THE EFFECTS OF COST OF CAPITAL AND RISK ON THE INVESTMENT BEHAVIOR OF U.S. ELECTRIC UTILITY INDUSTRY, 1949-1970

by

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Introduction

The investment behavior of the U.S. electric utility industry was the subject of recent studies of Jorgenson and Handel [10] and Sankar [15]. In this paper we have followed similar lines but we have emphasized more the role of the financial variables. We have also analyzed the effect of market disequilibrium on the investment behavior in this industry.

The plan of the paper is as follows: In section I we analyze the effects of risk and cost of capital on the firm's investment decision, and we discuss an operative measure of these variables. In section II we incorporate the risk and cost of capital in a neo-classical investment model of Jorgenson [8] and Eisner [5], and we also discuss the problem of the effect of disequilibrium stock of capital on investment. Section III presents the empirical results and compares them with the alternative models that were used by Sankar [15] for a very similar set of data. We present also some additional empirical results derived from our model with regard to the long run elasticities and the form of the distributed lag model. Finally, section IV summarizes the conclusion and the possible implications of the model.

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I. The Effects of Risk and Cost of Capital on Investment Decision by Regulated Firms

The theoretical effect of risk on investment is rather clear; in a period of higher risk the investor will discount heavily expected future return using the discount factor. That is because the investor required a risk premium above the riskless rate for a risky investment. The discount factor ρ for a risky investment with risk level s is given simply as

$$\rho = r_F + \delta(S)$$

where r_F is the riskless rate and $\delta(S)$ is the risk premium for a risk level s per unit of investment.

Assume that $\delta(S)$ is a monotonic function of S, i.e. $\delta'(S) > 0$. Comparing investment in the same period we can view the risk premium as a product of the risk level S by unit risk premium λ to get

$$\rho = r_F + \lambda \cdot S$$

which is consistent with the linear relationship between the risk and return in the one-period Sharpe-Lintner model (see Sharpe [16], Lintner [12]).

Intuitively, we can view the valuation of risky projects by investors in the simple two-stage discount approach that was suggested in Ben-Zion [2]. The model assumes that each stream of a risky future income is regarded by investors as having two characteristics[1]: (a) expected value and (b) risk. The valuation of the income stream depends, therefore, on these two

[1] The idea of the characteristic approach to market goods was suggested by Lancester [11] and Becker [1].

characteristics. If we assume that an investor can combine portfolios with different levels of expected income and risk, and that he has a risk aversion, we can define two types of "discount" processes in the market: (a) discount of risky future income to a riskless future income; and (b) discount of future riskless income to present income (or the simple present value procedure).

Assume that the given income stream Y has an expected future income of X and S units of risk. We can represent it at a point A in the left part of Figure 1.

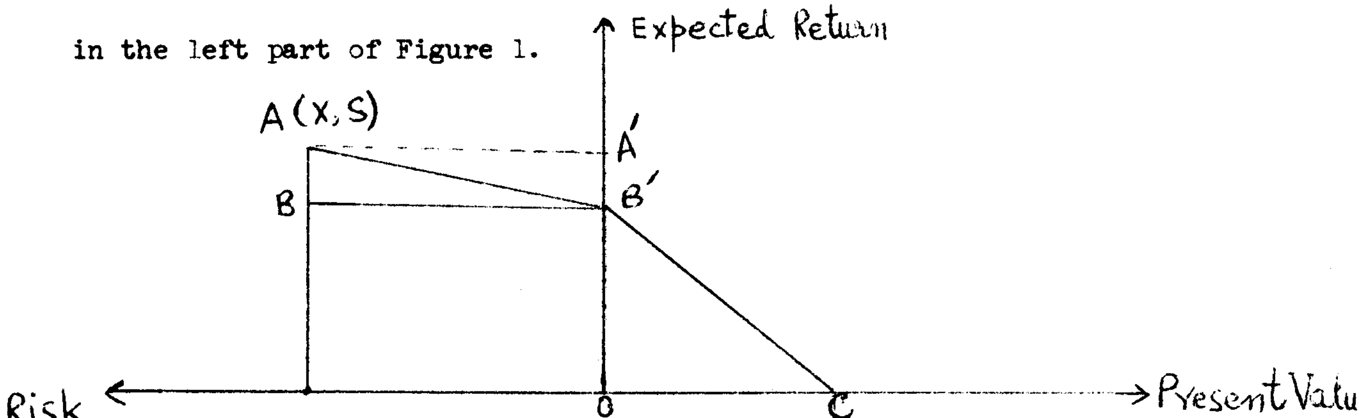

Figure 1: A simple two-dimensional representation of the "two stages" present value.

Then the riskless equivalent of the expected income X from investment in a risky activity can be shown by a point like B'. We can think of B'A', the difference between the expected incomes as the risk premium of asset i over the riskless asset. Finally, the present value of the risky investment is OC, which can also be regarded as the simple present value of the "riskless equivalent".

Using the characteristic approach we can write the value of the risky income to be equal to

(1) $Y_F = X - \lambda S$

where Y_F measured in future riskless income units is the riskless income which is equivalent to the risky income stream (X, S). Y_F is represented at point B' in Figure 1. λ is the risk premium in the market for a unit of risk. ($-\lambda$ is the "price" of risk in the market.) The present value of the income is given simply by the Fisher discount procedure:

$$(2)\quad Y_C = \frac{Y_F}{1+R_F}$$

which is shown as point C of Figure 1.

If ρ is the direct discount factor of the risky income, we can write:

$$(3)\quad Y_C = \frac{X}{1+\rho}$$

where Y_C is the market price for the one period risky income $Y = Y(X, S)$. The market equilibrium relationship can be simply derived by comparing the two-way discount procedure in (1) and (2) to the direct discount procedure

$$(4)\quad Y_C = \frac{X - \lambda S}{1+R_F} = \frac{X}{1+\rho}$$

or

$$(4')\quad (1+R_F)\, Y_C + \lambda S = Y_C(1+\rho)$$

which yields the equilibrium condition:

$$(5)\quad \rho = (R_F + \lambda s)$$

where $s = \frac{S}{Y_C}$ is the asset risk per unit of market price which can be viewed as a measure of the "risk class" of the investment.[1]

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[1]The "risk class" terminology was defined by Modigliani and Miller [13] where two income streams which have proportional distribution (i.e. same ratio of future income and risk in our case) have the same risk class.

The analysis above is useful both for comparing different investment alternatives at a given point in time and for analyzing investment behavior over time; in particular the analysis extends the classical results by emphasizing that the present value of an investment will depend on three factors:

(a) the cost of capital under certainty (or the riskless rate);

(b) the required risk premium; and

(c) the market subjective evaluation of the level of the investment risk.

Let I be the level of investment in a project and let $X = X(I)$ be the expected income and $S = S(I)$ be the expected risk. The present value of the investment will be:

$$(6) \quad Y(I) = \frac{X(I) - \lambda S(I)}{(I+R_F)}$$

and the present value of the marginal return is given as:

$$(7) \quad Y'(I) = \frac{X'(I) - \lambda S'(I)}{1+R_F}$$

where $Y'(I) = \frac{dY}{dI}$, $X'(I) = \frac{dX}{dI}$, $S'(I) = \frac{dS}{dI}$.

The necessary marginal condition for optimal level of investment is given by:

$$(8) \quad Y'(I) = \frac{X'(I) - \lambda S'(I)}{1+R_F} = 1$$

which can be interpreted as the condition that a \$1 increase in investment yields at the margin risky income whose present value is exactly \$1. Alternatively this condition means that the net present value of the marginal investment $(Y'(I)-1)$ is zero.

We derive from above the result:

$$(9) \quad X'(I)-1 = (R_F + \lambda S'(I))$$

which says that the net marginal expected income from an investment $(X'(I)-1)$ is equal to the riskless rate plus a risk premium.

The condition of diminishing returns to investment is written as $Y''(I) < 0$, where it is implied that increasing the level of investment I will result either in diminishing expected returns ($X''(I) < 0$) or in increasing marginal risk $S''(I) > 0$.

It is clear from (8) that an increase in the riskless cost of capital will reduce the marginal net return $Z(I) = Y'(I) - 1$, and lead firms to reduce the level of their investment which is the classical result under certainty. Furthermore, an increase in the required risk premium λ will tend to reduce the marginal net return and reduce investment. We can therefore conclude that if we view investment as a function of the riskless rate R_F and the required risk premium, i.e. $I = I(r_F, \lambda)$, we can expect from the theory that both will have partial negative effects on investment:

$$(10) \quad \frac{\partial I}{\partial r_F} < 0 \quad \frac{\partial I}{\partial \lambda} < 0.$$

The model above was based on a competitive firm for which the cost of capital and the expected income stream from a potential investment project are independent. An increase in the cost of capital will tend, therefore, to reduce the present value of the income. This, however, is not necessarily the case for a regulated firm where a regulator may take the cost of capital or the yield on alternative investment as a relevant factor in determining the appropriate rate of return. If in this case an increase in the rate of interest leads the regulator to allow the firm to obtain higher income from a given investment project (i.e. by raising price in the case where the demand elasticity is less than 1), then the net effect of cost of capital on the present value of the income from a given investment project is not unambiguous. In particular, if there is a lag between changes in the "allowed return" and changes in the cost of capital, it is possible that an increase in the cost of capital may encourage investment in expectation of a higher future return.[1]

Therefore, applying the model for investment decision to regulated firms we expected a negative effect of risk on investment, while the effect of the cost of riskless capital is ambiguous and depends on the relationship between the return on equity and the cost of capital.

II. Disequilibrium and Investment

The neo-classical theory of investment has assumed that the desired stock of capital is a function of the firm's output and the rental price of capital relative to output. The investment in the model is regarded as a distributed lag function of the changes in the desired capital.[2]

$$(10) \quad I_r = \sum_{j=1}^{\lambda} \alpha_j (K^*_{t-j} - K^*_{t-j-1})$$

where K^*_{t-j} is the desired stock of capital at the year t-j.

By assuming this particular form of the investment function, the neo-classical model ignores the effect of "over investment" by the firm in one period on its investment behavior in other future periods. In a realistic model, however, one would expect that the firm's investment decision will be affected by the difference

[1] See Currie, K.A. and S.Y. Wu [4] for a similar claim.

[2] See for example Jorgenson and Handel [10], Eisner and Nadiri [5] and Griliches and Wallace [18].

between the actual and the desired stock of capital. A positive difference (i.e. actual stock of capital above the desired stock) will discourage investment, while a negative difference will encourage investment. The idea that investment depends on the difference between the desired and actual capital was suggested in the pioneering work of Grunfeld, and it can also be incorporated into the neo-classical model.[1] The firm's investment can therefore be written as a distributed lag function of the changes in the desired stock of capital as well as of the initial difference between the desired stock of capital and the actual stock of capital.

$$(11)\quad I = \sum_{t=i-\ell}^{t-1} \alpha_i (K^*_{i+1} - K^*_i) + \beta_i (K_{t-\ell} - K^*_{t-\ell})$$

where $K_{t-\ell}$ is the actual stock of capital at t-1 and the last term with $\beta_i < 0$ represents the effect of "disequilibrium" in the period on the investment in future periods.

The Combined Empirical Model

In the above section we introduced three variables which we consider important additional variables in the analysis of investment by regulated firms (and by unregulated firms as well):

(a) the cost of capital;

(b) market evaluation of investment risk;

(c) differences between observed and desired stock of capital.

Since our main interest is to obtain empirical estimates of the partial effect of the above new variables, we simply

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[1] See also Griliches [7].

extended the empirical formulation used in Sankar. Sankar started with the general formulation of the investment function. Under the assumption of CES production function and the rational distributed lag specification of the lag structure, his investment function was:

$$(12)\quad I_t = \sum_{i=0}^{m'}[\gamma_{qi}\ \Delta \log O_{t-i} + \gamma_{pi}\ \Delta \log (P/C)_{t-i}] - \sum_{j=1}^{n} w_j\ \Delta \log K_{t-j} + \epsilon_t$$

where O, P, and C are respectively output, price of output and rental price of capital. However, his estimation results suggested that the more appropriate specification of investment function in this industry can simply be written as:

$$(13)\quad \Delta \log K_t = \sum_{i=0}^{m'} \gamma_i\ \Delta \log O_{t-i} - \sum_{j=1}^{n} w_j\ \Delta \log K_{t-j} + \epsilon_t$$

suggesting a Leontief type production model.

We have taken (13) as the model which is appropriate for analyzing investment decisions in this industry. By adding the three variables mentioned earlier we get:

$$(14)\quad \Delta \log K_t = \sum_{i=0}^{m'} \gamma_i\ \Delta \log O_{t-i} - \sum_{j=1}^{n} w_j\ \Delta \log K_{t-j} + \alpha_i \log R_{t-\lambda} + \beta_i \log S_{t-\lambda} + \delta_i(\log K^*_{t-\lambda} - \log K_{t-\lambda}) + \eta_t$$

where O_t is the output of the industry in period t, while $R_{t-\lambda}$, $S_{t-\lambda}$ respectively refer to the cost of capital and a market measure of the investment risk. The variable $(K^*_{t-s} - K_{t-s})$ refers to the distributed lag adjustment reflecting the disequilibrium force mentioned earlier.

III. Estimation

Data

The model presented in section II is applied to the annual data relating to investor-owned electric utilities in the United States for the period 1950-1968. The data on the real value of the capital stock and the output is the same as used by Sankar in his study [15]. For the cost of capital, we have used the yield on the long term government bonds. This was taken from the Business Statistics [17].

For the measure of market-risk premium, we have used a time-series measure of risk which was suggested in Ben-Zion [3] and is the difference between average yields on Moody's BBB bonds in public utilities and the yield on the long term government bonds.[1]

The investment function to be estimated is:

$$\Delta \log K_t = \sum_{i=0}^{m} \gamma_i \, \Delta \log O_{t-i} + \sum_{j=1}^{n} w_j \, \Delta \log K_{t-j}$$

$$+ \alpha_i \log R_{t-\ell} + \beta_i \log S_{t-\ell} + \delta_i (\log K^*_{t-\ell} - \log K_{t-\ell}) + \eta_t$$

when we have the same variables as before and use of m, n refers respectively to the length of the lag distribution on the output and the dependent variables.

In our empirical work, we decided to represent the disequilibrium in the capital stock by the deviations in the observed capital-output

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[1] For a justification for the yield differential on risky and riskless assets as a measure of market risk, see Ben-Zion [3].

ratio from its trend. Furthermore, we have restricted m to four and n to two in our estimation. We experimented with different lag structures on the variables and the regression equations which gave the best results are summarized in Table 1. Regression results in Column (1) are similar to Sankar's Leontief production model[1] whereas the results in Columns (2) and (3) show the effects of additional variables on the investment expenditure of the industry. The estimated coefficients of the cost of capital, market risk-premium and the disequilibrium factors are all significant and of the signs predicted by our theoretical considerations. The adjusted R^2 increases from .907 to .962 when these three additional variables are added to the investment function. We have reported the D-W statistic though we are aware that it is biased towards two if there are lagged dependent variables in the regression.[2] Estimates

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[1] [10], pp. 660. Sankar has reported estimates of the investment function corresponding to our regression (1) in Table 1, the constraint being $-4w_2 \geqq -w_1^2$. Formally, we have used $(\frac{\tilde{K}}{O})_{t-\ell} = (\frac{K}{O})_{t-\ell} - (\frac{\bar{K}}{O})_{t-\ell}$ to represent the disequilibrium in the capital market. Where $(\frac{K}{O})$ is observed capital-output ratio, $(\frac{K}{O})$ is the predicted value of (K/O) in a regression containing the time-trend. We did experiment with introducing the variables like the cost of capital and the relative factor price ratio but the results did not improve.

[2] However, we may make the following conjecture: If there are lagged dependent variables in the regression and if the "reported D-W statistic" is close to two, we cannot conclude anything about the autocorrelation property of the residuals. However, if the reported D-W statistic is very low (though theoretically it is biased to two), then it can clearly be taken as evidence in favor of the positive serial correlation. The reported D-W statistics in Table 1 clearly indicate that we are not under the second situation.

Table 1: Estimation Results of the Investment Function 1950-1968:

$$\Delta \log K_t = \sum_{i=2}^{3} \gamma_i \, \Delta \log O_{t-i} + \sum_{j=1}^{2} w_j \, \Delta \log K_{t-j} + \hat{\alpha} \log R_{t-3}$$

$$+ \beta \log S_{t-3} + \hat{\delta} \log \left(\frac{\tilde{K}}{O}\right)_{t-3} + e_{(t)}$$

	(1)	(2)	(3)
$\Delta \log K_{t-1}$	.9805 (7.000)	.7405 (6.052)	.6179 (4.556)
$\Delta \log K_{t-2}$	-.4174 (3.097)	-.2787 (-2.617)	-.1769 (-1.675)
$\Delta \log O_{t-2}$	.1264 (3.606)	.1700 (5.969)	.1545 (5.936)
$\Delta \log O_{t-3}$	.1032 (2.944)	.143 (5.092)	.107 (3.771)
$\log (\frac{\tilde{K}}{O})$		-.0953 (-3.674)	-.112 (-2.944)
$\log R_{t-3}$			-.0112 (-1.844)
$\log S_{t-3}$			-.0157 (-2.416)
DW	1.50	1.64	1.88
$\bar{R}^2$	.907	.950	.962
SEE	.0053	.0039	.0034

Terms in the brackets are the t-values.

of long run elasticities of capital with respect to output, cost of capital and risk variables are:[1]

$$\hat{E}_Q = \frac{\hat{\gamma}_1+\hat{\gamma}_2}{1-(\hat{w}_1+\hat{w}_2)} = 0.46$$

$$\hat{E}_R = \frac{-\hat{\alpha}}{1-(\hat{w}_1+\hat{w}_2)} = -.0200$$

$$\hat{E}_S = \frac{-\hat{\beta}}{1-(\hat{w}_1+\hat{w}_2)} = -.0281$$

Constrained Estimation

We can rewrite the estimated regression equation (3) in Table 1 as:

$$(1 - \hat{w}_1 L + \hat{w}_2 L^2)I = (\hat{\gamma}_1 L^2 + \hat{\gamma}_2 L^3)\ \Delta \log O + \hat{\alpha}\ L^3 \log R + \hat{\beta}\ L^3 \log S - \hat{\delta}\ L^3 \log (\frac{\tilde{K}}{O})$$

or

$$(15)\quad I = \frac{(\hat{\gamma}_1 L^2+\hat{\gamma}_2 L^3)}{1-\hat{w}_1 L+\hat{w}_2 L^2}\ \Delta \log O + \frac{\hat{\alpha}\ L^3}{1-\hat{w}_1 L+\hat{w}_2 L^2} \log R + \frac{\hat{\beta}\ L^3}{1-\hat{w}_1 L+\hat{w}_2 L^2} \log S - \frac{\hat{\delta}\ L^3}{1-\hat{w}_1 L+\hat{w}_2 L^2} \log (\frac{\tilde{K}}{O})$$

where $L^s X \equiv X(t-s)$ is the polynomial lag operator.

It is well known that in the case where $1-w_1L-w_2L^2$ has complex roots, the coefficients of $\frac{1}{1-w_1L-w_2L^2}$ will oscillate about zero, all such lags will therefore have some negative coefficients. Hence, if one has the prior assumption that the lag distribution on any variable is not oscillatory, one can impose that presumption as a constraint and reestimate the

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[1] In the above calculation of the long term output elasticity, we disregard the indirect effect of output on investment through the disequilibrium of the capital-output ratio. Taking into account this indirect effect, the long term output elasticity can be estimated as:

$$\hat{\hat{E}}_Q = \frac{\hat{\gamma}_1+\hat{\gamma}_2+\hat{\delta}}{1-(w_1+w_2)} = \frac{.1545 + .107 + .112}{.1 + .1769 - .6179} = 0.64$$

model.[1] The condition is that the equation $1-w_1L-w_2L^2$ has real roots which imply the following restriction on the coefficients:[2]

(16) $w_1^2 + 4w_2 \geqq 0$

We have reestimated the regression equations in Table 1 subject to the constraint (16). The constrained investment function along with the estimates of long run elasticities of capital stock with respect to output, the cost of capital and risk variables are presented in Table 2. The estimated coefficients of all variables are of the right sign and significantly different from zero. The results presented in Table 2 are consistent with the predictions made earlier that the cost of capital, risk and disequilibrium variables are quite important in the investment decisions. In fact, the adjusted R^2 increases from .42 to .87 when these three additional variables are added to the model.[3] The estimate of long term elasticities of capital with respect to output ($\hat{E}_Q$=.4775) is slightly lower than the estimate of Sankar's[4] ($\hat{E}_Q$=0.54589).

Time-Structure of Net Investment

As we pointed out before, the implied lag distribution of investment on the various variables can be derived by solving the polynomials given in (15). So we have presented in Table 3 the distributed lag coefficients of net investment on output,

[1] See Jorgenson [8].

[2] It is also well known that a necessary and sufficient condition for the lag distribution to be convergent is that the roots of the polynomial equation $1-w_1L-w_2L^2$ lie outside the unit circle. This is equivalent to requiring that a) $w_1+w_2 < 1$; b) $|w_2| < 1$.

[3] Strictly speaking, the comparison of $\bar{R}^2$ is not valid because the values of dependent variables are not the same in two regressions.

[4] However, the complete output elasticity is calculated to be $\approx .66$ $\left(\frac{.131 + .097 + .088}{1 + .0954 - .6179}\right)$ and there does not seem to be evidence in favor of significant returns to scale in the electric utility industry.

Table 2: **Constrained Estimation of the Investment Function 1950-1968:**

$$I_t = \sum_{i=2}^{3} \gamma_i \, \Delta \log O_{t-i} + \sum_{j=1}^{2} w_j \log \Delta K_{t-j} + \alpha \log R_{t-3}$$

$$+ \beta \log S_{t-3} + \delta \log \left(\frac{\tilde{K}}{O}\right)_{t-3}$$

	(1)	(2)	(3)
$\Delta \log K_{t-1}$	.9805	.7405	.6179
$\Delta \log K_{t-2}$	-.2403	-.1371	-.0954
$\Delta \log O_{t-2}$	.068 (2.259)	.114 (4.467)	.131 (6.025)
$\Delta \log O_{t-3}$	.068 (2.327)	.117 (5.302)	.097 (3.569)
$\log \left(\frac{\tilde{K}}{O}\right)_{t-3}$		-.074 (-2.985)	-.088 (-3.747)
$\log R_{t-3}$			-.015 (-2.557)
$\log S_{t-3}$			-.018 (-2.885)
$\bar{R}^2$	.42	.72	.87
SEE	.0062	.0047	.0035
DW	1.64	1.39	1.75
$\hat{E}_Q$	.5234		.4775
$\hat{E}_R$			-.0314
$\hat{E}_S$			-.0377

Table 3: Distributed Lag Coefficients: Responses of Investment to Output, Cost of Capital and Risk.

$$\Delta \log K_t = .6179\ \Delta \log K_{t-1} - .0954\ \Delta \log K_{t-2} + .131\ \Delta \log O_{t-2} + .097$$

$$\Delta \log O_{t-3} - .088\left(\frac{\tilde{K}}{O}\right)_{t-3} - .015 \log R_{t-3} - .018 \log S_{t-3} + \hat{\varepsilon}(t)$$

$$= \sum_{i=1}^{\infty} \left[\hat{\gamma}_i\ \Delta \log O_{t-i} - \hat{\alpha}_i \log R_{t-i} - \hat{\beta}_i \log S_{t-i} - \hat{\delta}_i \log \left(\frac{\tilde{K}}{O}\right)_{t-i}\right]$$

	Output			Cost of Capital			Risk		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i	$\hat{\gamma}_i$	$\sum_{k=1}^{i} \gamma_k$	$\sum_{k=1}^{i} \gamma_k / E_Q$	$\hat{\alpha}_i$	$\sum_{k=1}^{i} \alpha_k$	$\sum_{1}^{i} \alpha_k / E_R$	$\hat{\beta}_i$	$\sum_{1}^{i} \beta_k$	$\sum_{k=1}^{i} \beta_k / E_S$
1	0			0			0		
2	0			0			0		
3	.131	.131	.274	-.0150	-.0150	.478	-.0180	-.0180	.477
4	.178	.309	.647	-.0093	-.0243	.774	-.0111	-.0291	.772
5	.097	.406	.852	-.0043	-.0286	.911	-.0051	-.0342	.907
6	.043	.449	.940	-.0017	-.0303	.964	-.0022	-.0364	.966
7	.017	.466	.975	-.0006	-.0309	.984	-.0008	-.0372	.987
8	.007	.473	.990	-.0002	-.0311	.990	-.0003	-.0375	.995
9	.002	.475	.995	-.0001	-.0312	.994	-.0001	-.0376	.997
10	.001	.476	.997	-.0000	-.0312		-.0000	-.0376	.997
SUM (∞)	.477			-.0313		1.000	-.0377		1.000
Mean Lag	4.31			3.86			3.87		

the cost of capital and the market risk premium. The response of investment to output is given in columns (1-3), of cost of capital in columns (4-6) and of risk in columns (7-9).

In our model, the response of investment to output, cost of capital and risk variables is zero in the first two years. About 85 percent of response of investment to output occurs by the end of the fifth year in the public utilities.

Concluding Remarks

The main purpose of this paper has been to show the importance of cost of capital, risk and disequilibrium in the capital stock on the investment behavior of the public utility industries. It is our hope that further research will extend both the theoretical framework and the empirical test and will yield a better understanding of the role of the financial variable in the investment behavior of regulated and nonregulated industries.

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