Estimation and Projection of Fertility in Nepal

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Abstract

The text discusses the importance of indirect estimation techniques in understanding population dynamics, particularly in countries with limited or flawed data like Nepal. Indirect methods offer valuable insights into fertility and mortality rates when direct measures are unavailable or unreliable. Techniques like Brass P/F ratio and the logistic curve function are explored for estimating fertility trends and projecting Total Fertility Rates (TFR). These methods involve meticulous analysis and adjustment for data inconsistencies. Indirect estimation plays a crucial role in bridging data gaps and informing demographic analysis and planning, especially in regions undergoing demographic transition. Through these techniques, researchers gain valuable insights into fertility dynamics, contributing to a better understanding of population trends. The text explores fertility estimation in Nepal using Arriaga's method, analyzing data from the 2011 and 2021 censuses. It reveals disparities in lifetime fertility indices, particularly after age 20, with higher rates among women aged 20-24 and 25-34, tapering towards the end of the reproductive span. Arriaga's adjustments address issues like misreporting of children's ages, aiming to rectify discrepancies and estimate the Total Fertility Rate (TFR) for both years. Additionally, the study discusses fertility projections for 2026 and 2031, highlighting the importance of trend extrapolation models and the logistic curve for accurate estimation. The findings underscore the significance of meticulous adjustments and reliable methodologies in understanding fertility dynamics in Nepal.

Keywords: fertility, national data, Arriga method, changing P/F ratio, logistic

Introduction

Indirect techniques of fertility estimation involve inferring fertility rates from other demographic indicators, such as age-specific mortality rates, household composition, or age distribution of women who have completed childbearing. These methods are particularly useful when direct measures of fertility, such as birth registrations or censuses, are unavailable or unreliable. This seminal work by William Brass provides an in-depth exploration of various indirect methods for estimating fertility and mortality rates, offering insights into their strengths, limitations, and applications. The book covers techniques such as the Brass P/F ratio, the Bogue-Palmore method, and the Trussell-Wilson method, among others. It serves as a foundational reference for demographers and researchers seeking to understand and apply indirect estimation techniques in demographic analysis (Moultrie, et al., 2013).

Insufficient and inaccurate data limit our understanding of the country's population dynamics. For example, birthrate decline in Nepal has been tried and tested, and several studies have produced conflicting results from DHS and national census data. Similar fertility debates arise with data from developing countries. Inaccurate information leads to incorrect population development forecasting and planning, as outcome-based decisions can be compromised. As a result, indirect estimates of demographic parameters have been very useful in developing countries. This is because its application to census and survey data has greatly expanded our knowledge of the demographic situation in data-poor countries (Brass, 1996).

Insufficient and flawed data pose significant challenges to understanding population dynamics within a country. In Nepal, for example, the decline in fertility has been subject to scrutiny, with conflicting conclusions drawn from studies utilizing data from sources like the Demographic and Health Surveys (DHS) and national census data. Such inaccuracies lead to flawed population forecasts and compromised planning efforts based on erroneous information. Consequently, indirect estimation of demographic parameters has emerged as a valuable tool in developing countries, enriching our understanding of demographic trends despite data deficiencies (Brass, 1996).

Fertility, being intricately tied to socioeconomic development and population health, demands accurate estimation of its levels and trends. Traditional procedures utilize census or survey data, capturing information about women's ages, their total children ever born, and those born in the year preceding the census or survey. Techniques dating back to the 1940s by Grabill (1941), Mortara (1949), Henry (1970), and Arriaga and Iversen (1999). have laid the groundwork for such estimations. However, challenges arise due to underreporting, particularly with longer recall lapses where women may fail to report children due to various reasons like not living with them or their deaths (Potter, 1977). The accuracy of fertility measurement is influenced by factors like the age structure of women and the shape of age-specific fertility curves (Brass, 1964). Given the poor quality of data, indirect estimation techniques become essential in Nepal, with various methods developed to address incomplete and defective data. William Brass is recognized as the "intellectual father of indirect estimation," underscoring his contributions to this field (Coale and Trussell, 1996). The objective of indirect demographic techniques is to identify and minimize sources of error through meticulous analysis of models and hypotheses, bringing order and consistency to what would otherwise be a collection of errors (UN, 1983).

Despite the availability of census data spanning from 1961 to 2021, inconsistencies in trends highlighted by Myre's, Whipple's, and the UN age-sex accuracy index prompted the adoption of indirect techniques in this study. This underscores the potential discrepancies between census data and real-world scenarios, emphasizing the importance of indirect estimation. To address the gaps in fertility data, this research employs estimation and projection techniques. According to the 2021 Demographic Health Survey, variations in birth intervals exist, and the Total Fertility Rate (TFR) stands at 2.1 children per woman, with higher rates observed at the provincial level among different caste/ethnic groups (Ministry of Health, 2023). Given these disparities, the application of estimation and projection of fertility becomes essential for bridging these gaps and comprehending fertility dynamics in Nepal.

Study Objectives

To accomplish its goals, the study pursued the following specific objectives:

- To estimate and compare fertility levels and trends in Nepal
- To validate the logistic curve function through fertility projection

Methodology

Arriaga's fertility estimation technique revolutionized previous methods by eliminating the assumption of constant fertility, offering a more flexible and reliable approach. Unlike traditional methods, Arriaga's technique employs a simulation model to track changes in the number of children ever born linearly for mothers under 35 years old during fertility decline. By interpolating data from multiple censuses, it estimates children born around census dates without assuming constant fertility, thus providing age-specific fertility rates.

This technique assumes consistent birth recording, accurate reporting of children ever born for younger women, and no age misreporting among women of childbearing age. It utilizes factors (Zi factors) to assess data consistency, with factors close to one indicating reliability. Adjustments are unnecessary when comparing children ever born with cumulative fertility patterns. It can also be applied with single-date data, assuming constant fertility, but accuracy relies on data quality and meticulous analysis.Arriaga's method employs polynomial graduation, linear interpolation, and adjustments for older ages to ensure monotonically decreasing age-specific fertility rates. It calculates fertility rates for conventional age groups, even with data available for a single point in time, albeit under the assumption of constant fertility (Devkota, 2021).

In summary, Arriaga's technique offers a comprehensive solution for estimating fertility rates, accommodating changing fertility patterns and data quality considerations. Its flexibility and reliability make it a valuable tool for demographic analysis, contributing to a better understanding of fertility dynamics, especially in evolving contexts.

The Brass P/F ratio changing method, conceptualized by William Brass and refined by other demographers, offers a novel approach to adjust age patterns of fertility without relying on constant fertility assumptions. This method utilizes the ratio of lifetime fertility to cumulative fertility, acknowledging the relationship between the total number of children ever born and the fertility experience of a cohort. By assessing average parities and age-specific fertility rates, it provides a means to estimate recent fertility accurately. However, challenges arise, particularly in less developed countries, due to high levels of illiteracy and inaccuracies in reporting births, especially for older women. Despite these limitations, the Brass P/F ratio method remains valuable, particularly in countries with poor data quality. The methodological procedure involves several steps, including the calculation of reported average parities from each survey, determining parity increments based on inter-survey intervals, and estimating age-specific fertility rates for the inter-survey period (Devkota, 2022). Cumulated fertility for a hypothetical inter-survey cohort and average parity equivalent are then calculated. Finally, adjusted inter-survey age-specific fertility rates for conventional age groups are determined, culminating in the calculation of Total Fertility Rate (TFR). Through this method, researchers can obtain reliable estimates of recent fertility trends, providing valuable insights into demographic dynamics, particularly in contexts with evolving fertility patterns and data limitations.

The logistic function, named after Pierre François Verhulst in the mid-19th century, depicts an S-shaped growth pattern, modeling various population dynamics. Initially formulated to describe population growth, it considers reproduction rates in relation to available resources. Verhulst developed this equation, influenced by Thomas Malthus' theories, to capture self-limiting growth observed in demographic processes like marriage, fertility, mortality, and migration. Widely applied in diverse fields, the logistic function's sigmoid curve illustrates diffusion processes and is characterized by the equation $f(x) = 1 / (1 + e^{(-x)})$. Its derivative's ease of computation enhances its utility across artificial neural networks, biology, economics, and more. In demography, the logistic model aids in forecasting Total Fertility Rates (TFR) for national populations (Pearl & Reed, 1920). By complementing TFR with the logistic curve's lower bound, this method ensures that changes in national TFR translate proportionally to regional TFR, facilitating alignment between projected national and regional fertility rates. This approach guarantees consistency and accuracy in fertility projections for demographic analysis and planning.

Result

1.1 Estimation of fertility Arriaga method at national level, 2011

Arriaga's method was applied to assess current and lifetime fertility in Nepal using data from the 2011 and 2021 censuses (Table 2.1). Notably, significant differences in lifetime fertility indices, such as the number of children ever born and Age-Specific Fertility Rates (ASFR), emerged after age 20, with women aged 20-24 and 25-34 exhibiting higher fertility rates. This pattern mirrors trends observed among younger women in developing countries. However, fertility rates decline towards the end of the reproductive period, suggesting that the average Nepalese woman may have around three children by the end of her reproductive years.

Concerns about misreporting of children's ages among older women may lead to fluctuations in fertility patterns. Nonetheless, Arriaga's method allows for adjustments to match fertility levels inferred from fertility rates derived from data on children ever born. This approach eliminates the need for additional adjustments when comparing children ever born with cumulative fertility patterns, ensuring consistency between the two sets of data. Arriaga's technique remains applicable even when data on average children ever born and fertility patterns are available for only one date, assuming constant past fertility levels. However, reliance solely on children ever born data increases sensitivity to errors. Assumptions regarding consistent accuracy in recording births and precise reporting of children ever born for women under 30 or 35 underscore potential discrepancies between reported and actual fertility levels (Devkota, 2022). Comparison of data from the 2011 and 2021 censuses indicates slight changes in fertility, highlighting the dynamic nature of fertility trends and the need for robust estimation techniques like Arriaga's method.

Table 1: Estimation of ASFR based on 2011 census at national level

Age	ASFR from CEB	Cum. ASFR	ASFR Pattern	Cum. ASFR pattern	Adj factors	Adj. Fertility f*
15-19	0.060	0.060	0.028	0.028	2.177	0.0522
20-24	0.179	0.240	0.096	0.124	1.932	0.1814
25-29	0.142	0.382	0.079	0.203	1.884	0.1483
30-34	0.082	0.464	0.043	0.246	1.888	0.0811
35-39	0.040	0.504	0.023	0.269	1.873	0.0436
40-44	0.017	0.521	0.010	0.279	1.864	0.0197
45-49	0.006	0.526	0.003	0.283	1.862	0.0062
TFR						**2.631**

Source: Census, 2011 and 2021.

This study is centered on the Children Ever Born (CEB) data, categorized by the reproductive age groups of women at the national level, using the datasets from the 2011 and 2021 censuses. In Table 1, the data is structured according to specific age groups of women in their reproductive years at the national level for the 2011 census. The adjusted values were derived based on cumulative Age-Specific Fertility Rates (ASFR) and the cumulative ASFR pattern. These adjusted values show a declining trend as the age group increases. The adjusting factor of P_2/F_2 values (1.932) has resulted adjusted ASFR for all age group and the adjusted TFR value was 2.631 in February 2011. The mean age of childbearing was 27.2 years.

1.2 Estimation of fertility Arriaga method at national level, 2021

Fertility analyses typically focus on women aged 15-49 years, but extending age limits for fertility and childhood mortality questions has benefits. The 2011 and 2021 censuses included women aged twelve years or older for total live births and women aged 12-14 or fifty for births in the last twelve months. This reduces potential bias from excluding women close to conventional age limits. Tabulating current births revealed some women reporting up to nine births in twelve months, biologically implausible except for multiple births. The objective is to analyze children ever born (CEB) and current births reported by women of reproductive age, assuming recent fertility changes and uncorrelated errors in current birth data with mother's age. Arriaga (1983) demonstrated how the P/F ratio method can estimate changing fertility using data from the 2021 census.

Table 2: Estimation of ASFR based on 2021 census at national level

Age	ASFR from CEB	Cum. ASFR	ASFR Pattern	Cum. ASFR pattern	Adj factors	Adj. Fertility f*
15-19	0.055	0.055	0.031	0.031	1.780	0.0432
20-24	0.150	0.205	0.106	0.137	1.498	0.1479
25-29	0.114	0.318	0.089	0.226	1.411	0.1245
30-34	0.068	0.387	0.051	0.276	1.398	0.0711
35-39	0.017	0.404	0.022	0.298	1.354	0.0306
40-44	-0.003	0.401	0.009	0.307	1.307	0.0122
45-49	-0.001	0.400	0.004	0.311	1.286	0.0057
TFR						**2.001**

Source: Census, 2011 and 2021.

Table 2 presents age-specific data for women of reproductive age in Province 1 during the 2011 census, with adjusted values derived from cumulative ASFR patterns. Adjustments resulted in decreasing trends with age group increases, using a P2/F2 factor of 1.498. The adjusted TFR for June 2021 was 2.001, with a mean childbearing age of 27.01 years. Reported births prior to the 2011 census suggested an average of around 3 children per Nepali woman at the end of her reproductive years, lower than CEB data implied. Arriaga's method revealed significant fertility data discrepancies between the 2011 and 2021 censuses, raising concerns about the reported TFR. Adjustments based on younger age groups suggested more reliable fertility reporting among women in their 20s, emphasizing the need for accurate fertility estimates.

1.3 Comparison period Fertility average parities for hypothetical cohort at national level

When fertility patterns shift over time, expecting perfect alignment between cumulative period fertility rates and lifetime fertility is unrealistic. Adjusting these sets of data with an adjustment factor can address errors and changes' effects, but may obscure these impacts. Calculating period-specific average parities and comparing them with cumulated fertility rates for the same period is proposed. This involves using children ever born data from two surveys to determine average parities for a hypothetical cohort experiencing inter-survey fertility levels. Assumptions include minimal impact from mortality and migration on actual parity distributions. Average inter-survey fertility rates can be calculated by dividing births by woman-years lived, or approximated by averaging rates at the period's start and end. Adjustments ensure consistency if fertility rates are based on age groups shifted by six months. This pragmatic approach offers valuable insights into demographic dynamics amid changing fertility patterns.

Table 3a: Estimation of ASFR based on inter -survey cohort at national level

Age	2011P (i)	2021P(i)	Δ P(i)	P(i,s)	2011 f(i)	2021 f(i)
15-19	0.0804	0.0737	0.0737	0.0737	0.0231	0.0253
20-24	0.7578	0.6607	0.6607	0.6607	0.0937	0.1026
25-29	1.7225	1.4376	1.3572	1.4309	0.0810	0.0916
30-34	2.4438	2.0509	1.2931	1.9538	0.0450	0.0540

35-39	2.9562	2.4769	0.7544	2.1854	0.0243	0.0234
40-44	3.3398	2.7094	0.2656	2.2194	0.0112	0.0089
45-49	3.5827	2.8941	-0.0621	2.1232	0.0044	0.0054

Source: Census, 2011 and 2021.

Table 3b: Estimation of ASFR based on inter -survey cohort at national level

Age	**f(i)**	**□ (i)**	**F(i)**	**K**	**f+**	**f*(i)**
15-19	0.0242	0.1210	0.0330	2.231	0.0316	0.058
20-24	0.0981	0.6116	0.3581	1.845	0.1011	0.167
25-29	0.0863	1.0431	0.8402	1.703	0.0825	0.152
30-34	0.0495	1.2905	1.1792	1.657	0.0461	0.085
35-39	0.0239	1.4098	1.3554	1.612	0.0223	0.041
40-44	0.0100	1.4600	1.4295	1.553	0.0095	0.018
45-49	0.0049	1.4845	1.4769	1.438	0.0038	0.007
TFR						**2.439**

Source: Census, 2011 and 2021.

The national average reported parity, P(i, s) was calculated based on the average parity reported in the 2011 and 2021 censuses. The ASFR periods f(i) are taken from the 2011 Census and 2021 ASFR data sheets. It is based on the mean variance estimate and tracks the variance of the parity method calculated using manual procedure X in the P(i,s)/F(i) ratio. The total number of birth registrations from 2011 to 2021 was added to estimate the birth registration correction coefficient (K) and the reciprocal of the full birth registration estimate (1/K). Countable Nepal. It is the unadjusted ASFR multiplied by K. An adjusted value of 1,845 was estimated based on 2011 and 2021 census data (Tables 3a and 3b). Finally, the national adjusted TFR was 2.6 in August 2016.

1.4 Projection of fertility at national level, 2021 (Reference date June 2021)

The Total Fertility Rate (TFR) aggregates age-specific fertility rates across all age groups, providing an impartial measure of population fertility. Utilizing data from the 2011 census and other sources, the direct technique of the 2021 census reports a TFR of 2.001, aligning with Arriaga's method, estimating the same TFR with a June 2021 reference date. Projection methods, like trend extrapolation models, anticipate future growth by analyzing historical trends, acknowledging the demographic transition's pace. Despite variance in reference periods, the logistic curve function and Arriaga's method consistently yield a TFR of 2.001, validating the projection's reliability for 2026 and 2031. Parameters and TFR values from both methods remain identical, affirming the logistic curve method's validity in fertility projection.

1.5 Projection of fertility national level in 2031

Population projections are crucial for anticipating future changes in population size and characteristics, relying heavily on past data. Accuracy is paramount, necessitating rigorous assessment and adjustment of data quality and assumptions. The logistic curve is often used to model these assumptions due to its appropriateness. While projections offer valuable insigmhts, they are often based on current data lacking the detail necessary for effective planning. Age-specific fertility rates provide finer granularity, aiding in controlling bias introduced by fertility variations. Trend extrapolation models project future trends by considering historical growth patterns, recognizing the demographic transition's phases. The logistic curve, favored for its empirical and logical soundness, aligns projected trends with past ones effectively.

Fertility, a key population driver, is encapsulated by the Total Fertility Rate (TFR), representing the average number of children a woman would bear. For 2026 and 2031, TFR values of 1.76 and 1.61 are estimated using linear interpolation, derived from NDHS survey data preceding census years. This research adopts a point estimation approach with medium variant interpolation for precise projections. These projections inform development planning, highlighting the importance of accurate fertility estimations and appropriate projection methodologies.

Conclusion

The text delves into fertility rate estimation in Nepal using Arriaga's method, employing data from the 2011 and 2021 censuses. It notes significant differences in lifetime fertility indices in Nepal, particularly after age 20, with higher rates observed among women aged 20-24 and 25-34, tapering towards the end of the reproductive span, suggesting an average of three births per woman by the conclusion of their reproductive years. Addressing issues like misreporting of children's ages, it stresses consistent recording of births across age groups. Arriaga's adjustments aim to rectify these discrepancies and estimate the Total Fertility Rate (TFR) for 2011 and 2021. Additionally, the text discusses fertility projections for 2026 and 2031, underlining the significance of trend extrapolation models and the logistic curve for accurate estimation. It concludes by emphasizing the methods used for fertility rate estimation in Nepal, including adjustments for data inconsistencies and projections based on historical trends and demographic transition.

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