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The Shadow Prices of CO_2 Emission Abatement for Pacific-Rim Countries

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一、中文摘要

關鍵詞：資料包絡分析法、非意欲產出、CO_2減量、影子價格、投入距離函數

影子價格係在缺乏市場交易價格下，用來計算消費好財（good）的單位價值，或拋棄壞財（bad）所必須之單位成本。目前環境經濟學文獻中，常見利用資料包絡分析法（DEA）來估計多產出-多投入之決策單位（DMU）處理一單位壞財（例如：污染）所必須支付的影子價格。

既存文獻多應用此方法於估計個別廠商或地區污染減量的影子價格。資料包絡分析法也可以用來估計一個國家的生產力與效率，過去的生產力與效率文獻鮮少將環保因素直接當成一個國家的投入或產出。然而，忽略環境因素，可能會嚴重高估或低估一個經濟體或地區的生產力與效率。本研究利用Färe et al. (1993) 的一種資料包絡分析法（投入距離函數），來估計太平洋週邊地區國家各年度的人均CO_2排放減量的影子價格。

本研究採產出距離函數，將應用分析對象提高到國家層次，來估計亞太地區經濟體CO_2減量的影子價格，而資料包絡分析法會同時產生各國的技術效率值。本研究設定

每個經濟體有兩種產出：人均GDP（1996 年國際價格美元）及人均CO_2（立方噸碳）。其中GDP爲意欲產出，CO_2爲非意欲產出。每個經濟體有兩種投入：資本形成（1996 年國際價格美元）與勞動（人均勞動投入比率）。根據資料蒐集及研究對象區域，選擇了 19 個太平洋週邊經濟體，作爲研究對象：Australia, Canada, Chile, China, Columbia, Hong Kong, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Singapore, Taiwan, Thailand, and the United States。本計畫所選取的樣本期間爲 1987 至 1996 年，主要資料來源爲Penn World Table Version 6.1 及Carbon Dioxide Information Analysis Center。

我們首先利用線性規劃方法，求解超越對數投入距離函數的的各項參數值。接著利用這些參數值及實際觀察值，產生各經濟體的效率值、及人均CO_2排放減量的影子價格（以減少的人均GDP計算）。主要發現如下：(1) 在 1987-1996 的研究期間裡，各經濟體CO_2排放減量的影子價格皆呈現逐年遞增的趨勢。(2) 一般而言，已開發經濟體每人減量一立方噸碳排放的人均代價，遠高於開發中經濟體。(3) 雖然美國的平均效率值高居第 2 名，在研究期間內它的CO_2減量影子價格卻總是最高的。(4) 加拿大及澳大利亞的CO_2減量影子價格也很高。(5) 雖然中國大陸的平均效率值最低，在研究期間內它的CO_2減量影子價格卻很低。(6) 台灣的CO_2減量影子價格在研究對象中居中。

詳細的研究成果，煩請參閱所附的英文摘要及全文部份。

二、英文摘要與英文全文

The Shadow Prices of CO_2 Emission Abatement for Pacific-Rim Countries

Jin-Li Hu*

Abstract. We examine the overall macroeconomic performance and compute shadow prices of their per capita CO_2 reduction of nineteen APEC economies, including Australia, Canada, Chile, China, Columbia, Hong Kong, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Singapore, Taiwan, Thailand, and the United States during the 1987-1996 period. We first use the linear programming approach to solve for parameters of the translog input distance function. There are two inputs (per capita capital formation and per capita labor), one desirable output (per capita GDP), and one undesirable output (per capita CO_2 emission). All variables in monetary units are in USD in 1996 international prices. We then generate the efficiency scores and shadow prices (in per capita GDP) with data and parameters obtained from linear programming. Our major findings are as follows: (1) Shadow prices of CO_2 reduction were strictly increasing for every economy during the 1987-1996 research period. (2) Generally speaking, it is much costlier for a developed economy to reduce one metric ton of carbon per capita than a developing economy. (3) Although the U.S. had the second highest average macroeconomic efficiency among these APEC economies, its shadow prices of CO_2 reduction were always the highest during the research period. (4) It is also very costly for Canada and Australia to reduce CO_2 emission. (5) Although China had the lowest macroeconomic efficiency scores, its per capita shadow prices to reduce per capita CO_2 emissions were still very low. (6) Taiwan's shadow prices to reduce CO_2 emission were medium among APEC economies.

Keywords: Undesirable outputs, CO_2 reduction, input distance function, shadow prices, technical efficiencies.

JEL Classification: C61, O13, Q43

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1. Introduction

The Kyoto Protocol (1997) set a specific timetable for each country under the Convention on Climate Change. The specific country target for each country is to reduce the greenhouse gases emission from the year of 2008 to 2012 to less than the level of the year of 1990. The international and legally binding Kyoto Protocol has entered into force on February 16, 2005. Earlier on December 12th, 2003, the Chicago Climate exchange has started the emission trading of CFI (Carbon Financial Instrument). The relevant welfare changes after signing the Kyoto Protocol are major concerns for the individual state's decision in accession to the Kyoto Protocol. The US has indicated its intention not to ratify the Kyoto Protocol while Russia has ratified the Kyoto Protocol in October 2004.

In order to achieve the country target, the Kyoto Protocol establishes three innovative mechanisms. Aside from countries, businesses, environmental NGOs and other legal entities may participate in the mechanisms: (1). *Joint Implementation*: an Annex I Party of Kyoto Protocol may implement a project that reduces emissions (e.g., an energy efficiency scheme) or increases removals by sinks (e.g., a reforestation project) in the territory of another Annex I Party, and count the resulting emission reduction units against its own target. (2). *Clean Development Mechanism*: Annex I Parties may implement projects in non-Annex I Parties that reduce emissions and use the resulting certified emission reductions to help meet their own targets. The clean development mechanism also aims to help non-Annex I Parties achieve sustainable development and contribute to the ultimate objective of the Convention. (3). *Emissions Trading*: an Annex I Party may transfer some of the emissions under its assigned amount to another Annex I Party that finds it relatively more difficult to meet its emissions target.

The Framework Convention on Climate Change divides countries into three main groups according to differing commitments. Annex I Parties include the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition (EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States. Annex II Parties consist of the OECD members of Annex I, but not the EIT Parties. Non- Annex I Parties are mostly developing countries.

There are some famous cases for important APEC economies to reject the Kyoto Protocol: Australia, Canada, and the United States (the New Scientist website, 2005; Vedantam, 2005). These economies are developed economies while they still refuse to follow the goals of the Kyoto Protocol. However, most the developing APEC economies signed the Kyoto Protocol.

An economy's macroeconomic policies generally have two objectives: creation of wealth and good living condition for its citizens. Gross domestic product (GDP) is commonly used in assessing an economy's wealth. However, it does not constitute a measure of welfare say for example without dealing with environmental issues adequately. There is necessity to calculate environmental degradation as a correction factor into our regular definition of economic growth (van Dieren, 1995). For the last three decades, Asia has emerged as one of the most important economic regions of the world.

Since the 1960s, the economy of China, Hong Kong, Indonesia, South Korea, Malaysia, Singapore, Taiwan and Thailand together have grown more than twice as fast as the rest of Asia (Angel and Cylke, 2002). As Asia's economic activities began to shift toward industry and manufacturing, there has been a dramatic increase in pollution in the region (World Bank, 1998). For instance, fast-developing Asia is now one of the major contributors to the global increase in carbon emissions (Hoffert et al., 1998; Siddiqi, 2000). In fact, the highest percentage rises came from the Asia-Pacific region, including India, China and the newly industrializing 'tiger' economies (Masood, 1997). Because emissions of carbon dioxide are generally acknowledged as a cause of global warming, the United Nation has been trying to negotiate a global agreement to tackle carbon dioxide emissions. The Kyoto protocol in 1997 was an international milestone of this effort.

The conflict between economic priorities and environmental interests, for a long time, is at the national level since 1960s. However, as Mol (2003) states, there is an increasing clash of economic and environmental institutions, regimes and arrangements at international level in recent decades. Studies for economic versus environmental issues is now in a transnational arena. For OECD members, the objective to pursue a balance between pro-development and pro-environment has received considerable attention. Lovell et al. (1995) study the macroeconomic performance of 19 OECD countries by extended data envelopment analysis (DEA) approach, namely Global Efficiency Measure (GEM) for single period analysis. Japan is the only Asian country included in their sample. The study takes four services, real GDP per capita, a low rate of inflation, a low rate of unemployment, and a favorable trade balance as four outputs. When two environmental disamenities (carbon and nitrogen emissions) are included into the service list, the rankings change, while the relative scores of the European countries decline. According to the experience of the OECD countries, environmental indicators do seem to have crucial effects on a nation's relative performance.

The aim of this paper is to measure the macroeconomic performance of APEC economies by moderating unwanted externalities of economic growth using panel data over the period 1987-1996. In this study, performance is defined in light of an economy's ability to provide its citizens with both more wealth and less polluted environments. We will examine the overall macroeconomic performance and compute shadow prices of their per capita CO_2 emission of nineteen APEC economies, including Australia, Canada, Chile, China, Columbia, Hong Kong, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Singapore, Taiwan, Thailand, and the United States.

Based on the economic theory of production, inputs (such as capital and labor) are transformed into outputs (such as gross domestic product, GDP) in the production process. The environmental disamenities are added and the analysis as undesirable outputs. The CO_2 emissions are included as undesirable outputs.

There are three more sections besides this introductory section. The next section provides an introduction of the distance function and linear programming model. Section 3 describes data selection. Section 4 presents the empirical results.

2. The Parametric Linear Programming Method

An economy employs N inputs denoted by a vector $X = (x_1, x_2, \cdots, x_N)$ to produce M outputs denoted by a vector $Y = (y_1, y_2, \cdots, y_M)$. According to Shephard (1970), the input distance function can be defined as follows:

$$D_i(Y, X) = \sup_{\lambda} \{\lambda : (X/\lambda) \in L(Y)\} \tag{1}$$

where $L(Y)$ is the input sets of production technology, describing the sets of input vectors that can produce the output vector, Y. That is,

$$L(Y) = \{X : X \text{ can produce } Y\}. \tag{2}$$

The input distance function gives the maximum amount by which an input vector can be deflated and still remain producible with a given output vector. It is non-decreasing, linearly homogeneous and concave in X, non-increasing in desirable outputs, and non-decreasing in undesirable outputs (Hailu and Veeman, 2000; Kumbhakar and Lovell, 2000). We assume that undesirable outputs satisfy the property of weak disposability. Under weak disposability, undesirable outputs are not to be freely disposable.

Note that $D_i(Y,X)\geq 1$ if X belongs to the input set of Y $\left(X\in L(Y)\right)$ and that $D_i(Y,X)=1$ if X belongs to the frontier of the input set (the isoquant of Y). Furthermore, the Farrell input-oriented measure of technical efficiency coincides with the reciprocal of the input distance function (Färe and Primont 1995, Kumbhakar and Lovell 2000).

Suppose that L(Y) is convex. Then the input distance function $D_i(Y,X)$ and the cost function $C(Y,W)$ are dual (Färe and Primont, 1995):

$$C(Y,W)=\inf_{X}\ \left\{WX\ :D_i(Y,X)\geq 1\right\} \tag{3}$$

$$D_i(Y,X)=\inf_{W}\ \left\{WX:C(Y,W)\geq 1\right\} \tag{4}$$

where $W=\left(w_1,w_2,\cdots,w_N\right)$ denotes the input price vector and WX is the inner product of the input prices and quantity vectors. Equation (3) states that the cost function can be derived from the input distance function by minimization over inputs X, while equation (4) represents that the input distance is obtained from minimization with respect to input prices W.

Suppose that both $D_i(Y,X)$ and $C(Y,W)$ are differentiable. The cost function can be represented by forming Lagrange problem:

$$\min_{X} C\left(Y,W\right)=WX+\lambda\ (1-D_i(Y,X)), \tag{5}$$

where λ is the Lagrangian multiplier. Applying the envelope theorem, we have the output shadow price vector $R^*=\left(r_1^*,r_2^*,\cdots,r_M^*\right)$ by differentiating the cost function with respect to outputs,

$$R^*=\nabla_Y C\left(Y,W\right)=-\lambda\left(Y,W\right)\nabla_Y D_i(Y,X). \tag{6}$$

It can be shown that $\lambda\left(Y,W\right)$, the optimal value of the Lagrangian multiplier associated with equation (6), is equal to the value of the optimized cost function $C(Y,W)$ (Färe and Primont 1995). The shadow price of a given output is the increasing cost resulted from the production of additional unit of that output. The shadow price for the undesirable output can be interpreted as the measure of the marginal cost of reducing it to the economy. Since the input prices W are unable to obtain directly, the cost function $C(Y,W)$ cannot be accurately estimated. Equation (6) indicates that the ratio of the shadow prices of output *j* and output *k* is

$$\frac{r_j^*}{r_k^*} = \frac{\partial D_i(Y,X)/\partial y_j}{\partial D_i(Y,X)/\partial y_k}. \tag{7}$$

Equation (7) indicates how many units of output *k* (say CO_2 emission) the economy is willing to give up to reduce one more unit of output *j* (say NPL). Assume that the market price of output *k* equals its shadow price r_k^*. We then could calculate the shadow price of output *j* r_j^* by the following formula (Färe et al. 1993, Hailu and Veeman 2000):

$$r_j^* = r_k^* \frac{\partial D_i(Y,X)/\partial y_j}{\partial D_i(Y,X)/\partial y_k} \tag{8}$$

This study will employ equation (8) to calculate the shadow price of NPL. Because the cost minimization implies cost efficient, the shadow price discussed above should be computed at the production frontier. In other words, the shadow price formula of equation (8) should be evaluated at the technically efficient projection of the associated input vectors (Hailu and Veeman 2000).

In order to apply the shadow price formula, we have to parameterize and calculate the parameters of the input distance function. An appropriate functional form to the input distance function would ideally be flexible, easy to calculate, and permit the imposition of homogeneity. The flexible translog functional form provides a second-order Taylor approximation to the unknown technology. It satisfies all the above criteria and has been used by many researchers (Färe et al. 1993, Lovell et al. 1994, Grosskopf et al. 1996, Hailu and Veeman 2000).[1] Furthermore, this does not impose the strong disposability of outputs. The translog distance function with M outputs and N inputs is specified as:

$$\ln D_i(Y, X) = \alpha_0 + \sum_{n=1}^{N} \beta_n \ln x_n + \sum_{m=1}^{M} \alpha_m \ln y_m + \frac{1}{2} \sum_{n=1}^{N} \sum_{n'=1}^{N} \beta_{nn'} (\ln x_n)(\ln x_{n'})$$

$$+ \frac{1}{2} \sum_{m=1}^{M} \sum_{m'=1}^{M} \alpha_{mm'} (\ln y_m)(\ln y_{m'}) + \sum_{n=1}^{N} \sum_{m=1}^{M} \gamma_{nm} (\ln x_n)(\ln y_m) . \qquad (9)$$

This research employs the linear programming suggested by Aigner and Chu (1968) to estimate unknown parameters. This method relies on the minimization of the sum of deviations of the values of the logarithmic values of the input distance from the frontier. In other words, we try to estimate the parameters of a deterministic translog input distance function by solving the following problem:

$$\text{Min} \sum_{k=1}^{K} [\ln D_i(Y^k, X^k) - \ln 1] \qquad (10)$$

subject to

(i) $\ln D_i(Y^k, X^k) \geq 0, \qquad k = 1,..., K,$

(ii) $\dfrac{\partial \ln D_i(Y^k, X^k)}{\partial \ln x_n^k} \geq 0, \qquad n = 1, \cdots, N, \qquad k = 1, \cdots, K$

(iii) $\dfrac{\partial \ln D_i(Y^k, X^k)}{\partial \ln y_m^k} \leq 0, \qquad m = 1, \cdots, h, \qquad k = 1, \cdots, K$

(iv) $\dfrac{\partial \ln D_i(Y^k, X^k)}{\partial \ln y_m^k} \geq 0, \qquad m = h+1, \cdots, M, \qquad k = 1, \cdots, K$

(v) $\sum_{n=1}^{N} \beta_n = 1, \qquad n = 1, \cdots, N$

[1] The Cobb-Douglas functional form, which is one of the most popular functional forms in production analysis, only satisfies the latter two points, because of its restrictive elasticity of substitution and scale property. Moreover, it is not an appropriate model of a firm in a competitive industry since it is not concave in output dimensions (Klein 1953).

$$\sum_{n'=1}^{N}\beta_{nn'} = \sum_{n=1}^{N}\gamma_{nm} = 0 \qquad m = 1,\cdots,M, \qquad n = 1,\cdots,N$$

$$\text{(vi)} \quad \alpha_{mm'} = \alpha_{m'm}, \qquad m = 1,,\cdots,M, \qquad m' = 1,\cdots,M$$

$$\beta_{nn'} = \beta_{n'n}, \qquad n = 1,\cdots,N, \qquad n' = 1,\cdots,N$$

where $k = 1,\cdots,K$ indexes individual banks; $\ln D_i(Y^k, X^k)$ has the explicit functional form described in equation (9), the first h outputs are desirable; and the other $(K - h)$ outputs are undesirable.

The first constraint indicates that all banks are within the technology frontier. Constraint (ii) is the condition that the input distance function is non-decreasing in inputs. There exists a fundamental asymmetry between desirable and undesirable outputs that desirable outputs are freely disposable, while reducing undesirable outputs are costly. Constraints (iii) and (iv) are hence required to guarantee that the input distance function is non-increasing and non-decreasing function of, respectively, desirable and undesirable outputs. The last two constraints guarantee the linear homogeneity in inputs for the input distance function (v) and the parameters symmetry condition for the translog functional form (vi).

3. Data Sources

The nineteen selected economies are all APEC members: Australia (AUS), Canada (CAN), Chile (CHL), China (CHN), Columbia (COL), Hong Kong (HKG), Indonesia (IDN), Japan (JPN), Korea (KOR), Malaysia (MLS), Mexico (MEX), New Zealand (NZL), Papua New Guinea (PNG), Peru (PER), the Philippines (PHL), Singapore (SNG), Taiwan (TWN), Thailand (THA), and the United States (USA) during the 1987-1996 period. We then construct an APEC efficiency frontier for these ten years based on the macroeconomic data of these nineteen economies. Each economy in each year is compared to that ten-year APEC efficiency frontier and associative indices such as efficiency scores and shadow prices of CO_2 reduction can be hence found.

There are two inputs and two outputs. We take capital formation and labor force as two inputs and GDP per capita as a desirable output for a specific economy. These data are from Penn World Table Version 6.1 provided by Center for International Comparisons at the University of Pennsylvania (CICUP, 2002). The value of monetary inputs and outputs such as GDP per capita and capital formation are counted by USD in 1996 international prices. Although capital formation and labor force are not directly available from the data set, simple calculation can be applied: The capital formation is retrieved from the product of real GDP per capita and investment share of real GDP per capita (USD in 1996 international prices), while the labor force is calculated by dividing real GDP per capita with real GDP per worker. The data of per capita CO_2 emissions (metric tons of carbon) is from Carbon Dioxide Information Analysis Center (Marland et al., 2003). The data after 1996 are not included due to the lack of data for certain economies.

Macroeconomic performance is evaluated in terms of the ability of an economy to maximize the desirable output GDP while minimizing the CO_2 emissions. Summary statistics of these inputs and outputs are shown in Table 1.

[Insert Table 1 about here]

This study employs the mathematical programming software LINGO 6.0 to compute the parameters of the translog input distance function. Table 2 shows the values of estimated parameters. These parameter estimates were used to calculate the technical efficiencies, the reciprocal of the input distance function, and the shadow prices of CO_2 reduction (Equation (7)) for each economy in each year. Note that the price of the desirable output (real GDP per capita) is exactly one USD. I then use the statistical software TSP 4.5 to generate efficiency scores and shadow prices.

[Insert Table 2 about here]

4. Empirical Results

The macroeconomic efficiency scores with CO_2 emissions considered are listed in Table 3. These rankings are stable during the 1987-1996 research period. The APEC economies ranked from the highest to the lowest average efficiency scores are: Mexico (0.98678), the United States (0.95553), Australia (0.90097), Chile (0.89413), Malaysia (0.89097), Canada (0.88183), New Zealand (0.87940), Korea (0.86921), Peru (0.86341), Taiwan (0.86044), Columbia (0.85909), the Philippines (0.82211), Singapore (0.80371), Hong Kong (0.78436), Indonesia (0.79294), Japan (0.70282), Papua New Guinea (0.69539), Thailand (0.60005), and China (0.53212).

[Insert Table 3 about here]

The shadow prices (per capita USD in 1996 international prices) of per capita CO_2 reduction (metric tons of carbon) considered are listed in Table 4. Rankings in shadow prices are also stable during the 1987-1996 research period. The APEC economies ranked from the lowest to the highest average shadow prices are: Peru ($1.47), the Philippines ($1.85), Indonesia ($2.00), Papua New Guinea ($3.15), China ($5.09), Columbia ($9.46), Thailand ($11.35), Chile ($22.19), Mexico ($33.12), Malaysia ($35.54), Korea ($105.68), New Zealand ($220.56), Hong Kong ($211.61), Japan ($380.39), Singapore ($499.37), Taiwan ($150.59), Australia ($709.37), Canada ($740.38), and the United States ($1293.90) during the 1987-1996 period.

[Insert Table 4 about here]

Many interesting observations can be obtained from our empirical results:

(1) The shadow prices of CO_2 reduction were strictly increasing for every economy during the 1987-1996 research period. That is, it has been becoming costlier for each economy to reduce one metric ton of carbon per capita as time goes by.

(2) Generally speaking, it is much costlier for a developed economy to reduce one metric ton of carbon per capita than a developing economy.

(3) Although the U.S. had the second highest average macroeconomic efficiency among these APEC economies, its shadow prices of CO_2 reduction were always the highest during the 1987-1996 research period. This can explain why the U.S. still refuses to sign the Kyoto Protocol even until 2005.

(4) Cases similar to the U.S. also happened to Canada and Australia. It is also very costly for Canada and Australia to reduce CO_2 emission. This can explain why Australia and Canada still reject the Kyoto Protocol even until 2005.

(5) Although China had the lowest macroeconomic efficiency scores, its per capita shadow prices to reduce per capita CO_2 emissions were still very low.

(6) Taiwan's shadow prices to reduce CO_2 emission were medium among APEC economies.

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Table 1. Summary Statistics of Inputs and Outputs

	Mean	Standard Deviation	Minimum	Maximum
Inputs				
Real capital formation per capita (USD in 1996 international prices)	2766.156	2386.044	241.090	10955.910
Labor (per capita labor input ratio)	0.461	0.0874	0.320	0.650
Outputs				
Real GDP per capita (USD in 1996 international prices)	10587.256	7667.836	1344.610	29193.910
CO_2 Emission per capita (metric tons of carbon)	1.643	1.704	0.180	6.670
Number of observations		190		

Table 2. Parameter Estimates

α output		α output, output		β input		β input, input		γ input, output	
α_1	0.85772	α_{11}	-0.09999	β_1	0.30439	β_{11}	-0.00771	γ_{11}	-0.02267
α_2	-0.00059	α_{12}	0.00099	β_2	0.69561	β_{12}	0.00771	γ_{12}	-0.00074
Constant		α_{21}	0.00099			β_{21}	0.00771	γ_{21}	0.02267
α_0	-3.18418	α_{22}	-0.00111			β_{22}	-0.00771	γ_{22}	0.00074

Table 3. 1987-1996 Technical Efficiencies for APEC Economies

Number	Economy	Efficiency score										
		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Ave
1	AUS	0.85953	0.87567	0.89168	0.89392	0.89547	0.89891	0.90480	0.91323	0.93043	0.94605	0.90097
2	CAN	0.84309	0.86458	0.87920	0.88374	0.87715	0.87595	0.87979	0.89156	0.90709	0.91619	0.88183
3	CHL	0.88691	0.89279	0.89195	0.89001	0.89156	0.89080	0.88290	0.88976	0.90938	0.91527	0.89413
4	CHN	0.55289	0.54398	0.54173	0.53737	0.53182	0.52795	0.51954	0.52111	0.52154	0.52326	0.53212
5	COL	0.99114	0.98507	0.99218	1.00000	0.89957	0.80688	0.72551	0.72517	0.72975	0.73562	0.85909
6	HKG	0.62666	0.64181	0.65545	0.66599	0.72737	0.79482	0.87114	0.94858	0.94716	0.96462	0.78436
7	IDN	0.81094	0.80001	0.79222	0.78697	0.78458	0.78992	0.79155	0.79184	0.78406	0.79734	0.79294
8	JPN	0.64486	0.66138	0.67646	0.69232	0.71028	0.71552	0.72077	0.72651	0.73402	0.74611	0.70282
9	KOR	0.80106	0.81555	0.82287	0.83589	0.85953	0.87327	0.88971	0.91060	0.93411	0.94946	0.86921
10	MEX	0.99317	0.97152	0.97342	0.97635	0.98089	0.98558	0.99080	0.99727	0.99881	1.00000	0.98678
11	MYS	0.79275	0.79079	0.79006	0.79181	0.92140	0.93705	0.94600	0.96119	0.97863	1.00000	0.89097
12	NZL	0.87028	0.87715	0.87875	0.87800	0.86919	0.86577	0.87501	0.88205	0.89369	0.90407	0.87940
13	PER	0.99092	0.98084	0.97802	0.97166	0.89625	0.83544	0.77878	0.73181	0.73363	0.73677	0.86341
14	PHL	0.86488	0.85993	0.84827	0.84062	0.83567	0.81809	0.79873	0.78388	0.78619	0.78483	0.82211
15	PNG	0.69081	0.67576	0.68969	0.68997	0.68115	0.69187	0.70647	0.73074	0.70927	0.68820	0.69539
16	SGP	0.76206	0.79158	0.81592	0.83525	0.82255	0.79529	0.79130	0.78485	0.80865	0.82960	0.80371
17	THA	0.58743	0.58433	0.58537	0.58388	0.58961	0.59810	0.60539	0.61296	0.62271	0.63073	0.60005
18	TWN	0.80414	0.80698	0.81979	0.83104	0.84916	0.86303	0.88127	0.89800	0.91395	0.93706	0.86044
19	USA	0.89778	0.91738	0.93662	0.95153	0.95257	0.96113	0.96876	0.98070	0.98886	1.00000	0.95553

Table 4. 1987-1996 Absolute Shadow Prices of CO2 Reduction

ID	economy	Shadow price per capita (USD in 1996 international prices)										
		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Ave
1	AUS	488.56	523.22	602.75	635.57	639.72	695.67	767.34	805.73	915.33	1019.85	709.37
2	CAN	570.62	650.14	722.68	713.44	678.92	698.93	762.12	849.69	861.03	896.20	740.38
3	CHL	8.03	11.47	15.68	17.66	18.38	21.19	21.55	29.56	35.66	42.73	22.19
4	CHN	2.53	2.87	2.84	3.31	4.03	4.86	5.65	6.91	8.32	9.53	5.09
5	COL	5.90	6.17	6.87	8.99	10.06	11.26	11.21	10.71	11.47	11.96	9.46
6	HKG	141.58	162.80	188.20	173.74	203.22	257.01	307.89	245.29	225.39	210.98	211.61
7	IDN	0.83	0.76	0.86	1.53	1.54	2.12	2.53	2.69	2.49	4.62	2.00
8	JPN	215.41	263.26	304.26	352.88	398.63	416.21	418.65	459.81	475.84	498.96	380.39
9	KOR	34.04	47.06	54.07	66.62	83.94	102.88	124.56	147.65	183.40	212.62	105.68
10	MEX	29.31	24.89	28.16	37.67	37.31	41.23	38.34	40.91	39.25	38.35	35.54
11	MYS	11.62	12.80	15.93	19.58	24.12	30.29	39.53	43.27	62.04	72.05	33.12
12	NZL	176.69	192.97	209.46	193.20	199.78	218.61	224.01	243.84	253.79	293.27	220.56
13	PER	4.14	3.50	2.49	2.28	2.39	2.56	3.14	3.40	3.61	3.97	3.15
14	PHL	0.82	1.18	1.12	1.17	1.38	1.48	1.45	1.66	2.16	2.24	1.47
15	PNG	1.59	1.16	1.26	1.40	1.51	1.82	2.49	3.32	2.35	1.61	1.85
16	SGP	182.62	250.96	322.06	418.77	466.22	474.06	631.14	865.77	624.42	757.70	499.37
17	THA	2.07	2.98	4.11	5.66	8.10	10.31	13.44	16.96	22.24	27.64	11.35
18	TWN	58.54	73.58	91.88	106.04	131.58	151.18	178.58	204.82	233.38	276.35	150.59
19	USA	905.54	1044.44	1124.09	1198.86	1245.21	1315.28	1368.75	1531.53	1512.95	1692.39	1293.90