu_i + \frac{1}{\alpha}\left[\frac{q_{i,t} - p_t(1 - \Gamma_{i,t})}{1 - \tau_t}\right]. \tag{A5}$$

Equation A5 is not empirically implementable since q is unobservable. If we assume a constant returns to scale production function and perfect competition, we may equate marginal q to average q, defined for each firm as tax-adjusted q,

$$Q_{i,t} = (L_{i,t}V_{i,t} + B_{i,t} - A_{i,t})/K^*_{t-1}, \tag{A6}$$

where L is an indicator function equaling one if the firm is not paying dividends and η if the firm is paying dividends; A is the present value of the depreciation allowances on investment made before period t; and K^* is the replacement value of the firm's capital stock (including inventories). Hence we estimate

$$\frac{I_{i,t}}{K_{i,t-1}} = \mu_i + \frac{1}{\alpha}(1-\tau_t)^{-1}\left[\left(\frac{L_{i,t}V_{i,t} + B_{i,t} - A_{i,t}}{K^*_{i,t-1}}\right) - p_t(1-\Gamma_{i,t})\right]. \tag{A7}$$

The q formulation stresses a relationship between investment and the net profitability of investing, as measured by the difference between the value of an incremental unit of capital and the tax-inclusive cost of purchasing capital. Another interpretation is offered in the user cost or rental cost formulation suggested first by Jorgenson.[79] The user cost of

79. Jorgenson (1963).

capital is a rental rate on a unit of capital. In principle, the "price" of capital in the calculation is the shadow price, marginal q. Jorgenson's derivation instead relies on the price of the investment good, p.[80] In the user cost setup, the firm equates the marginal cash flow from an incremental unit of capital equal to the user cost, c:

$$(1 - \tau_t) F_K (K_{i,t-1}, N_{i,t}) - C_K(I_{i,t}, K_{i,t-1}) = c_{i,t}. \tag{A8}$$

In the steady state, C_K equals zero, so that

$$(1 - \tau_t) F_K (K_{i,t-1}, N_{i,t}) = c_{i,t}. \tag{A9}$$

Jorgenson and various collaborators used equation A9 to derive an expression for the desired capital stock as a function of the user cost of capital and net revenue. The gap between the desired and actual capital stock was closed by an ad hoc mechanism (such as delivery lags). In the application presented here, we follow Auerbach.[81] He begins with the Euler equation for investment and assumes a production function and adjustment cost function similar to those described above (but including productivity shocks). He approximates the optimal solution for perturbations by solving a linearized version of the Euler equation. The structure of the solution resembles equation A5, where the constant term is a function of the steady-state depreciation rate and a root of the linearized difference equation in K. The user cost coefficient ξ is a function of the steady-state average user cost and a root of the linearized difference equation in K.

APPENDIX B

Data Construction

To CONSTRUCT the depreciation rate δ and the replacement value of capital K^*, we begin with the firm's book value of capital stock in the first year for which it is reported continuously. We then employ the perpetual inventory method to estimate the rate of declining balance depreciation that is consistent with the firm's initial and terminal capital stocks.

80. The original derivation did not include adjustment costs.
81. Auerbach (1989).

Given this estimate of economic depreciation, we then estimate the current market value of the capital stock by multiplying the capital remaining from different vintages by the ratio of the price (using the price deflator for the capital stock) in the current year to that for the year in which the capital was purchased. This procedure necessarily assumes that the initial capital stock was correctly valued on the firm's books.

That is, we solve for δ from the equation:

$$K_T = (1 - \delta)^T K_0 + (1 - \delta)^{T-1} K_1 + \ldots + I_T, \tag{B1}$$

where K_t is the book capital stock at the end of the year t and I_t is investment in year t; the variables are expressed in constant 1987 dollars. Using the estimated values of δ, we estimate firms' capital stock following Salinger and Summers.[82]

For firms using the first in, first out method, inventories are valued at current cost so that their book value and replacement value are equal. For firms using the last in, first out (LIFO) method, inventories are valued at historical cost. To convert the book value to market value, we use the same method as that for converting the capital stock. That is, we roll forward

$$Invt_t^m = Invt_{t-1}^m \frac{P_t}{P_{t-1}} + Cinvt_t \quad \text{if } Cinvt_t \geq Cinvt_{t-1}, \tag{B2}$$

$$Invt_t^m = (Invt_{t-1}^m + Cinvt_t) \frac{P_t}{P_{t-1}} \quad \text{if } Cinvt_t < Cinvt_{t-l}, \tag{B3}$$

where $Invt_t^m$ is the replacement value of LIFO inventories at time t and $Cinvt_t$ is the change in LIFO inventories in year t.

82. Salinger and Summers (1983).

Comments and Discussion

Robert E. Hall: The fundamental approach of this paper—the use of major discrete tax reforms to find out how changes in the price of capital affect purchases of capital goods—is an important step forward. The paper exploits rich panel data within this general approach.

Before I turn to the substance of this approach, however, I will comment on what I see as a missed opportunity in the paper—a failure to clear up some confusions that have entered the investment literature. The introduction describes the user cost or neoclassical model of investment, developed by Dale Jorgenson, as supplanted by the q theory, developed by James Tobin. Although the paper does present the major components of the modern theory of investment, it does not stress the unity of the theory. It may escape the reader's attention that modern thinking puts the Jorgenson and Tobin relationships on equal footings as, in effect, the demand and supply equations for investment. The statement in the introduction, "By the 1980s, models based on the q representations had largely replaced those based on the user cost of capital for analyzing investment," strikes me as the equivalent of saying that the supply schedule has replaced the demand schedule. I was always taught to interpret price and quantity as determined by the intersection of demand and supply.

The modern theory, as shown by Fumio Hayashi and, most neatly and compactly, by Andrew Abel, portrays an internal market in the firm for installed capital.[1] Jorgenson's equation tells the firm to equate the marginal product of capital to the user cost, where the user cost takes the shadow value of installed capital, q, as its price, rather than the price charged by an outside supplier of capital goods. Thus, Jorgenson pro-

1. Hayashi (1982) and Abel (1990). Abel (1980) is also relevant.

vides the demand function for installed capital. On the supply side, the optimizing firm equates the marginal cost of purchasing and installing capital goods to the shadow value of installed capital, q. The supply side is Tobin's contribution.

Jorgenson's original model implicitly assumed perfectly elastic supply of installed capital at a price equal to the market price of capital goods. In other words, there were no adjustment costs in Jorgenson's original model. To the extent that Jorgenson has been "supplanted," as claimed by this paper, it is that the supply equation for installed capital has been made less than perfectly elastic. But the importance of the condition derived by Jorgenson—marginal product of capital equals some concept of user cost—remains just as great.

The modern analysis of the demand side is nowhere stated in the paper, although it is implicit in the derivation of equation 9. Appendix A states the "first-order condition for investment" (the supply condition) to get the basic investment supply relation, equation A7. It then characterizes Jorgenson's approach as an alternative. Equation A8 is the appropriate demand-side first-order condition needed to complete the modern theory, provided the user cost on the right-hand side is evaluated using the shadow price of installed capital, q (as noted but not pursued in the text). But even the reader who works carefully through appendix A is likely to emerge thinking that only the supply condition matters and that the demand-side condition has been outmoded.

Although the paper neglects the demand side of investment altogether, it does look at the intersection of supply and demand. Equation 9 is the solution of the supply and demand equations.[2] In other words, the two major empirical approaches taken in this paper are to estimate the supply equation and the intersection of supply and demand. Unfortunately, the authors label the second of these approaches the "User Cost of Capital Results." The authors note the relationship between the two approaches but without giving the reader much hint that the second is a hybrid. It would be redundant to work with supply, demand, and the intersection of supply and demand. The paper drops out demand. I would prefer the symmetrical approach of working with supply and demand, and then just commenting on the intersection. All of the foregoing are problems of presentation, not substance.

2. See Abel (1990) for a discussion.

I found the goal of this paper somewhat diffuse. The paper wants to "analyze" or "explain" investment. In fact, I think the paper actually has a much sharper research focus than it admits. More than anything else, it wants to overcome the problem that almost all other research on the supply side of the investment relationship has found—improbably high adjustment costs and thus improbably long lags in investment. The relation between q and the flow of investment found in earlier work was too weak to make sense. This paper does a nice job of isolating a stronger relationship by eliminating periods when noise dominates the movements of q.

Because the authors use rich panel data, they are able to exploit the important cross-sectional variation in the effects of tax rates. But, as I understand the results, they show that firms that invest a lot in the types of assets favored by a reform show the biggest effects of those reforms. The paper is not able to perform the more conclusive tests that would come from, say, purely experimental cross-sectional differences in taxes.

Ricardo J. Caballero: Like so many other papers in the investment literature, this one starts by summarizing the empirical failure of models that emphasize the role of "price" variables in investment equations and by listing the standard culprits (simultaneity, error in variables, and so forth). Unlike many others, it concludes on a very positive note. By isolating the "exogenous" cross-sectional elements of episodes covering important tax reforms, the authors claim to have eluded the standard problems and found evidence of a large short-run response of investment to price incentives.

The idea of isolating tax reform episodes is one that has proved successful before. For example, Peter Clark's 1993 *BPEA* report contains elasticities of equipment investment with respect to changes in the tax code that are substantially larger than the elasticities of investment with respect to other components of the cost of capital.[1] His estimates were about half the size of the preferred ones in the current paper and not very precise, however. They also implied that the full impact of changes in the investment tax credit on investment is not observed until one to

1. Clark (1993).

three years after these changes occur. The authors' main estimates use two-year innovations and disregard dynamics, so they are silent with respect to timing issues.

To me, the contribution of this paper is that by using more than the usual amount of econometric ingenuity, the authors have come out with estimates that are not only reasonable, as were Clark's, but also precise and stable across years. Overall, it is one of the most interesting attempts at measuring the effect of relative prices on investment I have seen lately. I have four quibbles and remarks, however. The first one is "expositional"; the second one refers to the potential role of intertemporal substitution in explaining the findings; the third one is about robustness; and the last one is about policy.

1. My "expositional" complaint is that while the authors succeed in generating an elasticity that I suspect we all like, they are less clear about exactly where it came from. Spread throughout the paper, rather than succinctly listed, are the standard culprits and the proposed remedies. But there is no precise statement as to which of the ingredients in their complex medicine "cured the patient" and as to whether the cure has left the patient with a "life worth living." In what follows, I propose a simple decomposition that may help clarify why their estimates came out the way they did.

Starting from the basic equation relating investment and Q linearly, one can decompose Q into four components. For this, let T and NT denote the tax and nontax components of Q. Further split each of these components, so that PT and PNT denote the linear projection of T and NT onto $t-2$ information, and let ΔT and ΔNT denote the corresponding forecasting residuals. Relaxing the assumption that the coefficient on each of these components is the same, we arrive at the regression equation:

$$\frac{I}{K} = \gamma_1 \Delta T + \gamma_2 \Delta NT + \gamma_3 PT + \gamma_4 PNT + \epsilon. \tag{1}$$

I believe most of the results in the paper can be understood in terms of this equation; and I even wonder why the authors did not estimate such an equation directly. The "standard q model" results presented in table 3 correspond to the case where all the γs are constrained to be equal. The "modified q model" results presented in table 4, by contrast, are obtained by constraining γ_1, γ_3, and γ_4 to be the same and by moving $\gamma_2 \Delta NT$

to the residual of the equation.[2] As pointed out in the paper, comparing the fifth column in table 3 with the first column in table 4 shows that the estimate of γ doubles with the removal of the nontax surprise.

What do we learn from this comparison? It depends on what explains the increase in γ. Under the authors' assumptions about timing, information, and the nature of adjustment costs, I see three possibilities. Relaxing these assumptions, I see another, potentially more damaging but perhaps more interesting, alternative. Let me postpone a description of the latter until after I have finished clarifying their results according to their structure. First, if γ_2 is greater than zero and the nontax and tax components are positively correlated, the omitted-variable problem generated by the exclusion of the nontax component is positive, so the results in table 4 are upwardly biased. My sense is that this is unlikely, since equilibrium considerations tend to imply the opposite correlation. Second, γ_2 may indeed equal zero, in which case the estimates of γ in table 3 are biased downward by the need to average across all the γs. And third, the nontax component may be negatively correlated with the residual of the equation (negative simultaneity and error-in-variable biases); in this case, the estimates in table 3 are again downwardly biased, while those in table 4 are fine as long the potential omitted-variable problem is not important. In the paper, the issues are mixed, for the authors write that to avoid the simultaneity bias they assume that $\gamma_2 = 0$, as if assumptions could solve the problem. I suspect they should use the third rather than the second argument.

The most impressive results of table 4, however, are those where major tax reform years are isolated. There γ rises substantially. Where does this increase come from? Restricting my interpretation to their proposed structure, I see their findings in the following terms: in years of tax reform the variance of the first regressor in equation 1 is likely to rise relative to that of the other regressors. If γ_1 is substantially larger than γ_3 and γ_4, then γ will be larger during tax reform years because it is there that γ_1 receives its largest weight. Tables 5 and 6 are consistent with this interpretation. There, by removing the projection on information at time $t-2$ from both sides, and maintaining the term $\gamma_2 \Delta NT$ in the residual, they estimate γ_1 directly.

2. This assumes that the projections are not too different from the actual values of the variables at $t-2$, which I suspect is more consistent with their assumptions than with the data.

At this point, their result is mostly good news if one is concerned with estimating γ_1. If we really want to explain investment, however, the answer may be different. This relates to the "quality of life" issue I mentioned above, where the question is how much of the variance of the left- and right-hand-side variables has been removed with each of their steps. In my view, they should have reported the fraction of the variance of investment accounted for by each of the terms on the right-hand-side of equation 1. At this point I can only raise a warning flag: going back to the comparison of the results in the fifth column of table 3 with those in the first column of table 4, we see that the increase in the estimated coefficient, when going from the former to the latter, comes at the cost of an *85 percent fall* in the R^2. They emphasize the role of their steps in reducing standard measurement error and simultaneity, but they are much less transparent about the loss of signal. Identification seems to have been achieved with a very small fraction of the variation of left- and right-hand-side variables. This may explain some of my problems reproducing their results, an issue I will come back to in the robustness section of my comments.

2. Up to now, I have followed the authors and interpreted the differences across γs mostly in terms of econometric issues. But there is also an *economic* reason for the γs to differ. If one abandons the basic neoclassical setup in favor of an arguably more realistic one, which emphasizes fixed costs and recognizes the strong intertemporal substitution effects that are likely to be involved in temporary and sometimes anticipated tax reforms, then γ_1 is naturally larger, especially so when tax reform years are isolated.

It is of great importance for policy design to find out whether their preferred estimates are capturing permanent level effects or intertemporal substitution effects. If the answer is the latter, then investment tax credits can be used as a countercyclical instrument, but for them to be powerful they have to be made transitory. Conversely, if they have identified a level effect, there is more scope for long-term policy.

Despite the importance of the issue, however, I do not think their handling of it adds much. They have three "quick" arguments against an intertemporal substitution interpretation of their findings, none of them very compelling, either in isolation or in conjunction. The first one is where they argue that Mark Doms and Timothy Dunne's finding—that 80 percent of U.S. manufacturing plants change their real capital stock by less than 10 percent in a given year—contradicts nonconvex adjustment cost models.[3] This is true only in an absurdly naive interpretation of the implications of models of fixed costs. Of course, literal inaction, as implied by pure fixed-cost models, is never observed in actual data: in real life, firms have many different forms of investment expenditure, some of which have no adjustment costs whatsoever or are completely unavoidable. Quite the contrary, I interpret the Doms and Dunne evidence as very supportive of fixed-cost theories, since it shows that firms that do nothing most of the time (such as investing in minor upgrades and repairs) experience infrequent but large adjustments that account for a large fraction of plants' *and* aggregate investment fluctuations.

The authors' second argument is contained in figure 8, where they report the transitions across sizes of the investment-capital ratio during and after the 1986 tax reform. Their conclusion is that there is no evidence of investment concentration during the reform year. In a sense, we already knew this. The entire paper, and to a large extent the empirical literature on investment, is about why we do not see much unless several factors are corrected for. I find quite remarkable that at this point they decided not to correct for individual effects and all the other things that only a few pages before they deemed so necessary before giving credence to empirical findings.

The last argument is based on the static implication of a model that does not take into consideration a series of dynamic issues that are quite important in models of nonconvex adjustment costs. Indeed, history dependence is one of the main features of fixed-cost models. The authors' implicit argument about asymmetries, when comparing 1982 and 1987, is meaningless without describing the set of circumstances that preceded each of these episodes and their effect over the cross-sectional distributions of pent-up investment.

3. As I intended to present more than conjectures, I asked the authors to send me a sample of their data. They were kind enough to send me not one but two samples: one with few firms (25) but many years (29), the other one with more firms (158) but fewer years (15). Unfortunately, I could not reproduce their results with these samples. Estimates of γ were quite constant across my counterparts of their tables 3, 4, and 5.

3. Doms and Dunne (1993).

Furthermore, my estimates of the four γs were quite similar at about 0.02, a result more along the "old" line.[4]

They have attempted to explain my results arguing that my samples were too small. But I do not believe that this is the whole story, since I ran panel regressions constraining the elasticity coefficients across all tax reform years, which means that most of my regressions had more degrees of freedom than their yearly regressions. (I included time and individual effects, of course.)

Although it is certainly not comforting that the main results of the paper did not hold in these subsamples, it should be noted that my samples were *not* randomly chosen. Perhaps they may use the sample selection issues to identify the source of their large estimates. An unlikely possibility, but one that should be considered, is entry. My samples were balanced, while theirs have a substantial flow of new firms over the years. And, as is often the case, incumbency may be positively correlated with size and age. It seems important to find out whether entry plays any substantive role in the estimate of γ. I suspect, however, that more may be needed, since entry does not influence their results early in the sample (relative to my sample), where they find the largest estimates for γ_1.

4. My final point is about heterogeneity and policy. If we were to model the microeconomic side more properly, we would find aggregate investment equations that contain many cross-sectional elements on the right-hand side. I wish we could take these into consideration when designing macroeconomic policy.

I am sure that to some extent this is done, but the authors' key identifying assumption suggests that this is rather imperfect. They argue that even though time-series information at the aggregate level cannot be used, because tax reforms are likely to be countercyclical, they are still able to use the cross-sectional variation. This implies, and I am sure they are right, that macroeconomic policy does not fully consider microeconomic heterogeneity; if it did, endogeneity problems similar to those of the aggregate time-series regressions would plague cross-sectional regressions too. I wonder whether in light of the heterogeneity they docu-

4. I experimented with different samples, methods of decomposing between tax and nontax components, and information sets. I ran yearly and panel regressions. For the latter, I used individual and time effects, as well as dummies for the years with tax reforms. I also ran panel regressions without these elements.

ment, and the mounting evidence of microeconomic nonlinearities, we should not spend more effort trying to generate useful measures of heterogeneity that can aid macroeconomic policy, even if as a result we are prevented from ever again running the authors' type of regressions.

General Discussion

In response to Robert Hall's criticism of "horse race" exercises, the authors explained that they had not run a race. Rather, they included *q* and the user cost equations to verify that alternative representations of the neoclassical theory yielded similar results. Daniel Sichel offered two reasons why horse races might be useful. First, even if an investigator is not testing competing theoretical frameworks, choices must be made about how to implement a model empirically, and a natural way to evaluate these choices is to subject different specifications to a forecast test. Second, forecasting is the goal of some research. However, Kevin Hassett noted that forecast tests can be misused by loading up an alternative specification with too many variables. Anil Kashyap noted that, while the two approaches were equivalent under the assumptions of constant returns, perfect competition, and quadratic adjustment costs, under alternative assumptions one of the approaches might be more useful than the other. Glenn Hubbard and William Brainard noted that implementing user cost models requires information about discount rates and expected future user costs. The *q* model relies on financial markets to provide this information. This difference would be important in a panel study where it is difficult to get firm-specific expected rates of return.

Responding to Ricardo Caballero's comments, Hassett suggested that there is no good economic reason to expect differences in the responses to the four components of tax-adjusted *q* identified by Caballero. Caballero responded that intertemporal substitution, combined with different persistence of components, provides a rationale for distinguishing among them. Hassett also noted that Caballero's inability to replicate the paper's results using the long, balanced panel the authors provided is not surprising. Only a small number of firms had a complete time series, drastically reducing the cross-sectional variation in that sample. Moreover, for that nonrandom sample, even the basic *q*-model diagnostic exercises provided nonsensical results.

Discussion turned to the policy question of how much tax changes affect investment. Hall highlighted the fact that knowing the coefficient on tax-adjusted q is not sufficient for policy purposes; tax changes, by altering the present discounted value of after-tax profits, affect q itself. Brainard identified another potential difficulty in using the paper's cross-sectional results for evaluating the aggregate effects of policy. The paper identifies the cross-sectional effects of tax surprises on individual firms; but these estimates include the reallocation of investment across firms, since some benefit relative to others. A tax change that affected all firms in the same way would not produce these reallocation effects and may have a smaller effect on aggregate investment than is suggested by the cross-sectional estimates.

Finally, Brainard noted that the cross-sectional variation in taxation may not be entirely exogenous. Presumably, the legislators considering tax reforms—for example, changing the depreciation allowances for different types of capital goods—were aware that they would especially benefit particular sectors; the reforms may have been motivated, in part, by a desire to boost investment in those sectors.

References

Abel, Andrew B. 1980. "Empirical Investment Equations: An Integrative Framework." *Journal of Monetary Economics* 12(6) Supplement (Spring): 39–91.

———. 1990. "Consumption and Investment." In *Handbook of Monetary Economics*, Volume 2, edited by Benjamin M. Friedman and Frank H. Hahn. Amsterdam: North-Holland.

———, and Olivier J. Blanchard. 1986. "The Present Value of Profits and Cyclical Movements in Investment." *Econometrica* 54(2): 249–73.

Abel, Andrew B., and Janice C. Eberly. 1994. "A Unified Model of Investment Under Uncertainty." *American Economic Review* 84(5): 1369–84.

Auerbach, Alan J. 1982. "The New Economics of Accelerated Depreciation." *Boston College Law Review* 23(5): 1327–55.

———. 1983a. "Corporate Taxation in the United States." *BPEA, 2:1983*, 451–513.

———. 1983b. "Taxation, Corporate Financial Policy, and the Cost of Capital." *Journal of Economic Literature* 21(3): 905–40.

———. 1989. "Tax Reform and Adjustment Costs: The Impact on Investment and Market Value." *International Economic Review* 30(4): 939–62.

———, and Kevin Hassett. 1991. "Recent U.S. Investment Behavior and the Tax Reform Act of 1986: A Disaggregate View." *Carnegie-Rochester Conference Series on Public Policy* 35(Autumn): 185–215.

———. 1992. "Tax Policy and Business Fixed Investment in the United States." *Journal of Public Economics* 47(2): 141–70.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. 1994. "The Financial Accelerator and the Flight to Quality." Working Paper 4789. Cambridge, Mass.: National Bureau of Economic Research (July).

Bernanke, Ben S., Henning Bohn, and Peter C. Reiss. 1988. "Alternative Nonnested Specification Tests of Time-Series Investment Models." *Journal of Econometrics* 37(3): 293–326.

Bertola, Giuseppe, and Ricardo J. Caballero. 1990. "Kinked Adjustment Costs and Aggregate Dynamics." In *NBER Macroeconomics Annual 1990*, edited by Olivier J. Blanchard and Stanley Fischer. Cambridge, Mass.: MIT Press.

Bizer, David S., and Daniel E. Sichel. 1991. "Asymmetric Adjustment Costs, Capital Longevity, and Investment." Working Paper 119. Washington: Board of Governors of the Federal Reserve System.

Blundell, Richard, and others. 1992. "Investment and Tobin's *Q*." *Journal of Econometrics* 51(1–2): 233–57.

Bosworth, Barry P. 1985. "Taxes and the Investment Recovery." *BPEA, 1:1985*, 1–38.

———, and Gary Burtless. 1992. "Effects of Tax Reform on Labor Supply, Investment, and Saving." *Journal of Economic Perspectives* 6(1): 3–25.

Caballero, Ricardo J., and Eduardo Engel. 1994. "Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S,s) Approach." Unpublished paper. Massachusetts Institute of Technology.

Caballero, Ricardo J., and Robert S. Pindyck. 1992. "Uncertainty, Investment, and Industry Revolution." Working Paper 4160. Cambridge, Mass.: National Bureau of Economic Research.

Calomiris, Charles W., and R. Glenn Hubbard. 1990. "Firm Heterogeneity, Internal Finance, and 'Credit Rationing'." *Economic Journal* 100(399): 90–104.

———. 1993. "Internal Finance and Investment: Evidence from the Undistributed Profits Tax of 1937–1938." Working Paper 4288. Cambridge, Mass.: National Bureau of Economic Research.

Chirinko, Robert S. 1987. "The Ineffectiveness of Effective Tax Rates on Business Investment: A Critique of Feldstein's Fisher-Schultz Lecture." *Journal of Public Economics* 32(3): 369–87.

———. 1993. "Business Fixed Investment Spending: Modeling Strategies, Empirical Results, and Policy Implications." *Journal of Economic Literature* 31(4): 1875–1911.

———, and Robert Eisner. 1983. "Tax Policy and Investment in Major U.S. Macroeconomic Econometric Models." *Journal of Public Economics* 20(2): 139–66.

Clark, Peter K. 1979. "Investment in the 1970s: Theory, Performance, and Prediction." *BPEA, 1:1979*, 73–113.

———. 1993. "Tax Incentives and Equipment Investment." *BPEA, 1:1993*, 317–39.

Cummins, Jason G., Trevor S. Harris, and Kevin A. Hassett. 1994. "Accounting Standards, Information Flow, and Firm Investment Behavior." In *International Taxation*, edited by Martin Feldstein, James R. Hines, and R. Glenn Hubbard. Chicago: University of Chicago Press (forthcoming).

Cummins, Jason G., and Kevin A. Hassett. 1992. "The Effects of Taxation on Investment: New Evidence from Firm Level Panel Data." *National Tax Journal* 45(3): 243–51.

Cummins, Jason G., and R. Glenn Hubbard. 1994. "The Tax Senstitivity of Foreign Direct Investment: Evidence from Firm-Level Panel Data." In Martin Feldstein, James R. Hines and R. Glenn Hubbard, eds., *International Taxation*. Chicago: University of Chicago Press (forthcoming).

Cummins, Jason G., Kevin A. Hassett, and R. Glenn Hubbard. 1994. "Using Tax Reforms to Study Investment Decisions: An International Study." Unpublished paper. Columbia University.

De Long, J. Bradford, and others. 1990. "Noise Trader Risk in Financial Markets." *Journal of Political Economy* 98(4): 703–38.

Dixit, Avinash K., and Robert S. Pindyck. 1994. *Investment under Uncertainty*. Princeton: Princeton University Press.

Doms, Mark, and Timothy Dunne. 1994. "Capital Adjustment Patterns in Manufacturing Plants." Discussion Paper 94-11. Washington: Center for Economic Studies, U.S. Bureau of the Census.

Eisner, Robert. 1969. "Tax Policy and Investment Behavior: Comment." *American Economic Review* 59(3): 379–88.

———. 1970. "Tax Policy and Investment Behavior: Further Comment." *American Economic Review* 60(4): 746–52.

———, and M. I. Nadiri. 1968. "Investment Behavior and Neoclassical Theory." *Review of Economics and Statistics* 50(3): 369–82.

Eisner, Robert, and Robert H. Strotz. 1963. "Determinants of Business Investment." In *Impacts of Monetary Policy*, studies prepared for the Commission on Money and Credit. Englewood Cliffs, N.J.: Prentice-Hall.

Fazzari, Steven M., R. Glenn Hubbard, and Bruce C. Petersen. 1988. "Financing Constraints and Corporate Investment." *BPEA, 1:1988*, 141–95.

Feldstein, Martin S. 1982. "Inflation, Tax Rules, and Investment: Some Econometric Evidence." *Econometrica* 50(4): 825–62.

Gertler, Mark, and R. Glenn Hubbard. 1988. "Financial Factors in Business Fluctuations." In *Financial Market Volatility*. Kansas City: Federal Reserve Bank of Kansas City.

Gilchrist, Simon, and Charles P. Himmelberg. 1991. "Tobin's *Q*, Fundamental *Q*, and Corporate Investment: A Comparison Using Panel Data." Unpublished paper. New York University.

———. 1992. "Evidence on the Role of Cash Flow for Investment." Unpublished paper. New York University.

Givoly, Dan, and others. 1992. "Taxes and Capital Structure: Evidence from Firms' Response to the Tax Reform Act of 1986." *Review of Financial Studies* 5(2): 331–55.

Goolsbee, Austan. 1994. "Investment Tax Incentives and the Price of Capital Goods." Unpublished paper. Massachusetts Institute of Technology.

Gould, John P. 1968. "Adjustment Costs in the Theory of Investment of the Firm." *Review of Economic Studies* 35(1): 47–55.

Griliches, Zvi, and Jerry A. Hausman. 1986. "Errors in Variables in Panel Data." *Journal of Econometrics* 31(1): 93–118.

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

Hassett, Kevin, and Gilbert E. Metcalf. 1994. "Investment with Uncertain Tax Policy: Does Random Tax Policy Discourage Investment?" Working Paper 4780. Cambridge, Mass.: National Bureau of Economic Research (June).

Hayashi, Fumio. 1982. "Tobin's Marginal *q* and Average *q*: A Neoclassical Interpretation." *Econometrica* 50(1): 213–24.

———. 1985. "Corporate Finance Side of the *Q* Theory of Investment." *Journal of Public Economics* 27(3): 261–80.

Hubbard, R. Glenn. 1994. "Investment Under Uncertainty: Keeping One's Options Open." *Journal of Economic Literature* 32(4): 1816–31.

———, and Anil K. Kashyap. 1992. "Internal Net Worth and the Investment Process: An Application to U.S. Agriculture." *Journal of Political Economy* 100(3): 506–34.

———, and Toni M. Whited. Forthcoming. "Internal Finance and Firm Investment." *Journal of Money, Credit, and Banking*.

Hulten, Charles R., and James W. Robertson. 1982. *Corporate Tax Policy and Economic Growth: An Analysis of the 1981 and 1982 Tax Acts*. Working paper. Washington: Urban Institute.

Hulten, Charles R., and Frank C. Wykoff. 1981. "The Measurement of Economic Depreciation." In *Depreciation, Inflation, and the Taxation of Income from Capital*, edited by Charles R. Hulten. Washington: Urban Institute.

Jorgenson, Dale W. 1963. "Capital Theory and Investment Behavior." *American Economic Review Papers and Proceedings* 53(2): 247–59.

———. 1971. "Econometric Studies of Investment Behavior: A Survey." *Journal of Economic Literature* 9(4): 1111–47.

———, and Martin A. Sullivan. 1981. "Inflation and Corporate Capital Recovery." In *Depreciation, Inflation, and the Taxation of Income from Capital*, edited Charles R. Hulten. Washington: Urban Institute.

King, Mervyn A., and Don Fullerton, eds. 1984. *The Taxation of Income From Capital: A Comparative Study of the United States, United Kingdom, Sweden, and West Germany*. Chicago: University of Chicago Press.

Leahy, John V., and Toni M. Whited. 1994. "The Effect of Uncertainty on Investment: Some Stylized Facts." Unpublished paper. Harvard University.

Lucas, Robert E., Jr. 1967. "Adjustment Costs and the Theory of Supply." *Journal of Political Economy* 75(4): 321–34.

Nickell, Stephen J. 1978. *The Investment Decisions of Firms*. Cambridge: Cambridge University Press.

Oliner, Stephen D., and Glenn D. Rudebusch. 1994. "Is There a Broad Credit Channel for Monetary Policy?" Working Paper 146. Washington: Board of Governors of the Federal Reserve System.

———, and Daniel Sichel. Forthcoming(a). "New and Old Models of Business Investment: A Comparison of Forecasting Performance." *Journal of Money, Credit, and Banking*.

———. Forthcoming(b). "The Lucas Critique Revisited: Assessing the Stability of Empirical Euler Equations for Investment." *Journal of Econometrics* (special annals issue).

Pagan, Adrian. 1984. "Econometric Issues in the Analysis of Regressions with Generated Regressors." *International Economic Review* 25(1): 221–47.

Pechman, Joseph A. 1987. *Federal Tax Policy*, fifth ed. Washington: Brookings.

Pindyck, Robert S. 1991. "Irreversibility, Uncertainty, and Investment." *Journal of Economic Literature* 29(3): 1110–48.

———, and Julio J. Rotemberg. 1983. "Dynamic Factor Demands under Rational Expectations." *Scandinavian Journal of Economics* 85(2): 223–38.

Pindyck, Robert S., and Andrés Solimano. 1993. "Economic Instability and Aggregate Investment." In *NBER Macroeconomics Annual 1993*, edited by Olivier J. Blanchard and Stanley Fischer. Cambridge, Mass.: MIT Press.

Poterba, James M., and Lawrence H. Summers. 1985. "The Economic Effects of Dividend Taxation." In *Recent Advances in Corporate Finance*, edited by Edward I. Altman and Marti G. Subrahmanyam. Homewood, Ill.: Richard D. Irwin.

Romer, Christina D., and David H. Romer. 1989. "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz." In *NBER Macroeconomics Annual 1989*, edited by Olivier J. Blanchard and Stanley Fischer. Cambridge, Mass.: MIT Press.

Sakellaris, Plutarchos. Forthcoming. "Investment under Uncertain Market Conditions." *Review of Economics and Statistics*.

Salinger, Michael A., and Lawrence H. Summers. 1983. "Tax Reform and Corporate Investment: A Microeconometric Simulation Study." In *Behavioral Simulation Methods in Tax Policy Analysis*, edited by Martin Feldstein. Chicago: University of Chicago Press.

Shapiro, Matthew D. 1986. "The Dynamic Demand for Capital and Labor." *Quarterly Journal of Economics* 101(3): 513–42.

Steigerwald, Douglas G., and Charles Stuart. 1993. "Econometric Estimation of Foresight: Tax Policy and Investment in the U.S." Unpublished paper. University of California, Santa Barbara.

Summers, Lawrence H. 1981. "Taxation and Corporate Investment: A *q*-Theory Approach." *BPEA, 1:1981*, 67–127.

Tobin, James. 1969. "A General Equilibrium Approach to Monetary Theory." *Journal of Money, Credit, and Banking* 1(1): 15–29.

U.S. Senate Committee on the Budget. 1986. *Tax Expenditures: Relationships to Spending Programs and Background Material on Individual Provisions*. Washington: Government Printing Office.

———. 1992. *Tax Expenditures: Compendium of Background Material on Individual Provisions*. Washington: Government Printing Office.