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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.
Keywords. Globalization, KOF index, Equi-marginal, Shapley value, Global optimization, China, India, Pakistan.
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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 & 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,

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many attempts have been made to measure the degree of globalization attained by different national economies. Andersen & Herbertsson (2005), Bhandari & 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 & 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 county-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=0.1704412)*

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	0.191947	0.126652	0.166496	0.201982	0.162737	0.150186
Weights of Sub-Indices for AEMC	0.138495	8.320873	8.148497	0.004086	3.452822	6.558127

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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	23.1736	38.5308	1992	39.61238	32.51066	43.16104
1971	18.49967	23.40904	38.16277	1993	40.77847	33.75316	43.38824
1972	19.41778	23.55155	38.27597	1994	41.34282	34.22974	42.59611
1973	20.10568	23.82373	38.37256	1995	42.33692	35.65223	41.95254
1974	20.60173	23.84540	38.41684	1996	42.65672	38.73829	42.54344
1975	20.82098	24.06422	38.18951	1997	44.14432	38.96795	43.00296
1976	20.96350	24.19693	38.12749	1998	48.33121	38.80650	45.85595
1977	21.25949	24.42602	38.77984	1999	48.87413	39.43394	46.35011
1978	21.33348	24.45398	38.62751	2000	50.29164	39.62388	48.98676
1979	21.19224	24.40394	38.28622	2001	57.76814	41.36842	52.11840
1980	21.33433	24.10631	38.01920	2002	52.99276	42.09173	59.01162
1981	24.26965	24.17732	37.52796	2003	54.18664	43.67633	52.79210
1982	24.58316	24.08245	37.30392	2004	60.39306	43.55735	52.94220
1983	25.06792	24.55408	37.58402	2005	63.04556	47.28149	53.73292
1984	25.27074	24.63272	37.81090	2006	58.43749	45.82832	51.59737
1985	25.90799	24.78942	37.44961	2007	61.67802	47.27128	51.43184
1986	28.16528	24.50626	36.97970	2008	60.32243	46.45579	51.27809
1987	28.36872	24.08954	36.79565	2009	61.30596	46.25534	54.83471
1988	29.11452	27.96263	36.78416	2010	60.08371	45.50034	54.06180
1989	29.51806	27.10282	41.10131	2011	57.65293	45.97559	51.00433
1990	37.55462	27.02449	41.03750	2012	58.65936	45.76340	53.55683
1991	39.07504	30.65273	41.92938	2013	59.63641	44.38698	54.75860

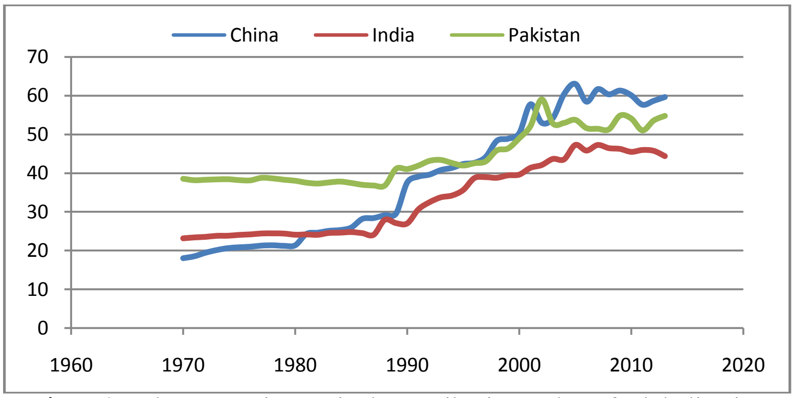

Figure1. *Almost Equi-Marginal Contribution Index of Globalization China, India and Pakistan*

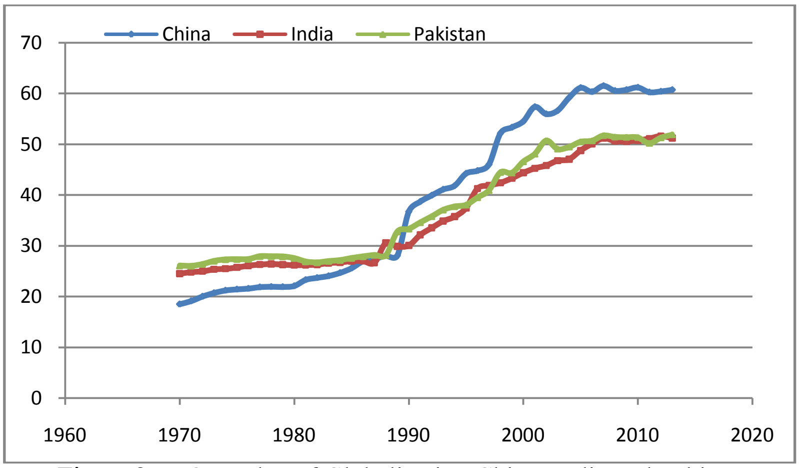

Figure 2. *KOF Index of Globalization China, India and Pakistan*

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 (0.92473). 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 cf. Table-1), which is theoretically implausible. This is improved to 0.30136 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 0.30136. 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	0.86428
A2	0.80750	1.00000	-0.34062	0.86697	0.83436	0.32923	0.76018	0.67701
B1	-0.06743	-0.34062	1.00000	-0.15810	-0.19320	0.01921	-0.05253	0.30136
B2	0.90919	0.86697	-0.15810	1.00000	0.93946	0.67391	0.95918	0.86799
B3	0.84626	0.83436	-0.19320	0.93946	1.00000	0.58541	0.90612	0.80865
C	0.67499	0.32923	0.01921	0.67391	0.58541	1.00000	0.83217	0.73212
KOF	0.92807	0.76018	-0.05253	0.95918	0.90612	0.83217	1.00000	0.92473
AEMC	0.86428	0.67701	0.30136	0.86799	0.80865	0.73212	0.92473	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 & 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 & 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. 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.

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

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

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
```

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