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A Linear Programming Formulation of Macroeconomic Performance: The Case of Asia Pacific

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Abstract A mathematical programming technique in productivity management, known as Data Envelopment Analysis, DEA, is used to estimate how well the nations in Asia and the Pacific utilize their resources. Based on selected input and output indicators, we apply an output-oriented DEA model of Charnes, Cooper and Rhodes to assess their relative performance. For each inefficient unit (nation), DEA identifies the peer units, sources and levels of inefficiency for each input and output. The efficient units are ranked using the Andersen-Petersen's DEA model. The results generated are analyzed and compared.

Keywords Linear programming, Data Envelopment Analysis, efficiency, macroeconomic performance.

1 Introduction

There is an increasing interest in measuring and assessing the macroeconomic performance of nations. A high growth rate (as indicated by the change in gross domestic product), a low rate of inflation, a low rate of unemployment and a favorable trade balance are four main targets or objectives of a nation's macroeconomic policy makers. These performance indexes are referred to in literature as the"magic diamond" of OECD (Organisation of Economic Cooperation and Development) with its four vertices synonimizing the four indicators [9]. The sum of the inflation rate and the unemployment rate defines the undesirable Okun's "misery index" and provides a pessimistic measure of the macroeconomic performance of a nation. An alternative undesirable measure is provided by the Calmfor's index, defined as the difference between the unemployment rate and the normalized trade balance.

Several studies on measuring, evaluating and assessing macroeconomic and development performance of regions, cities, provinces and nations have been conducted and reported in the literature. Charnes, Cooper and Li[3] used Data Development Analysis(DEA) to evaluate efficiency in the economic performance of 28 selected Chinese cities following the government's program of economic development. Sueyoshi [11] extended the study to measuring and evaluating the industrial performance which also explored the returns-to-scale of these cities. The macroeconomic performance of ten Asian economies with special attention to Taiwan was studied and summarized by Lovell [8] in terms of the four output indicators. Despotis [5] extended the applicability of the DEA model with variable returns to scale to estimate the relative efficiency of countries in Asia and the Pacific in converting incomes to human development. Other regional studies utilizing DEA include [7] and [10].

This paper seeks to assess the macroeconomic performance of selected economies in Asia and the Pacific for the years 1996, 2000 and 2003 by utilizing the basic output-oriented CCR DEA model based on one input (the government's expenditure expressed as percentage of gross domestic product) and four outputs on the vertices of the OECD's magic diamond. For each inefficient economy, a list of peer economies is identified and an improved target values of its input and outputs that would make it efficient are computed. The economies are further ranked using an output-oriented version of Andersen-Petersen's DEA model [1]. Results obtained are analyzed and compared.

2 DEA Methodology

A DEA formulation is motivated by the classical engineering-science definition of productivity, extended to multiple inputs and outputs. The mathematical programming formulation presented below was originally derived in [4] and is normally referred to as the "CCR ratio form of DEA".

Suppose there are S decision making units (DMUs) to be investigated, each utilising m inputs to produce n outputs. Further, let DMU_k $(1 \leq k \leq S)$ use a combination of m inputs denoted by $X_k = \{X_{k1}, X_{k2}, ..., X_{km}\}$ to produce n outputs, denoted by $Q_k = \{Q_{k1}, Q_{k2}, ..., Q_{kn}$. The productivity or relative efficiency, E_k for DMU_k is defined as

$$E_k = \frac{\sum_{j=1}^{n} h_j Q_{kj}}{\sum_{i=1}^{m} c_i X_{ki}}, \quad k = 1, 2, ..., S, \tag{1}$$

where the weights c_i represents the price (i.e. the value or shadow cost) of one unit of input X_{ki} , $1 \leq i \leq m$, $k = 1, 2, ..., S$, and h_j represents the price (or the value of contribution) of one unit of output Q_{kj} , $1 \leq j \leq n$, $k = 1, 2, ..., S$.

Direct application of the above definition is not easy since it requires the determination of the weights to be assigned to each input and output. The DEA methodology overcomes this by employing a mathematical programming technique whereby the efficiency ratio defined by equation (1) is further subjected to a number of constraints.

- The efficiency of each DMU must not exceed 100%. Thus $E_k \leq 1.0$, for $k = 1, 2, ..., S$. If $E_k = 1.0$, then DMU_k is efficient. Otherwise, if $E_k < 1.0$, then DMU_k is inefficient. This is mathematically equivalent to

$$\sum_{i=1}^{m} c_i X_{ki} - \sum_{j=1}^{n} h_j Q_{kj} \geq 0, \quad k = 1, 2, ..., S. \tag{2}$$

- Further, the costs of all inputs and the prices of all outputs must be strictly positive. To ensure this we must incorporate a system of inequalities,

$$c_i \geq \varepsilon > 0, \quad i = 1, 2, ..., m, \tag{3}$$

and

$$h_j \geq \varepsilon > 0, \quad j = 1, 2, ..., n, \tag{4}$$

where ϵ is an arbitrary small positive number. If $c_i = 0$, DEA is unable to detect and analyze any inefficiency related to the usage of input X_i . Similarly, if $h_j = 0$, DEA is unable to detect and analyze any inefficiency related to the production of output Q_j. Thus, imposing $\epsilon > 0$ as a requirement to be satisfied by each variable implies that all inputs and outputs are to be regarded as having at least some positive worth, although remains unspecified.

Conditions (2), (3) and (4) lead to the formulation of a fractional programming problem as follows:

$$\text{maximize} \qquad E_k = \frac{\sum_{j=1}^{n} h_j Q_{kj}}{\sum_{i=1}^{m} c_i X_{ki}}$$

subject to

$$\sum_{i=1}^{m} c_i X_{ki} - \sum_{j=1}^{n} h_j Q_{kj} \geq 0, \quad k = 1, 2, ..., S,$$

$$c_i \geq \varepsilon > 0, \quad i = 1, 2, ..., m,$$

$$h_j \geq \varepsilon > 0, \quad j = 1, 2, ..., n.$$

To simplify the computation, we transform the fractional programming problem to a linear programming problem by scaling the input prices so that the total cost of inputs for the DMU under evaluation, say DMU_0, equals 1.0. This calls for an additional constraint, namely, $\sum_{i=1}^{m} c_i X_{0i} = 1$. The computation of relative efficiency score for DMU_0 can thus be formulated as follows:

$$\text{maximize} \qquad E_0 = \sum_{j=1}^{n} h_j Q_{0j} \tag{5}$$

subject to

$$\sum_{i=1}^{m} c_i X_{ki} - \sum_{j=1}^{n} h_j Q_{kj} \geq 0, \quad k = 1, 2, ..., S, \tag{6}$$

$$\sum_{i=1}^{m} c_i X_{0i} = 1 \tag{7}$$

$$c_i \geq \varepsilon > 0, \quad i = 1, 2, ..., m, \tag{8}$$

$$h_j \geq \varepsilon > 0, \quad j = 1, 2, ..., n. \tag{9}$$

The above linear programming form of DEA model comprises $m + n$ decision variables and $S + m + n + 1$ linear constraints. To aid in ranking the efficient DMUs, we can apply the

Andersen-Petersen's efficiency score obtained by relaxing the binding constraint imposed on the efficient DMU [1]. In addition to providing values of the relative efficiency scores, DEA also makes it possible to identify sources and estimate levels of inefficiency for each inefficient DMU by utilizing the dual values associated with members of each peer group [12] by constructing a composite unit, say DMU_c, such that

$$Z_{ci} = \sum_p |\alpha_p| Z_{pi} \tag{10}$$

where α_p is the dual value of DMU_p in peer group ,
Z_{pi} is the input/output indicator-i of DMU_p , and
Z_{ci} is the input/output indicator-i of DMU_c .

This DMU_c is superior and acts as benchmark to an inefficient DMU under evaluation.

3 Empirical Analysis

Data acquisition

Data for 1996, 2000 and 2003 were collected for selected economies of Asia and the Pacific. The main references are [2] and [6]. Due to missing data, the number of economies varies from twenty two in 1996 to twenty five in 2000 and 2003. The countries are Australia, Azerbaijan, Bangladesh, Cambodia, China (Mainland), Fiji Island, Hong Kong, India, Indonesia, Japan, Kazakhstan, Korea (South), Kyrgyz, Macao (2000 and 2003), Malaysia, Myanmar (1996 and 2000), Nepal (2000 and 2003), New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, Uzbekistan (2000 and 2003) and Vietnam (2003). However, Myanmar, which was found to be performing reasonably well in 1996 and 2000, was excluded in 2003 due to incomplete data availability and replaced by Vietnam. We make an effort to include Brunei into the list but the available statistics were compiled differently and decomposing them into the required indicators is not an easy task.

Input and outputs

One input and four output indicators were chosen to characterize and reflect the macroeconomic performance of the selected economies. These are defined as follows.

- Input 1 (X1) : Government expenditure expressed as percentage of gross domestic product (GDP) which in some studies acts as control variable.
- Output 1 (Q1) : The annual rate of growth of GDP, expressed in percentage.
- Output 2 (Q2) : The rate of employment, expressed as percentage of employment to labour force.
- Output 3 (Q3) : The ratio of merchandise exported in free on board (f.o.b) prices to merchandise imported in charges, insurance and freight (c.i.f) prices as a proxy for balance of trade.
- Output 4 (Q4) : The rate of inflation as proxied by the rate of change of the consumer price index, CPI.

The indicators of input, rate of employment and balance of trade take a strictly positive value for all observations. The rate of growth and inflation indicators take on negative values for some observations, and DEA is not capable of handling negative values. Thus, for consistency all indicators were normalized on a scale of [1, 10] such that the following hold.

- For indicators whose large positive values are preferable (for example Q1), we adopted the transformation

$$X_{nor} = \frac{9(X_{act} - X_{\min})}{X_{\max} - X_{\min}} + 1 \tag{11}$$

  where X_{nor} is the value of the normalized indicator,

  X_{act} is the actual value of the indicator,

  X_{max} is the maximum value of the indicator,

  X_{min} is the minimum value of the indicator.

  This transformation ensures that $X_{nor} \in [1,\ 10]$.

- For indicators whose small values (positive or negative) are preferable (for example Q4), we adopted the transformation

$$X_{nor} = \frac{9(X_{\max} - X_{act})}{X_{\max} - X_{\min}} + 1 \tag{12}$$

  where X_{nor} is the value of the normalized indicator,

  X_{act} is the actual value of the indicator,

  X_{max} is the maximum value of the indicator,

  X_{min} is the minimum value of the indicator,

  This transformation ensures that $X_{nor} \in [1,\ 10]$.

Results and discussion

The data on input and output indicators for the selected economies for each period 1996, 2000 and 2003 are presented in Tables 1, 2 and 3 respectively, (columns 3 - 7). For each DMU, an appropriate output-oriented CCR DEA model was formulated and solved using LINDO. Column 8 summarizes the efficiency scores, column 9 identifies the peer group for inefficient DMUs and the alternative Andersen-Petersen's scores for the efficient DMUs while column 10 provides the ranking of all DMUs.

In 1996, only ten DMUs, namely Azerbaijan, Bangladesh, Cambodia, China, Indonesia, Japan, Malaysia, Singapore, Taiwan and Thailand showed best performance. Indonesia is top-ranked with the highest Andersen-Petersen's score of 1.98259. This means that in 1996, Indonesia had an outstanding performance compared to others. However, it only appeared twice in the peer group, whereas Malaysia and Japan (ranked 2^{nd} and 3^{rd}, respectively) appeared six and five times in the peer group. Thailand (which is ranked 6^{th}), on the other hand, appeared in ten peer groups. Thus there seems to be no correlation between the ranking based on Andersen-Petersen's score and the number of times an efficient DMU which appeared in the peer group. The three laggards were Philippines, India and Sri Lanka (with efficiency scores of 0.8921, 0.8458 and 0.8281, respectively).

Table 2 summarizes the results for the year 2000 (post East Asia economic crisis). Ten of the twenty-five selected economies, namely Azerbaijan, Bangladesh, Cambodia, Hong Kong, Indonesia, Japan, Kazakhstan, Nepal, Singapore and Uzbekistan showed the best performance. With an Andersen-Petersen's score of 2.45705, Bangladesh took the lead although it only appeared in three peer groups as compared to Azerbaijan (ranked 7^{th}), Kazakhstan (ranked 4^{th}) and Uzbekistan (ranked 8^{th}) which appeared thirteen, ten and eight times, respectively. The position achieved by Bangladesh can be strongly attributed to its lowest input utilization (of only 4.60). China, Malaysia, Taiwan and Thailand failed to maintain their respective 100% DEA efficiency scores achieved in 1996. The three laggards in 2000 were Fiji Islands, Philippines and India (lowest score of 0.6252), with Sri Lanka not far in front.

Table 1 Data and results (year 1996)

DMU	Country	*X1*	*Q1*	*Q2*	*Q3*	*Q4*	*E*	Peer group	Rank
1	Australia	18.50	4.30	91.8	0.9214	2.6	0.9392	(10, 14)	18
2	Azerbaijan	12.00	1.30	99.2	0.6566	19.3	1.0000	1.00294*	9
3	Bangladesh	4.40	4.60	97.5	0.5651	4.1	1.0000	1.00010*	10
4	Cambodia	5.90	4.60	99.1	0.6005	10.1	1.0000	1.02218*	5
5	China (PR)	11.50	9.60	97.0	1.0880	8.3	1.0000	1.04358*	4
6	Fiji Islands	16.00	3.10	94.2	0.7568	3.1	0.9482	(10,22)	16
7	Hong Kong	8.60	4.50	97.2	0.9104	16.3	0.9899	(4, 9, 22)	12
8	India	10.70	8.10	42.7	0.8553	9.0	0.8458	(3, 10, 14)	21
9	Indonesia	7.60	7.80	96.0	1.1801	18.0	1.0000	1.98259*	1
10	Japan	15.10	3.50	96.6	1.1773	0.1	1.0000	1.08205*	3
11	Kazakhstan	13.50	0.90	95.8	0.9433	39.3	0.9586	(21, 22)	13
12	Korea	10.20	6.80	98.0	0.8628	5.0	0.9969	(3,4,14,22)	11
13	Kyrgyz, Rep	18.50	6.90	95.5	0.6026	32.0	0.9472	(14, 22)	17
14	Malaysia	11.10	10.00	97.5	0.9987	3.5	1.0000	1.12182*	2
15	Myanmar	14.90	6.40	95.9	0.4656	16.3	0.9512	(14, 22)	14
16	New Zealand	17.60	3.20	93.9	0.9756	2.3	0.9485	(10, 22)	15
17	Pakistan	12.60	5.00	94.6	0.7444	10.4	0.9234	(2, 22)	19
18	Philippines	12.00	5.90	92.6	0.5920	9.0	0.8921	(10,14,22)	20
19	Singapore	9.50	7.70	97.0	0.9519	5.4	1.0000	1.00298*	8
20	Sri Lanka	10.50	3.80	88.7	0.8148	15.9	0.8281	(9, 21, 22)	22
21	Taiwan	14.30	6.10	97.4	1.1284	3.1	1.0000	1.00970*	7
22	Thailand	10.20	5.90	98.9	0.7705	5.8	1.0000	1.01159*	6

* *Andersen-Petersen's efficiency score*

Table 2 Data and results (year 2000)

DMU	Country	*X1*	*Q1*	*Q2*	*Q3*	*Q4*	*E*	Peer group	Rank
1	Australia	18.26	2.80	93.7	0.8929	4.5	0.9128	(2, 25)	21
2	Azerbaijan	13.20	11.40	98.8	0.8972	-1.2	1.0000	1.08877*	7
3	Bangladesh	4.60	5.90	97.5	0.5752	3.9	1.0000	2.45705*	1
4	Cambodia	6.70	5.40	97.4	0.7886	-0.8	1.0000	1.19692*	6
5	China (PR)	13.10	8.00	96.9	1.1073	0.3	0.9797	(2,10,25)	14
6	Fiji Islands	17.90	9.30	92.4	0.6868	1.1	0.8997	(2, 25)	23
7	Hong Kong	10.20	10.50	95.1	0.9486	-3.7	1.0000	1.23224*	5
8	India	12.90	5.20	40.4	0.8255	4.0	0.6252	(7,9,11)	25
9	Indonesia	7.08	4.90	93.9	1.8536	4.5	1.0000	1.77952*	2
10	Japan	6.69	2.40	95.3	1.2628	-7.0	1.0000	1.24504*	3
11	Kazakhstan	11.20	9.80	96.3	1.7484	8.2	1.0000	1.23849*	4
12	Korea	10.20	9.30	95.9	1.0734	2.2	0.9775	(2,3,4,7,11)	16
13	Kyrgyz, Rep	18.70	5.50	96.9	0.9146	8.7	0.9608	(2, 25)	17
14	Macao	11.86	1.50	93.2	1.1259	-1.6	0.9502	(4,9,10,25)	18
15	Malaysia	10.60	8.30	96.9	1.1985	1.6	0.9950	(2,4,9,11)	12
16	Myanmar	13.70	6.20	97.6	0.6855	1.7	0.9805	(2, 25)	13
17	Nepal	9.00	6.20	98.2	0.1297	2.6	1.0000	1.00045*	10
18	New Zealand	18.40	2.20	94.0	0.9544	2.6	0.9171	(2, 25)	19
19	Pakistan	11.00	4.40	92.8	0.8310	4.4	0.9156	(2,3,11)	20
20	Philippines	12.80	4.00	88.8	1.0744	4.4	0.8591	(2,11,25)	24
21	Singapore	10.50	10.30	96.5	1.0242	1.4	1.0000	1.00571*	9
22	Sri Lanka	10.50	6.00	92.4	0.7566	6.2	0.9086	(2,3,11)	22
23	Taiwan	13.00	6.00	97.0	1.0561	1.3	0.9796	(2,11,25)	15
24	Thailand	11.50	4.60	97.6	1.1152	1.5	0.9962	(2,4,11,25)	11
25	Uzbekistan	19.70	4.00	99.6	1.1259	-3.3	1.0000	1.03415*	8

* *Andersen-Petersen's efficiency score*

The results for the year 2003 are summarized in Table 3. Only seven of the twenty-five selected economies achieved 100% DEA efficient. Macao was ranked top of the sample with an Andersen-Petersen's score of 1.66691 and appeared in fifteen peer groups. Thailand, which, ranked 5^{th}, appeared in seventeen peer groups. Indonesia, Japan, Kazakhstan, Singapore and Uzbekistan lost their efficiency status and were replaced by Macao and Thailand. The three laggards were Uzbekistan (which was efficient in 2000), Philippines and India with a lowest score of 0.5947.

Results in Tables 1 - 3 also reveal some interesting observations. Not all developed nations can be categorized as efficient. Two developed economies, Australia and New Zealand, remained relatively inefficient throughout the study period although they achieved high relative efficiency scores of greater than 0.9000. Some economies experienced drops in their efficiency scores between 1996 and 2003. China and Malaysia are examples. Their scores dropped from 1.00 each in 1996 to 0.9797 and 0.9950 in 2000 and 0.9786 and 0.9934 in 2003, respectively. Thus in 2000 and 2003, these countries were actually falling behind some other key economies on a relative basis in utilizing their resources. Another result of potential interest is that some countries showed improvements in their efficiency scores over the years. Hong Kong improved its score from 0.9899 in 1996 to 1.00 in 2000 and 2003, while Macao exhibited a tremendous increment from 0.9502 in 2000 to 1.0000 in 2003, thereby improving its ranking from 18^{th} to 1^{st}.

It is worthwhile to explore discrepancies between DEA results and supposedly customary observations (or expectations) of the performance of some economies. Azerbaijan, Bangladesh and Cambodia are three nations that were surprisingly being designated by DEA as efficient performers for all the three years. In 1996, Azerbaijan recorded the highest rate of employment (99.2%) despite a low economic growth and high rate of inflation, while Bangladesh recorded the lowest input utilization (of 4.40), reasonable economic growth and inflation rate. Cambodia, on the other hand, indicated an input utilization of 5.90 and economic growth of 4.60, comparable to Bangladesh and a high employment rate of 99.1%, comparable to Azerbaijan. A similar analysis follows for the years 2000 and 2003. DEA methodology allows the flexibility of each DMU to choose its own weights to maximize its efficiency score. Thus the optimal choice is to assign the minimum feasible weights (almost zero) to unfavorable indicators and the maximum feasible weights to favorable indicators. This explains the efficient scores obtained by these DMUs despite the presence of some unfavorable indicators. On the other extreme, we have India, Philippines and Sri Lanka which remained inefficient. India appeared as a relatively poor macroeconomic performer in all DEA results. It scored 0.8458 in 1996, 0.6252 in 2000 and 0.5947 in 2003. In 1996, India recorded the lowest employment rate (of only 42.7%) and relatively high inflation rate and input utilization despite favorable economic growth. Philippines and Sri Lanka showed similar pattern. Thus a single very unfavorable indicator and/or combination of unfavorable indicators can result in a DMU being deemed inefficient.

It is also possible to identify sources and estimate the levels of inefficiency for each inefficient unit by utilizing the dual values associated with members of the peer group [12]. This provides information regarding by how much inefficient DMUs should reduce their inputs or increase their outputs to become efficient. The values of input and outputs that make each inefficient DMU efficient are given in Table 4 for the year 2003.

Although the set of targets is output oriented, all DMUs (except DMU25: Vietnam) should reduce input $X1$, the government expenditure (as percentage of GDP), in order to

Table 3 Data and results (year 2003)

DMU	Country	*X1*	*Q1*	*Q2*	*Q3*	*Q4*	*E*	Peer group	Rank
1	Australia	18.15	6.06	94.1	0.8581	2.79	0.9421	(16, 23)	17
2	Azerbaijan	9.36	15.64	98.6	0.6409	2.60	1.0000	1.01659*	6
3	Bangladesh	5.36	10.00	97.0	0.7096	5.69	1.0000	1.54089*	3
4	Cambodia	5.83	7.72	97.0	0.8749	1.17	1.0000	1.58091*	2
5	China (PR)	13.10	9.10	95.6	1.0532	1.20	0.9786	(14, 23)	13
6	Fiji Islands	10.55	7.60	92.0	0.4692	4.20	0.9093	(3,16,23)	21
7	Hong Kong	10.66	-2.17	92.1	1.0533	-2.62	1.0000	1.08090*	4
8	India	12.51	8.21	40.0	0.9750	4.34	0.5947	(14)	25
9	Indonesia	8.21	11.08	91.8	1.2400	10.04	0.9396	(4,14,23)	18
10	Japan	17.66	-1.53	94.6	1.1298	-0.91	0.9978	(14, 23)	8
11	Kazakhstan	11.27	14.74	91.2	1.1434	6.45	0.9464	(14, 23)	16
12	Korea	13.33	5.42	96.6	1.0708	3.55	0.9812	(16, 23)	12
13	Kyrgyz, Rep	17.24	10.69	96.8	0.9003	3.48	0.9956	(14, 23)	9
14	Macao	10.42	16.71	94.0	1.7219	-1.57	1.0000	1.66691*	1
15	Malaysia	13.75	8.69	96.4	1.2247	0.97	0.9934	(14, 23)	10
16	Nepal	10.49	5.90	98.0	0.4984	5.67	1.0000	1.00335*	7
17	New Zealand	18.09	4.11	95.3	1.0108	1.71	0.9675	(14, 23)	15
18	Pakistan	11.70	10.73	92.0	1.0061	2.91	0.9286	(14, 23)	19
19	Philippines	10.96	8.59	88.6	0.9496	2.93	0.8655	(14, 23)	24
20	Singapore	12.88	2.41	95.7	1.0748	0.50	0.9911	(14, 23)	11
21	Sri Lanka	7.91	11.22	91.2	0.8446	6.31	0.9241	(3,14,23)	20
22	Taiwan	12.59	3.30	95.0	1.1331	-0.30	0.9075	(14, 23)	22
23	Thailand	10.59	9.31	97.8	1.1141	1.76	1.0000	1.02081*	5
24	Uzbekistan	19.70	4.40	90.6	1.3120	4.00	0.9051	(14, 23)	23
25	Vietnam	6.90	12.93	93.5	0.8699	3.09	0.9679	(3,14,23)	14

** Andersen-Petersen's efficiency score* become efficient. This is not a difficult task since the government's expenditure is subjected to frequent review and is within the decision maker's control. On the output side, we observe that the rate of employment, $Q2$ is satisfactorily acceptable for all inefficient DMUs (except DMU8: India). This implies that omitting $Q2$ from the set of outputs will have no significant effect on the results (except for DMU8). Ten and fifteen DMUs should increase outputs $Q1$ and $Q3$, respectively and eleven DMUs should reduce output $Q4$ in order to be on the efficient frontier.

Table 4 Targets for inefficient DMUs (year 2003)

DMU	Country	*X1*	*Q1*	*Q2*	*Q3*	*Q4*
1	Australia	10.12	8.15	94.1*	0.9948	2.79*
5	China (PR)	10.35	10.67	95.6*	1.2300	1.20*
6	Fiji Islands	9.87	7.60*	92.0*	0.9397	3.30
8	India	7.66	8.21*	69.5	1.1579	3.71
9	Indonesia	7.88	11.18	91.8*	1.2400*	0.53
10	Japan	10.38	15.27	94.6*	1.6035	-0.91
11	Kazakhstan	10.02	14.74*	91.2*	1.5774	-0.49
12	Korea	10.35	8.94	96.6*	1.0708	2.12
13	Kyrgyz, Rep	10.47	10.69*	96.8*	1.2260	1.17
15	Malaysia	10.44	11.15	96.4*	1.2648	0.97*
17	New Zealand	10.29	9.72	95.3*	1.1551	1.71*
18	Pakistan	9.99	10.73*	92.0*	1.2521	1.39
19	Philippines	9.59	8.59*	88.6*	1.0969	2.58
20	Singapore	10.40	12.21	95.7*	1.3528	0.50*
21	Sri Lanka	7.54	11.22*	91.2*	1.0845	3.12
22	Taiwan	9.75	14.62	95.0*	1.5811	-0.30*
24	Uzbekistan	9.81	11.36	90.6*	1.3120*	1.19
25	Vietnam	6.90*	12.93*	93.5*	1.2694	1.34

* *Actual values*

Except for DMU8 and DMU25, all other inefficient DMUs have two of the indicators as satisfactorily acceptable (where the target values equal the actual values). For DMU8 (India), only output $Q1$ is satisfactorily acceptable, while for DMU25 (Vietnam) three of the indicators are satisfactorily acceptable. A closer quantitative observation reveals the following.

- Seven DMUs (namely Australia, China, Japan, Malaysia, New Zealand, Singapore and Taiwan) should reduce input $X1$ and increase outputs $Q1$ and $Q3$ while maintaining outputs $Q2$ and $Q4$. This is not unrealistic since $Q3$ (balance of trade) is one of the components of GDP and increasing $Q3$ results in increasing $Q1$ (the rate of growth of GDP) and reducing $X1$. Thus, the task of decision maker in this case reduces to finding ways of improving the balance of trade.

- Six DMUs (namely Fiji Islands, Kazakhstan, Kyrgyz, Pakistan, Philippines and Sri Lanka) should reduce input $X1$, increase output $Q3$ and reduce output $Q4$ while maintaining outputs $Q1$ and $Q2$. This is not an easy task since reducing the rate of inflation, $Q4$, calls for many drastic measures.

- Three DMUs (namely, Indonesia, Korea and Uzbekistan) should reduce input $X1$, increase output $Q1$ and reduce output $Q4$ while leaving outputs $Q2$ and $Q3$ unchanged. This again is not an easy task since it involves reducing the rate of inflation (for example, from 10.04% to 1.24% for Indonesia).

- One DMU (Vietnam) needs to improve its trade balance and reduce its rate of inflation from 3.09% to 1.34% in order to become efficient.

- One DMU (India) faces the task of improving all indicators, except $Q1$ if it is to be on the efficient frontier. This calls for reduction in $X1$ (from 12.5% to 7.66%), increment in $Q2$ (from 40.00% to 69.50%), increment in $Q3$ (from 0.9750 to 1.1579) and reduction in $Q4$ (from 4.34% to 3.71%). The main task here lies in creating and providing more jobs to increase the rate of employment in the hope of lowering the rate of inflation and improving the balance of trade.

From the above discussion, we see that DEA not only provides alternative means of assessing the relative efficiency and performance of DMUs but also identifies targets that will guide the decision makers in driving their DMUs towards the efficient frontier.

4 Conclusions

In this study we utilized the DEA mathematical programming evaluation methodology, and illustrate its applicability in measuring, assessing and analyzing macroeconomic performance of selected major economies of Asia Pacific. The technique exhibits a number of commendable features. It can handle production scenario involving multiple inputs and multiple outputs that are measured in their own units and are difficult to aggregate. No functional or relational specification which transformed inputs to outputs, such as production function, is required. Thus no statistical estimation, such as regression as the case in most production studies, is desired. Input and output indicators can be added, omitted or redefined to better reflect the real scenario.

In evaluating and analyzing the results, no attempt is made to comprehensively explain how these outcomes were achieved. A revised DEA model with additional control and explanatory variables that capture essential features of the country's economic, fiscal, monetary, social and environmental aspects might produce valuable information in identifying the variations and shortcomings inherent in the macroeconomic performance. An integrated model which incorporates alternative managerial methodologies, such as analytic hierarchy process and multiple objectives goal programming, provides the path and scope for future research.

References

[1] P. Andersen, & N.C. Petersen, *A Procedure for Ranking Efficient Units in Data Envelopment Analysis*, Management Science, **39** (1993), 1261 - 1264.

[2] Asian Development Bank, *Key Indicators 2001: Growth and changes in Asia and the Pacific*, Oxford University Press, 2001.

[3] A. Charnes, W.W. Cooper, & S. Li, *Using Data Envelopment Analysis to Estimate Efficiency in The Economic Performance of Chinese Cities*, Socio-Economic Planning Science,**23** (1989), 325 - 344.

[4] A. Charnes, W.W. Cooper, & E. Rhodes, *Measuring The Efficiency of Decision Making Units*, European Journal of Operational Research, **2** (1978), 429 - 444.

[5] D.K. Despotis, *Measuring Human Development Via Data Envelopment Analysis : The Case of Asia and The Pacific*, OMEGA, The International Journal of Management Science, **33** (2005), 385 - 390.

[6] International Monetary Fund, *International Financial Statistics Yearbook*, IMF, 2004.

[7] J. Karkazis, & E. Thanassoulis, *Assessing The Effectiveness of Regional Development Policies in Northern Greece Using Data Envelopment Analysis*, Socio-Economic Planning Science, **32** (1995), 123 - 137.

[8] C.A. K. Lovell, *Measuring The Macroeconomic Performance of The Taiwanese Economy*, International Journal of Production Economics, **39** (1995), 165 - 178.

[9] C. A. K. Lovell, J.T. Pastor, & J.A. Turner,*Measuring Macroeconomic Performance in The OECD : A Comparison of European and Non-European Countries*, European Journal of Operational Research, **87** (1995), 507 - 518.

[10] M. Martic, & G. Savic, *An application of DEA for Comparative Analysis and Ranking of Regions in Serbia with Regards to Social-Economic Development*, European Journal of Operational Research, **132** (2001), 343 - 356.

[11] T. Sueyoshi, *Measuring The Industrial Performance of Chinese Cities by Data Envelopment Analysis*, Socio-Economic Planning Science, **26** (1992), 75 - 88 .

[12] W. L. Winston, *Operations Research : Applications and Algorithms*, Duxbury Press, 3^{rd} edition, 1993.