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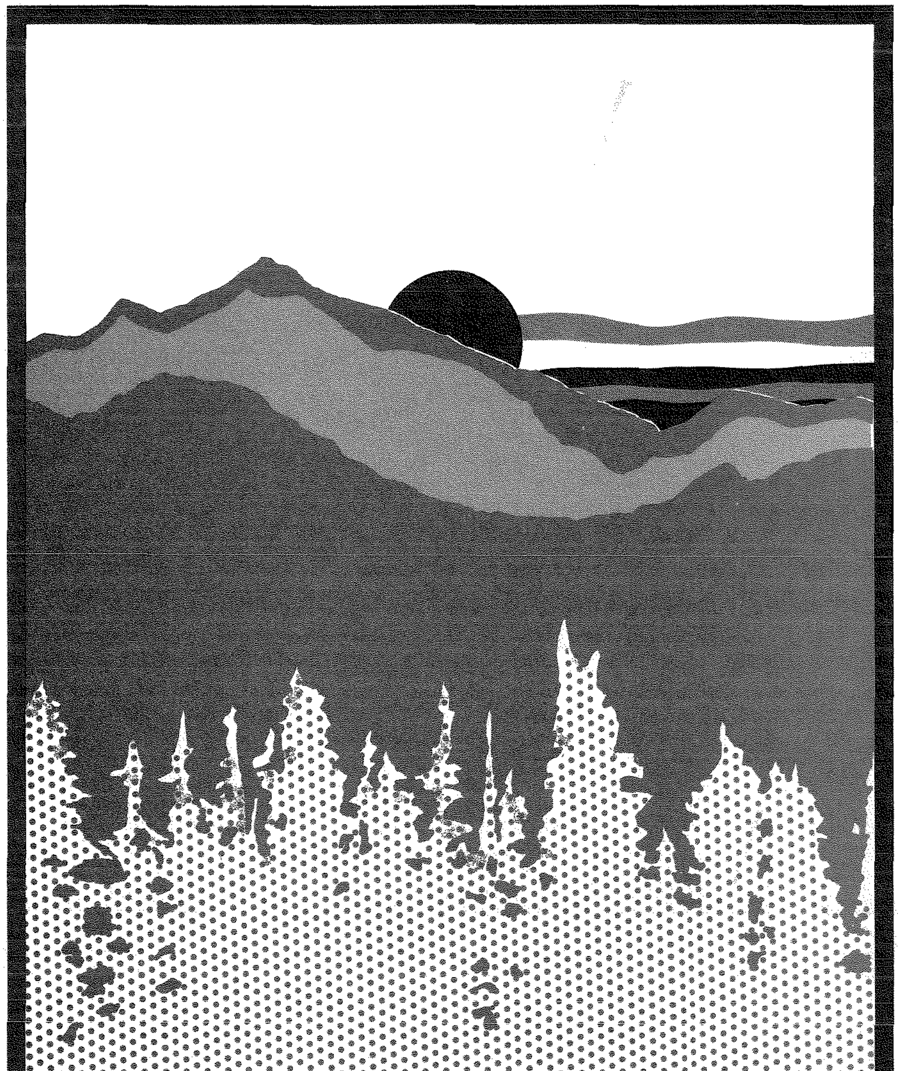

Problems of Resource Utilization

WINTER 1978

Pollution Control Legislation and the Capital Appropriations/Expenditure Lag

David Condon*

During the past decade, Congress has passed a major body of legislation to regulate industrial air, water, and solid-waste pollution. This legislation encompasses the Radiation Control for Health and Safety Act (1968), The National Environmental Policy Act (1969), the Clean Air Act Amendments (1970), the Occupational Safety and Health Act (1970), and the Federal Water Pollution Control Act (1972).[1] Virtually all private industry in the nation has been affected by this proliferation of government regulations. Thus, the private sector's capital-investment requirements for pollution-control equipment could reach $112 billion over the decade 1972–81. Again, six industries (non-ferrous metals, steel, paper, chemicals, petroleum, and electrical utilities) have allocated more than 10 percent of their total plant-equipment expenditures for pollution control and abatement during the 1972–76 period. And again, firms might have to invest $31 billion simply to meet the 85-decibel noise limit which the Environmental Protection Agency has recommended for work areas.[2] Costs of this magnitude should increase the rates of return required on new investment, and thus could tend to reduce the total amount of capital formation in the economy.[3]

Because pollution-control standards may—indeed, will—change in the future in some unknown way, business firms have hesitated to make forward commitments. This basic uncertainty, along with the necessity of preparing environmental-impact reports, has tended to delay new construction projects and to lengthen construction periods. As one noted economist said when discussing Dow Chemical's decision to drop its plans for a massive petro-chemical complex: "We have created a nightmare with the permit process. The problem is having some certainty as to what rules are and will be. Right now, you get a permit, or you take a couple of years and you think you've got a permit, and then you really haven't: you've got another two years."[4]

Since 1967, five industries (petroleum, chemicals, paper, steel, and nonferrous metals) have accounted for over 40 percent of all required industrial spending on pollution control.[5] This article attempts to measure the extent to which pollution-control standards have protracted the investment processes for industries. The evidence suggests that the time lag between capital appropriations and final expenditures for those industries as a group has been extended at least four quarters, with spending of roughly 15 percent of initial capital appropriations occurring over the additional quarters. The evidence also suggests that a considerable alteration in the time pattern of plant relative to equipment spending has taken place over the past decade.

Section I presents a model for the investment process. Section II presents the framework for our statistical model, and Section III provides the estimated results. Section IV presents a summary and conclusions.

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*Research Associate, Federal Reserve Bank of San Francisco. The author wishes to thank Dr. Jean Mater (Partner and General Manager, Mater Engineering, Corvallis, Oregon) for her contributions to the study. This paper was prepared under the direction of Dr. Herbert Runyon.

I. The Investment Process

Assume an initial condition of long-term equilibrium, where the capital stock is adjusted to a given state of technology and to given supply-and-demand conditions in product and factor markets. Then, let the industry's desired stock of capital increase for some reason—perhaps due to a fall in interest rates or to an increase in demand for the product. The adjustment to a new equilibrium will not be immediate, and capital investment will not be concentrated at one point in time but rather spread over a period of time. The available evidence indeed indicates that the investment response to a change in demand for capital stock is distributed over several years.[6] It takes time to plan capital outlays, arrange for financing, let construction contracts, order equipment, build or manufacture the ordered items, and construct the new facilities. In addition, business firms in an uncertain world are often reluctant to adjust production facilities immediately and fully to new market conditions. "They prefer to make a partial initial adjustment and wait to see if the new conditions persist before undertaking further expansion."[7]

Given the lag between changes in desired capital and final investment expenditures, the investment process can be characterized as a sequence of separate stages. The first stage involves a change in the demand for capital stock, and encompasses the initial capital budgeting and planning process. The second stage covers the appropriations process in which the capital budget is disaggregated and "tested by individual project." When top management authorizes a capital appropriation, it decides either to corroborate or change the capital budget. The approval of capital appropriations therefore formalizes planning decisions for each block of capital spending.[8] The third stage involves the letting of contracts for plant and equipment. Then, in the final stage, funds are expended for received capital goods.

Since the second stage encompasses a formalized business-planning process—involving continuous spending decisions and changes in those decisions—we assume that actual capital expenditures accrue entirely from previous appropriations. In other words, an expenditure (denoted here as E_t) is a weighted average of past appropriations made during the second stage. If w_i is the proportion of projects initiated in time t and completed in time t + i, then

$$E_t = w_0 A_t + w_1 A_{t-1} + \ldots + w_i A_{t-i} \qquad (1)$$

where A_t is the appropriation made in time t. The weights w_i are non-negative and, in the absence of cancellation of appropriations, sum to unity.

II. Development of Model

We use multiple correlation to estimate the weights w_i, where an expenditure at time t is determined by past appropriations. We assume that an appropriation made more than n periods past can be neglected, so that equation (1) can be rewritten as

$$E_t = \sum_{i=0}^{n} w_i A_{t-i} + e_t \qquad (2)$$

where it is customarily assumed that the exogenous variables A_{t-i} are independent of the error term e_t. However, multiple correlation will yield unreliable results when successive observations $A_t, A_{t-1}, \ldots$, etc. are too collinear, as is the case with the quarterly Conference Board data used in this study. In order to reduce the difficulties of multi-collinearity, we assume that final expenditures accrue entirely from previous appropriations made during the second stage in the investment process and restrict $w_i = 0$ for $i = -1$. Secondly, since we assume that an appropriation made more than n periods ago will have only a negligible effect on E_t, we restrict $w_i = 0$ for $i = n + 1$. Finally, we introduce the hypothesis that the successive weights w_i lie on a polynomial of degree k.[9]

In the final form, our statistical model includes a constant term and a variable defined as the ratio of opening-quarter appropriations backlogs (BL) at time t over expenditures at time t − 1.[10] The constant term is included because the capital-appropriations survey data contain an allowance for overstatement and understatement,[11] and also because some companies included in the survey report only major expenditures as appropriated.[12]

The (BL_t/E_{t-1}) variable compensates for the delayed spending resulting from changes in the business cycle by shifting the lag distribution, $(\sum_{i=0}^{n} w_i A_{t-i})$, forward—i.e., it raises the estimated values of the initial weights and lowers the values of the later weights.[13] "Postponements may also occur after the formal approval by the board of directors. Then, as the survey is presently constituted, we would not be formally aware of it. However, if such development were to become widespread, as in a recession, for example, it would show up as a relative rise in the backlog of appropriations with declining expenditures and commitments."[14] The ratio not only reflects these cyclical changes, but also adjusts for the delayed expenditures resulting from the unanticipated impact of the energy crisis.[15]

Autocorrelation has been a problem with previous studies using capital appropriations and expenditures data.[16] To correct for this problem, we transformed the data using the Cochrane-Orcutt iterative technique. The final form of our equation thus is

$$E_t = C + b(BL_t/E_{t-1}) + \sum_{i=0}^{n} w_i A_{t-i} + u_t. \quad (3)$$

where quarterly Conference Board data on capital appropriations, expenditures, and appropriations backlogs are seasonally adjusted and in constant dollars.

Parameters for our distributed-lag regression model are estimated for the five industries—singly and in the aggregate—which have accounted for over 40 percent of all industrial anti-pollution spending since 1967. These industries—petroleum, chemicals, paper, steel, and nonferrous metals—are classified as "Regulated" industries. The data cover the sample period 1953 I – 1976 IV and two subperiods—one preceding, and one following, the passage of pollution-control legislation (1953 I – 1976 IV and 1967 I – 1976 IV).

Following estimation of coefficients, a test is performed to determine whether there is a significant change in coefficient values between the two subperiods. The regression model is then reestimated for each industry and the industry aggregate, to determine whether the number of elements in the lag distribution (n) increased between the two subperiods.

Because of the probability that changes in estimated lag distributions reflect factors which are independent of pollution-control legislation, estimated results for "Regulated" group are compared with estimated results for a "Control" group of industries that have been minimally affected by pollution-control standards—specifically, electrically machinery, other nondurables, textile mill products, and transportation (excluding motor vehicles). These were the four industries in the McGraw-Hill pollution-control expenditures survey which maintained the lowest percentages of anti-pollution spending to total capital expenditures over the 1970–76 period.[17] Pollution-control expenditures amounted to 4.1 percent of total capital spending for the "Control" group from 1970 to 1976, versus 14.0 percent for the "Regulated" group and 5.4 percent for all industries surveyed by McGraw-Hill.[18] Pollution-control expenditures as a percentage of capital spending for individual industries (and group aggregates), and also as a percentage of total industrial anti-pollution spending, are presented in Appendix Tables A1 and A2.

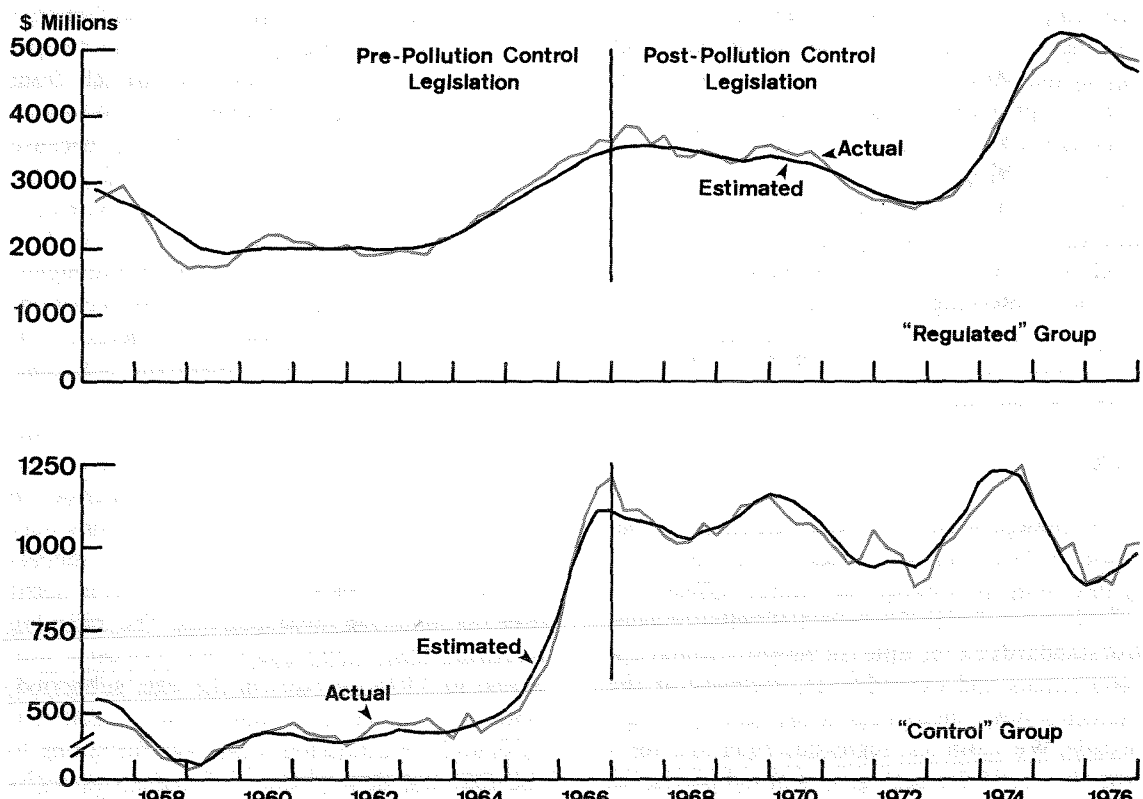
The industries in the "Control" group were not completely unaffected by pollution-control regulations. In other words, these regulations have accounted for a portion of a change in the time lag between capital appropriations and final expenditures for that group. Adjusting increases in the lengths of the "Regulated" group lag-distribution will therefore cause a slight understatement of the extent to which pollution-control standards have protracted the investment process.

III. Empirical Results

Before estimating the coefficients (w_i) and determining values for n pertaining to each industry and aggregate, we had to make an arbitrary decision regarding the value of k (the degree of the polynomial).[19] The initial value was set at 4 and n = 6, 7, . . . , 19 were tested for each industry and aggregate for the 1953 I – 1976 IV sample period. From among these 15 estimated distributed lags, one was chosen as "best" for each industry and aggregate using the following two criteria: (1) $\bar{R}^2$ (the coefficient of multiple determination adjusted for degrees of freedom), and (2) elimination of those distributed lags whose later weights are negative. Once the "best" distributed lag was selected for each industry and aggregate, the process was repeated for the two aggregates setting k = 2 and 3 to determine if there was an improvement in $\bar{R}^2$. In both cases, $\bar{R}^2$ deteriorated for those values of k. All results reported in this study are therefore derived using 4th degree polynomials.[20] Actual expenditures and values estimated using the "best"

Chart 1

ESTIMATED AND ACTUAL CAPITAL EXPENDITURES



distributed lag regressions are plotted for the "Regulated" and "Control" aggregates in Chart 1.

Since we hypothesize that the investment process for "Regulated" industries has lengthened as a consequence of pollution-control standards, it follows that any such alteration should be reflected in a change in estimated coefficient values between the two subperiods. Using the same values for n determined for the "best" distributed lag regressions over the entire sample period 1953 I – 1976 IV, coefficients are reestimated for each industry and aggregate over the two subsamples. These individual regressions are used to test this hypothesis as against the null-hypothesis (equal coefficients in both subperiods).

A comparison of the sums of squared residuals from the regressions estimated for the entire sample period with those estimated for the two sub-samples yields $F^5_{61} = 10.22$ for the "Regulated" aggregate and $F^5_{61} = 3.44$ for the "Control" aggregate, with an F^5_{61} – critical = 2.12 at the one-percent level of confidence.[21] The F-tests thus support the alternative hypothesis, which denotes a change in coefficient values between the early and later subperiods. The alternative hypothesis was also accepted at the one-percent level of confidence for each of the individual industries composing the "Regulated" and "Control" aggregates. Since both groups exhibit significant alterations in coefficient values between subperiods, we may conclude that investment activity is affected by other factors besides pollution-control regulations. However, these regulations must be responsible for at least some of the change in estimated coefficient values, because the "Control" industries are not completely free from their direct and indirect effects.

Next, we estimate the impact of pollution-control standards on the time lag between capital appropriations and expenditures, exclusive of the impact of other factors operating during the last decade. We again test regression equations for n = 6, 7, . . . , 19 for both groups of industries, select the "best' distributed lag, and compare the changes in the mean lags and in the orders of the estimated distributed lags between the two subperiods.[22] The two criteria specified earlier are used in selecting the "best" distributed lags for each industry and aggregate. Regression results for the early and later subperiods are presented in Tables 1 and 2, while plots of the "best" distributed lags are shown in Chart 2.

The results indicate a shift from an inverted "v" shaped distribution in the early period to a bi-modal distribution in the later subperiod. This suggests that an appropriation in the 1953–66 subperiod led to a symmetrically distributed set of expenditures over time for plant and equipment, while an appropriation in the 1967–76 subperiod led to quite a different distribution. In this later period, we see an initially higher percentage of expenditures on equipment—indicated by the left-skewed distribution in six of the individual industries as well as the "Regulated" aggregate—with a longer, and in the case of both group aggregates, a somewhat separate distribution reflecting delayed expenditures for plant. This explanation is consistent with the fact that the plant share of total appropriations for "Regulated" industries (except petroleum) fell from 25.93 percent in the early subperiod to 20.96 percent in the later subperiod. Again, because spending for plant involves longer and greater capital outlays than spending for equipment, it follows that final appropriations for new plant are subject to relatively longer delays and higher postponement rates because of all the uncertainties that have characterized the past decade—including the uncertainties attendant pollution-control regulations.

In the case of the "Control" aggregate, an estimated 100 percent of appropriations were spent by the eighth quarter in the early subperiod. In contrast, only 81 percent of appropriations were spent by the eighth quarter in the later subperiod, with an estimated 13.5 percent being spent over the following three quarters. The mean lag increased from 3.302 quarters in the early subperiod to 3.936 quarters in the later subperiod. Both the number of periods in the lag distributions and the estimated mean lags pertaining to the four individual "Control" industries registered similar increases. Electrical machinery registered the smallest increase, and transportation equipment the largest increase, between the two subperiods.

In the case of the "Regulated" aggregate, an

Table 1
"Best" Distributed Lags
Early Subperiod (1953.I – 1966.IV)

	"Regulated" Group						"Control" Group				
	"Regulated Aggregate"	Primary Iron and Steel	Primary Non-Ferrous Metals	Chemicals & Allied Products	Paper & Allied Products	Petroleum	"Control" Aggregate	Electrical Machinery & Equip.	Other Non-durables	Textile Mill Products	Transportation Equipment[2]
c	355.156	67.327	49.587	139.083	−12.140	−22.358	−48.561	38.723	−9.536	−0.393	59.227
	(1.135)	(0.744)	(1.669)	(3.080)	(−0.465)	(−0.173)	(−0.651)	(1.187)	(−0.720)	(−0.047)	(5.907)
BL/E_{t-1}	−74.209	−5.170	−3.446	−21.066	5.652	7.560	4.926	−9.217	−1.723	0.153	−14.678
Weight[1]	(−0.913)	(−0.633)	(−1.599)	(−1.706)	(0.945)	(0.143)	(−0.390)	(−1.842)	(−1.347)	(0.137)	(−3.267)
0	0.048	0.035	0.058	0.075	0.032	0.083	0.111	0.133	0.012	0.076	0.102
	(1.032)	(0.749)	(3.148)	(3.017)	(0.934)	(1.224)	(4.974)	(9.270)	(1.384)	(3.758)	(2.993)
1	0.114	0.070	0.095	0.127	0.067	0.162	0.157	0.179	0.127	0.155	0.205
	(2.784)	(1.517)	(4.893)	(6.064)	(1.891)	(2.891)	(8.734)	(12.745)	(3.588)	(11.572)	(6.500)
2	0.168	0.099	0.113	0.154	0.098	0.206	0.161	0.170	0.224	0.206	0.234
	(8.012)	(3.152)	(8.343)	(11.482)	(4.521)	(5.481)	(15.320)	(21.194)	(6.380)	(10.518)	(7.737)
3	0.190	0.119	0.118	0.157	0.120	0.200	0.145	0.134	0.255	0.214	0.173
	(7.309)	(4.117)	(8.716)	(8.713)	(7.192)	(4.797)	(7.966)	(15.069)	(6.210)	(9.604)	(8.101)
4	0.176	0.129	0.112	0.139	0.131	0.147	0.123	0.090	0.204	0.176	0.061
	(5.161)	(3.229)	(5.820)	(7.090)	(5.115)	(3.833)	(5.547)	(6.242)	(3.444)	(11.092)	(1.223)
5	0.128	0.127	0.099	0.106	0.129	0.068	0.102	0.054	0.105	0.107	
	(4.275)	(2.845)	(4.358)	(6.854)	(4.504)	(1.610)	(5.488)	(3.256)	(2.591)	(3.813)	
6	0.063	0.114	0.080	0.064	0.114	0.001	0.086	0.033		0.034	
	(2.341)	(2.814)	(3.668)	(3.615)	(4.944)	(0.026)	(4.231)	(2.269)		(0.920)	
7	0.007	0.091	0.059	0.025	0.090		0.071	0.028			
	(0.264)	(2.459)	(3.099)	(1.191)	(4.699)		(2.264)	(2.358)			
8		0.062	0.038		0.059		0.047	0.037			
		(1.478)	(2.174)		(2.240)		(1.489)	(2.298)			
9			0.017		0.026			0.047			
			(1.247)		(0.486)			(2.194)			
10								0.042			
								(2.228)			
Σ lag Coefs.	.897	0.880	.794	.849	.871	.871	1.000	.952	.931	.971	.777
Mean Lag	3.120	4.403	3.768	3.012	4.402	2.435	3.302	3.265	2.515	2.740	1.853
RHO	.42	.52	.69	.25	.56	.44	.70	.35	.63	.13	.00
$\bar{R}^2$	.98	.85	.97	.98	.96	.87	.98	.97	.86	.97	.97
D.W.	1.49	1.88	1.27	1.66	1.85	2.00	2.31	2.22	1.36	1.81	2.00
S.E.	77.01	52.77	10.00	23.03	12.90	66.70	23.91	16.85	6.25	6.31	12.14

[1] Distributed-lag weights for quarters
[2] Excluding motor vehicles

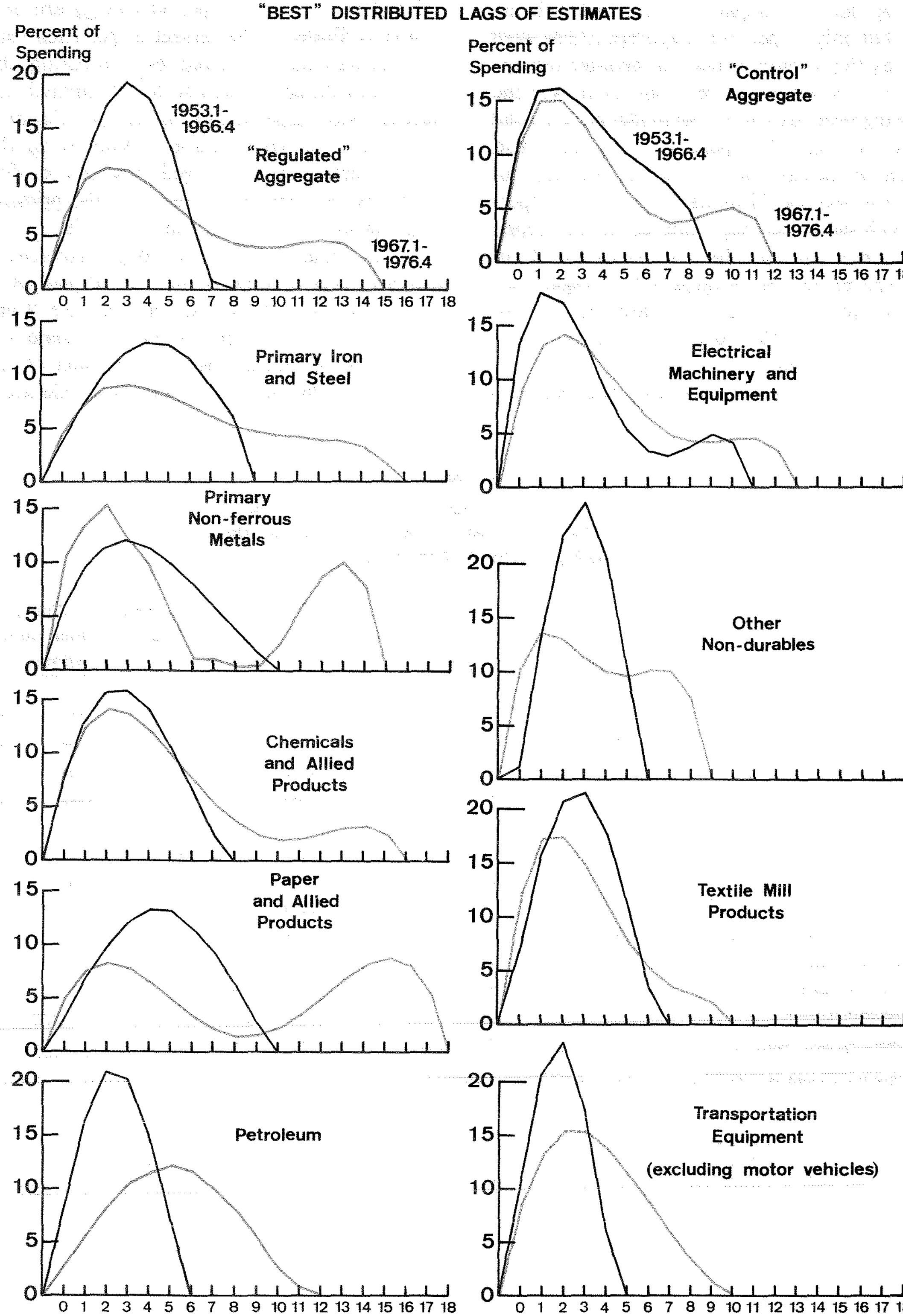
Table 2
"Best" Distributed Lags
Later Subperiod (1967.I – 1976.IV)

	"Regulated" Group						"Control" Group				
	"Regulated Aggregate"	Primary Iron and Steel	Primary Non-Ferrous Metals	Chemicals & Allied Products	Paper & Allied Products	Petroleum	"Control" Aggregate	Electrical Machinery & Equip.	Other Non-durables	Textile Mill Products	Transportation Equipment[2]
c	7.123	−14.258	88.847	9.439	80.882	−1.517	−35.519	−141.047	31.056	3.241	17.941
	(0.028)	(−0.135)	(3.194)	(0.171)	(0.756)	(−0.018)	(−0.136)	(−0.558)	(2.125)	(0.086)	(0.324)
BL/E_{t-1}	−58.508	−0.042	−19.900	−20.751	−11.586	−11.700	−5.323	11.868	−8.326	−2.994	−2.800
Weight[1]	(−1.452)	(−0.006)	(−4.887)	(1.412)	(−1.327)	(−0.653)	(−0.398)	(0.738)	(−2.370)	(−1.128)	(−0.531)
0	0.066	0.046	0.103	0.080	0.051	0.024	0.105	0.090	0.102	0.123	0.083
	(7.266)	(5.720)	(9.018)	(10.906)	(3.403)	(1.493)	(5.142)	(3.879)	(4.954)	(5.057)	(2.031)
1	0.100	0.073	0.132	0.123	0.076	0.052	0.148	0.131	0.134	0.172	0.131
	(8.493)	(6.696)	(10.027)	(12.497)	(3.537)	(2.750)	(5.778)	(4.296)	(6.513)	(6.306)	(3.288)
2	0.112	0.087	0.152	0.138	0.083	0.079	0.148	0.140	0.129	0.173	0.151
	(10.621)	(8.197)	(11.761)	(15.156)	(3.677)	(5.437)	(6.689)	(4.772)	(8.790)	(7.281)	(6.896)
3	0.109	0.090	0.121	0.135	0.077	0.102	0.126	0.128	0.112	0.147	0.150
	(14.737)	(10.498)	(14.767)	(20.218)	(3.750)	(12.014)	(7.683)	(5.042)	(7.697)	(5.964)	(7.585)
4	0.096	0.086	0.096	0.118	0.064	0.116	0.096	0.106	0.099	0.111	0.135
	(20.891)	(13.104)	(14.210)	(30.145)	(3.563)	(15.398)	(7.420)	(4.582)	(5.984)	(3.927)	(4.217)
5	0.080	0.079	0.049	0.096	0.048	0.120	0.066	0.082	0.095	0.076	0.112
	(16.479)	(12.908)	(5.490)	(28.682)	(2.905)	(11.372)	(5.374)	(3.506)	(6.597)	(2.661)	(3.200)
6	0.064	0.070	0.011	0.072	0.033	0.114	0.046	0.061	0.099	0.050	0.084
	(10.001)	(10.100)	(1.040)	(14.708)	(1.999)	(10.004)	(3.566)	(2.525)	(7.921)	(1.934)	(2.901)
7	0.051	0.061	0.010	0.051	0.022	0.099	0.036	0.047	0.100	0.035	0.056
	(7.393)	(7.882)	(0.940)	(8.321)	(1.300)	(10.773)	(2.442)	(1.879)	(5.783)	(1.364)	(1.853)
8	0.043	0.053	0.001	0.034	0.016	0.077	0.038	0.042	0.076	0.027	0.031
	(7.191)	(6.583)	(1.715)	(5.534)	(0.986)	(11.395)	(1.851)	(1.492)	(4.219)	(0.950)	(0.739)
9	0.039	0.048	0.003	0.023	0.017	0.051	0.045	0.042		0.019	0.012
	(8.942)	(5.599)	(0.419)	(4.522)	(1.085)	(5.213)	(1.661)	(1.283)		(0.787)	(0.299)
10	0.040	0.044	0.023	0.019	0.024	0.025	0.050	0.046			
	(7.531)	(4.464)	(1.971)	(4.856)	(1.542)	(1.837)	(1.653)	(1.197)			
11	0.043	0.042	0.056	0.020	0.036	0.006	0.040	0.046			
	(4.873)	(3.401)	(2.950)	(4.328)	(2.000)	(0.495)	(1.705)	(1.184)			
12	0.046	0.041	0.086	0.025	0.052			0.034			
	(3.735)	(2.680)	(3.426)	(3.485)	(2.190)			(1.204)			
13	0.043	0.039	0.098	0.031	0.068						
	(3.242)	(2.253)	(3.727)	(3.190)	(2.243)						
14	0.030	0.033	0.076	0.032	0.082						
	(3.009)	(2.007)	(3.942)	(3.143)	(2.243)						
15		0.021		0.024	0.087						
		(1.865)		(3.188)	(2.247)						
16					0.080						
					(2.252)						
17					0.053						
					(2.260)						
Σ lag Coefs.	.971	.918	1.045	1.018	.976	.871	.948	.999	.951	.939	0.950
Mean Lag	5.498	6.179	5.251	4.863	8.653	5.033	3.936	4.441	3.700	2.918	3.424
RHO	.526	.53	.13	.13	.80	.25	.22	.61	.06	−0.15	.37
$\bar{R}^2$	.99	.96	.91	.98	.91	.97	.83	.84	.92	.74	.91
D.W.	1.49	1.97	2.01	2.03	1.49	1.72	1.83	1.78	1.95	2.03	1.89
S.E.	85.93	27.54	27.56	27.949	22.46	58.55	38.73	33.48	13.49	11.89	16.90

[1] Distributed-lag weights for quarters
[2] Excluding motor vehicles

Chart 2

"BEST" DISTRIBUTED LAGS OF ESTIMATES



estimated 90 percent of appropriations were spent by the seventh quarter in the early subperiod —but only 68 percent of appropriations were spent by the seventh quarter in the later subperiod, with 28 percent more being spent over the following seven quarters. The modal period—the period of greatest expenditures—is the third quarter in the early subperiod, but the distribution then becomes bi-modal in the later subperiod, with peak spending centered in the second and twelfth quarters. In contrast to the "Control" aggregate, the "Regulated" aggregate has its first spending peak in the later period centered to the left of the mode pertaining to the earlier sample period.

The increases in the order (Δn), the mean lag ($\Delta\Theta$), and the total percentage of expenditures delayed in the later subperiod ($\%E_D$) are presented in Table 3. The impact of pollution-control regulations is derived by comparing the values calculated for each of the "Regulated" industries with those calculated for the "Control" aggregate. The paper industry shows by far the largest percentage of delayed expenditures, followed by primary nonferrous metals, primary iron and steel, petroleum and chemicals.

All the industries in both groups experienced increases over time in the number of periods in their respective lag distributions. Because "Control" industries were subject to at least some pollution-control regulations, some portion of the increases in the number of periods in "Control"

Table 3
Estimated Total Changes in Θ, n, and $\%E_D$ Between Subperiods, and Portion of Change Due to Pollution Control Regulations

	Early Subperiod		Later Subperiod		Total Change		Total Share Delayed Expen.	Portion of Change Due to Pollution Control Regulations[1]		
	n	Θ	n	Θ	n	Θ	($\%E_D$)	Δn	$\Delta\Theta$	($\%E_D$)
"Regulated" aggregate	7	3.120	14	5.498	7	2.378	28.4	4	1.744	14.9
Primary iron and steel	8	4.403	15	6.179	7	1.776	26.8	4	1.142	13.3
Primary non-ferrous metals	9	3.768	14	5.251	5	1.483	33.9	2	0.849	20.4
Chemicals and allied products	7	3.012	15	4.863	8	1.851	20.8	5	1.217	7.3
Paper and allied products	9	4.402	17	8.653	8	4.251	48.2	5	3.617	34.7
Petroleum	6	2.435	11	5.033	5	2.598	25.8	2	1.964	12.3
"Control" aggregate	8	3.302	11	3.936	3	0.634	13.5			
Electrical machinery and equip.	10	3.265	12	4.441	2	1.176	8.0			
Other non-durables	5	2.515	8	3.700	3	1.185	27.5			
Textile mill products	6	2.740	9	2.918	3	0.178	8.1			
Transportation equip. (excluding motor vehicles)	6	1.853	9	3.424	5	1.571	29.5			

[1] Represents difference between "Regulated" group and "Control" aggregate.

group lag distributions can therefore be attributed to the direct and indirect effects of those regulations. We therefore hypothesized that (ceteris paribus) the higher ratio of an industry's anti-pollution spending to its total capital spending, the larger the increase over time in the number of periods in the lag distribution—and the higher the percentage of appropriations spent over protracted periods.

To test this hypothesis, we first compute the mean lag (δ) of the percentage of appropriations spent over protracted periods in the later (1967–76) subperiod, using the formula

$$\frac{\sum_i i\, w_i}{\sum_i w_i}.$$[23]

Next we derive the industry rankings for the mean lag (δ) and for the ratio of antipollution spending to total capital spending (Table 4). Our hypothesis is strongly supported by the Spearman rank correlation coefficient (rho), which is computed to be .75 and is significant at the 2.5-percent level.[24]

Table 4
Ranking of Industries According To (1) Anti-pollution Expenditures/Total Capital Expenditures and (2) Mean Lag (δ)

Industry	Anti-pollution Share of Total Capital Spending (%)[1]	Rank	Mean Lag (δ)	Rank
Primary iron and steel	13.1	3	3.604	3
Primary non-ferrous metals	18.3	2	3.437	4
Chemicals and allied products	9.0	5	4.543	2
Paper and allied products	20.0	1	5.062	1
Petroleum	9.4	4	2.078	6
Electrical machinery and equip.	3.2	8	1.425	9
Other non-durables	2.9	9	1.916	7
Textile mill products	5.5	6	1.802	8
Transportation equip. (excluding motor vehicles)	4.6	7	2.142	5

[1] Based on annual data from Appendix Table A1

IV. Summary and Conclusions

The basic hypothesis tested in this paper is that the investment process for industries which have incurred heavy anti-pollution expenditures has been prolonged, partly because of the permit process itself and partly because of the increased investment uncertainty engendered by both the unpredictability of future legislation and the case-by-case application of pollution controls. Parameters for a distributed-lag investment function incorporating capital appropriations and final expenditures were estimated for two groups of industries for the sample period 1953 I–1976 IV, which covers the periods before and after the implementation of pollution-control legislation. The first of the two groups is composed of five industries which accounted for more than 40 percent of all industrial anti-pollution spending over the past decade. Because of the probability that some portion of an observed increase in the appropriations/expenditures time lag is due to factors independent of pollution-control legislation, parameters were also estimated for a second group composed of four industries negligibly affected by pollution controls. Estimated parameters for both groups were tested to determine structural changes in our investment model between the subperiods. The evidence suggested that there is a change in estimated coefficient values between subperiods for both groups.

In order to estimate the impact of pollution-control standards on the time lag between capital appropriations and final expenditures, estimated changes for the minimally-affected group were used to adjust the estimated increases over time in the mean lag and in the number of periods between appropriations and expenditures for the five industries heavily affected by pollution-control standards. Empirical evidence indicates that, for the five heavily-affected industries, roughly 15 percent of appropriated expenditures were delayed over a period of four quarters due to uncertainty and the permit process. The paper industry experienced the most severe delays, with 34.7 percent of expenditures postponed over a period of five quarters, while petroleum suffered the smallest delays, with 12.3 percent of expenditures postponed over a period of two quarters. Empirical evidence also supports the hypothesis of a strong positive correlation between the a priori estimate of the degree of pollution-control impact on an industry, as indicated by the ratio of anti-pollution to total capital spending, and the actual percentages of expenditures delayed as a result of pollution-control standards.

Direct pecuniary costs of course are involved in satisfying government mandated regulations. But in addition, the lengthening of the time frame of investment spending because of pollution-control standards represents an important secondary cost on industry through its tendency to lower the rate of capital formation.

Table A1
Pollution Control Expenditures As Percentage of Total Capital Spending by Industry, 1970–76*

	1970	1971	1972	1973	1974	1975	1976	Average 1970–76
"Regulated" aggregate	7.7	12.2	14.5	15.1	13.7	16.8	15.5	14.0
Primary iron and steel	10.3	12.8	12.3	11.7	9.3	14.9	11.5	13.1
Primary non-ferrous metals	8.1	10.3	15.3	18.0	28.3	25.5	20.4	18.3
Chemicals and allied products	4.9	8.2	10.9	10.2	7.3	8.9	12.3	9.0
Paper and allied products	9.3	20.6	23.3	22.8	16.6	21.9	25.7	20.0
Petroleum	6.0	9.0	10.7	12.7	7.2	12.8	7.5	9.4
"Control" aggregate	3.8	3.2	3.1	3.7	4.1	4.5	6.1	4.1
Electrical machinery and equipment	2.3	2.3	2.8	3.7	2.3	4.2	4.8	3.2
Other non-durable goods	5.5	1.0	5.0	3.1	2.2	1.4	2.2	2.9
Textile mill products	2.3	3.3	2.6	3.5	5.4	8.9	12.6	5.5
Transportation equipment (excluding motor vehicles)	5.0	6.2	2.0	4.3	6.4	3.5	4.0	4.6
All surveyed industries	3.1	4.0	5.1	5.7	6.2	6.8	7.1	5.4

Table A2
Pollution Control Expenditures as Percentage Of Total Industrial Anti-Pollution Spending by Industry, 1967–76*

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Average 1967–76
"Regulated" Aggregate	43.2	43.7	45.7	38.6	43.0	36.3	36.5	33.5	48.4	43.9	40.9
Primary iron and steel	12.2	10.5	10.7	8.2	6.7	4.3	3.6	3.5	7.2	9.1	6.6
Primary non-ferrous metals	4.0	1.4	2.5	4.0	3.4	4.0	5.3	9.5	8.2	5.2	5.9
Chemicals and allied products	8.6	9.6	8.4	6.8	8.7	8.4	8.0	6.0	7.2	9.6	7.9
Paper and allied products	8.8	7.7	8.6	6.1	7.9	7.1	7.5	6.2	8.4	9.8	7.9
Petroleum	9.6	15.0	15.6	13.5	16.2	12.5	12.2	8.3	17.5	10.2	12.7
"Control" Aggregate	7.6	8.2	5.3	5.6	3.6	3.4	3.3	2.4	2.4	3.2	3.4
Electrical machinery and equipment	1.6	4.7	1.9	2.1	2.1	1.4	1.8	0.9	1.2	1.5	1.6
Other non-durable goods	0.5	0.9	0.9	0.6	0.5	0.1	0.1	0.2	0.1	0.1	0.3
Textile mill products	4.9	1.8	1.9	2.4	0.4	1.3	0.8	0.5	0.3	0.4	0.8
Transportation equipment (excluding motor vehicles)	0.6	0.8	0.6	0.5	0.6	0.4	0.4	0.7	0.8	1.2	0.7

* Calculations based on "Annual McGraw-Hill Survey of Pollution Control Expenditures," Economics Dept., McGraw-Hill Publications Co.

1. For description of the specific purposes and function of each law, see Murray L. Weidenbaum, **Government-Mandated Price Increases: A Neglected Aspect of Inflation** (Washington, D.C.: American Enterprise Institute for Policy Research, 1975).
2. "Plant and Equipment: Spending for Pollution Abatement To Increase 11 Percent This Year," **Daily Report for Executives,** May 24, 1977; "Regulators: A Rising Clamor Over Noise Limits," **Business Week,** June 30, 1975, p.34.
3. For examples see Leonall C. Anderson, "Is There a Capital Shortage: Theory and Recent Empirical Evidence," **Journal of Finance,** May 1976; Anne P. Carter, "Energy, Environment, and Economic Growth," **Bell Journal of Economic and Management Science,** Autumn 1974; John Cremeans and Frank W. Segel, "National Expenditures for Pollution Abatement and Control 1972," **Survey of Current Business,** February 1975; and Beatrice N. Vaccara, **A Survey of Fixed Capital Requirements of the Business Economy,** 1971-1980 (Washington: U.S. Department of Commerce, Bureau of Economic Analysis, 1975).
4. Gene Conatser (Economist for Bank of America) before the (California) Assembly Permanent Subcommittee on Employment and Economic Development, October 1977. Extract from Laura R. Mitchel, "A Barometer Reading Of California's Business Climate," **California Journal,** May 1977.
5. Calculated from data presented in Annual McGraw-Hill Survey of Pollution Control Expenditures. This 41-percent figure becomes 61 percent if the electric-utilities industry is included in the calculation. However, that industry could not be included because of non-comparability of data.
6. L. M. Koyck, **Distributed Lags and Investment Analysis** (Amsterdam: North Holland, 1954); F. deLeeuw, "The Demand for Capital Goods by Manufacturers: A Study of Quarterly Time Series," **Econometrica** (July 1962), pp. 407-23; T. Mayer, "The Inflexibility of Monetary Policy," **Review of Economics and Statistics** (November 1958), pp. 359-74; R. Eisner, "Investment: Fact and Fancy," **American Economic Review** (May 1963); P.W. Jorgenson and J.A. Stephenson, "Investment Behavior in U.S. Manufacturing, 1947-1960," **Econometrica** (April 1967).
7. B. G. Hickman, **Investment Demand and U.S. Growth** (Washington D.C.: Brookings Institution 1965), p. 33.
8. M. Cohen, "The National Industrial Conference Board Survey of Capital Appropriations," in **The Quality and Economic Significance of Anticipations Data,** Universities—National Bureau Conference 10 (Princeton: Princeton University Press, 1960).
9. For a description of the polynomial distributed-lag regression technique see S. Almon, "The Distributed Lag Between Capital Appropriations and Expenditures," **Econometrica** (January 1965), pp. 178-196. Recent evidence offered by P.J. Dhrymes and others suggests that the imposition of this assumption may cause biases in estimation. Comparison of the sums of squared residuals of an ordinary least-squares regression model against the sums of squared residuals for our polynomial distributed-lag regression indicates no evidence in support of the alternative hypothesis that estimated w_i should be unconstrained. (The results of our tests are presented in Footnote 20).
10. Previous studies (Almon, [9], and J. Popkin, "Comment on 'The Distributed Lag Between Capital Appropriations and Expenditures'," **Econometrica,** Vol. 34, No. 3.) incorporating a cancellations variable in regression equations conforming to the above specification, and also in variable lag specifications, found the variable to be statistically insignificant. This was probably due to the impossibility of determining to which periods' appropriations the cancellations apply. We therefore do not include a cancellations variable in our equation, with the result that the distributed lags will subtract the average cancellation in every quarter.
11. M. Cohen, **op. cit.,** p. 305.
12. M. Cohen, **op. cit.,** p. 305.
13. See Almon, **op. cit.,** p. 190.
14. M. Cohen, **op. cit.,** p. 306.
15. "Regulated" industries are chiefly engaged in primary and intermediate-stage processing, whose production facilities tend to be more energy intensive than the intermediate-and advanced-stage processing industries composing the "Control" group. Hence, the impact of the energy crisis on investment spending could be greater for the "Regulated" group than for the "Control" group. To test this possibility, a dummy variable with a value equal to one during the period 1973I-1976IV and zero elsewhere was included in the two aggregate regressions estimated over the sample period 1953I-1976IV. Although the sign of the dummy variable was negative, as expected, the estimated coefficient was insignificantly different from zero at the 95 percent confidence level. That the dummy variable was statistically insignificant for both the "Regulated" and "Control" aggregates indicates that the backlogs variable effectively adjusted expenditures for the impact of the energy crisis.
16. S. Almon, **op. cit.,** pp. 187-189 and J. Popkin, **op. cit.,** pp. 720-721.
17. McGraw-Hill, **op. cit.**
18. For the period 1967-73, the percentage of capacity shutdowns due to environmental and safety regulations was 0.51 percent for our "Regulated" group, 0.13 percent for our "Control" group, and 0.35 percent for the twenty industries contained in the particular McGraw-Hill survey. (Calculations based on "Annual McGraw-Hill Survey of Pollution Control Expenditures," **op. cit.)**
19. "The choice of an appropriate specification for a distributed lag function. . . is a multiple decision problem of great complexity. No formal statistical procedure is available for such a problem, so that the choice must be made on some basis other than testing of a statistical hypothesis." Jorgenson and Stephenson, **op. cit.**
20. A comparison of the sums of squared residuals of an ordinary least-squares regression model against the sums of squared residuals from our 4th degree polynomial distributed-lag regression yields

$F^{5}_{63} = 1.62$, F^{5}_{63} – critical = 2.36 for the "Regulated" aggregate, and $F^{4}_{64} = 1.58$, F^{4}_{64} – critical = 2.51 for the "Control" aggregate.

Thus, there is no evidence for rejecting our null-hypothesis that the w_i are polynomially distributed. (For a description of this F-test see P. J. Dhrymes, **op. cit.** p. 227-229.)
21. The appropriate test statistics is defined by

$$F[Z, T_1 + T_2 - 2Z] = \frac{SSR_T-(SSR_1 + SSR_2) / Z}{(SSR_1 + SSR_2) / T_1+T_2 - 2Z},$$

where T_1 and T_2 are the sum of observations in the early and later subsamples, SSR_T is the sum of observations in the early and later subsamples, SSR_1 and SSR_2 are the sums of squared residuals in the early and later subsamples, and Z is the number of independent variables. For an explanation of this test statistic see F. M. Fisher, "Tests of Equality Between Sets of Coefficients in Two Linear Regressions: An Expository Note," **Econometrica** (March 1970), pp. 361-366. Since three-parameter distributions are estimated by fourth-degree polynomials, the number of independent variables associated with the regression term $\sum_{i=o}^{n} w_i A_{t-i}$ remains constant at 3 regardless of the value of n.

22. The mean lag (Θ) is defined as:

$$\Theta = \frac{\sum_{i=o}^{n} (i+1) \cdot w_i}{\sum_{i=o}^{n} w_i}$$

23. The mean lag (δ) of the percentage of appropriations spent is calculated at 3.912 for the "Regulated" group aggregate and 1.963 for the "Control" group aggregate.

24. A concomitant test of independence, using the alternative hypothesis of positive correlation between the two sets of rankings, is significant at the two-percent level. For a description of these tests, see E. Lehman, **Nonparametrics; Statistical Methods Based on Ranks.** (San Francisco: Holden-Day Inc., 1975), pp. 297-303.

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