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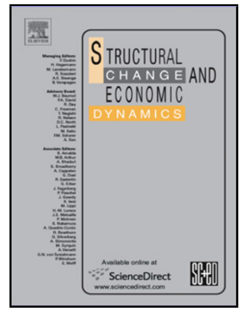

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The Effects of Dynamic Industrial Transition on Sustainable Development

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Highlights

- A conformational two-state mechanism for proton pumping complex I is proposed.
- Empirical evidence revealing significant impacts on the environmental stress that results
- from industrial transition and economic structural changes.
- MS and GMM estimations to predict the dynamics of industrial development and
- structural changes, and its influence on sustainable development in Taiwan.

Abstract

This paper analyzes the dynamics of industrial development and structural changes, and its impacts on sustainable development. The weak form of the Porter Hypothesis is examined under industrial transition and structural changes. Explicitly incorporating the Markov regime switching mechanism in a productivity framework, we measure how sustainable development is affected and how firms are adjusted when facing industrial transition and structural changes. Applied to Taiwan manufacturing industries, the model is implemented to identify structural changes and to evaluate the viability of sustainable development under new constraints. This study suggests industries to adopt more sustainable practices which can promote and even improve industrial competitiveness. Such practices would empower economies to assess current structural changes and, based on the environmental implications, recommend future economic policy for sustainable development.

Keywords: industry dynamics; sustainable development; industrial transition; structural changes.

JEL code: C5; L5; O3

1. INTRODUCTION

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 declared clearly to be the goal of the sustainable development supported by balancing growth in economic development with environmental protection. Adopting the values of sustainable development implies an increase in the industry's environmental and social costs[1]. For developing countries already struggling to provide basic needs, the extra environmental costs could potentially hinder further industrial development. In theory, the relationship between environmental goals and industrial competitiveness has been thought of as involving a tradeoff between social benefits and private costs. However, in practice, the role of regulation induced technological innovation in the course of industrial transition may help to avoid or reduce negative environmental impacts, while at the same time promoting economic efficiency thereby lowering the costs of the environmental improvements.

This paper assesses the economic structural changes, industrial transition on the sustainability in the developing countries. The weak form of the Porter Hypothesis is examined under industry cycles and structural changes. This paper investigates the existing and potential environmental impacts of industrial transition and economic structural changes. We analyze the relationships between industrial transition, economic structural changes and environmental impact assessment. The scope and characteristics of the economic structural changes and industrial transition in the developing countries are considered and whether it's corresponding to the principles of sustainable development is examined. In exploring industrial competitiveness and sustainable development, we aim at both industrial competitiveness and sustainable development for balanced growth. The purpose is to design effective sustainable development strategies to stimulate innovation and ask the following questions: What are the determinants for the sustainable development? What should be the future direction and strategic industrial planning based on sustainable development? What is the practice and implementation of the

[1] Social cost represents the total burden a regulation will impose on the economy; it may be defined as the sum of all opportunity costs incurred as a result of the regulation.

sustainable development from the regional advantage perspective?

In the earlier literature, the conflicts between industrial competitiveness and environmental performance seem quite obvious. In order to comply with the environmental standards, some ‘unproductive’ inputs have to be used for accommodating the environmental standard. 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; Conrad and Wastl 1995; etc.).

Recently, the environment-competitiveness debate has been shifted to a new dynamic paradigm. Markets have evolved some of the most innovative and useful solutions for global environment problems. (E.g. Barbara and McConnell, 1990; Gray and Shadbegian, 1998; Jaffe and Stavins, 1995; Porter and Linde, 1995; Jaffe, et al. 1995; Jaffe and Palmer 1997; etc.) Theoretical and empirical researches have provided debates of environment-competitiveness for both positive and negative relationships and have not been conclusive so far.

The empirical studies regarding the environment-competitiveness relationship had been quite different in manufacturing industries, depending on their market structure, industry characteristics, number and size structure of plants and factor shares. Gray and Shadbegian (1993) analyze the impact of pollution abatement expenditure on productivity and find that more regulated plants have lower productivity growth compared to less regulated plants. Hartman et al. (1999) apply a large US plant-level database to estimate the costs of abatement for major air pollutants (e.g. sulphur oxides, carbon monoxide, hydrocarbons, lead, etc.) in all US manufacturing sectors and conclude that command-and-control regulation in the US has incurred emissions reduction at unnecessarily high cost, leading to priority-setting foundation. Gray and Shadbegian (1998) examine investment allocation across existing plants and proclaim environmental investment "crowding out" productive investment within a plant, that firms shift investment towards plants facing less stringent abatement requirements.

The traditional econometric model proved not to be adequate in measuring output growth in the perspectives of sustainable development (Daly and Cobb, 1989; Constanza, 1991; Schleicher, 1993). The environmental impact assessment methods then span a wide spectrum from simple, limited in scope, and narrow in focus, to sophisticated, inclusive of many impacts, and explicit in valuation, e.g. the health hazard scoring (HHS) system, the material input per service-unit (MIPS), the sustainable process index (SPI), the Society of Environmental Toxicology (SETAC), the life-cycle impact assessment (LCA), the environmental priority system (EPS), etc.. The aggregation of information on diverse impacts to a single index invariably involves values and ethical principles. The identification of the proper trade-off between the conflicting demands for simple indicators and the avoidance of perverse outcomes is crucial for environmental assessment. Literatures on green structural transformation attempts to measure the changes in the national economy in which industries and/or companies conduct industrial transformation that lead to reduced environmental change impact. (Lü, Geng and He, 2015; OECD, 2013)

The relationship between economic or industrial restructuring and environmental changes was not widely explored, partly due to the difficulty of collecting suitable data and indicators with which to illustrate the impacts of structural changes on the environment. In part it was also due to the fact that economic growth and development had always been highly appraised than changes in the natural environment. More recently, the issues have finally received increasing importance since today's technological decisions face new economic realities that come closer to the principle of sustainability. Strategic measures evaluate the viability of processes under new constraints of competition and even have to count for the dynamics of the economic transition. Such practices would empower economies to assess current structural changes and, based on the environmental implications, recommend future economic policy for sustainable development.

The relationship between economic transition and environmental impact assessment is particularly important for the developing countries, like Taiwan. We analyze the relationship from the perspectives of the role of environmental impact assessment in the process of the economic transition, the potential effectiveness of the strategic environmental assessment to economic transition, and the influences of economic transition on the evolution and effectiveness of environmental impact assessment. Taiwanese industries are chosen as target industry because Taiwan's economy has recently gone through structural changes due to the industrial restructuring from traditional highly polluting manufacturing industries to high-technology industries. Also the particular challenges faced by Taiwanese industries appear to be less to do with rising environmental costs than experiencing structural change and industrial transition. For example, the plants in Taiwan are relocating to China which has recently proved to be with lower production cost and less environmental sensitivity.

This study involves empirical research into the workings of a number of industries in Taiwan. The study are intended to improve our understanding of the industries involved, and, more broadly, to help assess the relevance of a number of economic theories of competitiveness-environment complexity. The weak form of the Porter Hypothesis is examined under industrial transition and structural changes by measuring how sustainable development is affected and firms are adjusted when facing industrial transition and structural changes. It is suggested that industry's adoption of more sustainable practices will require, and could even promote, and improve industrial competitiveness. Such an examination would make it possible to appraise current structural changes and, on the basis of their environmental implications, suggest future directions for environmentally benign structural policies.

The rest of the paper is organized as follows. Section 2 proposes a dynamic model of production incorporating industry structural changes and abatement capital. The empirical results are presented in section 4. In the final section we provide a summary and conclusion. Data and variables' description are incorporated in the Appendix.

2. MODEL FORMULATION

We establish a two-stage model which provides empirically tractable procedures for incorporating industrial transition and structural changes. The first stage involves identifying the regime switching turning points and transition probabilities through estimating a Markov Regime-Switching Model. Conditioned on the estimated turning points and transition probabilities obtained from the first stage, the second stage builds up a functional specification for the optimal objective cost function and jointly estimates the structural equations of dynamic output supply and input demand to investigate the environmental effects of industrial transition and structural changes.

2.1. First-Stage Model

In the first stage, we define two states in Markov switching process to investigate the turning points of the industrial transition. The two states in Markov switching process are upturns (peak) and downturns (trough) and these 2 stages are switching through first order Markov process to catch asymmetry characteristics. The state parameter S_t is set up to be 1 (or 0) to catch the industry transition.

$$
\begin{aligned}
&Y_t = X_t\beta_{st} + e_t \qquad t = 1,\ldots,T \qquad e_t \sim N(0,\Sigma_{st}^2) \\
&X_t \equiv \left(X_{1t}, X_{2t}, \ldots, X_{nt}\right) \qquad t = 1,\ldots,T \\
&\beta_{st} \equiv \left(\beta_{1st}, \beta_{2st}, \ldots, \beta_{nst}\right) \qquad t = 1\ldots,T \qquad s = 0\ , \\
&\beta_{st} = \beta_0\left(1 - S_t\right) + \beta_1 S_t \\
&\Sigma_{st} = \Sigma_0\left(1 - S_t\right) + \Sigma_1 S_t\ 1
\end{aligned}
\tag{1}
$$

Where Y_t represents the homogeneous output of the firm,

X_t denotes n inputs,

β_{st} indicates estimated coefficients, and

Σ_{st} is the variance-covariance matrix.

Suppose the state parameter (S_t) is influenced by first order Markov chain. The transfer probability matrix is then specified as:

$$
P_r\begin{bmatrix} P_{00} & P_{01} \\ P_{10} & P_{11} \end{bmatrix}
\qquad
\begin{aligned}
&P_r[S_t = 0 \mid S_{t-1} = 0] = P_{00} \\
&P_r[S_t = 1 \mid S_{t-1} = 0] = 1 - P_{00} \\
&P_r[S_t = 1 \mid S_{t-1} = 1] = P_{11} \\
&P_r[S_t = 0 \mid S_{t-1} = 1] = 1 - P_{11} = P_{10} = P_{01}
\end{aligned}
\tag{2}
$$

where P_{ij} (i, j = 0, 1) denote the transition probabilities of $S_t = j$ given that $S_{t-1} = i$.

Due to the fact that the parameters could be co-linear, we specify multidimensional normal distribution for the parameters. The Maximum likelihood estimation (MLE) and Gibbs sample law are applied to estimate Markov Regime-Switching Model[2].

2.2. Second-Stage Model:

We define S value 1(0) to represent the changes of industry states in structural changes. The structural change functions are incorporated into the dynamic factor demand function model. The estimated coefficients will then reflect the impacts of different states. The production technique can be described by the factor requirement function:

[2] See Tsai and Lin (2015) for more detailed algebra launched in the Markov Regime-Switching Model specification.

$$M_t = M(Y_t, L_t, K_{t-1}, A_{t-1}, \Delta K_t, \Delta A_t, T_t) \tag{3}$$

The firm employs two variable inputs, material (*M*) and labor (*L*), and two quasi-fixed factors, physical capital (*K*) and abatement capital (*A*), in producing a single output (*Y*) from a technology with adjustment costs. We assume that producers' behavior may be affected by the capital of their competitors within and among the industries. K_{t-1}, A_{t-1} denotes the end-period-stocks of physical capital and abatement capital; ΔK_t, ΔA_t represents the internal adjustment costs in term of forgone output due to the stocks' change of physical capital and abatement capital respectively; and T_t is the index of exogenous technical change and learning. It is assumed that in each period *t*, each firm derives an optimal plan such that the present value of current and future cost streams is minimized.

$$\begin{aligned}\min E_t \sum_{\tau=t}^{\infty} \{ \ & M(Y_\tau, L_\tau, K_{\tau-1}, A_{\tau-1}, \Delta K_\tau, \Delta A_\tau, T_\tau) + (p_\tau^L) L_\tau + (p_\tau^K)[K_\tau - (1-\delta_\tau^K) K_{\tau-1}] \\ & + (p_\tau^A)[A_\tau - (1-\delta_\tau^A) A_{\tau-1}] \ \} \prod_{s=t}^{\tau} (1+r_s)^{-1}\end{aligned} \tag{4}$$

where *E* is the expectations operator conditional on information available at the beginning of the period *t* and *r* denotes the real discount rate. To incorporate industrial transition and structural changes that could cause the market volatility (or financial instabilities), and further impact on industry dynamics, we conceptualize the idea of structure turning point and define the transfer probability in Markov Regime-Switching Model. Thus, the objective function at time *t* for an infinite planning horizon is as follows

$$\begin{aligned}\sum_{\tau=t}^{\infty} \{ \ & G(E_t p_\tau^M, E_t Y_\tau, K_{\tau-1}, A_{\tau-1}, \Delta K_\tau, \Delta A_\tau, T_\tau) + (E_t p_\tau^K)[K_\tau - (1-\delta_\tau^K) K_{\tau-1}] \\ & + (E_t p_\tau^A)[A_\tau - (1-\delta_\tau^A) A_{\tau-1}] \} \prod_{s=t}^{\tau} (1+r_s)^{-1}\end{aligned} \tag{5}$$

where

$$\begin{aligned} E_t p^L &= \left(\beta_{10}\alpha_{s0t} + \beta_{11}\alpha_{s1t}\right) p_{t-1}^L \\ E_t p^K &= \left(\beta_{20}\alpha_{s0t} + \beta_{21}\alpha_{s1t}\right) p_{t-1}^K \quad , \\ E_t Y &= \left(\beta_{30}\alpha_{s0t} + \beta_{31}\alpha_{s1t}\right) Y_{t-1} \end{aligned}$$

$$\beta_{ist} = \beta_0 D_{0t} + \beta_1 D_{1t} \qquad i = 1 \sim 3$$
$$\varepsilon i_{st} = \varepsilon_0 D_{0t} + \varepsilon_1 D_{1t}$$

p^L and p^M denote respectively the prices of labor and materials, and p^K, p^A indicate prices of quasi-fixed inputs (physical capital, K, and abatement capital, A); δ_τ^k denotes the depreciation rate of physical capital (δ_τ^K) and abatement capital (δ_τ^A).

$$\begin{aligned} P_r[S_t = j \mid V_t] &= P_r[S_t = j \mid V_{t-1}, Y_t] \\ &= \frac{f(S_t = j, Y_t \mid V_{t-1})}{f(Y_t \mid V_{t-1})} = \frac{f(Y_t \mid S_t = j, V_{t-1}) P_r[S_t = j \mid V_{t-1}]}{\sum_{j=0}^{1} f(Y_t \mid S_t = j, V_{t-1}) P_r[S_t = i \mid V_{t-1}]}, \end{aligned} \tag{6}$$

where $V_t = \{V_{t-1}, Y_t\}$, V_t is information available at time t, that is, the vector of all exogenous variables at time t.

$$\alpha_{s1t} = P_r[S_t = 1 \mid V_t] \qquad V_t = \{V_{t-1}, Y_t, x_{k,t-1}, \Delta x_{k,t}, T_t\}$$

Assume $D_{1t} = 1$, $D_{0t} = 0$

$$\left\langle \begin{array}{l} \alpha_{s1t} \geq 0.5 = D_{1t} \\ \alpha_{s1t} < 0.5 = D_{0t} \end{array} \right. \qquad i = 0,1 \qquad t = 1 \sim \infty$$

α_{s1t} and α_{s0t} are the transitional probability estimated by Markov Regime-Switching Model. $x_{k,\tau-1}$ $(x_k = K, A)$ denotes the end-period-stocks of physical capital (K) and abatement capital (A); $\Delta x_{k,\tau}$ represents the internal adjustment costs due to changes in physical and abatement capital.

The empirical framework is then based on a normalized variable cost function $G(\cdot)$, assumed to be of the following linear quadratic form:

$$\begin{aligned} & G(p^i, x_{k,t-1}, \Delta x_{k,t}, T_t, Y) \qquad i = L, K \\ & = Y^{1/\rho} \left\{ \alpha_0 + \alpha_i p^i + \frac{1}{2}\gamma_{ii}(p^i)^2 + \beta_{iT} p^i T_t \right\} \\ & + \left\{ \alpha_k x_{k,t-1} + \beta_{ki} p^i x_{k,t-1} + \beta_{kT} x_{k,t-1} T_t + \alpha_{\dot{k}} \Delta x_{k,t} + \beta_{\dot{k}i} p^i \Delta x_{k,t} + \beta_{\dot{k}T} \Delta x_{k,t} T_t \right\}, \\ & + Y^{-1/\rho} \left\{ \frac{1}{2}\gamma_{kk}(x_{k,t-1})^2 + \frac{1}{2}\gamma_{\dot{k}\dot{k}}(\Delta x_{k,t})^2 + \beta_{k\dot{k}} x_{k,t-1} \Delta x_{k,t} \right\}. \end{aligned} \tag{7}$$

The linear quadratic restricted cost function is based on the dynamic factor demand model which is first proposed by Nadiri and Prucha (1996). The restricted variable cost function must satisfy the following theoretical restriction: continuous and second-order differentiable function; homogeneous of degree one in p^i; non-decreasing in Y, $\Delta x_{k,t}$, p^i and non-increasing in $x_{k,t-1}$. Therefore, there exist the following restrictions for the normalized restricted cost function: $\gamma_{kk} > 0$, $\gamma_{kk}\gamma_{\gamma\gamma} - \beta_{kr}^2 > 0$, $\gamma_{\dot{k}\dot{k}} > 0$, $\gamma_{ii} < 0$. The internal adjustment cost implied in the above restricted normalized cost function (14) is:

$$Y^{-1/\rho}\left\{\frac{1}{2}\gamma_{\dot{k}\dot{k}}(\Delta x_{x,t})^2\right\}.$$

The optimal quasi-fixed inputs are obtained by minimizing and satisfy the non-stochastic Euler equations, and follow Markov switching form of AR (1) to obtain factor demand equations.

$$\begin{aligned}\Delta K_t &= d_{KK}[\alpha_K + \beta_{KL}B_{1st}p^L + (r_s + \delta_K)B_{2st}p^K]\hat{Y}^{1/\rho} \\ &+ d_{KA}[\alpha_A + \beta_{AL}B_{1st}p^L + \beta_{AT}T_t + (r_s + \delta_A)p^A]\hat{Y}^{1/\rho} + [c_{KK}/\gamma_{\dot{K}\dot{K}}]K_{t-1} + [c_{KA}/\gamma_{\dot{K}\dot{K}}]A_{t-1}\end{aligned} \tag{8}$$

$$\begin{aligned}\Delta A_t &= d_{KA}[\alpha_K + \beta_{KL}p^L + \beta_{KT}T_t + (r_s + \delta_K)p^K]\hat{Y}^{1/\rho} \\ &+ d_{AA}[\alpha_A + \beta_{AL}p^L + \beta_{AT}T_t + (r_s + \delta_A)p^A]\hat{Y}^{1/\rho} + [c_{KA}/\gamma_{\dot{A}\dot{A}}]K_{t-1} + [c_{AA}/\gamma_{\dot{A}\dot{A}}]A_{t-1}\end{aligned} \tag{9}$$

And the optimal demand of variable inputs is obtained by Shephard's lemma.

$$\hat{L}_t = Y^{1/\rho}\left(\alpha_L + \beta_{LT}T_t + \gamma_{LL}p^L\right) + \left(\beta_{KL}K_{t-1} + \beta_{AL}A_{t-1}\right) \tag{10}$$

$$\begin{aligned}\hat{M}_t &= Y^{1/\rho}\left\{\alpha_0 - \frac{1}{2}\gamma_{LL}(p^L)^2\right\} + \left\{\alpha_{K_1}K_{1,t-1} + \alpha_A A_{t-1} + \beta_{KT}K_{t-1}T_t + \beta_{AT}A_{t-1}T_t\right\} \\ &+ Y^{-1/\rho}\left\{\frac{1}{2}\gamma_{KK}(K_{t-1})^2 + \frac{1}{2}\gamma_{AA}(A_{t-1})^2 + \beta_{KA}K_{t-1}A_{t-1} + \frac{1}{2}\gamma_{\dot{K}\dot{A}}(\Delta K_t)^2 + \frac{1}{2}\gamma_{\dot{A}\dot{A}}(\Delta A_t)^2\right\}.\end{aligned}, \tag{11}$$

where

$$\begin{aligned}p^L &= \left(\beta_{10}\alpha_{s0t} + \beta_{11}\alpha_{s1t}\right)p_{t-1}^L \\ p^K &= \left(\beta_{20}\alpha_{s0t} + \beta_{21}\alpha_{s1t}\right)p_{t-1}^K \\ \hat{Y} = Y &= \left(\beta_{30}\alpha_{s0t} + \beta_{31}\alpha_{s1t}\right)Y_{t-1}\end{aligned}$$

The estimated adjustment speed for different states can be obtained from the optimal solution of the quasi-fixed input behavior in the accelerator functions.

$$x_{k,t} = x_{k,t-1} + m_{kk}(x_{k,t}^* - x_{k,t-1}) + \sum_{k \neq r} m_{kr}(x_{r,t,}^* - x_{r,t-1}), \tag{12}$$

$k = K, A \qquad j = 0,1$

Empirical examination of both the regime switching process and the dynamic structure of an industry can thus be accomplished through a two-stage econometric model.

2.3. Total Factor Productivity (TFP) Measures

The productivity measurement in the dynamic factor demand production model, with abatement capital as effectively exogenous to the firm, are decomposed in this section. To measure the effect of abatement requirements on TFP, we re-specify the total cost:

$$C^* = C(p^L, p^M, Y, \alpha, \kappa, \Delta K, \Delta A, T) + C_K + C_A \tag{13}$$

where $\kappa = K_{t-1}, \alpha = A_{t-1}, p_t^K[K_t - (1-\delta_K)K_{t-1}] = C_K, p_t^A[A_t - (1-\delta_A)A_{t-1}] = C_A$. C_K, C_A are the investment required to maintain the current level of the stocks of quasi-fixed factors.

To measure the effect of abatement requirements on TFP, we first totally differentiate the cost function with respect to time for considering the impact of environmental regulation on productivity measurement and decomposing the growth rate of total cost into its source components.

$$\begin{aligned}\frac{d\ln C^*}{dT} &= S_c[S_L \frac{\dot{p}_L}{p_L} + S_M \frac{\dot{p}_M}{p_M} + E_{CY}\frac{\dot{Y}}{Y} E_{C\kappa}\frac{\dot{\kappa}}{\kappa} + E_{C\alpha}\frac{\dot{\alpha}}{\alpha} + E_{C\dot{K}}\frac{\ddot{K}}{\dot{K}} + E_{C\dot{A}}\frac{\ddot{A}}{\dot{A}} + \frac{d\ln C}{dT}] \\ &\quad + S_K\frac{\dot{C}_K}{C_K} + S_A\frac{\dot{C}_A}{C_A}\end{aligned} \tag{14}$$

where $S_C = C/C^*, S_L = P_L \cdot L/C, S_M = P_M \cdot M/C, S_K = C_K/C^*, S_A = C_A/C^*,$

$E_{CY} = \partial \ln C/\partial \ln Y, E_{C\kappa} = \partial \ln C/\partial \ln \kappa, \quad E_{C\alpha} = \partial \ln C/\partial \ln \alpha,$

$E_{C\dot{K}} = \partial \ln C/\partial \ln \dot{K}, \quad E_{C\dot{A}} = \partial \ln C/\partial \ln \dot{A}$ 。

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. The gross accounting approach defines the total factor productivity growth in terms of the shift of the cost function.

$$T\dot{F}P = -\frac{d\ln C^*}{dT} + \sum_i S_i \frac{d\ln P_i}{dT} + \frac{d\ln Y}{dT}$$

(15)

By substituting (14) into (15) to explore the productivity impacts, we can get the major components of $T\dot{F}P$:

$$T\dot{F}P = -S_c[E_{Ck}\frac{\dot{k}}{k} + E_{C\alpha}\frac{\dot{\alpha}}{\alpha} + E_{C\dot{K}}\frac{\ddot{K}}{\dot{K}} + E_{C\dot{A}}\frac{\ddot{A}}{\dot{A}} + \frac{d\ln C}{dT}] - S_K\frac{\dot{C}_K}{C_K} - S_A\frac{\dot{C}_A}{C_A} +$$

$$S_L(1-S_L)\frac{\dot{p}_L}{p_L} + S_M(1-S_M)\frac{\dot{p}_M}{p_M} + (1-S_C E_{CY})\frac{\dot{Y}}{Y} \qquad (16)$$

$$= IDEA + DAE + TC + ACE + SE + KE$$

The TFP growth is decomposed into six major components. The indirect effect (*IDAE*) is the shift in costs due to abatement capital purchases. It may contain innovation activity to at least partially offset the cost. A positive impact of *IDEA* on *TFP* could be interpreted as providing some evidence of the weak Porter hypothesis. Specifically, the inclusion of the *IDAE* term allows us to test whether or not there is a significant positive correlation between the dynamic innovation process and environmental regulation, which could partially offset the costs of pollution abatement. The direct effect (*DAE*) indicates the growth in the direct cost of abatement requirements per unit of conventional output. This effect increases the firm's opportunity costs, therefore it is always negative. *TC* is the technology effect, and *ACE* is the adjustment effect. *SE* is defined as the scale effects. *KE* is regarded as the capital effect. Six major components are listed in Table 1.

3. Empirical Findings

The empirical investigation is to decompose TFP to measure the effects of environmental regulation and derive dynamic innovation effect under industry transition and structural changes. The complete model includes two Euler equations of physical capital and abatement capital demand equations (8), and (9) and two variable factor (*L*, *M*) demand equations (10), and (11). Estimation of the complete model was carried out using generalized method of moments (GMM)[3], an instrumental variables technique, to adjust for the endogeneity of short run changes in the physical capital stock and abatement capital stock. The instruments chosen are the lagged values of the logarithms of relative variable inputs prices, the exogenous cost and demand arguments, output quantity, physical capital stock, R&D stock, and lagged values of net investment in R&D and physical capital endogenized to accommodate non-static expectations.[4]

The model is applied to Taiwan manufacturing plant level data. The databank is pooled over

[3] As shown by Pindyck and Rotemberg (1983), if the error terms are conditionally homoskedastic, the GMM (generalized method of moments) estimator proposed by Hansen (1982), Hansen and Singleton (1982), is equivalent to the NL3SLS.

[4] 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.

for the period 1992-2000.[5] The primary source of data is the Taiwan Industry Statistical Survey, published by the Ministry of Economic Affairs (MOEA) of the Government of the Republic of China.[6] For our analysis we chose 6 two-digit SIC industries. Three of our industries have the highest investment in abatement capital among the manufacturing industries: Electrical Machinery, Supplies and Equipment Manufacturing and Repairing (SIC31), Transport Equipment Manufacturing and Repairing (SIC32), and Plastic Products Manufacturing (SIC25), while the other three industries have the lowest investment in abatement capital: Fabricated Metal Products Manufacturing (SIC28), Food and Beverage Manufacturing (SIC11), Textiles Mills (SIC13). We present related information of the 6 industries, sample sizes and abatement capital expenditures in Table 2.

3.1. Structural Changes in the Markov Regime-Switching Model

In markets with structural changes or under industry transition, firms may have different dynamic decision rules facing upturns and downturns of the transition. To catch the industry transition, we employ the Markov Regime-Switching Model to measure the transition probability of the industry transition; that is, to explore whether Taiwan industries have structural change. The Markov Regime-Switching model which integrates regime switching with two regimes representing upturns and downturns of the transition is estimated to measure the firm's dynamic adjustments when facing upturns and downturns of structural changes. The model is estimated by numerical maximum likelihood estimation (MLE) with the initial values of p set to be 0.5. The estimated transition probability, switching variance, and test statistics of Markov Regime-Switching Models for industry SIC11, SIC13, SIC25, SIC28, SIC31, and SIC32 are shown in Table 3. The transition probability for each period indicates the probability of the state and reflects the possibility for structural changes. Table 4 presents the states and structural changes of the 6 industries. In the Plastic Products Manufacturing (SIC 25) industry, the structural change started from 1992, turned into the lower state 1994-1995, and recovered to the higher state in 1997. The other 5 industries also have structural changes in 1993.

3.2. Estimated Parameters of Dynamic Factor Model with Abatement Capital

[5] The period 1992-2000 is chosen because Taiwan manufacturing industries has gone through structurally upgrading from technology intensive industries to knowledge based technology industries in this period. The data bank does not contain data for the year 1996.

[6] The MOEA has conducted a periodic census by interviewing industrial plants with regard to production, labor and wages, equipment and materials, exports, R&D activities, total royalties, and technical and other professional fees remitted abroad, etc. See more detailed description on this databank in Tsai and Lin (2005).

For our empirical specification, we use the panel data to reduce multi-co-linearity and to control for unobserved heterogeneity. We take the parameters associated with the adjustment costs (C_{KK} , C_{AA} , C_{KA} , $\gamma_{\dot{K}\dot{K}}$, $\gamma_{\dot{A}\dot{A}}$) and exogenous technology (β_{LT} , β_{KT} , β_{AT}) as common for all industries. However, it is worth noting that this does not mean the adjustment cost effects and exogenous technology changes in all industries are all the same. As a matter of fact, technology change effects and adjustment effects also depend on the levels of inputs in the individual industries and individual industry characteristics[7].

The GMM estimated coefficients of the complete model for the six industries presented in Table 5 indicate that most estimated coefficients are significant at 5% significant level. For all industries, the estimated coefficients, α_L >0, denote the higher variable costs along with the higher relative factor prices. It also reflects the fact that the standardized variable cost function is non-decreasing in variable input prices. α_K , α_A <0 denote that variable costs decrease when quasi-fixed inputs, physical capital (*K*) and abatement capital (*A*) increase. It also demonstrates that standardized variable cost function is a non-increasing function of quasi-fixed inputs. γ_{LL} represents the relationship between input labor demand and labor price. They are all negative and significant in all industries. β_{KL} is positive that reflects the relationship between input labor demand and physical capital is complementary. β_{AL} shows the impact of environmental regulation on labor demand is positive, but the impact is small. β_{lT}, β_{KT} and β_{AT} are generally negative in each demand function for exogenous technology which is usually a save factor in input demand process. Alternatively, technology is often regarded as a cost saving factor in the production process.

Furthermore, the parameters satisfy the theoretical restrictions at all points in the samples. In particular, γ_{LL} <0, γ_{KK} >0, γ_{AA}>0, $\gamma_{\dot{K}\dot{K}}$ >0, $\gamma_{\dot{A}\dot{A}}$ >0, and γ_{KK} , γ_{AA} , γ_{KA} >0.

3.3. TFP Composition by Industries

We present the TFP composition and factor contributions by industry in Tables 6-11[8]. The highest growth rate of TFP is 3.29% in the Fabricated Metal Products (SIC28) and the lowest is

[7] The parameters associated with the adjustment costs (C_{KK} , C_{AA} , C_{KA} , $\gamma_{\dot{K}\dot{K}}$, $\gamma_{\dot{A}\dot{A}}$) and exogenous technology (β_{LT} , β_{KT} , β_{AT}) are taken as common across industries since the adjustment coefficients represent the differences between the stock in the beginning period and the long-term optimal stock of the quasi-fixed inputs in the theoretical dynamic model setting. However, the measured adjustment cost effects and exogenous technology change effects will still depend on the levels of inputs in the individual industries and individual industry characteristics in different industries. See Table 1 for detailed components of technology change effects and adjustment effects.

[8] The individual impacts are calculated from Equations 16.

1.01% for Food and Beverage Manufacturing (SIC 11) – one interesting point is that both of these industries are among the bottom three in terms of having the lowest investment in abatement capital. Compared to Tsai and Wang (2007), formulated as the baseline model with no industry transition and structural changes, the empirical results show that the Taiwan high technology industries (SIC 31 and 32) are very sensitive to the industry transition and structural changes. In Tsai and Wang (2007), the TFP growth is about 6.24% in the Electrical Machinery, Supplies and Equipment Manufacturing and Repairing Industry (SIC31) and 3.97% in the Transport Equipment Manufacturing and Repairing Industry (SIC32). After considering the impacts of industry transition and structural changes may have costs on the industry, the TFP growth rates on the Taiwan high-technology industry reduce to 1.70% for SIC 31 and 1.43% for SIC32.

The empirical results in this paper also provide us with a way to empirically examine the Porter hypothesis. Indisputably, the direct abatement cost will increase opportunity costs and have a negative influence on productivity growth. From our empirical results, we find that DAE in all industries has a negative effect on productivity growth as predicted by conventional theory. (Denison 1979; Christiansen and Haveman 1981; Gray 1987; Conrad and Wastl 1995; etc.) [9] The contribution ranges from -4.97% (for SIC 28) to -44.24% (for SIC32). This implies that environmental regulation has indeed caused an increase in the cost burden. As a matter of fact, the Porter hypothesis is dynamic. We test the Porter hypothesis by examining the relationship between abatement capital and innovation. We take a broad perspective of the dynamic effect by combining the indirect effect (*IDAE*), scale effect (*SE*) and adjustment cost effect (*ACE*). We find that *IDAE* is positive only in SIC13, which is part of the traditional highly polluting industries. We believe *IDAE* has a positive effect on productivity growth because the traditional industry has vigorously transformed to the high added value industry in the past few years.[10] For all other industries, even the high-technology industries (SIC31 and SIC32), which have paid great attention to the research and development to offset environmental costs, our research finds *IDAE* has a negative impact on TFP growth due to structural changes.

The contribution of scale effects (*SE*) is significant for all industries. 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 their profit margin. These effects are significant especially for some oligopolistic industries with high degrees of concentration and market power. Similar empirical evidence is also found in Tsai and Wang (2007) and Lanoie et al (2011), which find positive scale effects using a regression model. These results suggest that price and scale effects are important in explaining TFP growth, and the firm may find that pricing strategy and/or scale expansion, local expansion or foreign direct investment, to be important strategies to offset the

[9] In the traditional literatures, the abatement capital will increase the cost burdens. Then the productivity will decline.

[10] Recently, Taiwan government promotes traditional industry to transform to the high value-added industry and to improve competitiveness by CITD (Conventional Industry Technology Development).

constraints of environment regulation.

In contrast to the scale effect, the adjustment cost effect (*ACE*) is negative in all industries. The adjustment cost effects indicate the derived adjustment costs of the quasi-fixed inputs in facing environmental regulation. The *ACE* is much more significant in all industries when considering the firm needs to adjust to industry transition and structural changes. However, this study still shows *ACE* is lower in the high-technology industries, SIC 31 and SIC 32, than other industries. This indicates that high-tech industries have better adjustment mechanisms to reduce adjustment cost than other industries.

The last effect, the capital effect (*KE*), is also worth-noting as it contributes positively to the TFP growth in all industries. The positive contributions of *KE* are significant partially for the same reason as scale effects that investment in physical capital has contributed positively to TFP growth; another part reflects the fact that our sample contains all capital-intensive industries.

Of the 6 Taiwanese manufacturing industries we examined, the total indirect effects (the sum of the indirect abatement effects, price and scale effects, and the adjustment effects) are positive for 5 industries (SIC13, SIC25, SIC28, SIC31 and SIC32) and negative for the Food and Beverage Manufacturing (SIC11). This result could be explained by the following scenarios: (1) Most Taiwan manufacturing industries are flexible enough in terms of their input allocation to accommodate new environmental regulations, while still keeping total costs under control. (2) 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 more innovative activities in order to reduce production costs, thereby increasing technological efficiency. One clear implication of this result is that regulatory authorities should rely more heavily on market-based incentive regulatory mechanisms, instead of command and control mechanisms for the high-tech innovative industries.

4. Conclusions

This paper analyzes the dynamics of the structural changes, industrial transitions, and its impacts on sustainable development in Taiwan. We focus on the environmental stress (or burden) that results from industrial transition and economic structural changes. Explicitly incorporating the Markov regime switching mechanism in a productivity framework, this study measures the firm’s dynamic adjustments when facing industrial transitions and structural changes.

The empirical dimensions of the harmful or potentially benign environmental effects of structural changes are assessed. Taiwan high technology industries (SIC 31 and 32) are much more sensitive to the industry transition and structural changes than other industries, reflected in the impacts of direct abatement effects and indirect abatement effects. Meanwhile, the high-technology industries are more flexible in adjustment mechanism and the pricing and scale expansion strategies. Overall speaking, we find significant impacts on the environmental stress (or burden) resulting from industrial transition and economic structural changes.

This paper also provides valid empirical evidence that allows us to re-examine the Porter hypothesis in considering industrial transition and structural changes. The presence of Porter hypothesis indicates that the suitable environmental regulation will initiate the motives of innovation. There are many examples and phenomena supporting Porter hypothesis suggest that a more stringent regulation is not always detrimental to productivity, instead it could stimulate an innovation offset. In this study, we further provide the evidence this innovation offset could happen even for developing economies under industrial transition and economic structural changes. The 6 industries all had gone through industrial transition or economic structural changes more than once during our study period 1992-2000. The Porter hypothesis is valid in five of the 6 Taiwan manufacturing plant level data in a broadly perspective. Only the Food and Beverage Manufacturing (SIC11) is the exception due to huge adjustment effects in adjusting to the new environmental standards, which may offset the innovation motive. Overall speaking, our investigation supports Porter hypothesis under industrial transition and economic structural changes in this dynamic setting.

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. This study sheds light on the regulatory authorities to provide more insights in designing incentive regulation mechanism, instead of command and control mechanism for the high-tech innovation-induced industries. For example, in China, the industrial sectors were important sources of environmental emissions such as PCDD/Fs. Through policies such as closure or phase-out of industry companies with backward production capacity, energy consumption and emissions of environmental pollutants will be reduced.(Lü, Geng, and He, 2015) Another example, Taiwan government rewards traditional industry to promote and innovate in environmental emissions or green technologies by CITD (Conventional Industry Technology Development). CITD aims at encouraging enterprises to engage in research and development, assisting companies to obtain R&D funding, and promoting in innovation, in order to accomplish the overall goal of independent research capacity building and sustainable development for traditional industries.

Due to the importance of technological innovation and structural changes to the newly developing countries like Taiwan manufacturing industries, we perceive that the model better illuminates the relationship of industry competitiveness and sustainable development for the developing economies under industrial transition and structural changes. This study also indicates there may be strong innovation induced effects for the industries with strong economies of scale. And the implication is clear that the “right” industries are 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.

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Table 1 Definitions and Explanation of Six Major Components of TFP

Components	Definitions	Explanation
DAE	$-S_A \frac{d \ln C_A}{dT}$	the growth in the direct cost of abatement requirements per unit of conventional output (or the direct abatement effect)
IDEA	$-S_C (E_{C\alpha} \frac{d \ln \alpha}{dT})$	the shift in C due to abatement capital purchases (or the indirect abatement effect)
SE	$(1 - S_C E_{CY}) \frac{d \ln Y}{dT}$	scale effects
KE	$-S_C (E_{C\kappa} \frac{d \ln \kappa}{dT}) - S_K \frac{d \ln C_K}{dT}$	the shift in C due to physical capital purchases
ACE	$-S_C (E_{C\dot{K}} \frac{d \ln \Delta K}{dT} + E_{C\dot{A}} \frac{d \ln \Delta A}{dT})$	adjustment costs effects when the firms are adjusting to comply with new environmental standards
TE	$-S_C (\frac{\partial \ln C}{\partial T})$	the shift in C due to technical change

Table 2 Basic Statistics of the 6 Industries, 2000

SIC code	Industry name	Sizes	Abatement capital expenditure*	Mean Abatement capital expenditure
11	Food and beverage Manufacturing	North：11	3863	351.18
		Middle：7	6480	925.71
		South：8	5465	683.13
		Total：26	15808	608.00
13	Textiles mills	North：12	70615	5884.58
		Middle：16	37780	2361.25
		South：13	20437	1572.08
		Total：41	128832	3142.24
25	Plastic products Manufacturing	North：35	71504	2042.97
		Middle：47	267041	5681.72
		South：20	18292	914.60
		Total：102	356837	3498.40
28	Fabricated metal Products	North：18	45518	2528.78
		Middle：21	3614	172.10
		South：7	5785	826.43
		Total：46	54917	1193.85
31	Electrical Machinery, Supplies And Equipment Manufacturing and Repairing	North：66	2526648	38282.55
		Middle：15	71299	4753.27
		South：12	244661	20388.42
		Total：93	2842608	30565.68
32	Transport Equipment Manufacturing and Repairing	North：29	260954	8998.41
		Middle：21	139407	6638.43
		South：24	210298	8762.42
		Total：74	610659	8252.15

Note: *The unit of abatement capital is thousand dollars.

Table 3. Maximum Likelihood Estimates of the Transition Probability, with initial p =0.5

Industry	Transition Probability	Switching Variance	Standard Deviation
SIC11	0.5293*	4.47888E-05	0.0067
SIC13	0.5288*	4.3074E-05	0.0066
SIC25	0.5270*	8.0470E-05	0.0090
SIC28	0.5292*	4.4647E-05	0.0067
SIC31	0.5300*	4.8879E-05	0.0070
SIC32	0.5293*	4.4977E-05	0.0067

* indicates significance at 95% significant level.

Table 4 The Indicators of Industry Transition and Structural Changes

	Food and Beverage Manufacturing (SIC11)	Textiles Mills Manufacturing (SIC13)	Plastic Products Manufacturing (SIC25)
1992	0	0	0
1993	0	0	1
1994	1	1	1
1995	1	1	0
1997	1	1	1
1998	1	1	1
1999	1	1	1
2000	1	1	1

	Fabricated Metal Products Manufacturing (SIC28)	Electrical Machinery, Supplies and Equipment Manufacturing and Repairing (SIC31)	Transport Equipment Manufacturing and Repairing (SIC32)
1992	0	0	0
1993	0	0	0
1994	1	1	1
1995	1	1	1
1997	1	1	1
1998	1	1	1
1999	1	1	1
2000	1	1	1

Note: The number value 1 (0) represents the industry in the state 1(0) stage.

Table 5 GMM Estimates: 1992-2000

Parameter	Estimated Coefficients	t-statistics
ρ	2.2169*	2.9565
α_{L}	0.9219*	5.8209
γ_{LL}	-0.0111*	-2.1079
β_{LT}	-0.0382*	-2.2849
β_{KL}	0.1743*	2.4062
β_{AL}	0.1420*	1.8566
C_{KA}	-0.2917*	-4.5543
$\gamma_{\dot{K}\dot{K}}$	-0.2259*	-3.2547
$\gamma_{\dot{A}\dot{A}}$	2.7043*	4.4310
C_{KK}	-0.4349*	-3.4364
C_{AA}	-1.1486*	-3.3158
α_{0}	1.9681*	2.233
α_{K}	-1.3734*	-1.7794
α_{A}	-1.0490*	-1.5989
β_{KT}	-0.0890*	-2.2027
β_{AT}	-0.1111*	-2.3358

Note: *indicates significance at 95% significant level

Table 6 TFP Composition and Factor Contributions for the Food and Beverage Manufacturing (SIC 11), 1992-2000

Components	Growth rate	Contributions
DAE	-0.2457	-24.26%
IDEA	-0.0209	-2.06%
TE	1.1900	117.49%
SE	1.5285	150.90%
KE	0.2419	23.88%
ACE	-1.6809	-165.95%
TFP	1.0129	

Number of plants at 2000 = 26 Number of observations = 234

Table 7 TFP Composition and Factor Contributions for the Textiles Mills Manufacturing (SIC13), 1992-2000

Components	Growth rate	Contributions
DAE	-0.1853	-7.36%
IDEA	0.0274	1.09%
TE	1.0227	40.61%
SE	1.8556	73.68%
KE	1.6289	64.68%
ACE	-1.8308	-72.69%
TFP	2.5186	

Number of plants at 2000 = 41 Number of observations = 369

Table 8 TFP Composition and Factor Contributions for the Plastic Products Manufacturing (SIC 25), 1992-2000

Components	Growth rate	Contributions
DAE	-0.7307	-32.04%
IDEA	-0.0763	-3.34%
TE	1.4051	61.62%
SE	1.6590	72.76%
KE	0.7076	31.03%
ACE	-0.6844	-30.01%
TFP	2.2803	

Number of plants at 2000 = 102 Number of observations = 918

Table 9 TFP Composition and Factor Contributions for the Fabricated Metal Products Manufacturing (SIC 28), 1992-2000

Components	Growth rate	Contributions
DAE	-0.16349	-4.97%
IDEA	-0.0786	-2.39%
TE	0.6106	18.57%
SE	1.0386	31.58%
KE	2.6563	80.77%
ACE	-0.7748	-23.56%
TFP	3.2887	

Number of plants at 2000 = 46 Number of observations = 414

Table 10 TFP Composition and Factor Contributions for the Electrical Machinery, Supplies and Equipment Manufacturing and Repairing (SIC31), 1992-2000

Components	Growth rate	Contributions
DAE	-0.7132	-41.84%
IDEA	-0.0025	-0.15%
TE	0.8601	50.46%
SE	1.1510	67.52%
KE	1.2138	71.21%
ACE	-0.8047	-47.21%
TFP	1.7045	

Number of plants at 2000 = 93 Number of observations = 837

Table 11 TFP Composition and Factor Contributions for the Transport Equipment Manufacturing and Repairing (SIC 32), 1992-2000

Components	Growth rate	Contributions
DAE	-0.6347	-44.24%
IDEA	-0.1742	-12.14%
TE	0.8195	57.13%
SE	1.3347	93.04%
KE	0.3594	25.06%
ACE	-0.2703	-18.84%
TFP	1.4345	

Number of plants at 2000 = 74 Number of observations = 666