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Original Article

Analyzing age-sex structure patterns in Nepal using factor analysis

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Abstract

This study aimed to cluster the districts in Nepal based on the patterns of age-sex structures by applying factor analysis. The population data, which is grouped by 5-year age gap, by sex and by districts, was used. The factor analysis was applied to spline smooth single-year age population by sex and district. A three factor model was best fitted to the data. These three common factors were interpreted as three different patterns based on common characteristics of age and sex distribution. The study found that 23, 17 and 5 districts correlated purely to factor 1, 2 and 3, respectively. Thirty districts were found correlated with two or more factors. In conclusion, the age-sex structure varied substantially between the different districts of Nepal in 2011. The variations were explained well by a three-factor model. The method used in this study is straightforward and applicable to the further demographic study.

Keywords: demographic transition, age structure, sex structure, Nepal, factor analysis

1. Introduction

Nepal is in the late expanding phase of the demographic transition indicated by slowdown the natural increase rate due to the rapid decline of births and slow decline of deaths (Kunwar, 2012). The fertility, as well as the mortality rate, has declined and the life expectancy has increased. Also, internal and external migration has been found to be substantially rising (Sharma, Pandey, Pathak & Sijapati-Basnett, 2014). The Total Fertility Rate (TFR) was more or less constant (i.e. approximately 6 children per women) until the mid-eighties, classifying Nepal as having high levels of fertility rates (Gubhaju, 2007). Thereafter, these rates declined quickly (Karki and Krishna, 2008). Nepal Demographic and Health Survey (NDHS) provided an estimate of TFR to be 3.1 in 2006 (Ministry of Health and Population (MOHP) Nepal, New ERA, and ICF International Inc, 2007) and 2.6 in 2011 (MOHP *et al.*, 2012) demonstrating that Nepal has moved from a transitional level to a near-replacement level (Gubhaju, 2007). Similarly, mortality rates started to decline since 1930s (Feeney *et al.*, 2001). The declining mortality rates can be explained by improved accessibility and quality of public health services of the Nepalese population. Consequently, Nepal's population was increasing in a decreasing trend (Nepal Population Report, 2011). For the last five decades in 1952-2001, annual exponential growth rates were more than 2%; however, it has been on a decreasing trend since 1971. The population growth rate was 1.35 per annum in the recent census 2011. The overall population in the latest decade has

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increased by 3,343,081 with 14.44% inter-census changes (Central Bureau of Statistics (CBS), 2012). Population density has also increased in the 2011 population census (180 persons/square km) compared to 157 in the 2001 census. Other than fertility and mortality, migration has a profound effect on the structure, composition and growth of population in the country (Haupt *et al.*, 2011; Tiwari, 2014). The net migration rate for 2011 is estimated at -10.32 per thousand populations (CBS, 2014).

When observing these changes at the district level, the fastest (61.23 percent) population growth rate was found in Kathmandu, whereas the least (-31.80 percent) was found in Manang district. Of the total 75 districts, 27 districts recorded having a negative population growth rate during the latest decade. The household size was found to be the highest (6.44 persons/household) in Rautahat district and the lowest (3.92 persons/household) in Kaski district. The sex ratio was highest (127 males/100 females) in Manang district and lowest (76 males/ 100 females) in Gulmi district. Furthermore, the highest population density was found in the Kathmandu district (4,416 persons/square km) and lowest (3 persons/square km) in Manang district (Central Bureau of Statistics (CBS), 2012).

From the above mentioned background, we hypothesized that the age-sex structure may vary by district. Therefore, the following questions were raised: Are there any differences in the age-sex structure of all 75 districts in Nepal? If the answer is yes, does every district have a distinct structure or do some of these districts follow the same pattern? Also, if some districts follow a pattern, what are the characteristics of each pattern? Indeed, exploring these questions and further understanding their answers can have many policy implications. The probability of future population growth depends mainly on current age-sex structure of the population (Population Reference Bureau, 2009). One limitation, however, is that although extensive research based on age-sex structure are available at the national level, rarely is data available at the district level. Hence, this study aimed to cluster districts based on the age-sex structure patterns and their characteristics. In order to model the variation in age-sex structure of the population, advanced statistical method called factor analysis was the most appropriate method. This method has been applied widely in different areas (Costello & Osborne, 2005) to reduce the number of outcome variables into groups, but this would be a new application in this area of interest.

2. Materials and Methods

2.1 Data source

This study analyzed the population data of Nepal from the 2011 census. The census counts, which are grouped by 5-year age gap, by sex and by districts were retrieved from table number 16 of the National Population and Housing Census 2011 (National Report) Volume 01, NPHC 2011. There are 75 districts, 20 different age groups for each sex (male and female) in the data table.

2.2 Statistical methods

This study aimed to cluster the districts by using a multivariate statistical method.The factor model starts with a numerical data array whose columns are variables and whose rows are the occasions or subjects on which the variables are measured (Manly, 1994). In our study, the districts are the variables, in the columns, and population data grouped by a 5-year age gap and by sex, placed in the rows, are the occasions or subjects. There is a total of 75 columns as outcomes and 40 rows as subjects. In proceeding with the factor analysis, the data table requires several more rows than columns. Therefore, additional rows were inserted by extending the population into single-year age. For this purpose, the natural cubic spline (McNeil *et al.*, 2011) was used to interpolate single-year ages up to 100. Spearman rank-order correlation was used to construct the 75*75 covariance matrix for handling non-linear relationships between district variables. This matrix was used while fitting the factor model.

2.3 Factor model and extraction of factors

If y_{ij} is the outcome in row i and column j of the r × c matrix data array, the factor model is formulated as

$$y_{ij} = \mu_j + \sum_{k=1}^{p} \lambda_j^{(k)} f_i^{(k)}$$

Where, μ_j is the mean of variable in columns, the p column vectors $f^{(k)}$ in this model are called common factors and the p row vectors $\lambda^{(k)}$ are called their loadings.

In this study, the factor analysis used maximum likelihood method to account for correlations between the set of outcome variables in the data matrix and extraction of appropriate number of factors (Venables and Ripley, 2002; Costello and Osborne, 2005). We decided the number of factor simply by running multiple factor analysis and setting the number of factors to be retained manually by looking at the distribution of loading and variance explained by each factor.

2.4 Factor rotation and factor loadings

Factor rotation is a way of transforming the variables to obtain a clearer pattern and interpretable result in the form of factor loadings. The factor rotation can be orthogonal or oblique. The “varimax” rotation is orthogonal and the “promax” rotation is oblique. The goodness of fit of the model is unchanged by rotating the factors (Johnson and Wichern, 1988). The only desirable element in selection of type of rotation is that the factor loading should be either close to zero or very different from zero, so that the result will be clear and interpretable (Manly, 1994). In this study, “promax” rotation provided a clearer pattern. The factor loadings, obtained from the factor analysis, were used to determine the correlation between the districts and the common factors.

The factor model also provided the "uniqueness" corresponding to each district. Uniqueness is the variance 'unique' to the variable and not shared with other variables. It is equal to 1 – communality (variance that is shared with other variables). The values close to 1 provide evidence that they cannot be associated with any factor, and, thus, should be omitted from the factor model. In this study, the uniqueness ranged from 0.005 to 0.067, so no evidence emerged to omit any districts from the factor model. Therefore, all the variables (districts) were included in the 3-factor model. Data management and analysis in this study was completed using the R statistical software (R Core Team, 2012).

3. Results

This study examined the patterns of the age-sex structures in 75 districts and clustered the districts by applying factor analysis. The result is organized under three headings: loadings from factor analysis, interpretation of the three factors and geographic variation in age-sex structure pattern.

3.1 Loadings from factor analysis

The factor loading, presented in Table 1, reflects the correlation between districts (variables) and common factors. A three factor model explained 50% of the total variation in the data of which factor 1 accounted for 24% followed by 16% and 10% respectively by factors 2 and 3. Tabachnick and Fidell, (as cited in Costello and Osborne, 2005) suggested .32 as a good rule of thumb for the minimum loading of an item, we considered 0.33 cutoff value in this study. Twenty-three, seventeen and five districts were grouped respectively to factor 1, factor 2 and factor 3 without any "crossloading" more than the cutoff value. A "crossloading" is an item that loads more than 0.33 on two or more factors. We grouped such "crossloading" items and defined as mixed factors. Twenty-seven districts were loaded on two factors and three districts were loaded on all three factors.

3.2 Interpretation of the three factors in the model

In this study, three different factors corresponded to three different age-sex structure patterns. The spline-smoothed single-year age and sex plot (Figure 1) was examined carefully and three factors were interpreted as follows. The first factor, at the first row of the graph, shows that the young age (20-40 years) male population is missing and each new cohort (less than 10 years of age) is smaller. Thus, the first factor is interpreted as "missing young adult pattern". The second factor, at the second row of the graph, shows that each new cohort is larger or just began declining and the shape represents an exponential decay. So, the second factor is interpreted as a "traditional pattern". The third factor, at the third row of the graph, shows the peak of the young adult population as well as a steep decline in the new cohorts. This factor best represents age-sex structure of the urban industrial area. Therefore, the third pattern is interpreted as an "urban pattern".

3.3 Geographic variation in the age-sex structure pattern

The information on age-sex structure pattern of all 75 districts in Nepal, explored by the factor model was further plotted in the thematic map (Figure 2) using six different colors based on the factor analysis. The thematic map again shows a clear pattern of the distribution of districts having the same patterns from the factor model. The dominant missing young adult pattern, denoted by a red color, was mainly from the Western, Central and Western Hills of Nepal. The traditional pattern, denoted by a blue color, was found mainly in the districts of central Terai and Karnali. The third pattern was found in the three districts of Kathmandu valley including Manang and Mustang. The mixed pattern of factor one and two is another dominant pattern, denoted by a violet color, found mainly in the Mid- and Far-Western regions.

4. Discussion

The study found that the age-sex structure varied by districts in Nepal, but some of the districts shared similar types of age-sex structure. Factor model clustered the districts, mainly into three groups. However, some districts

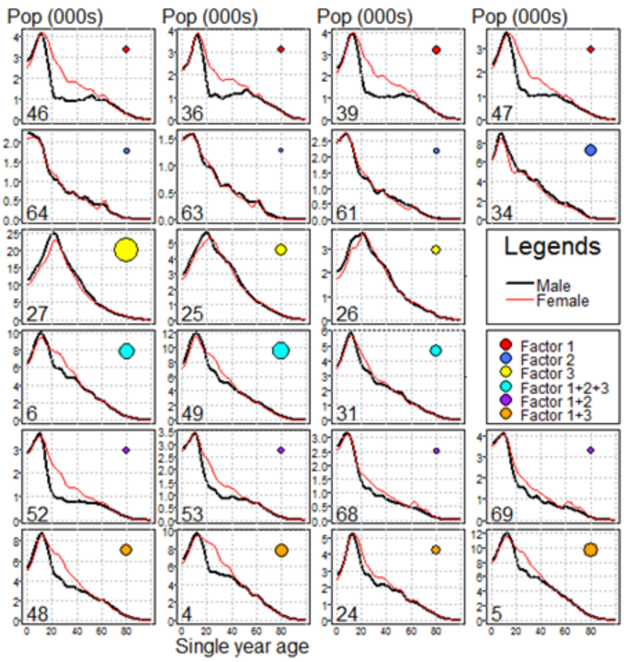

Figure 1. Spline-smoothed population distribution by single year age and sex from selected Districts in Nepal at 2011 Census
Notes: The size of each bubble indicates the population size of that specific district: The number at the bottom of each graph indicates District ID (DisID)

Table 1. Loadings obtained from three factor model for gender-age population of 75 districts at 2011 census in Nepal.

DisID	District Name	Factor1	Factor2	Factor3	DisID	District Name	Factor1	Factor2	Factor3
46	Gulmi	**0.948**			59	Surkhet	**0.352**	**0.471**	0.229
36	Gorkha	**0.905**			55	Salyan	**0.363**	**0.460**	0.229
39	Syangja	**0.899**			29	Rasuwa	**0.362**	**0.426**	0.262
37	Lamjung	**0.857**			20	Sindhuli	**0.417**	**0.419**	0.216
51	Arghakhanchi	**0.829**			24	Kavrepalanchok	**0.436**	0.210	**0.410**
44	Parbat	**0.791**			48	Nawalparasi	**0.452**	0.268	**0.336**
45	Baglung	**0.772**			4	Jhapa	**0.444**	0.231	**0.380**
47	Palpa	**0.743**			5	Morang	**0.408**	0.292	**0.356**
38	Tanahu	**0.736**			58	Bardiya	**0.403**	0.302	**0.351**
21	Ramechhap	**0.706**			40	Kaski	**0.409**		**0.543**
12	Okhaldhunga	**0.694**	0.223		35	Chitawan	**0.424**		**0.498**
22	Dolakha	**0.679**	0.209		3	Ilam	**0.406**		**0.476**
43	Myagdi	**0.678**	0.274		65	Mugu		**0.746**	
10	Bhojpur	**0.670**	0.217		66	Humla		**0.724**	
13	Khotang	**0.668**	0.247		64	Kalikot		**0.698**	
8	Terhathum	**0.654**		0.207	63	Jumla		**0.688**	
2	Panchthar	**0.606**	0.218	0.223	62	Dolpa		**0.688**	
7	Dhankuta	**0.598**		0.267	61	Jajarkot	0.215	**0.664**	
1	Taplejung	**0.531**	0.315	0.203	34	Parsa		**0.635**	0.221
30	Dhading	**0.527**	0.288	0.236	32	Rautahat	0.218	**0.629**	
28	Nuwakot	**0.480**	0.256	0.319	67	Bajura	0.291	**0.602**	
23	Sindhupalchok	**0.475**	0.312	0.265	33	Bara	0.240	**0.598**	0.208
11	Solukhumbu	**0.463**	**0.330**	0.259	19	Sarlahi	0.270	**0.575**	0.202
52	Pyuthan	**0.659**	**0.349**		60	Dailekh	0.315	**0.571**	
53	Rolpa	**0.508**	**0.431**		18	Mahottari	0.318	**0.555**	
9	Sankhuwasabha	**0.507**	**0.348**		50	Kapilvastu	0.291	**0.533**	0.225
14	Udayapur	**0.468**	**0.354**	0.230	15	Saptari	0.329	**0.527**	
56	Dang	**0.408**	**0.350**	0.297	17	Dhanusa	0.306	**0.523**	0.218
72	Kanchanpur	**0.393**	**0.364**	0.298	57	Banke	0.313	**0.437**	0.304
71	Kailali	**0.359**	**0.367**	0.329	41	Manang		0.244	**0.896**
68	Bajhang	**0.356**	**0.559**		27	Kathmandu			**0.884**
69	Achham	**0.383**	**0.541**		25	Lalitpur			**0.877**
70	Doti	**0.409**	**0.539**		42	Mustang			**0.846**
16	Siraha	**0.352**	**0.529**		26	Bhaktapur			**0.845**
75	Darchula	**0.356**	**0.519**		6	Sunsari	**0.377**	**0.330**	**0.35**
74	Baitadi	**0.407**	**0.496**		49	Rupandehi	**0.367**	**0.334**	**0.356**
54	Rukum	**0.371**	**0.487**		31	Makwanpur	**0.354**	**0.368**	**0.333**
73	Dadeldhura	**0.390**	**0.483**						

Note: - Cutoff value is >0.33, single loading >0.33 is considered as pure factors and other are associated with mixed factor
- Loadings below 0.2 are not shown and loadings that exceed 0.33 are in bold font

were found sharing two or more patterns as well. The first "missing young adult pattern" is not a usual or common pattern. A country facing high mortality due to any epidemic like HIV/AIDS in Uganda (Uganda Bureau of Statistics (UBOS) and ICF International Inc., 2012) or massive migration may have such pattern. The second, "traditional pattern", characterized by a larger new cohort, is also called "a young age population structure" and will probably experience further population growth (Abbasi-Shavazi, 2001). This pattern is common in underdeveloped countries where the child mortality and fertility rates are very high. The third pattern, having a higher proportion of young adults, is common in urban and industrialized area where young adults move for education and/or employment opportunities (Abbasi-Shavazi, 2001).

4.1 Possible reasons

As mentioned above, countries facing high mortality rates due to any epidemic or massive external migration have

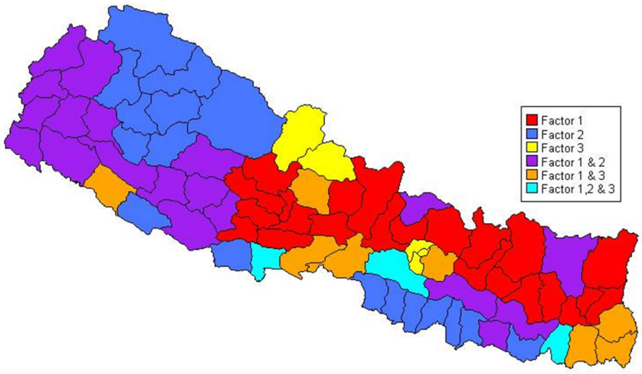

Figure 2. Thematic map of Nepal shows the regional variation in age-sex structure pattern in each district presented in colors from factor analysis for gender-age population at the 2011 census

generally a low number of young adults. However, in the context of Nepal, the higher number of female in the young adult population and smaller new cohorts, in the first pattern, can be explained possibly by underenumeration of young male adults and spousal seperation related to external migration for employment. Young males are prone to the higher rate of under-counts by the censuses.The districts such as Gulmi and Arghakhachi, grouped in first pattern, have reported missing a high proportion of their population. According to the 2011 population census in Nepal, one in every four households had reported that at least one member is living outside of the country (Central Bureau of Statistics (CBS), 2012). Furthermore, this study found that almost half of the absent population ranges specifically from 15-24 years of age. Many studies underscored that migration caused spousal separation and decreased fertility (Karki and Krishna, 2008; Ban, Karki, Shrestha and Hodgins, 2012; Agadjanian, Yabiku and Cau, 2011); this represents one important rationale for the low rates of fertility found in the first pattern.

Another traditional pattern, which is common in underdeveloped countries, was found in the districts from the poorest and most underdeveloped Mid-Western Mountain regions and Central Terai. These sub-regions have reported high fertility and high but declining child mortality over time. This may lead to growing female reproductive age population and hence increasing birth over time and tapering number with increasing age. According to Nepal Living Standard Survey 2010/11, the numbers of children per woman were found to be slightly higher (2.4) in the Mountain, Mid- and Far-Western Rural Hills and Rural Terai–Central Regions in comparison to the overall number (2.1) within the country (CBS, 2011). Similarly, TFR in Mid- and Far-Western regions were found to be higher than the total TFR (2.6) of the country in NDHS 2011 (MOHP *et al.*, 2012). According to population monograph 2014, infant and child mortality decreased significantly over time in Nepal, including these areas, but the rate is still high in these areas compared to other regions of the country. It is worth noting that the mixed pattern of missing young adults, as well as the traditional pattern, was found to be the most dominant pattern in the Mid- and Far-Western regions where young adults were absent, but, in contrary to the first pattern, each new cohort is still quite high. Labor migration is a major livelihood strategy in these areas. According to NDHS 2011, the majority of male migrants (55%) are from the Far-Western Region and head to India, followed by migrants from the Mid-Western region (31%). The migrant workers from the Eastern region, representing 46 percent followed by those from the Western region (37%), travel to countries other than India for work (MOHP *et al.*, 2012; Sherpa, 2010). Most of the migrant workers from these sub-regions migrate temporarily to India for seasonal work (Nepal, 2007). Therefore, these last migrants visit their families more often than those who work in other (more distant) countries. Unlike the first pattern, a couple separation effect on fertility trend was not observed in the districts having mixed pattern.

The urban pattern, steep decline in new cohorts and the peak of the young adult, was found in the three districts of the Kathmandu valley. Similar pattern is also found in the urban centers in the Philippines (Gultiano and Xenos, 2004) and in Thailand. Although, fertility rates are declining faster in the urban area and there is a vast difference between urban and rural fertility rates in Nepal (Gubhaju, 2007), the steep decline of new cohorts in the districts with third pattern might not necessarily be attributed entirely to the declining fertility rates. It may be, in fact, the result of the young adult population migrating from the rural to the urban areas as found in the case of the Philippines (Gultiano and Xenos, 2004). Kathmandu, the capital city of Nepal, had the highest inter census population growth in the latest decade (Central Bureau of Statistics (CBS), 2012). The rural-urban migration is selective of specific age and sex. The migrating workforce in Nepal has predominantly represented by the young male population while in the Philippines the majority are women (Gultiano and Xenos, 2004). Therefore, the third pattern could be explained by the decreasing fertility rates as well as the rural-urban migration patterns. However, the explanation is unable to satisfy the age-sex distribution pattern found in two mountainous districts Manang and Mustang.

In the light of the evidence presented in this study, we critically underscore that the changing age structure carries great variations across the one country and brings both challenges and opportunities for economic development of the country. The same program development and policy reform may not be applicable or possible within all the districts of Nepal. Therefore, the government must put in place effective policies to grasp the opportunities and handle challenges arrising from shifting and varying age-sex structure pattern in the country.

This study used a distribution free method called “Spearman rank–order” to create the correlation matrix that was used for factor analysis with maximum likelihood factor extraction methods. However, this issue needs further investigation; it is beyond the scope of this paper.

4.2 Conclusions

This study concluded that the age-sex structure in Nepal, in 2011, varied substantially between districts. The pattern in each district was approximated efficiently by using a 3-factor model. Therefore, the method used in this study is straightforward and applicable to the further demographic study. This study identified three patterns of age-sex structure. Internal and external migration, as well as the variation in declining fertility, was mainly responsible for the three different patterns of age-sex structure.

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