Environmental Compliance and U.S. Industrial Productivity

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Table 1 - Sample Industries

Chemical and Allied Products (CAP)	Electronic and Electrical Equipment (EEE)
Fabricated Metals Products (FMP)	Industrial Machinery and Equipment (IME)
Paper and Allied Products (PAP)	Primary Metals Products (PMP)
Petroleum and Coal Products (PCP)	Rubber and Plastics Products (RPP)
Stone and Glass Products (SGP)	Transportation Equipment Products (TEP)

- Environmental Regulation and Compliance

Table-2

Impact of Environmental Regulation on Selected 2-Digit Industries (1974-1991)

Industry	***Total Quantities of Air Pollutants Removed* (short tons)**	***PACE,* as Percentage of Total *a* Capital Expenditures**	**Polluting Fossil fuel Consumption as Percentage of Total Energy Costs**
Regulatory Impact:			
High:			
Petroleum and Coal Products (*PCI*)	14,156,654.6	11.8%	70%
Primary Metal Industries (*PMI*)	11,427,527.3	10.4	43
Stone and Glass Products (*SGI*)	16,239,718.18	5.3	64
Paper and Allied Products (*PPI*)	5,719,754.6	5.5	59
Chemical and Allied Products (*CPI*)	7,861,972.7	4.3	56
Medium:			
Transportation Equip. Industries(*TPI*)	390,745.5	1.5	31
Fabricated Metals Products (*FPI*)	212,372.7	1.4	36
Rubber and Plastic Products (*RPI*)	179,572.7	1.04	29
Low:			
Electronic and Electrical Equip. (*EEI*)	262,709.1	0.89	24
Machinery and Equipments (*MEI*)	292,363.6	0.77	33
Ten Industry Averages	5,674,339.1	4.31	45

Specific criteria air pollutants abated include SO_x, NO_x, *CO*, *PM*, and others.
Source: U.S Department of Commerce (various years).

Table-3
Costs and Quantities of Air Pollution Abatement For Selected Industries (1974-1991)

Year	**Quantity of Air Pollution Removed (*QAPR*) (short tons)**	**(*GAC*) Gross Anual Annual Costs of Pollution Abatement (1982 dollars)**	**Policy Variable (*E=GAC/QAPR)***
1974	5,402,310	$205,345,828	108.1
1975	5,658,387	$232,688,387	125.5
1976	5,825,370	$278,151,025	122.5
1977	5,603,200	$318207,720	146.7
1978	5,843,050	$332,036,343	127.1
1979	5,976,580	$367,603,562	146.8
1980	5,621,730	$358,540,922	159.1
1981	-----------	$377,964,612	155.6
1985	-----------	$372,608,913	202.3
1988	-----------	$346,356,556	227.4
1991	-----------	$345,976,755	240.3
Ten-Industry Average	5,674,339.1	$321,407,329	160.1

Source: U. S. Department of Commerce, Various years.

Figure1.

Trends in overall industrial air pollution Abatement (1974-80).

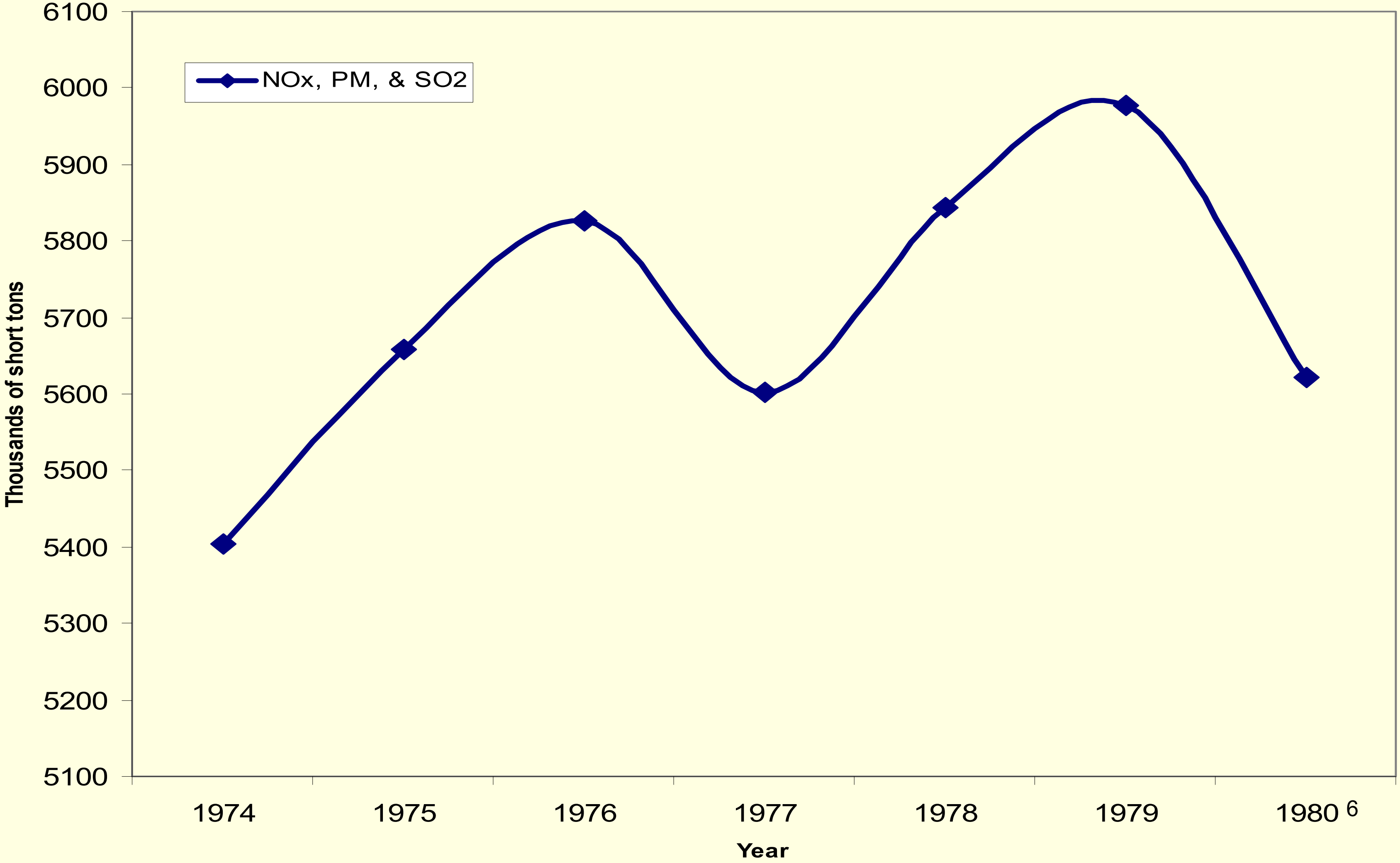


Figure 2.

Quantities of specific air pollutants abated by selected industry groups (1974-80).

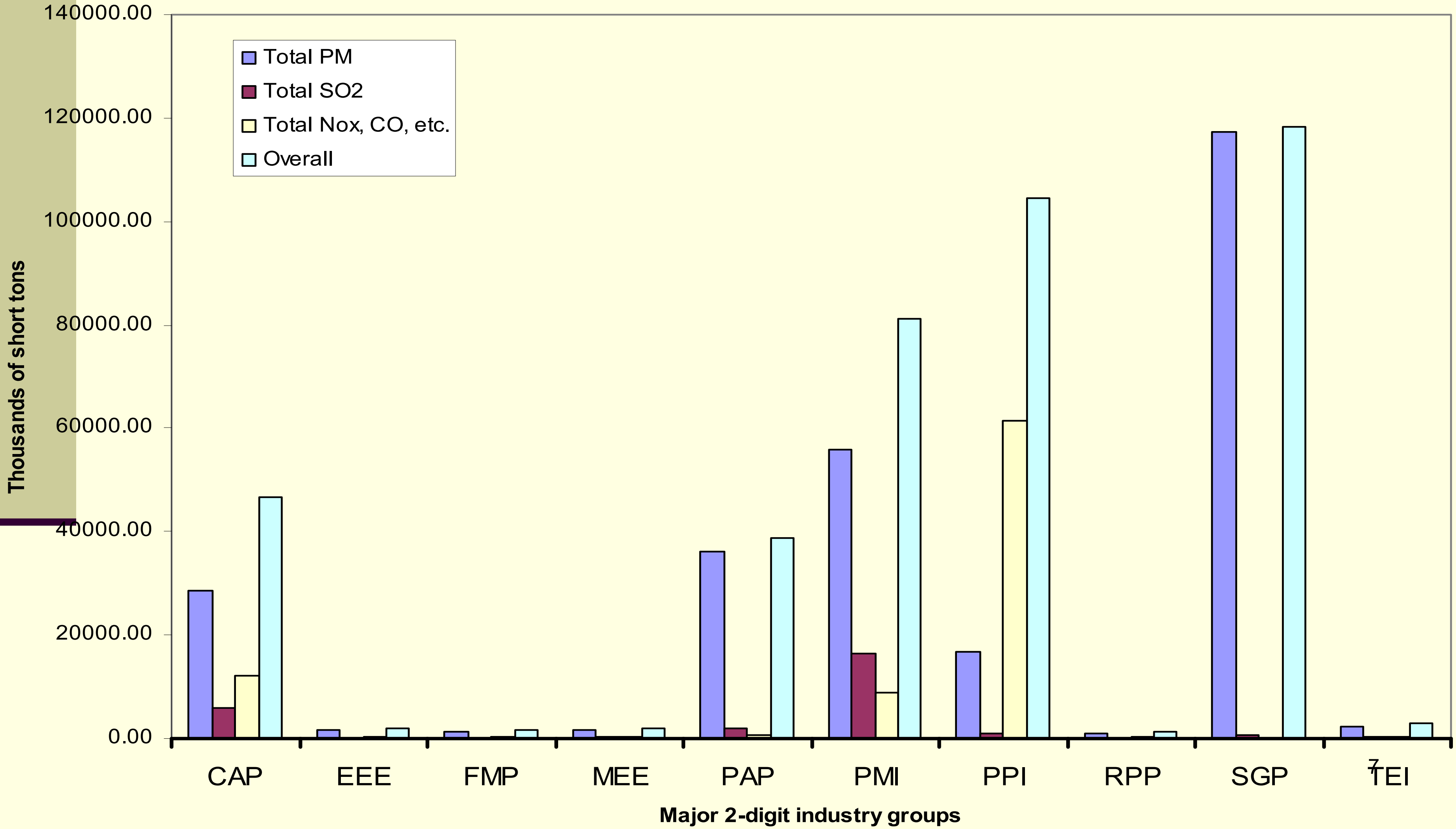
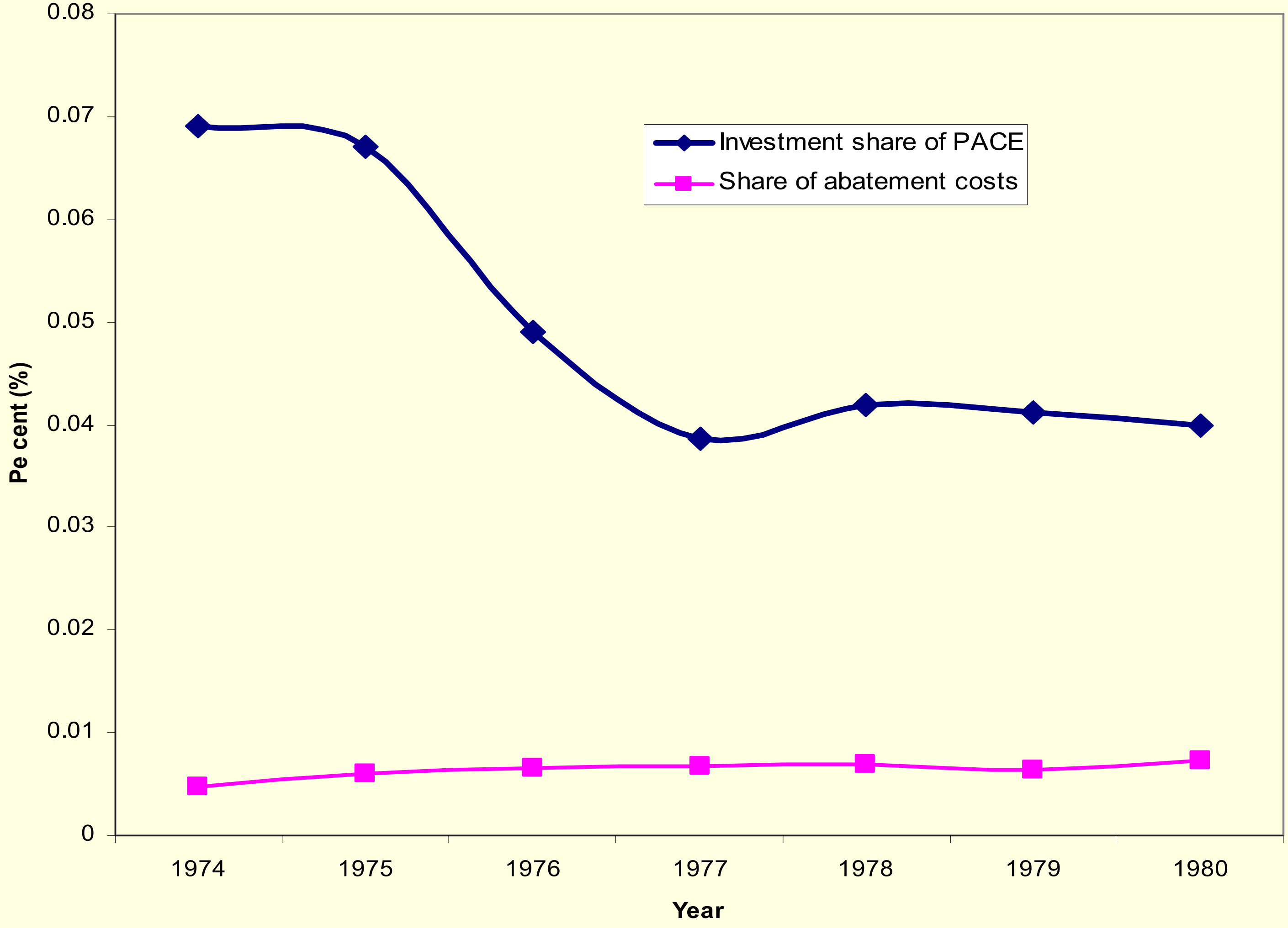


Figure 3.
Trends in average shares of abatement expenditures-U.S. Manufacturing



The Econometric Model

- A Dual Approach with Abatement Costs

The Model

- $TC = f\,[P_k, P_{pw}, P_{npw}, P_e\,(P_1, P_2, \ldots, P_5), R, Q, T]$ **(1)**

We use the Divisia Index of productivity growth as developed by Gollop and Jorgenson (1980):

- $D_{PG} = -(d\log TC/dT - d\log Q/dT) + \sum S_i\, d(\log Pi)/dT$ **(2)**

- Differentiating Eq. (1) we obtain:

  - $d \log TC / d T = \sum \log TC / \partial \log P_i \, (d \log P_i / d T) +$
  - $\partial \log TC / \partial \log R \, (\mathrm{d} \log R / \mathrm{d} T) +$
  - $\partial \log TC / \partial \log Q \, (d \log \mathrm{Q} / d T) +$
  - $\partial \log \mathrm{TC} / \partial \mathrm{T}$ **(3)**

  - Where according to Shephard lemma,

- $\partial \log TC / \partial \log P_i = \mathbf{S}_i$ **(4)**
- Where S_i is the associated factor shares
- and, where the second RH partial derivative measures the impact of mandatory compliance on production costs, namely:
- $\partial \log TC / \partial \log R = \boldsymbol{E}_r$ ***(5)***
- the third logarithmic partial differentiation represents the elasticity of total cost wrt output, namely
- $\partial \log TC / \partial \log Q = \boldsymbol{E}_q$ ***(6)***

Finally, the last term on the right measures the partial elasticity of total cost wrt technology, or the rate of technological change. This rate is equal to the negative of the rate of growth of total cost with respect to time, given output and input prices, namely:

$$-\partial \log TC / \partial T = \mathbf{E}_t \qquad \mathbf{(7)}$$

Substituting (3) into (2), and by rearranging terms we obtain the Divisia index of productivity growth:

$$\mathbf{D}_{pg} = -\mathbf{E}_r (d R / d T) + (1 - \mathbf{E}q) \, d \log Q / d T + \mathbf{E}_t \qquad \mathbf{(8)}$$

A Trans-log Cost Model (9)

$$\log TC = \alpha_0 + \alpha_i \sum_i \log P_i + \frac{1}{2} \sum_i \sum_j \alpha_{ij} \log P_i \ln P_j +$$

$$\beta_q \log Q + \frac{1}{2} \beta_{qq} (\log Q)^2 + \sum_i \beta_{qi} \log Q \ln P_i$$

$$+ \gamma_r \log R + \frac{1}{2} \gamma_{rr} (\log R)^2 + \sum_i \gamma_{ri} \ln R \log P_i +$$

$$\gamma_{rq} \log R \log Q + \tau_t T + \frac{1}{2} \tau_{tt} (T)^2 + \sum_i \tau_{ti} T \log P_i +$$

$$\tau_{tq} T \log Q + \tau_{tr} T \log R$$

Restriction of Linear Homogeneity (10)

$$\sum_i \alpha_i = 1$$

$$\sum_i \alpha_{ij} = \sum_j \alpha_{ij} = \sum_i \sum_j \alpha_{ij} = 0$$

$$\alpha_{ij} = \alpha_{ji}$$

$$\sum_i \beta_{qi} = 0$$

$$\sum_i \gamma_{ri} = 0$$

$$\sum_i \tau_{ti} = 0$$

Input Cost Shares (11)

$$\frac{\partial \log TC}{\partial \log P_i} = \alpha_i + \sum_j \alpha_{ij} \ln P_j +$$

$$\sum_i \beta_{qi} \log Q$$

$$+ \sum_i \gamma_{ri} \ln R +$$

$$\tau_{ti} T + +$$

$$= S_i$$

Compliance Cost Effect (12)

$$\frac{\partial \log TC}{\partial \log R} = \gamma_r + \gamma_{rr} (\log R) + \sum_i \gamma_{ri} \log P_i + \gamma_{rq} \log Q + \tau_{tr} T = E_r$$

Compliance Cost Input Bias (13)

$$\frac{\partial S_i}{\partial \log R} = \gamma_{ri}$$

Technology Cost Effect (14)

$$\frac{\partial \log TC}{\partial T} = \tau_t T + \tau_{tt} T + \sum_i \tau_{ti} \log P_i + \tau_{tq} \log Q + \tau_{tr} \log R = -E_t$$

Technology Input Bias (15)

$$\frac{\partial S_i}{\partial T} = \tau_{ti}$$

Table-4. IZEF estimates of parameters of the trans-log cost model with syestem of inter-related shares.

variable	coefficient	estimates	variable	coefficient	estimates
$logP_k$ α_K	-0.2903[a]	logRlogpk	γ rk	-0.0089	
$logP_P$ α_p	{0.4633}[c]	logpm	αm	0.5141[a]	
$logP_e$	αe	0.3129[a]	$(logQ)^2$	βqq	-0.4340[b]
$(logpP)^2$	α_{pp}	{-0.0245}	logpPlogQ	βPq	{-0.1665}
$(logpm)^2$	α_{mm}	0.0682	logpMlogQ	βmq	0.0208
$(logpe^2$	α_{ee}	0.07523[a]	logpelogQ	βeq	-0.0739[a]
$(logpK)^2$	α_{kk}	0.0056	logRlogQ	βrq	-0.1879
$logpelogP_m$	αem	-.0454[a]	logpklogQ	βkq	0.2196[a]
$LogpelogP_P$	αep	{-0.0028}[b]	*T*	τt	2.1689
$logpelogP_k$	γ_k	-0.0149c	$(T)^2$	τtt	-4.6197
$logpPlogP_m$	αpm	{-0.0093}	logpP(*T*)	τtP	{-0.2438} [b]
$logpPlogP_k$	γ_{PK}	{0.3651} [a]	logpm(*T*)	τtm	0.0382[a]
$logpklogP_m$	γek	-0.0271[a]	logpe (*T*)	τte	-0.0374[a]
logR	γr	-7.645[a]	logpk(*T*)	τtk	0.4230[a]
$(logR)^2$	γ_{rr}	-0.1667	logR(*T*)	τtr	7.6032
logpPlogR	γ_{Pr}	{-0.0460}[b]	logQ(T)	τtq	31.0591[a]
logpmlogR	γ_{mr}	0.0223b	logpelogR	γer	0.0327[a]
Summary Statistics:		R^2	Durbin-Watson		
Cost Model		0.85		1.82	
CS_m		0.94		1.74	
CS_e		0.94		1.59	
CS_k		0.90		1.46	
System Likelihood Value			1279.29		

Note: (a) (b) (c): Parameter significant at (5%)/(1%)/(10%) respectively.
(d): standard error of estimates in parenthesis.
(h): p=production worker; m=non-production worker; k=capital; e=energy.
{} = indicates parameter was obtained from equality/symmetry restrictions.

Table-4. Estimated average rates of partial effects of Env. Compliance, Technology, and Scale on cost-U.S. manufacturing (1974-91).

Biasing effects	Coefficient	Estimates
Env. Compliance	(E_r)	-0.0859[a]
Technology	$(-E_t)$	0.3961
Scale	(E_q)	0.6037[a]

Table-5. Estimated rates of factor share bias of technology and environmental compliance cost.

Factors	Env. Compliance	Technology	Scale effect
Capital	-0.00089	0.423	0.219[a]
Energy	0.0327[a]	-0.0374[a]	-0.0739[a]
Prod. Worker	-0.0461[b]	0.244[b]	-0.0166
Non-prod. Worker	0.0223[b]	0.0328[a]	0.0208

Table-6. Estimated productivity growth components-U.S. manufacturing (1974-91).

Productivity Effects	Coefficient	Estimates
Productivity Growth	(D_{pG})	-0.39514[a]
Env. Compliance	(- E_r)	0.000447
Technology	(E_t)	-0.3961
Scale	(1- E_q)	0.000509