Open Access

CO_2 Emissions and Productivity in APEC Member Economies

Tsz-Yi Ke[1] and Jin-Li Hu[*,2]

[1]*Department of Economics, Aletheia University, Taiwan*

[2]*Institute of Business and Management, National Chiao Tung University, Taiwan*

Abstract: Global warming is one of the most important issues globally. In 1997 the Kyoto Protocol regulated the greenhouse gas reduction obligation of developed economies. This study takes carbon dioxide as an undesirable output and respectively uses Malmquist and Malmquist-Luenberger indices to compute the productivity change of APEC member economies. A panel dataset of 15 APEC economies from 1995 to 2003 is constructed. Developed economies have higher productivity if CO_2 emission is not considered in the Malmquist index. Since developed economies face stricter CO_2 abatement obligations, they have lower productivity than developing nations if the CO_2 abatement is taken into account in the Malmquist-Luenberger index. This study has found that, in terms of the Malmquist productivity index, the average productivity indices and technical changes of 15 economies generally regressed during the observation period. There are productivity improvements in Oceania and Central and South America. In terms of the degree of development, the productivity of developed economies is superior to that of developing economies. Developed economies have generally accepted higher productivity while disregarding CO_2 emission.

Keywords: APEC, Carbon dioxide, Undesirable output, Malmquist index, Malmquist-Luenberger index.

INTRODUCTION

The Kyoto Protocol was passed in Kyoto, Japan in December 1997, with the purpose of restricting greenhouse gas emission in industrialized countries, so as to mitigate the danger of global warming. The threshold of 55 countries was reached for the first time in May 2002. This protocol was then mandated to take effect in February 2005, and 156 countries ratified this protocol by September 2005, however, the U.S.[1] and Australia did not ratify it immediately.

As specified in this protocol, every industrialized country must reduce greenhouse gas emission by 5.2% during 2008~2012, as compared to their greenhouse gas emissions in 1990. In order to ensure that countries achieve the goal, this protocol allows three methods of abatement: emissions trading among Annex I countries, joint implementation among Annex I countries, and clean development mechanisms involving both Annex I and Annex II countries.

Most countries in general measure their economic levels by GDP. Therefore, based on green GDP, when considering the national output level, negative factors should also be included. Therefore, output is divided into two parts: desirable and undesirable. Desirable output refers to the general output favored by producers, whereas undesirable output is a kind of by-product not favored by producers and consumers, such as pollution and noise derived in production or consumption. Therefore, when considering national production efficiency, negative environmental factors should be included to reflect the actual situation, so as to avoid overestimating or underestimating national productivity or efficiency.

Studies take pollutants as an undesirable output [1-6]. Others present non-performing loans as an undesirable output [7, 8]. We find that most of these articles show lower efficiency when taking undesirable output into account. Most researchers believe that considering undesirable output could achieve more accurate efficiency measures.

The growth of GDP per capita in Asian nations was quite rapid from 1950 [9], but this means pollution has increased greatly as industry developed at a high speed [10]. The main source of carbon dioxide emission is from Asian nations, especially around the Pacific Ocean. The Asia-Pacific Economic Cooperation (APEC) is the premier Asia-Pacific economic forum, with its primary goal to support sustainable economic growth and prosperity in the Asia-Pacific region. The population of the member economies is over 2.5 billion and total GDP in the APEC region was about 60% of the world's total in 2008. Examining the economic structure of these member economies is important when talking about national performance. Examples of studies focusing on productivity growth in APEC countries are [11-14].

In the current literature, one study incorporated the impact of CO_2 emission on APEC nations' productivity [15], but did not mention whether the Kyoto Protocol would have different influences on developing and developed countries, as economic development is the main policy of every country. This study considers borderless CO_2 emission and conducts cluster analysis based on geographic regions, in order to discuss whether CO_2 emission, as an undesirable

*Address correspondence to this author at the Institute of Business and Management, National Chiao Tung University, Taiwan;
Tel: +886-23812386, Ext. 57641; Fax: +886-23494922;
E-mail: jinlihu@gmail.com

[1]The U.S. signed the protocol in November 1998, but in March 2001 the Bush Administration refused to ratify the Kyoto Protocol under the excuse that abatement will hamper U.S. economic development and developing countries should also carry out the obligation of abatement and limit.

1876-3251/11 2011 Bentham Open

output, impacts the national productivity of APEC member economics according to the regulations of the Kyoto Protocol.

This study uses Malmquist and Malmquist-Luenberger productivity indices to evaluate APEC member economies in the Asia-Pacific Region under the Kyoto Protocol. CO_2 emission is treated as an undesirable output to measure the productivity change of member economies, in order to see if there is a significant difference when undesirable output is included in the model.

MATERIALS AND METHODOLOGY

1. Malmquist Productivity Index

Malmquist [16] employ the output distance function to measure the frontier change ratio of a production set. Some economists [17] apply the concept of the output distance function on productivity measurement and named it the Malmquist productivity index.

Suppose firm H (also called decision making units (DMUs)) uses N inputs to produce M desirable outputs, defined respectively as: $\mathbf{x}=(x_1,...,x_N)\in R_+^N$ and $\mathbf{y}=(y_1,...,y_M)\in R_+^M$. Hence, the production set can be expressed as:

$$P(\mathbf{x})=\{\ \mathbf{y}:\ \mathbf{x}\ can\ produce\ \mathbf{y}\}.. \tag{1}$$

Other economists [18] employ the Malmquist productivity index to measure the change of DMU from period t to period $t+1$.

$$M_t^{t+1}=\left[\frac{D_o^t(x^{t+1},y^{t+1})}{D_o^t(x^t,y^t)}\cdot\frac{D_o^{t+1}(x^{t+1},y^{t+1})}{D_o^{t+1}(x^t,y^t)}\right]^{\frac{1}{2}}. \tag{2}$$

When $M_t^{t+1}>1$, productivity rises. If $M_t^{t+1}<1$, then productivity falls. When $M_t^{t+1}=1$, productivity does not change[2].

The Malmquist productivity index is divided into two parts as shown below: efficiency change (EFFCH) and technical change (TECH):

$$EFFCH_t^{t+1}=\frac{D_o^{t+1}(x^{t+1},y^{t+1})}{D_o^t(x^t,y^t)}. \tag{3}$$

and

$$TECH_t^{t+1}=\left[\frac{D_o^t(x^{t+1},y^{t+1})}{D_o^{t+1}(x^{t+1},y^{t+1})}\cdot\frac{D_o^t(x_0^t,y_0^t)}{D_o^{t+1}(x^t,y^t)}\right]^{\frac{1}{2}}. \tag{4}$$

EFFCH is multiplied by TECH to obtain the Malmquist productivity index ($M_t^{t+1}=EFFCH_t^{t+1}\cdot TECH_t^{t+1}$).

2. Malmquist-Luenberger Productivity Index

When both desirable and undesirable outputs are considered, then the undesirable output is defined by $u=(u_1,...,u_J)\in R_+^J$ and analyzed using the output set in Equation (1). Before analysis, the null-joint output and weak disposability output are introduced as follows.

Null-Joint Output

Desirable and undesirable outputs are derived together, where $\boldsymbol{u}$ is the by-product of producing $\boldsymbol{y}$. There is a null-joint relation between desirable output vector $\boldsymbol{y}$ and undesirable output $\boldsymbol{u}$:

$$(\mathbf{y},\mathbf{u})\in P(\mathbf{x})\ \text{, and if}\ \mathbf{u}=0\ \text{, then}\ \mathbf{y}=0\,. \tag{5}$$

Weak Disposability of Outputs and Strong or Free Disposability

$$(\mathbf{y},\mathbf{u})\in P(\mathbf{x})\ \text{, and}\ 0\le\theta\le1\ \text{, implying}\ (\theta\mathbf{y},\theta\mathbf{u})\in P(\mathbf{x}), \tag{6}$$

$$(\mathbf{y},\mathbf{u})\in P(\mathbf{x})\ \text{, and}\ \mathbf{y}^0\le\mathbf{y}\text{, implying}\ (\mathbf{y}^0,\mathbf{u})\in P(\mathbf{x}). \tag{7}$$

Equation (6) indicates that the technology has weak disposability output. Equation (7) shows that the desirable output can be disposed without cost.

The researchers [1, 20, 21] employed the Malmquist-Luenberger productivity index to measure the total factor productivity change with undesirable output. The directional distance function enables both an expansion of desirable output and shrinkage of undesirable output, defined as follows [22]:

$$\vec{D}_o(\mathbf{x},\mathbf{y},\mathbf{u};\mathbf{g}_\mathbf{y},-\mathbf{g}_\mathbf{u})=\max\{\ \beta:(\mathbf{y}+\beta\mathbf{g}_\mathbf{y},\mathbf{u}-\beta\mathbf{g}_\mathbf{u})\in P(\mathbf{x})\}, \tag{8}$$

where $\mathbf{g}=(\mathbf{g}_\mathbf{y},-\mathbf{g}_\mathbf{u})$ is the directional vector to expand desirable output ($\boldsymbol{y}$) and to shrink undesirable output ($\boldsymbol{u}$) simultaneously under the given input set.

The output-oriented Malmquist-Luenberger productivity index is defined as in [22]:[3]

$$\mathrm{ML}_t^{t+1}=\left[\frac{\left(1+\vec{D}_0^t\begin{pmatrix}\mathbf{x}^t,\mathbf{y}^t,\mathbf{u}^t;\\ \mathbf{y}^t,-\mathbf{u}^t\end{pmatrix}\right)\left(1+\vec{D}_0^{t+1}\begin{pmatrix}\mathbf{x}^t,\mathbf{y}^t,\mathbf{u}^t;\\ \mathbf{y}^t,-\mathbf{u}^t\end{pmatrix}\right)}{\left(1+\vec{D}_0^t\begin{pmatrix}\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{u}^{t+1};\\ \mathbf{y}^{t+1},-\mathbf{u}^{t+1}\end{pmatrix}\right)\left(1+\vec{D}_0^{t+1}\begin{pmatrix}\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{u}^{t+1};\\ \mathbf{y}^{t+1},-\mathbf{u}^{t+1}\end{pmatrix}\right)}\right]^{\frac{1}{2}}. \tag{9}$$

The Malmquist-Luenberger productivity index can be also divided into efficiency change (MLEFFCH) and technical change (MLTECH) as follows:

$$\mathrm{MLEFFCH}_t^{t+1}=\frac{1+\vec{D}_0^t(\mathbf{x}^t,\mathbf{y}^t,\mathbf{u}^t;\mathbf{y}^t,-\mathbf{u}^t)}{1+\vec{D}_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{u}^{t+1};\mathbf{y}^{t+1},-\mathbf{u}^{t+1})}, \tag{10}$$

and

[2]The original Malmquist index uses Shephard output distance functions to represent technology [19]. The output distance function is defined as: $D_o(\mathbf{x},\mathbf{y})=\inf\{\ \theta:\ \mathbf{y}/\theta\ \in P(\mathbf{x})\}$.

[3]There is no problem to use this definition to measure the productivity index if in the same period. However, it is maybe a problem to obtain the productivity index if the value of directional distance function has been computed less than 1 in the different period. Fortunately, the problem does not appear in this study.

$$\text{MLTECH}_t^{t+1} = \left[\frac{\left(1+\vec{D}_0^{t+1}\begin{pmatrix}\mathbf{x}^t,\mathbf{y}^t,\mathbf{u}^t;\\ \mathbf{y}^t,-\mathbf{u}^t\end{pmatrix}\right)}{\left(1+\vec{D}_0^{t}\begin{pmatrix}\mathbf{x}^t,\mathbf{y}^t,\mathbf{u}^t;\\ \mathbf{y}^t,-\mathbf{u}^t\end{pmatrix}\right)} \frac{\left(1+\vec{D}_0^{t+1}\begin{pmatrix}\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{u}^{t+1};\\ \mathbf{y}^{t+1},-\mathbf{u}^{t+1}\end{pmatrix}\right)}{\left(1+\vec{D}_0^{t}\begin{pmatrix}\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{u}^{t+1};\\ \mathbf{y}^{t+1},-\mathbf{u}^{t+1}\end{pmatrix}\right)} \right]^{\frac{1}{2}}. \quad (11)$$

If the resulting Malmquist-Luenberger productivity index is greater than 1, then the total factor productivity is improving. If it is less than 1, then total factor productivity is regressing. If it is equal to 1, then total factor productivity does not change.

For h firm (h DMU), the $\vec{D}_0^t\left(\mathbf{x}^t,\mathbf{y}^t,\mathbf{u}^t;\mathbf{y}^t,-\mathbf{u}^t\right)$ linear programming equation is:

$$\vec{D}_0^t\left(\mathbf{x}^{t,h},\mathbf{y}^{t,h},\mathbf{u}^{t,h};\mathbf{y}^{t,h},-\mathbf{u}^{t,h}\right) = \max_{\beta,\lambda_1,\ldots\lambda_H} \beta \quad (12)$$

Subject to: (i) $\sum_{h=1}^{H} \lambda_h y_m^{t,h} \geq (1+\beta) y_{k'm}^{t,h}, \quad m=1,\ldots,M,$

(ii) $\sum_{h=1}^{H} \lambda_h u_j^{t,h} = (1-\beta) u_j^{t,h}, \quad j=1,\ldots,J,$

(iii) $\sum_{h=1}^{H} \lambda_h x_n^{t,h} \leq (1-\beta) x_n^{t,h}, \quad n=1,\ldots,N,$

$\lambda_h \geq 0, \quad h=1,\ldots,H.$

This study adopts both Malmquist and Malmquist-Luenberger productivity indices to calculate the productivity changes of APEC member economies and to explore the impact of CO_2 abatement on national productivity.

RESULTS AND DISCUSSION

Among the 21 APEC member economies, Brunei did not ratify the Kyoto Protocol, and Taiwan is not a United Nations member and hence cannot sign the Kyoto Protocol. The Kyoto Protocol does not apply to Hong Kong, which is a special administrative region of China. In terms of data integrity, the labor input of Papua New Guinea cannot be retrieved from the International Labour Organization (ILO) online database, and the capital data of Russia and Vietnam are only available since 1990 and 1989, respectively, which are insufficient to estimate capital inventory. Therefore, there are 15 APEC member economies in total that signed the Kyoto Protocol and have complete data.[4] The data period spans from 1995 to 2003.

1. Variables and Data Source

Most studies focus on the national productivity with GDP as the output, and labor and capital as the inputs [13, 14]. Taking undesirable output of CO_2 emission into account, this study adopts two outputs and two inputs as follows.

Outputs: Desirable Output (GDP) and Undesirable Output (CO_2)

To measure national productivity output, most studies take GDP as the output [14, 23]. Due to increasingly severe global warming, CO_2 emission has been regarded as an undesirable output in measuring national productivity [15, 24], in order to compute national productivity that is close to the actual situation.

Inputs: Labor and Capital

The inputs of this study are labor amount and capital stock. Because capital stock cannot be acquired directly from the Penn World Table 6.2 database, it is computed by the perpetual inventory method [14].

This study uses the Penn World Table 6.2 database, ILO online database (ILO), and Carbon Dioxide Information Analysis Center (CDIAC) to collect the output/input dataset, in order to analyze the APEC member economies that signed the Kyoto Protocol from 1995 to 2003. All variables are in 2000 US dollars.

2. Analysis of the Malmquist Productivity Index

The data envelopment analysis (DEA) approach is used to calculate the output-oriented Malmquist indices, which are listed in Table **1**. As seen there, during the observation period the average productivity indices of most economies exhibit improvement (>1), but the overall average of the productivity indices is regressing (<1). This indicates that the degree of national productivity improvement (>1) is obviously less than the regression (<1). In each annual average of national productivity, the greatest improvement (>1) is in 1999/2000, because the technical change has the biggest improvement (1.031) in study period.

The change in overall average efficiency presents a slight improvement (>1). The resource allocation of nations is optimal in 2000/2001 because of the highest value of MEFF index. Most technical changes rise, but the overall average of technical change regresses (<1) slightly. The national production technologies still have room for improvement, and technical improvement is better than others in 1999/2000, because there is a higher growth rate of GDP.

Table 1. Annual Average Malmquist Indices

Index / Year	M	MEFF	MTE
1995/1996	1.009	1.003	1.006
1996/1997	1.008	0.984	1.025
1997/1998	0.961	1.019	0.943
1998/1999	1.007	0.997	1.010
1999/2000	1.017	0.986	1.031
2000/2001	0.980	1.046	0.938
2001/2002	0.999	0.998	1.001
2002/2003	1.000	1.011	0.989
Average	**0.998**	**1.001**	**0.993**

Note: M denotes Malmquist index; MEFF denotes Efficiency Change (EFFCH); MTE denotes Technical Change (TECH).

This study classifies 15 APEC member economies in five continents: first, Oceania: Australia, New Zealand; second, East Asia: China, Japan, South Korea; third, Southeast Asia:

[4]The 15 countries are Australia, Canada, Chile, China, Indonesia, Japan, South Korea, Malaysia, Mexico, New Zealand, Peru, Philippines, Singapore, Thailand, and the U.S.

Indonesia, Malaysia, Philippines, Singapore, Thailand; fourth, North America: Canada, United States, Mexico; and fifth, Central and South America: Chile, Peru.

The UN to date has no criteria to determine which country or region is developed or developing, but it is generally accepted that the developed economies are Australia, Canada, Japan, New Zealand, the U.S., South Korea, Singapore, and Europe, while the others are rated as developing economies.

Table **2** shows the average Malmquist indices in terms of continent. All APEC member economies in Oceania and North America exhibit productivity improvement. As to efficiency change, only APEC member economies in East Asia and Southeast Asia exhibit productivity regression (<1). As to technical change, except for APEC member economies in North America maintaining their technical level, all other APEC member economies exhibit technical regression (<1); yet the regression is not so serious. Compared to developing economies, the productivity of developed economies has comprehensive advantages, and developed economies have higher productivity when CO_2 emissions are ignored.

Table 2. Average Malmquist Indices

Continent \ Index	M	MEFF	MTE
Oceania	1.013	1.017	0.998
East Asia	0.992	0.999	0.993
Southeast Asia	0.987	0.998	0.989
North America	1.012	1.013	1.000
Central and South America	0.995	1.011	0.985
Developed	1.004	1.006	0.998
Developing	0.992	1.004	0.989
Average	**0.998**	**1.001**	**0.993**

Note: M denotes Malmquist index; MEFF denotes Efficiency Change (EFFCH); MTE denotes Technical Change (TECH).

3. Analysis of the Malmquist-Luenberger Productivity Index

LINGO8.0[5] is employed to compute the directional output distance function, as well as the year-on-year productivity index. Table **3** lists the average Malmquist-Luenberger indices of various countries in the observation period. As it shows, by taking undesirable output into account, economies show productivity improvement (>1), except in 1995/1996, 1999/2000, and 2002/2003, because they have a higher growth rate of CO_2 emission. The efficiency changes improve except in 1996/1997 and 1999/2000, because they both have higher growth rates of input usage. The technical changes offer improvement, except in 1995/1996, 1999/2000, and 2002/2003, which is just similar to the Malmquist-Luenberger index.

Table 3. Annual Average Malmquist-Luenberger indices

Year \ Index	ML	MLEFF	MLTE
1995/1996	0.971	1.002	0.969
1996/1997	1.040	0.996	1.045
1997/1998	1.082	1.004	1.083
1998/1999	1.077	1.003	1.078
1999/2000	0.990	0.992	0.997
2000/2001	1.142	1.021	1.116
2001/2002	1.001	1.008	1.002
2002/2003	0.992	1.003	0.989
Average	**1.038**	**1.003**	**1.035**

Note: ML denotes Malmquist-Luenberger index; MLEFF denotes Efficiency Change; MLTE denotes Technical Change.

The 15 APEC member economies are divided into five categories in terms of continent and two types of degree of development. Table **4** lists the average indices. During the study period, the average Malmquist-Luenberger productivity indices of the continents are rising except for the Southeast Asian economies. However, the improvement in Central and South America is really smaller than for others.

The efficiency change of East Asia has a tiny regression, but there is a great improvement in technical change, indicating that East Asian economies have the highest productivity improvement (>1). There is better productivity in East Asia than for others when we take CO2 emission into account. All Oceania and North America economies, except for Mexico, are generally accepted as being developed economies, and thus their technical changes are better, and resource allocation is improved. Therefore, the average Malmquist-Luenberger productivity index exhibits improvement (>1).

Regardless of developed or developing economies, the average indices of all economies show improvement (>1). However, under CO_2 emission control, the developed economies encounter stricter emission standards, making their productivity and technical change increase be not as much as in case of developing economies.

In terms of efficiency change, developed economies have it higher than developing economies and present greater improvements (>1). Due to high economic growth in recent years, China has excelled with soaring technical change, while other developing economies show minimal regression or growth. Therefore, the average technical change of developing economies is higher than that of developed economies, and developing economies have sufficient technologies to make their average productivity index exceed that of developed economies.

4. Analysis of Productivity Indices

Table **5** shows significant difference among indices during the observation periods. When CO_2 emission is excluded, all three indices reach the significance level of

[5]LINGO 8.0 is a software tool designed to efficiently build and solve linear, nonlinear, and integer optimization models.

1%[6], but when CO2 emission is included, the indices have no significant difference. Efficiency change improves (>1), regardless of whether taking CO_2 emission into account. Technical change falls before taking CO_2 into account, but rises slightly after taking CO_2 into account. After the Knowledge-Based Economy Report[7] was published in 1996, all countries exerted efforts and thus technical change advanced during the research period. As CO_2 emission better reflects actual situations, technical change drives productivity change from a slight fall to a rise.

Table 4. Malmquist-Luenberger Average Indices

Continent \ Index	ML	MLEFF	MLTE
Oceania	1.040	1.009	1.036
East Asia	1.145	0.999	1.148
Southeast Asia	0.998	0.998	1.000
North America	1.020	1.013	1.005
Central and South America	1.0002	1.000	1.0002
Developed	1.036	1.005	1.032
Developing	1.039	1.001	1.038
Average	**1.038**	**1.003**	**1.035**

Note: ML denotes Malmquist-Luenberger index; MLEFF denotes Efficiency Change; MLTE denotes Technical Change.

Table 5. Test of Annual Average Indices

Year \ Index	M	MEFF	MTE	ML	MLEFF	MLTE
1995/1996	1.009	1.003	1.006	0.971	1.002	0.969
1996/1997	1.008	0.984	1.025	1.040	0.996	1.045
1997/1998	0.961	1.019	0.943	1.082	1.004	1.083
1998/1999	1.007	0.997	1.010	1.077	1.003	1.078
1999/2000	1.017	0.986	1.031	0.990	0.992	0.997
2000/2001	0.980	1.046	0.938	1.142	1.021	1.116
2001/2002	0.999	0.998	1.001	1.001	1.008	1.002
2002/2003	1.000	1.011	0.989	0.992	1.003	0.989
Average	**0.998**	**1.001**	**0.993**	**1.038**	**1.003**	**1.035**
P-value	**0.001*** **	**<0.001*** **	**<0.001*** **	**0.713**	**0.220**	**0.599**

Note: *** denotes 1% significance level.

The results of Table **5** are plotted into a trend map. Fig. (**1**) shows the annual trend of Malmquist indices, and the trend of the Malmquist productivity index (M) offers no significant difference from that of Technical Change (MTE). Most economies ratified the Kyoto Protocol during 1998/1999, but neither the Malmquist productivity index nor Technical Change (MTE) fell due to the signing of the Kyoto Protocol, except for a slight fall in Efficiency Change (MEFF). Because CO_2 emission is excluded, though it differs significantly during various periods, the indices are not affected by the protocol.

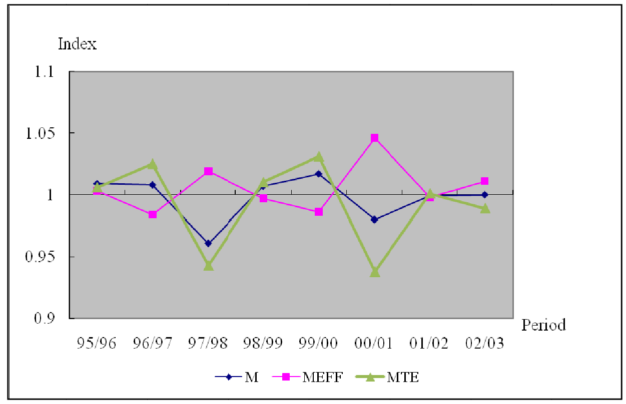

Fig. (1). Annual trend of Malmquist indices.

Fig. (**2**) shows the annual trend of Malmquist-Luenberger indices. The trend of the productivity index (ML) is similar to that of technical change (MLTE). The trend of efficiency change (MLEFF) is really slight, and so it affects the Malmquist-Luenberger productivity index rather little. As seen in the figure, when taking CO_2 emission into account, the Malmquist-Luenberger productivity index falls obviously after the signing of the Kyoto Protocol during 1998/1999, while maintaining productivity improvement (>1). Due to great improvement in technical change (MLTE), the Malmquist-Luenberger productivity index increased sharply during 2000/2001, but the terrorist attacks in the U.S. and the dot-com bubble led to a global panic, resulting in the great fall in technical change in 2001. Therefore, the Malmquist-Luenberger productivity index fell, too.

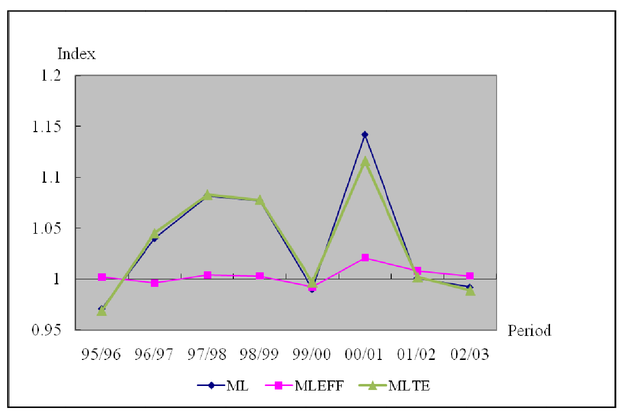

Fig. (2). Annual trend of Malmquist-Luenberger indices.

The U.S. signed the Kyoto Protocol in November 1998, but the Bush Administration refused to ratify it in March 2001 with the excuse that abating CO_2 emission would hamper U.S. economic development and developing economies should also bear the obligation of abatement and limits. In terms of national productivity change, will CO_2 abatement hamper the U.S. economy? As shown in Table **6**, if we disregard CO_2 emission, then the U.S. productivity fell (<1), but probably because of the terrorist attacks in 2001. When considering CO_2 emission, the productivity regressed

[6]We used the Kruskal-Wallis test and the hypotheses as follow: H_o: All types are equal; H_a: One of these types is different from others at least.
[7]Internet resource: http://www.oecd.org/dataoecd/51/8/1913021.pdf

(<1) before the protocol was rejected, yet improved afterwards, thus indicating that CO_2 emission does affect U.S. productivity.

Will productivity be affected if developing economies do not undertake the abatement and limit obligations? Taking China as a representative for developing economies, if we disregard CO_2 emission, then the U.S. average Malmquist productivity index during the research period is higher than that of China, as CO_2 emission is not considered a national obligation. In other words, U.S. national productivity is higher than that of China. If we consider CO_2 emission, as China is not subject to abatement and limit obligations, its average Malmquist-Luenberger productivity index is higher than the U.S., which is not acceptable to the U.S. who has to suffer worse national productivity while bearing the obligations of CO_2 abatement.

Table 6. Productivity Indices of the U.S. *vs* China

Index		U.S.	China
Malmquist productivity index (M)	2000/2001	1.021	
	2001/2002	0.987	
	Average during study period	1.015	0.997
Malmquist-Luenberger Productivity index (ML)	2000/2001	0.709	
	2001/2002	1.414	
	Average during study period	1.046	1.326

CONCLUSION

The Kyoto Protocol mandated restrictions of greenhouse gas emission in industrialized countries in 1997. The inclusion of the negative environment factor in measuring an economy's level can better reflect actual situations, so that national productivity or efficiency is not overestimated or underestimated. This study has measured national productivity while considering CO_2 emission under the Kyoto Protocol and has assessed APEC member economies in the Asia-Pacific Region under the Kyoto Protocol with productivity indices. By regarding CO_2 emission as an undesirable output and measuring member economies' productivity change, this study has explored whether there are significant differences when the economies take undesirable output into account and has discussed whether the signing of the Kyoto Protocol will result in a negative impact on national productivity. The analysis was done on APEC member economies that signed the Kyoto Protocol during 1995-2003.

This study has found that, in terms of the Malmquist productivity index, the average productivity indices and technical changes of 15 economies generally regressed (<1) during the observation period. If categorized by continent, there are productivity improvements (>1) in Oceania and Central and South America. In terms of the degree of development, the productivity of developed economies is superior to that of developing economies. Developed economies have generally accepted higher productivity while disregarding CO_2 emission.

Malmquist-Luenberger productivity indices on average are improving (>1), except for Southeast Asian economies. If East Asian economies can achieve breakthroughs in resource allocation and reduce CO_2 emission or create more GDP under a given technical level, then their average Malmquist-Luenberger productivity indices can rise. Regardless of the degree of development, the average indices of all economies exhibit improvement (>1). However, under CO_2 emission control, the developed economies face stricter emission standards, and the improvement levels of productivity indices and technical change are less than developing economies.

CO_2 emission regulation has affected national productivity in developed economies. The productivity in developing economies is better when not subject to abatement and limit obligations. As the Bush administration stated, reducing emissions would hamper the U.S. economic development, and therefore the Bush Administration refused to ratify the Kyoto Protocol in 2001. Although developing economies produce less greenhouse gas during the industrialization period, if they can share abatement responsibilities, then they will make contributions to relieving global warming to some extent.

ACKNOWLEDGEMENT

The authors thank two anonymous referees and an editor of this journal for their valuable comments. Financial support from the National Science Council in Taiwan (NSC100-2410-H-009-051) is gratefully acknowledged.

CONFLICT OF INTEREST

None declared.

REFERENCES

[1] Chung YH, Färe R, Grosskopf S. Productivity and undesirable outputs: a directional distance function approach. J Environ Manage 1997; 51: 229-40.
[2] Scheel H. Undesirable outputs in efficiency valuation. Eur J Oper Res 2001; 132: 400-10.
[3] Francesc HS, Andres PT, Ernest RM. Efficiency and environmental regulation an application to Spanish wooden goods and furnishings industry. Environ Resource Econom 2000; 15: 365-78.
[4] Fernández C, Koop G, Steel MFJ. Multiple-output production with undesirable outputs: an application to nitrogen surplus in agriculture. J Am Stat Assoc 2002; 97: 432-42.
[5] Yu MM. Measuring physical efficiency of domestic airports in Taiwan with undesirable outputs and environmental factors. J Air Transport Manage 2004; 10: 295-303.
[6] Atkinson SE, Dorfman JH. Bayesian measurement of productivity and efficiency in the presence of undesirable outputs: crediting electric utilities for reducing. J Economet 2005; 126: 445-68.
[7] Li Y, Hu JL, Liu HW. Non-performing loans and bank efficiencies: an application of the input distance function approach. J Stats Manage Syst 2009; 12: 435-50.
[8] Li Y. DEA efficiency measurement with undesirable outputs: an application to Taiwan's commercial banks. Int J Serve Technol Manage 2005; 6: 504-15.
[9] van den berg H. Economic growth and development. Boston: McGraw-Hill/Irwin 2001.
[10] World Bank. The East Asian Miracle: Economic Growth and Public Policy, World Bank, Washington, DC 1993.
[11] Hu JL, Kao CH. Efficient energy-saving targets for APEC economies. Energy Policy 2007; 35: 373-82.
[12] Mcguire G, Findlay C. Services trades liberalisation strategies for APEC member economies. Asian-Pac Econ Lit 2005; 19: 18-41.
[13] Färe R., Grosskopf S, Margaritis D. APEC and the Asian economic crisis: early signals from productivity trends. Asian Econ J 2001; 15: 325-41.
[14] Wu Y. Openness, productivity and growth in the APEC economies. Emp Econ 2004; 29: 593-604.

[15] Wang B, Yan P. Technical efficiency, technical progress and East-Asian economic growth – empirical analysis on APEC's view. Econ Res J 2007; 5: 91-103.

[16] Malmquist S. Index numbers and indifference surfaces. Trabajos de Estatistic 1953; 4: 209-42.

[17] Caves DW, Christensen LR, Diewert WE. The economic theory of index numbers and the measurement of input, output and productivity. Econometric 1982; 50: 1393-414.

[18] Chen Y, Ali AI. DEA Malmquist productivity measure: New insights with an application to computer industry. Eur J Oper Res 2004; 159(1): 239-49.

[19] Shephard RW. Theory of cost and production functions. Princeton: Princeton University Press 1970.

[20] Kumar S. Environmentally sensitive productivity growth: a global analysis using Malmquist-Luenberger index. Ecol Econ 2006; 56: 280-93.

[21] Oh DY. A metafrontier approach for measuring an environmentally sensitive productivity growth index. Energy Econ 2010; 32: 146-57.

[22] Färe R, Grosskopf S. New Directions: efficiency and productivity. Boston: Kluwer 2005.

[23] Lozano-Vivas A, Pastor JT. Relating macro-economic efficiency to financial efficiency: a comparison of fifteen OECD countries over an eighteen year period. J Product Anal 2006; 25: 67-78.

[24] Arcelus FJ, Arocena P. Productivity differences across OECD countries in the presence of environmental constraints. J Oper Res Soc 2005; 56: 1352-62.

Received: September 3, 2011 Revised: October 10, 2011 Accepted: October 20, 2011