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ENVIRONMENTAL REGULATIONS AND THE COST OF CAPITAL IN THE 1970s

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The taxation of externality producing activities has been given increased attention as a means of not only correcting imperfections in the marketplace, but also generating revenue. In 1987, for example, hearings were held on a proposed sulfur and nitrogen emissions tax which would have greatly reduced these pollutants, and generated more than $25 billion in revenues over a five year period.[1] While the U.S. currently levies a number of taxes on the basis of environmental concern, many are directed at providing funds for clean up, rather than the reduction of pollutants.[2]

In contrast to a taxed based approach,[3] U.S. environmental policy has tended to rely on direct controls. Firms were required to install devices in order to reduce the amount of pollution emitted from their production processes, even if other means were available to reduce emissions. The expenditures for these mandated pollution control methods, which were added to or modified the production process, increased the cost of purchasing and operating capital equipment. As a result, it is possible to view these direct regulations as a direct "tax" of the capital employed in production. The purpose of this paper is to provide estimates of the magnitude of these changes in the cost of capital.

While this paper will attempt to investigate the effect of environmental regulations on firm's investment decisions, it does not address the question of whether there is, or has been, "too much" regulation, or whether regulation has been "good" or "bad."

Such an evaluation would necessarily be much broader than presented here, and would encompass both the costs regulations have imposed on the economy, as well as the benefits.[4]

A Brief History of Federal Environmental Regulation

The regulation of air and water pollution in the U.S. was a local matter until the late 1940s. The passage of the Water Pollution Control Act of 1948, though it provided only research and technical assistance to the states, "legitimized federal entrance into the realm of water pollution."[5] While other bills were enacted which modified this role in the interim, it was with the passage of the Water Quality Act of 1965 that a national policy for controlling water pollution was established.

The emergence of air pollution regulation followed a similar path from state and local autonomy to the establishment of a federal role.[6] Municipal regulations were first enacted in 1881 in Chicago, Illinois, and Cincinnati, Ohio. The first county law took effect in Albany, New York in 1913. In 1952, Oregon became the first state to enact legislation controlling pollution, three years before the first federal act. In 1955, the Air Pollution Control Act was passed, and provided funding for research, training, and technical assistance. The passage of the Clean Air Act of 1963 provided grants-in-aid to establish and improve local programs. The provision of grants-in-aid led to the establishment of state legislation and programs in the 39 states which had not done so before 1963.

Seven years later, the passage of the Clean Air Act Amendments of 1970 mandated the setting of national ambient air quality standards and the establishment of new source performance standards.

The expenditures by firms to comply with environmental regulations grew with each piece of legislation. As a percentage of net investment, pollution abatement and control (PAC) expenditures peaked in 1975 (see Table 1). The burden of these expenditures was not even across industries. According to BEA data for non-durables manufacturers, 4 of the 10 industries (food, paper, chemicals, and petroleum) accounted for more than 95 percent of pollution control capital. In the case of durables, 6 of the industries accounted for approximately 55 percent of the pollution capital stock.

Model[7]

Regulation can be thought of as requiring firms to purchase an additional input, abatement capital (A), along with non-abatement capital (K). The firm's maximization problem becomes:

$$\max \Pi = PF(K,A,X_i) - \sum_{i \neq A,K} w_i X_i - w_K K - w_A A(K) \qquad (1)$$

where: Π is profit,
P is the market price of the output,
$F(\bullet)$ represents the production function, $F'>0$, $F''<0$,
X_i are factor inputs, $i = 1, \ldots, N$
and w_i is the price of the ith factor.

The first order conditions for profit maximization are:

$$\frac{\partial \Pi}{\partial X_i} = P\frac{\partial F}{\partial X_i} - w_i = 0 \Rightarrow P\frac{\partial F}{\partial X_i} = w_i \qquad (2a)$$

$$\frac{\partial \Pi}{\partial K} = P\frac{\partial F}{\partial K} + P\left(\frac{\partial F}{\partial A}\right)\left(\frac{\partial A}{\partial K}\right) - w_K - w_A\frac{\partial A}{\partial K} = 0$$

$$\Rightarrow P\frac{\partial F}{\partial K} = w_K + w_A\frac{\partial A}{\partial K} - P\left(\frac{\partial F}{\partial A}\right)\left(\frac{\partial A}{\partial K}\right) = c. \qquad (2b)$$

Equation (2a) is the usual result, regulation does not directly affect the marginal cost or productivity of the non-capital inputs. The interpretation of (2b) is best handled in parts.

The first term, w_K, is the price of a capital input. The second term, $w_A(\partial A/\partial K > 0$, is the additional expenditure required to purchase the necessary amount of abatement capital given a purchase of non-abatement capital. The third term represents the change in revenue $P(\partial F/\partial A)$ associated with the change in output caused by the addition of abatement capital $(\partial A/\partial K)$. If abatement capital is not productive (that is, its increased use does not increase output, $F_A < 0$) then this term will be greater than zero. Taken together, (2b) shows that the opportunity cost of non-abatement capital, c, is greater than its market price, w_K, and reflects the additional expenditures incurred by the firm to comply with regulations. If units of abatement and non-abatement capital sell for the same price, w_K, equation (2b) can be simplified to read

$$c = w_K\left(1 + \frac{\partial A}{\partial K}\right) - P\left(\frac{\partial F}{\partial A}\right)\left(\frac{\partial A}{\partial K}\right). \qquad (2c)$$

TABLE 1
MANUFACTURING INVESTMENT, 1961–1976
(IN BILLIONS OF 1972 DOLLARS)

	TOTAL NET INVESTMENT	NON-ABATEMENT	ABATEMENT	ABATEMENT SHARE
1961	4.84	4.53	.31	.0640
1962	5.10	4.77	.33	.0647
1963	5.57	5.21	.36	.0646
1964	7.71	7.25	.46	.0597
1965	11.62	11.05	.57	.0491
1966	15.21	4.44	.77	.0506
1967	15.11	4:12	.99	.0655
1968	12.67	1.53	1.14	.0900
1969	13.09	1.69	1.40	.1070
1970	11.12	9.35	1.77	.1592
1971	8.10	5.99	2.11	.2605
1972	10.09	7.88	2.21	.2190
1973	11.40	8.85	2.55	.2237
1974	15.57	2.95	2.62	.1683
1975	12.40	9.10	3.30	.2661
1976	12.69	9.72	2.97	.2340

For the firm to adjust to this higher cost higher cost, and still meet the equality condition imposed by (2b), the firm must increase the marginal product of its capital ($\partial F/\partial K$). This is achieved by decreasing the level of non-abatement capital, thereby decreasing the firm's demand for capital. The extent of the decrease is dependent on the technical relationships between abatement capital, non-abatement capital, and output. If abatement capital is "productive," in the sense that it contributes to the firm's output, the firm's demand for capital could increase. If, on the other hand, regulation induced capital expenditures are determined exogenously, and independent of A, A will be a constant and $\partial A/\partial K = 0$. In this case, regulation induced capital expenditures would have no effect on the marginal cost of non-environmental capital.

The price of a capital input, w_K, represents the cost to the firm of purchasing one additional unit of capital. Incorporating the federal tax structure into the cost of capital yields[8]

$$w_K = \frac{q(r + \delta)(1 - k - uz)}{(1 - u)} \tag{3}$$

where q is the purchase price of the capital good, r is the interest rate, u is the corporate tax rate, δ is the depreciation rate, z is the present value of depreciation, and k is the investment tax credit.

Gross investment is assumed to be given by a distributed lag of the form[9]

$$I_t = \sum_{s=0}^{\infty} u_s \Delta K^*_{t-s} + \delta K_t \tag{4}$$

where I_t is gross investment in period t,
K^* is the desired level of capital stock in period t,
u_s is the proportion of the change in capital which takes place in period t-s, and
δ is the rate of replacement of the current capital stock, K.

Net investment, N_t, is given by

$$N_t = I_t - \delta K_t = \sum_{s=0}^{\infty} u_s \Delta K^*_{t-s} \tag{5}$$

The amount of capital desired in each period is derivable from the profit function and its first order conditions. In order to obtain an explicit formulation it is necessary to posit a specific form for the firm's production function. We employ a translogarithmic, or translog, function. The translog function is one of a class of flexible functional forms which are second-order approximations to any production function, and imposes no restrictions on the relationships between inputs.[10] Specifically,

$$\ln Y = \ln \alpha_0 + \sum_i \alpha_i \ln X_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln X_i \ln X_j \tag{6}$$

where α, γ are parameters.

The derivative of this function with respect to the natural log of an input yields its logarithmic marginal product

$$\frac{\partial \ln Y}{\partial \ln X_i} = \alpha_i + \sum_j \gamma_{ij} \ln X_j \tag{7}$$

At this point it should be noted that

$$\frac{\partial \ln Y}{\partial \ln X_i} = \left(\frac{\partial Y}{\partial X_i}\right)\left(\frac{X_i}{Y}\right) \tag{8}$$

If markets are competitive, so that each input's price is equal to its marginal product, that is

$$w_i = P\left(\frac{\partial Y}{\partial X_i}\right) \tag{9}$$

a substitution of (9) into (8) yields

$$\frac{\partial \ln Y}{\partial \ln X_i} = \left(\frac{\partial Y}{\partial X_i}\right)\left(\frac{X_i}{Y}\right) = \left(\frac{w_i X_i}{PY}\right) = M_i \tag{10}$$

where M_i is the share of total cost devoted to purchasing X_i. Under perfect competition and constant returns to scale, M_i is also the elasticity of output with respect to the ith input.

In the case of capital, equation (2b) can be rewritten as

$$c = P\left(\frac{\partial F}{\partial K}\right) = PM_K\left(\frac{Y}{X_K}\right) \Rightarrow K^* = \left(\frac{PY}{c}\right)M_K$$

$$K^* = \left(\frac{PY}{c}\right)\left(\alpha_K + \sum_i \gamma_{Ki} \ln X_i\right) \tag{11}$$

Our investment equation (5) now becomes

$$N_t = \sum_{s=0}^{\infty} \Delta\left(\frac{P_{t-s}\, Y_{t-s}}{c_{t-s}}\right)(M_K)_{t-s} \tag{12}$$

To obtain estimates of the effects regulations have had on investment, the parameters of the investment equation (12) must be determined. Regulation enters this equation through two variables, c and M_K. What the values of each of these variables would have been in the absence of regulation can be estimated using the parameters of the production function.

To obtain estimates of the effects regulations have had on investment, we need to obtain estimates of the parameters of the production function (6), and the investment schedule (12). The estimates of (6) yield the parameters which define the effective cost of non-abatement capital, as derived in equation (2b) as well as the M_i's as defined in equations (7) and (10).

Maximum likelihood estimates of the production function were obtained by jointly estimating (6) with (7), the share equations, using feasible generalized least squares.[11] The net investment equation is estimated as a distributed lag.

DATA

The data for this paper were primarily drawn from the Census-SRI-Penn (CSP) dataset which contains annual observations on 18 variables for 1958–1976.[12] In addition to data regularly published in the Annual Survey of Manufactures and the Census of Manufactures, the CSP dataset contains measures of capital stock for both equipment and structures, and price deflators.[13] Pollution abatement capital stock data was taken from BEA.[14]

Estimates were made for the six industries for which detailed estimates of abatement capital stock is published: SIC 20, food and kindred products, SIC 26, paper and allied products, SIC 28, Chemicals

TABLE 2
CHANGE IN THE COST OF CAPITAL DUE TO REGULATION, SELECTED YEARS, 1958–1976

Industry Group	1958	1965	1970	1976
Food and kindred products	.040	.056	.065	.117
Paper and allied products	.066	.055	.046	.127
Chemicals and allied products	.031	.056	.066	.103
Petroleum and coal products	.168	.229	.233	.435
Primary metal products	.015	.039	.051	.109
Transportation equipment	.192	.253	.158	.201

and allied products, SIC 29, petroleum and coal products, SIC 33, primary metals, SIC 37, transportation equipment.

RESULTS

The estimated effects of regulation on the cost of capital are presented in Table 2. Table 3 presents a comparison of actual capital stock growth rates to those forecast in the absence of regulation. To understand the magnitude of the differences, Table 6 presents the sum of the differences between non-regulated and actual investment for each industry. Columns 1 and 2 list the 1976 stock of non-abatement and abatement capital. The next two columns report the sums of the annual differences between simulated

TABLE 3
CAPITAL STOCK GROWTH RATES
ANNUAL AVERAGES

1958 - 1965 act.	1958 - 1965 sim.	1965 - 1973 act.	1965 - 1973 sim.	1973 - 1976 act.	1973 - 1976 sim.	1958 - 1976 act.	1958 - 1976 sim.
SIC 20: Food and kindred products							
1.95	2.00	2.74	2.76	2.64	3.04	2.41	2.51
SIC 26: Paper and allied products							
4.34	4.41	3.37	3.51	2.97	3.31	3.68	3.83
SIC 28: Chemicals and allied products							
4.42	4.51	4.25	4.39	5.04	5.59	4.45	4.63
SIC 29: Petroleum and coal products							
-.629	-.412	.980	.910	1.28	4.17	.402	.927
SIC 33: Primary metal products							
1.50	1.51	2.22	2.41	.890	1.70	1.72	1.94
SIC 37: Transportation equipment							
2.56	2.64	3.51	3.49	2.88	2.84	3.03	3.05

act: actual growth in net capital stock
sim: simulated growth in net capital stock in the absence of regulation

TABLE 4
SIMULATION RESULTS

Industry	Capital Stock: non-pollution	abatement	foregone investment	share of total	"D"
Food and kindred products	33.841	1.580	0.571	0.017	0.361
Paper and allied products	23.129	2.540	0.601	0.026	0.237
Chemicals and allied products	49.569	4.630	1.624	0.033	0.351
Petroleum and coal products	18.084	6.350	1.782	0.099	0.281
Primary metal products	44.840	4.315	1.791	0.040	0.415
Transportation equipment	32.641	1.300	0.115	0.004	0.089

investment in the absence of regulation and actual net investment, and the sum as a percentage of the 1976 non-pollution capital stock.

Following Lurie (1984) a measure of the degree of diversion, D, was constructed as the ratio of the sum of foregone investment in production capital to the total amount of abatement capital. D is a measure of the trade-off between pollution and non-pollution expenditures. A negative value for D implies that investment would have been lower in the absence of regulation. A positive value less than one indicates that regulation diverted less than its amount of compliance expenditures from productive capital investment. A value greater than one indicates that regulation imposed more than a dollar for dollar reduction in non-abatement investment.

The results verify what we would have expected to occur: the increase in the effective price of production capital caused firms to decrease their amount of non-pollution net investment. However, the amount of diversion does not appear to be directly related to the increase in the cost of capital, or the percentage decrease in production capital. For example, petroleum and coal products, which was estimated to have experienced the largest increase in the cost of capital (more than twice the increase of any other), had the forth largest value of "D." The greatest value of "D" was found in primary metals, which was estimated to have experienced only the fifth largest increase in the cost of capital.

The results do allow us to conclude that environmental regulations have reduced the amount of capital available for the production of manufactured goods, but the diversion was far less than 1:1. For these industries, total capital stock, abatement plus non-abatement, were higher in 1976 than they otherwise would have been.

ENDNOTES

[1]See U.S. Congress (1987), particularly the testimony of C.E. Steuerle, Deputy Assistant Secretary of the Treasury (Tax Analysis), and J.M. Campbell, Acting Assistant Administrator for Policy, Planning, and Evaluation, Environmental Protection Agency.

[2]See Joint Committee on Taxation (1990) for an overview of current tax laws relating to the environment.

[3]A discussion the problems in establishing and administering environmental taxes can be found in Brashares and Gerardi (1988) and Cordes, et. al (1990).

[4]Such an evaluation is presented in Plesko (1985). Tests under a broad range of assumptions generally found the benefits of environmental regulations to have exceeded the costs for the period of study.

[5]A.C.I.R., (1981).

[6]This history is drawn from Stern (1982).

[7]This framework is taken from Plesko (1985).

[8]Hall and Jorgenson (1967).

[9]Ibid. Three assumptions are necessary for this formulation. First, the flow of capital services is assumed to be proportional to the stock. Second, changes in the demand for capital stockswill be met be proportional changes in the stock in each period. Third, replacement investment is made at a constant rate, also proportional to total capital stock.

[10]Berndt and Christensen (1973).

[11]For a more detailed description of the estimation technique and the restrictions imposed on the parameters, see Johnston (1977), Berndt and Christensen (1973). Owing to space constraints, parameter estimates are not presented. They are available from the author upon request.

[12]See Andrews and Zabala (1984) for a detailed description of the dataset.

[13]Additional data used to construct the cost of capital variables were drawn from Bradford and Fullerton (1981), Feldstein (1982), and Jorgenson and Sullivan (1981).

[14]Kappler and Rutledge (1982).

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