Almost equi-marginal principle based composite index of globalization: China, India and Pakistan

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Abstract

The present study proposes an alternative method to construct an index of globalization which is based on the principle of almost equi-marginal contributions (AEMC) or Shapley values of the constituent variables to the overall index rather than the correlation coefficients among the constituent variables and the overall index (the KOF index based on the principal component scores). This has been done by minimization of the Euclidean norm of the Shapley values of the constituent variables. As an exercise, secondary time series data (1970-2013) on the measures of globalization in three different dimensions (economic, social and political) of three economies (China, India and Pakistan) have been used. A comparison of the AEMC index with the KOF index reveals that while the former is more inclusive, the latter is more elitist in matters of inclusion of the weakly correlated constituent variables in the overall (composite) index. As a consequence, the AEMC index is more sensitive than the KOF index of globalization. Both indices capture the trends in globalization in the countries under study and are highly correlated between themselves. Thus, AEMC is an alternative or perhaps a better method to construct composite indices.

Key words: Globalization; KOF index; equi-marginal; Shapley value; global optimization, China, India, Pakistan

JEL code: C43, C61, C71, F60, P52

1. Introduction: After the dissolution of the USSR in 1991, the international economic and political scenario of the world changed dramatically. Zubok (2009) has rightly observed that the collapse of the Soviet empire was an event of epochal geopolitical, military, ideological, and economic significance. In a way, the premonition of Hayek (1944, 1988) came true. Many nations that planned their economies with an ideological basis of socialism and selective permeability to international economic forces yielded to liberalization and globalization. While liberalization is concerned with opening of the private sector investment in and management of economic activities within the national boundaries of an economy, globalization is concerned with opening of the national boundaries of economic activities to international finance, investment, management and trade. Globalization permits growing interaction of people at the world level with different ideas and cultures. It has far reaching socio-economic and cultural implications (Mishra and Nayak, 2006).

Globalization is progressing, but all national economies have not proceeded to open themselves with the same pace. It is understandable due to the fact that different economies have different types of political systems and domestic socio-economic conditions impinging on their international economic policies. They also have varied international political relations with other nations. In view of this, many attempts have been made to measure the degree of globalization attained by different national economies. Andersen and Herbertsson (2005), Bhandari and Heshmati (2005), OECD (2005), Dreher et al. (2008), Caselli (2012) and Grinin et al. (2012) are some notable works on the topic.

2. The KOF index of globalization: The KOF index of globalization measures the degree of globalization in three dimensions namely economic, social and political. It does not count on environmental dimension. It covers 122 countries since 1970, year-wise. For pre-1991 period, the series is not so pithy or exhaustive. But over time it has enriched its data base.

Under the three dimensions of globalisation, the first is economic globalization. It has two measures: actual economic flows (such as trans-border trade, direct investment and portfolio investment, A1) and restrictions on trans-border trade as well as capital movement by means of taxation, tariff, etc, A2). In social globalization, trans-border personal contacts (degree of tourism, telecom traffic, postal interactions, etc, B1), flow of information (B2) and cultural proximity (B3) are quantified. The political globalization (C) is measured by a single figure that quantifies the number of embassies and high commissions in a country, membership of international organizations, participation in UN peace missions, and the treaties signed between two or more states (Dreher, 2006; Dreher et al., 2008, Mishra and Kumar, 2012).

From the methodological point of view, the KOF index of globalization is constructed by using the principal components scores at stages. The principal component scores are obtained for A by a weighted merging (linear combination) of A1 and A2. Similarly, B is obtained from B1, B2 and B3. C has only one measure. Finally, a linear combination of A, B and C is obtained to represent the degree of globalization, which is called the (composite) index of globalization.

It is well known that principal component analysis has a marked preference to those variables that show up high correlation among themselves and by implication downplays the importance of those variables that are poorly correlated with their sister variables. This property makes the principal component analysis highly elitist in nature. It may be noted that correlation does not necessarily represent importance. Important variables need not move together linearly.

3. An almost equi-marginal contribution based index: To do away with the problem of elitism in construction of composite indices, Mishra (2016) proposed that instead of correlations among the composite index and its constituent variables, Shapley values of constituent variables in making the composite index may be an effective alternative. The concept and measurement of Shapley values have their origin in cooperative game theory when agents form coalition(s). Shapley values (Roth, 1988) are mean expected marginal contributions of different agents to the total value of the game. Shapley value decomposition of the total value of a cooperative game has many desirable properties such as linearity, efficiency, anonymity, symmetry and marginalism. The equi-marginal principle of allocation of resources (to consumption as well as production activities) introduced by the neo-classicist economists is well-known in economics, who showed that this principle implies optimal allocation characterized by linearity and efficiency. In the neoclassical theory of distribution the marginality principle is supported by Euler's product exhaustion theorem. Shapley value decomposition of the value of game is perfectly in tune with this principle.

The method suggested by Mishra (2016) constructs a composite index (a linear composition of constituent variables) in which weights are assigned to each constituent variable so as to minimize the Euclidean norm of their Shapley values. In case the equi-marginal solution is obtainable (in view that the composite index is a linear combination of the constituent variables), their Euclidean norm is minimal. However, in practice, only near-equi-marginal solutions are obtained. Nevertheless, an index constructed in this manner is more egalitarian in the sense that the role of poorly correlated constituent variables in the composite index may be substantially enhanced.

4. An algorithm to construct AEMC index: Let X(n, k) be the set of all k variables (each in n observations) that is used to construct the composite index, say Z = Xw (where w is a vector of weights with k positive elements). Let $Y_i \subset X$ in which $x_i \in X$ is not there or $x_i \notin Y_i$. Thus, Y_i will have only k-1 variables. We draw r (r=0, 1, 2, ... , k-1) variables from Y_i and let this collection of variables so drawn be called P_r such that $P_r \subseteq Y_i$. Also, $Y_i = Y_i \cup \emptyset$. Now, P_r can be drawn in L=kCr ways. Also, let $Q_r = P_r \cup x_i$. Regress (least squares) Z on Q_r to find R^2_q. Regress (least squares) Z on P_r to obtain R^2_p. The difference between the two R squares is $D_r = R^2_q - R^2_p$, which is the marginal contribution of x_i to Z. This is done for all L combinations for a given r and arithmetic mean of D_r (over the sum of all L values of D_r) is computed. Once it is obtained for each r, its mean is computed. Note that P_r is null for r=0, and thus Q_r contains a single variable, namely x_i. Further, when P_r is null, its R^2 is zero. The result is the arithmetic average of the mean (or expected) marginal contributions of x_i to Z. This is done for all x_i; i=1, k to obtain the Shapley value (S_i) of x_i; i=1, k. Once the Shapley value for x_i for each i is obtained its Euclidean norm is computed. If w (weight vector) is the decision variable and norm of the Shapley value is the objective function to be minimized, a suitable optimization method may be applied to optimize (minimize) the norm of the Shapley value by a suitable choice of w. Global optimization methods may be more suitable to this kind of optimization problem.

5. The present study: The present study is concerned with construction of an index of globalization based on almost equi-marginal contribution (AEMC) of constituent variable to the overall (composite) index. It is based on minimization of the Euclidean norm of Shapley values attributable to the constituent variables. The index so obtained has also been compared with the KOF index of globalization. The time series data (1970 through 2013) for three countries, China, India and Pakistan on economic, social and political globalization measures (and the Index of overall globalization), available at the KOF website, have been used, which are presented in the Appendix Tables A.1

through A.3 for China, India and Pakistan, respectively. We have used six sub-indices of globalization along three different dimensions. Thus, the constituent variables (to construct the overall index of globalization) are: A1, A2, B1, B2, B3 and C of the KOF study. The first two relate to economic dimension, the next three relate to social dimension and the last one (C) measures political dimension. However, unlike the KOF approach that merges A1 and A2 to make A, then B1, B2 and B3 to make B, and subsequently merges A, B and C to make the index of globalization, we have aggregated A1, A2, B1, B2, B3 and C at one go. Further, it may be mentioned that we have pooled the data for all the three countries for all the years, 1970-2013. The reason for this pooling is that we desire to use the same weight and optimize the Euclidean norm of Shapley values for all the countries jointly and not severely as done by the KOF. In our opinion, when we use different weights for different countries and accordingly compute Shapley values country-wise, comparability among the countries is lost. We argue that we cannot vary data and weights together. As a result of this approach, A1 through C are given appropriate weights (for the pooled data) so that the Shapley values (mean expected marginal contributions) have the overall minimal Euclidean norm (Table-1). The Host-Parasite Co-evolutionary algorithm (Mishra, 2013) has been used for optimization.

Table-1: AEMC Weights and Shapley Value of different Sub-Indices of Globalization (Min Norm=0.412421)						
Sub-Indices of Globalization	A1	A2	B1	B2	B3	C
Shapley Value Shares - KOF	0.211183	0.137522	0.006501	0.240367	0.199452	0.204832
Shapley Value Shares - AEMC	0.195630	0.137747	0.166577	0.200735	0.147458	0.151853
Weights of Sub-Indices for AEMC	0.001141	8.464233	6.603119	0.001303	0.652395	5.805689

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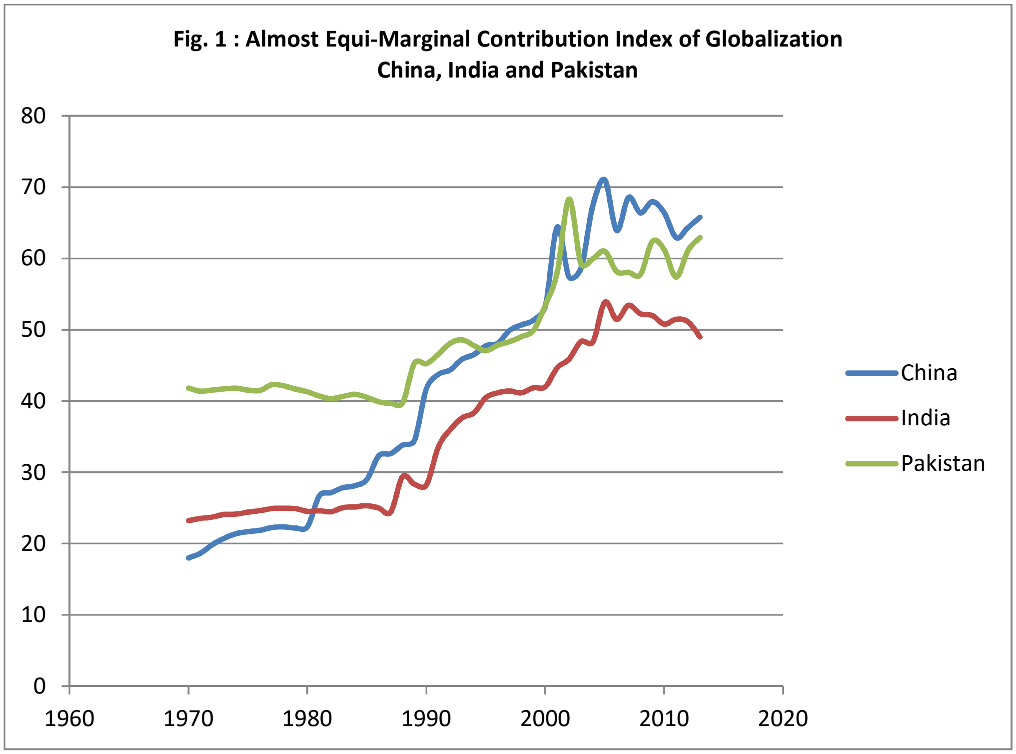
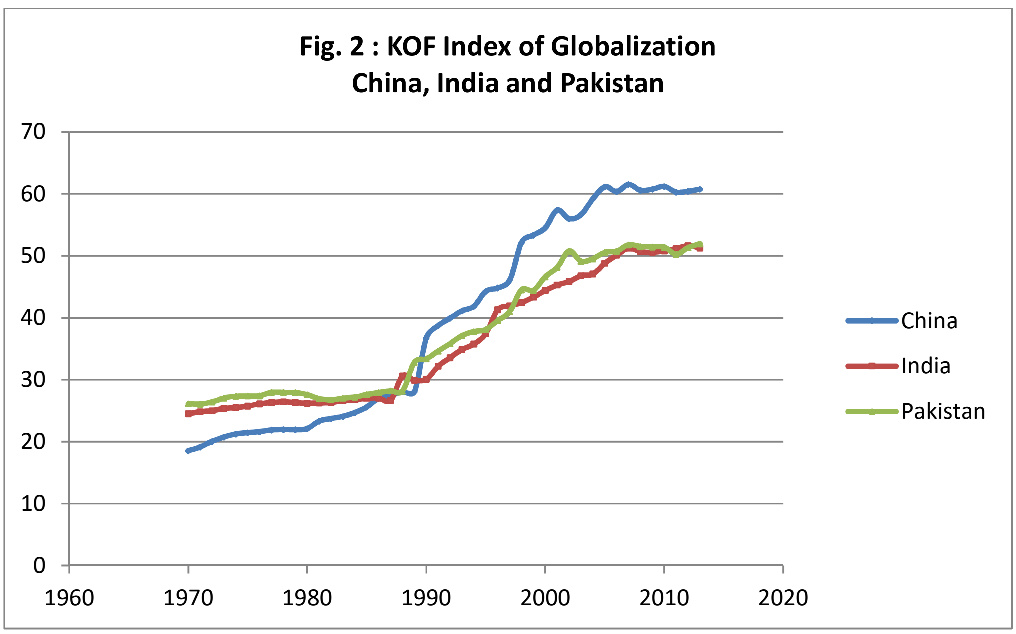
Table-2: Almost Equi-Marginal Contribution Index of Globalization: China, India and Pakistan							
Year	China	India	Pakistan	Year	China	India	Pakistan
1970	18.00000	23.23909	41.81145	1992	44.36082	36.00592	48.09744
1971	18.66683	23.55929	41.37310	1993	45.85398	37.65128	48.56453
1972	19.86232	23.74486	41.53005	1994	46.52025	38.35691	47.78129
1973	20.75806	24.11548	41.70900	1995	47.73699	40.48746	47.04306
1974	21.40397	24.15731	41.77686	1996	48.10008	41.17298	47.83438
1975	21.68946	24.43927	41.52392	1997	49.90666	41.42122	48.31899
1976	21.87503	24.63666	41.47094	1998	50.67685	41.16924	49.03800
1977	22.26045	24.93237	42.28702	1999	51.34817	41.87424	49.90502
1978	22.35680	24.98109	42.12474	2000	53.32353	42.02827	53.45437
1979	22.18845	24.91621	41.65369	2001	64.37920	44.67349	58.03209
1980	22.37048	24.55329	41.29082	2002	57.35537	45.90997	68.31786
1981	26.71172	24.62868	40.68248	2003	58.63977	48.36748	59.20980
1982	27.16321	24.50079	40.33777	2004	67.41849	48.31374	59.94512
1983	27.85223	25.07580	40.65360	2005	71.00086	53.87041	60.99980
1984	28.14079	25.16710	40.92801	2006	63.91840	51.46643	58.15357
1985	29.00047	25.34160	40.50284	2007	68.55669	53.44993	58.04878
1986	32.31727	24.99997	39.89639	2008	66.37454	52.25197	57.73460
1987	32.63662	24.43678	39.66515	2009	67.94210	52.01629	62.38946
1988	33.82060	29.41577	39.72106	2010	66.38932	50.79564	61.21695
1989	34.50079	28.33166	45.33277	2011	62.89426	51.48773	57.38729
1990	41.74329	28.23616	45.23281	2012	64.32471	51.13421	61.11587
1991	43.73445	33.54641	46.53928	2013	65.75001	49.01392	62.91616





6. Interrelation among sub-indices and the overall index of globalization: It would be interesting to look into the coefficients of correlation among different sub-indices of globalization and the indices of overall globalization, which are presented in Table-2. First of all, the correlation between the KOF index and the AEMC (Almost Equi-Marginal Contribution) index is appreciably high (0.91829). Secondly, as Table-3 reveals, correlation between KOF globalization index and B1 (degree of tourism, telecom traffic, postal interactions, etc) is negative (-0.05253, although insignificant; Shapley value negligible = 0.006501 vide Table-1), which is theoretically implausible. This is improved to 0.29555 when AEMC index is considered. Thirdly, correlation coefficients of all sub-indices (except B1) with KOF index of overall globalization are larger than those with the AEMC index of overall globalization. This is due to the trade-off in which the correlation between B1 and AEMC index is improved from -0.05253 to 0.29555. The Figures (Fig. 1 and Fig. 2) suggest that the AEMC index is more sensitive than the KOF index of globalization as the changes over the years are more vivid in the case of the former. Inclusion of B1 in AEMC is also a reason for the sensitivity of latter since B1 is declining for Pakistan over the years while it remained stable until the year 2000-2001 for India and China, but in the later years it started increasing for china and decreasing for India. These conflicting movements led to negative correlation of B1 with other sub-indices and consequently the underscoring of B1 in the KOF index, which is correlation-based. These conflicting trends, however, were captured by the AEMC index because this index is based on Shapley value, which is based on mean of expected marginal contributions derived through combinatorial selection of sub-indices.

Table-3 : Matrix of Correlation Coefficients among Different Sub-Indices and Indices of Globalization

Indices	A1	A2	B1	B2	B3	C	KOF	AEMC
A1	1.00000	0.80750	-0.06743	0.90919	0.84626	0.67499	0.92807	0.86649
A2	0.80750	1.00000	-0.34062	0.86697	0.83436	0.32923	0.76018	0.69180
B1	-0.06743	-0.34062	1.00000	-0.15810	-0.19320	0.01921	-0.05253	0.29555
B2	0.90919	0.86697	-0.15810	1.00000	0.93946	0.67391	0.95918	0.86323
B3	0.84626	0.83436	-0.19320	0.93946	1.00000	0.58541	0.90612	0.78488
C	0.67499	0.32923	0.01921	0.67391	0.58541	1.00000	0.83217	0.72609
KOF	0.92807	0.76018	-0.05253	0.95918	0.90612	0.83217	1.00000	0.91829
AEMC	0.86649	0.69180	0.29555	0.86323	0.78488	0.72609	0.91829	1.00000

7. Observations on the trends of globalization of China, India and Pakistan: Since the mid-1970s China showed a tendency to globalize her economy, but only slowly to pick up the tempo in 1980s. This was to become a significant deviation from the socialist policy. Since 1980s, pioneered by Deng Xiaoping who visualized and worked for a more economically open China, a series of reform policies were implemented to transform the Chinese economic system from a plan-guided economy to a market-guided economy (Xue et al., 2014). The Chinese have since then aggressively adopted the economic policy to adapt themselves to the international market forces and benefit from the opportunities. They have effectively exploited their comparative advantages over the interacting nations in Asia, Europe and elsewhere. This policy helped the Chinese GDP and export to increase manyfold. China emerged as an economic power to reckon with. However, with the beginning of the slump in the international economy around 2007-08, the pace of globalization of the Chinese economy slowed down to protect the domestic economy from the recession waves.

The case of India has been quite different from China. The main reform initiatives in India (like in many other developing countries) were undertaken in 1991 after a fiscal and foreign exchange crisis, which brought India to the verge of default on the foreign loans. Thus, the Indian globalization is a result of the decadence within and the pressure from without (Mishra and Nayak, 2006). That is why we see a very slow pace of globalization in the pre-1991 years, which, however, picked up momentum after 1991. To compare the Indian case of globalization with that of China, it is interesting to note that while China is filled with the 'spirit of capitalism' and 'modernization ideals', India lacks in the said spirit and ideals. Instead, India has a predominant spirit of profiteering and rent-seeking, which are detrimental to market-propelled development. It has only a weak political will to modernise the economy to benefit from its domestic comparative advantages and offshore opportunities. It may also be noted that, in case of India, planning (as a guiding force) is more or less dead, but the market has failed to replace planning. There are various domestic problems that limit the scope of fast globalization of the Indian economy in the immediate future. Disadvantages of globalization are, however, readily observable (Mishra and Nayak, 2006). Like any other open economy, India’s pace of globalization suffered a setback since 2007-08 on account of slump in the world economy. In short, globalization of India fundamentally differs from that of China.

Globalization of the Pakistan has exhibited significant sluggishness in the pre-1991 years, yet it is interesting to note that during those years, too, the Pakistan economy was more globalized than the economies of China and India, partly due to its inclination towards Bloc-1 nations, mostly triggered by its political aspirations. As Kakar et al. (2011) point out, “Pakistan started economic reforms in the beginning of 1980's in coordination with IMF and World Bank to improve the effectiveness of the economy by involving the private investor in economic development, price deregulation, and denationalization of industry, trade liberalization, and expansion in exports. The process of trade openness started during the first half of 1990's to transmit the close economic system to open economy.” Nevertheless, Pakistan opted for open economic policies by compulsion during the early 1990s. The economic liberalization of Pakistan has been opted not as a policy generated indigenously but largely as an obligation under the conditions imposed by the IMF and World Bank (Yoganandan, 2010). This is comparable to the case of globalization in India. Since 1991, the pace of globalization was appreciable and comparable with the pace of globalization of the Indian economy. However, since 2005, the pace of globalization has suffered a setback. The main issues arresting the pace of globalization of the Pakistan economy has been political instability (Yoganandan, 2010) impinging on the economic policy. It has never been able to follow a well defined line of economic policy for development.

8. Concluding remarks: In the present study we have proposed an alternative method to construct an index of globalization which is based on the principle of almost equi-marginal contributions (AEMC) of the constituent variables to the overall index rather than the correlation coefficients among the constituent variables and the final overall index (the KOF index based on the principal component scores). The principle of almost equi-marginal contribution is based on minimizing the differences of Shapley value shares (mean expected marginal contributions) attributable to the constituent variables in explaining (or synthesizing) the overall index. This has been done by minimization of the Euclidean norm of the Shapley values of the constituent variables. As an empirical exercise, secondary time series data (1970-2013) on the measures of globalization in three different dimensions (economic, social and political) of three Asian economies (China, India and Pakistan) have been used. A comparison of the AEMC index with the KOF index reveals that while the former is more inclusive, the latter is more elitist in matters of inclusion of the weakly correlated constituent variables in the overall (composite) index. As a consequence, the AEMC index is more sensitive than the KOF index of globalization. Both indices capture the trends in globalization in the countries under study and are highly correlated between themselves. Thus, AEMC is an alternative or perhaps a better method to construct composite indices.

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Appendix

Table - A.1 : KOF Sub-Indices of Economic (A1, A2) , Social (B1, B2, B3) and Political (C) Globalization, China 1970-2013

Year	A1	A2	B1	B2	B3	C	Index	Year	A1	A2	B1	B2	B3	C	Index
1970	16.21	33.13	10.60	11.29	1.65	24.82	18.51	1992	32.18	48.71	9.57	26.17	31.80	63.09	39.93
1971	16.21	33.13	10.35	11.29	1.65	27.18	19.12	1993	33.86	48.99	9.84	25.77	31.94	66.10	41.10
1972	16.21	33.13	10.35	11.29	1.65	30.53	20.03	1994	36.99	48.99	10.62	25.87	31.73	66.45	41.83
1973	16.21	33.13	10.35	11.29	1.65	33.04	20.72	1995	41.11	48.99	11.11	33.11	31.65	68.90	44.24
1974	16.21	33.13	10.35	11.29	1.65	34.85	21.22	1996	40.50	48.96	11.10	35.48	32.19	69.96	44.79
1975	16.21	33.13	10.35	11.29	1.65	35.65	21.43	1997	39.18	48.71	12.73	40.23	32.33	72.37	46.02
1976	16.21	33.13	10.35	11.29	1.65	36.17	21.58	1998	40.83	47.94	12.96	47.80	74.48	72.34	52.15
1977	16.21	33.13	10.35	11.29	1.65	37.25	21.87	1999	40.78	47.69	13.24	52.92	74.40	74.24	53.32
1978	16.21	33.13	10.35	11.29	1.65	37.52	21.94	2000	42.15	49.52	13.54	55.48	74.62	75.04	54.51
1979	16.21	33.13	10.11	11.29	1.65	37.52	21.91	2001	41.40	62.50	13.57	57.08	75.01	76.66	57.37
1980	16.44	33.13	10.11	11.29	1.65	38.03	22.09	2002	39.40	54.50	12.61	59.81	75.55	76.86	55.96
1981	16.98	38.17	10.11	11.29	1.65	38.83	23.30	2003	40.76	53.56	14.99	59.91	75.55	77.90	56.63
1982	17.25	38.62	10.11	12.82	1.65	39.08	23.70	2004	41.20	61.66	17.07	61.15	75.62	80.14	59.18
1983	16.99	39.13	10.09	13.58	1.65	39.90	24.06	2005	46.60	64.85	18.37	62.28	76.08	80.39	61.13
1984	18.29	39.36	9.82	14.72	1.65	40.72	24.68	2006	48.12	54.81	18.59	62.64	76.08	82.75	60.34
1985	20.09	39.86	9.80	15.87	1.65	42.04	25.59	2007	46.94	59.51	19.15	63.22	76.55	84.01	61.51
1986	21.93	43.72	9.82	17.39	1.65	42.59	26.96	2008	43.34	55.89	19.94	63.55	76.87	84.48	60.54
1987	23.28	44.40	9.80	19.30	1.65	41.99	27.40	2009	41.65	57.91	19.59	64.02	76.58	85.03	60.73
1988	23.81	46.21	9.57	21.97	1.50	41.69	28.04	2010	44.61	57.77	17.52	65.25	76.97	85.03	61.19
1989	24.09	47.57	9.55	22.35	1.36	40.58	28.06	2011	43.69	54.00	16.84	65.11	76.90	85.08	60.26
1990	26.65	48.43	9.53	23.50	31.65	56.48	36.72	2012	41.92	55.84	16.87	65.83	77.76	84.81	60.40
1991	28.97	48.71	9.57	25.02	31.51	61.36	38.70	2013	42.55	57.39	17.13	65.32	77.61	84.81	60.73

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Table - A.2 : KOF Sub-Indices of Economic (A1, A2) , Social (B1, B2, B3) and Political (C) Globalization, India 1970-2013

Year	A1	A2	B1	B2	B3	C	Index	Year	A1	A2	B1	B2	B3	C	Index
1970	13.55	21.04	15.03	3.81	1.50	58.07	24.51	1992	19.87	27.82	15.02	12.21	1.65	78.56	33.55
1971	13.55	21.04	14.82	3.81	1.50	59.38	24.84	1993	19.87	28.30	15.13	14.58	1.79	81.86	34.88
1972	13.55	21.04	14.82	3.81	1.50	59.90	24.99	1994	19.84	28.76	14.56	16.87	1.79	83.92	35.75
1973	13.55	21.04	14.57	3.81	1.50	61.43	25.37	1995	21.18	31.67	14.55	25.24	1.86	83.34	37.46
1974	13.55	21.04	14.36	3.81	1.50	61.96	25.49	1996	20.93	30.85	14.93	27.70	31.65	83.91	41.30
1975	13.78	21.04	14.36	3.81	1.50	62.75	25.75	1997	21.98	30.97	15.09	30.04	32.01	83.99	41.91
1976	13.78	21.04	13.98	4.19	1.50	64.05	26.10	1998	23.77	30.78	15.18	32.84	31.94	83.54	42.44
1977	13.78	21.04	14.02	4.19	1.50	64.80	26.32	1999	24.54	30.17	16.00	35.04	31.80	85.29	43.32
1978	13.78	21.04	13.83	4.19	1.50	65.31	26.43	2000	27.61	29.91	15.80	36.58	32.16	86.67	44.41
1979	13.51	21.04	13.88	4.19	1.50	65.03	26.31	2001	28.15	33.17	15.66	37.68	31.87	87.03	45.28
1980	13.51	21.04	13.50	4.19	1.50	64.76	26.19	2002	28.40	35.66	14.72	39.61	32.08	86.71	45.84
1981	13.52	21.04	13.76	4.95	1.50	64.46	26.24	2003	29.89	39.20	14.04	40.22	32.08	86.95	46.80
1982	14.05	21.04	13.72	5.33	1.50	64.18	26.31	2004	30.71	39.75	13.20	40.58	32.08	87.21	47.06
1983	14.31	21.04	14.27	5.72	1.50	64.71	26.62	2005	32.17	46.64	12.49	40.05	32.44	88.61	48.80
1984	14.58	21.04	14.27	5.72	1.57	64.96	26.74	2006	36.54	42.91	12.82	46.41	32.84	89.60	50.11
1985	15.12	21.04	14.25	5.72	1.79	65.47	27.00	2007	39.61	44.37	13.31	45.72	32.62	90.92	51.22
1986	14.89	21.04	13.76	6.48	1.86	65.47	27.01	2008	41.33	43.24	13.02	41.37	32.76	90.67	50.66
1987	15.12	21.04	13.78	6.86	2.01	63.84	26.67	2009	41.09	43.03	12.94	41.74	32.40	90.67	50.58
1988	15.91	21.04	14.01	7.24	2.37	77.31	30.61	2010	42.16	41.19	12.89	42.57	32.72	91.47	50.80
1989	16.45	21.04	14.32	8.77	1.79	73.71	29.90	2011	42.16	41.99	12.68	43.04	32.94	92.00	51.15

1990	17.78	21.04	14.32	9.02	1.57	73.46	30.07	2012	45.22	41.73	12.72	43.92	33.01	91.51	51.64
1991	20.13	26.81	14.45	10.68	1.36	75.09	32.17	2013	45.09	38.74	12.99	44.39	33.01	91.78	51.26

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Table - A.3 : KOF Sub-Indices of Economic (A1, A2) , Social (B1, B2, B3) and Political (C) Globalization, Pakistan 1970-2013

Year	A1	A2	B1	B2	B3	C	Index	Year	A1	A2	B1	B2	B3	C	Index
1970	15.68	24.80	42.01	8.88	1.86	48.57	26.12	1992	27.25	25.32	36.44	13.07	1.93	75.95	35.80
1971	15.68	24.80	41.38	8.88	1.86	48.58	26.06	1993	27.74	25.84	34.17	13.45	2.15	80.53	37.09
1972	16.34	24.80	41.10	8.88	1.86	49.57	26.42	1994	30.29	26.62	31.57	13.84	1.86	81.71	37.76
1973	16.79	24.80	40.19	8.88	1.86	51.86	27.03	1995	31.34	26.62	30.17	14.60	1.65	82.41	38.08
1974	17.45	24.80	39.90	8.88	1.86	52.62	27.33	1996	33.13	27.23	30.21	20.08	1.79	83.16	39.53
1975	17.23	24.80	39.28	8.88	1.86	53.13	27.37	1997	35.87	27.01	31.28	26.64	1.65	82.92	40.95
1976	16.79	24.80	38.94	8.88	1.86	53.65	27.40	1998	34.36	28.82	30.00	28.47	32.01	80.87	44.49
1977	17.41	24.80	39.33	8.88	1.86	55.17	27.96	1999	30.97	29.90	29.57	29.58	31.65	81.74	44.39
1978	16.88	24.80	38.88	8.88	1.86	55.60	27.94	2000	30.03	32.27	30.98	38.32	32.12	83.53	46.60
1979	18.83	24.80	38.90	8.88	1.86	54.24	27.91	2001	29.40	37.29	30.94	40.13	32.44	85.09	48.10
1980	19.00	24.80	39.10	8.88	1.86	52.83	27.58	2002	30.46	49.84	31.26	41.95	32.12	85.01	50.75
1981	17.44	24.80	38.93	8.88	1.86	51.46	26.91	2003	29.57	39.36	30.13	44.55	32.12	85.34	49.09
1982	19.12	24.80	39.41	8.88	1.86	49.55	26.74	2004	29.97	42.58	27.16	43.88	31.97	85.99	49.49
1983	20.64	24.80	39.86	8.50	1.86	49.55	27.00	2005	34.23	43.69	26.99	42.72	32.40	86.74	50.52
1984	20.67	24.80	40.06	8.88	1.93	49.92	27.19	2006	36.26	41.65	24.89	44.37	32.05	87.52	50.72
1985	22.57	24.80	39.33	9.64	1.72	50.18	27.60	2007	41.57	42.55	23.45	43.86	32.12	88.02	51.75
1986	23.60	24.80	38.32	10.40	2.15	50.43	27.92	2008	39.12	41.34	24.00	44.60	31.97	88.80	51.46
1987	24.66	24.80	37.86	10.79	2.22	50.68	28.20	2009	33.36	43.60	28.29	46.51	32.05	88.31	51.41
1988	23.05	24.80	37.44	11.17	2.01	51.68	28.17	2010	33.75	41.95	28.25	46.87	31.97	88.83	51.37
1989	24.61	24.80	37.41	11.55	1.93	67.47	32.80	2011	30.64	40.55	24.40	47.13	31.90	88.83	50.22
1990	27.20	24.80	37.15	11.93	1.93	67.70	33.35	2012	31.91	44.83	24.79	47.49	31.90	88.86	51.30
1991	25.69	25.32	36.28	14.60	1.79	71.91	34.61	2013	32.93	47.47	24.42	47.49	32.37	88.64	51.91

Fortran Code

```
PROGRAM SHAPLEY_COMPINDEX ! MAIN PROGRAM
CALL SHAPLEY_INDEX()
END

SUBROUTINE SHAPLEY_INDEX()
!SHAPLEY REGRESSION FOR SHAPLEY-BASED COMPOSITE INDEX
PARAMETER (NORETURN=1)! IF 1 THEN STOPS;DOES NOT RETURN TO INVOKER
PARAMETER (NMAX=500,MMAX=10)
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
DIMENSION X(NMAX,MMAX),Y(NMAX),XX(MMAX,MMAX),XY(MMAX),B(MMAX)
DIMENSION VX(MMAX,MMAX),VY(MMAX),YH(NMAX),CONTRIB(MMAX),Z(NMAX)
DIMENSION ARRAY(MMAX),BARRAY(MMAX),RMAT(MMAX,MMAX),RVECT(MMAX)
DIMENSION BETA(MMAX),AVX(MMAX),SDX(MMAX)
COMMON /HP/RMAT,RVECT,CONTRIB
CHARACTER *70 INFIL,OFIL,OUTFIL,FINRES
COMMON /DAT/X,Y
COMMON /RNDM/IU,IV
COMMON /IOFIL/INFIL,OFIL,OUTFIL,FINRES
COMMON /PARAM/NOB,MVAR
COMMON /REGPAR/COEFF(MMAX),FR
! ===============================================================
! THIS PROGRAM, THOUGH A SUBROUTINE, NEEDS ONLY TO BE INVOKED.
! IT TAKES INPUTS AND PRINTS OUTPUT WITHIN IT.
! FO THAT THE PARAMETER NORETURN IS USED
! ===============================================================
! ---------- NO. OF  OBSERVATIONS AND REGRESSOR VAIABLES --------
WRITE(*,*)'FEED N AND M'
READ(*,*) N,M

! N=50!NUMBER OF OBSERVATIONS
! M=7! NO. OF VARIABLES (REGRESSORS, NO CONSTANT)
! ------------------- FILE NAMES -------------------------------
WRITE(*,*)'FEED THE NAME OF INPUT & OUTPUT FILES; BOTH TXT FILES'
READ(*,*) INFIL, FINRES
INFIL='chinpa.txt'
! INFIL='LEVY.TXT' ! CONTAINS Y AND X DATA
! INTERMEDIATE FILES -------------------------------------------
 OFIL='ALLCOMB.TXT' ! STORES ALL COMBINATIONS
 OUTFIL='SHAPLEY_R.TXT'! STORES ALL COMBINATIONS WITH R SQUARE
! ---------------------------------------------------------------
!FINRES='SHAPLEY_RESULTS.TXT'
! ------------------- FORMATS ---------------------------------
1  FORMAT(8F10.2)
2  FORMAT(2I3,4F5.0,2X,F12.9)! BETTER TO MAKE IT RUN-TIME FORMAT
3  FORMAT(40X,2I3,4F5.0,2X,F12.9)! BETTER TO MAKE IT RUN-TIME FORMAT
4  FORMAT('REGRESSOR #',I2,' SHARED R_SQR =',F18.15,' [',F7.4,' %]')
5  FORMAT(9(F8.4))
6  FORMAT(2(F12.6))
! ***************************************************************
NOB=N
MVAR=M

OPEN(9,FILE=FINRES)
OPEN(7,FILE=INFIL) ! CONTAINS Y (REGRESSAND) AND X (REGRESSORS)
DO I=1,N
READ(7,*)(x(i,j),j=1,m)
```

```
! DATA DOES NOT HAVE CONSTANT

ENDDO
CLOSE(7)
! ----------------------------------------------------------------
!MAKING THE INDEX WITH EQUAL WEIGHTS TO ALL INDICATORS
WRITE(*,*)'FEED RANDOM NUMBER SEED'
READ(*,*) IU

DO J=1,M
CALL RANDOM(RAND)
BETA(J)=RAND
ENDDO
! UNITIZE
DO J=1,M
DO I=1,N
YH(I)=X(I,J)
ENDDO
CALL UNITIZE(YH,N)
DO I=1,N
X(I,J)=YH(I)
ENDDO
ENDDO


DO I=1,N
Y(I)=0.D0
DO J=1,M
Y(I)=Y(I)+X(I,J)*BETA(J)
ENDDO
ENDDO

DO I=1,N
YH(I)=Y(I)
ENDDO
CALL UNITIZE(YH,N)
DO I=1,N
Y(I)=YH(I)
ENDDO


CALL HOST_PARASITE(M,BETA,N,OPTM)
! COMPUTE IMPUTED R SQUARED VALUE
WRITE(9,*)'SHAPLEY-VALUE SHARES'
WRITE(9,*)(CONTRIB(J),J=1,M)
WRITE(9,*)'SHAPLEY-VALUE BASED WEIGHTS TO CONSTRUCT COMPOSITE Y'
WRITE(9,*)(BETA(J),J=1,M)

DO I=1,N
YH(I)=0.D0
DO J=1,M
YH(I)=YH(I)+ X(I,J)*BETA(J)
ENDDO
YH(I)=YH(I)/M
ENDDO
CALL RSQUARE(Y,YH,N,RM,RSQ)
WRITE(9,*)'COMPUTED SHAPLEY REGRESSION R_SQUARED =',RSQ
WRITE(9,*)'OPTIMAL NORM FUNCTION VALUE =',OPTM
WRITE(9,*)'--------------------------'
WRITE(9,*)'FOLLOWING ARE TWO COMPOSITE INDICES, THEY ARE SAME'
WRITE(9,*)'EXCEPT ORIGIN AND SCALE AND THE CORRELATION BETWEEN'
WRITE(9,*)'THEM [R_RSQR(INDEX1, INDEX2)] IS APPROX = 1, I.E.',RSQ
WRITE(9,*)'[SMALL ERROR MAY BE DUE TO ACCUMULATED ROUNDING OFF].'
```

```
WRITE(9,*)'///////////////////////////////////////////////////'
DO I=1,N
WRITE(9,6) Y(I),YH(I)
ENDDO
CLOSE(9)
WRITE(*,*)' '
WRITE(*,*)' '
WRITE(*,*)'THE JOB IS OVER. RESULTS ARE STORED IN FILE = ',FINRES

IF(NORETURN.EQ.1) THEN
STOP
ELSE
RETURN
ENDIF
END
! ----------------------------------------------------------------
SUBROUTINE UNITIZE(E,N)
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
DIMENSION E(*)
EM=0
ES=0
DO I=1,N
EM=EM+E(I)
ES=ES+E(I)**2
ENDDO
EM=EM/N
ES=SQRT(ES/N-EM**2)
DO I=1,N
E(I)=(E(I)-EM)/ES
ENDDO
RETURN
END
!----------------------------------------------------------------
SUBROUTINE INV(A,M,D)! MATRIX INVERSION
PARAMETER(MMAX=10)! MMAX IS THE MAXIMUM DIMENSION.
!MATRIX INVERSION - EXCHANGE METHOD:KRISHNAMURTHY EV & SEN SK(1976)
!COMPUTER-BASED NUMERICAL ALGORITHMS, AFFILIATED EAST-WEST PRESS,
!NEW DELHI, P.161
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
DIMENSION A(MMAX,MMAX)
! -------------------------------------------------------
! INVERSION BEGINS
D=1.D0 ! D IS THE DETERMINANT OF MATRIX A.
! THE RESULT (INVERSE OF A) IS STORED IN A ITSELF. A IS LOST
DO I=1,M
  D=D*A(I,I)
  A(I,I)=1.D0/A(I,I)
  DO J=1,M
    IF(I.NE.J) A(J,I)=A(J,I)*A(I,I)
  ENDDO
  DO J=1,M
    DO K=1,M
      IF(I.NE.J.AND.K.NE.I) A(J,K)=A(J,K)-A(J,I)*A(I,K)
    ENDDO
  ENDDO
  DO J=1,M
   IF(J.NE.I) A(I,J)=-A(I,J)*A(I,I)
  ENDDO
ENDDO
! INVERSION ENDS
! ------------------------------------------------------
! WRITE(*,*)'DETERMINANT=',D
RETURN
```

```
END
! ==================================================================
SUBROUTINE VINIT(VX,VY) ! INITIALIZES (INTERNAL USE)
PARAMETER (MMAX=10)
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
DIMENSION VX(MMAX,MMAX),VY(MMAX)
DO I=1,MMAX
DO J=1,MMAX
IF(I.EQ.J) THEN
VX(I,J)=1
ELSE
VX(I,J)=0
ENDIF
ENDDO
VY(I)=0
ENDDO
RETURN
END
! -----------------------------------------------------------------
SUBROUTINE RSQUARE(Y,YH,N,RM,RSQ) ! FINDS REGRESSION R SQUARE
PARAMETER (NMAX=500)
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
DIMENSION Y(NMAX),YH(NMAX)
AY=0
AYH=0
VY=0
VYH=0
VYYH=0
DO I=1,N
AY=AY+Y(I)
AYH=AYH+YH(I)
VY=VY+Y(I)**2
VYH=VYH+YH(I)**2
VYYH=VYYH+Y(I)*YH(I)
ENDDO
AY=AY/N
AYH=AYH/N
VY=VY/N-AY**2
VYH=VYH/N-AYH**2
VYYH=VYYH/N-AY*AYH
RM = VYYH/SQRT(VY*VYH)
RSQ=(VYYH**2)/(VY*VYH)
RETURN
END
!----------------------------------------------------------------
SUBROUTINE COMBIN(N,M,OFIL)
PARAMETER (MX=20)! MX IS MAXIMUM DIMENSION
INTEGER A(MX),B(MX),C
DOUBLE PRECISION NCM,IC
CHARACTER *70 OFIL
OPEN(15,FILE=OFIL)
NCM=1
  DO I=1,M
  A(I)=I ! A IS LEAST INDEXED COMBINATION
  B(I)=N-M+I ! B IS MAXIMUM INDEXED COMBINATION
  NCM=NCM*B(I)/I ! TOTAL POSSIBLE COMBINATIONS
  ENDDO
WRITE (15,*) (A(I),I=1,M)! INITIAL (LEAST INDEXED) COMBINATION
INCMPL=1
IC=1
! ---------------------------------------------------------------
DO WHILE (INCMPL.NE.0 .AND.INT(IC).LT.NCM)
INCM=0
```

```
  DO I=1,M
  INCM=INCM+(B(I)-A(I))
  ENDDO
INCMPL=INCM
A(M)=A(M)+1
  DO I=1,M
  II=M-I+1
    IF(A(II).GT.B(II)) THEN
    A(II-1)=A(II-1)+1
       DO J=II,M
       A(J)=A(J-1)+1
       ENDDO
    ENDIF
  ENDDO
IC=IC+1
WRITE(15,*)(A(K),K=1,M)
ENDDO ! END DO WHILE LOOP
! ---------------------------------------------------------------
CLOSE(15)
RETURN
END
! ================================================================
SUBROUTINE REGRESS(XX,XY,ARRAY,RSQ,N,MX)! OLS SUBROUTINE
PARAMETER (NMAX=500,MMAX=10)
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
DIMENSION X(NMAX,MMAX),Y(NMAX),XX(MMAX,MMAX),XY(MMAX),B(MMAX)
DIMENSION VX(MMAX,MMAX),VY(MMAX),YH(NMAX)
DIMENSION ARRAY(MMAX)
CHARACTER *70 INFIL
COMMON /DAT/X,Y
CALL VINIT(VX,VY)! INITIALIZE VX AND VY
M=MX
DO I=1,M
II=INT(ARRAY(I))
DO J=1,M
JJ=INT(ARRAY(J))
VX(I,J)=XX(II,JJ)
ENDDO
VY(I)=XY(II)
ENDDO
CALL INV(VX,M,DET)
! COMPUTE REGRESSION COEFFICIENT
DO I=1,M
B(I)=0
DO J=1,M
B(I) = B(I)+VX(I,J)*VY(J)
ENDDO
ENDDO
! FIND R SQUARE
DO I=1,N
YH(I)=0
DO J=1,M
JJ=INT(ARRAY(J))
YH(I)=YH(I)+X(I,JJ)*B(J)
ENDDO
ENDDO
CALL RSQUARE(Y,YH,N,RM,RSQ)
! ----- PRINT ORDINARY REGRESSION COEFFICIENTS AND R SQUARE -----
! WRITE(*,*)'ORDINARY REGRESSION COEFFICIENTS AND R SQUARE'
! WRITE(*,*)(B(J),J=1,M), ' RSQUARE =',RSQ
RETURN
END
! ----------------------------------------------------------------
```

```
FUNCTION NCR(IN,IR) ! FINDS NCR
NF=1
NR=1
DO I=1,IR
NF=NF*(IN-I+1)
NR=NR*I
ENDDO
NCR=NF/NR
RETURN
END
!-----------------------------------------------------------------
SUBROUTINE HOST_PARASITE(M,RBETA,NOB1,OPTM)
! ALGORITHM & PROGRAM BY PROF. SK MISHRA, DEPT. OF ECONOMICS
! NORTH-EASTERN HILL UNIVERSITY (SHILLONG), INDIA
PARAMETER (NOB=500, MVAR=10)
PARAMETER(NMAX=1000, MMAX=10)
PARAMETER(MAXREP=15, NREP=1)
! NMAX = MAXIMUM NUMBER OF BIRDS TO GENERATE
! MMAX = MAXIMUM DIMENSION OR NO. OF DECISION VARIABLES
PARAMETER(IPRN=1000) ! DISPLAY INTERMEDIATE RESULTS AT EVERY IPRN
!----------------------------------------------------------------
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
!----------------------------------------------------------------
PARAMETER(FSIGN=1, NSORT=0) !(FSIGN = -1 FOR MAXIMIZATION)
PARAMETER(MAXITER=10000000, EPS=1.0D-14)
! MAXITER = MAXIMUM NO. OF ITERATIONS
! !EPS IS USED AS A CONVERGENCE CRITERION)
!----------------------------------------------------------------
DOUBLE PRECISION LEVY ! FUNCTION LEVY(BETA) IS DOUBLE PRECISION
COMMON /RNDM/IU,IV ! TO GENERATE UNIFORM DISTR. RANDOM NUMBERS
COMMON /KFF/KF,NFCALL,FTIT ! KF IS FUNCTION CODE; NFCALL IS THE
!NUMBER OF FUNCTION CALLS; FTIT IS THE TITLE OF THE FUNCTION
CHARACTER *70 TIT(200),FTIT ! TIT IS TITLE OF FUNCTIONS, A BATTERY
! OF 100 TEST FUNCTIONS; FTIT = TITLE OF THE FUNCTION
CHARACTER *70 HISTORY ! OUTPUT FILE TO STORE HISTORY OF COVERGENCE
INTEGER IU,IV! FOR GENERATING UNIFORMLY DISTRIBUTED RANDOM NUMBERS
DIMENSION CUCKOO(NMAX,MMAX),CROW(NMAX,MMAX),ICU(NMAX),ICR(NMAX)
DIMENSION A(MMAX),FCU(NMAX),FCR(NMAX),TCUC(MMAX),TCRO(MMAX)
DIMENSION OPTVAL(MAXREP),NRAND(MAXREP),EXTIME(MAXREP)
DIMENSION EXCYCLE(MAXREP)
DIMENSION X(NOB,MVAR),Y(NOB)
CHARACTER *8 CLOCK, START_TIME, NOW_TIME
COMMON /HP/RMAT,RVECT,CONTRIB
COMMON /DAT/X,Y
DIMENSION RMAT(MMAX,MMAX),RVECT(MMAX),CONTRIB(MMAX),RBETA(MMAX)

DATA (NRAND(I),I=1,MAXREP)/44431,44421,44401,45671,53277,45331,
& 34567,23171,98267,49821,11387,17869,12352,12017,10501/
!----------------------------------------------------------------
! LINEAR FUNCTION
!DPROB(PROB)=0.3D0*(1.D0-PROB)
! GOMPERTZ CURVE
DPROB(PROB)=0.7D0*(EXP(-2*EXP(-(1.0D0/(1+DLOG(1+PROB))))))
! LOGISTIC FUNCTION
!DPROB(PROB)=(0.5-0.35D0/(1.D0+EXP(-PROB)))
! LOGIT FUNCTION
!DPROB(PROB)=-0.05D0*DLOG(PROB/(1.D0-PROB))


!PROB(IT,FN1,FN2)=0.7*(EXP(-2*EXP(-(0.00001D0/(1+DLOG(1+DABS(FN1
!* -FN2))))*IT)))
! THIS STATEMENT FUNCTION DEFINES THE DETECTION/REJECTION FUNCTION
! OF A CUCKOO EGG BY THE HOST (0.7 IS THE UPPER LIMIT OF PROB)
```

```
!-----------------------------------------------------------------
!-----------------------------------------------------------------
!WRITE(*,*)'FILE (NAME.TXT) TO STORE HISTORY OF CONVERGENCE ?'
! THIS FILE STORES THE HISTORY OF CONVEGENCE OF CUCKOOS AND CROWS
!READ(*,*) HISTORY
HISTORY='HIST.TXT'
OPEN(15,FILE=HISTORY)
! ==============================================================
DO IREP=1,NREP
 !-----------------------------------------------------------------
IF(IREP.EQ.1) THEN
! SELECT/CHOOSE THE FUNCTION TO OPTIMIZE
CALL FSELECT(KF,M,FTIT) ! CHOOSES THE FUNCTION TO OPTIMIZE
!WRITE(*,*)'NO. OF CUCKOOS (EQUAL TO NO. OF CROWS) ?'
!WRITE(*,*)'THIS COULD BE BETWEEN 30 AND 100, SAY.'
!READ(*,*) NCU, NCR  ! NO. OF CUCKOOS (& CROWS) TO GENETE.
!NCU SHOULD BE NOT BE MORE THAN A HALF OF NMAX (NMAX > 2*NCU)
!NCR=NCU ! THE CROWS ARE AS MANY AS THE CUCKOOS
!WRITE(*,*)'FEED THE RANDOM NUMBER SEED'
!READ(*,*) IU ! RANDOM NUMBER SEED (5 DIGITS ODD INTEGER NUMBER)
NCU=30
NCR=30

WRITE(*,*)' '
WRITE(*,*)' '
WRITE(*,*)'-----------------------------------------------------'
WRITE(*,*)'MAX TIME(SEC) TO RUN?. FIVE SECS ARE ENOUGH, FEED 5.'
!READ(*,*) AMAXSEC,VTHEN ! VTHEN IS REFERENCE VALUE
READ(*,*) AMAXSEC
VTHEN=9999
WRITE(*,*)'-----------------------------------------------------'
ENDIF
! INITIALIZATION ----------------------------------------------
BETA=3/2.D0  ! NEEDED TO GENERATE LEVY FLIGHTS (CUCKOOS)
GAMMA=5/3.D0 ! NEEDED TO GENERATE LEVY FLIGHTS  (CROWS)
! ---------------------------------------------------------------
BET=0.2D0  ! NEEDED TO GENERATE CAUCHY FLIGHTS (CUCKOOS)
GAM=0.8D0  ! NEEDED TO GENERATE CAUCHY FLIGHTS  (CROWS)
! --------------------------------------------------------------
SCALE=10 !(SCALING OF INITIAL VALUES OF DECISION VARIABLES)
FACTOR=SCALE ! SCALING FACTOR
NFCALL=0  ! NO. OF FUNCTION CALLS : INITIALIZED
CUSD=1.0D30 ! USED FOR CONVERGENCE CRITERION
CRSD=1.0D30 ! USED FOR CONVERGENCE CRITERION
PROX=0.00D0 ! DETERMINES CHOICE BETWEEN LEVY AND CAUCHY FLIGHTS
PROB=0.5D0
ALIF=1.0D-06 ! AFFECTS THE RATE OF COVERGENCE
SUCCESS=0.0D0
GHZ=2.4D0 ! CLOCK CYCLES (PER SECOND) OF THE CPU
!---------------------------------------------------------------
!GENERATE CUCKOOS RANDOMLY AND EVALUATE
!CALL TIME(CLOCK)
!START_TIME=CLOCK
CALL CPU_TIME(START)
IU=NRAND(IREP)
KSEED=IU
CALL RANDOM(RAND)
DO I=1,NCU
DO J=1,M
CALL RANDOM(RAND)
A(J)=(RAND)*FACTOR
CUCKOO(I,J)=A(J)
ENDDO
```

```
CALL FUNC(M,A,F)
FCU(I)=F*FSIGN
ENDDO
!GENERATE CROWS RANDOMLY AND EVALUATE
DO I=1,NCR
DO J=1,M
CALL RANDOM(RAND)
A(J)=(RAND)*FACTOR
CROW(I,J)=A(J)
ENDDO
CALL FUNC(M,A,F)
FCR(I)=F*FSIGN
ENDDO
IF(NSORT.EQ.1) THEN
CALL SORT(CUCKOO,FCU,NCU,M) ! SORT CUCKOO POPULATION
CALL SORT(CROW,FCR,NCR,M)  ! SORT CROW POPULATION
LOCU=1
LOKR=1
ELSE
CALL FINDBEST(FCU,NCU,TOPCU,LOCU)
CALL FINDBEST(FCR,NCR,TOPKR,LOKR)
ENDIF
!-----------------------------------------------------------------
ICOUNT=0
!---------------------------------------------------------------
IT=0 ! INITIALIZATION OF ITERATION
FEPS=0.0D0 ! INITIALIZATION OF TERMINATION CONDITION
!DO IT=1,MAXITER
DO WHILE (IT.LE.MAXITER.AND.FEPS.EQ.0.0)
FN1=FCU(LOCU) ! BEST VALUE OF CUCKOOS
FN2=FCR(LOKR) ! BEST VALUE OF CROWS
PDET=DPROB(PROB) ! DEFINED IN THE STATEMENT FUNCTION
! SET ICU AND ICR TO ZERO
DO I=1,NCU
ICU(I)=0
ENDDO
DO I=1,NCR
ICR(I)=0
ENDDO
! CUCKOOS REGENERATE THEMSELVES (FLY) WITH LEVY FLIGHT
DO I=1,NCU
DO J=1,M

CALL RANDOM(RAND)
ALPHA=ALIF+(RAND)**2  ! AFFECTS THE SPEED OF CONVERGENCE
CALL RANDOM(RAND)
OMEGA=ALIF+(RAND)**2  ! AFFECTS THE SPEED OF CONVERGENCE
CALL RANDOM(RC)
CALL RANDOM(RAND)
L=1+INT(NCR*RAND)
CALL RANDOM(RAND)
DIFFN=(CROW(L,J)-CUCKOO(I,J))
IF(RAND.GE.PROX) THEN
A(J)=CUCKOO(I,J)+ALPHA*(RC-0.5)*LEVY(BETA)*DIFFN
!A(J)=CUCKOO(I,J)+ALPHA*(RC-0.5)*BURR12()*DIFFN
!A(J)=CUCKOO(I,J)+ALPHA*(RC-0.5)*GAUSS()*DIFFN
!A(J)=CUCKOO(I,J)+ALPHA*(RC-0.5)*CAUCHY(BET)*DIFFN
ELSE
A(J)=CUCKOO(I,J)+ALPHA*(RC-0.5)*CAUCHY(BET)*DIFFN
ENDIF
ENDDO
CALL FUNC(M,A,F)
! A NEW S0LUTION IS ADMITTED ONLY IF IT IS BETTER
```

```
FNEW=F*FSIGN
IF(FCU(I).GT.FNEW) THEN
FCU(I)=FNEW
ICU(I)=1
DO J=1,M
CUCKOO(I,J)=A(J)
ENDDO
ENDIF
ENDDO
! TRY TO PLACE THE EGGS OF CUCKOOS INTO CROW-NESTS
DO I=1,NCU
CALL RANDOM(RAND)
IX=1+INT(NCR*RAND)
CALL RANDOM(RAND)
MK=0
IF(RAND.GT.PDET.AND.ICR(IX).EQ.0) MK=1
IF(MK.EQ.1.AND.ICU(I).EQ.1.AND.FCR(IX).GT.FCU(I)) THEN
ICR(IX)=1
ICU(I)=1
FCR(IX)=FCU(I)
DO J=1,M
CROW(IX,J)=CUCKOO(I,J)
ENDDO
ENDIF
ENDDO
! SET ICU TO ZERO
DO I=1,NCU
ICU(I)=0
ENDDO
! SET ICR TO ZERO AND CROW(I,J) TO RANDOM. ALSO FIND FITNESS
DO I=1,NCR
IF(ICR(I).NE.0) THEN
DO J=1,M
CALL RANDOM(RK)
CALL RANDOM(RAND)
L=1+INT(NCU*RAND)
CALL RANDOM(RAND)
DIFFN=(CUCKOO(L,J)-CROW(I,J))
IF(RAND.GE.PROX) THEN
A(J)=CROW(I,J)+OMEGA*(RK-0.5)*LEVY(GAMMA)*DIFFN
!A(J)=CROW(I,J)+OMEGA*(RK-0.5)*BURR12()*DIFFN
!A(J)=CROW(I,J)+OMEGA*(RK-0.5)*GAUSS()*DIFFN
!A(J)=CROW(I,J)+OMEGA*(RK-0.5)*CAUCHY(GAM)*DIFFN
ELSE
A(J)=CROW(I,J)+OMEGA*(RK-0.5)*CAUCHY(GAM)*DIFFN
ENDIF
ENDDO
CALL FUNC(M,A,F)
IF(FCR(I).GT.F*FSIGN) THEN
FCR(I)=F*FSIGN
DO J=1,M
CROW(I,J)=A(J)
ENDDO
ICR(I)=0
SUCCESS=SUCCESS+1
ENDIF
ENDIF
ENDDO
PROB=SUCCESS/(NCU*(IT+1))
IF(NSORT.EQ.1) THEN
CALL SORT(CUCKOO,FCU,NCU,M) ! SORT CUCKOO POPULATION
CALL SORT(CROW,FCR,NCR,M)  ! SORT CROW POPULATION
LOCU=1
```

```
LOKR=1
ELSE
CALL FINDBEST(FCU,NCU,TOPCU,LOCU)
CALL FINDBEST(FCR,NCR,TOPKR,LOKR)
ENDIF
BESTVAL=FCR(LOKR)
! DISPLAY RESULTS AT EVERY IPRN ITERATIONS
IF(INT(ICOUNT/IPRN).EQ.(FLOAT(ICOUNT)/IPRN))THEN
ICOUNT=0
WRITE(*,1)
1 FORMAT(/39('*='))
WRITE(*,*)'PROBLEM NO.=',KF,' DIMENSION=',M,' RANDOM SEED=',KSEED,
& ' EXPERIMENT NO. = ', IREP
WRITE(*,*)'CUCKOO COORDINATE VALUES'
WRITE(*,*)(CUCKOO(LOCU,J),J=1,M)
WRITE(*,*)'-----------------------------------------------------'
WRITE(*,*)'CROW COORDINATE VALUES'
WRITE(*,*)(CROW(LOKR,J),J=1,M)
WRITE(*,*)'-----------------------------------------------------'
WRITE(*,*)'FITNESS OF CUCKOOS AND CROWS =',FCU(LOCU), FCR(LOKR)
WRITE(*,*)'NO.OF FUNCTION CALLS=',NFCALL,' PROB OF REJECT=',PDET
WRITE(15,*)(NFCALL+.0D0),FCU(LOCU),FCR(LOKR),PROB,PDET
CALL MEANSD(FCU,NCU,CUMEAN,CUSD,CUSKEW)
CALL MEANSD(FCR,NCR,CRMEAN,CRSD,CRSKEW)
WRITE(*,*) 'FMEANS =',CUMEAN, CRMEAN,' FSD =',CUSD,CRSD
WRITE(*,*)'SKEWNESS IN CUCKOO & CROW POPULATIONS =',CUSKEW,CRSKEW
! CUMEAN & CRMEAN ARE MEAN FUNCTION VALUES - CUCKOOS & CROWS
! CUSD & CRSD ARE STD DEV OF FUNCTION VALUES - CUCKOOS & CROWS
! CUSKEW & CRSKEW ARE SKEWNESS FUNCTION VALUES - CUCKOOS & CROWS
! CUMED & CRMED ARE MEDIANS OF FUNCTION VALUES FOR CUCKOOS & CROWS

! IF(CUSD.LT.EPS.OR.CRSD.LE.EPS) FEPS=1 ! TERMINATION CONDITION
!CUSD=DABS(FCU(1)-FCU(N))
!CRSD=DABS(FCR(1)-FCR(N))
CALL CPU_TIME(FINISH)
!CALL TIME(CLOCK)
!NOW_TIME=CLOCK
!NOW_SEC=SECNDS(0.0)
!NSEC=NOW_SEC - START_SEC
CPUT=(FINISH-START)
WRITE(*,*) 'TIME_ELAPSED=', CPUT,' SECONDS.'
WRITE(*,*)'-----------------------------------------------------'
CYCL=CPUT*GHZ
WRITE(*,*)'CPU TIME(S) TAKEN =',CPUT,' CLOCK CYCLES(GIGA) =',CYCL,
&'  EXPERIMENT #', IREP
WRITE(*,*)'-----------------------------------------------------'
WRITE(*,*)' '
WRITE(*,*)'======= PLEASE WAIT. COMPUTATION IS GOING ON ======='
ENDIF
CALL CPU_TIME(FINISH)
CPUT=(FINISH-START)
IF(CPUT.GE.AMAXSEC) GOTO 2
IF(DABS(BESTVAL-VTHEN).LT.1.0D-12) GOTO 2

!----------------------------------------------------------------
IF(CUSD.LT.EPS.OR.CRSD.LE.EPS) FEPS=0 ! TERMINATION CONDITION
!----------------------------------------------------------------
!ENDIF
ICOUNT=ICOUNT+1
IT=IT+1
ENDDO ! END OF WHILE LOOP
!-----------------------------------------------------------------
WRITE(*,*)'TOTAL NO. OF FUNCTION CALLS =',NFCALL
```

```
   CLOSE(15)
2  OPTVAL(IREP)=BESTVAL
   ! EXTIME(IREP)=NSEC
   EXTIME(IREP)=CPUT
   EXCYCLE(IREP)=CYCL
   DO JH=1,M
   TCUC(JH)=TCUC(JH)+CUCKOO(LOCU,JH)
   TCRO(JH)=TCRO(JH)+CROW(LOKR,JH)
   ENDDO
   ENDDO ! ENDS THE IREPEAT LOOP
   WRITE(*,*)'-----------------------------------------------------'
   ! MEAN VALUE OF COORDINATES
   DO JH=1,M
   TCUC(JH)=TCUC(JH)/NREP
   TCRO(JH)=TCRO(JH)/NREP
   ENDDO
   WRITE(*,*)' '
   WRITE(*,*)'OPT F =',(OPTVAL(I),I=1,NREP)
   WRITE(*,*)' '
   EXTM=0.D0
   EXTS=0.D0
   OPTM=0.D0
   OPTS=0.D0
   EXCYCM=0.D0
   EXCYCS=0.D0
   DO I=1,NREP
   OPTM=OPTM+OPTVAL(I)
   EXTM=EXTM+EXTIME(I)
   EXCYCM=EXCYCM+EXCYCLE(I)
   OPTS=OPTS+OPTVAL(I)**2
   EXTS=EXTS+EXTIME(I)**2
   EXCYCS=EXCYCS+EXCYCLE(I)**2
   ENDDO
   OPTM=OPTM/NREP
   EXTM=EXTM/NREP
   EXCYCM=EXCYCM/NREP
   OPTS=DSQRT(DABS(OPTS/NREP-OPTM**2))
   EXTS=DSQRT(DABS(EXTS/NREP-EXTM**2))
   EXCYCS=DSQRT(DABS(EXCYCS/NREP-EXCYCM**2))
   IF(OPTM.EQ.0.D0) THEN
   CV=OPTS/(1+OPTM)
   ELSE
   CV=OPTS/OPTM
   ENDIF
   WRITE(*,*) 'MEAN, SD & CV',OPTM,OPTS,CV
   WRITE(*,*) 'MEAN TIME & SD',EXTM,EXTS
   WRITE(*,*) 'MEAN GIGA CYCLES & SD',EXCYCM,EXCYCS
   CLOSE(15)

   DO J=1,M
   RBETA(J)=CUCKOO(LOCU,J)
   ENDDO
   ! CONSTRUCTING Y
   DO I=1,NOB1
   Y(I)=0.D0
   DO J=1,M
   Y(I)=Y(I)+X(I,J)*RBETA(J)
   ENDDO
   ENDDO

   CALL SHAPLEY(M,RBETA,FVAL)
   !WRITE(*,*)'PROGRAM ENDS. THANK YOU'
   RETURN
```

```
END

!------------------------------------------------------------------
SUBROUTINE NORMAL(R1,R2)
! PROGRAM TO GENERATE N(0,1) FROM RECTANGULAR RANDOM NUMBERS
! IT USES BOX-MULLER VARIATE TRANSFORMATION FOR THIS PURPOSE.
 !------------------------------------------------------------------
!----- BOX-MULLER METHOD BY GEP BOX AND ME MULLER (1958) ---------
! BOX, G. E. P. AND MULLER, M. E. "A NOTE ON THE GENERATION OF
! RANDOM NORMAL DEVIATES." ANN. MATH. STAT. 29, 610-611, 1958.
! IF U1 AND U2 ARE UNIFORMLY DISTRIBUTED RANDOM NUMBERS (0,1),
! THEN X=[(-2*LN(U1))**.5]*(COS(2*PI*U2) IS N(0,1)
! ALSO,  X=[(-2*LN(U1))**.5]*(SIN(2*PI*U2) IS N(0,1)
! PI = 4*ARCTAN(1.0)= 3.1415926535897932384626433832795
! 2*PI = 6.283185307179586476925286766559
!------------------------------------------------------------------
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON /RNDM/IU,IV
INTEGER IU,IV
!------------------------------------------------------------------
CALL RANDOM(RAND) ! INVOKES RANDOM TO GENERATE UNIFORM RAND [0, 1]
U1=RAND ! U1 IS UNIFORMLY DISTRIBUTED [0, 1]
CALL RANDOM(RAND) ! INVOKES RANDOM TO GENERATE UNIFORM RAND [0, 1]
U2=RAND ! U1 IS UNIFORMLY DISTRIBUTED [0, 1]
X=DSQRT(-2.D0*DLOG(U1))
R1=X*DCOS(U2*6.283185307179586476925286766559D00)
R2=X*DSIN(U2*6.283185307179586476925286766559D00)
RETURN
END
!------------------------------------------------------------------
! RANDOM NUMBER GENERATOR (UNIFORM BETWEEN 0 AND 1,BOTH EXCLUSIVE)
SUBROUTINE RANDOM(RAND)
 DOUBLE PRECISION  RAND
 COMMON /RNDM/IU,IV
INTEGER IU,IV
 RANDX=REAL(RAND)
 IV=IU*65539
 IF(IV.LT.0) THEN
 IV=IV+2147483647+1
 ENDIF
 RANDX=IV
 IU=IV
 RANDX=RANDX*0.4656613E-09
 RAND= RANDX
 RETURN
 END
!------------------------------------------------------------------
DOUBLE PRECISION FUNCTION LEVY(BETA)
!GENERATING LEVY FLIGHT
! REFERENCE: GUTOWSKI, M. (2001) "LEVY FLIGHTS AS AN UNDERLYING
! MECHANISM FOR GLOBAL OPTIMIZATION ALGORITHMS", [JUNE 2001].
! HTTP://ARXIV.ORG/ABS/MATH-PH/0106003V1.
DOUBLE PRECISION BETA, R
COMMON /RNDM/IU,IV
INTEGER IU,IV
CALL RANDOM(R)
LEVY = 1.0D0/R**(1.0D0/BETA) - 1.0D0
RETURN
END
!------------------------------------------------------------------
DOUBLE PRECISION FUNCTION CAUCHY(BETA)
! FOLDED CAUCHY DISTRIBUTION
DOUBLE PRECISION R1,R2,BETA
```

```
      COMMON /RNDM/IU,IV
      INTEGER IU,IV
1     CALL NORMAL(R1,R2)
      CAUCHY=DABS(R1/R2)
      IF(CAUCHY.GT.500) GOTO 1
      RETURN
      END
!-----------------------------------------------------------------
      SUBROUTINE SORT(X,F,N,M)
! ARRANGING F(I) IN ORDER
      PARAMETER(NMAX=1000,MMAX=100)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION F(NMAX),X(NMAX,MMAX)
      DO I=1,N-1
      DO II=I+1,N
      IF(F(I).GT.F(II)) THEN
      T=F(I)
      F(I)=F(II)
      F(II)=T
      DO J=1,M
      T=X(I,J)
      X(I,J)=X(II,J)
      X(II,J)=T
      ENDDO
      ENDIF
      ENDDO
      ENDDO
      RETURN
      END
!-----------------------------------------------------------------
      SUBROUTINE FINDBEST(F,N,BEST,LO)
! ARRANGING F(I) IN ORDER
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION F(*)
      BEST=F(1)
      LO=1
      DO I=1,N
      IF(F(I).LT.BEST) THEN
      BEST=F(I)
      LO=I
      ENDIF
      ENDDO
      RETURN
      END
! ----------------------------------------------------------------
      SUBROUTINE MEANSD(X,N,A,S,SKEW)
      PARAMETER(NMAX=1000,MMAX=200)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION X(*)
      A=0.D0
      S=0.D0
      DO I=1,N
      A=A+X(I)
      S=S+X(I)**2
      ENDDO
      S=DSQRT(DABS(N*S-A**2)/(N*N))
      A=A/N
      SKEW=0.D0
      IF(S.GT.0.0001) THEN
      DO I=1,N
      SKEW=SKEW+((X(I)-A)/S)**3
      ENDDO
      SKEW=N*SKEW/((N-1)*(N-2))
```

```
      ENDIF
      RETURN
      END
!-----------------------------------------------------------------
      SUBROUTINE FSELECT(KF,M,FTIT)
!THE PROGRAM REQUIRES INPUTS FROM THE USER ON THE FOLLOWING ------
!(1) FUNCTION CODE (KF), (2) NO. OF VARIABLES IN THE FUNCTION (M);
      CHARACTER *70 TIT(200),FTIT
      WRITE(*,*)'----------------------------------------------------'
      DATA TIT(1)/'KF=1 SHAPLEY VALUE REGRESSION M-VARIABLES M=?'/
!-----------------------------------------------------------------
!DO I=1,1
!WRITE(*,*) TIT(I)
!ENDDO
!WRITE(*,*)'----------------------------------------------------'
!WRITE(*,*)'FUNCTION CODE [KF] AND NO. OF VARIABLES [M] ?'
!READ(*,*) KF,M
      KF=1
      FTIT=TIT(KF) ! STORE THE NAME OF THE CHOSEN FUNCTION IN FTIT
      RETURN
      END
!-----------------------------------------------------------------
      SUBROUTINE FUNC(M,X,F)
!TEST FUNCTIONS FOR GLOBAL OPTIMIZATION PROGRAM
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON /RNDM/IU,IV
      COMMON /KFF/KF,NFCALL,FTIT
      INTEGER IU,IV
      DIMENSION X(*)
      CHARACTER *70 FTIT
      PI=4.D+00*DATAN(1.D+00)! DEFINING THE VALUE OF PI
      NFCALL=NFCALL+1 ! INCREMENT TO NUMBER OF FUNCTION CALLS
C     KF IS THE CODE OF THE TEST FUNCTION
C     -----------------------------------------------------------------
      IF(KF.EQ.1) THEN
      do j=1,m
      if(x(j).le.0) then
      call random(rand)
      x(j)=rand
      endif
      enddo
      CALL SHAPLEY(M,X,F)
      RETURN
      ENDIF
      RETURN
      END
!-----------------------------------------------------------------
      SUBROUTINE CALCBET(M,BETA,F)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      PARAMETER (MMAX=10)
      COMMON /HP/RMAT,RVECT,CONTRIB
      COMMON /RNDM/IU,IV
      COMMON /KFF/KF,NFCALL,FTIT
      CHARACTER *70 FTIT
      DIMENSION RMAT(MMAX,MMAX),RVECT(MMAX),CONTRIB(MMAX),T(MMAX)
      DIMENSION BETA(*)

      IF(NFCALL.EQ.1) THEN
      DO J=1,M
      BETA(J)= CONTRIB(J)/RVECT(J)
      ENDDO
      ENDIF
```

```
      DO J=1,M
      T(J)=0.D0
        DO JJ=1,M
        T(J)=T(J)+RMAT(J,JJ)*BETA(JJ)
        ENDDO
      ENDDO
      F=0.D0
      DO J=1,M
      F=F + (BETA(J)*(2.0D0*RVECT(J)-T(J))- CONTRIB(J))**2
      ENDDO
      f=f
      RETURN
      END
      ! ================================================================
          ! -----------------------------------------------------------------
      SUBROUTINE SHAPLEY(MVR,WEIGHT,FVAL)
      !SHAPLEY REGRESSION FOR MULTICOLLINEARITY
      PARAMETER (NMAX=500,MMAX=10, NOSKIP=1)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION X(NMAX,MMAX),Y(NMAX),XX(MMAX,MMAX),XY(MMAX),B(MMAX)
      DIMENSION VX(MMAX,MMAX),VY(MMAX),YH(NMAX),CONTRIB(MMAX),Z(NMAX)
      DIMENSION ARRAY(MMAX),BARRAY(MMAX),RMAT(MMAX,MMAX),RVECT(MMAX)
      DIMENSION BETA(MMAX),AVX(MMAX),SDX(MMAX),WEIGHT(MMAX)
      COMMON /HP/RMAT,RVECT,CONTRIB
      CHARACTER *70 INFIL,OFIL,OUTFIL,FINRES
      COMMON /DAT/X,Y
      COMMON /IOFIL/INFIL,OFIL,OUTFIL,FINRES
      COMMON /PARAM/NOB,MVAR
      COMMON /REGPAR/COEFF(MMAX),FR
      COMMON /RNDM/IU,IV
      ! ------------------- FORMATS -----------------------------------
    1  FORMAT(8F10.2)
    2  FORMAT(2I3,4F5.0,2X,F12.9)! BETTER TO MAKE IT RUN-TIME FORMAT
    3  FORMAT(40X,2I3,4F5.0,2X,F12.9)! BETTER TO MAKE IT RUN-TIME FORMAT
    4  FORMAT('REGRESSOR #',I2,' SHARED R_SQR =',F18.15,' [',F7.4,' %]')
    5  FORMAT(5(F15.10,','))
      ! MAKE DEVIATED FROM THE RESPECTIVE MEAN
      N=NOB
      M=MVR

      IF(NOSKIP.NE.0) THEN
      DO J=1,M
      IF(WEIGHT(J).LE.0.D0) THEN
      CALL RANDOM(RAND)
      WEIGHT(J)=RAND
      ENDIF
      ENDDO
      ENDIF

      DO I=1,N
      Y(I)=0
      SW=0
      DO J=1,M
      Y(I)=Y(I)+X(I,J)*WEIGHT(J)
      SW=SW+WEIGHT(J)
      ENDDO
      Y(I)=(Y(I)/(SW/M))
      ENDDO

      DO J=1,M
      AM=0.D0 ! MEAN
      SD=0.D0 ! STANDARD DEVIATION
      DO I=1,N
```

```
AM=AM+X(I,J)
SD = SD + X(I,J)**2
ENDDO
AM=AM/N
SD = SQRT(SD/N - AM**2)
AVX(J)=AM
SDX(J)=SD
DO I=1,N
!X(I,J)=(X(I,J)-AM)/SD
ENDDO
ENDDO

AM=0.D0 ! MEAN
SD=0.D0 ! STANDARD DEVIATION
DO I=1,N
AM=AM+Y(I)
SD=SD+Y(I)**2
ENDDO
AM=AM/N
AMY=AM
SD = SQRT(SD/N - AM**2)
SDY=SD
DO I=1,N
Y(I)=(Y(I)-AM)/SD
ENDDO
! -----------------   PRINT DATA Y AND X  ----------------------
! DO I=1,N
! WRITE(*,*) Y(I),(X(I,J), J=1,M)
! ENDDO
! ----------------------------------------------------------------
! MAKE VARIANCE-COVARIANCE MATRIX
DO J=1,M
XY(J)=0.D0 ! COVARIANCE VECTOR OF Y WITH X
DO JJ=1,M  ! VAIANCE-COVARIANCE MATRIX OF X WITH ITSELF
XX(J,JJ)=0.D0
DO I=1,N
XX(J,JJ)=XX(J,JJ)+ X(I,J)*X(I,JJ)
ENDDO
XX(J,JJ)=XX(J,JJ)/N
ENDDO
DO I=1,N
XY(J)=XY(J)+X(I,J)*Y(I)
ENDDO
XY(J)=XY(J)/N
ENDDO
! -------------------PRINT VARIANCE COVARIANCE MATRIX ----------
!WRITE(*,*) 'VARIANCE COVARIANCE MATRIX'
!DO I=1,M
!WRITE(*,1) XY(I),(XX(I,J),J=1,M)
!ENDDO
!WRITE(*,*)'======================================================'
! STORE XX IN V
! CONSTRUCT CORREL MATRIX (RMAT:XX) AND CORREL VECTOR (RVAT: YX)
DO J=1,M
 DO I=1,N
 YH(I)=X(I,J)
 ENDDO
CALL RSQUARE(Y,YH,N,RM,RSQ)
RVECT(J)=RM
 DO JJ=1,M
   DO I=1,N
   Z(I)=X(I,JJ)
   ENDDO
```

```
 CALL RSQUARE(Z,YH,N,RM,RSQ)
 RMAT(J,JJ)=RM
 ENDDO
ENDDO
! CORRELATION MATRIX AND VECTOR
!WRITE(*,*)'CORRELATION MATRIX AND VECTOR'
DO J=1,M
! WRITE(*,5)(RMAT(J,JJ),JJ=1,M),RVECT(J)
ENDDO
!PAUSE
DO I=1,M
BARRAY(I)=0.D0 ! INTERMEDIATE VARIABLE FOR INTERNAL PURPOSES
ENDDO
OPEN(14,FILE=OUTFIL)! STORES ALL COMBINATIONS WITH R SQUARE
NSL=0
DO IX=1,M
KX=M-IX+1
NCOMB=NCR(M,KX)! NO. OF COMBINATION NCR
CALL COMBIN(M,KX,OFIL)
OPEN(7,FILE=OFIL) ! CONTAINS COMBINATIONS
DO I=1,NCOMB
READ(7,*)(ARRAY(J),J=1,KX)! COMBINATION ARRAY
CALL REGRESS(XX,XY,ARRAY,RSQ,N,KX)! CALLS ORDINARY LEAST SQUARES
NSL=NSL+1
WRITE(14,*)NSL,KX,(ARRAY(J),J=1,KX),RSQ !STORES REGRESSION RESULTS
!WRITE(*,*)'R-SQUARE=',RSQ
ENDDO
CLOSE(7)
! WRITE(*,*)'----------------------------------------------------'
ENDDO
CLOSE(14)
! MAKE TABLES
!WRITE(*,*)'////////////////// CHECKING //////////////////////////'
OPEN(14,FILE=OUTFIL)
NCOMBTOT=0
DO IX=1,M
KX=M-IX+1
MKX=M-KX
NCOMB=NCR(M,KX)
DO I=1,NCOMB
READ(14,*)NSL,KKX,(ARRAY(J),J=1,KX),RSQ
!WRITE(*,2)NSL,KKX,(ARRAY(J),J=1,KX),(BARRAY(J),J=1,MKX),RSQ
IF(KX.NE.KKX) THEN
!WRITE(*,*)'KKX AND KX ARE NOT EQUAL ',KX,KKX
!PAUSE
ENDIF
NCOMBTOT=NCOMBTOT+1 !TOTAL NO. OF REGRESSION
!PAUSE
ENDDO
ENDDO
CLOSE(14)
!PAUSE
!WRITE(*,*)'[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[['
!WRITE(*,*) 'TOTAL NO. OF REGRESSION =', NCOMBTOT
OPEN(14,FILE=OUTFIL)
TSUMSRQ=0.D0
DO KC=1,M
!WRITE(*,*)'FEED KC (DESIRED VARIABLE)'
!READ(*,*) KC
SUMSRQ=0
DO KPP=1,M
NTR1=0
NTR0=0
```

```
KP=M-KPP+1
! WRITE(*,*)'------- COMBINATION=',KP,' -------------------------'
KR=KP-1
! ----------------------------------------------------------------
SRSQ=0.D0
OPEN(14,FILE=OUTFIL)
DO I=1,NCOMBTOT
READ(14,*)SL,KX,(ARRAY(J),J=1,KX),RSQ
NT=0
DO J=1,KX
IF(KX.EQ.KP.AND.ARRAY(J).EQ.KC) THEN
NT=NT+1
! WRITE(*,*) '(',KX,(ARRAY(JJ),JJ=1,KX),RSQ,').(+)'
ENDIF
ENDDO
IF(NT.NE.0)THEN
! WRITE(*,*) '(',KX,(ARRAY(JJ),JJ=1,KX),RSQ,').(+)'
NTR1=NTR1+1
SRSQ = SRSQ + RSQ ! RSQ TO BE ADDED
ENDIF
NT=0
DO J=1,KX
IF(KX.EQ.KR.AND.ARRAY(J).NE.KC)THEN
NT=NT+1
! WRITE(*,*) '[',KX,(ARRAY(JJ),JJ=1,KX),RSQ,'].(-)'
ENDIF
ENDDO
IF(NT.EQ.KX)THEN
! WRITE(*,*) '[',KX,(ARRAY(JJ),JJ=1,KX),RSQ,'].(-)'
NTR0=NTR0+1
SRSQ = SRSQ - RSQ ! RSQ TO BE SUBTRACTED
ENDIF
ENDDO
CLOSE(14)

!WRITE(*,*)'NTR1 & NTR0,SRSQ,MEAN_SRSQ:',NTR1,NTR0,SRSQ,SRSQ/NTR1
SUMSRQ = SUMSRQ + SRSQ/NTR1
ENDDO ! FOR KPP
! WRITE(*,*)'SUM OF PROPERLY SIGNED RSQ & MEAN =',SUMSRQ,SUMSRQ/M
! ----------------------------------------------------------------
CONTRIB(KC) = SUMSRQ/M
TSUMSRQ = TSUMSRQ + SUMSRQ/M
ENDDO ! FOR KC
!WRITE(9,*)' '
!WRITE(9,*)'  -------- FINAL RESULTS OF SHAPLEY REGRESSION ------'
!WRITE(9,*)' CONTRIBUTION OF EACH INDIVIDUAL VARIABLE TO R_SQUARE'
!DO J=1,M
!WRITE(9,4) J,CONTRIB(J), (CONTRIB(J)/TSUMSRQ)*100
!ENDDO
!WRITE(9,*)' '
!WRITE(9,*)'TOTAL(JOINT) CONTRIBUTION R_SQ=F(X1,...,XM)=',TSUMSRQ
!WRITE(9,*)'NOTE: TOTAL CONTRIBUTION SUMS UP TO 100 PERCENT.'
CALL CALCBET(M,COEFF,FR)
!-----------------------------------------------------------------
FVAL=0.d0
!FVAL=CONTRIB(1)
DO J=1,M
!if(contrib(j).gt.fval) fval=contrib(j)!
FVAL=FVAL+abs(CONTRIB(J))**2
ENDDO
!FVAL=SQRT(FVAL)
fval=fval
!-----------------------------------------------------------------
```

```
RETURN
END
```