Oil-Price Vulnerability Index (OPVI) for the Developing Countries of Asia and the Pacific

Summary Paper

Dr. Patil Balachandra (IIM, Bangalor, India)
Dr. Nandita Mongia (UNDP / RCB, Bangkok, Thailand)

Regional Energy Programme for Poverty Reduction
UNDP Regional Centre in Bangkok

1 Introduction

Currently observed phenomenal increases in oil prices have seriously impacted the economic performances of majority of the countries of the world. This concern is more serious with oil importing developing countries, which have to spend enormous amount of their precious foreign exchange earnings on oil imports. In other words, the imported oil dependent developing countries are more vulnerable to this increase. Even within these countries, the vulnerability levels can vary depending on how much they are dependent on oil as an energy source, inherent capabilities derived out of strong economic and social well-being and access to alternate and modern technologies. Thus vulnerability of a country depends on its capacity to absorb, adopt, adapt, afford and mitigate the effects of oil price increases. Even this capacity is not static and it can vary with time. A country can be less vulnerable in the short-term but same thing cannot be said in the long-term scenario.

In general vulnerability is defined as the degree to which a system (human or natural) is susceptible to, or unable to cope with, adverse effects of an event. The three commonly accepted aspects of vulnerability are hazards, resistance and damage. The hazards are basically environmental (or external) variables, which are not under the control of a given country and they are the resultant outcomes of international events. The resistance is derived out of economic variables basically representing the fundamental strength of the economy. The damage is the acquired vulnerability over a period of time represented by social variables captured through level of human development. A vulnerability index for a country capturing the influences of all these variables would be a useful tool for many purposes like identifying specific problems, devising defense mechanisms, evolving strategic alternatives and planning for the future eventualities.

2 An oil-price vulnerability index

Is it possible to quantify the extent of this vulnerability? The degree of vulnerability will depend on many other factors such as the GDP growth rate, for example, and on the extent of foreign exchange reserves. And the extent to which poor people are vulnerable will vary accordingly, for example, to the types of energy they use. Factors and variables that influence a country's vulnerability to oil price changes, particularly in terms of impacts on poor households, are multiple and varied. These factors could be macroeconomic variables, such as GDP growth and foreign exchange reserves position, to more micro-level indicators, such as dominance of traditional fuels in the energy mix and incidence of poverty. This paper discusses such an attempt to develop a composite oil-price vulnerability index (OPVI) for the 24 developing countries of the Asia-Pacific region.

As a first level of classification, it may be possible to say that three kinds of factors (albeit not comprehensive) that can influence oil price vulnerability are economy-related, energy-related and social-related. Broadly, however, most of these major factors can be subsumed under two categories: economy-related and energy-related. With this preliminary understanding a set 15 variables have been identified to be influencing the oil price vulnerability level of a country. The data required for measuring these variables have been obtained from various secondary sources (Table 1). Among the 15 variables, the variables like Real GDP growth rate, GDP per capita, Balance of payments - current account, Budget balance, Import cover, Share of net oil fuel subsidy/tax revenue in GDP, Contribution of food and beverages to inflation, Trade as % of GDP, The Gini Index and Human Development Index could be broadly classified under economic variables and the variables

like Oil intensity of GDP, Oil import dependence, Share of oil in primary energy consumption, Oil reserves to production ratio and Share of transport in oil consumption could be classified under energy related variables.

Table 1: Data used for Ranking and categorization of countries on the basis of OPVI (oil price vulnerability)

Indicator Variables	Real GDP growth rate (%)	GDP per capita (PPP USD)	Balance of payments: current account (% GDP)	Budget balance (% GDP)	Import cover (months)	Share of net oil fuel subsidy/ tax revenue in GDP (%)	Contribution of food and beverages to inflation (% of annual change in CPI)	Oil intensity of GDP (toe/'000 USD)	Oil reserves to production ratio (years)	Oil import dependence (%)	Share of oil in primary energy consumption (%)	Share of transport in oil consumption (%)	Trade as % of GDP 2005	Gini index 2004	HDI 2004
Afghanistan	12.0	1,440	-1.50	-1.5	6.23	0.24	7.68	0.06	0.0	100.00	59.04	91.16	68	35.50	0.346
Bangladesh	6.2	2,135	-0.30	-3.3	2.21	0.17	4.89	0.07	22.6	91.98	27.17	43.00	40	31.8	0.530
Bhutan	12.7	4,437	-3.10	-7.1	9.76	0.77	1.90	0.09	0.0	100.00	11.88	91.36	82	34.1	0.538
Cambodia	5.0	2,534	-5.60	-1.5	2.54	1.01	2.68	0.05	0.0	100.00	95.04	95.85	139	40.4	0.583
China	10.0	8,004	7.20	-0.4	13.26	0.40	0.66	0.23	12.1	44.43	22.00	39.00	69	44.7	0.768
Fiji	2.6	6,610	-0.13	-2.9	2.46	8.53	0.95	0.31	0.0	100.00	74.51	97.56	78.9	49	0.758
India	8.3	3,550	-2.10	-6.4	9.73	1.54	2.29	0.20	19.5	67.96	32.53	33.00	45	32.5	0.611
Indonesia	5.2	4,753	0.20	-1.0	5.13	-0.50	7.38	0.28	12.5	2.12	52.95	53.00	63	34.3	0.711
Iran, Islamic Rep. Of	5.4	8,441	10.00	6.7	19.41	-7.63	6.73	0.40	91.2	-163.51	48.26	51.00	69	43.0	0.746
Lao People's Dem. Rep.	7.3	2,260	-14.60	-5.7	3.77	1.46	5.53	0.07	0.0	100.00	11.77	65.74	58	34.6	0.553
Malaysia	5.5	11,914	15.60	-2.6	6.18	-1.15	1.11	0.23	11.0	-49.51	41.20	67.18	223	49.2	0.805
Maldives	13.0	8,284	-37.60	-18.1	2.41	0.70	1.06	0.69	0.0	100.00	100.00	36.28	172		0.739
Mongolia	6.5	2,322	4.30	3.9	2.43	8.81	11.41	0.37	49.5	95.11	23.88	49.62	160	30.3	0.691
Myanmar	7.0	1,753	4.10	-4.0	3.96	1.82	13.99	0.12	7.4	50.00	37.94	77.00	1.1		0.581
Nepal	1.9	1,761	3.30	-1.8	7.96	1.24	2.79	0.13	0.0	100.00	51.05	38.00	49	47.2	0.527
Pakistan	6.2	2,830	-3.90	-4.2	3.61	2.36	4.32	0.21	15.6	80.56	34.67	77.00	35	30.6	0.539
Papua New Guinea	3.7	2,460	6.80	0.0	3.31	2.48	0.99	0.25	9.3	-177.78	80.60	43.14	98	50.9	0.523
Philippines	5.0	5,160	2.40	-1.0	4.17	1.41	4.58	0.25	16.4	92.60	53.74	67.00	99	46.1	0.763
Samoa	4.0	1,225	-0.02	-0.4	4.29	3.54	4.83	0.17	0.0	100.00	83.54	86.12	78	44	0.778
Solomon Islands	5.3	1,974	-15.80	0.6	6.44	4.95	4.76	0.33	0.0	100.00	100.00	92.40	94		0.592
Sri Lanka	5.6	4,705	-4.90	-8.9	2.71	1.46	10.32	0.31	0.0	100.00	84.99	71.00	80	33.2	0.755
Thailand	4.5	8,877	-0.80	0.1	4.29	1.48	1.75	0.33	6.9	74.44	54.04	64.00	149	42.0	0.784
Vanuatu	3.0	3,424	-8.80	-0.5	3.74	5.79	0.65	0.14	0.0	100.00	100.00	88.49	47.3		0.670
Viet Nam	7.8	3,255	0.10	-5.0	2.49	0.58	4.75	0.69	17.1	-73.91	50.07	60.00	145	37.0	0.709

Source: IMF, ADB, WTO, EA, GTZ, EIA, CIA, IEA, Country ministries, Country statistics offices and Country level contacts. For full list of sources please refer to Appendix Table C-9, Page 137, "*Overcoming Vulnerability to Rising Oil Prices: Options for Asia and the Pacific*", UNDP Regional Centre, Bangkok, Bangkok, 2006

Among these variables (Table 1), the first five economic variables (Real GDP growth rate, GDP per capita, Balance of payments - current account, Budget balance and Import cover) are expected to have positive influence in negating the vulnerability levels. The values of the variables determine the level of the influence (higher or lower) in negating the vulnerability levels. However, if these variables have negative values (e.g. negative balance of payments), even then they positively contribute to increase in the vulnerability levels. On the other hand, the four, energy related variables (Oil intensity of GDP, Oil import

dependence, Share of oil in primary energy consumption and Share of transport in oil consumption) are expected to have negative influence by contributing to enhancing the vulnerability levels. Higher the values of the variables there is a chance of experiencing higher vulnerability. Only the variable, oil reserves to production ratio, has opposite influence compared to the other four variables.

3 Logical Assessment

For the present study, a set of 15 variables (related to economic, energy and social indicators) is given. It is possible that all of the 15 variables may not be necessary to develop an OPVI. Even when one observes the list of variables there are indications that some of them could be dependent on each other, and others could be contributing to double counting. Thus to identify the relevant variables and to justify their inclusion in the model in order to facilitate the development of OPVIs, a logical assessment of variables was carried out. This has been done through the assessment of variables for possible association, uniqueness, double counting and significance by using the correlation analysis and logical reasoning methods.

3.1 Correlation Analysis

The results of the correlation analysis performed on the data (Table 1) are presented in Table 2. It may be observed from Table 2 that except for the variable "Share of transport in oil consumption" all other variables are significantly correlated with one or more variables. Naturally, the next step would have been to select one of the correlated variables among different sets of correlated variables to be included in developing the OPVI. However, this is not the correct approach in creating a composite OPVI because of the following reasons.

1. Here the objective is not to model the variations in OPVI through a set of independent variables. OPVI is not expected to be a dependent variable but it is an estimate derived from many variables.
2. The aim is to develop a composite index capturing the collective influence of relevant variables. Relevance need not be equated to independence.
3. Statistically related variables need not relate logically.

Therefore, it is felt that the correct approach would be to combine the results of correlation analysis and logical reasoning to arrive at a decision to either include or eliminate a variable from using it for deriving the composite OPVI.

3.2 Logical Reasoning

An attempt is made here to logically reason out the justification for the inclusion or elimination of a variable to develop a composite oil price vulnerability index (OPVI) by taking following aspects in to consideration.

1. The variables are independent (as far as possible) in the sense that each one measures a unique aspect of a system performance (economic or social performance).
2. Double counting or two or more variables measuring the same aspect should be avoided.
3. The variables significantly influence the levels of the vulnerability.

Table 2: Results of Correlation Analysis

	Significantly Correlated Variables		
Real GDP growth rate	Budget balance**(-ve)	Gini index 2004*(-ve)	
GDP per capita	Share of net oil fuel subsidy /tax revenue in GDP*(-ve)	Trade as per cent of GDP 2005**	HDI 2004**
Balance of payments: current account	Budget balance**	Oil import dependence* (-ve)	Share of oil in primary energy consumption*
Budget balance	Real GDP growth rate** (-ve)	Balance of payments: current account **	Oil reserves to production ratio**
Import cover	Share of net oil fuel subsidy /tax revenue in GDP**(-ve)	Oil reserves to production ratio**	
Share of net oil fuel subsidy /tax revenue in GDP	GDP per capita*(-ve)	Import cover**(-ve)	Oil import dependence**
Contribution of food and beverages to inflation	Gini index 2004**(-ve)		
Oil intensity of GDP	Trade as per cent of GDP 2005*	HDI 2004**	
Oil reserves to production ratio	Budget balance**	Import cover**	Oil import dependence**(-ve)
Oil import dependence	Balance of payments: current account *(-ve)	Share of net oil fuel subsidy /tax revenue in GDP**	Oil reserves to production ratio**(-ve)
Share of oil in primary energy consumption	Balance of payments: current account *(-ve)		
Share of transport in oil consumption			
Trade as per cent of GDP 2005	GDP per capita**	Oil intensity of GDP*	HDI 2004*
Gini index 2004	Real GDP growth rate* (-ve)	Balance of payments: current account **	Contribution of food and beverages to inflation** (-ve)
HDI 2004	GDP per capita**	Oil intensity of GDP**	Trade as per cent of GDP 2005*

** Correlation is significant at the 0.00 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

It is possible to argue that the variables can influence the vulnerability levels in two ways:

1. Positive influence: Higher observed values will reduce the vulnerability levels (economic variables).
2. Negative influence: Higher observed values will enhance the vulnerability levels (energy variables).

As explained earlier, among the fifteen variables, the first five economic variables are expected to have positive influence in negating the vulnerability levels. On the other hand, the four, energy related variables are expected to have negative influence by contributing to enhancing vulnerability levels. Only one variable, oil reserves to production ratio, has opposite influence compared to the other four variables.

1. **Real GDP growth rate:** This represents country's "dynamic ability to cope" with price increase. If we can assume that the current rate of growth is a reasonable indicator of immediate past and expected future growth rates of real GDP, this variable can have a positive influence in determining the vulnerability levels. Countries experiencing higher growth rates can be expected to be less vulnerable than those experiencing lower growth

rates. For example, a country like China will be significantly less vulnerable than Nepal. Afghanistan is an exception because of the past poor performance.

2. **GDP per capita:** This represents country's "inherent capability to cope" with oil price increase. This basically represents the economic strength of a country. In other words, it determines country's affordability levels with the price increase. The higher the GDP per capita the greater is its ability to be less vulnerable. For example, Malaysia is far less vulnerable compared to Samoa.

3. **Balance of payments - current account**: The current account is the sum of net sales from international trade in goods and services, net factor income (such as interest payments from abroad), and net unilateral transfers from abroad. This can be termed to represent country's "capability to pay in FOREX". A positive and higher (as a share of GDP) balance of payments on current account represents a comfortable position in terms of paying for the imported oil (especially to take care of oil price rise). Most importantly this will be the surplus generated in terms of foreign exchange. Countries with negative balance of payments will be more vulnerable to oil price rise. Oil importing counties like China will be less vulnerable compared to Maldives.

4. **Budget balance**: This represents country's "capability to pay from internal sources" to tackle the problem of oil price rises. Any budget surplus can act as a cushion at the time of crisis especially in regulating the oil prices to reduce the burden on consumers. Among the oil importing countries, Mongolia is best placed with respect to this aspect where as Maldives appears to be most vulnerable on this count.

5. **Import cover:** This basically suggests that how long a country can manage its monthly imports bills through accumulated foreign exchange reserves. For an oil importing country, the major portion of the import bill will be on account of oil imports. A higher import cover means the country will be more comfortable in tackling the price rise. This variable can be equated to country's "capability to sustain" the impact of oil price rise in terms of duration. In other words, how long a country can sustain the oil price rise? China is less vulnerable compared to Bangladesh.

6. **Share of net oil fuel subsidy/tax revenue in GDP:** This ratio gives the degree of oil subsidy burden on the economy. Tax revenue being the most important component of government income it is relevant to establish how much it goes for subsidizing oil prices. If it accounts for a small or negligible share, then there is scope for increasing it to tackle the impact of oil price rise. Countries with smaller shares will be less vulnerable than those with higher shares. At the outset, this variable appears to be not a relevant one. Because, both the components of oil fuel subsidy and tax revenue are part of budget estimates. Already, there is a variable "budget balance" which captures the position of a country in terms of vulnerability levels. Logically, we may state that this particular variable is redundant. However, this is not corroborated by the correlation analysis results indicating no significant correlation between the two variables. The reason could be negligible share of net oil subsidy in tax revenue resulting in negligible contributions to overall variations. Logically, this variable can be eliminated from index determination model.

7. **Contribution of food and beverages to inflation:** This basically indicates how developed a country is. A country with higher contributions from agricultural

commodities in the overall inflation is stated to be at the initial stages of development. Thus one could conclude that a country having higher contributions of food and beverages to inflation would be more vulnerable to oil price rise. However, this type of influence has already been captured through two variables "real GDP growth rate" and "GDP per capita" making this variable redundant. However, this is an indirect measure of influence on vulnerability levels. Instead of this variable, better variable could have been "contribution of OIL price changes to inflation". This can be expected to capture both the direct and indirect impact of oil price changes on the economy. This would have enabled obtaining a better indicator for arriving at a vulnerability index.

8. **Oil intensity of GDP**: This determines the oil dependency levels of a country. The higher the intensity, the greater is the vulnerability of a country to the oil price increase. Cambodia is less vulnerable compared to Maldives.

9. **Oil reserves to production ratio**: This basically indicates country's level of ownership of oil reserves and rate of exploitation. The higher the ratio, the greater is the comfortability of a country. Indigenous production of oil can act as an insurance cover for the international oil price rise. This indicator is more relevant for long-term vulnerability index. Countries, which do not have any reserves, are more vulnerable.

10. **Oil import dependence:** This is the most critical variable determining a country's vulnerability level. Those countries, which depend 100% on imported oil are the most vulnerable to the oil price rise. Logically, those who do not have any oil reserves will be forced to import 100% of oil requirement. This may indicate that one of the two variables "oil reserves to production ratio" and "oil import dependence" is redundant in deriving the OPVI. That does not mean that a country having oil reserves cannot have high import dependence. This is a possible situation for countries keeping their oil stock as strategic reserves and relying on imports for current requirements. In other words, it is possible to have countries with high oil import dependence and at the same time have high reserves to production ratio exhibiting less vulnerability to oil price shocks. Logically, both the variables are necessary for determining the OPVI however, the data states the opposite. The correlation analysis shows that both the variables are highly correlated and it is significant. Thus it may be advisable to retain "oil import dependence" and eliminate "oil reserves to production ratio" at least in the present context.

11. **Share of oil in primary energy consumption:** This variable indicates how important oil is in relation to other energy sources. The countries with higher share will be more vulnerable than those with lower share.

12. **Share of transport in oil consumption:** Just this variable alone would be inadequate to assess the linkage to vulnerability levels. It is also important to know how much transport sector is important to the economy. It may be possible that most of the oil is consumed by the transport sector (typically happens in less industrialized countries) but it need not be critical. With this variable alone it may not be possible to state the relationship with vulnerability level. It cannot be true if one states that the countries with higher share of transport in oil consumption will be more vulnerable to oil price shocks. It is necessary to include variable/s assessing the importance of transport. A derived variable capturing the essence of the two would be an ideal replacement.

13. **GDP as % of Trade:** Much cannot be interpreted from this. Typically, smaller countries with relatively small domestic market will have significantly higher international trade compared to the country's GDP. It is logically difficult to assess the influence of this variable on vulnerability. Even, the observed trend based on the data provided does not appear to provide much insight on vulnerability levels. Thus it may be eliminated from the basket of variables included for estimating OPVI.

14. **The Gini Index:** This is a measure of income inequality ranging from 0 (perfect equality) to 100 (perfect inequality). Higher values exhibit higher inequality. This may not be an appropriate variable for assessing the vulnerability levels. Income equality or inequality can happen at both extremes. A poor country can exhibit high equality and same might be the case with a rich country. Even the opposite can be true. For example, Afghanistan (35.5) exhibit higher equality compared to Malaysia (49.2) whereas Nepal with Gini index of 47.2 shows high inequality in comparison to Indonesia (34.3).We cannot state that countries with higher Gini index are more vulnerable or vice versa. Mere observation of the data related to Gini index of different Asian countries indicate that countries with higher Gini index values (higher inequality) are less vulnerable to oil price rise. This variable may be eliminated because it may not have much influence in determining the vulnerability index.

    Countries with a higher Gini index being less vulnerable to oil price rise can be logically argued in the case of India. On the basis of a composite index derived from the macro indicators, countries like India at the outset might look more vulnerable to the oil price rise. However, the reality may be different. This is due to the fact that a large majority of the population is not part of the energy mainstream (depending on modern energy carriers) and their role in oil economy is negligible. They hardly get impacted directly by the oil price rise. Even the indirect effects may be marginal because they are not a part of the mainstream market system. However, the macro indicators that are being used to arrive at the composite vulnerability index are derived taking into consideration even this section of the population (e.g., per capita GDP with and without this section of the population).

15. **Human Development Index:** This is a socio-economic indicator of well-being of a country that represents the overall social capacity of the population to respond to the adversities. The countries with higher HDI values tend to be less vulnerable to the oil price rise. It may be possible that HDI to be significantly correlated with "GDP Per capita" and "Oil intensity of GDP" because both of these variables are part of the indicators, which are used to determine HDI. However, logical considerations necessitate inclusion of all the three variables in the model determining the composite index. Because the three variables measures different aspects of economic system. Though HDI includes economic indicators, the advantage is that it also captures the influence of social indicators.

    However, in the present analysis, the HDI has been excluded because of the following reasons:

    - It is a relative index (across countries) unlike other variables included in the analysis. Other variables either indicate exact measurements or are relative to sectors/segments within the country.

- The main objective here is to develop a country's vulnerability index. All the variables facilitate this except the HDI. The HDI goes beyond this and attempts to capture the "social empowerment" levels, which are people-driven.

3.3 Summary

Based on the logical reasoning and statistical analysis, the following are the possible final status of the variables:

***Included Variables*:**

1. Real GDP growth rate
2. GDP per capita
3. Balance of payments-current account
4. Budget balance
5. Import cover
6. Oil intensity of GDP
7. Oil import dependence
8. Share of oil in primary energy consumption

***Excluded Variables*:**

1. Share of net oil fuel subsidy/tax revenue in GDP
2. Contribution of food and beverages to inflation
3. Oil reserves to production ratio
4. Share of transport in oil consumption
5. GDP as % of Trade
6. The Gini Index
7. Human Development Index

4 Developing an oil-price vulnerability index using Principal Component Analysis

Principal Component Analysis (PCA) is a popular dimensionality reduction technique used for reducing the number variables in a model (e.g., econometric models). It uses the correlation structure of the variables to perform this task. Basically, the PCA forms linear combinations of variables to arrive at a principal component and this principal component can be logically related to a dimension representing a set of variables. Taking the example of developing OPVI for 24 countries of Asia-Pacific region itself, the attempt here is to quantify the degree of vulnerability by using a set of eight variables which remain after the logical assessment. However, deriving an index with eight variables and then attempting to interpret it would be quite complex. Therefore the purpose of using PCA is to reduce these eight variables into a manageable number of dimensions (or principal components) to facilitate development of a composite OPVI. Ideally speaking, if we can get one principal component (or single dimension), which accounts for maximum variation, and then with few more simple steps we could obtain the composite OPVI. The values obtained for this principal component for each of the 24 countries can be used for developing the OPVI. However, in reality, that too with eight variables, this cannot be expected. Arriving at a composite OPVI with more than one Principal component is always complex (but easier than having eight variables). But the decision to use how many principal components is ours. The number of principal components depends on how much variance we want to account for. As a first step, the original data (Table 1) is transformed into standardized variables (Table 3). This is the form in which the input data is provided to the PCA and also these standardized values are used for arriving at the principal component values. The standardized values are estimated as follows:

$$\text{Standardized Value} = \frac{\text{(Actual Value – Mean Value)}}{\text{Standard Deviation}}$$

The actual values are from Table 1.

Table 3: Standardized Variables

Indicator Variables →	Real GDP growth rate	GDP per capita	Balance of payments: current account	Budget balance	Import cover	Oil intensity of GDP	Oil import dependence	Share of oil in primary energy consumption
Variables Short →	RGDPGR	GPPCAP	BPCA	BB	IC	OIGDP	OID	SOPEC
Afghanistan	1.87	-1.00	0.04	0.26	0.17	-1.09	0.58	0.13
Bangladesh	-0.07	-0.76	0.15	-0.13	-0.81	-1.04	0.49	-1.00
Bhutan	2.10	0.03	-0.12	-0.93	1.04	-0.96	0.58	-1.54
Cambodia	-0.47	-0.62	-0.36	0.26	-0.73	-1.19	0.58	1.40
China	1.20	1.27	0.88	0.49	1.90	-0.14	-0.08	-1.18
Fiji	-1.27	0.79	0.17	-0.04	-0.75	0.37	0.58	0.67
India	0.63	-0.27	-0.02	-0.78	1.03	-0.31	0.20	-0.81
Indonesia	-0.40	0.14	0.20	0.36	-0.10	0.15	-0.59	-0.09
Iran, Islamic Rep. of	-0.34	1.42	1.15	2.00	3.40	0.87	-2.58	-0.25
Lao People's Dem. Rep.	0.30	-0.72	-1.23	-0.64	-0.43	-1.03	0.58	-1.54
Malaysia	-0.30	2.62	1.69	0.02	0.16	-0.10	-1.21	-0.50
Maldives	2.20	1.37	-3.46	-3.27	-0.76	2.62	0.58	1.57
Mongolia	0.03	-0.70	0.60	1.40	-0.76	0.68	0.52	-1.11
Myanmar	0.20	-0.89	0.58	-0.27	-0.38	-0.74	-0.02	-0.62
Nepal	-1.50	-0.89	0.50	0.19	0.60	-0.70	0.58	-0.16
Pakistan	-0.07	-0.52	-0.20	-0.32	-0.47	-0.22	0.35	-0.73
Papua New Guinea	-0.90	-0.65	0.84	0.58	-0.54	-0.01	-2.75	0.89
Philippines	-0.47	0.28	0.41	0.36	-0.33	0.01	0.49	-0.06
Samoa	-0.80	-1.08	0.18	0.49	-0.30	-0.46	0.58	0.99
Solomon Islands	-0.37	-0.82	-1.35	0.70	0.22	0.49	0.58	1.57
Sri Lanka	-0.27	0.13	-0.29	-1.31	-0.69	0.35	0.58	1.04
Thailand	-0.64	1.57	0.10	0.60	-0.30	0.49	0.28	-0.05
Vanuatu	-1.14	-0.32	-0.67	0.47	-0.44	-0.62	0.58	1.57
Viet Nam	0.47	-0.37	0.19	-0.49	-0.74	2.59	-1.50	-0.19
Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Std. Dev.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

5 Principal Component Analysis – Reduced Model with eight variables

The principal component analysis resulted in extracting three principal components from the 8 variables considered for arriving at OPVI. The principal components having Eigenvalues of above one have been included in the model explaining the total variation resulting in three principal components. The individual Eigenvalues and the explained variance are given in Table 4. Principal Component 1 accounts for 32.74% variance, principal component 2 and 3 account for 23.1% and 19% variance and, cumulatively, all three account for 74.8% variance. Theoretically, we can account for 100% variance by including all the eight principal components (equal to eight variables).

Table 4: Principal Components and explained Variance (with 8 Variables)

Principal components	Eigenvalues	Percentage Variance	Cumulative Variance
Principal Component 1	2.619	32.739	32.739
Principal Component 2	1.846	23.080	55.818
Principal Component 3	1.519	18.993	74.811

The factor (or component) loadings of each of the 8 variables on the principal components are given in Table 5. The numbers are called factor loadings and these are equivalent of correlation coefficients. In other words, these numbers tell us how much the variable/s is/are correlated with the principal components. Principal component 1 has four significant variables loaded (are grouped under principal component 1), whereas PC 2 has two variables and PC 3 two variables (Table 6).

Table 5: Factor Loadings on the Principal Components (with 8 Variables)

	Principal Component 1	Principal Component 2	Principal Component 3
Real GDP growth rate	-0.392	0.516	-0.650
GDP per capita	0.199	0.748	0.135
Balance of payments: current account	0.902	-0.114	-0.049
Budget balance	0.820	-0.316	0.182
Import cover	0.600	0.430	-0.307
Oil intensity of GDP	-0.233	0.706	0.480
Oil import dependence	-0.613	-0.462	-0.340
Share of oil in primary energy consumption	-0.386	-0.101	0.777

From the above data, the significant factor loadings have been extracted to know which variables have been grouped into a single and given principal component. Table 6 contains these details. Principal component 1 has four variables loaded (or four variables are grouped under principal component 1), whereas 2 and 3 have two variables each. The principal component analysis is used for variable reduction. In this case, the linear combinations of four variables formed the first principal component (PC1). Linear combination of the next two variables formed principal component 2 (PC2), and similarly, the remaining two variables formed principal component 3 (PC3).

Table 6: Significant and Dominant Factor Loadings on the Principal Components (with 8 Variables)

	Principal Component 1	Principal Component 2	Principal Component 3
Real GDP growth rate			-0.650
GDP per capita		0.748	
Balance of payments: current account	0.902		
Budget balance	0.820		
Import cover	0.600		
Oil intensity of GDP		0.706	
Oil import dependence	-0.613		
Share of oil in primary energy consumption			0.777

Please not that in Table 6, the variable "Real GDP growth rate" has a negative sign for the factor loading and "share of oil in primary energy consumption" has a positive sign where logically the signs should have been opposite. Therefore for the subsequent analysis the signs have been reversed for the factor loadings of Principal Component 3 (Fourth column in Table 5).

From Table 6, the groupings of the variables under each of principal component are as follows:

Principal Component 1: "Economic Strength" (Strength)

- Balance of payments: current account
- Budget balance
- Import cover
- Oil import dependence

Strength represents the economic capacity to afford oil imports. A country will be less vulnerable if it has high and positive scores for balance of payments, budget balance and import cover, and a lower score for oil import dependence.

Principal Component 2: "Economic Performance" (Performance)

- GDP per capita
- Oil intensity of GDP

Better economic performance results in higher levels of GDP per capita, which should make a country less vulnerable. In developing countries that are shifting from low-quality traditional fuels to high-quality modern fuels such as petroleum products, this will lead to an increase in oil intensity. This may not be an attractive indicator from an environmental standpoint, but its is relevant at initial stages of economic development.

Principal Component 3: "Economic Growth with low share of Oil" (Low-Oil-Growth)

- Real GDP growth rate
- Share of oil in primary energy consumption (Reducing share)

Many countries initially base their development on primary energy sources other than oil, including traditional fuels or, as in the cases of China and India, coal and hydro. But they are likely to become increasingly oil-dependent. A country will be less vulnerable if it can combine a high GDP growth rate with a low share of oil in primary energy consumption.

The values of these three principal components are called factor scores. As mentioned earlier, the principal components are derived based on the linear combination of the variables. In other words, the values of the principal components can be derived from these linear combinations. The equation for this is as follows:

$$PC_n = \sum_{j=1}^{m} a_{jn}X_j, \qquad \text{for all 'n'}$$

Where, PC_n = The factor score for principal component "n" (here, n = 1, 2, …, 3)
a_j = Factor loading of variable 'j' on principal component "n" (here j = 1, 2, …, 8)
X_j = Standardized variable "j" (here j = 1, 2, …, 8)

In expanded form for principal component 1, the equation will be

$PC_1 = a_{11}X_1 + a_{21}X_2 + a_{31}X_3 + ….. + a_{81}X_8$

From Table 2 (for X_j) and Table 5 (for a_{jn}), we have

PC_1 = -0.392 * 1.87 + 0.199 * -1.00 + 0.902 * 0.04 + ….. + (- 0.386) * 0.13 = - 0.73 (for Afghanistan).

Factor loadings of all the variables (not limited to significant variables) are used while estimating the factor scores.

Similarly, the factor scores for all the principal components and for all the countries are estimated and presented in Table 7. These factor scores are standardized values of principal components and similar to the standardized values of variables presented in Table 3. Therefore, these are also amenable for ranking (or ranking of countries can be made based on the values of the principal components in the form of factor scores). Table 8 contains these ranking.

If for example, we have got only one principal component, then the ranking of the factor scores would have given us the country ranking of OPVI. The OPVI could have been developed using the using the following formula[1] on the factor scores.

$$\text{Dimension Index} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}}$$

However, that is not the case here. We have three principal components and developing composite OPVI needs few more steps to be performed.

[1] This formula draws on the methodology for development of the International Energy Agency's Energy Development Index

Table 7 presents the estimated factor scores whereas Table 8 shows the ranking of countries based on these factor scores.

Table 7: Factor Scores (with 8 Variables)

	Strength	Performance	Low-Oil-Growth
Afghanistan	-0.73	-0.85	1.98
Bangladesh	-0.25	-1.79	1.28
Bhutan	-0.61	1.08	3.69
Cambodia	-1.11	-2.31	-0.83
China	2.65	2.19	2.10
Fiji	-0.38	-0.47	-1.65
India	-0.08	0.59	1.75
Indonesia	0.97	0.11	-0.57
Iran, Islamic Rep. of	6.61	3.42	-0.77
Lao People's Dem. Rep.	-1.67	-1.07	2.11
Malaysia	3.24	2.22	-0.40
Maldives	-8.42	4.68	-0.84
Mongolia	1.04	-0.99	0.37
Myanmar	0.23	-1.16	1.04
Nepal	1.25	-2.05	-0.03
Pakistan	-0.67	-0.75	0.72
Papua New Guinea	2.48	-0.29	-2.35
Philippines	0.43	-0.55	-0.28
Samoa	-0.15	-2.22	-0.90
Solomon Islands	-1.60	-0.86	-1.51
Sri Lanka	-2.46	-0.02	-0.96
Thailand	0.70	0.74	-0.92
Vanuatu	-0.92	-1.95	-1.67
Viet Nam	0.17	2.78	0.05

Table 8: Ranking of Countries based factor scores for different Principal Components (with 8 Variables)

	Strength	Performance	Low-Oil-Growth
Afghanistan	18	15	4
Bangladesh	13	20	6
Bhutan	16	6	1
Cambodia	20	24	15
China	3	5	3
Fiji	14	12	22
India	11	8	5
Indonesia	7	9	13
Iran, Islamic Rep. of	1	2	14
Lao People's Dem. Rep.	22	18	2
Malaysia	2	4	12
Maldives	24	1	16
Mongolia	6	17	9
Myanmar	10	19	7
Nepal	5	22	10
Pakistan	17	14	8
Papua New Guinea	4	11	24
Philippines	9	13	11
Samoa	12	23	17
Solomon Islands	21	16	21
Sri Lanka	23	10	19
Thailand	8	7	18
Vanuatu	19	21	23
Viet Nam	15	3	20

Now, the next step is to combine these principal components to derive an integrated factor score. If the weights are same (or uniform) then easily one could have estimated the integrated factor score by taking the simple average. However, in the present case we are aware of the fact that the weights of the three principal components are different. We know that the principal component 1 accounts for highest variance (33%) principal component 2 accounts for 23% and principal component 3 for 19%. Here we have assumed that the percentage variance accounted by a principal component as equal to the weight (Last row of Table 9). Using these weights, the weighted total factor score was estimated (Table 9). The oil price rise vulnerability index (OPVI) for each of the countries was developed using the following formula on the weighted total scores.

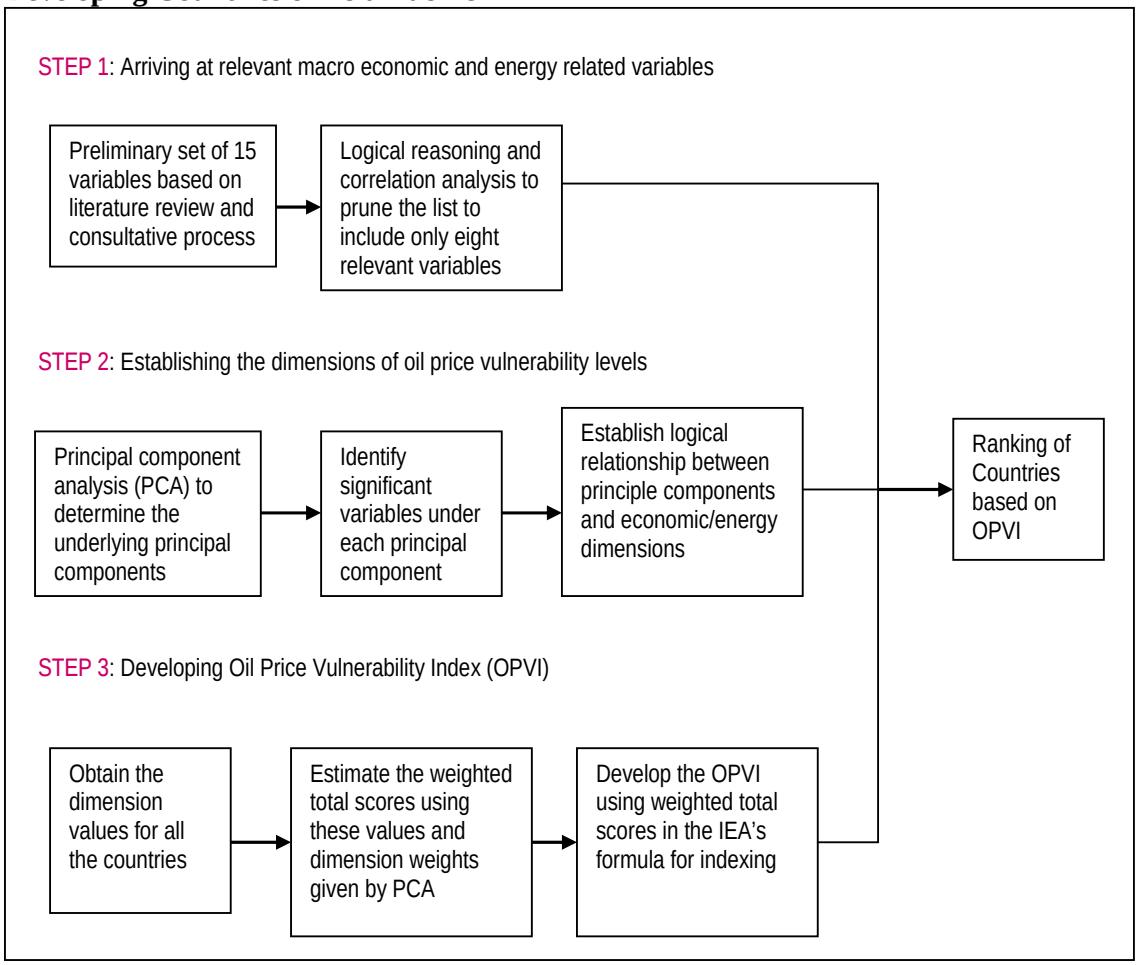
$$\text{Dimension Index} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}}$$

Table 9: Weighted factor scores, OPVI and Ranking based on OPVI (with 8 Variables)

	Strength	Performance	Low-Oil-Growth	Weighted Total Score	OPVI	Rank
Afghanistan	-0.24	-0.20	0.38	-0.06	**0.38**	**13**
Bangladesh	-0.08	-0.41	0.24	-0.25	**0.34**	**15**
Bhutan	-0.20	0.25	0.70	0.75	**0.56**	**4**
Cambodia	-0.36	-0.53	-0.16	-1.05	**0.17**	**22**
China	0.87	0.50	0.40	1.77	**0.78**	**2**
Fiji	-0.12	-0.11	-0.31	-0.55	**0.28**	**18**
India	-0.03	0.14	0.33	0.44	**0.49**	**5**
Indonesia	0.32	0.03	-0.11	0.23	**0.45**	**7**
Iran, Islamic Rep. of	2.16	0.79	-0.15	2.81	**1.00**	**1**
Lao People's Dem. Rep.	-0.55	-0.25	0.40	-0.39	**0.31**	**17**
Malaysia	1.06	0.51	-0.08	1.50	**0.72**	**3**
Maldives	-2.76	1.08	-0.16	-1.84	**0.00**	**24**
Mongolia	0.34	-0.23	0.07	0.18	**0.43**	**9**
Myanmar	0.08	-0.27	0.20	0.01	**0.40**	**11**
Nepal	0.41	-0.47	-0.01	-0.07	**0.38**	**14**
Pakistan	-0.22	-0.17	0.14	-0.25	**0.34**	**16**
Papua New Guinea	0.81	-0.07	-0.45	0.30	**0.46**	**6**
Philippines	0.14	-0.13	-0.05	-0.04	**0.39**	**12**
Samoa	-0.05	-0.51	-0.17	-0.73	**0.24**	**19**
Solomon Islands	-0.52	-0.20	-0.29	-1.01	**0.18**	**21**
Sri Lanka	-0.81	0.00	-0.18	-0.99	**0.18**	**20**
Thailand	0.23	0.17	-0.18	0.22	**0.44**	**8**
Vanuatu	-0.30	-0.45	-0.32	-1.07	**0.17**	**23**
Viet Nam	-0.18	0.53	-0.26	0.10	**0.42**	**10**
Weights based on Variance accounted (%)	**32.739**	**23.08**	**18.993**			

The summary of the process involved in developing the OPVI index is presented as a schematic diagram (Figure 1).

Figure 1: Schematic Process for Developing Oil Price Vulnerability Index (OPVI) for Developing Countries of Asia-Pacific



6 Discussions

The rankings obtained by using the model with eight variables presented above predominantly capture the influence of macroeconomic variables (including energy). The ranking of countries using OPVI with colour coding is presented in Table 10.

At the outset, the ranking of countries appears to be logical and they have been arrived at by combining the influence of economic and energy related factors. At the top of the list are countries with higher Strength and Performance, combined with Low-oil-growth. In first place is Iran, which although highly reliant on oil is a net oil exporter, followed by China and Malaysia. At the other end of the scale are countries with low economic strength, lower economic performance based outcomes and high oil dependency – such as Maldives, Vanuatu and Cambodia.

India ranks quite highly. Although its oil has to be imported this does not represent a high share of total primary energy consumption since India uses more coal. India is also showing excellent economic performance. A number of other countries are also less vulnerable by virtue of their energy profiles: Iran, Malaysia, China, Indonesia and Papua New Guinea.

Bhutan's high rank might appear odd however this can be explained as follows:

i. From the data presented in Table 1, it can be shown that Bhutan primarily relies on other energy resources for meeting its energy needs with a low share of oil in primary energy consumption at 11.88%.
ii. Again from the same table, Bhutan's oil intensity of GDP is very low at 0.09 toe/'000 USD and this indicate that Bhutan's economy is least dependent on oil.
iii. It may be observed from Table 1 that the Real GDP growth is high at 12.7% and GDP per capita of 4,437 PPP USD is better than average. Its economy is growing without depending much on oil consumption.

Table 10 -- Ranking of countries based on weighted dimension scores and composite OPVI (with 8 variables)

Rank	Countries	OPVI	Strength	Performance	Low-oil-growth	Weighted Total Score
1	Iran, Islamic Rep. of	1.00	2.16	0.79	-0.15	2.81
2	China	0.78	0.87	0.50	0.40	1.77
3	Malaysia	0.72	1.06	0.51	-0.08	1.50
4	Bhutan	0.56	-0.20	0.25	0.70	0.75
5	India	0.49	-0.03	0.14	0.33	0.44
6	Papua New Guinea	0.46	0.81	-0.07	-0.45	0.30
7	Indonesia	0.45	0.32	0.03	-0.11	0.23
8	Thailand	0.44	0.23	0.17	-0.18	0.22
9	Mongolia	0.43	0.34	-0.23	0.07	0.18
10	Viet Nam	0.42	-0.18	0.53	-0.26	0.10
11	Myanmar	0.40	0.08	-0.27	0.20	0.01
12	Philippines	0.39	0.14	-0.13	-0.05	-0.04
13	Afghanistan	0.38	-0.24	-0.20	0.38	-0.06
14	Nepal	0.38	0.41	-0.47	-0.01	-0.07
15	Bangladesh	0.34	-0.08	-0.41	0.24	-0.25
16	Pakistan	0.34	-0.22	-0.17	0.14	-0.25
17	Lao PDR	0.31	-0.55	-0.25	0.40	-0.39
18	Fiji	0.28	-0.12	-0.11	-0.31	-0.55
19	Samoa	0.24	-0.05	-0.51	-0.17	-0.73
20	Sri Lanka	0.18	-0.81	0.00	-0.18	-0.99
21	Solomon Islands	0.18	-0.52	-0.20	-0.29	-1.01
22	Cambodia	0.17	-0.36	-0.53	-0.16	-1.05
23	Vanuatu	0.17	-0.30	-0.45	-0.32	-1.07
24	Maldives	0.00	-2.76	1.08	-0.16	-1.84

Based on their OPVIs countries can be grouped into one of three categories: low, medium or high (Table 11). The dividing lines are based on how the OPVI scores are distributed around the mean value. In other words, the categorisation of countries into low, medium and high OPVI groups has been done using the mean (0.396) and standard deviation (0.215)

combination on the estimated OPVI –

Low OPVI countries → OPVI value ≥ Mean + Standard deviation
High OPVI countries → OPVI value ≤ Mean
Medium OPVI countries → all the countries between the two limits.

- *Low-OPVI countries* – High economic capacity, or strength, to absorb oil price shocks, performing better, with high per capita GDP and economic growth rate and with either low reliance on oil or net exports of oil.

- *Medium-OPVI countries* – Medium economic capacity, or strength, to absorb oil price shocks, performing better with high or medium per capita GDP and economic growth rate and either having a low reliance on oil or being a net exporter of oil

- *High-OPVI countries*– Low economic strength, lower economic performance and high oil dependency.

Table 11: Categorization of countries based on OPVI

Low OPVI	Iran, China, Malaysia
Medium OPVI	Bhutan, India, Papua New Guinea, Indonesia, Thailand, Mongolia, Vietnam, Myanmar
High OPVI	Philippines, Afghanistan, Nepal, Bangladesh, Pakistan, Lao PDR, Fiji, Samoa, Sri Lanka, Solomon Islands, Cambodia, Vanuatu, Maldives

It should be noted that these OPVI scores and categories reflect the current position of these countries based on the use of a limited set of variables. They do not consider future trends. Several countries, such as Iran and Malaysia, though currently among the least vulnerable, could be considered at future risk on account of their rapidly growing oil consumption relative to domestic supply. Similarly, Thailand and India could be at greater risk in future given their persistently high dependence on imported oil. It should also be noted that the index is relative to this group of countries, so even the least vulnerable countries on this list could be much more vulnerable than many countries outside the region.

Deeper assessment of the rankings and classification of some of the countries brings out the logic behind these rankings. The Philippines, for example, is a borderline case and it is categorised as high OPVI country because of its relatively high oil dependency both in terms of intensity and share in primary energy. On the other hand though Viet Nam compares poorly with the Philippines in terms of economic strength and low-oil-growth dimensions, its economic performance is excellent and it is a net oil exporter, thus has a higher rank compared to the Philippines. On the OPVI scale Maldives ranks last even though it is number one in terms of economic performance. Its rank is spoiled mainly because of its low score on dimension economic strength (last rank), which is affected by highly negative balance of payments and budget balance positions as well as high import dependence.