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RESEARCH ARTICLE

MIGRATION MODELS AND ITS APPLICATIONS

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ABSTRACT

The phenomenon of migration is known for its multidisciplinary nature and complexities. Here attempt is made to formulate migration model using the concept of physics like Newton's gravitational law and other laws, involving sophisticated mathematical and statistical tools which will be used later for studying the determinants of interstate migration in India during 1981-1991 and 1991-2001. National census data are the main data available for study of migration. Transition probabilities of interstate migration for fourteen major states in India during 1981-1991 and 1991-2001 have been estimated. According to probabilities highest inmigrants received states are Maharashtra, Madhya Pradesh, Karnataka Rajasthan and U.P.

INTRODUCTION

In view of the increased interest in scientific analysis in several fields of social sciences, the use of models has been extended to study the phenomenon of social sciences. Among these, the phenomenon of migration is also one, which is known for its multidisciplinary nature and complexities, several researchers have tried for formulate models using the concept of physics like Newtonian gravitational law (Zipf, 1946), laws of thermodynamics and the concept of entropy involving sophisticated mathematical and statistical tools.

Models can be constructed either by defining the process in mathematical terms such as equations, derivatives etc., will be called Mathematical models or by using certain empirical observations these will be called numerical models. In the field of social sciences, including migration, it is not an easy task to formulate a model to exactly reproduce the observed real situations, because of the difficulties in quantifying the social factors affecting the phenomenon under study. Also due to the interrelationships among the several socio-economic variables the analysis of the models becomes more problematic as compared to the models in physical sciences. (Sivamurthy, 1983).

The Study of migration models is increasing consistently, because of the increasing tendencies of population movements and importance of migration in national economics and population policies. Further, the availability of modern computer facilities and successive efforts in collecting and improving the quality of the data on migration by several agencies throughout the world has accelerated the studies on migration. In this paper the main concern will be to discuss the various models on migration and to formulate comprehensive models which will be used later for studying the determinants of interstate migration in India during 1981-91 and 1991-2001.

Migration Models

The literature on migration models and their use is now quite large and is spread over several fields of social sciences, which makes it difficult for the reviewers to cover the literature comprehensively. However some statisticians, mathematicians, sociologist and others like Ter Heide, 1963; Vaidyanthan, 1971, Ginsberg, 1971, Speare, 1974, Masser and Gould, 1975, Madagi, 1994. Have attempted to review the literature on migration models, and in the present study gives a brief summary of these reviewers and also other studies in this area.
The mathematical and numerical model can be classified as deterministic and stochastic models (Sivamurthy, 1983). Further the deterministic models of migration (Vaidyanthan,, 1971, Speare, 1974) can be reclassified as, (1) Gravity Models (2) Cost-Benefit and optimum location models and (3) Stress and Awareness models.

Using Newtonian gravitational law several models are formulated for studying the determinants of migration as well as for estimating migration flows between origin and destination places using marginal totals of migrants (Wilson,

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1970). The cost benefit models are formulated on the assumption that a person is more likely to move, if the present value of all the future monetary benefits (costs) in moving is greater than the monetary cost of moving (Sjaastod, 1962). Whereas the stress and awareness models (Simon, 1957) are formulated on the assumption that migration is an individual decision making process, which is the result of a response to a stress of a particular situation and rational action of an individual. The detailed discussions of these models are available in several reviews of literature (Ter Heide-1963; Vaidyanthan, 1971; Speare, 1974; Masser and Gould, 1975). However Speare (1974) has concluded that "The theories which tried to find a general understanding of mobility do not specify a model for use in empirical studies". Also Tobler (1975) remarks that "The literature on migration study is rather disappointing and frustrating, most of the models are of the push- pull economic motivation types and are stated in the form of single equation in which the migration is the dependent variable. In practice a wide variety of particular equations is used, all of which tend to be judged statistically significant for highly particular sets of data. The reader comes away from this literature without clear ideas of the process underlying human migrations and without a clear statement of variables amenable to control by policy instruments.

In spite of these criticisms, the study on migration plays an important role for the better understanding of the relative factors in brief. obiviously in this study much importance is given to the same which helps to know the determinants of migration.

Models used to study determinants of migration: an elaboration of gravity models

The use of gravity models in the study of migration constrained by the quality and quantity of data available. The information available from National census is the main source of data for the study of migration. Among the various migration models as mentioned earlier, of which gravity models are more widely spread in the literature because, these models explicitly deal with spatial questions, and it is easy to assess the strength and weakness of the models through empirical analysis (Masser and Gould, 1975). Also, it may be due to the simplicity of these models and that these apply match with census data on migration. It may be better to clarify at this stage that most of the spatial interaction models (Masser and Gould, 1975) and the regression models (Ginsberg, 1971) belongs to the family of gravity models (Tobler, 1976-1977; Fotheringham, 1983), because a gravity model is defined as "Any aggregate spatial interaction volume is a function of three variables; nodal propulsiveness; nodal attractiveness and cost of overcoming the spatial separation of nodes" (Fotheringham, 1983). Starting from a simple gravity model (Zipf, 1946), which uses the size of the population as origin and destination characteristics, and distance as intervening obstacles, several gravity models are formulated taking the socio-economic demographic and geographic factors as origin and destination characteristics and choosing them according to the suitability of study area following the push-pull hypothesis (Lee, 1966). These models have been used for studying determinants of migration in different part of the world. Among them the models which are used in the third world countries are well summarised by Masser and Gould (1975) some of the studies have also noticed the limitations of gravity models (Linsberg, 1971; Speare, 1974; Tobler, 1976, 1977; Fotheringham, 1983). Among which the major one is that most of the regression models are formulated without considering the "competitive term" (Linsberg, 1971) i.e., the variable which indicates competition among out-migrant's from a certain origin for the destination places, and also competition among destination for the migrants following this, Fotheringham (1983) strongly points out that, gravity models are miss-specified , Since they do not included the variable which explicitly measures the interaction between origin and destination places and the competition between destinations, Also most of the models are formulated without taking into account the residential satisfaction of persons which was found to be important variable, distinguishing whether or not a person considered moving (Spare, 1974). Some of the gravity models, e.g. Zipf model (1946), have also been criticised for their symmetrical nature (Tobler, 1976, 1977).

In Indian context, only few studies at the national level which have used migration models for studying determinants of migration. The one, which is based on 1961 census data, utilizes the spatial interaction model (Greenwood, 1971). Concludes that distance and urbanisation in the destination state are important determinants of migration. The specification and use of this model hampered due to many of the limitations stated above. Following Stouffer's principle of intervening opportunities (Rao, 1973). Formulated a model and analysed using national sample survey data on migration but this model does not fit well in the Indian context.

Study of determinants of rural-rural, rural-urban and urban-urban migration during the period 1961-1971 (Sivamurthy and Kadi, 1983, 1985) using deterministic models. This model is formulated on the lines of gravity models incorporating a selected socio-economic factor which appears to be important in the Indian Context. In addition to several variables used in the models as origin and destination characteristics and intervening obstacles, a new variable " Stayers" that is the number of "Stayers" among the past migrants(S_{ij}) at the destination used as proxy to represent the spatial correlation among the destinations. This affects the accessibility of a certain destination to the out-migrants from certain origin. This variable seems to satisfy the Nelsons (1959) and Greenwoods (1969) arguments that, the "stayers" among the past migrants would consist of friends and relatives at destinations makes that destination more attractive to the current migrants in the relation to others and that, it is unlikely that the migrants choose their destinations either randomly or with full comparative knowledge of the opportunities available in the different destinations.

The use of the variables "stayers" is seem to be a better substitute to the Greenwoods variable "Migrants Stock" (MS_{ij}) That is " past migrants" in the Indian context where, we found significant proportion of interstate return migration among past migrants (Sivamurthy and Kadi, 1984b). Also it has been shown using greenwood lag argument that, the variable "stayers" is a function of the past values of other variables used in the model. The result shows that the inclusion of the variables "stayers" helps to explain more than 80 percent of variation in the migration volumes (Kadi, 1984; Madagi, 1994). In fact this variable itself explains as much as 81 percent of rural-rural flow, 78 percent of rural-urban flow and 84 percent of urban-urban flow migration. It is also seen that the same conditions which could have influenced the past flow of migration from one state to another seems to affect the current flow of migration. The application of reformulated Singh and Yadav model on migration (Singh and Yadav, 1978 and 1979, Sivamurthy and Kadi, 1984a) also support the above contention. Further several studies on migration in different parts of world (Green wood 1969, 1970 and 1981: King 1978, Kim1979, Kadi and Sivamurthy, 1988; Kadi and Madagi, 1994) using migration module have also arrived at the same conclusion that the past migrants playan important role in determining current flow of migration. Hence an attempt is made in the next section to use the variable "stayers" as a single variable to estimate the current flow of migration as well as non-migrants in the population.

Formulation of the model

Earlier several studies have made an attempt to formulate a model to estimate migration flows between origin and destination places most of them are found to be of stochastic version (Goodman, 1961; Musham, 1961; Jaeuber, 1961; McGinnis *et al*., 1963; Roger, 1968; Mayers *et al*., -1982; Isserman *et al*., 1985). Among these, some have based on the axiom of stationary probability, that is the probability that an individual from state i at time t will move to state j at time (t+1) is the same as the probability of transition from i to j between times t_n and t_{n+1} for all n=0, 1, 2.... But the application of this model gives poor explanation of the mobility process (Blumen *et al*., 1955).

Following the identification of "Movers" and "stayers" dichotomy (Goldstein -1958,1964:Goodman-1961) i.e. movers are less permanently attached to a given state than stayers, McGinnis and others (1963) have modified the stationary probability model by making use of the axiom of cumulative inertia, the probability of moving from a certain place decreases as the duration of stay at that place increases. This model is further improved (Mayers *et al*., 1982) by breaking the transition matrix into sub matrices with respect to duration of residence. The application of these (Jaeuber, 1961, Mayers *et al*., 1982) on the United States data shown an improvement over the stationery probability model.

Further, Isserman and others (1985) have criticised the Demographic models of migration, which are based only on past history of migration probabilities and proposed a new model called Demo-Economic model of migration. The main criticism is that, the migration probabilities P_{ij}'s are not subjected to the change over time and also not with respect to the changes in the economic conditions at the i^{th} and j^{th} states and other destination states, hence the use of these models serves little in estimating and forecasting migration flows. In the proposed Demo-Economic model, the traditional constant migration probabilities are replaced by dynamic migration probabilities that are subjected to change with respect to the changes in the economic conditions. They have used changes in employment conditions as a proxy to the changes in economic conditions. The use of this model on United States data has shown 20 percent decrease in the total error in forecasting net migration by state as compared to standard demographic projections. Further the model is useful to forecast non-movers also. In less developed countries, the use of stochastic models for estimating and forecasting migration flows are found to be very few. Non availability of suitable data is the main constraint for this. In Indian context (Nair, 1985a ; 1985b) estimated period of migration flows using Bi-proportional adjustment algorithm (Leontief, 1941; Stone, 1962; Willekens, 1981) and draws the same criticisms observed in the case of models containing stationary migration probabilities.

In this section, main concern is to formulate stochastic model to estimate migration flows between the states in India using the limited available data from the census 1981-1991 and 1991-2001. The proposed model is too modified from the Isserman *et el* (1985). According to them, the migration flows between origin (i) and destination (j) is given by

$$Pij(t) = \frac{Mij(t)}{Pi(t-1)} = \frac{Mij(b)}{\sum_k Mik(b)} \frac{\left[\frac{Aj(t-1)}{Aj(b-1)}\right]^r}{\left[\frac{Ak(t-1)}{Ak(b-1)}\right]^r} \qquad \text{.......... (1)}$$

Where,

P_{ij} (t) = Migration probabilities between state i and state j during the Period (t-1, t).

M_{ij} (t) = Number of persons moved from state i to state j duringthe period (t-1, t).

P_i (t-1) = Population in state i that survive to year t.

$= \sum M_{ik}(t)$ k= 1, 2, 3..........n

A_j (t-1) = Attractive Index of state j at time (t-1).

A_k (b-1) = Attractive Index of state k in the base year (b-1).

"r" is the elasticity, measuring the percentage change in the migration probabilities for each percentage change in j , s relative attractiveness, while applying this model for forecasting migration flows in the context of united sates, they defined loosely "A" as "Economic attractiveness" and used change in the employment index as a proxy to this. Probably non-availability of other related, suitable data on socio-economic factors and difficulty in constructing composite index of attractiveness might have forced to define loosely "A" as economic attractiveness. This limitation can be overcome by replacing A_j (t-1) by S_j (t) that is total number of stayers among past migrants at the destination state j during the period of current flows. This determines the current flow of migration (Sivamurthy and Kadi, 1983; 1985). It has been shown that size of S_j (t) is determined by the socio-economic and geographic factors prevailing at the destination state j during the period of current flow of migration and hence, it serves as a better composite index of attractiveness. Introducing this place of "A" in model 1, we have

$$Pij(t) = \frac{Mij(t)}{Pi.(t-1)} = \frac{Mij(b)}{\sum_k Mik(b)} \frac{\left[\frac{S.j(t)}{Sj(b)}\right]^r}{\left[\frac{S.k(t)}{Sk(b)}\right]^r} \qquad \text{...... (2)}$$

Where k= 1, 2, 3..........n

Model 2 gives change in every migration probabilities with change in the attractiveness of any one region. Following Isserman and others (1985). "r" can be estimated by using two sets of migration matrices or it can be chosen in such a way that the root means square between estimated and observed transition probabilities is minimum. Migration probabilities at time t and b are same, if there is no change in the attractiveness of the regions or if migration is not affected by the attractiveness of region (i.e. r = 0).

M_{ij} (t)- Number of persons moved from state i to state j during the period 1991- 2001.

M_{ij} (b)-Number of persons moved from state i to state j during the period 1981- 1991.

$M_{i.}$ (t-1)-Number of persons moved out from state i to other

Table 1 Migration Probabilties 1981-1991

STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
1	-	0.0059	0.0254	0.0041	0.4034	0.0127	0.0527	0.2469	0.0871	0.0033	0.0089	0.1262	0.0097	0.0139	1.00
2	0.006	-	0.0158	0.0306	0.0047	0.0021	0.198	0.0326	0.0738	0.0513	0.0185	0.0026	0.1823	0.3817	1.00
3	0.0168	0.0046	-	0.0067	0.021	0.0088	0.0794	0.6373	0.0064	0.0072	0.1704	0.0103	0.022	0.009	1.00
4	0.0044	0.0043	0.0142	-	0.0034	0.0012	0.0695	0.018	0.0045	0.3912	0.3272	0.0014	0.152	0.0085	1.00
5	0.1771	0.0015	0.0145	0.0024	-	0.1089	0.0074	0.5694	0.002	0.0024	0.0094	0.0965	0.0058	0.0025	1.00
6	0.0423	0.0078	0.0489	0.009	0.25	-	0.0533	0.2099	0.0087	0.0043	0.022	0.317	0.0177	0.0091	1.00
7	0.0124	0.0204	0.0723	0.0189	0.0057	0.0053	-	0.3421	0.0832	0.0191	0.1949	0.0034	0.2078	0.0146	1.00
8	0.1034	0.0033	0.3592	0.0071	0.168	0.0252	0.2087	-	0.0037	0.011	0.0382	0.0273	0.0368	0.0081	1.00
9	0.1524	0.0958	0.0544	0.0073	0.0131	0.0058	0.3457	0.045	-	0.0122	0.0144	0.0052	0.0213	0.225	1.00
10	0.0083	0.014	0.0174	0.4282	0.0067	0.0041	0.05	0.0525	0.0062	-	0.2209	0.0042	0.1685	0.019	1.00
11	0.0137	0.0071	0.238	0.2272	0.0194	0.0023	0.1875	0.0914	0.005	0.0968	-	0.0124	0.0787	0.0205	1.00
12	0.1629	0.0041	0.0248	0.0033	0.3632	0.2699	0.0167	0.1222	0.0048	0.0032	0.0096	-	0.0081	0.0072	1.00
13	0.0058	0.0441	0.0696	0.1536	0.0063	0.0017	0.198	0.2491	0.0056	0.1165	0.0922	0.0025	-	0.0551	1.00
14	0.0336	0.3125	0.0319	0.0219	0.0154	0.0071	0.0884	0.0808	0.149	0.0283	0.0868	0.0167	0.1275	-	1.00

Table 2 Migration Probabilties 1991-2001

State	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1	-	0.0102	0.0316	0.0055	0.3818	0.0137	0.0521	0.2446	0.0759	0.0064	0.0132	0.1328	0.0167	0.0156	1.00
2	0.0146	-	0.027	0.0427	0.0082	0.002	0.0979	0.0599	0.0601	0.0617	0.0257	0.0038	0.2122	0.3832	1.00
3	0.0212	0.0084	-	0.0066	0.0265	0.0087	0.0916	0.605	0.0078	0.0092	0.1625	0.0145	0.026	0.0121	1.00
4	0.0075	0.0238	0.0194	-	0.0076	0.002	0.0269	0.0298	0.0032	0.3479	0.3661	0.0032	0.1529	0.0097	1.00
5	0.1511	0.0027	0.0174	0.0029	-	0.0636	0.0107	0.6233	0.0028	0.0032	0.0086	0.101	0.009	0.0038	1.00
6	0.0586	0.0097	0.0542	0.0119	0.2345	-	0.0535	0.1969	0.0087	0.0094	0.0224	0.3084	0.023	0.0089	1.00
7	0.0237	0.0326	0.0722	0.0136	0.0071	0.0064	-	0.2977	0.0597	0.0164	0.1988	0.0055	0.2501	0.0161	1.00
8	0.0638	0.004	0.3517	0.0081	0.1827	0.0246	0.2505	-	0.0046	0.0118	0.0294	0.0234	0.0359	0.0095	1.00
9	0.1513	0.0827	0.09	0.0074	0.0101	0.0041	0.2366	0.2161	-	0.0119	0.012	0.0071	0.0258	0.145	1.00
10	0.0127	0.0188	0.0254	0.4466	0.0145	0.0042	0.0515	0.0613	0.0054	-	0.1884	0.008	0.1387	0.0245	1.00
11	0.0237	0.0101	0.2152	0.2078	0.0273	0.0034	0.1822	0.128	0.0039	0.0748	-	0.0181	0.0867	0.0188	1.00
12	0.1858	0.0046	0.0211	0.0033	0.3542	0.2429	0.0166	0.1267	0.005	0.0058	0.0107	-	0.0129	0.0048	1.00
13	0.0106	0.0531	0.0731	0.1402	0.0082	0.0019	0.2047	0.2734	0.0049	0.0945	0.0884	0.0041	-	0.0429	1.00
14	0.0385	0.3894	0.0419	0.0211	0.0175	0.0067	0.0816	0.0938	0.1072	0.0274	0.0329	0.0157	0.1264	-	1.00

Note: 1.Andrapradesh 2 Bihar 3. Gujarat 4.Harayana 5. Karnataka 6. Kerala 7. Madhya Pradesh 8. Maharashtra 9. Orissa 10. Punjab 11. Rajasthan 12.TamilNadu 13. Uttar Pradesh 14.West Bengal

Table 3 interstate inmigration, outmigration and netmigration 1981-91, 1991-2001

	1981-1991			1991-2001		
States	**Inmigration**	**Outmigration**	**Netmigration**	**Inmigration**	**Outmigration**	**Netmigration**
1	364238	462040	-97802	439613	585793	-146180
2	239491	951822	-712332	396708	1327073	-930365
3	664935	278518	386417	848813	403490	445333
4	597535	335653	261882	761051	347018	414033
5	656170	525888	130282	734742	691973	42769
6	250260	391953	-141693	229153	368288	-139135
7	1013030	544583	468447	1226894	687561	539333
8	1478813	707347	771466	2169958	776861	1393097
9	236100	249731	-13631	246035	311823	-65788
10	469061	322706	146355	553412	305548	247864
11	583358	664177	-80819	709716	864282	-154566
12	281085	563294	-282209	332554	549604	-217050
13	546217	1588457	-1042240	758481	2471781	-1713300
14	561795	355769	206026	730535	446571	283964

Application of the model

For the convenient sake, model 2 is employed here, to estimate migration flows between fourteen major states in India during the period 1981 – 1991 and 1991 – 2001. The following modification in the model 2 has been done as follows

$$Pij(t) = \frac{Mij(t)}{Mi.(t-1)} = \frac{Mij(b)\ \left[\frac{S.j(t)}{Sj(b)}\right]^{r}}{\sum_k Mik(b)\ \left[\frac{S.k(t)}{Sk(b)}\right]^{r}} \quad \text{..................} \qquad (3)$$

i≠j and i≠k, i , k= 1, 2, 3..........n.

$S._j$ (t)-Total Number of Migrants at destination j with duration of stay (10+) years in the 2001 census, (stayers among past migrants).

S_j (b) - Total Number of Migrants at destination j with duration of stay (10+) years in the 1991 census.

Model gives change in every migration probabilities with change in the attractiveness of any one region.

CONCLUSION

The estimated probabilities are then applied on total out migration volumes during 1991- 2001 of each fourteen major states, under study to obtain flow matrix. From this flow matrix volume of in migration during 1991-2001 decade to each state is estimated. The volumes of in migration, outmigration and net migration during the period 1991-2001 along with corresponding observed figures of 1981-1991 are given in Table 3. Comparing 1981-1991 and 1991-2001 results, it has been observed that during 1991-2001 the states Uttar Pradesh , Bihar, Rajasthan and Maharashtra are continued to occupy the first , second , third and fourth places among out migrants states as observed in 1981-1991 period and the least out migrants is observed in Orissa and Punjab during 1981-1991 and 1991-2001 periods respectively. Whereas the states Maharashtra , Madhya Pradesh, Gujarat, Karnataka, Haryana , West Bengal and Rajasthan occupied first , second ,third, fourth, fifth ,sixth and seventh places among inmigrants states during 1981-1991 period while 1991-2001 fourth place occupied by Haryana in place of Karnataka rest all states continues with the same place. The volume of in migration to Maharashtra, Madhya Pradesh, Gujarat and Karnataka substantially higher as compared to other in migrants states which can be explained in terms of their development due to urbanization and industrialization etc. States like Uttar Pradesh, Andhra Pradesh, Bihar , Tamil Nadu , Kerala , Rajasthan and Orissa losing population through inmigration during 1981-1991 and 1991-2001 periods. The causes of outmigration would be lack of industrialization, poor agricultural development, natural calamities etc.

Transition probabilities (Migration Probabilities) of interstate migration for fourteen major states during 1981-1991 and 1991-2001 are estimated in Table 1 and 2. From table it has been observed that 1981-1991 and 1991-2001 periods, highest inmigrants received states are Maharashtra followed by Madhya Pradesh and Karnataka, Rajasthan and UP. Maharashtra received highest inmigrants from Gujarat followed by Karnataka during 1981-1991 and 1991-2001 Census. Uttar Pradesh the highest populous states of India recorded 0.207 proportion in migrants in 1981-1991 and 0.25 proportion in migration in 1991-2001 from Madhya Pradesh and Bihar. Punjab has received some inmigrants from Haryana followed by UP and Rajasthan. **Summary:** It is observed from the above table that during the period 1981-1991 and 1991-2001, outmigration is very high from Gujarat and Karnataka to Maharashtra with proportion 0.63 and 0.57. The state Maharashtra received highest inmigrants from many other states; it is an account of a greater height of development in spheres of socioeconomic aspects of the people such as urbanisation, industrialisation and others. In case of Bihar, Haryana and some of the few states are having low proportion of inmigrants due to lack of socioeconomic activities.

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