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Beyond Education and Contraceptive Use: Do Caste, Ethnicity, and Religion Influence Fertility Behaviour in Nepal? Evidence from Six Rounds of DHS

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Abstract

Background: Nepal has experienced a substantial decline in fertility over the past three decades; however, notable heterogeneity persists across sociocultural groups. This study examines how constitutionally defined caste, ethnicity, and religion shape fertility behaviour after accounting for education, wealth, and structural determinants. By applying a repeated cross-sectional framework, the study provides new evidence on long-term patterns and shifting trajectories across population subgroups.

Methods: The study analysed data from six rounds of the Nepal Demographic and Health Survey (1996-2022), comprising currently married women aged 15-49. Separate analyses (individual period and pooled) were done for lifetime (15-49 years) and completed (40-49) fertility. A survey-adjusted Poisson regression model was used to estimate associations with the number of children ever born (CEB). Duration since marriage was included as the exposure variable to account for variation in reproductive risk time. A pooled interaction model (caste/ethnicity x survey year) assessed temporal changes in sociocultural fertility differentials.

Results: Women's educational attainment was the strongest and most consistent predictor of lower fertility, with women aged 40-49 with post-secondary education having substantially lower expected CEB than those with no schooling. Among women aged 15-49, wealth, met need for contraception, and urban residence were also associated with reduced fertility. Sociocultural differentials persisted after adjustment: Muslim women had higher expected CEB than Arya women across most survey years; Madheshi women exhibited rising fertility relative to Arya women in interaction models; Janjati women showed accelerated fertility decline; and the pooled effect for Dalit women was not statistically significant.

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Conclusion: Fertility heterogeneity in Nepal reflects the combined influence of sociocultural identity and structural conditions. While education is the key driver of fertility reduction, persistent differences among Muslim and Madheshi communities indicate the need for culturally tailored reproductive health strategies. Policies should prioritise universal completion of secondary education for girls, as well as equity-focused empowerment and family planning initiatives to address remaining disparities.

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Background

Fertility, mortality, and migration are the principal drivers of demographic change, with fertility widely recognised as the dominant force shaping population growth, structure, and composition (Croix 2013). Historically, reproduction increased when resources were abundant; before the Industrial Revolution, higher-income households typically had more surviving children than poorer ones (Clark 2007; Malthus 1966). With sustained economic development, many countries transitioned from high to low fertility (Galor 2011). Today, wealthier and more educated households generally have fewer children than those with fewer resources (Kc et al. 2018; Skirbekk 2008). This study focuses on fertility and its heterogeneity, defined as multiple trajectories within a cohort of women (Keskin and Çavlin 2022).

Research on fertility decline in low- and middle-income settings highlights the role of socio-economic development and family planning programmes (DaVanzo and Adamson 1998; Götmark and Andersson 2020; Prosser et al. 2005; Zakiyah et al. 2016). Many South Asian and sub-Saharan African countries have experienced rapid declines in fertility (Bongaarts 2020; Corker, Rossier, and Zan 2022; Ghosh 2017). Nepal, a Lower-Middle-Income Country (WB 2017), reduced its total fertility rate from 6.3 children per woman in 1981 (Pradhan et al. 1997) to replacement level (2.1) in 2022 (Ministry of Health and Population Nepal, New ERA, and ICF 2023).

However, this aggregate success makes a critical policy concern: “significant and ‘undesirable’ inequalities” in reproductive outcomes among marginalised groups, for example, The Nepal Demographic and Health Survey (NDHS) 2022 shows higher fertility among Muslim women and lower fertility among Janajati groups, with variation among

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Madheshi and Dalit populations Previous research in Nepal has primarily focused on proximate determinants of fertility, such as marriage patterns, contraceptive use, postpartum infecundability, and induced abortion using aggregate modelling (Bongaarts 1987, 2015; Karki and Krishna 2008; Thapa 1987). Such models often fail to capture the persistent heterogeneity shaped by caste, ethnicity, and religion, which remain fundamental to Nepal's social stratification (Bennett, Dahal, and Govindasamy 2008; Gudbrandsen 2013; Pandey et al. 2013).

Integrating insights from Demographic Transition and Social Capital theories, this study addresses the limited evidence on long-term fertility heterogeneity across Nepal's educational and sociocultural groups. Whereas most existing research provides only cross-sectional snapshots, our analysis identifies shifting trends and long-term associations by analysing pooled data from six rounds of the NDHS (1996-2022). By examining both lifetime fertility (ages 15-49) and completed fertility (ages 40-49), we assess whether sociocultural identity continues to exert an independent influence on fertility behaviour as educational diffusion and contraceptive use become increasingly widespread. This analysis is vital for demographers and policymakers seeking to promote equitable development and design targeted reproductive health interventions in a post-transitional society.

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Conceptual Framework

The conceptual framework is grounded in an extensive literature review and is designed to move beyond descriptive associations to address the structural and cultural drivers of fertility heterogeneity in Nepal. Previous research demonstrates that women's fertility behaviour is shaped by a wide range of interrelated factors, including age, age at first marriage, marital status, caste/ethnicity, place of residence, household wealth, educational

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attainment, and contraceptive use (Adhikari 2010; Bongaarts 1987; Bongaarts and Hodgson 2022; Bora et al. 2022; Forty, Navaneetham, and Letamo 2022; Lutz, Skirbekk, and Kabat 2013; Rasul et al. 2022; Snopkowski et al. 2016; Uddin et al. 2016; Wilkins 2019). Drawing on this evidence, the framework integrates Demographic Transition Theory and Social Capital Theory to explain how sociocultural identities generate distinct fertility trajectories in the Nepali context.

Education is conceptualised as a central catalyst in this framework, influencing social norms, expanding women's empowerment and alerting to the opportunity costs of childbearing. The conceptual framework visualises the dynamic interplay among these structural, intermediate, and proximate determinants, illustrating their collective influence on fertility outcomes (

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Figure 1).

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Figure 1 Conceptual Framework for the determinants of fertility heterogeneity in Nepal

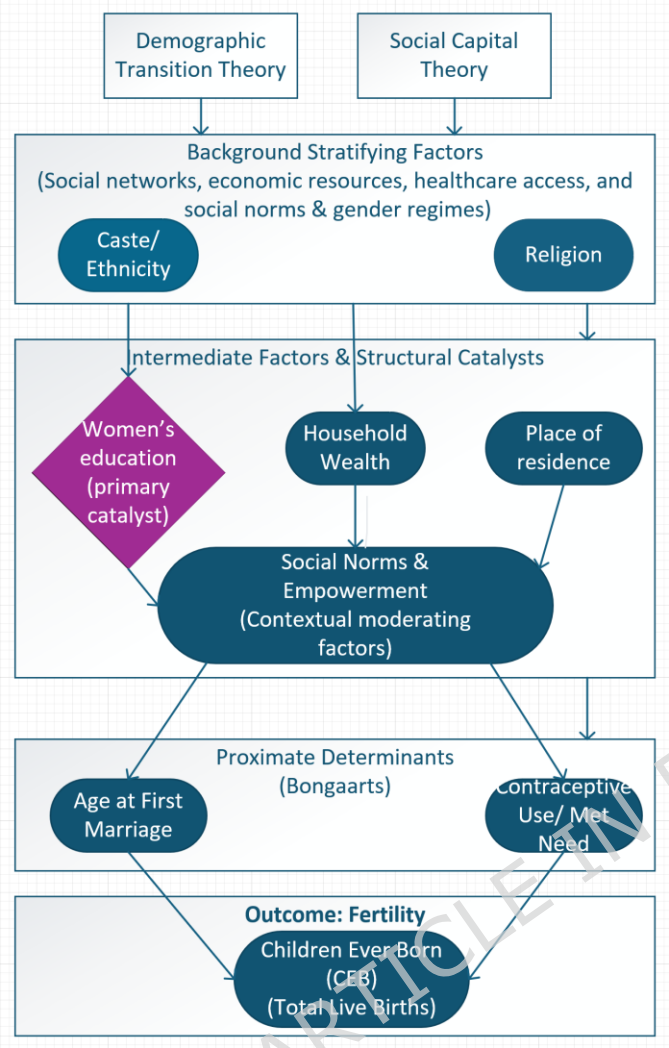

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Figure 1 illustrates the conceptual framework guiding this study. The model is structured across three hierarchical levels. At the upstream level, caste/ethnicity and religion function as background stratifying factors that shape women's access to social networks, economic resources and healthcare. These structural positions influence intermediate factors, including educational attainment, household wealth, place of residence, social norms and women's empowerment. Education operates as the primary catalyst within this layer, affecting human capital, reproductive autonomy and the opportunity costs of childbearing. The proximate determinants - age at first marriage and contraceptive use – represent the most immediate influences on fertility behaviour. Together, these pathways lead to the fertility outcome, measured as Children Ever Born (CEB). The framework conceptualises how sociocultural identity interacts with structural and proximate factors to produce long-term fertility heterogeneity in Nepal.

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Methods and Materials

Study design, data sources, and study population

The study employed a repeated cross-sectional design using pooled data from six rounds of the Nepal Demographic and Health Survey (NDHS) conducted in 1996, 2001, 2006, 2011, 2016, and 2022. A repeated cross-sectional rather than cohort design was adopted because the NDHS does not follow the same women over time. This design is well-suited for tracking population-level fertility trends across successive survey rounds; however, it limits causal inference, as unobserved time-invariant characteristics of individuals cannot be controlled in the same way as in longitudinal data (Levin and Fox 2013).

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All six NDHS rounds employed a stratified, multi-stage cluster random sampling design, providing nationally representative data on fertility and reproductive health. The sampling frame for each round was derived from the Population and Housing Census of Nepal conducted immediately prior to that survey: the 1996 and 2001 NDHS rounds used census frames derived from the 1991 census, while the 2006 and 2011 NDHS rounds used the 2001 census frame. The 2016 and 2022 NDHS rounds were based on the 2011 census frame.

Minor adjustments in stratum boundaries and cluster definitions were made across rounds to reflect administrative changes, including Nepal's federal restructuring in 2015. All six available rounds were included in the analysis; no rounds were excluded. No special harmonisation of sampling frames was required for the pooled dataset, as survey-provided design variables – strata- primary sampling units (PSUs), and individual-level sampling weights – were applied independently for each round via Stata's svyset command. This approach ensured appropriate variance estimation and weighting when analysing the combined dataset.

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Full details of the sample design and survey methodology for each round are available on the Demographic and Health Survey (DHS) program's official website (http://dhsprogram.com). Individual-level datasets are publicly available from the DHS data repository and can be accessed upon request (DHS 2022).

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Table 1 presents the sample sizes for each NDHS round implemented in Nepal.

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Table 1 Sample coverage of the Nepal Demographic Health Survey (NDHS) in 1996-2022[1]

Survey Year	Number of Households	Ever Married		Sample Cluster			Field Work
		Women	Men	Urban	Rural	Total	
1996	8,082	8,429	None	34	219	253	Jan 1996 – Jun 1996
2001	8,602	8,726	2,261	42	209	251	Jan 2001 – Jun 2001
2006	8,707	8,640	2,634	82	178	260	Feb 2006 – Aug 2006
2011	10,826	9,837	2,677	95	194	289	Jan 2011 – Jun 2011
2016	11,040	10,236	2,722	140	243	383	June 2016 – Jan 2017
2022	13,786	11,722	3,234	248	228	476	Jan 2022 – Jun 2022
Total	61,043	57,590	13,528	641	1,271	1,912	
Notes: Data are from Survey Summary, Nepal: Standard DHS 1996, 2001, 2006, 2011, 2016, and 2022.							

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Study population

The primary analysis was restricted to currently married women aged 15-49 years to ensure comparability in exposure to marital fertility risk. In Nepal, childbearing occurs almost exclusively within marriage, making currently married women the analytically appropriate population for the study of marital fertility (Bongaarts 1987). In addition, the Poisson rate framework applied in this study – with duration since first marriage specified as the exposure variable – is conceptually valid only for women who are currently married. Consequently, never-married and formerly married women were excluded from the analysis (n=13,302), representing 18.8% of all women of reproductive age in the pooled dataset. This exclusion does not affect estimates of marital fertility differentials, which are the primary

[1] Household numbers are from survey documentation, not the analytical sample. All six rounds of the NDHS were included in the analysis.

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focus of the study. However, it may limit generalisability to the relatively small volume of non-marital fertility in Nepal.

After applying these restrictions, the pooled analytical sample comprised 55,243 currently married women aged 15-49 years. Completed fertility was examined separately among currently married women aged 40-49 years (n = 11,958) to capture cohort-level reproductive outcomes among women who had largely completed their childbearing. **Table 2** provides the sample selection for the study population.

Table 2 Sample Selection of Study Population

Age Group	1996	2001	2006	2011	2016	2022	Total
All Women of Reproductive Age							
15-19	2,229	2,335	2,437	2,753	2,598	2,643	14,995
20-24	1,909	2,001	1,995	2,297	2,251	2,637	13,090
25-29	1,671	1,744	1,773	2,101	2,135	2,435	11,859
30-34	1,387	1,464	1,336	1,734	1,806	2,144	9,871
35-39	1,136	1,191	1,220	1,557	1,572	2,025	8,701
40-44	933	1,042	1,121	1,285	1,388	1,629	7,397
45-49	836	849	912	947	1,113	1,332	5,988
Total	10,101	10,626	10,793	12,674	12,862	14,845	70,901
Ever-Married Women							
15-19	982	941	787	797	714	571	4,791
20-24	1,626	1,658	1,637	1,778	1,702	1,812	10,214
25-29	1,594	1,666	1,696	1,954	1,988	2,237	11,135
30-34	1,361	1,427	1,314	1,698	1,762	2,092	9,656
35-39	1,119	1,168	1,202	1,535	1,560	1,999	8,582
40-44	923	1,030	1,107	1,269	1,369	1,616	7,314
45-49	824	837	900	934	1,098	1,314	5,907
Total	8,429	8,726	8,644	9,966	10,193	11,642	57,599
Currently Married Women (Analytical Sample)							
15-19	965	930	784	792	704	563	4,738
20-24	1,602	1,643	1,606	1,761	1,684	1,783	10,079
25-29	1,560	1,625	1,664	1,914	1,957	2,198	10,917
30-34	1,292	1,377	1,265	1,659	1,726	2,027	9,345
35-39	1,042	1,099	1,135	1,461	1,510	1,906	8,152
40-44	828	936	1,016	1,190	1,283	1,515	6,767
45-49	695	732	788	832	1,011	1,188	5,246

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Total	7,982	8,342	8,257	9,608	9,875	11,180	55,243

Ethical Considerations

The NDHS protocols were approved by the Nepal Health Research Council (NHRC) (Ref. #678: 494/2021) (Acharya, Sharma, and Bietsch 2024) and by the ICF Institutional Review Board. Written informed consent was obtained from all participants before household and individual interviews. This study used anonymised secondary data accessed with permission from the DHS Program. No additional ethics approval required for the pooled analysis, consistent with DHS data-use terms that explicitly permit secondary analysis of de-identified pooled datasets for non-commercial research purposes.

Study Variables

Outcome Variable

The primary outcome variable was Children Ever Born (CEB), defined as the total number of live births reported by a woman at the time of survey. CEB is a discrete count variable representing cumulative fertility. CEB was selected over period-specific fertility measures for three reasons: (i) CEB captures cumulative reproductive history, which is appropriate for studying structural influences of caste/ethnicity and education over the life course; (ii) modelling CEB as a Poisson rate with duration since first marriage as the exposure converts it into a fertility rate per unit of marital exposure time, thereby adjusting for heterogeneity in marriage duration; and (iii) period measures based on recent births are more susceptible to recall truncation and seasonality effects in multi-round analyses. A recognised limitation is potential recall bias for older women (aged 40-49) whose births span 20-30 years. The NDHS mitigates this through detailed birth history modules and internal consistency checks,

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but some under-reporting of early or deceased births cannot be fully excluded. Two fertility measures were examined (Kanteh and Palamuleni 2019):

- Lifetime fertility of currently married women aged 15-49, and
- Completed fertility from currently married women aged 40-49.

Exposure variable

Duration since first marriage (years from age at first marriage to age at survey) was included as the exposure variable in all Poisson regression models, constructed as: duration marriage = current age – age at first marriage. Duration since first marriage was preferred over current age for two reasons: (i) it directly measures the period of marital exposure to the risk of childbearing, which is the relevant risk time in the Poisson rate framework; and (ii) current age confounds pre-marital and post-marital periods, producing biased rate estimates for late-marrying women. Women with zero duration (newly married in the same survey month; n = 1254; 2.3% of currently married women) were assigned 0.5 years to prevent undefined values in the log offset term (ln[0] = ∞), following established practice in marital fertility rate modelling (Ariho, Kabagenyi, and Nzabona 2018). The offset was therefore ln(duration since marriage), where duration marriage ≥ 0.5 years for all observations. Sensitivity models excluding women with zero-duration and years of reproductive age produced materially identical results.

Predictor Variables

All predictor variables were harmonised across survey rounds to ensure comparability. The demographic, socio-economic and sociocultural factors considered as predictors in this study include (a) age of respondents, (b) age at first marriage, (c) place of residence, (d) caste/ethnicity, (e) educational attainment, (f) household wealth status, (g) unmet need of

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family planning and (h) women's empowerment. These variables were selected based on a comprehensive review of the fertility literature (Samad et al. 2022; Shakya and Gubhaju 2016; Watkins 1987) and their hypothesised association with CEB, as well as demonstrated significance in previous studies (Adhikari 2010; Angko, Arthur, and Yussif 2022; Bora et al. 2022; Forty et al. 2022; Karki and Krishna 2008). Variable categories follow established demographic conventions and prior research practice; several variables were regrouped from their original NDHS classifications to enhance analytical meaning and comparability across survey rounds. Table 3 presents the availability of variables across survey rounds.

Table 3: Variable Availability Across Survey Rounds

Variables	1996	2001	2006	2011	2016	2022
CEB	√	√	√	√	√	√
Age of respondent	√	√	√	√	√	√
Age at first marriage	√	√	√	√	√	√
Place of residence	√	√	√	√	√	√
Caste/ethnicity	√	√	√	√	√	√
Educational attainment	√	√	√	√	√	√
Household wealth status	√	√	√	√	√	√
Unmet need for family planning	√	√	√	√	√	√
Marital status	√	√	√	√	√	√
Women's empowerment	√	√	√	√	√	√
a) Decides alone on own health care	-	√	√	√	√	√
b) Decides alone on major household purchases	-	√	√	√	√	√

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c) Controls use of own earnings	√	√	√	√	√	√
d) Decision-making for spending husband's earnings	-	-	√	√	√	√
e) Can visit family/friends alone	-	√	√	√	√	√
f) Participates in contraceptive decisions	-	√	√	√	√	√
g) Can refuse sex to husband	-	-	-	√	√	√

The following paragraph summarises the categorisation of the study variables.

- Age at first marriage: Categorised as ≤ 19 years and ≥ 20 Years, consistent with demographic definitions of adolescent marriage and national policy standards.
- Place of residence: Rural (reference) versus urban, following the NDHS classification for each survey year.
- Caste/ethnicity: Caste/ethnicity categories were harmonised to five analytical groups consistent with the Constitution of Nepal (GON 2015): Khas/Arya (Brahmin/ Chhetri/ Thakuri; reference), Janajati (indigenous nationalities; (NFDIN 2002), Madheshi (Terai communities; (Madheshi Commission 2022), Dalit (scheduled castes; (NDC 2017), and Muslim. Women self-identifying as Muslim were coded to the Muslim category regardless of their primary ethnic classification in earlier rounds. A detailed crosswalk mapping NDHS subcategories to these five groups across all six rounds is presented in Supplementary Table S2. A detailed crosswalk mapping NDHS

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subcategories to these five groups across all rounds is presented in Supplementary Table S1.

- Religion: Recoded as Hindu (reference) versus non-Hindu, given small counts for minority religions
- Educational attainment: Harmonised using the International Standard Classification of Education ISCED 2011 (UNESCO 2012) framework and categorised into six groups: no education, incomplete primary, primary, lower secondary, upper secondary, and post-secondary. All categories were derived from the educational attainment and years of schooling variables in the NDHS datasets, ensuring comparability across survey rounds despite changes in the education system. All mappings were verified against the NDHS recode manuals.
- Household wealth index: The NDHS wealth quintiles are constructed separately for each survey round via principal component analysis of household assets, meaning quintile thresholds are round-specific and not directly comparable in absolute terms across survey years. Round-specific quintiles appropriately capture relative economic position, with each round's population distribution. For pooled analyses, they serve as controls for within-round socioeconomic positioning.
- Unmet needs for family planning: Categorised as unmet need (reference) versus met need. Women who are not sexually active were excluded from regression analysis to maintain conceptual alignment with marital fertility risk.
- Women's empowerment index: The index is a summative score (range 0-7) derived from seven binary items: (i) healthcare decision making; (ii) major household purchases; (Iii) control over own earnings, (iv) control over spending husband's earnings)(v) freedom of mobility, (vi) contraceptive decision-making, and (vii) ability

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to refuse sex. Items not collected in the NDHS rounds; for that round, these items were scored as zero, and the maximum achievable score will be determined. The index was categorised as **low** (score 0; reference), **medium** (1–3), and **high** (≥4). This threshold-based categorisation aligns with the distributional characteristics of the analytical sample and DHS-based fertility research conventions. Full item availability by survey round is presented in **Table 3**.

All categorical variables were entered as dummy indicators in regression models with clearly specified reference categories.

Data Management and Statistical Analysis

All analyses were conducted using Stata version 19. The complex survey design was accounted for using the svyset command, incorporating sampling weights, stratification, and clustering to obtain design-adjusted estimates and robust standard errors. A pooled analytical approach was employed to examine temporal patterns and differential effects across social groups. Multivariate Poisson regression models with a log link function were fitted to estimate incidence rate ratios (IRRs) for children ever born, adjusting for key sociodemographic and reproductive factors. An interaction term between ethnicity and survey year was included to assess changes in fertility differentials over time. Covariates included social group/religion, place of residence, educational attainment, household wealth quintile, unmet need for family planning, and women's empowerment index. Duration since marriage was included as an exposure term to account for differential reproductive exposure across women.

In addition to the pooled analysis, round-specific models were estimated to examine cross-sectional associations within each survey year. These models used consistent reference

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categories to ensure comparability of estimates across survey rounds. For the analysis of completed fertility, a subpopulation of currently married women aged 40–49 years was selected. This restriction enabled the assessment of near-complete reproductive histories.

Adjusted predicted fertility rates were derived using post-estimation marginal standardisation, yielding model-based estimates that account for the survey design. Standard errors for these estimates were computed using unconditional variance estimation methods. All statistical tests were two-sided, and statistical significance was assessed at conventional levels. Analytical scripts used for the data management and analysis are available from the corresponding author upon reasonable request.

Descriptive and Bivariate Analysis

Weighted frequencies and proportions were calculated to describe respondent characteristics. Mean CEB was estimated across categories of predictors.

Normality of the CEB distributions was assessed using the Kolmogorov-Smirnov normality test ($D=0.167$, $p<0.001$), the Shapiro–Wilk test ($W = 0.959$, $z = 18.60$, $p < 0.001$), and the Shapiro–Francia test ($W' = 0.960$, $z = 20.56$, $p < 0.001$), all confirming departure from normality. The CEB distribution displayed right skewness (1.03) and excess kurtosis (4.32), consistent with count data. Despite these departures, the large analytical sample ($N = 55,168$ for lifetime fertility; $N = 11,958$ for completed fertility) justifies the use of ANOVA for descriptive mean comparisons, as the Central Limit Theorem ensures approximate normality of the sampling distribution of means for large samples (Iyer and Weeks 2020). Robust F-statistics (Welch's and Brown-Forsythe's F) were computed using the robnova Stata module to account for heteroscedasticity. As a sensitivity check, Kruskal–Wallis non-parametric tests

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were conducted for all predictors; results were consistent with ANOVA findings across all variables (all $p < 0.001$; see Supplementary Table S2).

Bivariate differences in mean CEB were assessed using one-way analysis of variance (ANOVA) with robust F-statistics to account for unequal variances. Given the large sample size, ANOVA was considered robust to deviations from normality.

Multivariate Analysis

Poisson Regression Model

Survey-adjusted Poisson regression models were estimated separately for lifetime fertility (15-49 years) and completed fertility (40-49 years). The Poisson regression model is expressed as (Tand, He, and Tu 2023),

$$\ln(\hat{\mu}) = \ln(\text{time}) + \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + \varepsilon$$

where $\hat{\mu}$ is the predicted count of the outcome variable given the predictors X_1, X_2, ..., X_p. Where ln refers to the natural logarithm, β_0 is the intercept, β_1 is the regression coefficient for the first predictor X_1, and ln(time) represents an offset variable. The Poisson error structure (ε) resolves issues with applying Ordinary Least Squares (OLS) regression to count outcomes, such as non-constant variance and the non-normal conditional distribution of errors. Coefficients are exponentiated and expressed as Incident Rate Ratios (IRRs) with 95% confidence intervals (Kanteh and Palamuleni 2019; Martin 2021). Each IRR represents the multiplicative factor by which the expected number of children ever born per year of marriage changes for a given category relative to the reference category, holding all other predictors constant. An IRR > 1 indicates a higher rate of childbearing per marriage-year; an IRR < 1 indicates a lower rate. For example, an IRR of 0.95 for urban residence indicates that

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urban women have a 5% lower expected childbearing rate per year of marriage compared with rural women, after adjusting for all other covariates.

Interaction Terms

To assess whether caste/ethnic fertility differentials changed over time, interaction terms between caste/ethnicity and survey year were included in the pooled regression models. The survey year was specified as a categorical variable with 1996 as the reference category, allowing flexible estimation of group-specific temporal effects without imposing linear trend assumptions. This specification enabled the independent estimation of fertility differentials for caste/ethnic groups across successive survey rounds, while adjusting for relevant sociodemographic and reproductive covariates.

The interaction terms were interpreted as deviations in fertility outcomes for each caste/ethnic group relative to the reference year, thereby capturing the extent to which disparities widened, narrowed, or remained stable over time. To formally evaluate the contribution of these interaction terms, adjusted Wald F-tests were conducted, accounting for the complex survey design. These tests assessed the joint significance of the caste/ethnicity-by-survey year interaction coefficients at both the overall level and within specific group comparisons.

The results of these tests, presented in Table 4, indicate that the interaction terms were jointly statistically significant, providing strong evidence that fertility differentials across caste/ethnic groups have not remained constant but have evolved over the study period. This finding supports the inclusion of interaction effects in the model and underscores the importance of examining temporal heterogeneity in fertility patterns across social groups.

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Table 4. Adjusted Wald F-Tests for Joint Significance of Caste/Ethnicity × Survey Year Interaction Terms (Lifetime Fertility, Ages 15–49)

Interaction Group	Adjusted Wald F-statistic	p-value
All ethnic groups jointly (20 df)	F(20, 1301) = 19.74	< 0.001
Muslim × Survey Year (5 df)	F(5, 1301) = 14.82	< 0.001
Madheshi × Survey Year (5 df)	F(5, 1301) = 24.11	< 0.001
Dalit × Survey Year (5 df)	F(5, 1301) = 8.93	< 0.001
Janajati × Survey Year (5 df)	F(5, 1301) = 10.46	< 0.001

Notes: Adjusted Wald F-tests (Stata testparm) following survey-adjusted Poisson regression. Subpopulation: currently married women aged 15–49. Design df = 1,343 (denominator).

Model Diagnostics and Selection

Model diagnostics were performed prior to final model selection. First, although the descriptive variance-to-mean ratio of CEB was 1.53, the Negative Binomial dispersion parameter (α) was effectively zero ($\alpha = 1.35 \times 10^{-16}$), indicating a complete absence of extra-Poisson variation conditional on covariates. The likelihood ratio test comparing Poisson and Negative Binomial models yielded $\chi^2(1) = 0.00$, $p = 1.000$, confirming that the two specifications are statistically indistinguishable. Second, goodness-of-fit further confirmed model adequacy (Deviance/df = 0.625; Pearson χ^2/df = 0.611), both below 1.0, indicating no evidence of misspecification. Third, Zero-inflated Poisson (ZIP) models produced higher BIC values (BIC ZIP = 177,910 vs BIC Poisson = 177,905) and unstable inflation components with very large standard errors for the education parameters, indicating that the zero-inflation process is not substantively different from the standard count process. Zero-Inflated Negative Binomial (ZINB) models failed to converge after 300 iterations. Based on these converging diagnostics, the survey-adjusted Poisson regression was retained as the

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preferred specification (Hilbe 2011; Twisk 2019; Whittaker and Schumacker 2022). Full model comparison statistics are reported in Supplementary Table S3a.

Final Model

Based on dispersion diagnostics, likelihood ratio testing, goodness-of-fit statistics, and information criteria, Poisson regression with duration since first marriage as an exposure variable was retained for both lifetime and completed fertility analyses.

Multicollinearity

Multicollinearity was assessed through pairwise Pearson correlations and Variance Inflation Factors (VIFs). No pairwise correlations among predictors exceeded 0.38 (educational attainment and household wealth). VIF values ranged from 1.22 (met need for contraception) to 2.89 (richest wealth quintile), with a mean VIF of 1.83, all well below the conventional threshold of concern (VIF > 10; O'brien 2007). This confirms the absence of problematic multicollinearity among the sociocultural and socioeconomic predictors. Full VIF results are presented in Supplementary Table S3b.

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Missing Data

Missing data were addressed as follows. The primary outcome variable (CEB) had no missing values among currently married women. The exposure variable (duration since first marriage) was missing for 10,739 women in the full pooled dataset (15.7%), predominantly never-married women for whom duration is undefined; these were excluded during subpopulation restriction. Among currently married women (n = 55,168), no missing duration values remained after the 0.5-year recoding of zero-duration cases. The women's empowerment index had missing values for approximately 5.3% of currently married

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women, primarily due to the 1996 NDHS round, which collected only one item. These cases were handled using Stata's subpopulation (subpop) option, which retains all observations for variance estimation while restricting point estimates to the analytic subpopulation—the recommended approach for complex survey data (West, Berglund, and Heeringa 2008). Given that missing data affected fewer than 6% of predictor values and that missing patterns were primarily related to the survey round (1996) rather than the outcome, substantial bias due to missing data is unlikely.

Temporal Comparability and Harmonisation

Several harmonisation challenges were addressed to ensure comparability across the six NDHS rounds. First, the urban/rural classification changed substantially following Nepal's 2015 federal restructuring, which converted many Village Development Committees (VDCs) into rural and urban municipalities. This accounts for the dramatic shift in urban proportions between 2011 (13.1%) and 2016 (61.1%) observed in Table 3. The urban/rural variable follows the NDHS classification for each round, limiting direct comparability of 'urban' across pre- and post-2015 rounds; this is acknowledged as a limitation. Second, educational attainment categories were harmonised to ISCED 2011 levels as described above. Third, the women's empowerment index was restricted to items available across all rounds (Supplementary Table S3). Fourth, caste/ethnicity coding was standardised using constitutional and commission-based classifications (Supplementary Table S2). Fifth, the unmet need variable was harmonised to a binary classification (unmet need vs met need), with women who were not sexually active excluded from regression analyses. Question wording for CEB, age at first marriage, and contraceptive use was verified against the NDHS recode manuals for each round and found to be consistent in all substantive dimensions.

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Methodological Limitations

The following limitations should be noted in interpreting the findings. First, the repeated cross-sectional design precludes causal inference; estimated associations reflect statistical relationships and may be confounded by unobserved factors. Second, DHS caste/ethnic categories aggregate internally diverse populations, and the analytical categories cannot capture within-group variation in fertility behaviour. Third, completed fertility is operationalised as CEB among women aged 40–49 years; women who bear children after age 49 — though rare in Nepal — are missed by this measure. Fourth, several substantively important confounders are not captured in the NDHS, including internal and international migration, media exposure, community-level social norms, and male partner characteristics (e.g., husband's education and occupation), which may bias estimates to an unknown degree.

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Results and Discussions

Characteristics of Respondents

The total weighted sample of 55,243 currently married women of reproductive age (15-49 years) was used for this study, drawn from the individual and pooled NDHS datasets. **Error! Reference source not found.** presents the mean and variance of children ever born (CEB) across six rounds of the NDHS from 1996 to 2022. Among all women of reproductive age, mean CEB declined steadily from 3.41 in 1996 to 2.25 in 2022, with a corresponding reduction in variance, indicating both declining fertility and increasing concentration around lower parity levels. A similar but higher-level decline was observed among women aged 40-49 years, whose mean completed fertility fell from 5.93 in 1996 to 3.31 in 2022, reflecting substantial fertility transition across successive cohorts.

Table 5 Mean and Variance of Children Ever Born, NDHS (1996-2022)

Age Group	1996		2001		2006		2011		2016		2022		Pooled	
	Mean	Var	Mean	Var	Mean	Var	Mean	Var	Mean	Var	Mean	Var	Mean	Var
15–49 Years	3.41	6.24	3.29	5.63	3.04	4.72	2.68	3.63	2.48	3.06	2.25	2.22	2.81	4.27
40–49 Years	5.93	6.60	5.60	6.08	5.06	5.03	4.36	4.37	3.83	3.54	3.31	2.63	4.50	5.32
Notes: N = Weighted N. Data are from the author's computation from the pooled six-round NDHS dataset (1996 – 2022)														

Table 6 provides the distribution of currently married women aged 15-49 years by selected demographic characteristics. Over time, there was a marked shift toward later age at first marriage, increasing urban residence, higher educational attainment, and improved household wealth status. The proportion of women with no education declined sharply from over 80% in 1996 to about one-third in 2022, while post-secondary education increased more than fourfold. Although Hindu women remained the majority, the relative

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composition of caste/ethnic groups remained broadly stable, allowing meaningful assessment of fertility differentials over time.

With respect to family planning needs, the proportion of women with unmet need for contraception declined substantially over the study period, while the share with met need increased, consistent with expanded access to modern contraceptive services in Nepal. Nevertheless, a non-trivial proportion of women – particularly in earlier survey rounds – continued to report unmet need, underscoring persistent gaps in effective contraceptive coverage.

Regarding women's empowerment, the distribution of the decision-making empowerment index improved gradually over time. The proportion of women classified as having high decision-making autonomy increased across successive survey rounds, while the share with low empowerment declined. Despite these improvements, a sizeable fraction of women remained in the low or medium empowerment categories, suggesting ongoing gender-based constraints on reproductive decision making.

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Overall, the descriptive results highlight substantial improvements in socio-economic conditions, contraceptive access, and women's empowerment alongside persistent social and structural inequalities, providing important context for the multivariate analysis that follows.

Table 6 Distribution of currently married women of reproductive age (15-49 years) by selected characteristics at the time of the survey, NDHS (1996 – 2022).

Variables	1996		2001		2006		2011		2016		2022		Pooled	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Age at First Marriage														

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≤ 19 years	7074	88.6	7314	87.7	6981	84.5	7519	78.3	7474	75.7	8020	71.7	44382	80.3
≥20 Years	908	11.4	1028	12.3	1276	15.5	2089	21.7	2401	24.3	3159	28.3	10861	19.7
Place of Residence														
Rural	7314	91.6	7550	90.5	7031	85.1	8346	86.9	3844	38.9	3627	32.4	37712	68.3
Urban	668	8.4	792	9.5	1226	14.8	1261	13.1	6031	61.1	7553	67.6	17531	31.7
Caste/Ethnicity														
Muslim	407	5.1	392	4.7	330	4	366	3.8	504	5.1	528	4.7	2526	4.6
Madheshi	1142	14.3	1589	19	1071	13	935	9.7	1760	17.8	1705	15.3	8202	14.8
Dalit	1390	17.4	1131	13.6	1183	14.3	1455	15.1	1296	13.1	1734	15.5	8189	14.8
Janajati	2586	32.4	2712	32.5	3093	37.5	3646	37.9	3408	34.5	4042	36.2	19487	35.3
Arya	2458	30.8	2517	30.2	2579	31.2	3206	33.4	2907	29.4	3171	28.4	16838	30.5
Religion														
Hindu	7,064	88.5	7,298	87.5	7,094	85.9	8,152	84.9	8,554	86.6	9,342	83.6	47,505	86.0
Non-Hindu	918	11.5	1,044	12.5	1,163	14.1	1,455	15.1	1,320	13.4	1,838	16.4	7,738	14.0
Educational Attainment														
No Education	6433	80.6	6139	73.6	5226	63.3	4695	48.9	4101	41.5	3547	31.7	30141	54.6
Incomplete Primary	630	7.9	811	9.7	916	11.1	1187	12.4	1149	11.6	1259	11.3	5951	10.8
Complete Primary	430	5.4	667	8	904	10.9	1370	14.3	1402	14.2	2370	21.2	7143	12.9
Lower Secondary	263	3.3	393	4.7	665	8.1	1006	10.5	1362	13.8	2208	19.8	5898	10.7
Upper Secondary	132	1.7	228	2.7	325	3.9	777	8.1	714	7.2	1328	11.9	3503	6.3
Post Secondary	95	1.2	104	1.3	222	2.7	573	6	1147	11.6	468	4.2	2610	4.7
Household Wealth Status														
Poorest	1680	21	1835	22	1537	18.6	1664	17.3	1687	17.1	2031	18.2	10434	18.9
Poorer	1522	19.1	1622	19.4	1642	19.9	1846	19.2	1946	19.7	2217	19.8	10795	19.5
Middle	1687	21.1	1586	19	1747	21.2	2022	21	2088	21.1	2323	20.8	11453	20.7
Richer	1589	19.9	1670	20	1640	19.9	2052	21.4	2107	21.3	2381	21.3	11439	20.7
Richest	1504	18.8	1629	19.5	1692	20.5	2023	21.1	2047	20.7	2228	19.9	11123	20.1
Unmet Need of Family Planning														
Unmet Need	2504	31.4	2316	27.8	2032	24.6	2639	27.5	2346	23.8	2320	20.8	14157	25.6
Met Need	5478	68.6	6025	72.2	6225	75.4	6968	72.5	7528	76.2	8860	79.3	41084	74.4
Women's Empowerment Index														
Low empowerment	7301	91.5	3050	36.6	1628	19.7	166	1.7	268	2.7	101	0.9	12514	22.7
Medium Empowerment	682	8.5	4412	52.9	2838	34.4	3361	35.0	3728	37.7	2452	21.9	17472	31.6
High Empowerment	-	-	879	10.5	3792	45.9	6081	63.3	5879	59.8	8627	77.2	25257	45.7
Total	7982	100	8342	100	8258	100	9607	100	9875	100	11180	100	55243	100

Notes: N = Weighted N. Data are from the author's computation from the pooled six-round NDHS dataset (1996 – 2022)

Bivariate Analysis

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Bivariate analysis (**Table 7**) confirmed that all primary predictors were significantly associated with mean CEB for both lifetime and completed fertility (p<0.001). Mean CEB was consistently higher among women who married before age 20, resided in rural areas, and belonged to Muslim, Madheshi, or Dalit communities. A sharp inverse gradient was observed for education and wealth; for example, women with no education had a mean CEB of 3.62 compared to 1.27 for those with post-secondary attainment.

Table 7 Bivariate Analysis (Based on ANOVA) of Individual Variables with Total Number of Children Ever Born (CEB) with Currently Married Women of Reproductive Age, NDHS (1996 – 2022)

Variables	All Women (15-49 years)				Women Aged 40 - 49			
	Mean CEB	SD	95% CI	F-Score	Mean CEB	SD	95% CI	F-Score
Age at First Marriage								
≤ 19 years	3.02	2.1	2.98 - 3.05	2327.8***	4.79	2.3	4.71 - 4.88	818.2***
≥ 20 years	1.97	1.6	1.92 - 2.01		3.33	1.9	3.23 - 3.44	
Place of Residence								
Rural	3.05	3.1	3.01 - 3.09	1662.0***	5.05	2.4	4.96 - 5.14	1475.8***
Urban	2.29	2.3	2.24 - 2.34		3.43	1.8	3.33 - 3.54	
Caste/Ethnicity								
Muslim	3.45	2.5	3.29 - 3.6	119.2***	6.20	2.6	5.86 - 6.55	115.6***
Madheshi	2.97	2.0	2.91 - 3.03		4.62	2	4.48 - 4.76	
Dalit	2.99	2.2	2.92 - 3.06		5.06	2.3	4.90 - 5.23	
Janajati	2.68	2.1	2.62 - 2.75		4.34	2.4	4.21 - 4.48	
Arya	2.69	2.0	2.65 - 2.74		4.20	2.2	4.09 - 4.32	
Religion								
Hindu	2.79	2.0	2.76-2.82	31.4***	4.43	2.2	4.35-4.51	62.7***
Non-Hindu	2.93	2.3	2.83-3.04		4.91	2.6	4.68-5.14	
Educational Attainment								
No Education	3.62	2.2	3.58 - 3.65	2752.0***	4.95	2.3	4.87 - 5.03	370.3***
Incomplete Primary	2.43	1.6	2.37 - 2.48		3.69	1.8	3.54 - 3.83	
Complete Primary	1.96	1.4	1.92 - 2.01		3.24	1.6	3.1 - 3.38	
Lower Secondary	1.60	1.1	1.56 - 1.64		2.57	1.2	2.42 - 2.72	
Upper Secondary	1.43	1.0	1.39 - 1.47		2.49	1.1	2.33 - 2.65	
Post-Secondary	1.27	0.9	1.22 - 1.31		2.08	0.9	1.95 - 2.2	
Household Wealth Status								
Poorest	3.4	2.4	3.34 - 3.46	474.8	5.54	2.4	5.41 - 5.67	297.7

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Poorer	3.0	2.1	2.95 - 3.05	***	4.82	2.3	4.7 - 4.95	***
Middle	2.83	2.1	2.77 - 2.88		4.63	2.2	4.51 - 4.75	
Richer	2.60	1.9	2.55 - 2.65		4.29	2.2	4.15 - 4.43	
Richest	2.27	1.6	2.21 - 2.32		3.42	1.9	3.29 - 3.54	
Unmet Need of Family Planning								
Unmet Need	2.76	2.2	2.69 - 2.83	11.3***	5.37	2.7	5.19 - 5.55	283.0 ***
Met Need	2.83	2.0	2.79 - 2.86		4.36	2.2	4.28 - 4.44	
Women's Empowerment Index								
Low Empowerment	2.95	2.5	2.88 - 3.02	37.7***	5.91	2.6	5.76 - 6.06	675.7 ***
Medium Empowerment	2.78	2.1	2.73 - 2.82		4.85	2.3	4.74 - 4.95	
High Empowerment	2.76	1.8	2.71 - 2.81		3.92	2.0	3.83 - 4.01	
Notes: SD = Standard deviation. Data are from the author's computation from the pooled six-round NDHS dataset (1996 – 2022)								
***p< 0.001; **p < 0.01; *p < 0.05								

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Multivariate Poisson Regression: Lifetime Fertility (women aged 15-49 years)

Error! Reference source not found. presents results from multivariate survey-adjusted Poisson regression models for lifetime fertility, examining factors associated with Children Ever Born (CEB) among currently married women, both by survey round (1996-2022) and pooled across the entire period. All models were adjusted for survey design and used the duration since first marriage as the exposure (offset) variable. Estimates are reported as Incidence Rate Ratios (IRR) with 95% Confidence Intervals (CI). Findings are summarised by (i) survey round (1996-2022), (ii) pooled across the entire period without interaction, and (iii) pooled interaction model.

Round-specific models

Across the six survey rounds, the multivariate Poisson models revealed substantial and persistent fertility differentials by caste/ethnicity, education, wealth, and contraceptive need after adjusting for duration since first marriage. Urban women consistently exhibited lower fertility than their rural counterparts, with reductions reaching statistical significance in 2006, 2011, and 2016. Marked sociocultural gradients were observed across all surveys. Muslim women consistently had significantly higher fertility compared with Arya women, and this advantage grew larger in the more recent rounds. Madheshi women, who initially had slightly lower fertility in 1996, exhibited significantly higher fertility from 2006 onward. Dalit women likewise showed persistently elevated fertility relative to Arya women in all rounds. In contrast, Janajati women demonstrated a modest fertility advantage in most years, but by 2022, they had shifted to significantly lower fertility.

Educational attainment showed a clear, statistically robust positive association with fertility, even after controlling for the duration since first marriage. Women with incomplete

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primary, primary, or secondary schooling generally had 5–15% higher expected fertility than women with no schooling, and the magnitude of these effects increased over time. Upper-secondary and post-secondary education were associated with the largest fertility elevations, particularly in the 2016 and 2022 surveys. These positive coefficients reflect the shorter marital exposure among educated women and indicate higher rates of childbearing per marriage-year rather than higher completed fertility.

Strong wealth gradients were evident in every round. Compared with the poorest households, fertility decreased steadily across all wealth groups, with the richest households consistently exhibiting about 30–40% lower expected fertility per unit of marital exposure. Met need for contraception was associated with substantially lower fertility in each round, though the magnitude of the association diminished modestly over time. Women's empowerment variables displayed weak and inconsistent associations with fertility, with occasional modest reductions appearing in 2006 and 2016 but without a consistent pattern over the full period.

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Pooled model without interaction

In the pooled model combining all survey rounds, these long-term patterns remained evident. Urban women continued to exhibit significantly lower fertility. Muslim, Janajati, and—on average—Madheshi women displayed significant deviations from Arya fertility levels. However, the direction for Madheshi women in the pooled model masks the strong upward trend revealed in the year-specific models. Dalit women were not significantly different from Arya in the pooled model despite showing higher fertility in nearly all individual rounds, indicating heterogeneity over time. Educational attainment remained positively associated with fertility across all levels of schooling, reinforcing the dynamic

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produced by later marriage and shorter exposure times among more educated women. Wealth-related reductions remained large, and the 'met need' for contraception continued to lower fertility substantially. High empowerment had a small but statistically significant negative association with fertility.

Comparison of round-specific versus pooled models highlighted substantial temporal heterogeneity. Pooled estimates aggregate across 26 years and mask critical dynamics: ethnic differentials reversed or amplified, wealth gradients intensified, and associations with education and contraception evolved substantially, indicating uneven fertility decline across social strata during Nepal's demographic transition.

The following tables present the complete survey-adjusted Poisson regression results for both the round-specific and pooled models. All IRRs are extracted directly from the Stata survey-adjusted output (svy: poisson with subpopulation restriction and duration since first marriage as the offset). Values are presented as IRR (95% CI). Significance: *** $p<0.001$; ** $p<0.01$; * $p<0.05$.

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Table 8 Multivariate Survey-Adjusted Poisson regression of Individual-Level Factors Associated with Children Ever Born (CEB) – Currently Married Women Aged 15-49 Years, Nepal, NDHS 1996–2022.

Variables	NDHS Survey Round (15 - 49 Age Group)						Pooled 1996 - 2022
	1996	2001	2006	2011	2016	2022	
Place of Residence							
Rural®							
Urban	0.954*	0.992	0.948**	0.963**	0.937***	0.983	0.951***
	(0.906 - 1.005)	(0.938 - 1.049)	(0.909 - 0.990)	(0.928 - 0.999)	(0.906 - 0.970)	(0.956 - 1.012)	(0.934 - 0.968)
Caste/Ethnicity							
Arya ®							
Muslim	1.081*	1.034	1.267***	1.446***	1.425***	1.495***	1.082**
	(0.997 - 1.172)	(0.942 - 1.134)	(1.150 - 1.396)	(1.287 - 1.625)	(1.318 - 1.540)	(1.394 - 1.604)	(1.016 - 1.152)
Madheshi	0.945***	0.995	1.110***	1.194***	1.269***	1.308***	0.929***
	(0.910 - 0.982)	(0.951 - 1.041)	(1.059 - 1.164)	(1.131 - 1.260)	(1.210 - 1.330)	(1.251 - 1.368)	(0.891 - 0.968)
Dalit	1.041**	1.066***	1.101***	1.083***	1.135***	1.191***	1.014
	(1.002 - 1.082)	(1.017 - 1.118)	(1.054 - 1.151)	(1.035 - 1.133)	(1.087 - 1.185)	(1.151 - 1.232)	(0.975 - 1.055)
Janajati	1.077***	1.075***	1.059***	1.046**	1.018	0.964**	1.080***
	(1.041 - 1.114)	(1.030 - 1.121)	(1.016 - 1.104)	(1.004 - 1.089)	(0.980 - 1.057)	(0.932 - 0.997)	(1.043 - 1.118)
Religion							
Hindu ®							
Non-Hindu	1.018	1.070**	0.974	1.005	1.026	1.002	1.013
	(0.958 - 1.082)	(1.005 - 1.139)	(0.934 - 1.016)	(0.956 - 1.056)	(0.975 - 1.079)	(0.964 - 1.041)	(0.989 - 1.037)
Educational Attainment							
No Education®							
Incomplete Primary	1.076***	0.995	1.054**	1.054***	1.035*	1.039**	1.039***
	(1.033 - 1.120)	(0.959 - 1.033)	(1.008 - 1.102)	(1.016 - 1.093)	(0.999 - 1.072)	(1.004 - 1.075)	(1.023 - 1.056)
Primary	1.058*	1.047**	1.070***	1.093***	1.050***	1.099***	1.058***
	(0.996 - 1.123)	(1.003 - 1.092)	(1.022 - 1.121)	(1.049 - 1.138)	(1.015 - 1.085)	(1.068 - 1.131)	(1.041 - 1.076)
Lower Secondary	1.061	1.051*	1.106***	1.088***	1.081***	1.174***	1.080***
	(0.984 - 1.144)	(0.992 - 1.113)	(1.039 - 1.178)	(1.041 - 1.136)	(1.041 - 1.123)	(1.133 - 1.217)	(1.059 - 1.101)
Upper Secondary	1.094	1.092*	1.101**	1.151***	1.091***	1.272***	1.118***
	(0.964 - 1.242)	(0.996 - 1.197)	(1.012 - 1.197)	(1.085 - 1.221)	(1.033 - 1.152)	(1.215 - 1.331)	(1.089 - 1.149)
Post-Secondary	1.014	1.018	1.043	1.135***	1.180***	1.217***	1.097***
	(0.873 - 1.178)	(0.906 - 1.144)	(0.947 - 1.149)	(1.066 - 1.208)	(1.124 - 1.239)	(1.132 - 1.309)	(1.063 - 1.132)
Household Wealth Status							
Poorest®							
Poorer	0.936***	0.966**	0.906***	0.844***	0.848***	0.824***	0.896***
	(0.904 - 0.969)	(0.935 - 0.999)	(0.875 - 0.939)	(0.807 - 0.884)	(0.818 - 0.880)	(0.796 - 0.852)	(0.882 - 0.911)
Middle	0.901***	0.974	0.849***	0.763***	0.784***	0.756***	0.845***

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	(0.867 - 0.937)	(0.937 - 1.013)	(0.816 - 0.883)	(0.726 - 0.801)	(0.753 - 0.817)	(0.729 - 0.784)	(0.830 - 0.860)
Richer	0.919***	0.919***	0.800***	0.713***	0.718***	0.689***	0.801***
	(0.887 - 0.952)	(0.887 - 0.953)	(0.772 - 0.830)	(0.677 - 0.752)	(0.686 - 0.752)	(0.664 - 0.715)	(0.786 - 0.815)
Richest	0.843***	0.813***	0.723***	0.607***	0.600***	0.577***	0.702***
	(0.807 - 0.881)	(0.774 - 0.853)	(0.686 - 0.762)	(0.576 - 0.640)	(0.571 - 0.630)	(0.551 - 0.605)	(0.687 - 0.718)
Unmet Need for Contraception							
Unmet Need®							
Met Need	0.745***	0.778***	0.822***	0.863***	0.874***	0.902***	0.826***
	(0.728 - 0.762)	(0.759 - 0.797)	(0.799 - 0.846)	(0.838 - 0.889)	(0.849 - 0.900)	(0.880 - 0.924)	(0.816 - 0.835)
Women's Empowerment							
Low Empowerment®							
Medium Empowerment	0.977	1.016	0.991	0.980	0.943	0.962	1.011
	(0.941 - 1.015)	(0.989 - 1.045)	(0.948 - 1.036)	(0.860 - 1.117)	(0.879 - 1.012)	(0.820 - 1.127)	(0.992 - 1.029)
High Empowerment		1.012	0.931***	0.908	0.838***	0.842**	0.922***
		(0.974 - 1.051)	(0.891 - 0.973)	(0.796 - 1.035)	(0.782 - 0.898)	(0.717 - 0.988)	(0.904 - 0.941)
Model Statistics							
Observations (N)	7,978	8,324	8,244	9,460	9,904	11,258	55,168
F-statistic (df)	F(17,100) = 60.44	F(18,96) = 40.16	F(18,1219) = 48.71	F(18,1100)= 50.17	F(18,957)= 55.46	F(18,957) = 84.64	F(43,1301) = 175.55
***p< 0.001; **p < 0.01; *p < 0.05; Confidence Intervals (CIs) are in parentheses.							

Notes: Values are incidence rate ratios (IRR) with 95% confidence intervals (in parentheses). All models are survey-adjusted Poisson regressions with duration since first marriage as the exposure. Round-specific models exclude survey year indicators. The pooled model includes year fixed effects and caste/ethnicity × year interactions (not shown). Data are from the author's computation from the pooled six-round NDHS dataset (1996 – 2022)

Pooled Interaction Model (1996-2022)

The pooled interaction model reveals that while fertility declined across all groups, sociocultural differentials evolved significantly over the 26 years (**Figure 2**). The model highlights a persistent relative advantage for Arya women in fertility reduction and reveals three distinct group-specific trajectories:

- **Muslim and Madheshi Women:** These groups exhibited widening fertility differentials relative to Arya women. For **Muslim women**, higher fertility persisted and intensified in post-2006 waves, suggesting that sociocultural factors—such as group cohesion or distinct family size norms—influence reproductive behaviour beyond measured socio-economic variables. **Madheshi women** showed a notable temporal shift: while their fertility was comparable to Arya women in earlier rounds, interaction terms for later waves indicated significantly higher relative fertility. This divergence may reflect region-specific dynamics in the Terai, including political mobilisation and migration patterns.

- **Janajati Women:** Initially tracking closely with the Arya reference group, Janajati fertility declined more rapidly in later rounds. Significant interaction effects in 2016 and 2022 suggest that accelerated educational expansion and migration exposure within Janajati communities have driven a faster demographic transition.

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- **Dalit Women:** Contrary to expectations based on socio-economic disadvantage, Dalit interaction terms remained largely non-significant after adjustment. This indicates that the observed crude disparities for Dalit women are primarily explained by socio-economic factors rather than a distinct, independent sociocultural fertility trajectory.

Figure 2 illustrates these adjusted predicted mean Children Ever Born (CEB) trends, confirming that despite an overall national decline, Nepal's fertility landscape is becoming increasingly divergent across sociocultural lines.

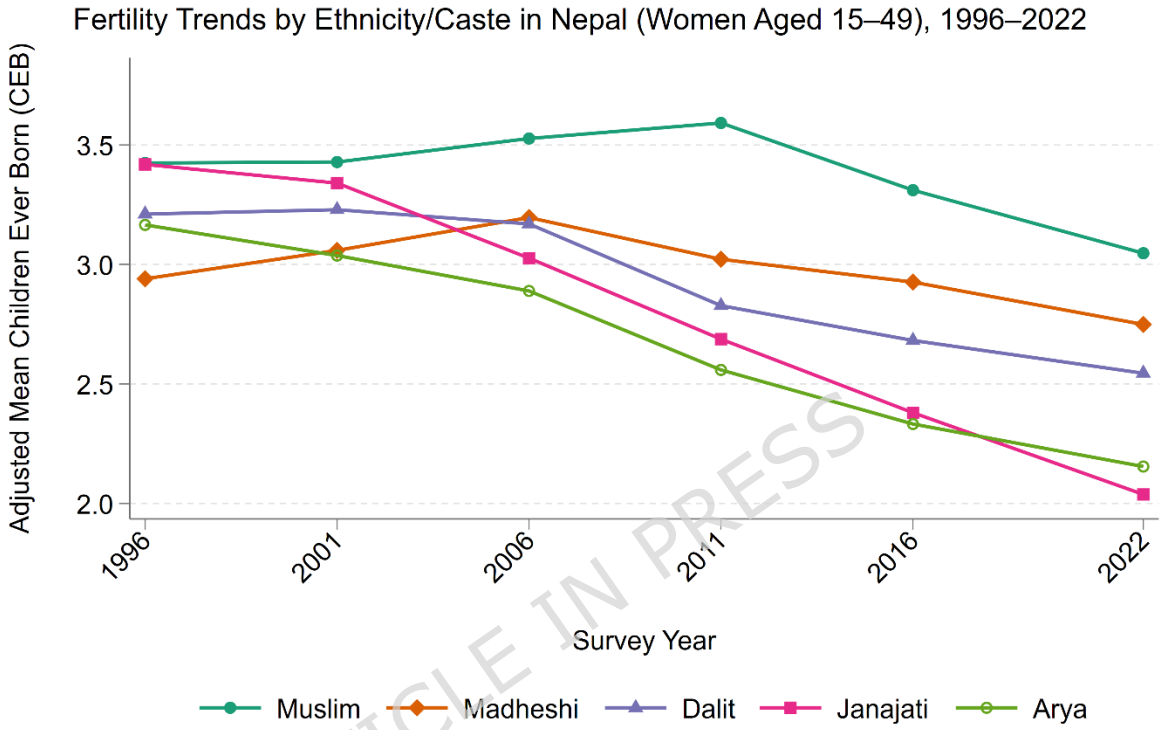

Figure 2: Predicted lifetime fertility (aged 15-49) by Caste/Ethnicity in Nepal, 1996–2022

In the pooled interaction model, the base coefficient for each ethnic group (e.g., Muslim) represents the fertility rate differential relative to Arya women in 1996 (the reference year). The interaction coefficients (e.g., Muslim × 2022: IRR = 1.307, 95% CI: 1.205–1.418, $p < 0.001$) represent the additional change in that group's differential between 2022 and 1996. A significant positive interaction IRR > 1 indicates divergence — that group's fertility declined more slowly than Arya women's (widening gap); a significant negative interaction IRR < 1 indicates convergence — that group's fertility declined faster (narrowing gap). The joint Wald test, $F(20, 1301) = 19.74$, $p < 0.001$, confirms that temporal changes in all

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sociocultural fertility differentials are statistically significant as a group. For Janajati women, the progression from non-significant interaction terms in 2001–2011 to significantly negative terms in 2016 (IRR = 0.945, p = 0.039) and 2022 (IRR = 0.876, p < 0.001) documents a statistically significant convergence — accelerating fertility decline — over the period. For Muslim and Madheshi women, monotonically increasing interaction IRRs confirm a statistically significant divergence throughout the period. Details on the pooled-interaction model coefficients are presented in the supplementary Table S4.

Multivariate Poisson Regression: Completed Fertility (women aged 40-49 years)

Round-specific models

Patterns of completed fertility were similar in structure but often opposite in direction to those observed among women aged 15–49, reflecting differences between *fertility rates per exposure year* and *completed reproductive outcomes (**Error! Reference source not found.**).* Also, excluding younger cohorts from the completed fertility (aged 40-49) analysis fails to capture more recent dynamics in fertility behaviour. Urban women consistently had lower completed fertility across most rounds, though the significance varied. Sociocultural patterns remained prominent. Muslim women exhibited substantially higher completed fertility in all survey rounds, with the largest differentials observed in 2006 and 2011. Madheshi women showed lower completed fertility than Arya women in 1996, but significantly higher fertility from 2006 onward. Dalit women displayed slight but consistent fertility elevations in the more recent rounds, while Janajati women showed modestly higher fertility in early surveys but significantly lower fertility by 2022.

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In contrast to the lifetime fertility models, educational attainment was strongly and consistently associated with lower completed fertility. Women with any level of schooling exhibited significantly fewer lifetime births than women with no education, and the magnitude of these reductions increased with schooling level. Post-secondary educated women had 20–40% lower completed fertility in most rounds, reflecting the cumulative impact of delayed marriage, fertility limitation, and greater autonomy over the life course. Wealth also exhibited strong negative gradients, with middle-, richer, and richest households showing large, statistically significant reductions in completed fertility across all survey years. Met need for contraception was associated with substantially lower completed fertility through 2011, though estimates for 2016 and 2022 had confidence intervals approaching unity, reflecting reduced variation at higher ages. Empowerment measures again showed limited and inconsistent associations.

Pooled model without interaction

In the pooled completed-fertility model (**Error! Reference source not found.**), the long-term effects of education and wealth remained the strongest predictors of lower lifetime fertility. Urban residence and 'met need' for contraception were also associated with reduced fertility. Sociocultural differences were more muted after adjustment: Muslim women no longer exhibited significantly higher completed fertility in the pooled estimate. In comparison, Madheshi women had significantly lower completed fertility overall—a reversal of the lifetime-fertility pattern that underscores the importance of modelling exposure and exclusion of younger cohorts. Janajati women exhibited slightly higher completed fertility in the pooled model, despite declining relative fertility over time, whereas Dalit women showed no significant difference from Arya women.

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Table 9 Multivariate Survey-Adjusted Poisson Regression of Individual-Level Factors Associated with Children Ever Born (CEB) – Currently Married Women Aged 40-49 Years, Nepal, NDHS 1996–2022.

Variables	NDHS Survey Round (40 - 49 Age Group)						Pooled 1996 - 2022
	1996	2001	2006	2011	2016	2022	
Place of Residence							
Rural®							
Urban	0.942	1.023	0.888***	0.949*	0.928***	0.990	0.941***
	(0.860 - 1.033)	(0.949 - 1.103)	(0.820 - 0.962)	(0.895 - 1.007)	(0.883 - 0.976)	(0.953 - 1.027)	(0.916 - 0.966)
Caste/Ethnicity							
Arya ®							
Muslim	1.103	1.125	1.361***	1.607***	1.381***	1.296***	1.065
	(0.970 - 1.254)	(0.951 - 1.331)	(1.173 - 1.580)	(1.297 - 1.992)	(1.225 - 1.557)	(1.167 - 1.440)	(0.984 - 1.153)
Madheshi	0.882***	0.946	1.068*	1.205***	1.167***	1.160***	0.865***
	(0.807 - 0.963)	(0.884 - 1.013)	(0.989 - 1.154)	(1.097 - 1.323)	(1.086 - 1.255)	(1.099 - 1.225)	(0.792 - 0.944)
Dalit	1.064	1.052	1.047	1.057	1.078**	1.080***	1.039
	(0.985 - 1.149)	(0.973 - 1.137)	(0.977 - 1.122)	(0.971 - 1.151)	(1.011 - 1.149)	(1.028 - 1.135)	(0.967 - 1.116)
Janajati	1.077**	1.091***	1.073**	1.057*	0.981	0.909***	1.072**
	(1.013 - 1.145)	(1.025 - 1.161)	(1.011 - 1.139)	(0.997 - 1.120)	(0.928 - 1.037)	(0.867 - 0.954)	(1.010 - 1.138)
Religion							
Hindu ®							
Non-Hindu	1.002	1.068	0.998	0.974	1.082*	1.072**	1.033*
	(0.907 - 1.106)	(0.962 - 1.185)	(0.942 - 1.058)	(0.907 - 1.046)	(0.995 - 1.177)	(1.013 - 1.135)	(0.998 - 1.070)
Educational Attainment							
No Education®							
Incomplete Primary	1.030	0.908**	0.909**	0.998	0.889***	0.883***	0.915***
	(0.904 - 1.175)	(0.824 - 0.999)	(0.827 - 0.998)	(0.926 - 1.075)	(0.836 - 0.946)	(0.837 - 0.932)	(0.886 - 0.946)
Primary	0.921	0.905**	0.795***	0.989	0.890***	0.912***	0.885***
	(0.804 - 1.055)	(0.823 - 0.995)	(0.667 - 0.946)	(0.900 - 1.088)	(0.820 - 0.965)	(0.866 - 0.961)	(0.851 - 0.921)
Lower Secondary	0.836**	0.719***	0.854	0.846***	0.874**	0.823***	0.806***
	(0.716 - 0.976)	(0.596 - 0.868)	(0.677 - 1.077)	(0.749 - 0.955)	(0.778 - 0.981)	(0.776 - 0.873)	(0.768 - 0.846)
Upper Secondary	0.772***	0.661***	0.808*	0.935	0.886**	0.852***	0.825***
	(0.647 - 0.922)	(0.539 - 0.810)	(0.650 - 1.006)	(0.835 - 1.047)	(0.806 - 0.974)	(0.774 - 0.936)	(0.782 - 0.872)
Post-Secondary	0.670***	0.607***	0.669***	0.905	0.789***	0.834***	0.757***

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	(0.575 - 0.781)	(0.496 - 0.742)	(0.589 - 0.760)	(0.775 - 1.056)	(0.708 - 0.880)	(0.748 - 0.931)	(0.712 - 0.805)
Household Wealth Status							
Poorest®							
Poorer	0.962	0.929*	0.896***	0.845***	0.834***	0.822***	0.891***
	(0.893 - 1.035)	(0.861 - 1.002)	(0.839 - 0.956)	(0.796 - 0.899)	(0.785 - 0.885)	(0.782 - 0.863)	(0.867 - 0.915)
Middle	0.945*	0.958	0.832***	0.741***	0.750***	0.773***	0.839***
	(0.885 - 1.009)	(0.898 - 1.023)	(0.779 - 0.888)	(0.691 - 0.794)	(0.703 - 0.801)	(0.734 - 0.814)	(0.817 - 0.863)
Richer	0.977	0.916**	0.796***	0.701***	0.695***	0.711***	0.805***
	(0.916 - 1.043)	(0.857 - 0.979)	(0.743 - 0.853)	(0.649 - 0.758)	(0.646 - 0.747)	(0.672 - 0.752)	(0.783 - 0.829)
Richest	0.894***	0.792***	0.777***	0.603***	0.623***	0.633***	0.728***
	(0.830 - 0.963)	(0.730 - 0.860)	(0.717 - 0.843)	(0.557 - 0.653)	(0.576 - 0.673)	(0.592 - 0.677)	(0.705 - 0.752)
Unmet Need for Contraception							
Unmet Need®							
Met Need	0.703***	0.716***	0.810***	0.843***	0.951*	0.975	0.814***
	(0.674 - 0.733)	(0.681 - 0.753)	(0.762 - 0.861)	(0.797 - 0.892)	(0.897 - 1.007)	(0.936 - 1.015)	(0.796 - 0.833)
Women's Empowerment							
Low Empowerment							
Medium Empowerment	0.971	1.005	0.970	0.963	0.873**	1.170	0.997
	(0.887 - 1.062)	(0.956 - 1.057)	(0.879 - 1.071)	(0.836 - 1.110)	(0.769 - 0.991)	(0.897 - 1.526)	(0.960 - 1.035)
High Empowerment		1.012	0.931***	0.908	0.838***	0.842**	0.969
		(0.974 - 1.051)	(0.891 - 0.973)	(0.796 - 1.035)	(0.782 - 0.898)	(0.717 - 0.988)	(0.931 - 1.008)
Model Statistics							
Observations (N)	1,540	1,672	1,736	1,993	2,260	2,757	11,958
F-statistic (df)	F(17,100) = 40.78	F(18,96) = 24.45	F(18,1219) = 25.41	F(18,1100) = 26.33	F(18,957) =36.03	F(18,957) = 46.46	F(43,1301) = 98.26
***p< 0.001; **p < 0.01; *p < 0.05; Confidence Intervals (CIs) are in parentheses.							

Notes: Values are Incidence Rate Ratios (IRR) with 95% confidence intervals in parentheses. All models are survey-adjusted Poisson regressions with duration since first marriage as the exposure (offset) variable. The pooled model includes caste/ethnicity × survey year interaction terms (full interaction IRRs in Supplementary Table S1e). Reference categories as for Table 8. High empowerment was not estimable in 1996 (shown as — n/a).

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Pooled Interaction Model (1996-2022)

The interaction model for completed fertility (see **Figure 3**) confirmed temporal divergence similar to that observed among all women aged 15–49. Muslim and Madheshi women experienced increasing relative fertility over time, while Janajati women transitioned toward lower completed fertility by the most recent rounds. Dalit interactions remained largely non-significant, consistent with heterogeneous fertility patterns across time. These findings indicate that long-term sociocultural shifts in fertility behaviour persist even after most childbearing is completed and suggest a widening gap among several population groups. Details on the pooled-interaction model coefficients are presented in the supplementary **T**able S4.

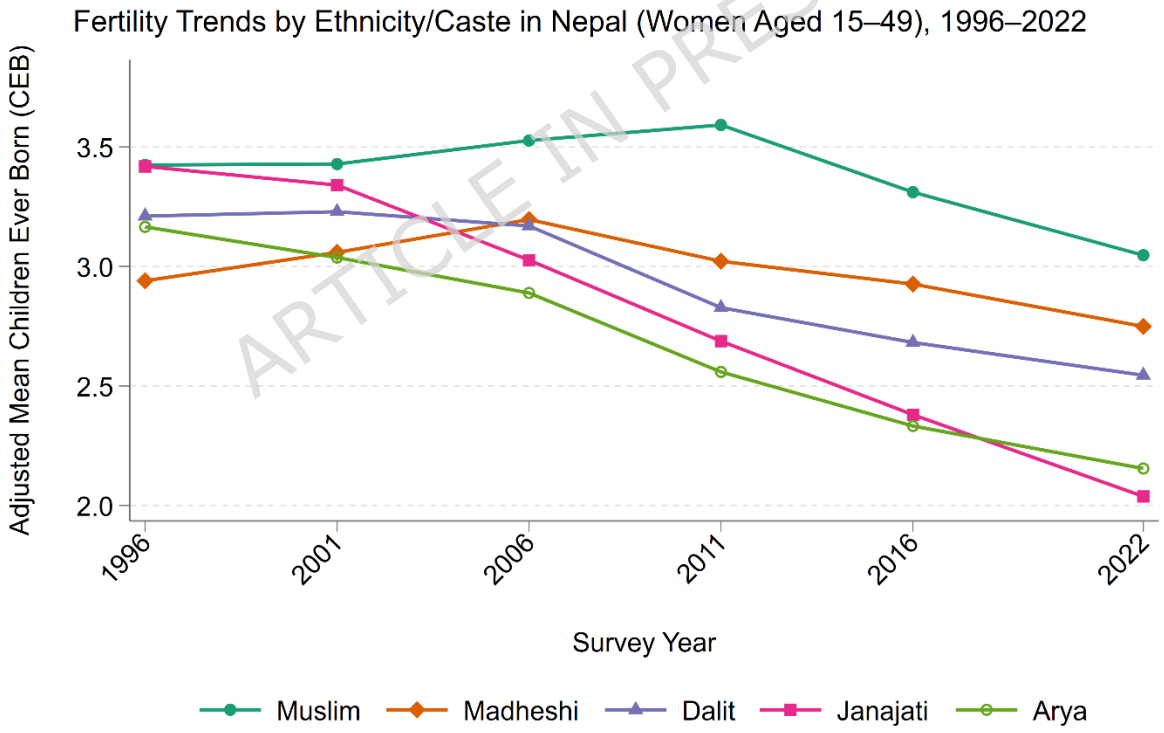

Figure 3: Predicted completed fertility (aged 40-49) by Caste/Ethnicity in Nepal, 1996–2022

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Discussions

The primary objective of this study was to investigate the heterogeneity of fertility in Nepal within the broader context of demographic transition theory and the proximate determinants of fertility. Although previous studies have debated the relative roles of urbanisation, education, and family planning programmes in driving Nepal's declining fertility, a comprehensive understanding of how sociocultural, economic and demographic factors shape fertility remains incomplete. This study, therefore, examined whether caste/ethnicity and women's educational attainment – alongside established covariates – constitute the primary sources (and changes over time) of fertility differentials in Nepal, using Poisson regression models based on children ever born (CEB) among currently married women.

Descriptive findings confirmed that early marriage is associated with higher fertility, consistent with global evidence that longer exposure to childbearing increases lifetime fertility (Bongaarts, Mensch, and Blanc 2017; Islam and Rahman 2020; Kwon and Sohn 2023; Rahman et al. 2022; Sagalova et al. 2021; Scott et al. 2021). Although early age at marriage was strongly associated with higher CEB in descriptive and bivariate analysis, it was not included in the multivariate Poisson models because duration since first marriage served as the exposure variable, capturing women's length of time at risk of childbearing.

Place of residence remained an important long-term determinant, with urban women consistently exhibiting lower fertility. This aligns with demographic transition mechanisms – greater access to education, employment opportunities, and reproductive health services – and is consistent with evidence from other low-income settings (Bora et al. 2022; International Institute for Population Sciences (IIPS) 2021; Lerch 2019; Ministry of Health and Sports (MoHS) and ICF 2017; Srithanaviboonchai et al. 2014). The inconsistent round-

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specific associations likely reflect Nepal's rapidly changing settlement patterns; NDHS classifications do not fully distinguish between urban and peri-urban environments, complicating interpretations of urbanisation (DEGURBA 2024).

Caste/Ethnicity and Religion were also significant predictors of fertility over time, underscoring deep-rooted sociocultural and structural differences. Higher fertility among Muslim and Madheshi women corresponds with documented constraints related to gender norms, geographic marginalisation in the Terai, and uneven access to family planning services. In contrast, Janajati women showed a faster fertility decline, potentially linked to higher labour migration, changing gender norms, and broader exposure to socio-economic transitions. Dalit women exhibited elevated fertility in several survey rounds but did not show a consistent pooled pattern, highlighting the internal heterogeneity. These findings demonstrate that fertility behaviours reflect not only socio-economic factors but also group-specific histories, identities, and fertility intentions.

The positive association between education and Children Ever Born in lifetime fertility models—reaching 21.7% higher for post-secondary educated women by 2022—represents a methodological artifact arising from marital exposure confounding. Educated women marry later but are observed at the same ages (15-49 years), resulting in higher fertility per marriage-year despite lower ultimate completed fertility (Bongaarts et al. 2017).

Completed fertility models confirmed the expected negative relationship, with post-secondary educated women showing 24.3% lower fertility than uneducated women. This discordance underscores the importance of appropriately modelling tempo effects during periods of rapid educational expansion and rising age at marriage. Substantively, education emerged as the strongest predictor of fertility decline across all groups, eclipsing even the

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effects of household wealth. This aligns with findings in other South Asian countries (Bora et al. 2022; Chaudhry et al. 2014; International Institute for Population Sciences (IIPS) 2021; Rahman, Islam, and Yeasmin 2020). Education affects fertility through delayed marriage, improved reproductive health knowledge, increased autonomy, and higher aspirations (Caldwell 2001; Frini and El Lahga 2002; Hakim and Mahmood 1994; Jain 1981; Martin 1995). Prior work in Nepal and similar settings supports these pathways (Adediran, Fakoya, and Sikhweni 2021; Adhikari 2010; Gudbrandsen 2013; Kanteh and Palamuleni 2019; Samad et al. 2022; Wayack-Pambè, Gnoumou Thiombiano, and Kabore 2014). Education, therefore, remains a central axis of fertility inequality in Nepal.

Household wealth exhibited strong, consistent, and intensifying negative associations with fertility. The richest-poorest differential expanded from 15.7% in 1996 to 42.3% by 2022, indicating growing socio-economic stratification during Nepal's transition. This pattern contrasts with the convergence predictions of classical transition theory. This finding aligns with studies in Bangladesh (Rahman et al. 2022; Uddin et al. 2016), Kenya (Odwe 2015), and Ghana and Nigeria (Yaya, Osanyintupin, and Akintande 2018), as well as Nepal (Gudbrandsen 2010; Johnson and Bradley 2008). Increased economic status is correlated with mass media exposure (Werwath 2011). helping women access reproductive health information and empowering them compared to women from poor households. From a policy perspective, the intensifying wealth gradient signals incomplete transition and equity concerns. Poorest quintile women remain with fertility 40% higher than the richest, suggesting persistent barriers to reproductive autonomy.

Unmet need for contraception contributed to higher fertility, though with variability across survey rounds. This aligns with research highlighting the complex behavioural and structural

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components of unmet need, including access to barriers, partner opposition, and ambivalence (Anik, Islam, and Rahman 2022; Casterline and Sinding 2000; Machiyama et al. 2017; Sarah E.K. Bradley et al. 2012; Wulifan et al. 2016). The decline in unmet need across NDHS rounds reflects improved service delivery, but persistent inequities remain among marginalised groups.

Women's empowerment showed modest, inconsistent effects, with confidence intervals frequently approaching 1.0. High empowerment was associated with a 7.8% lower pooled fertility rate, but round-specific estimates varied considerably. These weak direct associations do not imply that empowerment is unimportant. Rather, empowerment likely operates through indirect pathways already controlled: supporting educational attainment, enabling contraceptive use, and facilitating delayed marriage.

Over the long term, empowered women made more rational fertility decisions and opted for fewer children. Living in urban areas, having secondary education, and being from middle- or high-income household backgrounds moderate women’s empowerment in the household, which, in turn, affects fertility. Similar results were found in other studies (Forty et al. 2022). Our household decision-making index may inadequately capture relevant dimensions such as intimate partner communication and sexual negotiation.

Policy Implications

Our findings carry several implications. First, aggregate national statistics mask substantial heterogeneity. Targeted interventions addressing barriers for Muslim, Madheshi, and Dalit women may be warranted. Second, education emerges as the strongest lever for fertility decline, suggesting continued investments in girls' schooling will yield demographic dividends. Third, the intensifying wealth gradient signals equity concerns—ensuring the

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poorest women have quality contraceptive access remains critical. Fourth, empowerment programs, while intrinsically valuable, may not directly reduce fertility unless coupled with education and economic opportunity.

Conclusions and Recommendations

This study examined fertility heterogeneity across caste/ethnic groups during Nepal's rapid demographic transition from 1996 to 2022. Using six rounds of nationally representative NDHS data and survey-adjusted Poisson regression models with duration since first marriage as the exposure, we identified substantial and evolving fertility differentials that persisted after adjusting for education, wealth, contraceptive access, and women's empowerment. These findings reinforce that fertility behaviour in Nepal is deeply embedded in social structures and cannot be understood solely through national trends.

Caste and ethnic differentials – fertility decline in Nepal has been profoundly stratified rather than uniform. We observed three distinct temporal patterns: divergence (Muslim and Madheshi women shifted from similar or lower fertility in 1996 to substantially higher by 2022), convergence (Janajati women transitioned from higher to lower fertility relative to the Arya reference group), and heterogeneous persistence (Dalit women showed varying differentials across time, with consistently elevated fertility in individual rounds despite a non-significant pooled estimate). These patterns indicate that social stratification along caste/ethnic lines shapes fertility trajectories in enduring ways during demographic transitions, challenging universalistic assumptions of classical transition theory.

Education emerged as the dominant predictor of fertility decline across all groups, eclipsing even household wealth in completed fertility models. Women with post-secondary education had 24.3% lower completed fertility compared to uneducated women, with the

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association strengthening over time. This dominant role likely reflects education's multiplier effects: educated women have access to better reproductive health information, use family planning services more effectively, delay marriage, and exercise greater autonomy in fertility decisions. Educational diffusion within communities may amplify these effects, as less-educated women adopt low-fertility norms through social learning.

Household wealth and place of residence differentials – socio-economic stratification of fertility intensified during the study period. The richest-poorest wealth differential expanded from 15.7% in 1996 to 42.3% by 2022, indicating that fertility decline has been faster and more complete among economically advantaged households. This growing gap signals incomplete transition and persistent reproductive inequities, with the poorest quintile "left behind" despite overall progress.

Overall, these findings show that Nepal's fertility decline is progressing but remains stratified. Achieving equitable fertility and reproductive health outcomes will require addressing both structural inequalities and sociocultural barriers.

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Contributions and Implications

Our findings advance understanding of fertility transitions in hierarchical societies in three ways. Methodologically, we demonstrated that pooled models aggregating decades of data can mask critical temporal dynamics. Fertility determinants are not static; their associations evolve as transitions unfold unevenly across subpopulations. Explicitly modelling caste/ethnicity-by-time interactions revealed patterns that conventional approaches obscure.

Substantively, we showed that caste/ethnic differentials cannot be reduced to socio-economic gradients alone. Even after controlling for education, wealth, and contraceptive

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access, Muslim and Madheshi women exhibited widening differentials while Janajati women converged toward lower fertility. These divergent trajectories likely reflect complex interactions among minority status, regional dynamics, political mobilisation, migration patterns, and group-specific norms, which merit further investigation through mixed-methods research.

Theoretically, our results challenge the assumption that modernisation uniformly erodes traditional social boundaries. Instead, we found that some ethnic boundaries—particularly those marked by minority status and political mobilisation—may strengthen or persist during demographic transitions, shaping fertility regimes in durable ways. Nepal's experience suggests that fertility transitions in diverse, stratified societies may produce heterogeneity rather than convergence.

From a policy perspective, these findings underscore the inadequacy of one-size-fits-all approaches to population policy. National aggregate statistics mask substantial variation, with specific groups—Muslim, Madheshi, and poorest Dalit women—experiencing slower fertility decline despite socio-economic development. Targeted interventions addressing barriers these groups face may be warranted alongside universal programs.

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Recommendations

1. **Prioritise equitable, high-quality girls' education.** Universal completion of secondary education—especially among disadvantaged groups such as Muslim, Madheshi, and Dalit communities—would substantially reduce fertility disparities. Strengthening reproductive health content in school curricula and addressing quality gaps between urban and rural schools are essential to maximising the impact of education.

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2. **Strengthen equitable access to reproductive health and family planning.** To address wealth- and caste/ethnicity-based inequalities, reproductive health services should be expanded in underserved regions, including rural and Terai districts. Efforts must address discrimination, improve counselling quality, broaden contraceptive method choice, and reduce financial barriers for the poorest households. Culturally sensitive delivery approaches are needed to ensure meaningful access for marginalised communities.

3. **Implement disaggregated monitoring and targeted interventions.** National averages obscure persistent disparities. Routine monitoring of fertility, contraceptive use, and maternal health outcomes should be disaggregated by caste/ethnicity, wealth, and region. Community-engaged, context-specific interventions—designed with local leaders and women—can more effectively address barriers faced by groups experiencing slower fertility decline.

4. **Promote women's empowerment through economic and social opportunities.** Expanding women's economic participation, enforcing gender-equality policies, and supporting decision-making autonomy can indirectly reduce fertility by strengthening women's ability to make informed reproductive choices. Empowerment initiatives should be explicitly linked to education, employment, and access to healthcare.

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Future Research Directions

Future studies should employ more granular caste and ethnic classifications to capture within-group variation masked by broad constitutional categories. Longitudinal or cohort-based analyses would improve understanding of how education, empowerment, and

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fertility intentions evolve. Further investigation is warranted into the role of male labour migration, urban–peri-urban transitions, and contraceptive dynamics, particularly among marginalised communities. Qualitative or mixed-methods approaches could illuminate the sociocultural meanings of fertility and reproductive decision-making across diverse groups. Such work will strengthen the evidence base for designing culturally responsive and equity-focused reproductive health policies in Nepal.

Strengths and limitations of the study

Major strengths include six rounds of nationally representative household survey data spanning 26 years, interaction models explicitly testing temporal dynamics, and survey-adjusted Poisson regression with robust standard errors. Important limitations include: (i) DHS categories aggregate diverse populations with internal heterogeneity; (ii) unmeasured confounders (migration, media exposure, community norms) may bias estimates; (iii) cross-sectional data limit causal inference; (iv) completed fertility restricted to ages 40-49 may exclude late births; (v) we cannot definitively adjudicate among multiple proposed mechanisms; and (vi) our focus on quantum excludes tempo, intentions, and maternal health outcomes.

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Authors' Contribution

D.G. and S.KC made substantial contributions to the conception and design of the work. D.G. carried out the data acquisition and analysis. Both D.G. and S.KC interpreted the data. Both D.G. and S.KC drafted and revised the manuscript, and both authors approved the final version. The Authors have received no funding for this work.

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Data availability

The data used in this study are freely available for download from the official DHS Program website, subject to registration and approval. Six rounds of DHS data can be assessed from the official DHS program website.

Ethics approval and consent to participate

Data for this study were from the Nepal Demographic and Health Survey 2022, which was reviewed by the Nepal Health Research Council (NHRC) and the ICF Institutional Review Board. Written informed consent was obtained from all participants prior to their inclusion in the study.

Consent for publication

Not applicable

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Competing interests

The authors declare that they have no competing interests.

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Supplementary Tables

Supplementary Table S1. Crosswalk of Caste/Ethnicity Sub-categories to Analytical Groups Across Six NDHS Rounds (1996-2022)

Analytical Category	NDHS Sub-categories Included	1996	2001	2006	2011	2016	2022
Khas/Arya (Reference)	Brahmin, Chhetri, Sanyashi, and Thakuri (GON 2015)	√	√	√	√	√	√
Janajati	1. Sherpa, 2. Bhote (Bhutia), 3. Thakali, 4. Byansi, 5. Walung, 6. Chhairotan, 7. Dolpo, 8. Tangbe, 9. Tin Gaule Thakali, 10. Topkegola (Dhokpya), 11. Bara Gaunle Thakali, 12. Marphali Thakali, 13. Mugali, 14. Lhopa, 15. Lhomi (Shingsawa), 16. Siyar (Chumba), 17. Thudam, 18. Magar, 19. Tamang, 20. Newar, 21. Rai, 22. Gurung, 23. Limbu, 24. Bhujel, 25. Sunuwar, 26. Chepang, 27. Thami, 28. Yakkha, 29. Pahari, 30. Chhantyal, 31. Jirel, 32. Dura, 33. Lepcha, 34. Hayu, 35. Yehlmo, 36. Kushbadia, 37. Kusunda, 38. Phree (Free), 39. Bankaria, 40. Baramo/ Baramu, 41. Larke, 42. Surel, 43. Kumal, 44. Majhi, 45. Danuwar, 46. Darai, 47. Bote, 48. Raji, 49. Raute, 50. Tharu, 51. Dhanuk (Rajbanshi), 52. Rajbansi (Koch), 53. Satar/Santhal, 54. Jhagar/Jhangar/Uraon, 55. Gangai, 56. Dhimal, 57. Tajpuriya, 58. Meche (Bodo), 59. Kisan, 60. Rana Tharu (NFDIN 2002)	√	√	√	√	√	√
Madheshi	1. Kayastha, 2. Brahmin, 3. Bhumihar, 4. Rajput, 5. Agrahari, 6. Kalwar, 7. Kalal, 8. Keshari, 9. Teli, 10. Poddar, 11. Porwal, 12. Barnwal, 13. Marwari, 14. Rastogi, 15. Sudi, 16. Halwai, 17. Kisan, 18. Kurmi, 19. Koiri/Kushwaha, 20. Tiyar, 21. Turaha, 22. Pasi, 23. Bhar, 24. Yadav, 25. Rajbhar, 26. Lodh, 27. Kusunda, 28. Koche, 29. Gond, 30. Dhimal, 31. Munda, 32. Meche, 33. Rajdhami, 34. Raji, 35. Santhal, 36. Khatik, 37. Chamar,	√	√	√	√	√	√

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	38. Dom, 39. Tatma, 40. Dusadh/Paswan, 41. Dhobi, 42. Bantar, 43. Badi, 44. Bind, 45. Mushar, 46. Halkhor, 47. Badhai, 48. Badiya, 49. Bahardar, 50. Baheliya, 51. Balmiki, 52. Banjara, 53. Banpar, 54. Bansphor, 55. Barai, 56. Bari, 57. Beldar, 58. Bengali, 59. Bhat, 60. Bhuj, 61. Biltau, 62. Bot, 63. Bote, 64. Chai, 65. Chanau, 66. Chauhan, 67. Chidimar, 68. Danuwar, 69. Darai, 70. Dasnami Sanyasi, 71. Dev, 72. Dham, 73. Dhandi, 74. Dhankar, 75. Dhanuk, 76. Dhimar, 77. Dhuniya, 78. Dosar Vaishya, 79. Gadedeya, 80. Gangai, 81. Gaud, 82. Godhi, 83. Godiya, 84. Gwala, 85. Hajam, 86. Jhangad/Dhangad, 87. Kahar, 88. Kakaihiya, 89. Kalabaj, 90. Kalar, 91. Kamakad, 92. Kamalapuri Vaishya, 93. Kamar, 94. Kansakar, 95. Kanu, 96. Karuwa, 97. Kasodhan, 98. Kathbaniya/Sinduriya, 99. Kavar, 100. Kevat, 101. Kevrat, 102. Khadiya, 103. Khatwe, 104. Khawas, 105. Khulwat, 106. Kol, 107. Kori, 108. Kulin, 109. Kumal, 110. Kumhar, 111. Kushma, 112. Kushwadia, 113. Laheri, 114. Lakhera, 115. Lohar, 116. Mahapatra, 117. Majhi, 118. Mali, 119. Mallah, 120. Malpande, 121. Mangta, 122. Mestar, 123. Mudiyari, 124. Murau, 125. Nair, 126. Natuwa, 127. Nuniya, 128. Nurang, 129. Pahan, 130. Pathera, 131. Patwa, 132. Pawariya, 133. Punjabi/Sindhi, 134. Rad, 135. Rajbanshi, 136. Rajdhob, 137. Rauniyar, 138. Rautiya, 139. Saithwar, 140. Sarbhang, 141. Sarniyak, 142. Sarwariya, 143. Shivhare Vaishya, 144. Sikh, 145. Sonar, 146. Soraiya, 147. Tajpuriya, 148. Tamoli, 149. Thathera, 150. Amat (Madheshi Commission 2022)						
Dalit	1. Biswokarma, 2. Pariyar, 3. Sarki, 4. Gandharwa (Gaine), 5. Badi, 6. Pode, 7. Chhyame, 8. Kalar, 9. Kakaihiya, 10. Kori, 11. Khatik, 12. Khatwe, 13. Chamar, 14. Chidimar, 15. Dom, 16. Tatma, 17. Dushad, 18. Dhobi, 19. Pasi, 20. Batar, 21. Mushahar, 22. Mestar, 23. Sarbhanga, 24. Natuwa, 25. Dhandi, 26. Dhrikar/ Dhanka, and 27. Pattharkatta (NDC	√	√	√	√	√	√

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	2017)						
Muslim	Muslim, and Churaute	√	√	√	√	√	√

Notes: "√" indicates categories that were consistently available and harmonised across all six survey rounds. For the purpose of this analysis, any sub-categories identified as Janjati or Dalit within the broader Madheshi caste/ethnic classifications (e.g., Madheshi Dalit, Terai Janjati) were reassigned to the Janajati and Dalit analytical groups, respectively. This recoding was undertaken to maintain conceptual consistency and ensure comparability of caste/ethnic groups across survey rounds.

Supplementary Table S2. One-Way ANOVA Robust F-Statistics for Mean CEB – Currently Married Women (Ages 15-49 and 40-49) by Predictor, NDHS Pooled 1996-2022

Variable	Ages 15–49: F-stat	df	p-value	Ages 40–49: F-stat	df	p-value
Age at First Marriage	2,327.8	1	< **0.001**	818.2	1	< **0.001**
Place of Residence	1,662.0	1	< **0.001**	1,475.8	1	< **0.001**
Caste/Ethnicity	119.2	4	< **0.001**	115.6	4	< **0.001**
Religion	31.4	1	< **0.001**	62.7	1	< **0.001**
Educational Attainment	2,752.0	5	< **0.001**	370.3	5	< **0.001**
Household Wealth	474.8	4	< **0.001**	297.7	4	< **0.001**
Unmet Need	11.3	1	0.001	n/a	—	—
Women's Empowerment	37.7	2	< **0.001**	675.7	2	< **0.001**

Notes: Weighted ANOVA (aweight = perweight) with Welch/Brown-Forsythe robust F via robnova. Kruskal–Wallis tests confirmed all results (all p < 0.001 for 15–49 sample). Normality rejected by K-S (D=0.167), Shapiro-Wilk (W=0.959), and Shapiro-Francia (W'=0.960) tests; ANOVA robust for N > 50,000 (CLT). Source: ndhs_bivariate.txt.

Supplementary Table S3. Model Diagnostics

Supplementary Table S3a: Count-Data Model Comparison — Poisson vs Negative Binomial vs Zero-Inflated Models (Lifetime Fertility, N = 55,168)

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Diagnostic / Criterion	Poisson	Neg. Binomial	ZIP	ZINB
Log-likelihood	−88,712.31	−88,712.31	−88,654.72	−88,654.72
Parameters (df)	44	44 (+1 α)	55	56 (+1 α)
AIC	177,512.62	177,512.62	177,419.44	177,421.44
BIC	177,905.01	177,905.01	177,909.93	177,920.78
Dispersion parameter (α)	N/A	$1.35 \times 10^{-16} \approx 0$	N/A	≈ 0 (unstable)
LR test vs Poisson (p)	Reference	p = 1.000	—	—
Deviance/df	0.625	—	—	—
Pearson χ^2 / df	0.611	—	—	—
Zero proportion	10.1%	10.1%	10.1%	10.1%
Is the inflation component stable?	N/A	N/A	No (huge SE edu)	No (huge SE edu)
PREFERRED MODEL	✓ **YES**	Equivalent	Not preferred	Not preferred

Notes: Standard (unweighted) Poisson used for model comparison diagnostics; Stata svy commands do not support nbreg/zip/zinb natively. ZINB convergence not achieved after 300 iterations (inflation component identical to ZIP). Poisson retained as preferred model: α ≈ 0, LR test p = 1.000, Deviance/df = 0.625, Pearson/df = 0.611. AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; ZIP = Zero-Inflated Poisson; ZINB = Zero-Inflated Negative Binomial.

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Supplementary Table S3b: Variance Inflation Factors (VIF) — Lifetime Fertility Poisson Regression (Ages 15–49)

Variable	VIF	1/VIF (Tolerance)
Age at first marriage (≥20 vs. ≤19)	1.24	0.807
Place of residence (Urban)	1.39	0.720
Caste/Ethnicity – Muslim	1.28	0.781
Caste/Ethnicity – Madheshi	1.41	0.709

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Caste/Ethnicity – Dalit	1.34	0.746
Caste/Ethnicity – Janajati	1.52	0.658
Religion (Non-Hindu)	1.44	0.694
Education – Incomplete Primary	1.35	0.741
Education – Primary	1.57	0.637
Education – Lower Secondary	1.84	0.543
Education – Upper Secondary	1.96	0.510
Education – Post-Secondary	1.71	0.585
Wealth – Poorer	2.11	0.474
Wealth – Middle	2.28	0.439
Wealth – Richer	2.44	0.410
Wealth – Richest	2.89	0.346
Met Need (contraception)	1.22	0.820
Empowerment – Medium	1.98	0.505
Empowerment – High	2.76	0.362
Mean VIF	1.83	—

Notes: VIFs from standard (unweighted) Poisson regression on pooled sample (N = 55,168). All VIF < 4.0 (threshold: VIF > 10; O'Brien, 2007). Max pairwise r = 0.38 (education × wealth). Survey-year dummies and interactions were excluded from the VIF computation.

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Supplementary Table S4. Full Interaction Model Results: Caste/Ethnicity x Survey Year Effects on Fertility

Survey-weighted Poisson Regression with Exposure (Duration of Marriage); Incidence Rate Ratios (IRR) with 95% Confidence Intervals

	All Currently Married Women (15–49 years)			**Completed Fertility Women (40–49 years)**		
Parameter	**IRR**	**95% CI**	**p-value**	**IRR**	**95% CI**	**p-value**
Caste/Ethnicity (ref: Arya/Hill Brahmin–Chhetri)						

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Muslim	1.082	1.016–1.152	0.014	1.065	0.984–1.153	0.121
Madheshi	0.929	0.891–0.968	<0.001	0.865	0.792–0.944	0.001
Dalit	1.014	0.975–1.055	0.478	1.039	0.967–1.116	0.295
Janajati	1.080	1.043–1.118	<0.001	1.072	1.010–1.138	0.022
Survey Year (ref: 1996)						
2001	0.960	0.924–0.996	0.030	0.945	0.890–1.003	0.062
2006	0.913	0.879–0.948	<0.001	0.887	0.826–0.951	0.001
2011	0.808	0.776–0.842	<0.001	0.793	0.739–0.851	<0.001
2016	0.737	0.703–0.773	<0.001	0.752	0.697–0.812	<0.001
2022	0.681	0.654–0.709	<0.001	0.689	0.645–0.736	<0.001
Caste/Ethnicity × Survey Year Interactions						
Muslim interactions						
Muslim × 2001	1.043	0.963–1.130	0.298	1.137	0.969–1.333	0.115
Muslim × 2006	1.128	1.022–1.246	0.017	1.240	1.068–1.438	0.005
Muslim × 2011	1.298	1.146–1.469	<0.001	1.375	1.121–1.686	0.002
Muslim × 2016	1.312	1.197–1.438	<0.001	1.310	1.173–1.464	<0.001
Muslim × 2022	1.307	1.205–1.418	<0.001	1.231	1.101–1.377	<0.001
Madheshi interactions						
Madheshi × 2001	1.084	1.016–1.157	0.014	1.105	0.993–1.230	0.066
Madheshi × 2006	1.191	1.120–1.266	<0.001	1.229	1.096–1.378	<0.001
Madheshi × 2011	1.271	1.189–1.360	<0.001	1.366	1.202–1.552	<0.001
Madheshi × 2016	1.351	1.269–1.438	<0.001	1.322	1.180–1.480	<0.001
Madheshi × 2022	1.374	1.291–1.461	<0.001	1.330	1.200–1.474	<0.001
Dalit interactions						
Dalit × 2001	1.048	0.997–1.102	0.065	1.018	0.918–1.130	0.731
Dalit × 2006	1.082	1.020–1.147	0.009	1.002	0.907–1.107	0.962
Dalit × 2011	1.090	1.028–1.155	0.004	1.037	0.927–1.159	0.527
Dalit × 2016	1.134	1.068–1.204	<0.001	1.046	0.949–1.152	0.369
Dalit × 2022	1.164	1.104–1.228	<0.001	1.039	0.953–1.134	0.385
Janajati interactions						
Janajati × 2001	1.018	0.975–1.063	0.407	1.041	0.965–1.123	0.294
Janajati × 2006	0.970	0.924–1.018	0.218	0.991	0.916–1.072	0.824
Janajati × 2011	0.973	0.923–1.025	0.295	0.970	0.895–1.052	0.466
Janajati × 2016	0.945	0.895–0.997	0.039	0.916	0.843–0.994	0.036
Janajati × 2022	0.876	0.836–0.918	<0.001	0.855	0.795–0.920	<0.001
Covariates						
Non-Hindu (ref: Hindu)	1.013	0.989–1.037	0.299	1.033	0.998–1.070	0.067
Urban (ref: Rural)	0.951	0.934–0.968	<0.001	0.941	0.916–0.966	<0.001
Education (ref: No Education)						
Incomplete Primary	1.039	1.023–1.056	<0.001	0.915	0.886–0.946	<0.001
Primary	1.058	1.041–1.076	<0.001	0.885	0.851–0.921	<0.001
Lower Secondary	1.080	1.059–1.101	<0.001	0.806	0.768–0.846	<0.001
Upper Secondary	1.118	1.089–1.149	<0.001	0.825	0.782–0.872	<0.001
Post Secondary	1.097	1.063–1.132	<0.001	0.757	0.712–0.805	<0.001
Wealth Quintile (ref: Poorest)						
Poorer (ref: Poorest)	0.896	0.882–0.911	<0.001	0.891	0.867–0.915	<0.001
Middle	0.845	0.830–0.860	<0.001	0.839	0.817–0.863	<0.001
Richer	0.801	0.786–0.815	<0.001	0.805	0.783–0.829	<0.001

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Richest	0.702	0.687–0.718	<0.001	0.728	0.705–0.752	<0.001
Met Need (ref: Unmet)	0.826	0.816–0.835	<0.001	0.814	0.796–0.833	<0.001
Women's Empowerment (ref: Low)						
Medium Empowerment	1.011	0.992–1.029	0.253	0.997	0.960–1.035	0.876
High Empowerment	0.922	0.904–0.941	<0.001	0.969	0.931–1.008	0.120

Notes: IRR = Incidence Rate Ratio. All models use survey-weighted Poisson regression with robust standard errors accounting for the complex survey design (261 strata, 1,604 PSUs). Duration of marriage used as an exposure variable

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