

**Environmental Policy and Technological Innovation:
Evidence from Taiwan Manufacturing Industries**

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Abstract

Michael Porter suggested that the traditional trade-off between environmental regulation and competitiveness may have overestimated environmental compliance costs, neglected innovation offsets, and disregarded the affected industry's initial competitiveness. We examine the stylized facts regarding environmental abatement investments and innovation in various industries. This paper examines the role of market innovation and the incurred necessary adjustments in explaining the apparent contradiction between markets and the environment. It argues that market innovation can serve as a powerful tool of environmental policy operating together with a competitive market environment. To capture the market innovation and the incurred adjustments for enterprises in complying with the environmental standard requires a model with dynamic adjustment features. This paper applies an empirical industry dynamic model to explicitly incorporate associated adjustments in analyzing the efficiency of the abatement investment by industry. By investigating abatement investments in various industries, we analyze the innovation and adjustment effects of environmental policy. We apply the empirical industry dynamic model to Taiwan manufacturing industries and investigate how well the double-focus of industry efficiency and environmental perpetual development has been developed in the process of industrialization. The Taiwan manufacturing industries were chosen since it has been characterized by increasing innovation and investment in R&D, especially the rapid innovation in electronics, computers, materials, and processes which had marked as the source of the substantial growth before Asia financial crisis. The industries with higher innovation spillover effects and lower adjustment effects are identified to effectively enhance optimal policy in aiming at both economic efficiency and environmental perpetual development for Taiwan's balanced growth.

JEL Classification: C5; L5; L6; O3

Keywords: Environmental policy; Technological innovation and diffusion; Adjustment effects

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I. Introduction

The relationship between environmental goals and industrial competitiveness has conventionally been thought of as involving a tradeoff between social benefits and private costs. The traditional view is that firms pursue efficiency at the expense of environmental protection because one firm's consumption is irrevocably linked to those of others. This leads to ill-defined private choices and to the failure of industry competitiveness. Markets can therefore induce over-consumption of environmental resources, such as clean air. Reciprocally, environmental concerns are often blamed for undermining market performance. Environmental regulation can lead to undue costs and prevent the unfettered behavior needed for achieving industry developments. (e.g. Denison 1979; Christiansen and Haveman 1981; Gray 1987; Conrad and Wastl 1995; etc.). In the recent decade, the environment-competitiveness debate has been shifted to a new dynamic international competitiveness paradigm. Michael Porter suggested that the traditional trade-off between environmental regulation and competitiveness may have overestimated environmental compliance costs, neglected innovation offsets, and disregarded the affected industry's initial competitiveness. Markets may have evolved some of the most innovative and useful solutions for global environment problems. (e.g. Barbera and McConnell 1990; Gray and Shadbegian 1993; Jaffe and Stavins 1994; Porter and Linde, 1995; Jaffe, et. al. 1995; and Jaffe and Palmer 1996; etc.)

This paper examines the role of market innovation and the incurred necessary adjustments in explaining the apparent contradiction between markets and the environment. It argues that market innovation can serve as a powerful tool of environmental policy operating together with a competitive market environment. This study is then to analyze the inter-connection relationship among enterprise efficiency, industrial technological innovation, the measure of environmental policy tools, and the associated adjustments. The focus is to examine the direct and indirect effects of the environmental regulation on enterprise technological factors. Will the impacts of environmental regulation affect the technological changes and stimulate the technological innovation of the enterprise? Does there exist a connection between economies of scale and the environmental costs? The industry characteristics, scale economies and the associated adjustment costs will be the focus of analyzing economic efficiency and the environmental investment in this study.

To capture the market innovation and the incurred adjustments for enterprises in complying with the environmental standard requires a model with dynamic adjustment features.¹ We apply an

¹ Recently there are significant advancements in modeling dynamic factor demand model. (See for a detailed survey in Nadiri and Prucha 1999) And a vast literature shows the wide spread use factor demand models for empirical analysis. (See, e.g., Prucha and Nadiri 1996; Galeotti 1996; and Good, Nadiri and Sickles 1997 for partial references.)

empirical dynamic model to Taiwan manufacturings and investigate how well the double-focus of industry efficiency and environmental perpetual development has been developed in the process of industrialization. The purposes are two folds. First, if indeed there exists the indirect positive effects of environmental regulation that promote technological innovation, invention, and diffusion, optimal regulatory policy may require imposing a lighter regulatory burden on high technology industries or being designed to be more innovative-oriented. Second, we investigate how well the double-focus of industry efficiency and environmental perpetual development has been developed in the process of Taiwan's industrialization. Have the high-technology, high-growth, low-adjustment costs, and high innovative-oriented environmental impacts industries been higher priority in Taiwan's development? This study is then considered to serve for two purposes: 1) to provide the economic evidence for implications of business strategy in pursuing efficiency and growth; and 2) to identify the "right" industries for Taiwan and to effectively enhance optimal policy in aiming at both economic efficiency and environmental perpetual development for a balanced growth.

The Taiwan manufacturing industries were chosen since it has been characterized by increasing innovation and investment in R&D, especially the rapid innovation in electronics, computers, materials, and processes which had marked as the source of the substantial growth before Asia financial crisis. The study is concerned with the sustainable development of the Taiwan economy and in particular with the future industry competitiveness-environment partnership. Adopting the values of sustainable development also implies an increase in the industry's environmental and social costs. For an industry already in poor situation this is potentially a problem. To pursue sustainable development, the Executive Yuan (EY) of the Republic of China (ROC) on Taiwan established the National Council for Sustainable Development (NCSO) in August 1997². In Taiwan, the meaning of sustainable development is apparently more than just chopping down less trees than you plant or, in the sea, not fishing at a level greater than that of natural recruitment and cohort survival measured over an extended time scale. As an island country, Taiwan's industrial growth has to be 'adhering to the principle of sustainable development.'

This paper involves empirical research into the workings of a number of industries in Taiwan. The study improves our understanding of the industries involved, and, more broadly, to help assess the relevance of a number of economic theories of competitiveness-environment complexity. This paper examines the role of market innovation and the incurred necessary adjustments in explaining the apparent contradiction between markets and the environment. It argues that market innovation can serve as a powerful tool of environmental policy operating together with a competitive market environment. This paper applies an empirical industry dynamic model to explicitly incorporate associated adjustments in analyzing the efficiency of the abatement investment by industry. We

² Ever since the 1992 United Nations Earth Summit, the pursuit of sustainable development has been the common goal of nations around the world. The partnership relationship of the industry-environment has been

apply the empirical industry dynamic model to Taiwan manufacturing industries and investigate how well the double-focus of industry efficiency and environmental perpetual development has been developed in the process of industrialization. The industries with higher innovation spillover effects and lower adjustment effects are identified to effectively enhance optimal policy in aiming at both economic efficiency and environmental perpetual development for Taiwan's balanced growth.

In order to initiate the process of unraveling the productivity-environmental-regulations nexus, this study investigates the direct and indirect innovation effects of the environmental regulation on industry productivity by 15 Taiwan manufacturing industries. A dynamic production model is built up to include the economic effects of technological characteristics on firms and complies with conventional environmental regulations. This paper is organized as follows. Section 2 reviews the literatures survey the impact of environmental regulations on enterprise efficiency and/or industrial productivity. Section 3 specifies a dynamic model of production incorporating abatement capital and internal adjustment costs, and decomposes the impact of environmental regulations on TFP to direct and indirect effects. Section 4 presents the empirical model and results for 15 Taiwan manufacturing industries. Section 5 summarizes our results and develops their implications for environmental regulation and for future research.

II. Previous Findings on the Trade-off between Environmental Regulations and Competitiveness

In the earlier literature, the impact of environmental regulation on industrial productivity seems quite obvious. In order to comply with the environmental standards, some 'unproductive' inputs have to be used for complying with the environmental standards. The process did not increase outputs but decrease measured TFP (total factor productivity) because more will be subtracted from the growth rate of output. From this perspective the effect of environmental regulation on productivity is obviously negative; open questions only are how to measure it and does the impact matters. (Denison 1979; Christiansen and Haveman 1981; Gray 1987; Liu and Chiu 1992; Conrad and Wastl 1995; etc.).

In measuring the impacts of different forms of environmental regulations on productivity change, Denison (1979) used a TFP approach to estimate the effect of environmental regulations on TFP for all manufacturing (0.35% less per year). Gray (1987) also used this approach to examine the impact of health, safety and environmental regulation on productivity growth looking at data for 450 manufacturing industries. He attributes about 30% of the decline in TFP growth to such regulations (0.44% less per year). Further parametric TFP studies have been applied by Norsworthy, Harper and Kunze (1979) and Conrad and Morrison (1989). Norsworthy, Harper and Kunze (1979) found the decrease in aggregated labor productivity from abatement capital cost to be between 0.1% - 0.2%. In

declared clearly to be the goal of the sustainable development supported by balancing growth in economic development with environmental protection.

Conrad and Morrison (1989), cost shares were modified by abatement capital, and the contribution of regulation on productivity in the U.S., Canadian and German steel industries were compared. Gollop and Roberts (1983) investigate the impact of environmental regulation on 56 electric utilities using a cost function approach. They found air pollution regulations reduced firm-level productivity growth by 0.59%. Christensen and Haveman (1981) reveal reduced labor productivity growth by 0.27% using an econometric approach with environmental regulation intensity as an explaining variable. Barbera and McConnell (1986) estimate a system of factor demand equations and find that abatement requirements have reduced capital and labor productivity in several industries.

Recently an increasing number of economic literatures have explored the possibility that environmental regulations may also give some positive spillover effects on productivity. Whether these effects are large enough to cover the negative effects is then an empirical question and cannot usually be determined a priori. Gray and Shadbegian (1993) state that: "In some cases, regulations may increase productivity. In response to pressures to reduce waste water discharges, some plants adopted 'closed-loop' production processes and discovered after doing so that the cost savings from recycling raw materials reduced total costs." Barbera and McConnell (1990) and Jaffe and Stavins (1994) all indicate the possibility that for some industries environmental regulations can stimulate innovations that reduce costs by lowering input prices or by increasing the productivity of an industry's inputs. Jaffe (1995) further verifies if there do exist indirect positive effects of environmental regulation on the technology changes and productivity growth, the analogy would not be so straightforward. In this framework, environmental regulations are seen as being not only benign in their impacts on international competitiveness, but actually a net positive force driving private firms and the economy as a whole to become more efficient and competitive in international markets.

In the long run, the development and widespread adoption of new technology can greatly ameliorate what, in the short run, sometimes appear to be overwhelming conflicts between economic well-being and environmental quality. The literatures measuring the spillover effects of the environmental regulations on industrial productivity focus on the improved rates of invention, innovation and technology diffusion. Kemp and Soete (1990) suggest that the impact of environmental regulation can be beneficial if regulations designed to protect or enhance environmental quality were designed to foster rather than inhibit technological invention, innovation, and diffusion. Barbera and McConnell (1990) investigate both the direct and indirect impacts of the environmental regulations using a flexible functional form cost function. The direct impact of environmental regulation on productivity growth is due to the diversion of resources toward required abatement capital. The further indirect effect is then as conventional inputs and production processes are changed in response to requirements to purchase abatement capital. They estimate total factor productivity and the direct and indirect productivity effects of environmental regulations for five polluting industries (Paper; Chemicals; Stone, Clay, and Glass; Iron and Steel; and Non-ferrous metals) and find that net impact of environmental regulation on total factor productivity growth is fairly small even for only about

10-30% of the productivity decline of the 1970s in these industries. Porter and van der Linde (1995) comment that studies finding high environmental compliance costs have traditionally focused on static cost impacts, ignoring any offsetting productivity benefits from innovation. These studies typically overestimated compliance costs, neglected innovation offsets, and disregarded the affected industry's initial competitiveness.

Environmental regulation had a very uneven impact on manufacturing industries, depending on their market structure, industry characteristics, number and size structure of plants and factor shares. Pashigian (1984) proves that small companies have been harmed relatively more than large companies and shows how optimal plant size and the size distribution of plants will be changed under environmental regulation. Gray and Shadbegian (1993) analyze the impact of pollution abatement expenditure on productivity and find that the more regulated plants have significantly lower productivity growth than the less regulated plants. Jaffe and Stavins (1994, 1995) develop the framework for comparing empirically the effects of alternative environmental policy instruments on the diffusion of new technology. Tisato and Porter (1996) present a graphical analysis of how profit-maximizing firms would respond when required to control pollution. The graphical presentations in this study attempts to integrate the two pollution reduction responses open to firms: output reduction and use of abatement technology. Hartman et al. (1997) apply a large US plant-level database, created from PACE and ASM, to estimate the costs of abatement for major air pollutants (e.g. sulphur oxides, carbon monoxide, hydrocarbons, lead, etc.) in all US manufacturing sectors. They conclude that command-and-control regulation in the US has achieved emissions reduction at unnecessarily high cost and provide a consistent foundation for priority-setting. Gray and Shadbegian (1998) examine investment allocation across existing plants and test whether environmental regulation affects investment decisions. They conclude environmental investment "crowding out" productive investment within a plant, and firms shifting investment towards plants facing less stringent abatement requirements.

As Porter and Linde (1995) interpreted the new paradigm of environment-competitiveness relationship, the paradigm defining competitiveness has been shifting, particularly in the last 20 to 30 years, away from the static model to a new dynamic paradigm of international competitiveness, based on innovation. Recently an increasing number of economic literatures have theoretically and empirically proved the importance of innovation in environment-competitiveness relationship. Gray and Shadbegian (1993) state that: "In some cases, regulations may increase productivity. In response to pressures to reduce waste water discharges, some plants adopted 'closed-loop' production processes and discovered after doing so that the cost savings from recycling raw materials reduced total costs." Barbera and McConnell (1990) and Jaffe and Stavins (1994) all indicate the possibility that for some industries environmental regulations can stimulate innovations that reduce costs by lowering input prices or by increasing the productivity of an industry's inputs. Jaffe (1995) further verifies if there do exist indirect positive effects of environmental regulation on the technology changes and productivity

growth, the analogy would not be so straightforward. In this framework, environmental regulations are seen as being not only benign in their impacts on international competitiveness, but actually a net positive force driving private firms and the economy as a whole to become more efficient and competitive in international markets.

In this paper, we focus on the role of innovation in sustainable development. We examine the stylized facts regarding environmental abatement investments and innovation in a panel of manufacturing firms in various industries and regions. And we re-examine the testable hypotheses raised from the existing literatures in the presence of adjustment process in the dynamic framework.

III. A Dynamic Model of Production with Abatement Capital

Theoretical Model

Suppose Y represents the homogeneous output of the firm net of pollution and U represents pollution, these two outputs produced using I costlessly adjustable inputs $\mathbf{x} = (x_1, \dots, x_i, \dots, x_I)$ and M quasi-fixed inputs $\mathbf{k} = (k_1, \dots, k_m, \dots, k_M)$ whose adjustment costs are significant and positive³. Then the transformation function for a two-output multiple-input technology is $f(Y, U, \mathbf{x}, \mathbf{k}, \dot{\mathbf{k}}, t) = 0$, where $\mathbf{k}$ is the level of quasi-fixed inputs at the beginning of the period; $\dot{\mathbf{k}}$ is the adjustment vector of changes in the quasi-fixed inputs during the period, the continuous changes in quasi-fixed inputs can be represented by discrete changes $k_t - k_{t-1}$; and t is time.

If pollution were unregulated or untaxed, the firm would ignore it and use combinations of the other inputs to produce the revenue generating good, Y . Due to the environmental regulation, however, firms must also employ techniques for reducing pollution caused by the production of Y . We treat emissions as a function of abatement capital in place, A , and the amounts of other inputs of production, $U = U(A, \mathbf{x}, \mathbf{k}, \dot{\mathbf{k}}, t)$. And the production function for Y as $Y(A, \mathbf{x}, \mathbf{k}, \dot{\mathbf{k}}, t)$, where the inputs are used to produce Y or in conjunction with abatement capital to reduce pollution. We assume that the firm minimizes net production costs (C_s) subject to an exogenous level of production, input prices, abatement capital and technology. Thus, there exists a restricted cost function, which can be written as $C_s(Y, \mathbf{p}, \mathbf{k}, \dot{\mathbf{k}}, A, t)$, where C_s is short run production cost; $\mathbf{p}$ is the vector of prices of the inputs $\mathbf{x}$.

³ We use k_t to denote the physical capital stock at the end of period t for which the firm chooses how much of the beginning-of-period stocks will be left over at the end of the period, e.g. to choose appropriate levels of maintenance. That is, the firm can choose endogenously the rate of depreciation for those stocks. To formalize this, we can write $I_t^k = \dot{k} + \delta k_{t-1}$, where δ (the geometric depreciation rate for quasi-fixed input k) is endogenously defined, and the adjustments $\dot{k} = k_t - k_{t-1}$ generate adjustment costs.

That is, the enterprise is assumed to determine the appropriate level of production and minimize $C_S = \mathbf{p} \cdot \mathbf{x} + \phi(\dot{\mathbf{k}}) + \mathbf{p}_k^* \dot{\mathbf{k}} = C_v + \phi(\dot{\mathbf{k}}) + \mathbf{p}_k^* \dot{\mathbf{k}}$, where C_S includes the conventional variable cost $C_v = h(\mathbf{p}, \mathbf{k}, Y, A)$, the adjustment costs borne by the enterprise $\phi(\dot{\mathbf{k}})$, and the long run cost of the addition to the quasi-fixed factors which are valued at $\mathbf{p}_k^*$, the long run service prices of the quasi-fixed factors. Necessarily, $\phi(\dot{\mathbf{k}}) = 0$ when $\dot{\mathbf{k}} = 0$, which is consistent with and defines long run equilibrium. Replacement investment -- that investment required to maintain the current level of the stocks of quasi-fixed factors -- is assumed to be costless in adjustment terms.⁴

An equation for optimal short run gross investment in the presence of internal adjustment costs is readily developed from the Euler equations⁵ when an explicit form is imposed on ϕ . Thus we specify internal adjustment costs as⁶

$$(1) \quad \phi(\dot{\mathbf{k}}) = \left[\prod_i p_i^{h_i} \right] \cdot (\Gamma_x x_{i,t-1} + \Gamma_y \dot{y} + \Gamma_A A + .5 \Gamma_k (\dot{\mathbf{k}} - \Delta \mathbf{k}_{t-1}))' (\dot{\mathbf{k}} - \Delta \mathbf{k}_{t-1}),$$

where Γ_x is an $M \times I$ matrix such that γ_{ik} measures the adjustment cost associated with lagged of the variable input x_i and quasi-fixed factor k_m ; Γ_y is an $M \times J$ matrix such that γ_{ym} measures the adjustment cost associated with output y_j and quasi-fixed factor k_m ; Γ_A is an $M \times 1$ vector such that γ_{Am} measures the adjustment cost associated with abatement capital A and quasi-fixed factor k_m ; Γ_k is an $M \times M$ matrix such that γ_{mn} measures the second order effect of disequilibrium in quasi-fixed factors k_m and k_n on adjustment cost.⁷ The premultiplied product of prices (whose exponents sum to 1) ensures that the function is homogeneous in the first degree in prices of variable inputs.^{8,9}

⁴ The concept of adjustment costs and implications in production modeling, see Morrison (1994) and Tsai (1999).

⁵ The Euler equations state that the net change in expected discounted costs from hiring one more unit of quasi-fixed inputs at t is zero. That change is then the sum of the increase in variable costs (which is negative), the expected discounted value of the extra expenditures which the firm must incur by holding (at t only) one extra unit of quasi-fixed inputs, and expected discounted price of the future quasi-fixed inputs.

⁶ See for a more elaborated formulation in Tsai (1999). The pattern of the adjustment cost function can be roughly categorized into 4 types, see details in Hamermesh & Pfann (1996).

⁷ Necessarily, $\phi(\dot{\mathbf{k}}) = 0$ when $\dot{\mathbf{k}} = 0$, which are consistent with long run equilibrium. Replacement investment -- that required to maintain the current level of the stocks of quasi-fixed factors -- is costless in adjustment terms.

⁸ We must impose $\phi(\dot{\mathbf{k}}) \geq 0$ because negative adjustment costs make no economic sense.

⁹ The parameterization of equation (11) require that

$$\gamma_x, \gamma_y, \gamma_A, \gamma_k > 0; \quad \sum_i \gamma_{im} = \sum_m \gamma_{im} = 0; \quad \sum_r \gamma_{rm} = \sum_m \gamma_{ym} = \sum_m \gamma_{Am} = 0; \quad \text{and} \quad \sum_m \gamma_{mn} = \sum_n \gamma_{mn} = 0.$$

Given a specification of the adjustment cost function, the Euler equation for physical capital demand is¹⁰

$$\dot{k}_m = - \left(\left(\prod_i p_i^{h_i} \right)^{-1} \left(\frac{\partial C_v}{\partial k_m} + p_{km}^* \right) + \left[\sum_i \gamma_{im} x_{i,t-1} + \sum_r \gamma_{rm} \dot{y}_r + \gamma_{Am} A + \sum_{n \neq m} \gamma_{mn} (\dot{k}_n - \delta_n k_{n,t-1}) \right] \right) / \gamma_{mm} + \delta_m k_{m,t-1}. \quad (2)$$

Given a twice-differentiable functional form for the variable cost function and the assumption of short run cost minimization, derivatives of the short run cost function by Shepard's Lemma yield cost share equations:

$$(3) \quad s_i = \frac{\partial \ln C_v}{\partial \ln p_i} + \frac{\partial \phi}{\partial \ln p_i} = \frac{\partial \ln C_v}{\partial \ln p_i} + \sum_m \gamma_{im} x_{i,t-1} (\dot{k}_m - \delta_m k_m).$$

The input demand equation for variable input i is thus

$$(4) \quad q_i = \frac{C_v}{p_i} \left(\frac{\partial \ln C_v}{\partial \ln p_i} + \sum_m \gamma_{im} x_{i,t-1} (\dot{k}_m - \delta_m k_m) \right) + e_i.$$

This model treats abatement capital as effectively exogenous to the firm¹¹. The total cost function (C_s) defines the cost of producing the conventional output, Y , in terms of the conventional inputs, $\mathbf{x}$ and $\mathbf{k}$, given the requirement of purchase abatement capital. In this framework, two effects are distinguished -- direct and indirect effects -- as the impacts of required abatement capital on total factor productivity growth of the manufactured output. First, the requirement to buy abatement capital imposes a direct cost on the industry causing total input costs to be higher for the same level of output. Second, the requirement to operate a stock of abatement capital is likely to affect the amount or combination of conventional inputs necessary to produce the manufactured output. This is a shift in the production function for manufactured output and it will be referred to as the indirect effect. The total costs of producing Y are these “indirect” costs plus the direct costs of the abatement capital, C_A ($=P_A A$):

¹⁰ The short run cost is reduced by adding to the quantity of input m only when $|\partial C_v / \partial k_m| > p_{km}^*$; i.e., when the shadow value of capital exceeds its service price. Thus the short run cost minimizing condition for quasi-fixed input m is given by $\partial \phi(\dot{k}) / \partial k_m = \partial C_v / \partial k_m - p_{km}^*$, $\forall m$.

¹¹ This approach did not consider technology based requirements which is complying with performance standard so far.

$$(5) \quad \begin{aligned} C^* &= C(Y, \mathbf{p}, \mathbf{k}, \dot{\mathbf{k}}, A, t) + C_A, \\ &= C_v + \phi(\dot{\mathbf{k}}) + \mathbf{p}_k^* \dot{\mathbf{k}} + C_A. \end{aligned}$$

To measure the effect of abatement requirements on TFP, we first totally differentiate (5) for considering the impact of environmental regulation on productivity measurement. Total costs may be decomposed into factor price change; output change; the effect of abatement on the cost function; the changes in quasi-fixed inputs; technical change; adjustment costs in quasi-fixed inputs; and the direct abatement costs. We begin this exploration of productivity impacts with the cost-side definition of productivity growth, letting dots above variables denote the derivative with respect to time:

$$(6) \quad \varepsilon_{C^*t} = S_C \left(\sum S_i \frac{\dot{p}_i}{p_i} + \varepsilon_{CY} \frac{\dot{Y}}{Y} + \varepsilon_{CA} \frac{\dot{A}}{A} + \varepsilon_{CK} \frac{\dot{k}}{k} + \varepsilon_{Ct} \frac{\dot{h}}{h} + \frac{d\phi}{dk} \frac{\ddot{k}}{\dot{C}_v} + p_k^* \frac{\ddot{k}}{C_v} \right) + S_A \frac{\dot{C}_A}{C_A},$$

where $S_C = C_v / C^*$, $S_A = C_A / C^*$, $S_i = x_i p_i / C_v$.

TFP is defined as the growth in cost not accounted for by growth in prices and output and may be written in terms of C^* as

$$(7) \quad \begin{aligned} TFP &= \varepsilon_{C^*t} - \sum S_i \frac{\dot{p}_i}{p_i} - \frac{\dot{k}}{k} - \frac{\dot{Y}}{Y} \\ &= TC + IDAE + DAE + PSE + ACE. \end{aligned}$$

$$\begin{aligned} \text{where} \quad TC &= S_C \varepsilon_{Ct} \frac{\dot{h}}{h} \\ IDAE &= S_C \varepsilon_{CA} \frac{\dot{A}}{A} + S_C \varepsilon_{CK} \frac{\dot{k}}{k} \\ DAE &= S_A \frac{\dot{C}_A}{C_A} \\ PSE &= \sum S_i (S_i - 1) \frac{\dot{p}_i}{p_i} + (S_C \varepsilon_{CY} - 1) \frac{\dot{Y}}{Y} \\ ACE &= S_C \frac{d\phi}{dk} \frac{\ddot{k}}{\dot{C}_v} + S_C p_k^* \frac{\ddot{k}}{C_v} - \frac{\dot{k}}{k} \end{aligned}$$

Equation (7) shows that TFP may be decomposed into five major components: (a) the shift in C_v due to

technical change; (b) the shift in C_v due to abatement capital purchases (or the indirect abatement effect); (c) the growth in the direct cost of abatement requirements per unit of conventional output (or the direct abatement effect); (d) price and scale effects; and (e) adjustment costs effects when the firms are adjusting to comply with new environmental standards.

Empirical Implementation

To implement empirically, we approximate C_v with the translog restricted variable cost function for a single output y and a single quasifixed input k .

$$\begin{aligned}
 \ln C_v = & a_0 + \sum_i a_i \ln p_i + .5 \sum_i \sum_j a_{ij} \ln p_i \ln p_j \\
 & + a_y \ln y + \sum_i a_{iy} \ln p_i \ln y + .5 a_{yy} \ln^2 y \\
 & + a_k \ln k + \sum_i c_{ik} \ln p_i \ln k + .5 b_{kk} \ln^2 k \\
 (8) \quad & + b_{yk} \ln y \ln k + b_A \ln A + \sum_i c_{iA} \ln p_i \ln A \\
 & + .5 b_{AA} \ln^2 A + b_{yA} \ln y \ln A \\
 & + b_{Ak} \ln A \ln k + b_{tA} \ln p_t \ln A \\
 & + .5 b_{tt} t^2 + b_{yt} \ln y t + b_{kt} \ln k t + b_{At} \ln A t.
 \end{aligned}$$

The usual restrictions for homogeneity of degree one in prices and for short run cost minimizing production are imposed on the parameters of (8):

$$\begin{aligned}
 & \sum_i a_i = 1; \\
 (9) \quad & \sum_i a_{ij} = \sum_j a_{ij} = \sum_i a_{iy} = \sum_i c_{ik} = \sum_i c_{iA} = \sum_i c_{it} = 0, \quad \forall i, j; \text{ and} \\
 & b_{iy} + b_{ik} = 0, \quad \forall i.
 \end{aligned}$$

The adjustment cost for a single quasifixed input is adapted as

$$\begin{aligned}
 (10) \quad \phi(\dot{k}) = & \left[\prod_i p_i^{h_i} \right] \left(\sum_m \sum_i \gamma_{im} x_{i,t-1} (\dot{k}_m - \delta_m k_{m,t-1}) + \sum_m \sum_r \gamma_{rm} \dot{y}_r (\dot{k}_m - \delta_m k_{m,t-1}) \right. \\
 & \left. + \gamma_{Ak} (\dot{k} - \delta k_{t-1}) A + .5 \sum_m \sum_n \gamma_{mn} (\dot{k}_m - \delta_m k_{m,t-1}) (\dot{k}_n - \delta_n k_{n,t-1}) \right).
 \end{aligned}$$

There are two disadvantages of estimating a demand model based on share equations.¹² First, the calculated share (s_i) incorporates both exogenous (p_i) and endogenous decision variables (q_i) in the dependent variable. Consequently in a small sample, least squares-based estimation (GLS, 3SLS, GMM) where demand quantities are the targeted variables, the minimized quantity is less relevant than when the demand quantities are specified as the dependent variables. Second, in a system with n demand variables, only $n-1$ of the share equations are independent, while all n demand equations are independent. Thus the demand system incorporates additional stochastic information and is therefore more efficient. Accordingly, we specify the estimable demand equations as

$$(11) \quad q_i = \frac{C_v}{P_i} (a_i + \sum_j a_{ij} \ln p_j + a_{iy} \ln y + c_{ik} \ln k + c_{iA} \ln A + c_{it} t) + (\gamma + \gamma_i)(\dot{k} - \delta k_{t-1}) + e_i$$

The estimable equation for $\dot{k}$ is derived by (7) and expanding $\partial \ln C_v / \partial \ln k$

$$\dot{k}_m = - \left(\left(\prod_i p_i^{h_i} \right)^{-1} \left(\frac{\partial C_v}{\partial k_m} + p_{km}^* \right) + \left[\sum_i \gamma_{im} x_{i,t-1} + b_{Ak} \ln A + \sum_r \gamma_{rm} \dot{y}_r + \sum_{n \neq m} \gamma_{mn} (\dot{k}_n - \delta_n k_{n,t-1}) \right] \right) / \gamma_{mm} + \delta_m k_{m,t-1} + e_m. \quad (12)$$

The complete estimable model then consists of the variable cost function (8), the variable input demand equation (11), and the quasifixed input adjustment equation (12). The endogenous variables are C_v , q_i , and $\dot{k}$ as dependent variables in (8) (11) and (12).

IV. Empirical Findings

The dynamic model of production with abatement capital is applied to analyze the direct as well as indirect effects of environmental regulations on total factor productivity growth for 15 Taiwan manufacturing industries, 1987-97. The measures presented in this section were generated using output and input price and quantity data of these industries from Taiwan Statistics Bureau Office of

¹² Conventional procedure is to estimate the cost function jointly with two of the three share equations. McElroy (1987) proposed and demonstrated that the Additive General Error Model (AGEM) proved to be more advantageous in that it incorporates more information, and the error terms have direct interpretations as input

Productivity. The capital data is constructed using the perpetual inventory method with a 10% depreciation rate.¹³ The abatement capital expenditures have been obtained from Industrial Statistical Surveys and Industrial Census Report (provided by Statistics Division, Taiwan Ministry of Economic Affairs).

The translog variable cost function, augmented by adjustment costs and the full cost of new quasifixed inputs, is the basis for a short run cost function that merges seamlessly into a long run function as adjustment costs decline. Estimation of the adjustment cost model was carried out using generalized method of moments (GMM)¹⁴, an instrumental variables technique, to adjust for the endogeneity of short run changes in the capital stock. The instruments chosen are the relative variable inputs prices¹⁵, the lagged values of the exogenous cost arguments and output quantity, the beginning of the year capital stocks for physical capital stock and abatement capital stock, and lagged values of net investment in physical capital and abatement capital endogenized to accommodate non-static expectations.¹⁶

The estimation results for 15 Taiwan manufacturing industry for the period 1982-1997 indicate a high degree of precision in the model, gauged in terms its explanatory power. All equations exhibit R^2 s of .9 or better, except for the Euler equation for physical capital that explains 72% of the variation in the capital input. The estimated coefficients are adjusted for serial correlation and heteroskedasticity, and hence the quantities inferred from them -- economies of scale, adjustment costs, total factor productivity, and the impacts of environmental regulation on TFP, etc. -- are unbiased. The usefulness of this

quantities. See also Norsworthy and Jang (1992, chapter 3) for a discussion of the advantages of the demand equation over the share equation.

¹³ A depreciation rate of 10% has been used in many studies in dynamic production modeling (see, for example, Bernstein and Nadiri 1991; Nadiri and Prucha 1994; Manuneas 1999).

¹⁴ As shown by Pindyck (1982) and Pindyck and Rotemberg (1983), if the error terms are conditionally homoskedastic, the GMM estimator proposed by Hansen (1982), Hansen and Singleton (1982), is equivalent to the NL3SLS.

¹⁵ The variable input prices are instrumented because in the Euler equations it is the expectations of future prices for p_L , p_M that are relevant.

¹⁶ The instrumental variables chosen didn't include any current variables appearing in the estimated equations since measurement errors, optimization errors or technological shocks might be correlated with variables in the cost function, input demand equations and the Euler equations.

specification was also suggested from the overall significance of the higher-order terms. In the following subsections, the measure of investment incentives, scale economies, and adjustment costs will first be analyzed, and then the impacts of the environmental regulations on TFP will be decomposed into 5 categories of sources: pure technical changes, direct abatement effects, indirect abatement effects, price and scale effects, and adjustment effects.

4.1 Measure of Investment Incentives, Economies of Scale, and Adjustment Costs

Measures of economies of scale and adjustment costs are presented in Table I. The scale economies, defined as the inverse of the sum of output coefficients minus the quasi-fixed input coefficients,¹⁷ have important implications on the interpretation of productivity-growth measures. This linkage emerges because cost changes arising from fixities and output growth given the existing technology, as well as those from technical change, will be captured in standard productivity-growth measures. This will affect measures of environmental regulation on both financial and productive performance. For all 15 Taiwan manufacturing industries, there are significant economies of scale: e.g. Precision Machinery Manufacturing (1.67), Rubber Products (1.56), Leather Products (1.68), Miscellaneous Products Manufacturing (1.54), and Electricity and Electronics Manufacturing (1.52), etc.. We also found higher price and scale effects induced by the environmental regulation (in Table IV) for the industries with higher measures of the economies of scale. So these measures also indicate there may be strong innovation induced effects for the industries with strong economies of scale.

The adjustment costs of quasi-fixed factors net investment provides the linkage between current marginal costs and expected future benefits. It can be seen from Table I that all the adjustment costs are positive, as the theory requires.¹⁸ Although adjustment costs for physical stocks tend to be quite significant for most industries, it may not indicate the speed of the adjustment process. Rapid adjustment may be due to a large marginal value of the capital stock, a decline in the relative price of high-tech capital, a lack of significant adjustment costs, or the low cost share of this type of capital.

¹⁷ As it is defined in Denny, Fuss and Waverman (1981).

Although adjustment costs for physical capital are significant for most industries, adjustment costs tended to be between 4% and 30% of per unit capital (rental) costs, which, in turn, are a small share of total costs.

Shadow values of physical capital and indexes of the shadow-value ratios are presented in Table II. The marginal shadow value $Z_k = -\partial C_v / \partial x_k$ shows the savings on variable inputs allowed by a marginal increase in x_k . The shadow value ratio ($ZKRAT = Z_k / p_k$) will fall short of 1 to the extent that the value to the firm of an addition to the asset stock is less than the market price. These measures can be used to assess the economic motivation underlying differences and similarities in investment decisions between industries. The increases in shadow-value ratios for physical capital reveal that when investment incentives increase in the sense that the marginal valuation (product) increases relative to the market price. This suggests that there was less pressure to reduce the capital stock to accommodate utilization problems, even with positive net investment still not clearly “economical” given current costs. The shadow-value ratio can be interpreted as an overall measure of investment motivations and short-term cost effects. These measures in Table II show strong investment incentives for the following industries: Textile Industry, Petroleum & Coal Products, Non-Metal Industry, Basic Metals Industry, Metal Products Manufacturing, Machinery Equipment Manufacturing, and Electricity and Electronics Manufacturing.

4.2 The Decomposition of the Impacts of Environmental Regulations on TFP

As a basis for our analysis, the impacts of environmental regulation on industry TFP are decomposed into five major components: (a) the pure technical change; (b) the direct abatement effect (growth in the direct cost of abatement requirements per unit of conventional output); (c) the indirect abatement effect (the shift in C_v due to abatement capital purchases); (d) price and scale effects; (e) adjustment costs effects due to changes in quasi-fixed inputs. The empirical results of estimating total productivity and the direct and indirect productivity effects of environmental regulations are shown in

¹⁸ The variable cost function should be increasing and convex in net investment. This is satisfied at all points of

Table III - V.

The direct effect of environmental regulations on productivity growth is due to the growth in the direct cost of abatement requirements per unit of conventional output as conventional inputs and production processes are changed in response to requirements to purchase abatement capital. For the overall manufacturing industries, we have found negative relationship between pollution abatement costs and total factor productivity level and growth rate, shown in Table III. These measures coincide with the conventional wisdom that the effect of environmental regulation on productivity is negative. The magnitudes of the estimated coefficients of direct effects in this study are different across manufacturing industries, with Garments & Clothing, Textile Industry and Foods Industry are more significant than other manufacturing industries.

There can be further indirect abatement effects revealed by the diversion of resources toward required abatement capital and the shift in C_v due to abatement capital purchases. It indicates the overall impact on the reallocation effects on the outputs and inputs. To achieve better environmental quality, the firm may have to reduce the use of pollution-intensive inputs, reduces output quantity, or lowers short run profits. In recent work, Gray and Shadbegian (1998) also reflects this effect by showing that environmental investment "crowd out" productive investment within a plant, and firms shifting investment towards plants facing less stringent abatement requirements. The negative indirect abatement effects also show for all 15 Taiwan manufacturing industries, with more significant effects in Machinery Equipment Manufacturing, Non-Metal Industry, Basic Metals Industry, and Transportation Tools Manufacturing than other manufacturing industries.

Technical changes are the pure Solow residues of productivity growth, indicating what left over unexplained of the technological changes. The technical changes are most notable in the following order: Electricity and Electronics Manufacturing, Metal products Manufacturing, Basic Metals Industry, Forest & Furnitures, and Non-Metal Industry. (Table III) Price and scale effects indicate that to some extents the industries have some monopoly power to raise the price or expand the scale in order to maintain the profit margin. These effects are significant especially for some oligopolistic

industries with highly concentration and market power. Table IV shows for all 15 Taiwan manufacturing industries there are positive price and scale effects, with the significance in the following order: Petroleum & Coal Products, Non-Metal Industry, Basic Metal Industry, Metal Products Manufacturing, Machinery Equipment Manufacturing, Electricity and Electronics Manufacturing, and Transportation Tools Manufacturing, etc..

Adjustment costs effects occur due to the dynamic adjustments of “quasi-fixed” factors. The internal adjustment costs incorporated in this dynamic setting represent the aggregate of the internal purchased costs and installation costs of the changes in quasi-fixed inputs (physical capital). The investment and then the resulting internal adjustment costs are endogenous in the production function. The adjustment cost effects show that the changes in the quasi-fixed inputs induced by the environmental regulation in effect improve the enterprise efficiency for all 15 manufacturing industries. (Table IV) The positive adjustment effects for all manufacturing industries show the adjustment process has positive impacts on enterprise efficiency, and reflecting how enterprise strive for efficiency gains. The role of physical capital (and in this case, human capital and R&D are not divided from the capital category) and its adjustments play important role for enterprise in complying with the new environmental standard. The positive and statistically significant internal adjustment costs show important dimension that should not be ignored in the industrial transformation process to the new environmental standard.

Of all 15 manufacturing industries, the total indirect effects (the sum of the indirect abatement effects, price and scale effects, and the adjustment effects) are positive for all 15 Taiwan manufacturing industries. It could explain by the following scenarios: (1) Most Taiwan manufacturing industries have input allocation flexibilities to some extent to accommodate the environmental regulations and still keep the expansion of total costs in control. (2) Or alternatively, some industries may have some monopoly power to raise the price or expand the scale in order to keep the profit margin. (3) The extra abatement requirements push the firms to seek for more innovative activities in order to cut down the production costs, and furthermore increases the productive technology efficiency. And the implication is clear that the regulatory authorities should provide more insights in designing incentive regulation mechanism, instead of command and control mechanism for the high-tech

innovation-induced industries.

The overall impacts of environmental regulation on enterprise efficiency for most industries are the increase of the productive performance. Comparing the manufacturing industries, we find that Basic Metals, Metal Products Manufacturing, and Electricity and Electronics Manufacturing show the greatest indirect spillover effects of environmental regulations. Due to the significant indirect effects, the enterprises are willing to invest in R&D in order to exert more indirect effects that generate benevolent cycles. And the overall effects of the environmental regulation on TFP are significantly positive for all 15 Taiwan manufacturing industries. It reflects the fact that the implementation of environmental regulation is not crowding out the production costs, but instead it stimulates industry's innovation and diffusion, and furthermore increases the productive technology efficiency. However, environmental regulation had a very uneven impact on manufacturing industries, depending on their market structure, industry characteristics, number and size structure of plants and factor shares.

V. Concluding Remarks

This paper provides an empirical dynamic framework to explicitly incorporate associated adjustments in analyzing the inter-connection relationship among enterprise efficiency, technological factors, adjustment costs, economic incentives and the measure of environmental regulations. The model is convincing in that it accounts for more than 90 percent of the variation in variable costs, and in the demands for labor and materials inputs, and captures 72 percent of the variation in the capital input. Overall, the model performs well in decomposing the direct and indirect effects of environmental regulation abatements on industry productivity and in clarifying the role of capital as quasi-fixed inputs and the resulting investment behavior. The model exhibits positive adjustment costs for all time period. While the overall adjustment cost results are plausible, we consider that the particular specification reported here is only an example of what may be achieved in the future with more industry-specific detail introduced into the adjustment cost function. Because of the importance of technological innovation and structural changes in Taiwan manufacturing industry, we expect that adjustment cost model illuminates in the production modeling analysis for Taiwan manufacturing

industry.

The dynamic production modeling is applied to estimate total factor productivity and the direct and indirect productivity effects of environmental regulation. The empirical results for 15 Taiwan manufacturing industries show a positive total effects of environmental regulations on overall industry productivity for all 15 Taiwan manufacturing industries. For the overall manufacturing industries, we have found a significant negative relationship between pollution abatement costs and total factor productivity level and growth rate. The magnitudes of the estimated coefficients of direct effects are different across manufacturing industries, with Petroleum & Coal Products and Basic Metals Industry are more significant than other manufacturing industries. Though there are negative direct effects and indirect abatement effects reveal the environmental investment crowding out productive investment, the induced significant positive price and scale effects and adjustment cost effects result in positive total indirect effects for most of Taiwan manufacturing industries. Comparing the 15 manufacturing industries, we find that Basic Metals, Metal Products Manufacturing, and Electricity and Electronics Manufacturing show the greatest indirect spill-over effects of environmental regulations. And the positive adjustment effects for all manufacturing industries show the adjustment process has positive impacts on enterprise efficiency, and reflecting how enterprise strive for efficiency gains. The role of physical capital (and in this case, human capital and R&D are not divided from the capital category) and its adjustments play important role for enterprise in complying with the new environmental standard. The positive and statistically significant internal adjustment costs show important dimension that should not be ignored in the industrial transformation process to the new environmental standard.

The empirical evidence of this study also shows environmental regulation had uneven impacts on Taiwan manufacturing industries, depending on their market structure, industry characteristics, number and size structure of plants and factor shares. For all 15 Taiwan manufacturing industries, there are significant economies of scale: e.g. Precision Machinery Manufacturing, Rubber Products, Leather Products, Miscellaneous Products Manufacturing, and Electricity and Electronics Manufacturing, etc.. For the industries with more significant economies of scale and lower adjustment costs (e.g. Basic Metals, Metal Products Manufacturing, and Electricity and Electronics

Manufacturing), we found greater indirect spill-over effects of environmental regulations. So these measures also indicate there may be strong innovation induced effects for the industries with strong economies of scale. And the implication is clear that the “right” industries should be identified with higher economies of scale, lower adjustment costs, and greater indirect spill-over effects of environmental regulations to effectively enhance optimal policy in aiming at both economic efficiency and environmental perpetual development for a balanced growth. This study also sheds light on the regulatory authorities should provide more insights in designing incentive regulation mechanism, instead of command and control mechanism for the high-tech innovation-induced industries.

To inform the regulatory process, it is important to investigate the decomposition of TFP growth into components due to pure technical changes, direct abatement effects, indirect abatement effect (growth in the direct cost of abatement requirements per unit of conventional output), price and scale effects, and adjustment costs effects due to changes in quasi-fixed inputs. The empirical evidence shows that higher price and scale effects induced by the environmental regulation associate with the industries with higher measures of the economies of scale and lower adjustment costs. And the measures of indirect abatement effects, price and scale effects and adjustment effects also indicate there may be strong innovation induced effects for the industries with strong economies of scale. It indeed provides insights in designing incentive regulation mechanism, instead of command and control mechanism for high-tech innovation-induced industries. However, TFP differences signal differences in unit cost reduction. The economic logic of the Laffont-Tirole framework suggests that differences in management practice and in regulatory oversight may account for part of the differing productivity performance records in different industries.

Further studies of the above discussion issues using plant level data as comparative case studies might also improve the information base for regulatory authorities. The plant level dataset may also shed light on the geographical variation and the different policy tools that might generate more effective level of technological innovation. Other future research and the ongoing work are focused in the following directions. The adjustment costs should be occurred not only for productive quasi-fixed inputs but also for abatement capital. The model is not yet incorporating all the indirect effects into consideration, e.g., the spill-over effects induced by protecting or enhancing environmental

quality, new technology invention, innovation, diffusion, etc..

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<Table I> The Economies of Scale and Adjustment Costs for 15 Taiwan Manufacturings, 1987 - 1997

Industry	Economies of Scale	Adjustment Costs
Foods Industry	1.49032	0.05592
Textile Industry	1.50212	0.20107
Garments & Clothing	1.51966	0.36765
Leather Products	1.68555	1.59950
Forest & Furnitures	1.62423	0.45538
Petroleum & Coal Products	1.52407	0.28147
Rubber Products	1.55742	0.58008
Non-Metal Industry	1.50732	0.34720
Basic Metals Industry	1.50215	0.10803
Metal Products Manufacturing	1.51507	0.17947
Machinery Equipment Manufacturing	1.50186	0.16979
Electricity and Electronics Manufacturing	1.52122	0.40677
Transportation Tools Manufacturing	1.49754	0.11997
Precision Machinery Manufacturing	1.66757	0.28127
Miscellaneous Products Manufacturing	1.54011	0.37098

<Table II> The Shadow Costs of Capital and Shadow Value Ratios for 15 Taiwan Manufacturings, 1987 -1997

Industry	Shadow Costs of Capital	Shadow Value Ratios
Foods Industry	-1.33562	-0.89913
Textile Industry	-1.83475	-1.80652
Garments & Clothing	-0.83608	-0.83724
Leather Products	-0.82293	-0.84177
Forest & Furnitures	-0.31527	-0.31401
Petroleum & Coal Products	-2.71284	-2.68764
Rubber Products	-0.54628	-0.55404
Non-Metal Industry	-2.14063	-2.24337
Basic Metals Industry	-2.08047	-2.02570
Metal Products Manufacturing	-1.64654	-1.61951
Machinery Equipment Manufacturing	-2.19932	-2.04786
Electricity and Electronics Manufacturing	-1.72300	-1.69331
Transportation Tools Manufacturing	-0.33552	-0.87243
Precision Machinery Manufacturing	-0.63964	-0.66568
Miscellaneous Products Manufacturing	-0.86794	-0.85279

<Table III> The Technical Changes, Direct and Indirect Abatement Effects of Environmental Regulations on Productivity Growth for Each Industry

Industry	Technical Changes	Direct Abatement Effects	Indirect Abatement Effects
Foods Industry	0.0088916	-0.035122	-0.044327
Textile Industry	0.0084377	-0.035531	-0.043091
Garments & Clothing	0.0072751	-0.037780	-0.038308
Leather Products	0.0053275	-0.023677	-0.028496
Forest & Furnitures	0.010232	-0.025785	-0.034273
Petroleum & Coal Products	0.0090706	-0.030595	-0.043480
Rubber Products	0.0079545	-0.028902	-0.035852
Non-Metal Industry	0.0097960	-0.032881	-0.045235
Basic Metals Industry	0.010085	-0.033720	-0.044917
Metal Products Manufacturing	0.010109	-0.032475	-0.044277
Machinery Equipment Manufacturing	0.0096933	-0.033490	-0.045547
Electricity and Electronics Manufacturing	0.010995	-0.033559	-0.044481
Transportation Tools Manufacturing	0.0093787	-0.034423	-0.044861
Precision Machinery Manufacturing	0.0071983	-0.026228	-0.036336
Miscellaneous Products Manufacturing	0.0080412	-0.032360	-0.037983

<Table IV> The Scale Effects and Adjustment Costs Effects of Environmental Regulations on Productivity Growth for Each Industry

Industry	Price & Scale Effects	Adjustment Costs Effects
Foods Industry	0.047347	0.051688
Textile Industry	0.046027	0.051718
Garments & Clothing	0.040917	0.052453
Leather Products	0.030438	0.051470
Forest & Furnitures	0.036608	0.052592
Petroleum & Coal Products	0.046442	0.051653
Rubber Products	0.038295	0.051403
Non-Metal Industry	0.048317	0.051700
Basic Metals Industry	0.047977	0.051693
Metal Products Manufacturing	0.047293	0.051765
Machinery Equipment Manufacturing	0.048650	0.051677
Electricity and Electronics	0.047511	0.051709
Manufacturing		
Transportation Tools Manufacturing	0.047917	0.051821
Precision Machinery Manufacturing	0.038811	0.051705
Miscellaneous Products Manufacturing	0.040571	0.052362

<Table V> The Indirect Effects and Total Effects of Environmental Regulations on Productivity Growth for Each Industry

Industry	Indirect Effects	Total Effects
Foods Industry	0.063600	0.028477
Textile Industry	0.063092	0.027560
Garments & Clothing	0.062337	0.024557
Leather Products	0.058740	0.035062
Forest & Furnitures	0.065159	0.039374
Petroleum & Coal Products	0.063686	0.033090
Rubber Products	0.061801	0.032898
Non-Metal Industry	0.064578	0.031696
Basic Metals Industry	0.064838	0.031117
Metal Products Manufacturing	0.064890	0.032414
Machinery Equipment Manufacturing	0.064473	0.030984
Electricity and Electronics Manufacturing	0.065734	0.032175
Transportation Tools Manufacturing	0.064256	0.029833
Precision Machinery Manufacturing	0.061378	0.035151
Miscellaneous Products Manufacturing	0.062991	0.030631