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# MARKOV CHAINS ANALYSIS AND MECHANISM OF MIGRATION IN INDONESIA IN THE PERIOD 1980-2010

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**ABSTRACT**

The aims of this study are to find the Markov Chain model for the migration in Indonesia, to find the properties of the transition probability matrices, to find the stationary probability, and to find the behavior of the mechanism of the migration in 1980,1990, 2000, 2010 and the combined data from 1980 to 2010. In the Markov Chain model the states are Sumatra, Jawa, Kalimantan, Sulawesi, and Maluku and Papua and are abbreviated as S, J, K, SL and OI respectively. From the transition probability matrices, the states are communicated to each other and irreducible. From the results of analysis, there are similar stationary probability within the states Jawa, Sulawesi and Maluku and Papua, but slightly change in the Sumatra and Kalimantan. From the stationary probability results it shows that in the long run that the stationary probability of migration enter Sumatra decrease from 0.3895 in 1980 to 0.2720 in 2010. On the other hand, the stationary probability of migration enter Kalimantan increase from 0.0726 in 1980 to 0.1537 in 2010. From the analysis of mechanism of migration in 1980, 1990, 2000 and 2010. Jawa becomes the main destination of migration from other islands. The people from Sumatra, if they migrate high probability they will migrate to Jawa. On the other hand, the people from Jawa, if they migrate high probability they will migrate to Sumatra. The people from Kalimantan, if they migrate high probability they will migrate to Jawa or Sulawesi in 1980 and in 2010, but high probability only to Jawa in 1990 and in 2000. The people from Sulawesi, if they migrate high probability they will migrate to Jawa, Kalimantan or Maluku and Papua in 1980 and in 1990, but in 2000 and in 2010, high probability they will migrate to Kalimantan and Maluku and Papua. The people from Maluku and Papua, if they migrate high probability they will migrate to Sulawesi or Jawa.

**Keywords:** migration, transition probability matrix, stationary probability, mechanism of migration.

## INTRODUCTION

The migration population has become important research topic in mathematical modeling and stochastic modeling as well as in social sciences [Keyfitz and Caswell, 2005; Impagliazzo, 1985; Smith and Keyfitz, 2013; Juha and Spencer, 2005]. Migration has become one of the major factors in population change in Europe today (Coleman 2008; Taran 2009) and the resulting significant amount of research in social sciences.

Migration is an important element in the growth of the population and the labor force of an area. Knowledge of the number and characteristics of persons entering or leaving an area is required, together with census data on population size and vital statistics, to analyze the changes in the structure of the population and labor force of an area

(Edmonston and Michalowski, 2004, in Siegel and Swanson 2004). Consequently, migration and mobility typically affect more than just total numbers of inhabitants. Over time, a population may be changed or transformed as people realize their intentions to enter or leave an area (Morrison, et. al, 2004, in Siegel and Swanson 2004). In developing probability models of migration and migrants, the occurrence of an event (migration) is assumed to be the result of an underlying random mechanism. The occurrence of a migration depends on both personal attributes (systematic factors) and chance. Our approach is to model the random mechanism by specifying a probability model (Raymer and Willekens, 2008). Sociologists and economists have long sought theoretical models for studying human mobility. Markov chain models have been developed and used by many researchers. In these models, various geographical locations are the states in Markov chains, and the transition probabilities are either empirically estimated or assumed to possess certain properties (McGinnis, 1968; Bartholomew, 1967; and Henry, McGinnis and Tegtmeyer, 1971).

In this paper, we are going to analyze the mechanism of migration in Indonesia by using Markov Chain model; the data used in this study are from the Central Bureau of Statistic Indonesia from 1980 to 2010. Besides, this study also is going to find the properties of the behavior of transitions probability matrices.

## MARKOV CHAINS ANALYSIS

Consider the data from observation in finite Markov chain with states (1, 2, ..., k) until $m_{..}$ Transitions have taken place. Let $m_{ij}$ be a number of transitions from state i to state j (i,j=1,2, ... ,k). Let the row sum $\sum_{j=1}^{k} m_{ij} = m_{i.}$

**Table-1.** Transition count matrix.

| States | 1 | 2 | ....... | k | Total |
|---|---|---|---|---|---|
| 1 | $m_{11}$ | $m_{12}$ | ....... | $m_{1k}$ | $m_{1\bullet}$ |
| 2 | $m_{21}$ | $m_{22}$ | ....... | $m_{2k}$ | $m_{2\bullet}$ |
| : | : | : | : | : | : |
| : | : | : | : | : | : |
| k | $m_{k1}$ | $m_{k2}$ | ....... | $m_{kk}$ | $m_{k\bullet}$ |
| | | | | | $m_{\bullet\bullet}$ |

Let the transition probability matrix of finite Markov chains be P,

$$P=\begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1k} \\ p_{21} & p_{22} & \cdots & p_{2k} \\ : & : & : & : \\ p_{k1} & p_{k2} & \cdots & p_{kk} \end{bmatrix} \quad (1)$$

We are interested with the estimate of the elements of P; we denote the estimate by $\hat{p}_{ij}$. For a given initial state i and a number of trial $m_i$, the sample of transition counts ($m_{i1}$ $m_{i2}$ .... $m_{ik}$) can be considered as a sample of size $m_i$ from multinomial distribution with probabilities ($p_{i1}$ $p_{i2}$ .... $p_{ik}$), such that $\sum_{j=1}^{k} p_{ij} = 1$ (Bhat and Miller, 2002). The probability of this outcome can therefore be given as

$$P(p_{i1}, p_{i2}, ..., p_{ik}, m_{i.}) = \frac{m_{i.}}{m_{i1}! m_{i2}! .. m_{ik}!} p_{i1}^{m_{i1}} p_{i2}^{m_{i2}} .. p_{ik}^{m_{ik}} \quad (2)$$

By using the method of maximum likelihood estimation (Basawa and Prakasa Rao, 1980; Bhat and Miller, 2002; Billingsley, 1961). The likelihood function f(P) and its natural logaritm L(P) are as follow

$$f(P) = \prod_{i=1}^{k} \frac{m_{i.}}{m_{i1}! m_{i2}! ... m_{ik}!} p_{i1}^{m_{i1}} p_{i2}^{m_{i2}} ... p_{ik}^{m_{ik}} \quad (3)$$

and

$$L(P) = \ln \Omega + \sum_{i=1}^{k} \sum_{j=1}^{k} m_{ij} \ln p_{ij} \quad (4)$$

where $\ln \Omega$ contains all terms independent of the $p_{ij}$'s.

From (3) also be noted that $m_{ij}$ is sufficient statistic for the estimation of $p_{ij}$ (i, j=1, 2, 3,...,k). To find the maximum likelihood estimation, we incorporate the condition of (5)

$$\sum_{j=1}^{k} p_{ij} = 1 \quad (5)$$

into (4) and we can find that as;

$$L(P) = \ln \Omega + \sum_{i=1}^{k} \sum_{j=1}^{k-1} m_{ij} \ln p_{ij} + \sum_{i=1}^{k} m_{ik} \ln(1 - p_{i1} - p_{i2} - ... - p_{i,m-1}) \quad (6)$$

For a specific value of i, we have from (6)

$$L_i(P) = \ln \Omega + \sum_{j=1}^{m-1} m_{ij} \ln p_{ij} + m_{ik} \ln(1 - p_{i1} - p_{i2} - ... - p_{i,m-1}) \quad (7)$$

Now we differentiated with respect to $p_{ij}$ for j=1,2,..,k. Setting the resulting to k-1 derivatives equal to zero, and we have that

$$\hat{p}_{ij} = \frac{m_{ij}}{m_{i.}} \qquad i, j = 1,2,..., k. \quad (8)$$

## MARKOV CHAIN ANALYSIS OF MIGRATION

The data of migration and its transition probability matrix from 1980, 1990, 2000 and 2010 are given below.

**Table-2.** Number of migrants who migrate and stay in other islands, in 1980.

| Island | S | J | K | SL | OI |
|---|---|---|---|---|---|
| S | 0 | 718398 | 25480 | 22649 | 19897 |
| J | 2905894 | 0 | 374260 | 167413 | 137301 |
| K | 19598 | 121808 | 0 | 9752 | 4627 |
| S | 145402 | 136733 | 123431 | 0 | 139623 |
| OI | 30788 | 114876 | 11279 | 74196 | 0 |

Source: Central Bureau of Statistics, Indonesia, 2012.

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Based on the Table-2 and the application of the maximum likelihood estimation given by (8), then the transition probability matrix for migration in Indonesia in 1980 with states S= {S, J, K, SL, OI}, where S is stand for Sumatra, J is stand for Jawa, K is stand for Kalimantan, SL is stand for Sulawesi and OI is stand for Other Islands (Maluku and Papua) is given below as;

$$P_1 = \begin{bmatrix} 0 & 0.9135 & 0.0324 & 0.0288 & 0.0253 \\ 0.8106 & 0 & 0.1044 & 0.0467 & 0.0383 \\ 0.1258 & 0.7819 & 0 & 0.0626 & 0.0297 \\ 0.2667 & 0.2508 & 0.2264 & 0 & 0.2561 \\ 0.1332 & 0.4970 & 0.0488 & 0.3210 & 0 \end{bmatrix}$$

**Table-3.** Number of migrants who migrate and stay in other islands, in 1990.

| Island | S | J | K | SL | OI |
|---|---|---|---|---|---|
| S | 0 | 1069156 | 47967 | 27276 | 31273 |
| J | 3523590 | 0 | 842367 | 315319 | 371915 |
| K | 23522 | 197951 | 0 | 18025 | 8096 |
| S | 92455 | 177568 | 189977 | 0 | 189718 |
| OI | 59839 | 163405 | 47766 | 168014 | 0 |

Source: Central Bureau of Statistics, Indonesia, 2012.

Based on the Table-3 and the application of the maximum likelihood estimation given by (8), then the transition probability matrix for migration in Indonesia in 1990 is given as;

$$P_2 = \begin{bmatrix} 0 & 0.9094 & 0.0408 & 0.0232 & 0.0266 \\ 0.6973 & 0 & 0.1667 & 0.0624 & 0.0736 \\ 0.0950 & 0.7995 & 0 & 0.0728 & 0.0327 \\ 0.1423 & 0.2733 & 0.2924 & 0 & 0.2920 \\ 0.1363 & 0.3722 & 0.1088 & 0.3827 & 0 \end{bmatrix}$$

**Table-4.** Number of migrants who migrate and stay in other islands, in 2000.

| Island | S | J | K | SL | OI |
|---|---|---|---|---|---|
| S | 0 | 1560305 | 78015 | 36099 | 36442 |
| J | 3365746 | 0 | 1184871 | 337382 | 492889 |
| K | 24609 | 230081 | 0 | 22496 | 12334 |
| S | 114985 | 212633 | 287578 | 0 | 162254 |
| OI | 88601 | 280990 | 103438 | 226821 | 0 |

Source: Central Bureau of Statistics, Indonesia, 2012.

Based on the Table-4 and the application of the maximum likelihood estimation given by (8), then the transition probability matrix for migration in Indonesia in 2000 is found as;

$$P_3 = \begin{bmatrix} 0 & 0.9120 & 0.0456 & 0.0211 & 0.0213 \\ 0.6255 & 0 & 0.2202 & 0.0627 & 0.0916 \\ 0.0850 & 0.7947 & 0 & 0.0777 & 0.0426 \\ 0.1479 & 0.2735 & 0.3699 & 0 & 0.2087 \\ 0.1266 & 0.4015 & 0.1478 & 0.3241 & 0 \end{bmatrix}$$

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**Table-5.** Number of migrants who migrate and stay in other islands, in 2010.

| Island | S | J | K | SL | OI |
|---|---|---|---|---|---|
| S | 0 | 2217168 | 117387 | 43196 | 62720 |
| J | 3714884 | 0 | 1528109 | 420905 | 762126 |
| K | 43051 | 330434 | 0 | 43791 | 18021 |
| S | 109860 | 263886 | 486822 | 0 | 376592 |
| OI | 105630 | 334996 | 123319 | 270416 | 0 |

Source: Central Bureau of Statistics, Indonesia, 2012.

Based on the Table-5 and the application of the maximum likelihood estimation given by (8), then the transition probability matrix for migration in Indonesia in 2010 is given as;

$$P_4 = \begin{bmatrix} 0 & 0.9085 & 0.0481 & 0.0177 & 0.0257 \\ 0.5781 & 0 & 0.2378 & 0.0655 & 0.1186 \\ 0.0989 & 0.7591 & 0 & 0.1006 & 0.0414 \\ 0.0888 & 0.2133 & 0.3935 & 0 & 0.3044 \\ 0.1266 & 0.4015 & 0.1478 & 0.3241 & 0 \end{bmatrix}$$

**Table-6.** Number of migrants who migrate and stay in other islands, in period 1980-2010.

| Island | S | J | K | SL | OI |
|---|---|---|---|---|---|
| S | 0 | 5565027 | 268849 | 129220 | 150332 |
| J | 13510114 | 0 | 3929607 | 1241019 | 1009231 |
| K | 110780 | 880274 | 0 | 94064 | 43078 |
| S | 462702 | 790819 | 1087808 | 0 | 868187 |
| OI | 284858 | 894267 | 285802 | 739447 | 0 |

Source: Central Bureau of Statistics, Indonesia, 2012.

Based on the Table-6 and the application of the maximum likelihood estimation given by (8), then the transition probability matrix for migration in Indonesia in 1980 to 2010 (Combined data) is given below:

$$P_5 = \begin{bmatrix} 0 & 0.9103 & 0.0440 & 0.0211 & 0.0246 \\ 0.6861 & 0 & 0.1996 & 0.0630 & 0.0513 \\ 0.0982 & 0.7802 & 0 & 0.0834 & 0.0382 \\ 0.1442 & 0.2464 & 0.3389 & 0 & 0.2705 \\ 0.1292 & 0.4057 & 0.1297 & 0.3354 & 0 \end{bmatrix}$$

## TEST FOR FIRST ORDER MARKOV CHAIN

In this section we are going to test whether the transition probability matrix of the migration in 1980, 1990, 2000, 2010 and the transition probability matrix for the period the combined data are satisfied the assumption of the first order Markov Chain. The hypothesis to be tested is the null hypotheses that the observation collected are independent against the alternative that the process observed is a first order Markov Chain. The hypothesis is

Ho: P = Po

where Po has identical rows under the assumption of independence. The $\chi^2$ statistic to test independence against the first order Markov Chain [Bhat and Miller, 2002; Billingsley, 1961; Basawa and Prakasa Rao, 1980] has the form

$$\chi^2 = \sum_{i=1}^{k}\sum_{j=1}^{k} \frac{(m_{ij} - m_{i.}m_{.j}/m_{..})^2}{m_{i.}.m_{.j}/m_{..}} \qquad (9)$$

with the degrees of freedom $(k-1)^2$-d, where d is number of zero cells. For the data given in Table-2 to Table-6, $\chi^2$ statistic should have 16 degrees of freedom when k=5. However 5 degrees of freedom are lost due to the diagonal entries being fixed at zero. The results of $\chi^2$ statistic for the data given in Table-2 to Table-6 are given in Table-7 below:

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**Table-7.** Chi-Squares test of independence for data migration in 1980 to 2010 and the combined data.

| Migration Data | $\chi^2$ statistic | p-value | Cramer's V |
|---|---|---|---|
| 1980 | 4944653 | <0.0000 | 0.483 |
| 1990 | 6988055 | <0.0000 | 0.481 |
| 2000 | 7757867 | <0.0000 | 0.468 |
| 2010 | 10341129 | <0.0000 | 0.477 |
| Combined Data | 30364405 | <0.0000 | 0.484 |

From Table-7. The $\chi^2$ statistic tests all lead us to the conclusion that the assumption of independence can be rejected (p-value< 0.0000). Based on these results, the conclusion that the data can be modeled as the first order Markov Chain are justified.

The graph of those transition probability matrices $P_1$, $P_2$, $P_3$, $P_4$, and $P_5$ are the same and given below.

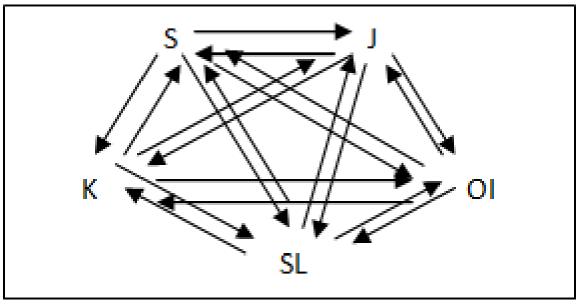


**Figure-1.** The graph of transition probability matrix $P_1$, $P_2$, $P_3$, $P_4$ and $P_5$.

From the graph it is clear that all the states are accessible and therefore communicate to each other [Bhat and Miller, 2002].

S→J, J→S, then S↔ J
S→K, K→ S, then S↔ K
S →SL, SL→S, then S↔ SL
S→OI, OI→S, then S↔ OI
J→K, K→J, then J↔ K
J→SL, SL→J, then J↔ SL
J→OI, OI→J, then J↔ OI
K→SL, SL→K, then K↔ SL
K→OI, OI→K, then K↔ OI
SL→OI, OI→SL, then SL↔OI

Therefore, we can conclude that from the transition probability matrix of migration in 1980 to 2010, all states are accessible and communicate to each other. Therefore it forms the class C(S)=C(J)=C(K)=C(SL)=C(OI)= {S, J, K, SL, OI}. So the states are irreducible. Also it can be shown that the transition probability matrix is aperiodic, namely has period 1[Castaneda, *et al*., 2012]

$$\lambda_i = GCD \quad \{n \geq 1 : p_i^n > 0\}.$$

The period can be calculated by GCD (Greatest Common Divisor) of the number of steps that started from state i and return to state i:

$$\lambda_{(S)} = 1 \rightarrow 2,3,4,5,\ldots \rightarrow GCD = 1$$
$$\lambda_{(J)} = 1 \rightarrow 2,3,4,5,\ldots \rightarrow GCD = 1$$
$$\lambda_{(K)} = 1 \rightarrow 2,3,4,5,\ldots \rightarrow GCD = 1$$
$$\lambda_{(SL)} = 1 \rightarrow 2,3,4,5,\ldots \rightarrow GCD = 1$$
$$\lambda_{(OI)} = 1 \rightarrow 2,3,4,5,\ldots \rightarrow GCD = 1$$

Thus, $\lambda_{(S)} = \lambda_{(J)} = \lambda_{(K)} = \lambda_{(SL)} = \lambda_{(OI)} = 1.$

## THE COMPARISON OF STATIONARY DISTRIBUTION

Because the states are aperiodic, irreducible and has finite states, then it is recurrent states. (Bhat and Miller, 2002), namely that started from state j with probability one that it will return back to states j. It has been showed that in the transition probability matrix $P_i$, i=1, 2, 3, 4, 5 all states are communicate, aperiodic, finite states space and recurrent states. Therefore there is a stationary probability π which satisfied, $\pi_j = \sum_{i\in S} \pi_i \, p_{ij}$ and $\sum_j \pi_j = 1$ [Bhat and Miller, 2002; Castaneda, *et.al.*, 2012, and Medhi, 2004]. In the matrix notation it can be written as

$$\pi = \pi P_i \qquad i=1, 2, 3, 4, 5 \tag{10}$$

The stationary probability also can be found from limiting transition probability matrix [Basawa and Prakasa Rao, 1980; Castaneda, *et al*., 2012],

$$\lim_{n\to\infty} p_{ij}^{(n)} = \pi_j . \tag{11}$$

**Table-8.** Stationary probability.

| Transition matrix | Stationary probability ($\pi$) | | | | |
|---|---|---|---|---|---|
| | $\pi_S$ | $\pi_J$ | $\pi_K$ | $\pi_{SL}$ | $\pi_{OI}$ |
| $P_1$ | 0.3895 | 0.4460 | 0.0726 | 0.0500 | 0.0419 |
| $P_2$ | 0.3284 | 0.4297 | 0.1115 | 0.0669 | 0.0635 |
| $P_3$ | 0.2983 | 0.4290 | 0.1419 | 0.0654 | 0.0653 |
| $P_4$ | 0.2720 | 0.4140 | 0.1537 | 0.0750 | 0.0853 |
| $P_5$ | 0.3250 | 0.4324 | 0.1284 | 0.0622 | 0.0519 |

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The comparison of the stationary distribution among the periods 1980, 1990, 2000 and 2010 for each island Sumatera, Jawa, Kalimantan, Sulawesi, and other islands is given in Figure-2. The figure shows that the stationary for the fifth period has no significant change, the distribution model are very closed to each other, the stationary distribution has variation, but the variation are relatively very small. Based on the stationary probability distribution for each period 1980, 1990, 2000 and 2010. For Sumatra (S) are 0.3895, 0.3284, 0.2983 and 0.2720, respectively. For Jawa are 0.4460, 0.4297, 0.4290 and 0.4140, respectively; For Kalimantan 0.0726, 0.1115, 0.1419 and 0.1537, respectively. For Sulawesi 0.0500, 0.0669, 0.0654 and 0.0750, respectively; and other Islands 0.0419, 0.0635, 0.0653 and 0.0853, respectively.

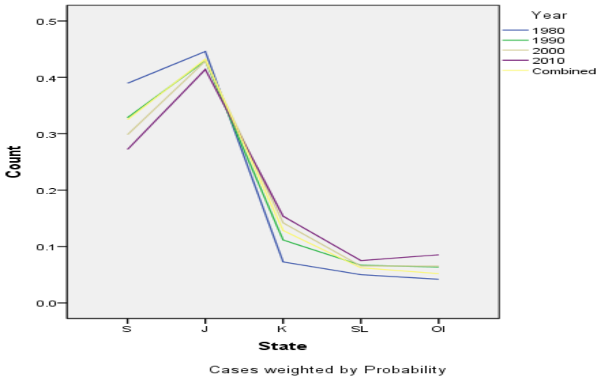


**Figure-2.** The comparison of the stationary distribution among the period.

From the Figure-2 and the results of stationary probability, it shows that the variation within Sumatra and Kalimantan are higher compared to other states Jawa, Sulawesi and Maluku and Papua. From the stationary probability results it shows that the transition probability of migration enter Sumatra decrease from 0.3895 in 1980 to 0.2720 in 2010. On the other hand, the transition probability of migration enter Kalimantan increase from 0.0726 in 1980 to 0.1537 in 2010.

The stationary probability for the combined data from 1980 to 2010 are 0.3250, 0.4324, 0.1284, 0.0622, and 0.0519. Based on this result, we can conclude that on the long run the migrants will enter Sumatra with probability 0.3250, enter Jawa with probability 0.4324, enter Kalimantan with probability 0.1284, enter Sulawesi with probability 0.0622 and enter Other Island (Maluku and Papua) with probability 0.0519. From this result it is shown that Jawa still in the future become the main destination of migration compare to other islands.

## MECHANISM OF MIGRATION

To find the mechanism of the migration, first we need to find the transition probability matrix following the procedure given in Bhat and Miller (2002), and Miall (1973) as follow:

**Table-9.** Transition count matrix.

| States | 1 | 2 | ....... | k | Total |
|---|---|---|---|---|---|
| 1 | 0 | $m_{12}$ | ....... | $m_{1k}$ | $m_{1\bullet}$ |
| 2 | $m_{21}$ | 0 | ....... | $m_{2k}$ | $m_{2\bullet}$ |
| : | : | : | : | : | : |
| : | : | : | : | : | : |
| k | $m_{k1}$ | $m_{k2}$ | ....... | 0 | $m_{k\bullet}$ |
| | $m_{\bullet 1}$ | $m_{\bullet 2}$ | ....... | $m_{\bullet k}$ | $m_{\bullet\bullet}$ |

Then we estimate the transition probability matrix as follow:

$$P^0 = \begin{bmatrix} 0 & \frac{m_{.2}}{m_{..}-m_{.1}} & \frac{m_{.3}}{m_{..}-m_{.1}} & ..... & \frac{m_{.k}}{m_{..}-m_{.1}} \\ \frac{m_{.1}}{m_{..}-m_{.2}} & 0 & \frac{m_{.3}}{m_{..}-m_{.2}} & ...... & \frac{m_{.k}}{m_{..}-m_{.2}} \\ : & : & : & ...... & : \\ \frac{m_{.1}}{m_{..}-m_{.k}} & \frac{m_{.2}}{m_{..}-m_{.2}} & \frac{m_{.3}}{m_{..}-m_{.k}} & ...... & 0 \end{bmatrix} \quad (12)$$

Based on equation (12) and using data from Table-2 to Table-6, we can obtain the estimate for entries transition probability matrix $P_1^0, P_2^0, P_3^0, P_4^0$ and $P_5^0$ that is;

$$P_1^0 = \begin{bmatrix} 0 & 0.4959 & 0.2427 & 0.1244 & 0.1370 \\ 0.7365 & 0 & 0.1269 & 0.0650 & 0.0716 \\ 0.6504 & 0.2289 & 0 & 0.0574 & 0.0632 \\ 0.6167 & 0.2171 & 0.1063 & 0 & 0.0590 \\ 0.6201 & 0.2183 & 0.1068 & 0.0548 & 0 \end{bmatrix}$$

$$P_2^0 = \begin{bmatrix} 0 & 0.4160 & 0.2918 & 0.1367 & 0.1555 \\ 0.6210 & 0 & 0.1894 & 0.0887 & 0.1009 \\ 0.5747 & 0.2498 & 0 & 0.0821 & 0.0934 \\ 0.5257 & 0.2285 & 0.1603 & 0 & 0.0854 \\ 0.5312 & 0.2309 & 0.1620 & 0.0759 & 0 \end{bmatrix}$$

$$P_3^0 = \begin{bmatrix} 0 & 0.5003 & 0.3623 & 0.1364 & 0.1555 \\ 0.6117 & 0 & 0.2815 & 0.1060 & 0.1009 \\ 0.5525 & 0.3511 & 0 & 0.0957 & 0.0934 \\ 0.4769 & 0.3031 & 0.2195 & 0 & 0.0854 \\ 0.4821 & 0.3064 & 0.2219 & 0.0835 & 0 \end{bmatrix}$$

$$P_4^0 = \begin{bmatrix} 0 & 0.4252 & 0.3048 & 0.1052 & 0.1648 \\ 0.4830 & 0 & 0.2742 & 0.0946 & 0.1482 \\ 0.4358 & 0.3451 & 0 & 0.0854 & 0.1337 \\ 0.3750 & 0.2970 & 0.2129 & 0 & 0.1151 \\ 0.3913 & 0.3099 & 0.2221 & 0.0767 & 0 \end{bmatrix}$$

and

$$P_5^0 = \begin{bmatrix} 0 & 0.4523 & 0.3100 & 0.1226 & 0.1152 \\ 0.5934 & 0 & 0.2301 & 0.0910 & 0.0855 \\ 0.5367 & 0.3037 & 0 & 0.0823 & 0.0773 \\ 0.4767 & 0.2697 & 0.1849 & 0 & 0.0687 \\ 0.4746 & 0.2686 & 0.1841 & 0.0728 & 0 \end{bmatrix}$$

In order to infer properties of migration mechanism, a matrix of differences of the transition probability under the assumption transition probability be given by (1) and be given by (12). In this case we calculate the difference matrices

$$D_i = P_i - P_i^0 \quad i=1, 2, 3, 4, 5. \qquad (13)$$

and the results are given below.

$$D_1 = \begin{bmatrix} 0 & 0.4176 & -0.2103 & -0.0956 & -0.1117 \\ 0.0741 & 0 & -0.0225 & -0.0183 & -0.0333 \\ -0.5246 & 0.0530 & 0 & 0.0052 & -0.0335 \\ -0.3500 & 0.0337 & 0.1201 & 0 & 0.1971 \\ -0.4869 & 0.2787 & -0.0580 & 0.2662 & 0 \end{bmatrix}$$

$$D_2 = \begin{bmatrix} 0 & 0.4934 & -0.2510 & -0.1135 & -0.1289 \\ 0.0763 & 0 & -0.0227 & -0.0263 & -0.0273 \\ -0.4797 & 0.5497 & 0 & -0.0093 & -0.0607 \\ -0.3834 & 0.0448 & 0.1321 & 0 & 0.2066 \\ -0.3949 & 0.1413 & -0.0532 & 0.3068 & 0 \end{bmatrix}$$

$$D_3 = \begin{bmatrix} 0 & 0.4117 & -0.3167 & -0.1153 & -0.1329 \\ 0.0138 & 0 & -0.0613 & -0.0433 & -0.0282 \\ -0.4675 & 0.4436 & 0 & -0.0180 & -0.0656 \\ -0.3290 & -0.0296 & 0.1504 & 0 & 0.1153 \\ -0.3555 & 0.0951 & -0.0741 & 0.2406 & 0 \end{bmatrix}$$

$$D_4 = \begin{bmatrix} 0 & 0.4833 & -0.2567 & -0.0875 & -0.1391 \\ 0.0951 & 0 & -0.0364 & -0.0291 & -0.0296 \\ -0.3369 & 0.4140 & 0 & 0.0152 & -0.0923 \\ -0.2862 & -0.0837 & 0.1806 & 0 & 0.1893 \\ -0.2647 & 0.0916 & -0.0743 & 0.2474 & 0 \end{bmatrix}$$

and

$$D_5 = \begin{bmatrix} 0 & 0.4580 & -0.2660 & -0.1014 & -0.0906 \\ 0.0928 & 0 & -0.0305 & -0.0280 & -0.0343 \\ -0.4385 & 0.4766 & 0 & 0.0011 & -0.0329 \\ -0.3325 & -0.0233 & 0.1541 & 0 & 0.2018 \\ -0.3454 & 0.1371 & -0.0544 & 0.2627 & 0 \end{bmatrix}$$

The positive elements of the different matrices $D_1$, $D_2$, $D_3$, $D_4$ and $D_5$ represent those transitions that have higher probability of occurrence than one would have expected from an independent assumption [Bhat and Miller, 2002]. Therefore, for the data migration in 1980, the mechanism of migration (Figure-3) process can be identified as follows: Sumatra(S) →Jawa (J) → Sumatra(S), Kalimantan (K) →Jawa(J) or Sulawesi (SL) → Maluku and Papua (OI)→Sulawesi (SL) or Jawa(J). The pattern of migration in 1980's the main destination of migration is Jawa, it is make sense that during that era, Jawa was the most developed island compared with other islands in Indonesia. The people from Sumatra in this era, if they migrated high probability they will migrate to Jawa. On the other hand, the people from Jawa in this era, if they migrated high probability they will migrate to Sumatra. Sumatra and Jawa are western region of Indonesia and they are very closed. The people from Kalimantan with high probability if they migrate, they will migrate to Jawa or Sulawesi. Kalimantar is in the middle region of Indonesia and closed to Jawa and Sulawesi. The people from Sulawesi with high probability if they migrate, they will migrate to Jawa or Kalimantan or Maluku and Papua. Sulawesi and Maluku and Papua are eastern part of Indonesia.

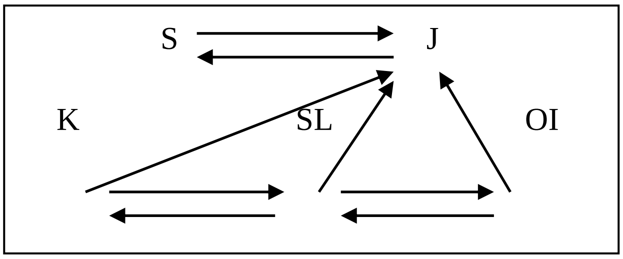


**Figure-3.** The mechanism of migration in 1980.

The data migration in 1990, the mechanism of migration (Figure-4) process can be identified as follows: Sumatra(S) →Jawa(J) → Sumatra(S), Kalimantan(K) →Jawa(J), Sulawesi(SL) → Jawa(J) or Kalimantan (K) or Maluku and Papua(OI)→Sulawesi(SL) or Jawa(J). The pattern of migration in 1990's the main destination of migration is still Jawa the same as in 1980's. The pattern of mechanism of migration in 1990 compared to 1980 only slightly change, namely that the people from Kalimantan if they migrate, high probablity they will migrate to Jawa. While the other pattern of the mechanism of migration are the same as in 1980's.

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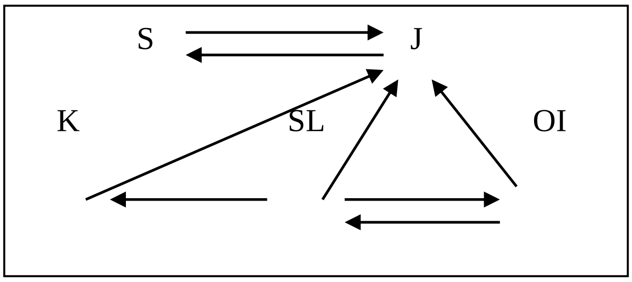


**Figure-4.** The mechanism of migration in 1990.

The data migration in 2000, the mechanism of migration (Figure-5) process can be identified as follows: Sumatra(S) →Jawa(J) → Sumatra(S), Kalimantan(K) →Jawa(J), Sulawesi(SL) → Kalimantan (K) or Maluku and Papua (OI) → Sulawesi(SL) or Jawa(J). The pattern of migration in 2000's the main destination of migration is still Jawa for the people from Sumatra, Kalimantan and Maluku and Papua. The pattern of mechanism of migration in 2000 compared to 1990 only slightly change, namely that the people from Sulawesi, if they migrate, high probablity they will migrate to Kalimantan or to Maluku and Papua. While the other pattern of the mechanism of migration are the same as in 1990's.

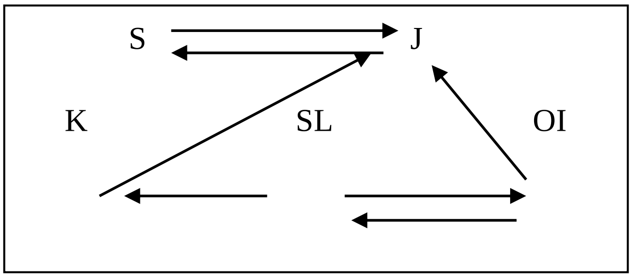


**Figure-5.** The mechanism of migration in 2000.

The data migration in 2010, the mechanism of migration (Figure-6) process can be identified as follows: Sumatra(S) →Jawa(J) → Sumatra(S), Kalimantan(K) →Jawa(J) or Sulawesi (SL) → Kalimantan (K) or Maluku and Papua (OI) → Sulawesi(SL) or Jawa(J). The pattern of migration in 2010's the main destination of migration is still Jawa for the people from Sumatra, Kalimantan and Maluku and Papua. The pattern of mechanism of migration in 2010 compared to 2000 only slightly change, namely that the people from Sulawesi, if they migrate, high probablity they will migrate to Kalimantan or to Maluku and Papua. The people from Kalimantan if they migrate, they will migrate to Jawa or Sulawesi. While the other pattern of the mechanism of migration are the same as in 2000's.

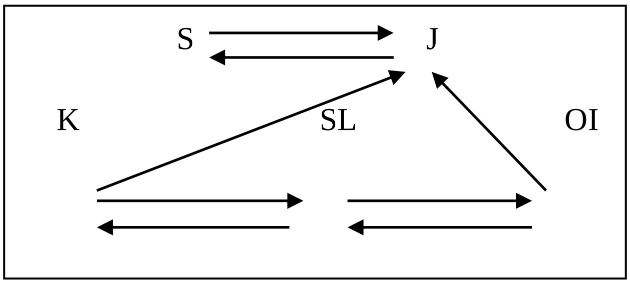


**Figure-6.** The mechanism of migration in 2010.

For over all data migration in 1980 to 2010 (The combined data), the mechanism of migration (Figure-7) process can be identified as follows: Sumatra(S) →Jawa(J) → Sumatra(S), Kalimantan(K) →Jawa(J) or Sulawesi(SL) → Kalimantan (K) or Maluku and Papua(OI)→Sulawesi(SL) or Jawa(J). The pattern of migration in the last thirty years the main destination of migration is Jawa. The people from Sumatra in this era, if they migrated high probability they will migrate to Jawa. On the other hand, the people from Jawa in this era, if they migrated high probability they will migrate to Sumatra. Sumatra and Jawa are western region of Indonesia and they are very closed. The people from Kalimantan with high probability if they migrate, they will migrate to Jawa or Sulawesi. Kalimantar in middle region of Indonesia and closed to Jawa and Sulawesi. The people from Sulawesi with high probability if they migrate, they will migrate to Kalimantan or Maluku and Papua. Sulawesi and Maluku and Papua are eastern part of Indonesia.

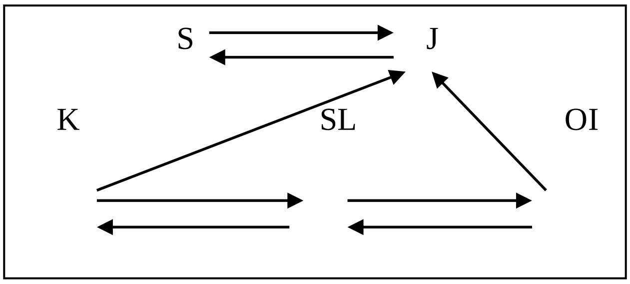


**Figure-7.** The mechanism of migration combined data (from 1980 to 2010).

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