Environmental Regulation and Productivity Growth: An Analysis of U.S. Manufacturing Industries

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Abstract

We show that traditional measures of productivity change that ignore the unproductive nature of pollution abatement capital within the production process are likely to underestimate the true productivity gains that most manufacturing industries are able to generate in any given year. While the average bias of traditional measures is not large in absolute terms, the bias can be substantial for industries with relatively large pollution abatement capital expenditures. We also find that environmental regulation has a non-trivial adverse effect on productivity change, lowering productivity growth by roughly 0.3% across all industries, and by more than 1% for some industries.

JEL Codes: D24, L51, Q00

Keywords: Productivity Change, Pollution Abatement Capital Expenditure, Capital Adjustment Bias, Environmental Regulation Bias, U.S. Manufacturing Industries

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I. INTRODUCTION

One of the economic indicators closely watched by the Federal Reserve, policymakers on Capital Hill, stock market investors, as well as a large media contingent is the monthly report on U.S. productivity growth. While high levels of productivity growth are generally seen as benign, low levels or a "slowdown" in productivity change are interpreted as warning signals about the health of the economy, evoking fears of rising inflation, declining growth, and a loss in international competitiveness. Not surprisingly, given its importance among key economic indicators, productivity change has assumed a central role as a research topic among academic economists. Two issues have dominated the literature on productivity growth. First, how is productivity growth best measured?[1] Second, what factors cause productivity to change, or are at least significantly correlated with productivity growth?[2]

While most papers on productivity growth concentrate on either measuring or explaining changes in productivity, some studies, such as Conrad and Morrison (1989), deal with both issues. The novel insight of the Conrad and Morrison paper is the treatment of pollution abatement capital (or PA capital for short) as a costly, but unproductive input in the production process. Specifically, the authors divide the total capital stock into "typical," productive capital and PS capital, recognizing that the two capital types have different implications for productivity growth. This departure from the traditional view (which fails to distinguish between the different capital types) leads to a theoretical formulation of productivity change that enables one to

[1] See Nadhiri (1970) for an early survey of the literature. Other, more recent articles on this topic include Maddison (1987) and Bernard and Jones (1996), among others.

[2] The literature on the determinants of productivity change is enormous. For an early survey, see Nelson (1981). The slowdown in U.S. productivity growth during the 1970s and 1980s has been researched extensively. For an overview, see the 1988, volume 2(4) edition of the *Journal of Economic Perspectives*, which contains a number of articles on the topic. More recent studies on the productivity slowdown include Hulten (1992) and Wolf (1996), among many others.

identify the bias associated with traditional measures of productivity growth. The bias, referred to as capital aggregation or CA bias from here on, measures the difference between the true level of productivity growth and its level according to a more traditional measure based on the aggregate capital stock.

Once their improved measure of productivity change has been established, Conrad and Morrison modify it to estimate a second "bias," referred to as the environmental regulation or ER bias hereafter. The ER bias captures the difference between true productivity growth (as measured by Conrad and Morrison's measure) and the growth rate that would exist if all environmental regulations were eliminated.[3]

In this paper, we revisit the theoretical approach presented by Conrad and Morrison and apply it to an industry-level panel data, comprised of U.S. manufacturing industries over the period 1984 - 1993. Compared to the study by Conrad and Morrison, who apply their theory to country-level data from the United States, Canada, and Germany, our approach has several advantages. First, defining the unit of observation at the industry-level should improve data quality and, consequently, inference, as data quality usually declines with the level of aggregation. Second, observing a cross-section of industries over time allows one to test whether the most heavily regulated industries – those with the highest share of pollution abatement capital expenditure – exhibit the largest bias, as predicted by theory. With a country-level data set that includes only a handful of countries, a cross-section comparison yields few new insights due to the small cross-section dimension of the sample. In addition, the fact that environmental

[3] The second "bias" is not a bias in the traditional sense of the measurement literature. Rather, it is a measure of the impact that a particular policy (here environmental regulation) has on productivity change. However, in order to avoid confusion with the terminology used in Conrad and Morrison, we will refer to this impact measure as "bias."

regulation differs across countries is also problematic. Third, we perform a number of sensitivity tests to provide evidence on the robustness of our results.

The main findings of this paper are as follows. First, we find both cross-section and time-series evidence for the existence of a positive capital aggregation bias. A positive CA bias implies that the traditional measure *underestimates* true productivity growth. Second, we also find cross-section and time-series evidence for a negative environmental regulation bias. A negative ER bias implies that environmental regulation had an adverse effect on productivity growth. Both biases increase in absolute value with the pollution abatement intensity of the industry. Thus, as one would expect a priori, the biases are of greater magnitude in industries with relatively high pollution abatement expenditure. Third, we find that the results are robust to alternative measures of the capital stock, different depreciation rates, and differences in price deflators.

The paper is organized as follows. In section 2 we introduce the theoretical model and derive the specifications for both types of biases. We describe the data set in section 3. Section 4 contains the empirical results, while we discuss the results of the sensitivity analysis in section 5. Section 6 concludes.

II. Theoretical Model

Our theoretical model is a simplified version of Conrad and Morrison (1989). The representative firm maximizes profits through the optimal choice of output, x, labor input, L, and investment in productive capital, I, and non-productive pollution abatement capital, IPA, subject to equations of motion for productive capital, K, pollution abatement capital, KPA, an emission production function, and an emission constraint imposed by the government. The firm's intertemporal maximization problem can thus be stated as:

$$\text{Max } \Sigma e^{-rt}\{p_{xt}x_t - G(x_t, K_t, w_t) - p_{I_t}(I_t + IPA_t)\} \tag{1}$$

subject to

$$K_{t+1} = K_t + I_t - \delta \cdot K_t \tag{1a}$$

$$KPA_{t+1} = KPA_t + IPA_t - \delta \cdot KPA_t \tag{1b}$$

$$TE_t = \xi \cdot x_t \tag{1c}$$

$$\overline{NE}_t - f(KPA_t) \cdot TE_t \geq 0. \tag{1d}$$

where p_{x_t} denotes the output price, *G(·)* denotes the variable cost function, w_t denotes the unit cost of labor, p_{I_t} denotes the common price of both types of investment goods, δ is the fixed depreciation rate for productive and abatement capital, and ξ is a parameter that represents the constant relationship between the level of production and the level of pollutant emissions. The total level of (unrestricted) emissions is denoted by TE_t. Note that *KPA* is not included in the cost function since it is not productive.[4] In contrast to *K*, *KPA* is not in the production function and thus not in its dual, the variable cost function. *KPA* does affect overall cost, but as a fixed cost, not as a variable cost. Reducing emissions requires additional investment in PA capital, captured by the function *f(KPA)*. The function *f(KPA)* exhibits diminishing returns, *f'* < 0, *f''*>0, as the marginal productivity of emission reduction falls with each additional unit of installed abatement capital.

[4] Whenever possible without causing confusion, time subscripts are omitted.

Incorporating conditions (1c) and (1d) into the objective function, the constrained optimization problem of the firm may be written as:

$$\text{Max } \Sigma e^{-rt}\{p_{xt}x_t - G(x_t, K_t, w_t) - p_{It}(I_t + IPA_t)\} - \bar{\tau}[f(KPA_t)\cdot \xi x_t - \overline{NE}_t] \tag{2}$$

subject to (1a) and (1b).

The first-order optimality conditions for this problem are:

$$p - \tau f(KPA)\xi = G_x \tag{3a}$$

$$q_K = -G_K \tag{3b}$$

$$q_K = -\tau f\,'(KPA)\xi x = 0 \tag{3c}$$

where $\tau = \bar{\tau}\cdot(1+r)^t$ is the current shadow value of non-abated emissions, and q_K is the rental price of both productive and PA capital.

Eqs. (3a-c) can be rewritten to facilitate the definition of the homogeneity properties the cost functions:

$$p_x x / G - \tau f(KPA)\xi x / G = p_x x / G - \tau NE / G = \partial \ln G / \partial \ln x, \tag{5a}$$

$$-q_K K / G = \partial \ln G / \partial \ln K, \tag{5b}$$

$$q_K KPA / G = -\tau f\,'(KPA) KPA \xi x / G = \tau NE / G\,, \tag{5c}$$

where the last equality in (5c) requires that *f(KPA)* is homogeneous of degree (-1). While this assumption is not necessary for our analysis, we impose it as a useful simplification.

The expressions in (5) are useful in two ways. First, they allow one to motivate the definition of the total cost function *C*. Second, they can be employed to define the homogeneity properties of both *C* and *G*. Homogeneity of degree one in output of G implies that $\partial \ln G / \partial \ln x + \partial \ln G / \partial \ln K = 1$. From (5), this implies that $p_x x / B - \tau NE / G - q_K L / G = 1$.

Rewriting this equality yields $p_x x = G + \tau NE + q_K K$, which, using (5c) is equivalent to $p_x x = G + q_K KPA + q_K K$, the firm's total costs, *C*. In addition to variable costs, the firm incurs a capital cost for the use of productive capital as well as for the use of pollution abatement capital.

The specification of the above cost function can be used to derive a cost-side measure of productivity growth, $\partial \ln C / \partial \ln t$, similar to traditional accounting productivity measures but adjusted for the fact that *KPA* is not a productive input. This adjusted productivity growth measure can be written as[5]:

$$\varepsilon_C' = -\partial \ln C / \partial \ln t = [(p_x x - q_K KPA)/C]\dot{x}/x - (wL/C)\dot{L}/L - (q_K K/C)\dot{K}/K. \tag{6}$$

Since productivity change leads to a reduction in cost, $\partial \ln C / \partial \ln t < 0$, which implies that ε_C' is a positive number. Eq. (6) differs from the traditional productivity measure in two ways: (i) the *KPA* component has been removed from the capital stock, and (ii) the effect of pollution abatement has been purged from the output value measure. Thus, the traditional productivity measure can be written as the sum of the correct measure (6) and a bias term composed of the two adjustments mentioned above:

$$\begin{aligned}
\varepsilon_C &= -\partial \ln C' / \partial \ln t = (p_x x/C)\dot{x}/x - (wL/C)\dot{L}/L - (q_K(K + KPA)/C)(\dot{K} + K\dot{P}A)/(K + KPA) \\
&= [(p_x x - q_K KPA)/C]\dot{x}/x - (wL/C)\dot{L}/L - (q_K K/C)\dot{K}/K \\
&\quad - q_K (KPA/C)[(K\dot{P}A/KPA) - (\dot{x}/x)] \\
&= \varepsilon_C' - b_1,
\end{aligned} \tag{7}$$

[5] For a proof, see the Appendix in Conrad and Morrison (1989).

where b_1 is the CA bias, and distinguishes the true measure (6) from the traditional productivity growth measure (7).

The sign of b_1 is ambiguous and depends on the relative size of changes between PA capital spending and changes in output. A positive value of b_1 implies that the true measure is greater than the traditional measure. In this case, the traditional measure *underestimates* the true change in productivity. Such a situation will arise when pollution abatement growth exceeds output growth, as is to be expected in years when regulation is initially put into place or increases suddenly.

The second bias we are interested in measures the impact of environmental regulation, as manifested by investments in PA capital, on productivity growth. To derive the environmental regulation bias, we use the true productivity measure (7) but then impose the counterfactual condition that no regulation exists, i.e. $KPA = 0$. In addition, the computation of K must be adapted since the return to capital in (6) depends on the existence of pollution abatement capital. Without regulation, the ex-post rate of return to capital is higher, which in turn implies that the price of capital paid by the firm is higher as well. We thus multiply the last term in (6) by a factor *1 + KPA/K*. The new productivity growth measure that corresponds to the case of no regulation is thus defined as:

$$\bar{\varepsilon}_C = -\partial \ln C'' / \partial \ln t = (p_x x)\dot{x}/x - (wL/C)\dot{L}/L - q_K(1+KPA/K)(K/C)\dot{K}/K$$

$$= [(p_x x - q_K KPA)/C]\dot{x}/x - (wL/C)\dot{L}/L - (q_K K/C)\dot{K}/K$$

$$- q_K(KPA/C)[(\dot{K}/K) - (\dot{x}/x)]$$

$$= \varepsilon_C' - b_2, \tag{8}$$

where b_2 is the ER bias, and distinguishes the correct measure in the presence of regulation (6) from the correct measure of productivity growth measure in the absence of regulation (8).

As with the CA bias, the sign of the ER bias term is ambiguous as well and depends on the change in productive capital spending relative to the change in output. A negative value of b_2 implies that productivity growth without regulation, $\bar{\varepsilon}_C$, is higher than productivity growth in the presence of regulation, ε_C'. Such a situation will arise when output growth exceeds growth of productive capital, as is to be expected in years (or industries) with high levels of regulation.

III. Data

Annual data on PA capital expenditures, *IPA*, are taken from the Census Bureau's Pollution Abatement Costs and Expenditures.[6] Since the data for 1987 are not available, we estimate the missing values using an extrapolation method.[7] Three-digit SIC level data on value-added, *x*, and total new capital expenditures, *IPA* + *I*, are taken from the Annual Survey of Manufactures.[8] However, data on the actual stocks of capital are unavailable, and therefore must be constructed as in many studies of this nature.

We construct stocks of productive and pollution abatement capital, *K* and *KPA*, respectively, from their corresponding flow variables utilizing two different methods. First, we follow Acemoglu and Zilibotti (2001) (A-Z from here on) and construct the estimated capital

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[6] U.S. Department of Commerce, Bureau of the Census, "Pollution Abatement Costs and Expenditures," Current Industrial Reports MA200, Washington, D.C., GPO, various years.

[7] See Jaffe and Palmer (1997) for a similar procedure.

[8] U.S. Department of Commerce, Bureau of the Census, "Annual Survey of Manufactures", Washington, D.C., GPO, various years.

stock for industry i at time t, K_{it}^{e}, as the ratio of the weighted average investment flow at time t, $\hat{I}_{it}^{T}$ and the time-invariant depreciation rate, d (i.e. $K_{it}^{e} = \hat{I}_{it}^{T} / d$). Letting T denote the first year that investment data are available, the weighted average investment flow is defined as:

$$\hat{I}_{it}^{T} = \frac{\sum_{s=T_i}^{t} (1-d)^{t-s} I_{is}}{\sum_{s=T_i}^{t} (1-d)^{t-s}}.$$

As an alternative measure, we construct a starting value for total capital using the stylized fact that the value of the capital stock is approximately three times the value of output. Once the initial value of the total capital stock has been determined, we use the perpetual inventory method to derive the changes in the stock of capital over time. We then use the fraction of I and IPA in total investment in order to decompose the total capital stock into its two parts, K and KPA. Both methods of constructing the two capital stock data are based on the assumption of an annual depreciation rate of 8%, as in A-Z.

Annual data on the output price index, p_x, the price index for investment, p_I, the size of the labor force, L, as well as wages, w, are taken from the NBER-CES Manufacturing Database (Bertelsman and Gray, 1996). The price of capital, q_K, is calculated from the zero profit condition as the ex-post price of the total capital stock, including both productive and pollution abatement capital. Four-digit SIC level data have been aggregated to the three-digit SIC level, weighted by value-added, if necessary.

IV. Empirical Results

Table 1a contains three different productivity indexes for each manufacturing industry in our sample: the first index is computed using the traditional method (7); the second index using the correct (*KPA*-adjusted) definition (6); and, the third index using the *KPA*-adjusted definition but with the zero regulation conditions imposed (8). In addition, Table 1a contains two bias terms for each industry: the capital aggregation (CA) bias, which we use to rank the industries in the table, and the environmental regulation (ER) bias. The indexes and bias terms in Table 1a are based on the A-Z method of estimating the capital stock and a depreciation rate of 8%. In addition, we have applied a uniform deflator to all nominal variables.

Table 1a shows that the CA bias is positive for most industries. Therefore, the traditional productivity measure (6) *underestimates* the true productivity gains for almost all industries. For the few industries for which the reverse is true, the magnitude by which the traditional measure overestimates productivity growth is minimal, except for one industry - primary nonferrous metals (SIC 333). Overall, the magnitude of the CA bias is fairly small for most industries. Close to 60% of all industries exhibit a CA bias of one tenth of one percent or less (in absolute terms), and only 9 industries have a CA bias that exceeds half a percentage point (in absolute terms).

More important then the magnitude of the bias, however, is that most of the industries with a strong CA bias are heavy investors in pollution abatement equipment, exactly as one would expect from our theoretical model. This can be seen by a comparison of the ranking of industries by CA bias in Table 1a with the ranking of industries by PA intensity (defined as the fraction of *IPA* in total investment) in Table 3. The correlation between the ranking of these two measures is very high, with a correlation coefficient of approximately 0.6 that is statistically significant at the 1% level.

In terms of the ER bias, the bias is negative in all cases except petroleum refining (SIC 291). Thus, environmental regulation lowers productivity growth, even in industries that are not particularly PA-intensive. The mean loss in productivity because of environmental regulation across all industries is roughly 0.3%, with some industries losing 1% or more. On average, the productivity loss is more substantial for industries that are PA-intensive; the correlation coefficient is -0.4 and statistically significant at the 1% level.

Using the alternative capital stock measure (based on the rule-of-thumb method) does not change the results in a qualitative sense (see Table 1b). As before, PA-intensive industries are more likely to exhibit high values of the CA bias, with a significant correlation coefficient of roughly 0.4. The ER bias is negative for most industries and increases, in absolute terms, with an industry's PA-intensity (the correlation coefficient is approximately -0.5 and significant at the 1% level).

A few differences do emerge, however. Overall, the results based on the rule-of-thumb method are smaller in magnitude, with a mean true productivity growth rate (6) of 2.7% for all industries, compared to a value of 8.3% in the previous table. Similarly, the mean bias terms for CA and ER bias are now roughly 0.0% and -0.1%, respectively, compared 0.2% and -0.3% in Table 1a.

Table 2a presents the annual productivity measures, pooled across industries. The time-series results for the A-Z capital measure are presented in Table 2a. Similar to the cross-section evidence, we find time-series evidence for the existence of both CA and ER bias. The CA bias is positive except for 2 years, 1987 and 1988, both years of higher than average productivity growth. In these years, the impact of strongly increasing output growth overwhelms the small changes in *KPA*. As noted by Conrad and Morrison, when output growth is strong, lowering the valuation of output to its marginal cost has a large impact relative to the increase in pollution abatement capital. In the first half of our sample, from 1984 - 1988, the average CA bias is close zero as a result of the two outliers, while the CA bias is positive, as most researchers would expect, in each of the remaining years. From 1989 - 1993, the traditional measure of productivity growth underestimates the correct value by roughly 0.4% per year. In particular, the CA bias is largest in magnitude in 1991, underestimating productivity by nearly 1%. Interestingly, average mean PA-intensity across all industries was highest in 1991, more than 20% higher than any other year.

The ER bias is negative in both sub-periods, as expected. However, the absolute value of the regulation bias is declining over time. This is surprising since PA capital expenditures by all manufacturing industries (SIC codes 20 - 39) increased from 2.9% of new capital expenditure in 1984 to 7.0% in 1993 (see Nandy and Osang, 2000). Thus, while firms increased their relative expenditure on pollution abatement equipment between 1984 and 1993, the adverse impact of these investments on productivity growth diminished over time. One explanation for this result may be that early pollution abatement investments were easier to identify for firms since they often involved retrofitting existing plants, typically with end-of-pipe abatement technologies. Over time, as abatement technologies became an integral part of new technologies, the distinction between regular and pollution abatement capital spending became increasingly difficult and arbitrary for most firms, leading to abatement data that are noisier than in the earlier years.

As Table 2b reveals, there are no qualitative differences in the time-series evidence when the alternative, rule-of-thumb capital measure is used. As before, the main difference from Table 2a lies in the reduced absolute value of all three indexes and the two bias terms.

V. Sensitivity Results

To test the robustness of the previous results, we perform two sets of sensitivity tests.[9] First, we re-estimate Tables 1 and 2 for different depreciation rates (d = 5% and d = 10%). While raising or lowering depreciation rates alters the absolute values of the indexes, there is no change to the results in a qualitative sense. Second, we abandon the assumption of a uniform deflator for all nominal variables, using instead variable-specific deflators when available. In particular, we use the shipment deflator for value-added and total labor cost and the investment deflator for both productive and PA capital. Using specific deflators causes only minor changes in the results. In effect, both cross-section and time-series results are nearly identical to our findings reported in Tables 1 and 2. For example, with variable-specific deflators, the average CA bias across all years and industries is 0.2%, while the average ER bias is -0.27%. With a uniform deflator, the corresponding numbers are 0.2% and -0.29% (see Table 1a).

VI. Summary and Conclusion

In this paper, we have shown that environmental regulation - requiring firms to invest in unproductive pollution abatement equipment – creates a challenge for researchers as far as the correct measurement of productivity growth is concerned. Unless properly adjusted, traditional measures of productivity change are likely to *underestimate* the true productivity gains that most industries are able to generate in any given year. While the average bias of traditional measures is not large in absolute terms, it is nonetheless important to know that the true change in productivity is slightly higher than official statistics indicate. This is particularly true in years when low (unadjusted) productivity growth rates lead to widespread pessimism about the overall health of the economy.

With regard to the overall impact of environmental regulation, we find that, for almost all industries and for most years, the existence of such regulation leads to a non-trivial reduction in productivity growth. Knowledge about the impact of environmental regulation on productivity growth, both in terms of the sign of the change and its magnitude, is important and should play a role in the public debate about cost and benefits of stricter environmental standards.

[9] All results that pertain to this section are available upon request.

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Table 1a: Productivity Growth Indexes, CA and ER Bias: Cross-Section Analysis

	Productivity			Biases	
SIC	Traditional	KPA-adj.	KPA=0	CA bias	ER bias
291	4.27%	6.07%	5.76%	1.80%	0.31%
261	2.51%	3.46%	3.83%	0.95%	-0.36%
281	4.93%	5.78%	6.69%	0.85%	-0.91%
203	10.37%	11.10%	11.53%	0.74%	-0.43%
311	4.24%	4.95%	5.21%	0.71%	-0.26%
341	1.48%	2.12%	2.32%	0.63%	-0.20%
262	3.70%	4.29%	4.52%	0.59%	-0.23%
286	6.53%	7.07%	7.58%	0.54%	-0.51%
282	6.10%	6.55%	6.97%	0.45%	-0.42%
324	4.05%	4.46%	4.82%	0.41%	-0.36%
287	5.55%	5.96%	6.62%	0.41%	-0.66%
386	18.22%	18.50%	18.80%	0.28%	-0.30%
364	8.81%	9.02%	9.24%	0.21%	-0.22%
331	5.87%	6.08%	6.27%	0.21%	-0.19%
284	13.10%	13.30%	13.70%	0.19%	-0.41%
343	8.29%	8.47%	8.70%	0.18%	-0.23%
299	9.34%	9.52%	10.09%	0.18%	-0.57%
295	10.38%	10.55%	10.78%	0.17%	-0.23%
322	9.10%	9.25%	9.52%	0.15%	-0.26%
205	12.38%	12.49%	12.61%	0.10%	-0.12%
342	6.47%	6.56%	6.78%	0.09%	-0.22%
332	2.82%	2.90%	3.12%	0.08%	-0.22%
283	12.01%	12.09%	12.52%	0.07%	-0.43%
201	7.50%	7.56%	7.81%	0.06%	-0.25%
206	11.77%	11.83%	12.11%	0.05%	-0.29%
251	6.25%	6.30%	6.50%	0.05%	-0.19%
355	7.90%	7.94%	7.98%	0.04%	-0.04%
371	7.58%	7.62%	7.86%	0.04%	-0.23%
289	7.53%	7.57%	7.98%	0.04%	-0.41%
352	9.54%	9.57%	9.79%	0.03%	-0.22%
243	7.66%	7.68%	7.87%	0.02%	-0.19%
207	11.51%	11.53%	12.12%	0.02%	-0.59%
345	5.58%	5.60%	5.72%	0.02%	-0.12%
221	5.64%	5.66%	5.86%	0.02%	-0.19%
275	7.27%	7.28%	7.41%	0.02%	-0.13%
351	8.80%	8.82%	8.91%	0.02%	-0.09%
242	10.25%	10.26%	10.50%	0.01%	-0.24%
346	6.21%	6.21%	6.28%	0.01%	-0.06%
349	7.10%	7.11%	7.29%	0.01%	-0.18%
335	9.61%	9.61%	9.91%	0.00%	-0.30%
225	7.91%	7.91%	8.01%	0.00%	-0.10%
344	7.30%	7.29%	7.40%	-0.01%	-0.11%
265	7.09%	7.08%	7.19%	-0.01%	-0.11%
204	15.91%	15.89%	16.28%	-0.01%	-0.39%
367	8.35%	8.33%	8.48%	-0.02%	-0.15%
208	16.05%	16.01%	16.38%	-0.04%	-0.38%
285	11.30%	11.20%	11.75%	-0.10%	-0.55%
333	8.89%	8.05%	9.12%	-0.85%	-1.08%
Mean:	8.15%	8.34%	8.64%	0.20%	-0.29%

Note: A-Z capital stock measure, d=8%, uniform price deflator,
Industries ranked by CA bias.

Table 1b: Productivity Growth Indexes, CA and ER Bias: Cross-Section Analysis

	Productivity			Biases	
SIC	Traditional	KPA-adj.	KPA=0	CA bias	ER bias
291	2.68%	4.08%	3.91%	1.40%	0.17%
261	3.32%	3.86%	4.08%	0.54%	-0.21%
262	0.44%	0.64%	0.61%	0.20%	0.03%
286	5.22%	5.29%	5.47%	0.07%	-0.17%
282	2.68%	2.74%	2.82%	0.06%	-0.08%
203	2.21%	2.26%	2.31%	0.05%	-0.05%
324	1.25%	1.28%	1.31%	0.03%	-0.04%
341	-0.89%	-0.88%	-0.87%	0.01%	-0.01%
322	3.21%	3.22%	3.23%	0.01%	-0.01%
331	3.83%	3.84%	3.85%	0.01%	-0.02%
205	3.09%	3.09%	3.10%	0.00%	-0.01%
355	0.74%	0.73%	0.74%	0.00%	0.00%
364	1.43%	1.43%	1.44%	0.00%	-0.01%
346	0.49%	0.49%	0.50%	0.00%	0.00%
343	1.63%	1.63%	1.64%	0.00%	-0.01%
344	0.85%	0.84%	0.85%	0.00%	0.00%
295	2.57%	2.56%	2.58%	0.00%	-0.02%
351	2.56%	2.56%	2.56%	0.00%	0.00%
345	-0.09%	-0.10%	-0.09%	0.00%	0.00%
275	0.79%	0.78%	0.79%	0.00%	-0.01%
265	0.46%	0.46%	0.46%	-0.01%	-0.01%
225	2.34%	2.33%	2.34%	-0.01%	-0.01%
386	9.77%	9.77%	9.79%	-0.01%	-0.02%
251	1.34%	1.34%	1.35%	-0.01%	-0.01%
367	2.11%	2.10%	2.11%	-0.01%	-0.01%
349	1.20%	1.19%	1.20%	-0.01%	-0.01%
221	1.33%	1.32%	1.33%	-0.01%	-0.01%
352	2.03%	2.02%	2.03%	-0.01%	-0.01%
342	1.59%	1.58%	1.59%	-0.01%	-0.01%
243	2.31%	2.30%	2.31%	-0.01%	-0.01%
242	4.31%	4.29%	4.31%	-0.01%	-0.02%
332	0.92%	0.91%	0.93%	-0.02%	-0.02%
201	1.52%	1.50%	1.52%	-0.02%	-0.02%
206	2.84%	2.82%	2.85%	-0.02%	-0.03%
335	3.78%	3.76%	3.78%	-0.02%	-0.02%
371	3.20%	3.17%	3.20%	-0.02%	-0.02%
208	5.59%	5.56%	5.59%	-0.03%	-0.04%
284	3.46%	3.43%	3.48%	-0.04%	-0.06%
299	3.62%	3.58%	3.65%	-0.04%	-0.07%
285	2.60%	2.56%	2.60%	-0.04%	-0.04%
289	1.96%	1.92%	1.97%	-0.04%	-0.05%
311	3.18%	3.14%	3.23%	-0.04%	-0.09%
207	4.79%	4.74%	4.80%	-0.05%	-0.06%
204	5.09%	5.04%	5.10%	-0.05%	-0.06%
283	5.08%	5.00%	5.12%	-0.07%	-0.12%
287	4.08%	3.99%	4.24%	-0.10%	-0.26%
281	2.84%	2.74%	2.94%	-0.10%	-0.20%
333	8.48%	8.02%	8.49%	-0.46%	-0.48%
Mean:	2.58%	2.62%	2.65%	0.03%	-0.04%

Note: "Rule of thumb" capital stock measure, d=8%, uniform price deflator,
Industries ranked by CA bias.

Table 2a: Productivity Growth Indexes, CA and ER Bias: Time-Series Analysis

	Productivity			Biases	
Year	Traditional	KPA-adj.	KPA=0	CA bias	ER bias
1985	7.26%	7.63%	8.00%	0.36%	-0.38%
1986	14.41%	14.60%	15.10%	0.19%	-0.50%
1987	18.09%	17.82%	18.70%	-0.27%	-0.88%
1988	13.30%	12.94%	13.61%	-0.36%	-0.67%
1989	0.77%	0.96%	0.86%	0.19%	0.09%
1990	5.47%	5.86%	5.99%	0.39%	-0.13%
1991	1.87%	2.82%	2.75%	0.95%	0.07%
1992	4.98%	5.16%	5.26%	0.17%	-0.10%
1993	7.16%	7.31%	7.44%	0.15%	-0.13%
1984-88	13.26%	13.24%	13.85%	-0.02%	-0.61%
1989-93	4.05%	4.42%	4.46%	0.37%	-0.04%
1984-93	8.15%	8.34%	8.64%	0.20%	-0.29%

Note: A-Z capital stock measure, d=8%, uniform price deflator

Table 2b: Productivity Growth Indexes, CA and ER Bias: Time-Series Analysis

	Productivity			Biases	
Year	Traditional	KPA-adj.	KPA=0	CA bias	ER bias
1985	-2.01%	-2.01%	-2.00%	0.00%	-0.01%
1986	4.52%	4.51%	4.53%	-0.02%	-0.03%
1987	10.91%	10.79%	10.93%	-0.12%	-0.15%
1988	7.28%	7.06%	7.33%	-0.21%	-0.27%
1989	-0.39%	-0.39%	-0.32%	0.01%	-0.07%
1990	0.73%	0.82%	0.81%	0.09%	0.01%
1991	-2.52%	-2.29%	-2.38%	0.23%	0.09%
1992	2.54%	2.68%	2.69%	0.14%	-0.01%
1993	3.29%	3.38%	3.38%	0.10%	0.00%
1984-88	5.17%	5.09%	5.20%	-0.09%	-0.11%
1989-93	0.73%	0.84%	0.83%	0.11%	0.01%
1984-93	2.70%	2.73%	2.77%	0.02%	-0.05%

Note: "Rule of thumb" capital stock measure, d=8%, uniform price deflator

Table 3: Ranking of Industries by PA Intensity
time averages

SIC	PA-Intens.
291	0.2276
281	0.1861
333	0.1798
311	0.1636
261	0.1630
287	0.1559
286	0.1444
324	0.1353
262	0.1056
332	0.0946
282	0.0876
331	0.0741
299	0.0708
341	0.0594
289	0.0592
285	0.0505
207	0.0502
283	0.0437
342	0.0408
371	0.0404
203	0.0397
335	0.0392
284	0.0372
295	0.0346
201	0.0346
386	0.0344
251	0.0340
322	0.0324
242	0.0306
243	0.0297
221	0.0288
204	0.0280
343	0.0273
208	0.0268
364	0.0248
206	0.0235
349	0.0230
352	0.0225
345	0.0202
367	0.0180
275	0.0169
344	0.0153
265	0.0151
225	0.0132
205	0.0102
346	0.0095
351	0.0088
355	0.0055

Note: PA-intensity = IPA/(I+IPA)