The Effect of Environmental Regulation on the Productivity of Korean Steel Industry*

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I. Introduction

Since the 1960s, economic development has been a top priority in Korea. Whereas, little attention was given to environment up to recent

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years. Environmental problems are now emerging as one of growing concerns in Korea. As economy has developed and stand of living has risen, demand for better and cleaner environment is increasing as well. Damages to environment, once considered a symbol of economic growth, are now regarded as one of factors threatening nation's economic growth.

In the meantime, the steel industry has been a fastest growing industry since the late 1960s, being a great contributor to the nation's economic development. The Korean Government lent a full support for this steel industry and demand from domestic side was high until recently. The production of steel requires large amount of capital investments and energy while generating a significant level of pollutants. This industry now confronts both external and internal problems: Decreasing domestic demand, weakening international competitiveness, and stiffer environmental restrictions are being combined to make the Korean steel industry increasingly difficult.  

There are two conflicting results on the effects of environmental regulations on productivity of polluting industries. Numerous empirical studies including Denison (1989), Conrad & Morrison (1989), Gray (1983), Christensen & Haveman (1981), Gray & Shadbegian (1993), Gollop (1983), and Barbera & McConnell (1990) suggest that environmental regulations will reduce productivity growth in industry. Even though much of this empirical evidence shows the negative effect of environmental regulations on the industry, other studies have sustained the different view that the regulation may improve productivity by improving efficiency and

1) The steel industry has produced a significant amount of waste matter such as steel slag, mill-scale, particle, and sludge. However, the rate of waste matter recycling is increasing faster than its production.
innovation. However, a limited number of studies support this view. Porter (1990), Tobey (1990), and Jaffe et al. (1993) in the U.S. and You & Yang (1994), Jung & Choi (1994), and Kwon (1986) in Korea suggest that there is a possibility that some regulation could improve productivity growth by stimulating innovation and efficiency of production.

Environmental regulations are often cited as a partial explanation for the slowdown in the growth of productivity as experienced in most industrialized countries. And productivity growth in the Korean steel industry has also been slow. Therefore, the purpose of this study is to examine if environmental regulation is a factor of productivity slowdown.2)

II. Model

In this study, we adopt used translog TFP model to estimate the impact of environmental regulation on productivity growth in the Korean steel industry for the period 1967–1996.

The translog model is designed to examine the impact of abatement requirements on the cost in industry and TFP growth in the Korean steel industry. To calculate the effect of abatement requirements, a translog cost function for production of the manufactured output is used. The industry is assumed to minimize cost subject to the chosen output, a vector of input prices, and abatement capital. The model is decomposed to evaluate growth in TFP into technology (its effect on the shifts of the

2) Kang (1996), Kim & Hong (1992), and Lee (1992) show that the steel industry has experienced a productivity slowdown.
production function and the cost function), and direct and indirect effects.\(^3\) Capital is separated into productive and abatement capital.\(^4\) To examine the pollution abatement effect, twofold effects of required abatement capital on TFP are separated into direct and indirect effects of abatement requirements: Direct cost refers to the abatement capital cost imposed on the steel industry as total cost is likely to be higher for the same level of steel production; Indirect cost is related to the abatement capital due to changes in the combination of input to produce steel. The direct effect is always negative; However, the indirect effect may be positive or negative.

If we assume that \(Q\) represents the homogeneous output of firms and \(B\) represents pollution, then the transformation function for a two-output (\(Q\) and \(B\)), four-inputs (\(K, L, E\) and \(M\)), and technology is

\[
D(Q, B, K, L, E, M, t) = 0
\]

where \(K, L, E, M\) and \(t\) represent productive capital, labor, energy, and non-energy materials, and time (technology), respectively. As environmental regulations are imposed by government, firms should

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\(^3\) The direct abatement effect reduces TFP as long as abatement capital costs are increasing. The indirect effect of abatement requirements can either increase or decrease TFP depending on how these requirements affect the production process for output, therefore, the total effect can be either positive or negative depending on the magnitude of the changes.

\(^4\) We define productive capital as capital used to produce conventional output such as steel. Abatement capital is used to reduce pollution. Abatement capital costs (\(AC\)) always decrease productivity growth since that impose a direct cost on production. However, abatement capital (\(AK\)) could increase or decrease productivity growth depending on how abatement capital affects the production process for output.
comply with them and get to employ facilities to reduce pollution. If pollution is considered as a function of abatement capital \((AK)\), then:

\[
B = B(AK, K, L, E, M, t)
\]  

(2)

From equations (1) and (2), following production function for \(Q\) can be derived:

\[
Q = Q(AK, K, L, M, E, t)
\]  

(3)

where inputs are used to produce \(Q\) or to reduce pollution associated with abatement capital.

Under the assumption that industry minimize production costs \((C)\) subject to an exogenous level of production, input prices, abatement capital and technology, there is a restricted cost function. The cost function can be written as follows:

\[
C = C(Q, P_i, AK, t)
\]  

(4)

where \(AK\) is defined as abatement capital which is measured in quantity. \(AK\) is included to examine indirect abatement effects by changing the input combination used to produce output.

In equation (5), the total costs \((C^{**})\) of producing output, \(Q\) are indirect cost plus direct cost of the abatement capital, \(P_{AK} \cdot AK\), which we call \(AC\), where \(P_{AK}\) is the price of abatement capital, \(AK\) is abatement capital, and \(AC\) is cost of abatement capital. \(AC\) as a cost of production is included to examine direct abatement effects. By including
pollution abatement capital cost and capital we are able to examine direct
and indirect environmental effects on productivity side:

\[ C^{**} = C(Q, P_i, AK, t) + AC \]  

(5)

We differentiate equation (5) and divide by \( t \) to obtain an explanation
which decomposes the change over time in total cost into its source
components to calculate the effect of environmental requirements on TFP,

\[
\frac{dC^{**}}{dt} = \sum \frac{\partial C}{\partial P_i} \frac{dP_i}{dt} + \frac{\partial C}{\partial Q} \frac{dQ}{dt} \\
+ \frac{\partial C}{\partial AK} \frac{dAK}{dt} + \frac{\partial C}{\partial t} + \frac{dAC}{dt}
\]  

(6)

In equation (6), total cost is decomposed into five effects: factor price
change, output change, the indirect effect of abatement on the cost
function, technical change, and the direct abatement cost. If we divide
equation (6) by total costs, \( C^{**} \), which consists of the abatement cost,
and apply Shepard's Lemma, we obtain an expression for the growth in
total costs,

\[
\frac{d\ln C^{**}}{dt} = S_C \left( \sum S_i \frac{\ln P_i}{dt} + E_{cq} \frac{\ln Q}{dt} \\
+ E_{cak} \frac{\ln AK}{dt} + \frac{\partial \ln C}{\partial t} \right) + S_{AC} \frac{\ln AC}{dt}
\]  

(7)

Where:
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\[
S_C = \frac{C}{C^{**}}
\]

\[
S_{AC} = \frac{AC}{C^{**}}
\]

\[
S_i = \frac{X_i P_i}{C}, \quad i = K, L, E, M
\]

\[
E_{CAK} = \frac{\partial \ln C}{\partial \ln AK}
\]

\[
E_{CQ} = \frac{\partial \ln C}{\partial \ln Q}
\]

TFP is defined as:

\[
TFP = - \frac{d \ln C^{**}}{dt} + \sum S_i \frac{d \ln P_i}{dt} + \frac{d \ln Q}{dt} \tag{8}
\]

By using this definition of TFP and the assumption of CRS \((E_{CQ} = 1)\), we join equation (7) and (8) which yields:\(^5\)

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\(^5\) Barbera & McConnell (1990) point out that an assumption of CRS is necessary in the translog cost function to estimate the cost function by using an industry data set. Because, in order to relax the CRS assumption, we need a more abundant data set than the annual industry data set. Without the assumption of CRS, the cost function, it is difficult to satisfy the concavity and monotonicity conditions that marginal production should always be stable. And they find out that most of manufacturing industries are CRS. Kim & Hong (1992) also point out that an assumption of CRS in the translog function is necessary, because, in general, it is difficult to obtain reasonable results from the translog function. To obtain a satisfaction results, the translog function should satisfy the monotonicity condition. To do this, all of \(r_o\) should be zero \((\sum r_o = \sum r_y = 0)\). And if we accept CRS assumption, the translog function can be simplified (since \(E_{CQ} = \frac{\partial \ln C}{\partial \ln Q} = 1)\).
\[ TFP = \left( - S_C \frac{\partial \ln C}{\partial t} \right) - \left( S_C E_{CAK} \frac{d \ln AK}{dt} \right) \]
\[ - \left( S_{AC} \frac{d \ln AC}{dt} \right) + S_{AC} \left( \sum_i S_i \frac{d \ln P_i}{dt} + \frac{d \ln Q}{dt} \right) \] (9)

Equation (9) demonstrates that TFP can be decomposed into three major components: the shift in \( C \) because of technical change \( S_C \frac{\partial \ln C}{\partial t} \), the shift in \( C \) because of abatement capital purchase, or the indirect abatement effect \( S_C E_{CAK} \frac{d \ln AK}{dt} \), and the increase in the direct cost of abatement requirements per unit of conventional output (or the direct abatement effect, \( S_{AC} \frac{d \ln AC}{dt} \)). Other components are price and scale terms.

In order to decompose TFP, structural information about the production process is required. This information can be obtained from estimating the cost function for the Korean steel industry. Elasticities can also be estimated from the cost function.

To estimate the necessary values, a four-input translog variable cost function with constant returns to scale is used. Using equation (4), a cost function can be approximated by the second-order translog cost function.

\[ \ln C = \beta_0 + \sum_i \beta_i \ln P_i + 0.5 \sum_i \sum_j \tau_{ij} \ln P_i \ln P_j + \beta_i t \]
\[ + 0.5 \tau_{tt} t^2 + \beta_{AK} \ln AK + 0.5 \tau_{AKAK} \ln AK^2 \]
\[ + \tau_{AKt} \ln AK t + \theta_Q \ln Q \]
\[ + \sum_i \tau_{iAK} \ln P_i \ln AK + \sum_i \tau_{it} \ln P_i t \]

where \( I = (K, L, E, M) \).
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To estimate equation (10) requires additional information. Firstly, to calculate (10) alone would cause a degree of freedom problem. Annual industry data is available from 1967 through 1996 for the steel industry (we have 29 parameters with 30 observations). Secondly, if we calculate (10) alone, it is not obvious that the resulting parameter estimates would be based on a cost function which satisfies convexity and monotonicity conditions. Both of these problems can be resolved by calculating jointly with the cost function (10), the factor share equations (11).

We can get factor shares by the partial derivatives at the cost function (10) with respect to the factor prices.

\[ S_i = \beta_i + \sum r_q \ln P_i + \tau_{iAK} \ln AK + \tau_{it}t, \]

where \( I, j = K, L, E, M \)

(11)

To ensure linear homogeneity in factor prices in the cost function, the following restrictions are required.

6) The system of cost-share equations is assumed to have no contemporaneous cross equation correlation in the vector of error terms \( (e_1, e_2, \ldots, e_n) \) for all \( t \). The cost share equations can be obtained from Shephard's lemma as \( S_i = \frac{\partial \ln C}{\partial \ln P_i} \). The fact that \( \sum S_i = 1 \) implies the constraints \( \sum \beta = 1, \sum r_q = 0, \) and \( \sum r_n = 0 \). The second-order approximation property of the function implies the additional constraints \( r_q = r_n \). As a result, the matrix of \( r_q \)'s in cost function is equivalent to the Hessian of the Taylor series expansion of the true cost function. Thus, this matrix must be symmetric or \( r_q = r_n \).

7) The definition of linear homogeneity (if \( \frac{\partial \ln C}{\partial \ln Q} = K, \) a constant, then the structure of production is homogeneous) is that proportional rise in prices should not change composition of cost minimize bundle, or cost must rise by exactly fraction of price increase. Some restrictions require linear homogeneity in factor prices in the cost function such as \( \sum \beta = 1, \sum r_q = \sum r_o = 0, \sum r_n = 0 \)(Christensen et al., 1973).

The parameters \( (r_q) \) are related to variable elasticities of substitution and of factor...
\[ \sum_i \beta_i = 1, \quad \sum_i \tau_{ii} = \sum_i \tau_{ii} = 0, \quad \sum_i \tau_{iAK} = \sum_i \tau_{i} = 0 \quad (12) \]

The system of equations consisting of the cost function (10) and four cost share equations (11) can be estimated as a simultaneous system. The change in \( C \), attributable to technical change is found by taking the partial derivative of (10) with respect to \( t \). Technical change can be calculated after the parameters of the cost function are estimated.

\[ \frac{\partial \ln C}{\partial t} = \beta_t + \tau_{At} + \tau_{AKt} \ln AK + \sum \tau_{it} \ln P_i \quad (13) \]

In order to separate the abatement effects from the technical change effects, we need an estimate of the cost abatement elasticity \( (E_{CAK}) \). The cost abatement elasticity \( E_{CAK} \) is obtained from the parametric estimates of the model in the cost function. We can obtain \( E_{CAK} \) by partial derivation of (10) with respect to \( \ln AK \).

\[ \frac{\partial \ln C}{\partial \ln AK} = \beta_{AK} + \tau_{AKAK} \ln AK + \sum \tau_{AKi} \ln P_i + \tau_{AKt} \quad (14) \]

To estimate TFP, we can directly calculate some components of TFP by using available data such as direct abatement effect, price, and scale demand. The first constraint is related to cost shares \( (\sum_i \beta_i = 1) \) which should sum up to one. The second constraint is related to the linear homogeneity in factor prices in the cost function. The coefficients in the cost share equations should have symmetry specification \( \tau_{ij} = \tau_{ji} \) (symmetry condition). The third constraints show the technical interaction among the inputs such as capital, labor, energy, and materials and non-neutral technical change \( (\sum r_a = 0) \).
terms. However, the components of indirect abatement effects and technical change cannot be calculated by available data. To estimate these components, we need to estimate equation (10) and equation (11) together with respect to the constraints in (12) employing an iterative version of Zellner's seemingly unrelated regression technique.8)

After estimating the cost function and deriving the expression for \( E_{CAK} \) and \( \frac{\partial \ln C}{\partial t} \), we plug these components into equation (9), we get TFP with all the components.

III. Data

The basic data used for this study is from the Report on Mining and Manufacturing Survey, publication of the Economic Planning Board and the Steel Statistical Yearbook compiled by the Korean Iron and Steel Association. The annual data covers 1967 through 1996. All price and

8) The system can be estimated by Zellner's (1962) seemingly unrelated regression technique. In this procedure regression coefficients in all equations are estimated simultaneously by applying Aitken's Generalized Least-Squares (GLS) to the whole system of equations. The feature of the application of using this technique is that the independent variables of different equations are not highly correlated. To avoid serial correlation of this translog cost function, we use Zellner's technique to estimate the cost function because the error terms across share equations are correlated.

In our model, restrictions across equations \( (r_o = r_p) \) are imposed. This implies the following parameter restrictions: \( \sum_j \beta = 1, \sum_j r_{v} = \sum_j r_o = 0, \sum_j r_{u} = 0 \) OLS estimators are no longer efficient despite the fact that all equations constrain the same explanatory variables on the right-hand side. Thus, the seemingly unrelated regression is applied.
cost data are in the current Korean Won (Korean currency). To convert the data into a constant value for the TFP analysis, the wholesale price index of the Bank of Korea with the base year 1990 was employed.

To obtain output \( (Q) \), we used gross output from the Report on Mining and Manufacturing Survey. To make comparisons, output data from the Kim & Hong (1992) was taken into account. Capital cost \( (KC) \) data is from the Report on Mining and Manufacturing Survey and Steel Statistical Yearbook.\(^9\) Price of capital \( (P_K) \) is from the Bank of Korea. To make a reliable data set, we referred to those of capital stocks in Kim & Hong (1992) and Pyo (1992). The abatement capital cost is estimated by using abatement capital stock \( (AK) \).\(^{10}\) The abatement investment data set of the Steel Statistical Yearbook is used to estimate \( AK \).\(^{11}\)

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\(^9\) Capital cost \( (KC) \) can be estimated by multiplying the price of capital \( (P_K) \) and the capital stock \( (K) \) \( KC = P_K \cdot K \), see Barbera & McConnell, 1990; Kwon, 1986, and Kim & Hong, 1992). The data of capital cost is directly available from the Report on Mining & Manufacturing Survey. The data of price of capital is also directly available from the Bank of Korea.

\(^{10}\) See Conrad & Morrison (1989) and Barbera & McConnell (1986, 1990). Conrad and Morrison separate pollution abatement cost \( (AC) \) from total capital cost \( (TKC) \). Barbera and McConnell separate pollution abatement capital \( (AK) \) from total capital stock \( (TK) \) by use of abatement capital expenditures. We assume that a unit of productive capital and pollution abatement capital cost and price are the same. Based on this assumption, we separate pollution abatement cost from total capital cost by use of abatement capital stock.

\(^{11}\) Abatement cost \( (AC) \) can be calculated by multiplying the price of capital \( (P_K) \) and the abatement capital \( (AK) \) \( AC = P_K \cdot AK \). To calculate the abatement capital stock, we assumed that the rate of depreciation is 10 percent since most of the average span of furnace life and environmental facilities are 10 years, the environmental equipment usually install when the new furnace is installed or the old furnace changes.
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Information on employment, working hours, and wages are taken directly from the Report on Mining and Manufacturing Survey and Steel Statistical Yearbook. The price of labor is the implicit price derived by dividing the quantity of labor into the total employee expenses (Denny et al. 1981).

Expenditures for coal and electricity are obtained from the Report on Mining and Manufacturing Survey. Energy price was calculated as weighted average of price of coal and electricity. Prices of coal and electricity are from the Yearbook of Energy Statistics. Coal and electricity are chosen due to the importance of being the two major source of energy for the Korean steel industry.\(^{12}\)

Material cost is from the Report on Mining and Manufacturing Survey. Price of material is from Kim & Hong (1992). It was assumed in this study that technical change is represented by time trend (Barbera & McConnell, 1990; Denny et al., 1981). Total cost is defined as the sum of expenditures on capital, labor, energy, and materials (Barbera &

Abatement capital stock \((AK)\) is \(AK_t = \xi_t + (1 - a)AK_{t-1}\)

where, \(AK_t = \) capital stock

\(AK_{t-1} = \) capital stock (one year lag)

\(a = \) amortization ratio of investment

\(\xi_t = \) capital investment

\(^{12}\) The weighted average energy price was calculated as follows:

\[
P_C \times \left[ \frac{C_C}{(C_C + C_{ELEC})} \right] + P_{ELEC} \times \left[ \frac{C_{ELEC}}{(C_C + C_{ELEC})} \right]
\]

where, \(P_C = \) price index of coal

\(C_C = \) coal consumption (amount)

\(P_{ELEC} = \) price index of electricity

\(C_{ELEC} = \) Consumption of electricity (amount)
McConnell, 1990; Kwon, 1986; Christensen & Haveman, 1981). This total cost is directly available from the Report on Mining and Manufacturing Survey. To know about the cost share of capital, labor, energy, and materials, respectively, total cost is calculated and then each expenditure is divided by this total cost.

IV. Empirical Analysis

Econometrics problems can arise in estimating a translog cost function for the Korean steel industry due to the use of industry and time series data and the translog model. Degrees of freedom and serial correlation are the major concerns.

The lack of degree of freedom can be a problem since the translog cost function gains explanatory power with many fewer input variables.\(^{13}\) To avoid this, equation (10) was run with cost-share equations composed of four cost-shares of capital, labor, energy, and materials. This provides 30 observations for each equation, thus allow 120 degrees of freedom.

Another difficulty in this estimation is serial correlation among independent variables of different equations. To solve this problem, Zellner’s seemingly unrelated regression technique was used as it assumes that the error terms are serially uncorrelated.

The \(t\)-test was used to test the hypothesis of individual regression coefficients. This \(t\)-test is appropriate when the stochastic error terms

\(^{13}\) To obtain a translog cost function, we use the Taylor series expansion. We have 29 parameters to estimate in the cost function with 30 observations.
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〈Table 1〉 Parameter Estimate of Constrained Translog Cost Function:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimates (t-ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0$</td>
<td>5534.9810(3.023***)</td>
</tr>
<tr>
<td>$\beta_K$</td>
<td>-15.3396(-2.185**)</td>
</tr>
<tr>
<td>$\beta_L$</td>
<td>-2.1841(-0.908)</td>
</tr>
<tr>
<td>$\beta_E$</td>
<td>-7.9827(-1.351*)</td>
</tr>
<tr>
<td>$\beta_M$</td>
<td>26.5065(3.318***)</td>
</tr>
<tr>
<td>$\tau_{KK}$</td>
<td>0.1554(2.594***)</td>
</tr>
<tr>
<td>$\tau_{LL}$</td>
<td>0.02642(3.973***)</td>
</tr>
<tr>
<td>$\tau_{EE}$</td>
<td>0.04027(1.952***)</td>
</tr>
<tr>
<td>$\tau_{MM}$</td>
<td>-0.1640(-4.160***)</td>
</tr>
<tr>
<td>$\tau_{KL}$</td>
<td>-0.0354(-2.296**)</td>
</tr>
<tr>
<td>$\tau_{LE}$</td>
<td>-0.01239(-1.682**)</td>
</tr>
<tr>
<td>$\tau_{EM}$</td>
<td>0.10784(4.715***)</td>
</tr>
<tr>
<td>$\tau_{KE}$</td>
<td>-0.1415(-6.187***)</td>
</tr>
<tr>
<td>$\tau_{LM}$</td>
<td>0.02041(1.846**)</td>
</tr>
<tr>
<td>$\tau_{KM}$</td>
<td>0.0328(0.813)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>-5.6790(-3.011***)</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.00292(2.999***)</td>
</tr>
<tr>
<td>$\beta_Q$</td>
<td>0.9533(14.903***)</td>
</tr>
<tr>
<td>$\tau_{KL}$</td>
<td>0.00772(2.147**)</td>
</tr>
<tr>
<td>$\tau_{LM}$</td>
<td>0.00111(0.956)</td>
</tr>
<tr>
<td>$\tau_{EM}$</td>
<td>0.0040(1.340*)</td>
</tr>
<tr>
<td>$\tau_{KE}$</td>
<td>-0.0130(-3.172***)</td>
</tr>
<tr>
<td>$\beta_{AK}$</td>
<td>18.7266(2.376***)</td>
</tr>
<tr>
<td>$\tau_{AK}$</td>
<td>0.0324(1.883**)</td>
</tr>
<tr>
<td>$\tau_{AK1}$</td>
<td>-0.0096(-2.367***)</td>
</tr>
<tr>
<td>$\tau_{KA}$</td>
<td>0.0136(0.851)</td>
</tr>
<tr>
<td>$\tau_{LAK}$</td>
<td>-0.0079(-1.459*)</td>
</tr>
<tr>
<td>$\tau_{EAK}$</td>
<td>-0.0043(-0.341)</td>
</tr>
<tr>
<td>$\tau_{MAK}$</td>
<td>-0.0013(-0.080)</td>
</tr>
</tbody>
</table>

Notes: 1) $t$-ratio are in the parenthesis.
2) $K, L, E, M, I, Q$ and $AK$ are capital, labor, energy, material, technology, and steel output, respectively.
3) * 10% level of significance.
   ** 5% level of significance.
   *** 1% level of significance.
are normally distributed and when the variance of that distribution must be estimated. One-sided \( t \)-test is employed to test a null hypothesis; And a critical \( t \)-value (1% level of significance: critical \( t \)-value is 2.358, 5% level of significance: 1.658, and 10% level of significance: 1.289) is used to reject the null hypotheses. The level of significance indicates the probability of observing an estimated \( t \)-value greater than the critical \( t \)-value if the null hypothesis were correct.

Parameter estimate of constrained translog cost function in the Korean steel industry during the period 1967~1996 are shown in <Table 1>.

The <Table 1> indicates that most \( t \)-values are high enough to make the inference that the null hypothesis is rejected. However, some \( t \)-values of parameters are lower than the critical \( t \)-value, so the null hypothesis may not be rejected. For instance, the \( t \)-value of \( \beta_L \) is not statistically significant since cost components of labor are relatively low compared to the industry's total cost. Overall, the results of these significant parameter estimates and \( t \)-values can be taken meaningfully even though some of the results prove not to be statistically significant.

<Table 2> describes the estimate abatement requirement coefficients which are used to obtain cost elasticities and indirect abatement effects. These coefficients can be used to explain how the Korean steel industry have adjusted its cost minimizing factor ratio in reacting to demanded abatement purchase.

The values of \( \beta_{AK} \) and \( t_{AKAK} \) from the estimate parameters represent increasing cost since \( E_{CAK} \) has positive sign (see <Table 3>). Abatement-related estimate coefficient for capital is 0.0136. This positive coefficient means that abatement capital is related to more capital used.
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(Table 2) Abatement-Related Estimate Coefficient

<table>
<thead>
<tr>
<th></th>
<th>$\beta_{AK}$</th>
<th>$\tau_{AKAK}$</th>
<th>$\tau_{EAK}$</th>
<th>$\tau_{MAK}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron and Steel</td>
<td>18.7266</td>
<td>0.0324</td>
<td>0.0136</td>
<td>-0.0079</td>
</tr>
<tr>
<td></td>
<td>(7.8829)</td>
<td>(0.0172)</td>
<td>(0.0160)</td>
<td>(0.0054)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0043)</td>
<td>(0.0128)</td>
<td>(0.0167)</td>
</tr>
</tbody>
</table>

Note: Figures in parenthesis refer to standard error.

(Table 3) Cost Elasticity to Abatement, $E_{CAK}$: Average for Selected Period

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron and Steel</td>
<td>0.03005</td>
<td>0.01538</td>
<td>0.00055</td>
<td>0.01434</td>
</tr>
</tbody>
</table>

However, the coefficients of labor, energy, materials are -0.0079, -0.0043, and -0.0013, respectively, which implies that abatement capital is likely to be related less use of labor, energy, and materials, respectively.

Estimate of $E_{CAK}$ based on equation (14) is presented in <Table 3>. These elasticities represent the effect of abatement requirements on non-abatement cost and comprise an important part of indirect productivity effect (see equation (9)).

As <Table 3> indicates, the average elasticities for the entire period are positive. Abatement requirements still drive unit cost to grow, implying that abatement purchases do not lead to higher productivity growth. Therefore, the regulations do not seem to induce greater innovation. Rather, they may force this industry to increase use of all inputs to maintain a given level of steel production. However, the decrease of $E_{CAK}$ over time may imply that the efficiency of abatement capital use may improve during the period examined.
Kim, Dong-Yeub · Kang, Shin-Won

\textit{Table 4} Average Annual Productivity Growth and Direct and Indirect Effects of Abatement Requirements for the Selected Period

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron and Steel</td>
<td>1.5343</td>
<td>0.7135</td>
<td>0.1364</td>
<td>0.7481</td>
</tr>
<tr>
<td>Abatement effect</td>
<td>-0.6793</td>
<td>-0.6543</td>
<td>-0.2949</td>
<td>-0.5300</td>
</tr>
<tr>
<td>Direct</td>
<td>-0.0655</td>
<td>-0.1522</td>
<td>-0.2911</td>
<td>-0.1771</td>
</tr>
<tr>
<td>Indirect</td>
<td>-0.6138</td>
<td>-0.5021</td>
<td>-0.0038</td>
<td>-0.3529</td>
</tr>
</tbody>
</table>

In equation (9), the three main components of TFP for the steel industry are 1) technical change \( S_C(-\frac{\partial \ln C}{\partial t}) \), 2) direct effect of the abatement capital purchase \( S_{AC}(-\frac{\partial \ln AC}{\partial t}) \), and 3) indirect effect \( S_CE_{CAR}(-\frac{\partial \ln AK}{\partial t}) \) on the other factors which are combined to produce steel.

\textit{Table 4} presents average annual productivity growth and direct and indirect effect of abatement requirements for the selected period.\(^{14}\) The total abatement contribution to TFP is also shown in \textit{Table 4}, along with its two components, the direct and indirect abatement effects as defined earlier.

TFP grows more slowly between 1976 and 1985 than 1967 and 1975. For 1986~1996, TFP is slowing down continuously. This result implies that environmental requirements can contribute to the slowdown in TFP.

\(^{14}\) For economic and comparison reasons, we divided the data set into three periods: 1967~1974, 1975~1983, and 1984~1996. The years 1967 to 1974 represent a self-sustaining growth economy and the beginnings of the steel industry. The Pohang Iron and Steel company started producing steel after 1973. During the second period, the Korean government implemented the strong heavy/chemical intensive policy. From 1984 to 1996, the rate of growth in the steel industry was relatively slower than in the previous stage and the environmental issues gained attention.
The Effect of Environmental Regulation on the Productivity of Korean Steel Industry

<table>
<thead>
<tr>
<th>Time period</th>
<th>change in TFP</th>
<th>change productivity due to abatement</th>
<th>TFP decline due to abatement(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976<del>85 vs 1967</del>75</td>
<td>-0.82</td>
<td>-0.25</td>
<td>31.76</td>
</tr>
<tr>
<td>1986<del>96 vs 1976</del>85</td>
<td>-0.57</td>
<td>-0.35</td>
<td>36.48</td>
</tr>
</tbody>
</table>

during 1986~1996 since then environmental regulation was stiffer than other times.

The direct effect of abatement capital cost has increased over the entire period due to an increase in the environmental requirements. However, even though the total abatement requirement effect has been negative on TFP growth during the whole period, its negative effect has decreased, implying that the extent of the negative influence of abatement capital on input prices has been decreasing over time.15)

<Table 5> shows the difference in TFP by making comparisons between 1976~1985 and 1967~1975, and 1986~1996 and 1976~1985. It shows that abatement requirements may have contributed to the productivity slowdown in the steel industry during the period investigated. The second column of <Table 5> describes the percentage point change in TFP from the previous stage.

15) The results of Barbera and McConnell's study (1990) show that the total abatement effect in the U.S. steel industry was −0.219 during the period 1960~1980. The indirect and direct abatement effects were −0.095 and −0.124 during the same period. The abatement effects in the Korean steel industry are significantly higher than U.S. effects reported in the Barbera and McConnell study. It could be that Korea, as a developing country, has a relatively high environmental standard for the steel industry. The industry imports most of its capital goods and environmental standards from advanced countries.
The percentage point change in TFP is $-0.82$ percent comparing the second to the first stage, and it was $-0.57$ percent when comparing the third to the second stage. The third column shows percentage point change in productivity due to the abatement effect, and demonstrates that abatement requirements affect productivity growth negatively. The fourth column presents difference in the pollution abatement contribution to TFP over the period. The results show that productivity has fallen due to pollution abatement in the first compared to the second and the second compared to the third period of time by $31.76$ percent and $36.48$ percent, respectively.\footnote{Barbera and McConnell found that the percentage of TFP decline due to abatement in the U.S. steel industry during the period 1960–1980 was 10.8 percent, much lower than our result for the steel industry in Korea.}

\section*{V. Conclusions}

This study examines whether environmental regulation can be a factor of productivity slowdown in the Korean steel industry. In general, the result of this study shows a significant negative relationship between pollution abatement requirements and productivity growth.

Specific important findings are summarized as following. First, environmental regulation is one of the factors for declining productivity of the Korean steel industry by $36$ to $31$ percent over the study period. Second, the direct abatement cost has decreased the TFP while abatement cost has increased over time. However, the size of the effect
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decreases over the time even though the indirect abatement effect may result in productivity slowdown. Third, abatement capital effect has decreased the use of labor, energy, and materials. It maybe that abatement capital has improved efficiency of labor, energy, and materials. In sum, the results of this study still support the view that environmental regulation can be one important partial explanatory variable for the slowdown of productivity growth.

According to this study, environmental regulation has had negative effects on productivity growth in the Korean steel industry. Even though environmental regulation has reduced productivity growth in the Korean steel industry, there is strong evidence that abatement capital can enhance efficiency of labor, energy, and material use. And the pace of total abatement effect has decreased over time, implying that the percentage of negative abatement effect is decreasing.

The results of this study can be extended to make some implications. First, in order to enhance productivity, Korean steelmakers will be able to reduce cost through facility efficiency, technology development, and R&D for the development of high value-added and specialty steel. Currently the industry is producing only a small amount of high value-added steel products. Second, Korean steelmakers should be alert and informed about environmental issues. The demand for better environment, domestically and abroad, has increased and this affects international competitiveness. Recycling should be better utilized and conventional processes should be replaced by more environmentally sound processes to reduce waste and cost of production.

Recommendations for future research are several. First is the need for updating data and expanding the study to include more number of
industries. Updating data will allow an examination of the effect of changing regulations over time, and expanding the study to include more industries will facilitate accurate analysis of environmental effect on other industries and the economy. Second, better variables to measure other factors such as capital utilization, expansion of production capacity, spending for automation, energy conservation, R&D spending, labor quality, and market structure may help to improve the explanation on productivity change. Finally, production and cost-oriented studies may not be interested in measuring social benefits of abatement requirement. However, it will be worth while to attempt to include these benefits in the study in that the resulting environment improvement will be a benefit to the society after all, and that this is to be taken into account in the model as total cost vs. total benefit of environmental regulation.

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2. ______, *National Accounts*, The Bank of Korea (BOK), Seoul, Korea, Various Years.
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환경규제가 한국 철강산업의 생산성에 미치는 효과

김동엽·강신원

환경오염을 유발하는 산업에 대한 환경규제의 효과는 모순되는 두 가지 측면이 있다. 즉, 환경규제는 기업의 생산성 증가를 감소시킬 것이라는 생산성에 대한 부정적인 효과와 환경규제가 효율성 증대와 기술혁신을 유발시켜 생산성을 증가시킨다는 것이다.

최근 한국은 소득이 증가함에 따라 환경에 대한 인식이 점점 높아지고 있으나 철강산업의 생산성 증가율은 감소하고 있다. 이러한 경제구조에서 환경규제가 한국철강산업의 생산성에 어떠한 영향을 미치는지를 검증하고자 하였다.

본 연구는 1967년부터 1996년까지의 한국 철강산업의 시계열 자료를 사용하여 환경규제의 총요소생산성에 대한 직접·간접적인 효과를 검증하였다. 검증결과 환경규제는 한국 철강산업의 총요소생산성 감소의 31~36%를 차지하는 것으로 나타났다.