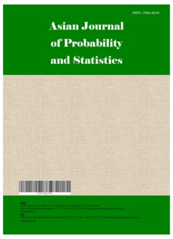

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Rationalization of the Pattern of Rural Out Migration: An Application of a Composite and Inflated Probability Models

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Authors' contributions

This work was carried out in collaboration among all authors. BPS developed the problem and statistical model. SS and UDD derived the statistical properties and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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Abstract

Migration is a term that encompasses a permanent or temporary change in residence between some specific defined geographical or political areas. In recent years, it has not only contributed a lot to the change in size and composition of the population, but also it leaves a significant impact on the socio-economic characteristics of the origin and destination population. In the present paper an attempt has been made to examine the distribution of the number of rural out migrants from household through composite probability models based on certain assumptions. Poisson distribution compounded with exponential distribution and its composite and inflated form has been examined for some real data set of rural out migration. The parameters of the proposed models have been estimated by method of moments. The distributions are quite satisfactory to explain the phenomenon of rural out migration. Also the distribution of average number of adult migrants has been examined for all the data sets.

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1 Introduction

Migration is one of the major determinants affecting the distribution of population. In India most of the population lives in rural area where social amenities, job opportunities, education facilities are either absent or insufficient. For getting better above mentioned facilities people moved from one place to another, thus these are the possible reasons of migration and play a vital role in determination the flow of adult rural out migration. Therefore rural out migration is a primary issue that affects population composition of a community. It is a process that includes several factors like age, sex, marital status, education and some other population event, affecting the movements of an individual of a household. Adults are more prone to migrate than other persons. Many attempts have been made to explore the migration process at micro level. Migration believed as an event, is highly selective with regard to age, with young adults generally being the most mobile group in any population. The probability models can also be adopted for explanation of any population event very efficiently. Several studies have been done to explain rural out migration (Singh & Yadava [1], Singh et al. [2], Sharma [3], Yadava & Yadava [4], Yadava et al. [5, 6], Aryal [7], Singh & Singh [8]) with the help of different probability models.

First attempt of probabilistic model building in this direction was initiated by Singh & Yadava 1981, explained rural out migration with the help of probability model using negative binomial distribution. Further, Yadava & Singh [9] introduced an idea of cluster for the number of migrants from a household and proposed a model assuming that migrants from a household occur in clusters. Moreover, Singh et al. [10] has applied a mixture of negative binomial and Thomas distribution to describe the pattern of total number of migrants from a household. He applied the inflated geometric distribution as well as the inflated generalized Poisson distribution for probability modeling to describe the trends in rural out-migration at the micro level. Yadava and Yadava [4] proposed a model with displaced geometric distribution instead of taking Poisson distribution for the occurrence of number of migrants and truncated a truncated polya-aeppli distribution. An alternative estimation technique using likelihood function for inflated geometric distribution is proposed by Iwunor [11] and also obtained the variance and covariance for the estimators. The likelihood function using multinomial combination is only derived, but finally estimates of the parameters obtained by mean-zero frequency method by Iwunor [11]. Hossain [12] and Aryal [13] used maximum likelihood method to estimate the parameters of the model considered and applied it to different data set. Hossain [12] has also used the geometric model for describing the pattern of migration in Bangladesh. Again, Aryal [7] has used the same model to examine the pattern of migration in Nepal.

Recently, Singh et al. [14] developed a model for adult out migration for the fixed household size to know the effect of size of household on the adult migration and used inflated binomial and beta binomial distribution. Singh et al. [15] introduced inflated Poisson-Lindley distribution for the pattern of adult migration in the household. Further Singh et al. [8] has applied inflated geometric and beta-geometric based models for explaining the pattern of rural out migration. Singh et al. [16, 17], has applied a set of some zero adjusted and size biased distributions for exploring the pattern of adult out migration. In this article an attempt is made to examine the suitability of the models applying them to various datasets to explore pattern of rural out migration of some regions with probability models in aggregate. The probability models are employed to explore the real data set of adult migration to examine the suitability of model.

2 Development of Probability Models

For development of model we assume that the number of adult migrants from household is a random variable and thus follows a discrete distribution. Some time the simple distribution fails to explain the migration process. Therefore we need some modification in the simple distribution. These modifications may be a mixture of distribution or compounding of the simple distribution with another distribution or both. It is worthwhile to mention here that some of the households have varying number of adult migrants from rural to urban and some household have no adult migrants. Also number of adult migrants from household varies and random in nature. Keeping this fact into consideration an attempt has been made with such assumptions we put forward a probability model for the number of rural adult out migrants from a household:

(i) At any point of time, let α be the proportion of household with no adult migration and the proportion of household having adult out migration is $(1-\alpha)$.

(ii) Let X be the number of adult migrants from a household and follows Poisson distribution with parameter λ. Further it is assumed that this parameter is a random variable and varies according to exponential distribution. The reason of this variation is due to huge disparity in terms of social standard of the household present in the society which affects the amount of migration.

2.1 Model-I

2.1.1 Poisson Exponential Distribution

Let the number of adult migration follows Poisson distribution with parameter λ, further it is assumed that expected number of adult migration i.e. λ is a random variable and follows exponential distribution with parameter μ. Thus

$$P[X=x|\lambda]=\frac{e^{-\lambda}\lambda^{x}}{x!};\quad \lambda>0 \tag{2.1}$$

$$g(\lambda)=\mu e^{-\mu\lambda};\quad \mu>0 \tag{2.2}$$

The joint distribution is given by $P[X=x|\lambda]\times g(\lambda)=\frac{e^{-\lambda}\lambda^{x}}{x!}\mu e^{-\mu\lambda}$
Therefore marginal distribution of X is written as

$$P[X=x]=\int_{0}^{\infty}\frac{e^{-\lambda}\lambda^{x}}{x!}.\mu e^{-\mu\lambda}d\lambda \tag{2.3}$$

$$P[X=x]=\frac{\mu}{x!}.\frac{\Gamma(x+1)}{(\mu+1)^{(x+1)}}=\frac{\mu}{(\mu+1)^{(x+1)}}=\left(\frac{\mu}{\mu+1}\right)\left(\frac{1}{\mu+1}\right)^{x} \tag{2.4}$$

This is probability density function for the Poisson Exponential distribution. This distribution is a geometric distribution with parameter $\left(\frac{\mu}{\mu+1}\right)$.

2.2 Model-II

2.2.1 Composite Poisson Exponential Distribution

We assume at any point of time, let α be the proportion of household with adult migration and the proportion of household having no adult out migration is $(1-\alpha)$. Moreover, we assume the number of migrants in the household where migration present follows truncated Poisson exponential distribution. Thus the probability distribution for number of adult migrants according to the above assumption is given below

$$p(X=x)=\begin{cases} 1-\alpha & x=0 \\ \alpha\left(\frac{\mu}{\mu+1}\right)\left(\frac{1}{\mu+1}\right)^{x} \Big/ \left(1-\frac{\mu}{\mu+1}\right) & x=1,2,3.... \end{cases}$$

or

$$p(X=x)=\begin{cases} 1-\alpha & x=0 \\ \alpha\left(\frac{\mu}{\mu+1}\right)\left(\frac{1}{\mu+1}\right)^{x-1} & x=1,2,3.... \end{cases} \tag{2.5}$$

2.3 Model-III

2.3.1 Inflated Poisson Exponential Distribution

When we think about the number of adult migrants from household in a society, some households have varying number of adult migrants and some household have no adult migrants. At the same time we can also think that some household have intention of migration but reported no migration. Thus number of household with no migration becomes inflated. At the same time we can also think that some household have intention of migration (or temporarily migrated) but reported no migration. Keeping this fact into consideration under some assumptions an attempt has been made to develop a probability model for the number of adult out migrants from a household. Therefore, we assume α be the proportion of household with adult migration and the proportion of household having no adult out migration is $(1-\alpha)$. Moreover, we assume the number of migrants in the household follows Poisson exponential distribution. Thus the probability distribution for number of adult migrants according to the above assumption is given below

Therefore, an inflated form of this distribution is applied to set up the model as

$$f(x)=\begin{cases} 1-\alpha+\alpha\frac{\mu}{\mu+1} & ; & x=0 \\ \alpha\left(\frac{\mu}{(\mu+1)}\right)\left(\frac{1}{(\mu+1)}\right)^{x} & ; & x=1,2,3,.... \end{cases} \tag{2.6}$$

Here α and θ are two parameters which are estimated by the method of moments and maximum likelihood method. The excess frequency at zeroth cell can be assumed as two division, first having no migration at all (with probability $(1-\alpha)$), second having intension of migration (or temporarily migrated) but reported no migration (with probability $\frac{\alpha\mu}{\mu+1}$).

3 Estimation of Parameters

3.1 Model-I

3.1.1 Method of Moments

Since the Model-I is a geometric distribution with parameter $\left(\frac{\mu}{\mu+1}\right)$. Therefore the $E(x)=\left(\frac{1}{\mu}\right)$. Thus the parameter μ can be estimated as $\hat{\mu}=\frac{1}{\bar{x}}$.

3.1.2 Maximum Likelihood Estimation

Let $x_1, x_2, ..., x_n$denote a random sample of size n. Each x_i count the number of adult migrant. The likelihood function of estimating the parameter μ can be expressed as below:

$$L=\prod_{x}\left[\left(\frac{\mu}{\mu+1}\right)\left(\frac{1}{\mu+1}\right)^{x}\right]=\left(\frac{\mu}{\mu+1}\right)^{n}\left(\frac{1}{\mu+1}\right)^{s} \tag{3.1}$$

where $s = \sum_{i=0}^{n} x_i = n\bar{x}$.

Taking log and differentiating (3.1) with respect to p respectively and equating to zero, we have,

$$\frac{\partial \log L}{\partial p} = \frac{n}{p} - \frac{s}{1-p} = 0 \Rightarrow \frac{p}{1-p} = \frac{n}{n\bar{x}} \tag{3.2}$$

where, $p = \frac{\mu}{\mu+1}$ after solving the above equation (3.2) we have $\mu = \frac{1}{\bar{x}}$ which is the same as moment estimate.

3.2 Model-II

3.2.1 Method of Moments

Expected value of the above distribution is

$$E(x) = \alpha \left\{ \frac{\frac{1}{\mu}}{1 - \left(\frac{\mu}{\mu+1}\right)} \right\} = \frac{\alpha(\mu+1)}{\mu} \tag{3.3}$$

Also we know that $p_0 = (1-\alpha)$ the zeroth cell proportion, putting this into the above equation we get

$$E(x) = \bar{x} = \frac{(1-p_0)(\mu+1)}{\mu} \Rightarrow \frac{\bar{x}}{1-p_0} = \frac{(\mu+1)}{\mu} = k \quad (say)$$

$$\Rightarrow \hat{\mu} = \frac{1}{k-1} \tag{3.4}$$

3.2.2 Maximum Likelihood Estimation

Let $p = \frac{\mu}{\mu+1}$ in the model, then the likelihood function for this composite Poisson exponential distribution is

$$L = (1-\alpha)^{n_0} \prod_k \left[\alpha p q^{k-1}\right]^{n_k} = (1-\alpha)^{n_0}\, \alpha^{n-n_0} p^{n-n_0} q^s \tag{3.5}$$

where, $s = \sum_{k=1}^{m} (k-1)\, n_k$

Taking log and differentiating (3.5) with respect to α and p in respectively and equating to zero, we have,

$$\frac{\partial \log L}{\partial \alpha} = \frac{n_0}{1-\alpha} - \frac{n-n_0}{\alpha} = 0 \tag{3.6}$$

$$\frac{\partial \log L}{\partial p} = \frac{n-n_0}{p} - \frac{s}{1-p} = 0 \tag{3.7}$$

From the above equations we have the estimate of α

$$\frac{n_0}{1-\alpha} = \frac{n-n_0}{\alpha} \Rightarrow \frac{\alpha}{1-\alpha} = \frac{n-n_0}{n_0} \tag{3.8}$$

$$\frac{1}{\alpha} = \frac{n}{n-n_0} \Rightarrow \hat{\alpha} = 1 - \frac{n_0}{n} = 1 - p_0 \tag{3.9}$$

For the estimate of μ (in the form of p)

$$\frac{n-n_0}{p} = \frac{s}{1-p} \Rightarrow \frac{1-p}{p} = \frac{s}{n-n_0} \tag{3.10}$$

$$\frac{1}{p} = \frac{s+n-n_0}{n-n_0} \Rightarrow \hat{p} = \frac{n-n_0}{s+n-n_0}$$

Now putting $p = \frac{\mu}{\mu+1}$

$$\frac{\mu}{\mu+1} = \frac{n-n_0}{s+n-n_0} \tag{3.11}$$

Since $s = \sum\limits_{k=1}^{m} (k-1)\, n_k = \sum\limits_{k=1}^{m} kn_k - \sum\limits_{k=1}^{m} n_k = n\bar{x} - (n-n_0)$
Therefore the estimate for μ

$$\frac{\mu}{\mu+1} = \frac{n-n_0}{n\overline{x} - (n-n_0) + n - n_0} = \frac{n-n_0}{n\overline{x}}$$

$$\Rightarrow 1 + \frac{1}{\mu} = \frac{n\overline{x}}{n-n_0}$$

$$\Rightarrow \frac{1}{\mu} = \frac{n\overline{x} - n + n_0}{n-n_0} \Rightarrow \hat{\mu} = \frac{n-n_0}{n\overline{x} - n + n_0} \tag{3.12}$$

The estimated value of parameters is also same as the moment estimates.

3.3 Model-III

3.3.1 Method of Moments

Now we know that

$$p_0 = 1 - \alpha + \alpha\left(\frac{\mu}{\mu+1}\right) \quad \text{and} \quad E\,(x) = \frac{\alpha}{\mu} \tag{3.13}$$

Solving these two equations, we can obtain the estimates of α and μ.

$$\alpha = (\mu+1)\,(1-p_0) \quad \text{and} \quad \mu = \frac{1-p_0}{E\,(x) - 1 + p_0} \tag{3.14}$$

3.3.2 Maximum Likelihood Estimation

Let $x_1, x_2, ..., x_n$ denote a random sample of size n. Each x_i count the number of adult migrant. Assuming that $n_k\,(k = 1, 2, ..., m)$denotes the number of observations with value k. The likelihood function of estimating the parameters α and μ can be expressed as below:

$$\begin{aligned} L &= \left(1 - \alpha + \alpha\frac{\mu}{\mu+1}\right)^{n_0} \prod_k \left[\alpha\left(\frac{\mu}{\mu+1}\right)\left(\frac{1}{\mu+1}\right)^k\right]^{n_k} \\ &= \left(1 - \alpha + \alpha\frac{\mu}{\mu+1}\right)^{n_0} \alpha^{n-n_0}\left(\frac{\mu}{\mu+1}\right)^{n-n_0}\left(\frac{1}{\mu+1}\right)^{s} \end{aligned} \tag{3.15}$$

where, $s = \sum\limits_{k=1}^{m} k.n_k$
Taking log and differentiating (3.15) with respect to α and p respectively and equating to zero, we have,

$$\frac{\partial \log L}{\partial \alpha} = \frac{n_0\,(p-1)}{(1-\alpha+\alpha p)} + \frac{n-n_0}{\alpha} = 0 \tag{3.16}$$

$$\frac{\partial \log L}{\partial p} = \frac{n-n_0}{p} - \frac{s}{1-p} + \frac{n_0 \alpha}{(1-\alpha+\alpha p)} = 0 \tag{3.17}$$

where, $p = \frac{\mu}{\mu+1}$ after solving the above equations we have

$$\hat{\alpha} = \frac{n-n_0}{n\left(1 - \frac{\mu}{\mu+1}\right)} = \frac{n-n_0}{n\left(\frac{1}{\mu+1}\right)} \Rightarrow \hat{\alpha} = \frac{(n-n_0)\,(\mu+1)}{n} \tag{3.18}$$

Same as moment estimate.

$$p = \frac{n - n_0}{n\overline{x}} \quad \text{or} \quad \frac{\mu}{\mu + 1} = \frac{n - n_0}{n\overline{x}} \Rightarrow \frac{1}{\mu} = \frac{n\overline{x}}{n - n_0} - 1 = \frac{n\overline{x} - n + n_0}{n - n_0} \tag{3.19}$$

$$\hat{\mu} = \frac{n - n_0}{n\overline{x} - n + n_0}$$

4 Application of the Model

The parameters estimated for the proposed models with maximum likelihood. Further to check the suitability, when the model has been applied to various real data sets. In Table 1. the suitability of proposed model is examined by several sets of data collected under a survey entitled "Migration and related characteristics-a case study of North-Eastern Bihar" conducted during October 2009 to June 2010 used by Singh et al. [15]. Again, the suitability of proposed model is examined by another set of data. Varanasi data was collected under a sample survey "Rural development and population growth (RDPG) survey" conducted in 1978 in Varanasi district and used by Sharma [10] and Iwunor [11]. The Nepal data is taken from a sample survey of the Rupandhi and Palpa districts in Nepal and used by Aryal [13]. The Western Uttar Pradesh data has been taken from Gupta et al. [18] given in Table 2. In the Table 4. the data used is Bangladesh data which was collected under a sample survey "Impact of Migration on Fertility in Bangladesh: A study of Comilla district" conducted in 1997 and used by Hossain [12].

5 Discussions and Conclusion

Fig 1. shows the distribution of average number of adult migrants from households for different data sets. For the data set from Kosi, Bihar 26 percent households having on an average more than one adult migrant from the household. However both the data sets from Uttar Pradesh are only about one percent. In Nepal and Bangladesh data sets it is about 7 percent. The area from where the data have been taken in Bihar is flooded area thus there are more chance that an adult person migrate with some other persons. The areas from where data have been collected in Uttar Pradesh seems to be more developed than the survey areas of Nepal and Bangladesh, because the average adult migration is more than one adult is fewer in Uttar Pradesh than Nepal and Bangladesh. The observed and expected frequency and the value of chi-square along with p-value allow us to consider that the models considered in the study are suitable to explain the pattern of migration. Inflated and composite model are better than the simple model. The interpretation of mixing parameter in inflated model has a meaning i.e. this much amount is not governed by the plain distribution, actually this amount shows the extra proportion of household with migrants any way but reported no migration. Sometimes the inflated and composite models provide better insight about the phenomenon.

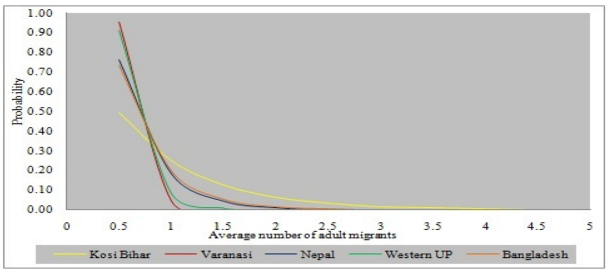

Fig. 1. The distribution of average number of adult out migrants from household

Table 1, 2, 3, 4 and 5 shows the estimated values of parameters, mean, variance, observed and expected number of total households according to the number of adult migrants for households of the different set of data. The value of χ^2 with degree of freedom and $p-$value are also given in the respective tables. The value of χ^2 shown in the tables clearly indicates that both the distributions describe the pattern of number of migrants from households. According to the $p-$value, composite Poisson exponential distribution is found better than Poisson exponential distribution. From the composite Poisson exponential distribution, the value of parameter α is about 40 percent households in Koshi, Bihar, 11 percent in Varanasi, 23 percent in Nepal, 17 percent in western Uttar Pradesh and 27 percent in Comilla, Bangladesh. This indicates that much proportions of households are expected to have no adult migrants but the estimate of α from inflated Poisson exponential distribution is different than the estimate of α from composite Poisson exponential distribution. The difference of these estimates is the proportion of those households who have migrants but not reported. The maximum difference has been observed in western Uttar Pradesh and Comilla, Bangladesh.

Table 1. Observed and expected frequency of the number of households according to the migrants in flooded area of Kosi river, Bihar

Number of migrants	Observed number of households	Expected number of households		
		Poisson Exponential	Composite Poisson Exponential	Inflated Poisson Exponential
0	401	382.3 9	401.00	401.00
1	147	162.18	141.45	141.45
2	57	68.78	65.37	65.37
3	29	29.17	30.21	30.21
4	16	12.37	13.96	13.96
5	8	5.25	6.45	6.45
6	5	2.23	2.98	2.98
7	1	1.64	2.56	2.56
Total	664	664.00	664.00	664.00
Mean=0.7365 Variance=1.4471		χ^2=8.03 (after pooling)	χ^2=2.04 (after pooling)	χ^2=2.05 (after pooling)
		$p-$value =0.090(df=4)	$p-$value =0.728(df=4)	$p-$value =0.726(df=4)
Estimated value of parameters		μ=1.3579	μ=1.1637 α=0.3961	μ=1.1637 α=0.8570

Table 2. Observed and expected frequency of the total number of households according to migrants in Western Uttar Pradesh

Number of migrants	Observed number of households	Expected number of households		
		Poisson Exponential	Composite Poisson Exponential	Inflated Poisson Exponential
0	2679	2669.31	2679.00	2679.00
1	445	459.25	443.24	443.32
2	78	79.01	82.76	82.71
3	19	13.59	15.45	15.43
4	3	2.82	3.55	3.54
Total	3224	3224.00	3224.00	3224.00
Mean=0.2078 Variance=0.2596		χ^2=2.39 (after pooling)	χ^2=0.75 (after pooling)	χ^2=0.75 (after pooling)
		$p-$value= 0.302(df=2)	$p-$value= 0.385(df=1)	$p-$value= 0.385(df=1)
Estimated value of parameters		μ=4.8123	μ=4.3557 α=0.1690	μ=4.3557 α=0.9061

Table 3. Observed and expected frequency of the total number of households according to migrants in Nepal

Number of migrants	Observed number of households	Expected number of households		
		Poisson Exponential	Composite Poisson Exponential	Inflated Poisson Exponential
0	623	602.31	623.00	623.00
1	126	154.99	125.78	125.78
2	42	39.88	41.63	41.63
3	13	10.26	13.78	13.78
4	4	2.64	4.56	4.56
5	2	0.68	1.51	1.51
6	1	0.24	0.75	0.75
Total	811	811.00	811.00	811.00
Mean=0.3465 Variance=0.5717		χ^2=9.01 (after pooling)	χ^2=0.05 (after pooling)	χ^2=0.05 (after pooling)
		$p-$value= 0.011(df=2)	$p-$value= 0.974(df=2)	$p-$value= 0.974(df=2)
Estimated value of parameters		μ=2.8861	μ=2.0215 α=0.2318	μ=2.0215 α=0.7004

Table 4. Observed and expected frequency of the number of households according to migrants in Comilla district of Bangladesh

Number of migrants	Observed number of households	Expected number of households		
		Poisson Exponential	Composite Poisson Exponential	Inflated Poisson Exponential
0	1941	1938.92	1941.00	1941.00
1	542	532.48	529.47	529.47
2	124	146.23	146.49	146.49
3	48	40.16	40.53	40.53
4	13	11.03	11.21	11.21
5	4	3.03	3.10	3.10
6	1	1.15	1.19	1.19
Total	2673	2673.00	2673.00	2673.00
Mean=0.3786 Variance=0.5353		χ^2=5.59 (after pooling)	χ^2=5.52 (after pooling)	χ^2=5.52 (after pooling)
		$p-$value= 0.133(df=2)	$p-$value= 0.137(df=3)	$p-$value= 0.137(df=3)
Estimated value of parameters		μ=2.6413	μ=2.0215 α=0.2738	μ=2.0215 α=0.9898

Table 5. Observed and expected frequency of the total number of households according to the migrants in Varanasi District

Number of migrants	Observed number of households	Expected number of households		
		Poisson Exponential	Composite Poisson Exponential	Inflated Poisson Exponential
0	1032	999.20	1032.00	1032.00
1	95	139.25	88.52	88.52
2	19	19.41	27.78	27.78
3	10	2.70	8.72	8.72
4	2	0.38	2.74	2.74
5	2	0.05	0.86	0.86
6	0	0.01	0.27	0.27
7	1	0.00	0.12	0.12
Total	1161	1161.00	1161.00	1161.00
Mean=0.1619 Variance=0.3114		χ^2=20.95 (after pooling)	χ^2=3.66 (after pooling)	χ^2=3.66 (after pooling)
		$p-$value= 0.0001(df=1)	$p-$value= 0.056(df=1)	$p-$value= 0.056(df=1)
Estimated value of parameters		μ=6.1755	μ=2.1864 α=0.1111	μ=2.1864 α=0.3540

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Competing Interests

There is no competing interests exist among authors.

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