Environmental Regulation and Productivity Growth: A Study of the APEC Economies

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Abstract

Environmental regulation has become more and more important in policy making among the world economies. How has it affected productivity growth and hence economic growth? The answer to this question is either controversial or yet to be explored in many cases. The objective of this paper is to present a case study of 17 Asian Pacific Economic Cooperation (APEC) economies. A directional distance function approach is employed to estimate output-oriented Malmquist-Luenberger productivity indices. The latter are in turn decomposed into efficiency changes and technological progress. Work in this paper differs from the existing literature by taking into consideration of the impact of environmental regulation on productivity growth. Three scenarios are modeled, ie. no control on CO_2 emissions (unregulated), maintaining current emission level and a partial reduction of emissions. In general, it is found that the rates of productivity growth incorporating CO_2 as an undesirable output are slightly higher than those estimated following the traditional method. Furthermore, the causes of productivity changes are also investigated in this paper.

Key Words Technical efficiency, technological progress, total factor productivity, directional distance functions, Malmquist–Luenberger index, DEA

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1. Introduction

There is an abundant literature on economic growth, in particular the sources of growth across countries as well as among individual economies. However, investigations of the relationship between economic growth and the environment only appeared in the early 1990s.[1] Since then, the effect of environmental regulation on economic growth has attracted a lot of attentions among both policy-makers and academia. Underlining the increased interest in this topic is the growing awareness of the environmental consequences of economic growth in the world. The latter has led to the United Nations Framework Convention on Climate Change (UNFCCC) with the aim to stabilize greenhouse gas (GHG) concentration in the atmosphere at a desirable level and in the meantime to maintain economic growth. The UNFCCC was negotiated at the Earth Summit in Rio de Janeiro in 1992. Subsequently, according to the 1997 Kyoto Protocol, industrialized countries agreed to reduce CO_2 emissions by about five percent of the 1990 level during the period of 2008-2012. 168 countries and one regional economic bloc have ratified this Protocol to date. With the recent policy changes towards climate change in the US, the campaigns for environmental protection among the nations are likely to gain new momentum and bring about tough regulations. Environmental regulations may result in resources being diverted away from the production of goods to pollution abatement activities (Färe et al. 2001a). How would these changes affect economic growth especially productivity growth? The latter is the main driving force of economic growth.

A number of studies have focused on the effect of environmental regulations on traditional measures of total factor productivity (eg. Jaffe et al. 1995). However, traditional measures of total factor productivity, e.g. Törnquist and Fischer indices, concentrate only on the production of desirable or good outputs and fail to consider environmentally hazardous (undesirable or bad) by-products of production processes because no prices are available for the undesirable outputs. In the meantime, the cost of abatement activities is included in the inputs. Hence, traditional approaches may yield biased measures of productivity growth. This problem may be overcome by considering the Malmquist productivity index which does not require information on prices. For example, Färe, Grosskopf, Norris and Zhang (1994) developed an approach which can decompose the Malmquist productivity index into technological progress and efficiency change components. This decomposition has been used to compare the differences and similarities in growth patterns across regions. In an application to Swedish paper and pulp mills, Chung et al. (1997) further introduced a directional distance function approach, ie. the Malmquist-Luenberger productivity index, to analyze models of joint production of good outputs and bad outputs. This index considers the reduction of bad outputs as well as the increase in good outputs. It also possesses all the desirable properties of the Malmquist productivity index.

The objective of this paper is to apply the Malmquist-Luenberger index method to a sample of 17 APEC economies over the period of 1980-2004. This paper contributes to the existing literature at least in two directions. First, three types of productivity indices are estimated and compared according to different policy scenarios, ie. no regulatory constraints, no change in current emissions levels and a partial reduction of emissions. Second, the determinants of productivity changes are also examined. The remainder of the paper is organized as follows. In section 2, a brief review of the related literature is

[1] Examples include Selden and Song (1994) and Grossman and Krueger (1995).

conducted. In section 3, the analytical framework is presented. In section 4, the data issues and empirical results are discussed. In section 5, the sources of productivity variation are investigated. Finally, section 6 concludes the paper.

2. Literature Review

When resources are employed for pollution abatement activities, measured inputs in an economy increase. As a result, traditional measures of total factor productivity (TFP) as the ratio of outputs over combined inputs are likely to be lower. This bias has led some observers to suggest that current methods of productivity measures almost always lead to the conclusion that environmental protection efforts and productivity performance are inversely related (Repetto et al. 1997). This may distort our assessment of economic performance and resultant changes in social well-being and hence lead to potentially misguided policy recommendations (Hailu et al. 2000).

Economists have long recognized that failure to account for non-market activities may lead to biases in the measurement of productivity change. Pittman (1983) provided the earliest attempt by introducing shadow prices and thus incorporating undesirable outputs in efficiency measurement.[2] Chung et al. (1997) extended the literature and developed the Malmquist-Luenberger (ML) productivity index which allows producers to increase the production of desirable outputs and reduce the production of undesirables simultaneously. This approach also accommodates the decomposition of changes in total factor productivity into changes in efficiency and technological progress. Although the Malmquist productivity index has been used widely, only a limited number of empirical studies have employed the Malmquist-Luenberger index to measure productivity growth. A brief review of these studies is presented here.

Using micro-level panel data, Färe et al. (2001a) estimated the Malmquist-Luenberger indices for the US state manufacturing sectors during the period of 1974-1986. They found that average annual productivity growth was 3.6%, whereas it was 1.7% when emissions are ignored. Similar conclusions were drawn by Domazlicky and Weber (2004) who applied the same technique to six US chemical industries at the three-digit SIC level for the period of 1988-1993. Domazlicky and Weber (2004) further argued that while there are costs associated with environmental regulations, those costs are overwhelmed by subsequent productivity growth. Lindmark et al. (2003) adopted the similar approach to analyze global convergence in productivity by using a sample of 59 countries for the period of 1965-1990. They found that, when bad outputs are included, total factor productivity growth is lower and so are the growth rates of technological progress and efficiency change.

Another study by Jeon and Sickles (2004) who applied both Malmquist and Malmquist-Luenberger indices to examine the impact on productivity growth due to the consideration of carbon dioxide as a bad output in OECD and Asian economies over the period 1980-1990 and 1980-1995, respectively. They found little change in average growth rates of total factor productivity for OECD countries and significant negative productivity growth in Asian economies except Japan. However, they could not decide whether changes are due to catch-up (efficiency change) or innovation (technological progress). Yoruk and Zaim (2005) also applied both Malmquist and

[2] Other studies following the same concept include Färe et al. (1993), Coggins and Swinton (1996), Swinton (1998) and Reig-Martínez et al. (2001).

Malmquist-Luenberger indices to measure productivity growth for all but two OECD countries over the period of 1985-1998. The Malmquist index showed an average productivity growth of at least about 10% for the OECD countries from 1985 to 1998, while the index that includes nitrogen oxide and organic water pollutant emissions implied a productivity growth of 20%. In comparison with the conventional Malmquist indices, the ML indices record at least 7% higher productivity growth for OECD countries. In addition, they also investigated the determinants of the variation in productivity growth across countries. They found that the dummy variable reflecting the ratification of the UNFCCC protocol on CO_2 emissions has a significant, positive effect on the ML index.

More recently, Kumar (2006) employed the Malmquist-Luenberger index to examine conventional and environmentally sensitive total factor productivity in 41 developed and developing countries over the period of 1971-1992. It is found that TFP indices are not different when CO_2 emissions are assumed to be freely disposable. As for the productivity growth components, ie. technological progress and efficiency changes, the null hypothesis of no changes under two different scenarios could not be accepted. Kumar also examined global catch-up and convergence or divergence in productivity growth which is environmentally sensitive.

Finally, several studies exclusively focused on productivity growth in APEC economies (Table 1). Chambers et al. (1996) calculated productivity growth and its components for 17 APEC economies over the period of 1975-1990 using an Luenberger productivity indicator which is based on the concept of directional distance function. They computed three versions of the productivity index by specifying three different "directions" for the distance function. Generally speaking, average annual productivity growth declined due to falling efficiency while technological progress was generally positive.

Chang and Luh (1999) calculated productivity growth and its components using the Malmquist productivity indices for 19 APEC member economies over the periods of 1970-1980 and 1980-1990, respectively. Regression analyses are also conducted to investigate the role of FDI and education in catch-up (moving along the production frontier) and innovation (shifting the production frontier). Their results indicate that the United States was not the sole innovator among 19 APEC member economies. Instead, Hong Kong and Singapore have shown their capability to shift the grand frontier of the APEC economies during the 1980s. This result is quite inspiring because it implies that the NIEs not only are good at moving towards the frontier, but also potential innovators. Chang and Luh (1999) showed that FDI contributed to TFP growth either through catch-up or technological progress. Färe et al. (2001b) also employed the Malmquist index to measure TFP growth and its two components, i.e. efficiency change and technological progress, in a sample of 17 APEC economies over the period of 1975-1996. In all economies the main cause of low TFP growth was a poor (negative) efficiency record. The average TFP growth rate for Japan and Malaysia was positive during 1975-1996, but the efficiency change component remained negative. They found that the main contributor to labour productivity growth was capital accumulation among APEC economies. Unlike previous studies they found no evidence of a poor TFP growth performance for Singapore.

Table 1: Summary of main studies on productivity growth in APEC economies

Author	Sample	Method	Period	TFP(%)	EC(%)	TP(%)
Chambers et al. (1996)	17	DEA	1975-1990	-0.26	-0.84	0.58
				-2.46	-4.39	1.93
				-0.52	-0.37	-0.15
Chang and Luh (1999)	19	DEA	1970-1980	-1.38	-1.50	0.10
			1980-1990	0.03	0.35	-0.32
Färe et al. (2001b)	17	DEA	1975–1990	0.07	-1.13	1.21
			1975–1996	0.28	0.48	0.76
Wu (2004)	16	SFA	1980s	3.98	1.32	2.66
			1990s	2.71	-0.66	3.38

Notes: TFP, EC and TP represent the rate of total factor productivity growth, efficiency changes and technological progress, respectively. Chambers et al (1966) computed three versions of the indices by specifying three different "directions" for the component distance functions. Efficiency changes in Wu include scale efficiency. DEA and SFA are abbreviations for data envelopment analysis and stochastic frontier analysis.

Among the studies reviewed so far, Wu (2004) is an exception. Wu applied a stochastic frontier (parametric) approach to analyze the relationship between openness, productivity and growth among the APEC economies for the period of 1980-1997. He found that openness affects not only efficiency changes but also the structure of production technology. In general, the empirical analyses have shown that, in terms of productivity growth, APEC developed members have performed better than their developing counterparts. In particular, APEC developed economies, led by the US, are found to be more innovative than APEC developing members. However, Japan appears to lag behind other developed economies in terms of technological progress. According to Wu (2004), APEC developing members have shown rapid catch-up with their rich neighbours. Korea and Taiwan were the lead performers in the 1980s. Mainland China took over to become the leader in the 1990s.

The above brief review suggests several gaps in the existing literature. While Chambers et al. (1996), Chang and Luh (1999), Färe et al. (2001b) and Wu (2004) examined APEC economies, their productivity estimates ignored undesirable outputs. Färe et al. (2001a), and Domazlicky and Weber (2004) focused on micro-level productivity growth. Other studies applied macro-level data, but only considered two types of productivity indices. Jeon and Sickles (2004) is an exception. However they did not examine the causes of productivity changes. This paper attempts to fill these gaps in the literature. The analytical framework is introduced next.

3. Analytical Framework

To introduce the analytical framework, it is assumed that a vector of inputs $x=(x_1,\cdots,x_N)\in R_+^N$ are employed to produce a vector of good outputs $y=(y_1,\cdots,y_M)\in R_+^M$, and undesirable or bad outputs $b=(b_1,\cdots,b_I)\in R_+^I$. Let *P(x)* be the feasible output set for the given input vector *x*. The technology is modeled by its output sets

$$P(x)=\{(y,b):\text{x can produce}(y,b)\},x\in R_+^N \tag{1}$$

It is assumed that the output sets are closed and bounded sets and that inputs are freely disposable.[3] In addition, three axioms are proposed

$$\text{if } (y,b)\in P(x) \text{ and } b=0 \text{ then } y=0. \tag{2}$$
$$\text{if } (y,b)\in P(x) \text{ and } 0\le\theta\le 1 \text{ then } (\theta y,\theta b)\in P(x). \tag{3}$$
$$\text{if } (y,b)\in P(x) \text{ and } y^{'}\le y \text{ imply } (y^{'},b)\in P(x). \tag{4}$$

The first axiom in equation (2) known as the null-jointness implies that the country cannot produce good output in the absence of bad outputs. The second axiom in equation (3) means that good and bad outputs are weakly disposable, implying that there is a cost for pollution control and that abatement activities would typically divert resources away from the production of desirable outputs and thus affect the good output negatively. The third axiom in equation (4) indicates that good outputs are strongly disposable. That is, the good output is freely disposable, but this is not a maintained condition for the bad output.

To formulate a DEA model that satisfies the above conditions, it is assumed that for each period $t=1,\cdots,T$, there are $k=1,\cdots,K$ observations of inputs and outputs, that is, (x_k^t,y_k^t,b_k^t). This database is then employed to construct the following output set that satisfies the above three axioms

$$\begin{aligned} P^t(x^t)=\{(y^t,b^t):\sum_{k=1}^{K} z_k^t y_{km}^t \ge y_m^t, m=1,\cdots,M \\ \sum_{k=1}^{K} z_k^t b_{ki}^t = b_i^t, i=1,\cdots,I \\ \sum_{k=1}^{K} z_k^t x_{kn}^t \le x_n^t, n=1,\cdots,N \\ z_k^t \ge 0, k=1,\cdots,K\} \end{aligned} \tag{5}$$

$$\sum_{k=1}^{K} b_{ki}^t > 0, i=1,\cdots,I \tag{6}$$

$$\sum_{i=1}^{I} b_{ki}^t > 0, k=1,\cdots,K \tag{7}$$

[3] For more details, refer to Färe and Primont (1995).

The z_k^t are the nonnegative weights assigned to each observation when constructing the production set, and imply that the production technology exhibits constant returns to scale. The latter ensures that total factor productivity indices are computed (Färe and Grosskopf 1996). The inequality constraints in equation (5) on the good outputs and input variables imply that these outputs and inputs are freely disposable. Furthermore, equations (6) and (7) ensure the property of the null-jointness of outputs.

Although the representation of the technology in equations (5), (6) and (7) is conceptually useful, it is not very helpful from a computational viewpoint. For functional representation of the technology, the following directional output distance function is employed.[4] This technique accommodates the production of byproducts, and is conceptually consistent with the above axiomatic approach.

3.1. Directional output distance functions

The objective of environmental protection is to reduce pollution (bad output) while economic growth (good output growth) is still maintained. To model such a production process, the directional output distance function is used. It is a generalization of the Shephard output distance function, and can accommodate non-proportional changes in output. Formally, it is defined as

$$\vec{D}_o(x, y, b; g) = \sup\{\beta : (y, b) + \beta g \in P(x)\} \tag{8}$$

where $g = (g_y, g_b)$ is the vector of directions in which outputs can be scaled. The directional distance function allows for a variety of direction vectors which depend on whether the technology exhibits free or weak disposal of bad outputs.[5] This study mainly considers three scenarios, that is,

- Scenario 1 (S1): the direction vector is $g = (y, 0)$ and the bad outputs are ignored in constructing the reference technology
- Scenario 2 (S2): the direction vector is $g = (y, 0)$ and the technology exhibits weak disposability in bad output
- Scenario 3 (S3): the direction vector is $g = (y, -b)$ and the technology exhibits weak disposability in bad outputs.

The first scenario implies that no environmental regulations exist. Under the second scenario, environmental regulations allow good outputs to increase while bad outputs are held constant. This is a direction that seems most in agreement with the goals of the Kyoto Protocols in terms of CO_2 emissions (Jeon and Sickles 2004). The third scenario deals with reduction of bad outputs at the same proportion that good outputs are allowed to increase. This direction can be viewed as a compromise between the goals of the pro-growth and anti-growth environmental movements (Jeon and Sickles 2004). It is also consistent with current practices and the objectives of UNFCCC as far as the control of CO_2 emissions is concerned. To simulate the three proposed scenarios, the following linear programming (LP) problem is to be solved

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[4] The directional output distance function is a variation of Luenberger's shortage function, see Luenberger (1992, 1995).

[5] For more discussions, see Chambers et al. (1996) and Färe et al. (2005).

$$\vec{D}_o^t(x_{k'}^t, y_{k'}^t, b_{k'}^t; y_{k'}^t, -b_{k'}^t) = \text{Max}\beta$$

s.t.

$$\sum_{k=1}^{K} z_k^t y_{km}^t \geq (1+\beta) y_{k'm}^t, m = 1, \cdots, M$$

$$\sum_{k=1}^{K} z_k^t b_{ki}^t = (1-\beta) b_{k'i}^t, i = 1, \cdots, I$$

$$\sum_{k=1}^{K} z_k^t x_{kn}^t \leq x_{k'n}^t, n = 1, \cdots, N$$

$$z_k^t \geq 0, k = 1, \cdots, K \tag{9}$$

This LP problem corresponds to scenario 3 of which scenarios 1 and 2 are special cases. A description of the latter is presented in the appendices. The directional output distance function takes a minimum value of zero for countries that are technically efficient, that is, they operate on the frontier of *P(x)*. A value of the directional output distance function greater than zero indicates technical inefficiency. The derived directional distance functions are then used to construct total factor productivity indices.

3.2. Productivity indices

Following Chung et al. (1997), the output oriented Malmquist-Luenberger (ML) productivity index between period *t* and *t+1* is expressed as

$$ML_t^{t+1} = \left\{ \frac{[1+\vec{D}_o^t(x^t, y^t, b^t; g^t)]}{[1+\vec{D}_o^t(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}]} \times \frac{[1+\vec{D}_o^{t+1}(x^t, y^t, b^t; g^t)]}{[1+\vec{D}_o^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1})]} \right\}^{\frac{1}{2}} \tag{10}$$

The ML index can be decomposed into an index of efficiency change (EFFCH) and an index of technological progress (TECH):

$$\text{ML} = \text{EFFCH} \times \text{TECH} \tag{11}$$

where

$$EFFCH_t^{t+1} = \frac{1+\vec{D}_o^t(x^t, y^t, b^t; g^t)}{1+\vec{D}_o^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1})} \tag{12}$$

$$TECH_t^{t+1} = \left\{ \frac{[1+\vec{D}_o^{t+1}(x^t, y^t, b^t; g^t)]}{[1+\vec{D}_o^t(x^t, y^t, b^t; g^t)]} \times \frac{[1+\vec{D}_o^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1})]}{[1+\vec{D}_o^t(x^{t+1}, y^{t+1}, b^{t+1}; g^{t+1}]} \right\}^{\frac{1}{2}} \tag{13}$$

A value of greater (less) than one for ML, EFFCH and TECH indicates productivity growth (decline), efficiency improvement (deterioration) and technical progress (regress), respectively. Under the three scenarios considered, there are three directional distance functions and hence three productivity indices. In order to get each productivity index, four programs need to be solved. Two programs involve observations and technology from the same time period *t* or *t+1*, and the other two use observations and technology of different time period, for example, period *t* technology with observations from period *t+1*. The latter problems can cause difficulties in calculation if the observed data in period *t+1* is not feasible in period *t*. To reduce the number of infeasible solutions in computing the ML index, each year's reference technology is determined by observations of the current and the past two periods.[6] Hence the reference technology for 2000, for example, would be constructed from data in 2000, 1999 and 1998. Following this approach, the productivity index and its two components are estimated for 17 APEC economies over the period of 1980 to 2004.

4. Data and Empirical Results

4.1. Data issues

CO_2 emissions account for over 80% of total greenhouse gas emissions. In this study GDP and CO_2 are considered as proxies of good and bad outputs respectively, and labor force and capital stock as inputs. The real GDP measured in 2000 US dollars is obtained by using population and real GDP per capita (RGDPCH) data from the Penn World Tables PWT6.2 (Heston, Summers and Aten 2006). Labor force is obtained by dividing the real GDP by the real GDP per worker (RGDPW) in the PWT6.2. Capital stock values are estimated using capital formation statistics drawn from the PWT6.2 (see the appendices for details about capital stock derivation). World Development Indicators (World Bank 2007) is the source for CO_2 emissions measured in thousand metric tons.[7]

Summary statistics of the sample are presented in Table 2. China, Malaysia, Thailand and the four East Asian NIEs have indeed achieved high growth since 1978. This high growth was matched by the rapid expansion of capital stock and CO_2 emissions in those economies. To take into account of the possible impact of UNFCCC and Kyoto Protocol on growth in CO_2 emissions, the discussions here focus on two sub-periods, i.e. without UNFCCC (1978-1991) and with UNFCCC (1992-2004), and two economic groups: Annex-I countries (Canada, USA, Japan, Australia, New Zealand) and Non-Annex-I countries.[8] Non-Annex-I countries can be further grouped into

[6] This technique was also adopted by Färe *et al*. (2001b) who provided the technical details about infeasible solutions in constructing index numbers.

[7] Taiwan's CO_2 emission figures were drawn from the Oak Ridge Data set (Marland et al 2003) and multiplied by 3.664 in order to be consistent with the world development indicators (WDI) statistics (because CO_2 emission is expressed in thousand metric tons of carbon in the Oak Ridge Data set). CO_2 emissions data for 2003 and 2004 are estimated using data from Euromonitor (2007) and WDI CO2 data for 2000-2002.

[8] The impact of Kyoto Protocol is not considered since the earliest date of enforcement was February 16 2005 which is out of our sample period. The Annex-I parties to the United Nations Framework Convention on Climate Change (UNFCCC) are listed in the Annex-I of the Climate Convention. They mainly include developed countries and regional organizations (EU).

Table 2: Summary statistics of the sample

Country code	Average growth (%, 1978-2004)			Average growth in CO_2 emissions (%)			Emission shares (%)	Date of ratification	
	Y	L	K	1978-1991	1992-2004	1978-2004		UNFCCC	Kyoto Protocol
AUS	3.3	1.78	3.7	2.57	2.64	2.65	2.58	30/12/92(21/3/94)	—
CAN	2.89	1.57	3.68	0.24	2.15	1.18	4.08	4/12/92(21/3/94)	7/12/02(16/2/05)
CHL	4.49	2.39	4.32	2.54	4.05	3.31	0.36	22/12/94(22/3/95)	26/8/02(16/2/05)
CHN	9.57	1.56	9.61	4.17	3.01	3.66	23.46	5/1/93(21/3/94)	30/8/02(16/2/05)
HKG	5.52	2.36	6.68	4.51	2.7	4.05	0.27	—(5/5/03)	—
IDN	4.54	2.8	6.53	4.37	4.0	4.54	1.64	23/8/94(21/11/94)	3/12/04(3/3/05)
JPN	2.46	0.71	3.62	1.36	0.89	1.13	9.85	28/5/1992(21/3/94	2/6/04(16/2/05)
KOR	6.65	2.06	9.42	7.24	4.02	5.82	2.61	14/12/92(21/3/94)	8/11/02(16/2/05)
MEX	2.84	3.09	3.58	3.83	0.99	2.62	3.22	11/3/1993(21/3/94	7/9/00(16/2/05)
MYS	6.48	2.85	8.25	8.58	6.66	7.73	0.75	13/7/94(11/10/94)	4/9/02(16/2/05)
NZL	2.52	1.67	2.51	2.36	2.59	2.59	0.24	16/9/93(21/3/94)	29/12/02(16/2/05)
PER	1.89	3.18	1.61	-0.38	2.12	0.81	0.22	7/6/93(21/3/94)	12/9/02(16/2/05)
PHL	3.1	2.73	3.4	1.59	3.58	2.82	0.49	2/8/94(31/10/94)	20/11/03(16/2/05)
SGP	6.66	3.23	5.84	2.63	3.00	2.76	0.42	29/5/97(27/8/97)	12/4/06(11/7/06)
THA	5.59	1.93	6.5	9.65	6.24	8.05	1.17	28/12/94(28/3/95)	28/8/02(16/2/05)
TWN	6.52	1.39	8.04	5.44	4.53	5.09	1.34	—	—
USA	3.04	1.36	3.9	0.11	1.64	0.82	47.29	15/0/92(21/3/94)	—
Mean 1	2.84	1.42	3.48	1.33	1.6	1.67	64.04	—	—
Mean 2	5.32	2.46	6.15	4.51	3.74	4.27	35.95		
Mean 3	4.81	2.57	5.48	4.29	3.1	4.19	31.31	—	—
Mean4	6.34	2.26	7.5	4.96	4.01	4.43	4.64	—	—
Mean5	4.59	2.16	5.36	3.58	2.25	3.51	99.99	—	—

Notes: Means 1-5 correspond to the group means of Annex-I, Non-Annex-I, Developing Countries, East Asian NIEs (Hong Kong, South Korea, Singapore, Taiwan) and APEC. The country codes represent in turn Australia (AUS), Canada (CAN), Chile (CHL), China (CHN), Hong Kong (HKG), Indonesia (IDN), Japan (JPN), Korea (KOR), Mexico (MEX), Malaysia (MYS), New Zealand (NZL), Peru (PER), Philippines (PHL), Singapore (SGP), Thailand (THA), Taiwan (TWN) and the United States (USA). The column "emission shares" reports a country's total percentage contribution to APEC CO_2emissions for the period from 1980 to 2005. The date in the parentheses indicates the date of ratification for each economy.

developing countries (Mexico, Chile, China, Indonesia, Malaysia, Philippines, Peru, Thailand) and East Asian newly industrialized economies (NIEs) (Hong Kong, South Korea, Singapore, Taiwan). By 1994, all APEC members but Singapore had ratified UNFCCC. Australia and USA have not yet ratified the Kyoto Protocol. Annex-I countries and China are the major contributors of CO_2 emissions, accounting for 87.5% of the total emissions from the APEC group. During the entire sample period, the highest growth rate with respect to CO_2 emissions was observed in Thailand (8.05%). It is also shown that the average annual growth in CO_2 emissions has slowed down since 1992 indicating the potentially positive impact of UNFCCC as supported by Yoruk and Zaim (2005).

4.2. Estimation Results

A summary of the empirical findings about productivity growth and its components under three scenarios is presented in Table 3. Under scenario 1 (the presence of CO_2 emissions is ignored), the average productivity index (PI) value of 1.0025 indicates that the annual productivity growth for the sample countries was 0.25% over the entire period, 1980-2004. On average, this growth was due to technical efficiency change (EC) of 0.20% and technological progress (TP) of 0.05%. A comparison across country groups indicates that, over the entire period, productivity growth and technological progress were higher in the Annex-I countries (0.59% and 0.49%) than in the Non-Annex-I countries (0.11% and -0.13%), but technical efficiency change was higher in the Non-Annex-I countries. For the sample of the four East Asian NIEs the average productivity index values are 1.0093 which is due to technological progress of 0.62% and improvements in efficiency of 0.32%. The average productivity growth for the developing economy group is -0.3%. This negative growth is largely due to technical regress. Among individual economies, 65% (11/17) of APEC members showed a positive productivity growth rate during 1980-2004. The economies that showed the highest productivity growth were Singapore (3.06%), Japan (1.60%) and USA (1.12%). In these countries, technological progress accounted for a greater portion of productivity growth than efficiency changes, in particular Japan has recorded a negative rate of technical efficiency change. This finding is consistent with that of Färe et al. (2001b) who found Singapore was ranked first among APEC in terms of efficiency change during the period of 1975-1996.

Table 3: Average productivity growth, 1980–2004

	Scenario 1			Scenario 2			Scenario 3		
	PI	EC	TP	PI	EC	TP	PI	EC	TP
AUS	1.0010	1.0003	1.0007	1.0021	0.9957	1.0064	1.0071	0.9963	1.0108
CAN	0.9992	1.0017	0.9975	1.0076	0.9979	1.0097	1.0075	0.9978	1.0097
CHL	0.9909	0.9939	0.9970	1.0029	1.0058	0.9971	1.0041	1.0055	0.9986
CHN	1.0042	1.0190	0.9854	0.9653	0.9981	0.9672	1.0002	1.0114	0.9889
HKG	1.0001	0.9989	1.0012	1.0199	1.0000	1.0200	1.0140	1.0000	1.0140
IDN	0.9853	0.9936	0.9918	0.9921	1.0016	0.9905	0.9935	1.0010	0.9925
JPN	1.0160	0.9985	1.0175	1.0151	0.9973	1.0179	1.0125	0.9980	1.0145
KOR	1.0003	0.9988	1.0015	1.0038	0.9984	1.0054	0.9961	0.9998	0.9963
MEX	0.9980	1.0007	0.9972	0.9929	0.9927	1.0002	0.9936	0.9944	0.9992
MYS	0.9946	0.9976	0.9970	0.9919	0.9953	0.9966	0.9930	0.9965	0.9966
NZL	1.0020	1.0032	0.9988	1.0031	0.9945	1.0087	1.0016	0.9952	1.0065
PER	0.9972	0.9972	0.9999	1.0066	1.0046	1.0020	1.0038	1.0023	1.0015
PHL	1.0057	1.0052	1.0006	1.0113	1.0000	1.0114	1.0071	1.0000	1.0071
SGP	1.0306	1.0127	1.0177	1.0305	1.0117	1.0186	1.0250	1.0094	1.0154
THA	1.0001	1.0088	0.9914	1.0009	0.9971	1.0038	0.9954	0.9928	1.0026
TWN	1.0066	1.0023	1.0043	1.0184	1.0007	1.0176	1.0084	1.0007	1.0077
USA	1.0112	1.0013	1.0099	1.0144	1.0006	1.0138	1.0035	1.0005	1.0030
Mean 1	1.0059	1.0010	1.0049	1.0084	0.9972	1.0113	1.0064	0.9976	1.0089
Mean 2	1.0011	1.0024	0.9987	1.0029	1.0005	1.0024	1.0028	1.0011	1.0017
Mean 3	0.9970	1.0020	0.9950	0.9954	0.9994	0.9960	0.9988	1.0005	0.9984
Mean 4	1.0093	1.0032	1.0062	1.0181	1.0027	1.0154	1.0108	1.0025	1.0083
Mean5	1.0025	1.0020	1.0005	1.0045	0.9995	1.005	1.0039	1.0001	1.0038

Note: The country codes are the same as in Table 2. These annual average growth indices are geometric means. The LP problems required for these exercises are solved using the software package GAMS. The authors are grateful to Carl Pasurka for providing us the GAMS codes used in Färe et al. (2001a). These codes have been the starting point for preparing the codes for this paper.

Under scenario 2 (CO_2 emissions are held constant), the average productivity index value of 1.0045 is slightly higher than the value under scenario 1. This result is supported by the findings of Jeon and Sickles (2004). In their research, the productivity indices under scenario 2 are on an average higher than those under scenario 1 for both OECD and Asian economies. Table 3 also shows that productivity growth was due to technical efficiency change of −0.05% and technological progress 0.50%. A comparison across country groups indicates that, over the entire period, productivity growth and technological progress were higher in the Annex-I countries (0.84% and 1.13%) than in the Non-Annex-I countries (0.29% and 0.24%), but technical efficiency change were relatively high in the Non-Annex-I countries. At the economy level, 76 % (13/17) of the economies showed a positive growth rate of productivity during 1980-2004. The countries that showed the highest productivity growth within the APEC group were Singapore (3.05%), Hong Kong (1.99%) and Taiwan (1.84%). In these economies, technological progress accounted for a greater portion of productivity growth than efficiency change. Overall, productivity index under scenario 2 has a higher value than that under scenario 1 for Canada, Chile, Hong Kong, Indonesia, Mexico, Peru, the Philippines and Thailand. However, the opposite is true for the developing countries and the East Asian NIEs. Thus, generalization of the results is difficult. Higher CO_2 growth does not necessarily imply low productivity growth.

In order to incorporate negative externalities into the measures of productivity, weights have to be assigned to the bad outputs. The Malmquist-Luenberger productivity index under scenario 3 imposes a restriction on CO_2 emissions and is consistent with concerns of global warming. The idea is to recognize producers for simultaneously increasing outputs and reducing CO_2 emissions. This technique thus offers an alternative way of assigning weights to the bad outputs. The average ML productivity index value of 1.0039 indicates that the annual productivity growth for the sample countries was 0.39% over the entire period of 1980-2004. This is higher than the rate under scenario 1 but is lower than the value under scenario 2, a finding supported by Jeon and Sickles (2004). On an average, this growth was due to technical efficiency change of 0.01% and technological progress 0.38%. A comparison across sub-groups indicates that, over the entire period, productivity growth and technological progress were higher in the Annex-I countries (0.28% and 0.17%) than in the Non-Annex-I countries (0.29% and 0.24%).

Among the APEC members, 71% (12/17) of the economies showed a positive productivity growth rate over the entire period. The economies that showed the highest productivity growth were Singapore (2.50%), Hong Hong (1.40%) and Japan (1.25%). The productivity indices under scenario 3 have relatively high values in comparison with the values under scenario 1 for Australia, Canada, Chile, China, Hong Kong, Indonesia, Mexico, Peru, the Philippines and Thailand. On an average productivity indices under scenario 1 are higher than those under scenario 3 for Annex-I countries, but the reverse is true for the Non-Annex-I countries. This finding contradicts that by Kumar (2006). However, technological progress is higher in the Annex-I countries than in the Non-Annex-I countries if the goal is to reduce CO_2 emissions. Kopp (1998) argued that developed countries experienced technological progress in a way that economizes on CO_2 emissions but the same did not happen in the developing economies during 1970-1990.

Finally, under the three scenarios, productivity growth, efficiency change and technological progress for the two sub-periods, i.e. 1980-1991 and 1992-2004, are also calculated and reported in the appendices. Under scenario 1, between 1980-1991 and 1992-2004 periods, 41% (7/17) of APEC members showed improvement in productivity with the greatest gains being obtained in Indonesia, Peru and Canada. Under scenario 2, between 1980-1991 and 1992-2004 periods, 47% (8/17) of the APEC economies showed productivity improvement with the largest gains being recorded in Peru, New Zealand and Malaysia. Under scenario 3, between 1980-1991 and 1992-2004 periods, 47% (8/17) of the economies showed an increase in productivity with the largest gains being shown in New Zealand, Malaysia and Mexico.

4.3 Identifying Innovators

The estimation results reported so far have shown technological progress indices for the economies between two adjacent years, but they do not allow us to identity which countries are shifting the frontier over time, that is, the innovators. In order to identify the innovators who actually cause the best-practice frontier to shift, Färe et al. (2001a) and Kumar (2006) used the following criteria

$$\begin{aligned} &TECH_t^{t+1} > 1 \\ &\vec{D}_o^t(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}) < 0 \\ &\vec{D}_o^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}) = 0 \end{aligned} \tag{14}$$

Economies satisfying the above criteria are regarded as innovators. The first condition, $TECH_t^{t+1} > 1$, ensures that the production possibility frontier shifts in the direction with more good and fewer bad outputs. It implies that, given the input vector in period *t+1*, it is possible to increase the good output and reduce the bad output (CO_2 emissions) relative to period t. The second condition guarantees that the production in period *t+1* occurs outside the production frontier of period *t* (i.e. technological progress has occurred). Thus, the technology of period *t* cannot produce the output vector of period *t+1* given the input vector of period *t+1*. Hence the value of directional distance function relative to the reference technology of period t is less than zero. The third condition implies that the country must be on the production frontier in period *t+1*. According to these criteria, the innovating countries are identified and listed in Table 4. Out of 24 two-year periods, under scenario 1 where CO_2 emissions are ignored, USA shifted the frontier 19 times, Taiwan shifted the frontier 11 times. Under scenario 2 where CO_2 emissions are held constant, USA shifted the frontier 20 times, Hong Kong and Taiwan shifted the frontier 17 times respectively. Under scenario 3 where CO_2 emissions are reduced, Hong Kong, Taiwan and USA shifted the frontier 17, 16 and 13 times respectively. Overall, eight different countries shifted the frontier at least once. In addition, according to Table 4, only one country shifted the frontier during 1997-1998 (ie. immediately after the 1997 Asian Economic Crisis) and no country shifted the frontier during 2000-2001 due to the world economic recession. Färe et al. (2001a) argued that there might exist a relationship between the business cycle and the number of countries that shift the frontier in a given year.

5. Explaining Productivity Growth

The estimation results in the preceding section have shown considerable variation in productivity performance across APEC economies. An examination of the sources of the cross-economy variation would contribute to the understanding of productivity growth with the presence of environmental regulations. There is no formal theory identifying the factors that affect productivity growth. Researchers often resort to previous studies and their own beliefs. In some cases, the choice of the factors is also dictated by the availability of cross-economy statistics. This study is subjected to those constraints too.

Table 4: Countries Shifting the Frontiers

	Scenario 1	Scenario 2	Scenario 3
1980-1981	-*	Hong Kong、New Zealand、Philippines、USA	Hong Kong、New Zealand、Philippines、USA
1981-1982	-	Philippines	Philippines
1982-1983	USA	Hong Kong、New Zealand、Philippines、Taiwan、USA	Hong Kong、New Zealand、Philippines、Taiwan、USA
1983-1984	Taiwan、USA	Hong Kong、New Zealand、Philippines、Taiwan、USA	Hong Kong、New Zealand、Philippines、Taiwan、USA
1984-1985	Taiwan、USA	Taiwan、USA	Taiwan、USA
1985-1986	Taiwan、USA	Hong Kong、Philippines、Taiwan、USA	Hong Kong、Philippines、Taiwan、USA
1986-1987	Taiwan、USA	China、Hong Kong、Taiwan、USA	Hong Kong、Taiwan
1987-1988	Taiwan、USA	Hong Kong、Philippines、Taiwan	Hong Kong、Philippines、Taiwan
1988-1989	Taiwan、USA	Hong Kong、Philippines、Taiwan、USA	Hong Kong、Japan、Philippines、Taiwan、USA
1989-1990	USA	Hong Kong、Taiwan、USA	Hong Kong、Taiwan、USA
1990-1991	Taiwan	Hong Kong、Taiwan	Hong Kong、Taiwan
1991-1992	Taiwan、USA	Chile、Hong Kong、Taiwan、USA	Chile、Hong Kong、Taiwan、USA
1992-1993	Philippines、Taiwan、USA	Chile、Hong Kong、Taiwan、USA	Chile、Hong Kong、Taiwan
1993-1994	Philippines 、Taiwan、USA	Chile、Hong Kong、Taiwan、USA	Hong Kong、Taiwan
1994-1995	USA	Taiwan、USA	Chile、Hong Kong、Taiwan、USA
1995-1996	USA	Hong Kong、Taiwan、USA	Hong Kong、Taiwan
1996-1997	Philippines、USA	Hong Kong、Taiwan、USA	Hong Kong、Taiwan
1997-1998	USA	USA	USA
1998-1999	USA	Taiwan、USA	Taiwan
1999-2000	Philippines、USA	Philippines、Taiwan、USA	Philippines、Taiwan
2000-2001	-	-	-
2001-2002	-	Hong Kong、Philippines、Taiwan、USA	Hong Kong、Philippines、USA
2002-2003	Taiwan、USA	Hong Kong、Taiwan、USA	Hong Kong、USA
2003-2004	Philippines、USA	Chile、Hong Kong、Indonesia、Philippines、Taiwan、USA	Chile、Hong Kong、Indonesia、Philippines、USA

* This implies that the frontier shifted backward slightly.

To examine the relationship between productivity growth and its determinants, the following simple regression involving panel data is employed here

$$PI = \alpha + \Sigma \alpha_i z_i + u \quad (15)$$

where PI and z_i represents productivity indices (the dependent variable) and their determinants (the explanatory variables), α's are parameters to be estimated and u is the standard white noise. To take environmental regulations into consideration, the PI's from both scenarios 2 and 3 are employed in equation (15). The explanatory variables are GDP per capita (*GDPPC*) in constant prices, the share of industrial value-add over GDP (*IND*), technical inefficiency in the previous year (TI_{t-1}), capital-labor ratios (*KL*), energy use per capita (*EPC*), openness index (*OPEN*) and a dummy variable (*UNFCCC*) that takes the value of one for the year in which the sample country ratified the UNFCCC and all subsequent years, and zero otherwise.[10] The squares of both GDP per capita and the share of industrial value-added over GDP are included to capture any quadratic relationships between the productivity index and these variables. Data for the GDP per capita and openness index are taken from PWT6.2. The share of industrial value-added over GDP and energy use per capita are drawn from the World Development Indicators database (World Bank 2007).[11]

The estimation results are presented in Table 5. The Hausman statistics indicate that the fixed-effect specification is preferred for both regressions. All coefficients are statistically significant. Table 5 shows a positive relationship between the GDP per capita and productivity index. In the meantime, the negative coefficient of the squared income variable implies that the relationship between the productivity index and income per capita follows an inverted-U shape with a turning point at approximately $39003 (scenario 2) or $38235 (scenario 3). Hence, once an 'average' APEC economy reaches this threshold income level, a downward trend in productivity growth is observed. This may reflect the catch-up movement of less developed APEC

[10] As Färe et al. (2001a) argued, a change in the composition of the industry sector of a country can also affect the level of CO_2 emissions. For example, presumably a shift away from pollution-intensive sector would yield a decline in CO_2 emissions.

[11] Some missing cells are filled by mean values of the observations in the past five years.

Table 5: Factors Associated with Changes in Productivity

Variable	Scenario 2				Scenario 3			
	Fixed effect		Random effect		Fixed effect		Random effect	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	2.0468*	24.4003	0.9936*	15.5336	1.7229*	26.1308	1.1259*	18.8822
GDPPC	2.2700*	11.3577	0.2520‡	1.3311	1.6900*	9.9009	0.5090*	2.8462
GDPPC2	-2.9100*	-9.8123	-0.3140	-0.795	-2.2100*	-8.5357	-0.6410†	-1.6971
IND	-0.3235*	-2.8261	0.2119	1.2438	-0.1291†	-1.8244	0.2298‡	1.4494
IND2	0.7432*	4.589	-0.3635‡	-1.4247	0.3608*	3.5179	-0.3676‡	-1.5445
TI_{t-1}	0.1385*	9.6554	0.0162‡	1.3912	0.1606*	11.2917	0.0582*	4.5809
LN(KL)	-0.1142*	-13.5134	-0.0037	-0.5009	-0.082*	-11.3659	-0.0193*	-2.9312
EPC	-1.3400*	-4.349	-0.2070	-1.1264	-1.0100*	-4.8698	-0.3260†	-1.7134
OPEN	-0.0171*	-4.082	0.0046**	1.9239	-0.0047‡	-1.4138	0.0033‡	1.3335
UNFCCC	-0.0058*	-3.1022	-0.007**	-1.9253	-0.0073*	-3.8877	-0.0069**	-2.1134
Turning point (GDPPC)	39003		40127		38235		39704	
Turning point (INDS)	0.22		0.29		0.18		0.31	
R2	0.5881		0.0717		0.4807		0.076	
Hausman test			81.8104				51.3601	
Number of observations	408		408		408		408	

Notes: The Hausman test indicates that the fixed-effects specification is preferred in both cases.
* Significance at the 1% level. ** Significance at the 5% level. † Significance at the 10% level. ‡ Significance at the 20% level.

economies. In contrast, Yoruk and Zaim (2005) showed an U-shaped relationship for OECD economies probably because these economies are more homogeneous in terms of the level of development. Table 5 also shows a negative relationship between the share of industrial value-added over GDP and the productivity index. However, the coefficient of the squared term demonstrates that the quadratic relationship is U-shaped with a turning point at approximately 22% (scenario 2) or 18% (scenario 3). Hence, once the share of industrial value-added over GDP exceeds this threshold for an economy, productivity growth trends upwards. Yoruk and Zaim (2005) made the similar observation for the OECD group. This phenomenon may be due to the fact that productivity grows relatively fast as an economy becomes more industrialized.

Furthermore, it is shown that the productivity index and the lagged technical inefficiency are positively related while the coefficient of the capital labor ratio variable is negative. One argument is that these relationships indicate convergence between APEC economies. Economies producing closer to the production frontier would have a lower level of productivity growth than those being farther away so that the latter can catch up with the former group (Lall et al. 2002). Kumar (2006) also supports this convergence hypothesis.

Finally, the openness and energy use per capita variables are both negatively related to the productivity indices. The openness variable could be a proxy for institutional and policy framework of an economy and capture the impact of international trade on productivity growth in particular (Etkins et al. 1994, Taskin and Zaim 2001, Kumar 2006). Thus the results imply that the environmentally undesirable effects may stem from the increased volume of trade and use of energy. In addition, the coefficient of the dummy variable is negative and statistically significant in both cases. This is contradictory to Yoruk and Zaim (2005) who provided empirical evidence of a positive impact of UNFCCC on productivity growth in OECD countries that have ratified the convention.

6. Conclusions

To sum up, traditional measures of productivity ignore the undesirable outputs and abatement activities and hence are likely to be biased. This study applied a well-developed approach to examine productivity growth under three policy options for environmental regulation. Using a sample of 17 APEC economies during the 1980-2004 period, it is found that in the absence of environmental regulations the average productivity growth was 0.25% which was largely due to technical efficiency change. However, if the policy objective is to maintain or reduce current level of CO_2 emissions, average productivity growth is estimated to be 0.45% or 0.39% which was largely due to technological progress. Thus, with environmental regulations, TFP growth for 17 APEC economies on average is slightly higher than that without regulations. This finding is supported by other studies.[12] This study also shows that out of 17 countries eight countries shifted the frontier at least once.

The determinants of the variation in productivity growth among APEC members are also investigated under two regulatory options. In general, more industrialized and advanced economies have shown better productivity performance. However,

[12] Examples include Boyd et al. (1999), Ball et al. (2001) and Jeon and Sickles (2004).

productivity index is found to be negatively associated with technical efficiency and the capital labor ratio, indicating the possibility of catch-up movement among the economies. In addition, energy intensity and openness of an economy are shown to be negatively related to productivity growth. Thus there are potentially undesirable effects from energy inefficiency and expanded international trade.

Appendices

A1. Linear programming problems for scenarios 1 and 2:

Scenario 1 (no environmental regulations)

$$\vec{D}_o^t(x_{k'}^t, y_{k'}^t, 0;\ y_{k'}^t, 0) = \text{Max}\beta \quad \text{(A1)}$$

s.t.

$$\sum_{k=1}^{K} z_k^t y_{km}^t \geq (1+\beta) y_{k'm}^t, m = 1, \cdots, M$$

$$\sum_{k=1}^{K} z_k^t x_{kn}^t \leq x_{k'n}^t, n = 1, \cdots, N$$

$$z_k^t \geq 0, k = 1, \cdots, K$$

Scenario 2 (the bad output, CO_2 emissions, is held constant)

$$\vec{D}_o^t(x_{k'}^t, y_{k'}^t, b_{k'}^t;\ y_{k'}^t, 0) = \text{Max}\beta$$

s.t.

$$\sum_{k=1}^{K} z_k^t y_{km}^t \geq (1+\beta) y_{k'm}^t, m = 1, \cdots, M$$

$$\sum_{k=1}^{K} z_k^t b_{ki}^t = b_{k'i}^t, i = 1, \cdots, I$$

$$\sum_{k=1}^{K} z_k^t x_{kn}^t \leq x_{k'n}^t, n = 1, \cdots, N \quad \text{(A2)}$$

$$z_k^t \geq 0, k = 1, \cdots, K$$

A2. Capital stock estimates

Capital stock data are derived following Wu (2004) who applied the conventional perpetual inventory approach, that is,

$$K_t = \Delta K_t + (1-\delta) K_{t-1} \quad \text{(A3)}$$

where K_t is the capital stock at time *t* for each economy, δ a given rate of depreciation and ΔK_t the incremental capital at time *t*. ΔK_t is computed from the real investment share of GDP presented in the PWT6.2 for the period 1950-2004 for most economies (The data for Hong Kong, Indonesia and Singapore cover the period 1960-2004). The data series for ΔK_t are backcasted to the year 1900. Accordingly, Equation (A3) is expanded into:

$$K_t = \sum_{k=0}^{t-1901} (1-\delta)^k \Delta K_{t-k} + (1-\delta)^{t-1900} K_{1900} \tag{A4}$$

Equation (A4) implies that, given the value of capital stock in 1900 and an appropriate rate of depreciation, a capital stock series for each economy can be derived. In this study, K_{1900} is assumed to be zero. This assumption is made due to the fact that the value of capital stock existed in 1900 would be zero by the 1980s and 1990s due to capital decay. While the potential impact of the choice of the rate of depreciation is noted, due to data constraints, this paper applies a unified rate of depreciation of 7% for all economies in the sample. A sensitivity analysis is applied to shed some light on the possible impact of effective depreciation rates. We choose a rate of depreciation of 4% for developing countries and Taiwan, and 7% for other economies. The estimation results hardly change.

A3. Estimation results for sub-periods

Table A1: Average indices and changes under scenario 1

	1980-1991			1992-2004			Change		
	PI	EC	TP	PI	EC	TP	PI	EC	TP
AUS	1.0022	0.9939	1.0084	1.0000	1.0063	0.9938	-0.0022	0.0124	-0.0146
CAN	0.9919	0.9910	1.0009	1.0059	1.0117	0.9942	0.0140	0.0207	-0.0067
CHL	1.0031	0.9965	1.0067	0.9791	0.9909	0.9880	-0.0240	-0.0056	-0.0187
CHN	1.0083	1.0484	0.9617	1.0007	0.9944	1.0064	-0.0076	-0.0540	0.0447
HKG	1.0010	0.9997	1.0014	0.9992	0.9982	1.0011	-0.0018	-0.0015	-0.0003
IDN	0.9788	1.0006	0.9782	0.9902	0.9866	1.0036	0.0114	-0.0140	0.0254
JPN	1.0278	1.0133	1.0142	1.0066	0.9850	1.0219	-0.0212	-0.0283	0.0077
KOR	1.0053	0.9971	1.0082	0.9957	1.0003	0.9955	-0.0096	0.0032	-0.0127
MEX	0.9954	0.9867	1.0088	1.0002	1.0139	0.9865	0.0048	0.0272	-0.0223
MYS	0.9842	0.9795	1.0047	1.0038	1.0143	0.9897	0.0196	0.0348	-0.0150
NZL	1.0002	1.0001	1.0002	1.0037	1.0064	0.9974	0.0035	0.0063	-0.0028
PER	0.9876	0.9826	1.0050	1.0058	1.0105	0.9953	0.0182	0.0279	-0.0097
PHL	1.0028	1.0103	0.9926	1.0088	1.0009	1.0079	0.0060	-0.0094	0.0153
SGP	1.0314	1.0169	1.0142	1.0324	1.0099	1.0223	0.0010	-0.0070	0.0081
THA	1.0016	1.0074	0.9943	0.9987	1.0108	0.9880	-0.0029	0.0034	-0.0063
TWN	1.0153	1.0050	1.0103	0.9993	1.0000	0.9993	-0.0160	-0.0050	-0.0110
USA	1.0094	1.0014	1.0080	1.0138	1.0014	1.0124	0.0044	0.0000	0.0044
Mean 1	1.0062	0.9999	1.0063	1.0060	1.0021	1.0039	-0.0002	0.0022	-0.0024
Mean 2	1.0011	1.0024	0.9987	1.0011	1.0025	0.9986	0.0000	0.0000	-0.0000
Mean 3	0.9952	1.0013	0.9939	0.9984	1.0027	0.9956	0.0032	0.0014	0.0017
Mean 4	1.0132	1.0046	1.0085	1.0065	1.0021	1.0045	-0.0067	-0.0025	-0.0040
Mean5	1.0026	1.0017	1.0010	1.0025	1.0024	1.0001	-1E-04	0.0007	-0.0009

Table A2: Average indices and changes under scenario 2

	1980-1991			1992-2004			Change		
	PI	EC	TP	PI	EC	TP	PI	EC	TP
AUS	1.0053	0.9868	1.0188	0.9993	1.0037	0.9956	-0.0060	0.0169	-0.0232
CAN	1.0062	0.9885	1.0180	1.0095	1.0065	1.0030	0.0033	0.0180	-0.0150
CHL	1.0063	1.0091	0.9972	1.0000	1.0033	0.9967	-0.0063	-0.0058	-0.0005
CHN	0.9785	1.0181	0.9611	0.9506	0.9800	0.9701	-0.0279	-0.0381	0.009
HKG	1.0256	1.0000	1.0256	1.0165	1.0000	1.0165	-0.0091	0.0000	-0.0091
IDN	0.9844	1.0034	0.9811	0.9985	1.0001	0.9983	0.0141	-0.0033	0.0172
JPN	1.0271	1.0059	1.0211	1.0056	0.9892	1.0165	-0.0215	-0.0167	-0.0046
KOR	1.0071	0.9963	1.0109	1.0010	1.0002	1.0008	-0.0061	0.0039	-0.0101
MEX	0.9872	0.9777	1.0097	0.9975	1.0061	0.9915	0.0103	0.0284	-0.0182
MYS	0.9841	0.9844	0.9996	0.9985	1.0050	0.9935	0.0144	0.0206	-0.0061
NZL	0.9945	0.9757	1.0192	1.0113	1.0115	0.9998	0.0168	0.0358	-0.0194
PER	0.9971	0.9899	1.0074	1.0160	1.0187	0.9974	0.0189	0.0288	-0.0100
PHL	1.0143	0.9987	1.0156	1.0096	1.0012	1.0084	-0.0047	0.0025	-0.0072
SGP	1.0306	1.0108	1.0196	1.0330	1.0134	1.0193	0.0024	0.0026	-0.0003
THA	1.0116	0.9968	1.0149	0.9912	0.9970	0.9941	-0.0204	0.0002	-0.0208
TWN	1.0321	1.0016	1.0304	1.0075	1.0000	1.0075	-0.0246	-0.0016	-0.0229
USA	1.0128	1.0000	1.0128	1.0171	1.0012	1.0158	0.0043	0.0012	0.003
Mean 1	1.0091	0.9913	1.0180	1.0085	1.0024	1.0061	-0.0006	0.0111	-0.0119
Mean 2	1.0047	0.9988	1.0059	1.0015	1.002	0.9994	-0.0032	0.0032	-0.0065
Mean 3	0.9954	0.9972	0.9982	0.9951	1.0014	0.9937	-0.0003	0.0042	-0.0045
Mean 4	1.0238	1.0022	1.0216	1.0144	1.0034	1.0110	-0.0094	0.0012	-0.0106
Mean5	1.006	0.9966	1.0094	1.0036	1.0021	1.0014	-0.0024	0.0055	-0.0080

Table A3: Average indices and changes under scenario 3

	1980-1991			1992-2004			Change		
	PI	EC	TP	PI	EC	TP	PI	EC	TP
AUS	1.0041	0.9888	1.0154	1.0105	1.0028	1.0076	0.0064	0.014	-0.0078
CAN	1.0043	0.9896	1.0148	1.0111	1.0052	1.0058	0.0068	0.0156	-0.009
CHL	1.0092	1.0090	1.0002	0.9998	1.0027	0.9970	-0.0094	-0.0063	-0.0032
CHN	1.0248	1.0196	1.0051	0.9782	1.0050	0.9734	-0.0466	-0.0146	-0.0317
HKG	1.0191	1.0000	1.0191	1.0105	1.0000	1.0105	-0.0086	0.000	-0.0086
IDN	0.9895	1.0021	0.9874	0.9967	1.0001	0.9966	0.0072	-0.0020	0.0092
JPN	1.0220	1.0049	1.0170	1.0049	0.9915	1.0135	-0.0171	-0.0134	-0.0035
KOR	1.0001	1.0008	0.9993	0.9921	0.9988	0.9933	-0.0080	-0.0020	-0.006
MEX	0.9884	0.9839	1.0046	0.9978	1.0036	0.9942	0.0094	0.0197	-0.0104
MYS	0.9869	0.9884	0.9985	0.9981	1.0036	0.9945	0.0112	0.0152	-0.004
NZL	0.9946	0.9763	1.0188	1.0082	1.0125	0.9959	0.0136	0.0362	-0.0229
PER	0.9994	0.9958	1.0036	1.0082	1.0084	0.9997	0.0088	0.0126	-0.0039
PHL	1.0079	0.9988	1.0091	1.0070	1.0011	1.0059	-0.0009	0.0023	-0.0032
SGP	1.0237	1.0078	1.0157	1.0282	1.0116	1.0165	0.0045	0.0038	0.0008
THA	0.9966	0.9903	1.0064	0.9939	0.9946	0.9993	-0.0027	0.0043	-0.0071
TWN	1.0162	1.0015	1.0147	1.0021	1.0000	1.0021	-0.0141	-0.0015	-0.0126
USA	1.0063	1.0000	1.0063	1.0012	1.0010	1.0002	-0.0051	0.001	-0.0061
Mean 1	1.0062	0.9919	1.0145	1.0072	1.0026	1.0046	0.001	0.0107	-0.0099
Mean 2	1.0051	0.9998	1.0053	1.0010	1.0024	0.9985	-0.0041	0.0026	-0.0068
Mean 3	1.0003	0.9984	1.0018	0.9974	1.0024	0.9950	-0.0029	0.004	-0.0068
Mean 4	1.0147	1.0025	1.0122	1.0081	1.0026	1.0056	-0.0066	0.000	-0.0066
Mean5	1.0054	0.9975	1.0080	1.0028	1.0025	1.0003	-0.0026	0.005	-0.0077

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