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TAX POLICY AND BUSINESS FIXED INVESTMENT DURING THE REAGAN ERA*

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Abstract

We examine the impact of major tax legislation on business capital investment during the 1980-88 period. We detail the tax changes and imbed them into a neo-classical rental price of capital goods.

We then use this rental price in two popular models of business fixed investment, a standard and a modified neo-classical model. We estimate these two models along with an accelerator model of capital investment. The models, in general, exhibit parameter instability regardless of fit. We then develop a model incorporating expected delivery lags for new capital goods and embed a forecasted output and the rental price of capital services. Again, parameter instability and fit are examined.

Finally we conduct simulations of tax, price and output shocks. We conclude that the new model has parameter stability, and that the net effect of Reagan's tax policies was small.

I. Introduction

The Reagan administration carried out a series of major legislative changes in tax incentives affecting business fixed investment that has been perceived by casual observers as both favorable and unfavorable to American businesses.[1] The question of the overall quantitative impact on investment naturally arises. If this question is to be answered, the first requirement is agreement on the best model relating the decisions of businesses to make capital investments to the presumed determinants. This paper examines contending models, and then essays an answer to the quantitative issue.

A number of studies have compared investment equations developed in the 1960s and 1970s.[2] These studies show that equations purporting to explain postwar investment spending are notable for their parameter instability and/or their inability to provide accurate ex-post forecasts beyond the sample period.

In this paper we focus on one plausible explanation for this instability, the one suggested by Lucas [1976], in what has become known as the Lucas Critique. Lucas noted that endogenous economic time series often depend on the decisions of policy-makers or on other forces which may be modeled as exogenous. A regime change occurs when the policy-making process changes or when the exogenous forces change. If an economic decision-maker must forecast the dependent series in order to make his decision, he will have to use different forecasting equations before and after the

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[1] Throughout this paper we will refer to the Reagan tax program as if President Reagan alone shaped it. Congress, of course, also had a role in the legislation.

[2] See Bischoff, [1971b], Clark [1979], Kopcke, [1977, 1982, 1985], and Bernanke, et al., [1988].

change, if his forecasts are to be rational. This implies that model builders should expect the parameters of their lag functions to vary when regimes change.

In what follows, we first outline how taxes are introduced into the various models, then review the Reagan tax initiatives with this in mind. Next we discuss several models and report the results of estimation using quarterly data through 1988. We then posit a new model recognizing the influence of regime changes and fit the model to the same data. We next evaluate the quantitative impact of the tax initiatives of President Reagan's tenure, and finally draw conclusions.

II. The Rental Price of Capital Services

The centerpiece of the neoclassical theory of investment behavior is the rental price of capital services denoted by the letter c, which represents the rental price capital goods could command in a perfect market. In the presence of taxes, the rental price may be written as:

$$c = q\,(\delta + r)(1 - uz - k)/(1 - u). \tag{2.1}$$

Here, q denotes the price of new capital goods, δ the rate of economic decay of capital, r the after tax real interest rate, u the rate of taxation of business income, z the present discounted value of the stream of depreciation deductions from a dollar's worth of capital goods,[3] and k the rate of investment tax credit.

In this paper, we will frequently specify equations as if the desired ratio of capital to output is proportional to the ratio p/c, where p is the price of output. This ratio is the inverse of the real rental price of capital. This specification may be derived theoretically from the assumption of a Cobb-Douglas production

[3] With the basis adjusted for any deduction of part or all of the investment tax credit.

function. However, even if the desired capital-output ratio is specified proportional to p/c, this does not guarantee that the estimated price elasticity of the investment or capital stock with respect to the inverse of the real rental will be unity. If the equation contains an intercept, and also if the actual capital stock appears in a gross investment equation with a free coefficient, almost any estimated price elasticity may result.

In this paper, investment is disaggregated into two major asset groups: producers' durable equipment, denoted E, and non-residential structures, denoted S. The estimates of δ, k, and z, are weighted averages of these variables for 20 different types of equipment and 14 types of structures.[4] The real discount rate for equipment, r_ε, is given as:

(2.2) $r_\varepsilon = ((2RB - p^e) + RD)(1-hu)$.

Here RB is Moody's Industrial bond yield, RD is a splicing of Moody's and Standard and Poor's Industrial dividend price ratios, p^e is the expected rate of price change derived in Ando et. al. [1974], u is the combined rate of corporate tax by federal, state and local governments, and h is the proportion of debt in the corporate capital structure. The formula for r_s, the real discount rate for structures, is given as:

(2.3) $r_s = 2RD(1 - hu)$.[5]

III. President Reagan's Investment Tax Policies

Five major pieces of tax legislation which directly affected the rental price of capital services were passed during President Ronald Reagan's two administrations.

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[4] The disaggregated details for these estimates come from Hulten and Wykoff [1981], Jorgenson and Sullivan [1981], Fullerton and Henderson [1984], Fullerton, Gillette, and Mackie [1987], and Fullerton, Henderson and Mackie [1987].

[5] Bischoff [1971b] used both of these formulas.

Of course, the impact of Reagan's tax policies on business investment was not limited to direct effects through the rental price of capital. Other major tax and non-tax policies clearly affected demand and output, and had effects on investment via these channels. Also, Reagan's fiscal policies affected interest rates, which indirectly affected the rental price. These effects, however, are beyond the scope of this paper.

The first piece of Reagan tax legislation was the Economic Recovery Tax Act (ERTA) of 1981, which shortened the lifetimes to be used to depreciate equipment and structures for tax purposes. We model this shortening of lives as decreasing the weighted average lifetime for equipment, which we calculate to move from 7.947 years to 4.858 years, and the weighted average lifetime for structures, calculated to move from 20.303 years to 12.021 years.[6] ERTA also changed the patterns by which these assets could be depreciated. We model these changes by assuming that before ERTA, 14% of equipment investment was depreciated by straight-line methods, 43% by double-declining-balance with switch to straight-line, and 43% by sum-of-the-years' digits. After ERTA, all equipment investment was depreciated by 150%-declining-balance with switch to straight-line. Similarly, before ERTA it is assumed that 14% of structures investment was depreciated by straight-line methods and 86% by 150%-declining-balance with switch to straight-line, whereas after ERTA all structures investment was depreciated by 175%-declining-balance with switch to straight-line. ERTA increased the tax credit for autos, trucks, buses, and trailers. ERTA also instituted the Safe-Harbor Leasing method, by which unused investment tax credits could be shifted between firms. We model these two provisions, by changing the effective rate of tax

[6] These and the other underlying calculations in this section were done by applying the tax changes to specific asset classes as appropriate, and by aggregating the classes to obtain an overall effect for equipment and structures.

credit for equipment from 8.50% in 1980 to 9.80% in 1981. Of this rise, 0.32% is due to the increase for vehicles. Similarly, the effective rate of tax credit on structures is increased from 2.52% to 2.80%.

The Tax Equity and Fiscal Responsibility Act (TEFRA) of 1982 changed several of these provisions. The basis for depreciation of both equipment and structures is modeled as reduced by 50% of the effective rate of tax credit. Safe-Harbor-Leasing was effectively repealed. This is modeled as reducing the effective investment tax credit rate to 8.82% for equipment and 2.52% for structures.

Further tax changes in the first quarter of 1984 increased our measure of the weighted average depreciation lifetime for structures from 12.021 years to 13.087 years; another increase during the second quarter of 1985 increased it to 13.401 years.

Finally, the Tax Reform Act of 1986 made three major changes. The investment tax credit was repealed. The maximum federal tax rate on corporate income was lowered from 46% to 34%. Depreciation changes also were made. After the tax reform act, we model all equipment investment depreciation as double-declining-balance with switch to straight-line, and 61.016% of structures investment depreciation as straight-line, 22.877% as 150%-declining-balance, and 16.107% as double-declining-balance. The weighted average depreciation lifetime for equipment investment is increased from 4.858 to 6.545 years, while for structures investment the increase is from 13.401 to 17.434 years.

Between the fourth quarter of 1980, or 1980:4, and 1988:4, we find the real rental price of capital service, c/p, fell from 0.329 for equipment and 0.182 for structures to 0.283 for equipment and 0.112 for structures. The drop for structures occurred because the discount rate for structures is based heavily on the stock market. The present value of the depreciation deduction for equipment rose from

0.601 to 0.689; for structures the rise was from 0.314 to 0.532. The repeal of the investment tax credit counteracts these increases.

Turning to individual pieces of legislation, the changes from ERTA in 1981 directly reduced our calculated rental price (rent) for equipment by 7.25%, and for structures by 11.34%. TEFRA, in 1982, raised equipment rent by 3.96% and structures rent by 0.82%. The 1984 and 1985 laws increased structures rentals by 1.66% and 0.46%, respectively. The Tax Reform Act of 1986 pushed up equipment rent by 15.51% by repealing the investment tax credit and 0.68% by depreciation changes. The same two shifts increased structures rentals by 3.92% and 7.56% respectively. The cut in corporate tax rates reduced equipment rent by 6.66% and structures rent by 8.80%. Computing the real rental price of capital services for 1988:4, but using all of the 1980:4 tax parameters, we calculate that the Reagan changes raised the rental price for equipment by 2.71% but lowered the rental price for structures for 8.43%. The rest of the changes in real rentals noted in the last paragraphs were due to changes in relative prices, in real discount rates, and in nominal discount rates.

IV. Traditional Models of Investment Expenditure

Three popular models of business fixed investment are analyzed in this section. Two are versions of the neoclassical model; the third, the accelerator model, is one in which tax policy plays no direct role through a rental price of capital term. Each of the three models is applied to data on two components of real nonresidential fixed investment: producers' durable equipment and nonresidential structures.[7]

[7] Tobin's "Q" model, based on the ratio of market value to the replacement cost of capital, was excluded because of the absence of an accepted theory relating tax changes to equity and bond prices.

A. The Generalized Accelerator Models

As first formulated by J.M. Clark [1917], the accelerator model postulated a proportional relationship between net investment and the change in output. Later, flexible accelerator models allowed for partial adjustment of capital stock by making net investment a linear function of the deviation between current output and existing capital stock. In some variants, current output was replaced by expected output. We allow for both the formation of expectations and partial adjustment by estimating the parameters of two long lag distributions on levels and on changes in output.

Our accelerator equations are given as:

$$X_t = A_1 + \sum_{i=1}^{21} M_{1i} Q_{t-i} + D_1 K_t + U_{1t}, \text{ and} \tag{4.1}$$

$$X_t = A_2 + \sum_{i=1}^{21} M_{2i} \Delta Q_{t-i} + D_2 K_t + U_{2t}. \tag{4.2}$$

Here, $X' = [E\ S]$ where E represents quarterly seasonally adjusted expenditures on producers' durable equipment in billions of 1982 dollars, and S represents quarterly seasonally adjusted expenditures on nonresidential structures in billions of 1982 dollars, Q denotes quarterly seasonally adjusted business gross national product in billions of 1982 dollars. ΔQ_{t-i} represents the change in Q, $Q_{t-i} - Q_{t-i-1}$. The vector $K' = [KE\ KS]$ denotes the stocks of equipment and structures at the beginning of period t, computed using the geometric mortality distribution and data from U.S. Department of Commerce [1987] extending back to 1832 for structures and 1877 for equipment.[8] The terms A and D and the twenty-one terms in M are vectors of parameters and the U's are vectors of error terms.[9]

The parameters were estimated using Almon [1965] polynomial distributed lags. The 21 quarter lags were chosen to approximate five-year lags used by Clark [1979]. However, unlike Clark, we used no current right-hand variables in any equation in this paper. In all cases, third-degree polynomials with no zero restriction are used. Thus, each equation in (4.1) and (4.2) had seven parameters to be estimated: the intercept, four parameters for the lag distribution, the coefficient of capital stock, and the autoregressive parameter.

B. The Standard Neoclassical Models

Jorgenson's [1965] standard neoclassical model is also fitted in levels and first differences versions given as:

$$(4.3) \qquad X_t = A_3 + \sum_{i=1}^{21} M_{3i}[(p/c)_{t-i}\ Q_{t-i}] + D_3K_t + U_{3t}, \text{ and}$$

$$(4.4) \qquad X_t = A_4 + \sum_{i=1}^{21} M_{4i}[\Delta[(p/c)_{t-i}\ Q_{t-i}]] + D_4K_t + U_{4t}.$$

The variables and parameters are as defined above.

[8] All variables, including the intercept, are divided by Gordon's [1987] version of natural real Gross National Product (GNP), following Clark [1979], as a heteroskedasticity correction.

[9] Each vector U has elements which we denote by v's. Each v is assumed to be a first order autoregressive processes with $v_t = \rho v_{t-1} + e_t$. We used the Beach-MacKinnon [1978] maximum likelihood algorithm to estimate the equations. Below, we will refer to s_v, which is an estimate of the square root of the variance of v, and s_e which is an estimate of the square root of the variance of e. Note that the structures and equipment equations were estimated separately.

C. The Modified Neoclassical Models

The modified neoclassical equations which are based on the putty-clay model are a bit different. The idea behind these equations is that changes in capital intensity can only take place when gross additions to capacity are already occurring.[10] Thus, in the quasi-difference version of this equation each lagged term is $(Q_{t-i} - (1-\delta)Q_{t-i-1})\ (p/c)_{t-i-1}$. For comparison to the other equations we fitted a levels equation for equipment given as:

$$(4.5) \qquad E_t = A_5 + \sum_{i=1}^{21} M_{5i}\ [(p/c)_{t-i-1}\ Q_{t-i}] + \sum_{i=1}^{21} N_{5i}\ [(p/c)_{t-i-1}\ Q_{t-i-1}] + D_5K_5 + U_{5t}.$$

We also fitted a differences version:

$$(4.6) \qquad E_t = A_6 + \sum_{i=1}^{21} M_{6i}\ [(p/c)_{t-i-1}\ \ \Delta Q_{t-i}] + D_6K_t + U_{6t}.$$

Finally, we fitted a quasi-differences version:

$$(4.7) \qquad E_t = A_7 + \sum_{i=1}^{21} M_{7i}[(p/c)_{t-i-1}\{Q_{t-i} - (1 - \delta)Q_{t-i-1}\}] + D_7K_t + U_{7t}.$$

The putty-clay paradigm seems less applicable to structures, and empirical results bear this out. The modified neoclassical structures equation is simply a standard neoclassical equation with p/c raised to the power 0.5.[11]

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[10] See Bischoff [1971a].

[11] See Bischoff [1970].

D. Estimation Results of Contending Models

Summary statistics for equations (4.1) through (4.7) are contained in Table 1, and parameter stability tests results are given in Table 2. The sample period for all equations in Table 1 is from 1953:1 through 1988:4. The modified neoclassical levels equation appears the best among the equipment equations shown in Table 1. All of the other equations have only seven parameters, while this one has eleven, but the statistics s_e and s_v, are adjusted for degrees of freedom.

The variation between the best and worst s_e statistic for equipment is less than 12%. Two of the three versions of the modified neoclassical equation fit best by this statistic and the standard neoclassical equations are worst. For s_v, the variation is greater but the ordering is the same. There is substantial serial correlation of residuals in all equations as evidenced by the value of rho.

The picture for structures is different, as all equations are the same in terms of s_e, and the range in s_v is less than 16%. The accelerator equations are best by the second measure. The serial correlation is worse, and the Durbin-Watson statistics indicate that a first-order autoregressive process may not be general enough.

The likelihood ratio tests of stability in Table 2 confirm our earlier doubts about the stability of time series investment equations. The null hypothesis for each of the tests reported in Table 2 is that all parameters, and the variance of the error e, are constant across all subperiods. If the null hypothesis is true the test statistic asymptotically will be distributed as a chi-square variate with λ degrees of freedom. For all equations except the modified neoclassical equation in levels, the parameter λ is equal to 8, except for the test in the third column, where

λ is 16. For the modified neoclassical equation in levels, λ is equal to 12, except for the third test where it is 24.

The best-fitting equipment equation, the modified neoclassical equation in levels, fails every stability test at least at the .01 significance level. But the performance of the other equations is not much better. Only the standard neoclassical equipment equation, in differences form, with the worst s_e and s_v, emerges unscathed. Every other equation rejects the null hypothesis for at least three of the tests. Of course, these tests are not independent of one another, but the impression of instability is strong. Things are no better for structures. For every equation except one, the null hypothesis is rejected for at least three divisions of the sample. For that one equation the null hypothesis is rejected when the sample is split at the end of 1980.

We are left with a situation in which we must project the effects of the Reagan tax policies either with an equation that fits very badly and can be rejected on the basis of comparative fit, or an equation which exhibits parameter instability, especially around the Reagan inauguration.[12] Alternatively, we can try to find a different equation that is stable.

V. A New Model of Expectations and Investment

Changing expectations may enter the investment process if there is a lag between the placement of orders and deliveries of capital goods. Even if adjustment costs are zero, so that investment decisions do not lock producers in beyond the delivery

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[12] Chirinko [1988] studied the effect of the "Reagan Revolution" on the forecasts of four models explaining business fixed investment. He found (p. 209) that "these investment equations considered as a whole do not show any signs of important structural instability." Chirinko's methods for testing for stability differ considerably from ours, and we have not attempted to reconcile our results with his.

lag, expectations over this period are important. Between the different policy regimes, measured variables may have differing relationships to expected variables. In the putty-clay model the commitment by firms is considerably longer as factor proportions are fixed for as long as the equipment is in place. In both cases, the Lucas Critique clearly is relevant. We develop models which deal with these concerns.

Consider a simple accelerator model with zero adjustment cost but with a finite, distributed, time-to-build lag between the time orders are placed for investment goods and the time the goods become productive. Suppose that each industry uses a different kind of capital good, for which the lag is discrete, and that the output of each industry is a fixed fraction of aggregate output. Assume that all industries have the same technologically fixed capital-output ratio and that an efficient market for second-hand assets exists.

Under these conditions, the decision on how much output the j^{th} firm wishes to produce in period t completely determines the firm's orders for capital goods in period $t - L_j$, where L_j denotes the time-to-build lag for the j^{th} firm. At time $t - L_j$ we assume that the firm makes a rational forecast of its output, then orders enough investment goods so that, given necessary replacement and previous orders, it will later have enough capital stock to produce that expected output. Formally, let V be the capital-output ratio for all firms.[13] Then new orders, NO, for expansion investment by firm j are given by:

$$(5.1) \qquad NO_{j,t} = V\{(Q^e_{j,t+L_j} \mid \Omega_{t-1}) - (Q^e_{j,t+L-1_j} \mid \Omega_{t-2})\},$$

[13] The assumption that all industries have the same capital-output ratio may be relaxed with no change in the results.

where Ω_t is the information set at time t and where we assume a one-quarter information lag. As before, the superscript e denotes expectations.

If the proportion of investment carried out by firms with lead time L is W_L, then the proportion of output produced by those firms also is W_L. Let the maximum lead time be m. Aggregate net investment, NI, may then be written as:

$$(5.2) \qquad NI_t = \sum_{L=0}^{m} W_L V\{(Q_t^e \mid \Omega_{t-L-1}) - (Q_{t-1}^e \mid \Omega_{t-L-2})\}.$$

Now suppose that between period t and period t+1 there is a change in the process of generating Q^e. All orders placed in periods up to t would be based on forecasts generated under the old process. All orders placed in t+1 and afterwards would be based on the new process, assuming knowledge of the new process is disseminated immediately. For a few periods there is an ambiguity about what initial conditions should be used to start up the new forecasts. We assume that actual output under the old process is used here. Let $(Q_{t+i}^{e\,old} \mid \Omega_t)$, i=0, . . .m, be the forecasts of output under the old process. Then if W_L, L = 0, . . . m, are known, we define Z_t as:

$$(5.3) \qquad Z_t = \sum_{L=0}^{m} W_L V(Q_t^{e\,old} \mid \Omega_{t-L-1}), \ t=1, \ . \ . \ . \ T.$$

For periods after T+m, Z_t is defined by

$$(5.4) \qquad Z_t = \sum_{L=0}^{m} W_L V(Q_t^{new} \mid \Omega_{t-L-1}), \ t=T+m+1, \ . \ . \ .$$

For time periods starting in T+1. and including T+m, Z_t is a mixture of forecasts based on the old and new processes:

$$(5.5) \qquad Z_{T+i} = \sum_{L=0}^{i-1} W_L V(Q_t^{e\,new} \mid \Omega_{t-L-1}) + \sum_{L=i}^{m} W_L V(Q_t^{e\,old} \mid \Omega_{t-L-1}), \ i=1, \ . \ . \ .m.$$

If this model of expectational change has explanatory power, a regression of the form

(5.6) $NI_t = \beta_0 + \beta_1 (Z_t - Z_{t-1}) + \text{error},$

should provide an explanation superior to one in which the Z's are based on the same expectational form throughout the sample. To allow for the presence of decision and other lags, we estimate

(5.7) $E_t = A_8 + \sum_{k=0}^{3} M_{8i} Z_{t-k} + D_8K_t + U_{8t},$ and

(5.8) $E_t = A_9 + \sum_{k=0}^{3} M_{9i} \Delta Z_{t-k} + D_8K_t + U_{9t},$

which are the analogs to our equations (4.1) and (4.2). Only the equations for equipment were estimated because of the lack of data on new structures orders.

In order to construct the variable Z_t we need equations for the laws of motion of output. There is a good deal of controversy today over whether output is a random walk or whether it reverts to a trend. Since the controversy has not yet been resolved, we use a simple form to represent output. An ARI(1,1) process was fitted for the period from 1947:1 to 1988:4, and then for the three subperiods 1947:1 to 1973:3, 1973:4 to 1980:4, and 1981:1 to 1988:4.[14] The process was found to differ significantly over these subperiods. The estimated equations are:

1947:1-1988:4

$(Q_t - Q_{t-1}) = 10.579 + .3254 (Q_{t-1} - Q_{t-2}),$

1947:1-1973:3

$(Q_t - Q_{t-1}) = 10.062 + .2490 (Q_{t-1} - Q_{t-2}),$

1973:4-1980:4

$(Q_t - Q_{t-1}) = 10.720 + .1997 (Q_{t-1} - Q_{t-2}),$ and

1981:1-1988:4

$(Q_t - Q_{t-1}) = 9.430 + .5761 (Q_{t-1} - Q_{t-2}).$

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[14] These divisions of the sample period represent possible structural breaks or regime changes. They occur at the time of the OPEC boycott and at the Reagan inauguration.

The overall equation implies that output reverts to trend growth of \$15.7 billion (1982 dollars) per year, while the three equations for the subperiods imply trend growth of \$13.4 billion, \$13.4 billion, and \$22.2 billion respectively.

To compute the variable Z, we also need a set of estimated weights, W_L. We used the Department of Commerce's series on orders and shipments of producer capital goods. We estimated a fixed weight lag, and found the best results in terms of a minimum standard error were obtained with a polynomial distributed lag ranging up to 14 quarters. Thus, in equations (5.3) through (5.5), m equals 14. Half of the weight is on the current quarter and the first two lags, and three quarters of the orders are filled within five quarters. The mean lag is 3.47 quarters.

Using equations (5.3) through (5.5) two versions of Z_t were derived, one assuming a single regime for output and one assuming three regimes.

The real rental price of capital services in the neoclassical model may be forecasted in a similar fashion. Instead of equations such as (5.3) through (5.5) in which the capital ratio is fixed, it can be made a function of expected c/p. We construct a term ZJ and define it as:

$$(5.9) \qquad ZJ_t = \sum_{L=0}^{14} W_L(Q_t^e \mid \Omega_{t-L-1})/((c/p)_t^e \mid \Omega_{t-L-1}).$$

As in the case of output, we estimated autoregressive equations for the whole period and for three subperiods for c/p for equipment. The chosen specification was AR(2) and the estimated equations were:

1947:1-1988:4

$$(c/p)_t = 0.01554 + 1.1531(c/p)_{t-1} - 0.1998(c/p)_{t-2},$$

1947:1-1973:3

$$(c/p)_t = 0.01105 + 1.2154(c/p)_{t-1} - 0.2483(c/p)_{t-2},$$

1973:4-1980:4

$$(c/p)_t = 0.02614 + 1.1245(c/p)_{t-1} - 0.2148(c/p)_{t-2}, \text{ and}$$

1981:1-1988:4

$$(c/p)_t = 0.03923 + 1.0734(c/p)_{t-1} - 0.1880(c/p)_{t-2}.$$

The parameters for the subperiods differ significantly by a likelihood ratio test. The equations imply that the equilibrium real rent for the whole period was about 33.3 cents per year per dollars' worth of equipment, while for the subperiods it was 33.5 cents, 29.0 cents, and 34.2 cents, respectively.

The equations estimated using ZJ are similar to (5.7) and (5.8), except that ZJ is substituted for Z, and we estimated the parameters A_{10}, A_{11}, M_{10}, M_{11}, D_{10}, and D_{11}.[15]

Turning to the choice of factor proportions in a putty-clay model, the situation seems much different. However, it may be shown that if certain conditions hold then the optimal amount of capital per unit of output capacity for equipment installed at time t should be proportional to p/c at the time of installation. These conditions are that the firm is assumed to minimize the present value of total costs per unit of equipment, over the economic lifetime of that equipment, and to set the price of output as a markup on the present discounted value of average cost on the marginal vintage. We define:

(5.10) $$ZB_{1t} = \sum_{L=0}^{14} W_L \; [Q_t^e \mid \Omega_{t-L-1}]/[(c/p)_{t-1}^e \mid \Omega_{t-L-2}],$$

(5.11) $$ZB_{2t} = \sum_{L=0}^{14} W_L \; [Q_{t-1}^e \mid \Omega_{t-L-2}]/[(c/p)_{t-1}^e \mid \Omega_{t-L-2}], \text{ and}$$

[15] As earlier, all equations are estimated as first-order autoregressive processes and are adjusted for heteroskedasticity. As with the accelerator equations, for each version of the standard neoclassical model there is one equation which is fitted with one expectational regime, and one equation fitted with three expectational regimes. This also applies to the modified neoclassical equations below.

$$(5.12) \qquad ZB_{3t} = \sum_{L=0}^{14} W_L \{[\dot{Q}_t \mid \Omega_{t-L-1}] - [\dot{Q}_{t-1} \mid \Omega_{t-L-2}]\}/[(\dot{c/p})_{t-1} \mid \Omega_{t-L-2}].$$

Analogs to (5.7) using ZB_1, and ZB_2, and to (5.8) using ZB_3 were developed. These in turn were estimated yielding the estimators A_{12}, A_{13}, M_{12}, N_{12}, M_{13}, D_{12}, and D_{13}. In additions a quasi-differences version was estimated which is given as:

$$(5.13) \qquad E_t = A_{14} + \sum_{k=0}^{3} M_{14k} [ZB_{1t-k} - (1-\delta) ZB_{2t-k}] + D_{14}K_t + U_{14t}.$$

The modified neoclassical equations were estimated using the same expectational scheme used throughout the sample (the one regime equations) and also with three sets of expectational schemes (the three regime equations).

The results are given in Tables 3 and 4. As compared to Table 1, the fits in Table 3 are slightly worse. Judging by the statistic s_v, the modified neoclassical equations once again seem best among the expectational equations, although the differenced accelerators are close. The three regime equations fit no better than the one regime equations except in the case of the modified neoclassical equations, when judged by s_v. However, regardless of the number of regimes, the differences and quasi-differences equations reported in Table 4 are all stable, while the levels equations all fail at least four tests. We are not certain what accounts for this stability, but it is possible that the Almon polynomial technique does not sufficiently constrain the lag distributions and that they shift about randomly from period to period. On the other hand, our combination of the orders-shipment lag plus the expectational lag apparently puts on sufficient constraints.

The reasons why the levels versions of these equations failed the stability tests are not clear. One possibility is Hall's [1977] observation that investment equations estimated in level form may really be savings equations and suffer from simultaneous equations bias.

VI. Lag Distribution and Elasticities

In this section we report the results of several dynamic simulations of equations we have fitted above. We simulate the effects of various permanent shocks on the path of the predicted values in each equation.

In the case of the expectational equations, in order to be consistent in our treatment of expectations and to avoid the critique of Lucas, when simulating a permanent shock we should adjust the expectational equation to reflect the assumed path of the shocked variable. At this point, we avoid the necessity for doing this by simulating a small shock so that the change in the expectational equation is negligible.

We report simulations only for the traditional standard neoclassical equation for equipment and two versions of the expectational modified neoclassical equipment equation. According to the traditional standard neoclassical equipment equation in differences form, when simulated with a permanent change in real rental price starting in the first quarter of 1981, the maximum (in absolute terms) elasticity of investment is -0.40. This occurs in the sixth-quarter after the shock (see the left-most column of Table 5). The response over-shoots and by the seventeenth quarter, the elasticity is positive. It remains positive for four quarters, then settles down in the neighborhood of -0.15, which is the elasticity after eight years. The eight year elasticity of the capital stock with respect to the rental price is about -0.12. The elasticities for a change in output are of the same magnitude but of opposite signs.

The modified neoclassical three regime equation in differences form is the best-fitting expectational equation. The responses in this equation to shocks were computed but are not shown. Using this model, the output elasticity of investment rises to 1.59 after four quarters and settles down to about 0.49 after eight years. However, the rental price elasticity is positive for the first eight quarters of non-zero response, and even when it becomes negative it never rises above 0.08 in absolute value during the first eight years. After eight years the stock of equipment is only 0.04% higher for each 1% drop in the real rental price. The response in the first eight quarters may be explained by noting that all relative price effects are forced to act multiplicatively with the change in output. With several negative output changes in the 1981-82 recession, the equation is forced to predict that a fall in the rental price of capital services will increase the capital intensity of disinvestment which means lower, not higher investment. But this is a defect of that specific model, not a reflection of the real world. A more attractive specification is the modified neoclassical quasi-differences version.

The second and third columns of Table 5 report on the simulation of the expectational modified neoclassical three regime equipment equation in quasi-differences form. The output elasticity peaks at 1.50 in the fourth quarter, and settles down near 0.73 after eight years. The real rental price elasticity is always negative and builds gradually to -0.32 after eight years. Eight years after a negative shock of 1% in the real rental price, the stock of equipment has risen by 0.21 percent.

An elasticity of -0.32 is much smaller in absolute terms than the theoretical elasticity in the Cobb-Douglas model of minus one. Our results are in fact much smaller than some earlier results, but higher than others. Hall and Jorgenson [1971] and Bischoff [1971a] simulated equipment spending under the assumption that the investment tax credit had never been adopted. Hall and Jorgenson found that in this case equipment spending would have been 10.0% lower in 1966, while Bischoff found it would have been 8.8% lower in 1966:4. Our simulation found spending would have been 4.2% lower for all of 1966, and 4.3% lower in the fourth quarter. All of these simulations involved single equations only.

Chirinko and Eisner [1983] used six leading large-scale macroeconometric models to simulate a doubling of the investment tax credit for equipment to 14% in 1973 and 20% in 1975 and thereafter. They carried out both single equation and full model simulations. Because we do not have a full model, we compare only single equation simulations. Using the original models, the simulated results ranged from an increase in investment in 1977:4 of 1.5% (Michigan) to 14.2% for DRI and 15.1% for MPS, with an average of 8.4%. After Chirinko and Eisner made various adjustments which seemed reasonable to them, the results were dramatically lower, with the response ranging from 1.7% to 8.6% and a mean response of 3.7%. The authors emphasized that there was now a consensus: Chase, DRI, MPS, and Wharton all predicted between 2.8% and 3.1%.

Our results show an increase of 6.8%, more than double the revised Chirinko-Eisner consensus, and below three of their six original models but above their remaining three.

VII. Policy Analysis

Traditionally, policy analysis has been carried out by computing a baseline simulation and then a second simulation with one or more policy parameters changed. The difference in results is attributed to a policy change. Some policy analysis of this sort is criticized by Lucas [1976]. In one of our simulations below, we attempt to respond this point. We also report traditional simulations.

Using the traditional standard neoclassical equipment equation in differences form, we compare a simulation of the path of equipment spending under the assumption that none of the Reagan tax changes took place, to a simulation with all the actual changes (see the fourth column in Table 5).

We also compare two similar simulations using the expectational modified neoclassical three regime equipment equation in quasi-differences form (see the fifth column, Table 5). In this case, the expectational parameters for the counterfactual case are held at their values computed using the actual policies. Since the tax parameter changes are large in this simulation, the counterfactual case is based on inconsistent expectations.

In the sixth column of Table 5, we report the use of the same equation but with a change in the expectational equation for the real rental prices to the counterfactual case. The equation we use, fitted to counterfactual data for 1981:1 to 1988:4 is:

$$(c/p)_t = 0.02365 + 1.3525(c/p)_{t-1} - 0.4223(c/p)_{t-2}.$$

According to the standard neoclassical equipment equation in differences form, we calculate that, between 1981 and 1985, the tax changes led to increase in investment totalling about $7.3 billion (1982 dollars). In the subsequent three years, this equation indicates that equipment investment was reduced by $23.5 billion. The net effect is to reduce the stock of equipment at the beginning of 1989 by $17.6 billion, or about one percent. Because this equation indicates a tendency to overshoot, investment is predicted to be lower between 1984:1 and 1985:4 than it would have been in the absence of the policy. Also, the response between 1986:3 and

1988:2 to the repeal of the investment tax credit and the depreciation change is large and rapid.

The modified neoclassical expectational three regime equipment equation in quasi-differences form presents a more gradual response to the tax policy changes. This is so whether it is simulated with inconsistent or consistent expectations. In the latter version, the response between 1981 and 1985 is about $10.6 billion (1982 dollars). The reduction between 1986 and 1988 is only $6.4 billion. The effect on the stock of equipment in 1989 is only -$1.0 billion or less than one-tenth of one percent.

Because the absolute value of the long-run rental price elasticity for the modified neoclassical equation simulated here appears to be higher than the similar elasticity for the standard neoclassical equation, the long-run negative response of investment and of capital stock from all of the Reagan tax policies together should be projected to be larger under the modified neoclassical equation. Since the real rental price is calculated to have increased about three percent, as a result of these policies, the eight year elasticities suggest an effect on investment and capital stock of less than one percent.

The results using consistent expectations are not much different from the results using the same equation with inconsistent expectations. This is not surprising, since the coefficients of the two fitted regressions for the real rental price for the period 1981 to 1988 do not differ significantly by conventional statistical standards.

VIII. Conclusions

In this paper we have presented evidence supporting the proposition that traditional models of business investment in equipment and structures suffer from parameter instability, as predicted by the Lucas Critique. We have also developed new expectational models of equipment spending which, in differences form, appear to have stable parameters.

Thus, our new model of expectations and investment, in the differences and quasi-differences forms, seems to be promising for future research. The expectational version of the modified neoclassical equipment equation, in quasi-differences form, seems slightly superior to the corresponding accelerator equation. The expectational modified neoclassical equation appears useful for future research into tax policy effects on investment.

As for the direct effects of the Reagan tax policies on equipment investment, the net effects are calculated to be small, because the policies cancelled each other out. Nevertheless, the stable equations simulated indicate that a sustained tax policy can have substantial effect, either positive or negative, on equipment investment.

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Table 1. Summary Statistics, Traditional Equations.

Equation	S_e [a]	S_v [b]	$\bar{R}^2$	Log of Likelihood Function	Durbin Watson Statistic	Rho [c]
<u>Equipment</u>						
Accelerator						
Levels	.17	.35	.98	914	1.92	.87
Differences	.17	.37	.98	912	2.06	.88
Standard Neoclassical						
Levels	.19	.47	.97	902	1.68	.92
Differences	.19	.51	.97	900	1.56	.93
Modified Neoclassical						
Levels	.16	.24	.98	923	1.92	.74
Differences	.17	.26	.98	917	1.99	.77
Quasi-differences	.18	.38	.98	912	1.94	.89
<u>Structures</u>						
Accelerator						
Levels	.11	.46	.96	977	1.67	.97
Differences	.11	.43	.95	972	1.58	.96
Standard Neoclassical						
Levels	.11	.49	.96	976	1.58	.97
Differences	.11	.49	.96	979	1.62	.97
Modified Neoclassical						
Levels	.11	.49	.96	978	1.61	.97
Differences	.11	.50	.96	979	1.65	.98

[a] Estimate of standard deviation of white noise error e, measured in fractions of one percent of "natural" real GNP.

[b] Estimate of standard deviation of autocorrelated error v, measured in fractions of one percent of "natural" real GNP.

[c] Estimated autocorrelation coefficient of errors u.

Table 2. Tests of Stability, Traditional Equations, Calculated Chi-Square Values.

Equation	Period 1[a] vs 2 & 3	Period 1[a] vs 4 & 5	Period 1[a] vs 4,7 & 8	Period 1[a] vs 6 & 8	Period 6 vs 4 & 7	Period 5 vs 7 & 8
Equipment						
Accelerator						
Levels	23.1	19.0	52.5	31.6	20.9	33.4
Differences	13.1[b]	11.5[b]	41.9	18.2	23.7	30.4
Standard Neoclassical						
Levels	25.3	30.8	36.8	10.5[b]	26.3	6.0[b]
Differences	5.9[b]	9.0[b]	15.2[b]	3.5[b]	11.7[b]	6.2[b]
Modified Neoclassical						
Levels	27.7	31.7	65.9	25.0	40.9	40.1
Differences	6.6[b]	5.6[b]	38.4	18.3	20.1	32.8
Quasi-Differences	22.6	22.9	42.9	22.8	20.2	20.0
Structures						
Accelerator						
Levels	11.1[b]	12.6[b]	54.6	34.0	20.6	42.0
Differences	9.1[b]	11.9[b]	25.0[b]	22.4	2.6[b]	13.0[b]
Standard Neoclassical						
Levels	16.8	23.4	50.9	36.3	14.6[b]	27.5
Differences	15.1[b]	16.8	70.8	52.4	18.5	54.0
Modified Neoclassical						
Levels	17.4	24.6	49.2	36.8	12.4[b]	24.6
Differences	14.2[b]	16.5	50.4	38.2	12.2[b]	33.9

[a] Period 1 - 1953:1 through 1988:4; Period 4 - 1953:1 through 1973:3; Period 7 - 1973:4 through 1980:4; Period 2 - 1953:1 through 1970:4; Period 5 - 1973:4 through 1988:4; Period 8- 1981:1 through 1988:4. Period 3 - 1971:1 through 1988:4; Period 6 - 1953:1 through 1980:4;

[b] The null hypothesis (parameter stability) is not rejected at the 0.05 level.

Table 3. Summary Statistics, Expectational Equations, Equipment.

Equation	S_e [a]	S_v [b]	$\bar{R}^2$	Log of Likelihood Function	Durbin Watson Statistic	Rho [c]
Accelerator						
Levels						
1 Regime	.18	.81	.98	908	1.94	.98
3 Regimes	.18	.83	.98	910	1.96	.98
Differences						
1 Regime	.18	.42	.98	905	1.83	.90
3 Regimes	.18	.42	.98	906	1.83	.90
Standard Neoclassical						
Levels						
1 Regime	.20	.59	.97	894	1.39	.94
3 Regimes	.20	.60	.97	894	1.39	.94
Differences						
1 Regime	.20	.53	.97	892	1.32	.92
3 Regimes	.20	.52	.97	892	1.33	.92
Modified Neoclassical						
Levels						
1 Regime	.18	.38	.98	913	1.74	.88
3 Regimes	.17	.37	.98	915	1.76	.88
Differences						
1 Regime	.18	.41	.98	904	1.79	.89
3 Regimes	.18	.40	.98	906	1.81	.89
Quasi-Differences						
1 Regime	.18	.41	.98	906	1.80	.90
3 Regimes	.18	.41	.98	908	1.83	.90

See Table 1 for definition of notes.

Table 4. Tests of Stability, Expectational Equations, Equipment, Calculated Chi-Square Values.

Equation	Period 1[a] vs 2 & 3	Period 1[a] vs 4 & 5	Period 1[a] vs 4,7 & 8	Period 1[a] vs 6 & 8	Period 6 vs 4 & 7	Period 5 vs 7 & 8
Accelerator						
Levels						
1 Regime	25.5	20.2	29.1	12.3[b]	16.8	8.8[b]
3 Regimes	23.4	19.5	50.6	9.1[b]	41.5	31.1
Differences						
1 Regime	5.8[b]	5.4[b]	11.9[b]	5.1[b]	6.8[b]	6.5[b]
3 Regimes	5.0[b]	4.6[b]	9.0[b]	2.2[b]	6.8[b]	4.4[b]
Standard Neoclassical						
Levels						
1 Regime	22.4	28.5	32.3	6.2[b]	26.2	3.9[b]
3 Regimes	21.8	28.2	32.6	7.3[b]	25.3	4.5[b]
Differences						
1 Regime	4.6[b]	1.9[b]	3.4[b]	1.5[b]	1.9[b]	1.5[b]
3 Regimes	3.8[b]	1.6[b]	3.4[b]	2.0[b]	1.5[b]	1.8[b]
Modified Neoclassical						
Levels						
1 Regime	27.7	31.0	44.8	11.1[b]	33.1	13.8[b]
3 Regimes	26.9	30.4	39.8	7.0[b]	32.9	9.4[b]
Differences						
1 Regime	5.8[b]	6.4[b]	17.0[b]	7.7[b]	9.4[b]	10.6[b]
3 Regimes	5.3[b]	5.8[b]	12.3[b]	3.6[b]	8.7[b]	6.5[b]
Quasi-Differences						
1 Regime	9.8[b]	12.9[b]	23.2[b]	8.8[b]	14.4[b]	10.3[b]
3 Regimes	9.8[b]	13.0[b]	20.9[b]	7.3[b]	13.6[b]	7.9b

See Table 2 for definition of notes.

Table 5. Simulation Results.

	Simulation Elasticities			Simulated Effects of Reagan Tax Policies* Quarterly Flow, Billions of 1982 Dollars at Annual Rates		
Period	I	II	III	IV	V	VI
1981:1	-.00	.00	-.00	0.0	0.0	0.0
1982:1	-.38	1.37	-.06	6.7	1.1	1.4
1983:1	-.36	.62	-.12	3.3	1.4	2.4
1984:1	-.17	.78	-.22	-0.4	2.2	2.2
1985:1	.005	.67	-.24	-2.3	2.6	3.6
1986:1	-.08	.65	-.26	1.1	2.8	2.9
1987:1	-.14	.68	-.27	-11.5	0.0	-1.0
1988:1	-.15	.71	-.31	-11.6	-4.0	-5.9
1988:4	-.15	.73	-.32	-1.9	-2.2	-4.0

I. Simulation results of a permanent equipment rental price shock on producers' durable equipment, traditional equation, standard neoclassical model, differences. Elasticity with respect to output shocks is the same with opposite sign.

II. Simulation results of a permanent output shock on producers' durable equipment, modified neoclassical expectational equation, three regimes, quasi-differences.

III. Simulation results of a permanent equipment rental price shock on producers' durable equipment, modified neoclassical expectational model, three regimes, quasi-differences.

IV. Differences between a simulation with Reagan tax parameters and a simulation with all tax parameters held at 1980:4 levels on producers' durable equipment, traditional equation, standard neoclassical model, differences.

V. Differences between a simulation with Reagan tax parameters and a simulation with all tax parameters held at 1980:4 levels on producers' durable equipment, expectational equation, modified neoclassical model, three regimes, quasi-differences (constant tax simulation based on inconsistent expectations).

VI. Differences between a simulation with Reagan tax parameters and a simulation with all tax parameters held at 1980:4 levels on producers' durable equipment, expectational equation, modified neoclassical model three regimes, quasi-differences (constant tax simulation based on consistent expectations).

* Positive sign indicates Reagan simulation higher.

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