

Beyond Coverage: Quality and Continuity of Maternal Care in India

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Abstract

Expanding maternal healthcare coverage has not produced proportionate gains in maternal and child health across low- and middle-income countries, raising the question of what coverage-based monitoring fails to capture. While the contribution of antenatal, delivery, and postnatal care to child health outcomes is well recognized, the quality and continuity of care across these stages, and the social distribution of gaps within the continuum, remain largely unexplored because standard indicators record contacts rather than the content of care received. This study addresses this gap by examining how stage-specific maternal care quality is associated with infant survival and birth weight in India, characterizing the sequential structure of the maternal care continuum, and testing whether discontinuities in care quality are systematically distributed across social and geographic groups. India presents a relevant context given its substantial coverage expansion alongside persistently uneven outcomes and pronounced social inequalities. Using 132,172 births from India's National Family Health Survey (2019–21), we construct a quality-adjusted index of maternal care across the three stages and estimate its association with infant survival and birth weight using discrete-time survival and multinomial models. Higher-quality care is associated with improved outcomes at every stage, most strongly for postnatal care ($HR = 0.595$), with the protective association of earlier care operating partly through later care. The care

continuum fractures sharply at the delivery-to-postnatal transition, and this fracture is socially graded: Scheduled Tribe women record relatively high antenatal and postnatal quality but a delivery-quality deficit of -0.300 standard deviations, invisible in coverage statistics that show near-parity. The results show how social disadvantage reaches infant biological outcomes not through a single deficit but through a structurally located break in the continuum of care.

Keywords: Birth weight; Caste; India; Infant mortality; Maternal care quality; Women's Health
JEL classification codes: I12; I14; J13; R12

1 Introduction

Maternal health during pregnancy, delivery, and the postnatal period shapes infant survival and long-term child development. In low- and middle-income countries, the burden of preventable maternal and child morbidity and mortality remains high (Finlay et al., 2015; Usman et al., 2021b; Lassi et al., 2013; Rai et al., 2022; Meitei and Singh, 2024). India provides an instructive case. The country has substantially expanded maternal health coverage over past two decades through programmes such as Janani Suraksha Yojana, the National Health Mission, and Anaemia Mukh Bharat, reducing the maternal mortality ratio from 556 in 1990 to 97 per 100,000 live births by 2018–20 (Registrar General of India, 2022). Yet improvements in maternal and child health outcomes have not progressed proportionately. Approximately 6,200 newborns die each day within their first month of life, representing 47 percent of all under-five deaths (WHO, 2024; UNICEF, 2024), and inequalities in care quality across population groups and regions remain pronounced (Singh and Vellakkal, 2021). This raises an important question, why does expanded health coverage not translate into proportionate gains in outcomes?

A large empirical literature documents that antenatal, delivery, and postnatal care each contribute to improved maternal and child health outcomes (Usman et al., 2021b; Meitei and Singh, 2024; Shibamura et al., 2018). However, two limitations of this literature constrain its ability to address the coverage-outcomes puzzle. First, most studies measure utilisation (ANC visits, institutional delivery, postnatal contact) rather than the content, timing and quality of care actually received (Usman et al., 2021b; Kothavale and Meher, 2021; Sharma, 2023; Longchar et al., 2025). A woman who attended four antenatal visits with cursory examinations is counted identically to one who received comprehensive screening. Second, the three stages are typically analysed in isolation rather than as a connected continuum, even though earlier-stage care plausibly shapes both the utilisation and quality of subsequent care (James et al., 2022; Usman et al., 2021b). These limitations matter because they

leave open the possibility that the coverage-outcomes gap reflects not unmet need for care but discontinuities in quality across stages, discontinuities that coverage-based monitoring systems cannot detect.

This study addresses these gaps in three ways. First, we construct a quality-adjusted Maternal Continuum of Care Quality Index (MCCQI) for India using the 2019–21 National Family Health Survey (NFHS-5). Unlike conventional coverage measures that capture only whether services were accessed, the MCCQI incorporates the content, intensity, and timing of care received across antenatal, delivery, and postnatal stages, providing a more comprehensive assessment of maternal healthcare quality following the SWPER methodology of [Ewerling et al. \(2017\)](#). Second, we investigate who receives high-quality maternal care and where disparities persist by examining the social and geographic distribution of stage-specific care quality across caste groups, household wealth, and geographic zones. This analysis identifies population groups and regions where deficiencies in care quality are most pronounced. Third, we examine how quality of care at one stage influences care received at subsequent stages by using regression-based pathway decomposition to characterise the sequential structure of the maternal care continuum. This approach helps identify where women are most likely to discontinue or experience deterioration in the quality of care, thereby highlighting critical points for policy intervention.

The analysis yields several key findings. Higher-quality maternal care is consistently associated with improved child health outcomes, with postnatal care exhibiting the strongest association with infant survival. Care received at earlier stages is associated with subsequent care utilisation, and the association between antenatal and delivery care quality and infant survival operates partly through postnatal care quality. The maternal care continuum shows substantial fragmentation at the transition from delivery to postnatal care: a sizeable share of women who receive moderate or high-quality delivery care subsequently move into low-quality postnatal care. Most importantly, this discontinuity is socially patterned. Scheduled Tribe women, in particular, document relatively high antenatal and postnatal utilisation but

markedly lower delivery care quality, indicating that the structural fracture in the continuum varies systematically across social groups.

These findings suggest that gaps in maternal and child health outcomes in India may reflect not only limited access to care but also systematic discontinuities in the quality of care received across stages, discontinuities that current coverage-based monitoring systems cannot detect and that fall unevenly across social groups. The remainder of the paper is organised as follows. Section 2 presents the conceptual framework. Section 3 describes the data, construction of key variables, and measures of maternal healthcare continuity and quality. Section 4 outlines the empirical strategy. Section 5 presents the main findings. Section 6 reports the robustness checks. Section 7 discusses the findings and Section 8 concludes.

2 Conceptual Framework and Hypothesis

2.1 Quality and continuity in the maternal care continuum

Maternal healthcare is conventionally measured through coverage indicators, including the share of women who attend antenatal visits, deliver in institutions, or receive postnatal care. These indicators have driven decades of program design and monitoring in India and other low- and middle-income countries ([Kothavale and Meher, 2021](#); [Sharma, 2023](#)). Yet a growing body of evidence suggests that coverage and outcomes have decoupled: countries that have substantially expanded access to maternal care have not always seen proportionate reductions in maternal and child mortality ([Singh and Vellakkal, 2021](#); [Gebremedhin et al., 2023](#)). One explanation is that coverage indicators capture contacts rather than quality of care; they record whether a woman attended a service but not the content, timing, or intensity of what she received ([Longchar et al., 2025](#)).

A life-course perspective on maternal health ([Elder et al., 1992](#); [Lawn and Sadoo, 2018](#)) signifies why this matters. Pregnancy, delivery, and the postnatal period are biologically

and socially interconnected windows during which the timing and quality of care shape outcomes that compound across the early life course (Finlay et al., 2015; Ferreira et al., 2024). Antenatal care provides opportunities for risk identification, nutritional support, and clinical surveillance; delivery care determines whether obstetric complications are managed safely; and postnatal care is critical for preventing neonatal infections and supporting early infant survival (Lincetto et al., 2012; Lee et al., 2022). The effectiveness of each stage depends on the content of services delivered, not merely on whether contact occurred. Measuring maternal care without attention to quality, therefore, risks overstating the strength of the relationship between healthcare exposure and health outcomes and misdiagnosing the source of persistent gaps in maternal and child health.

In the Indian context, where coverage expansion has been substantial, but outcomes have improved more slowly, the quality dimension is salient. Earlier work has examined components of care quality in isolation, for instance, the content of antenatal services received (Nadella et al., 2021) or the role of skilled birth attendance (Lee et al., 2022), but few studies have constructed integrated measures of care quality that span the full continuum and are comparable across women and settings. This leads to our first hypothesis:

H1 (Quality of care and infant outcomes).

A quality-adjusted measure of the maternal continuum of care exhibits stronger associations with infant survival and normal birth weight than conventional coverage-based indicators.

2.2 Sequential structure and the integrating role of postnatal care

A second limitation of the existing literature is its tendency to analyse antenatal, delivery, and postnatal care as independent inputs into maternal and child health outcomes. The reality is closer to a connected continuum, in which care received at one stage shapes engagement with, and quality of care at later stages (James et al., 2022; Usman et al., 2021a). Women who receive comprehensive antenatal care are more likely to deliver in institutional

settings; women who experience supportive delivery care are more likely to engage with postnatal follow-up. Earlier-stage care may operate through familiarity with the health system, established provider relationships, and accumulated information about the importance of continued contact (Andersen, 1995; James et al., 2022).

This sequential structure has two implications for how we should think about the effects of maternal care on outcomes. First, the protective association between care at any one stage and downstream outcomes likely reflects both the direct effect of that stage and an indirect effect operating through subsequent care. Estimating stage-specific effects in isolation may therefore obscure the cumulative role of continuity across the continuum. Second, postnatal care occupies a structurally distinctive position. Because neonatal mortality risk concentrates in the early postnatal period (Lawn and Sadoo, 2018; Lee et al., 2022), and because postnatal care is the final stage at which the benefits of earlier care can be reinforced or eroded, postnatal care plausibly serves as an integrating node, the pathway through which the protective effects of antenatal and delivery care reach infant survival outcomes.

Empirical evidence on these sequential relationships in the Indian context is limited. Studies that examine the continuum-of-care framework typically focus on coverage transitions rather than quality transitions (Kothavale and Meher, 2021), and the role of postnatal care as a mediating pathway for earlier-stage investments has not been systematically tested. This motivates two further hypotheses:

H2 (Inter-stage continuity).

Higher-quality care at earlier stages of the continuum is positively associated with the uptake and quality of care at subsequent stages, reflecting the sequential and reinforcing structure of maternal healthcare delivery.

H3 (Postnatal care as integrating pathway).

The association between antenatal and delivery care quality and infant survival is partly accounted for by postnatal care quality, such that improvements in earlier-stage care are

linked to improved infant survival in part through strengthened engagement with and quality of postnatal services.

2.3 Social distribution of the maternal care continuum

A third dimension of the maternal care continuum that has received less attention is its social distribution. Coverage-based monitoring tends to ask whether maternal care reaches different population groups; less attention has been given to whether the continuum itself operates differently across social and economic strata ([Pezzulo et al., 2023](#); [Striessnig and Bora, 2020](#)). Drawing on Andersen’s behavioural model of healthcare utilisation ([Andersen, 1995](#)), the predisposing, enabling, and need factors that translate health needs into care-seeking are themselves socially distributed. Education, household wealth, social-group membership, and place of residence shape both the demand for care and the supply of care a woman is likely to encounter ([Bloom et al., 2001](#); [Gopalakrishnan et al., 2024](#)). The Mosley–Chen framework of child survival ([Mosley and Chen, 1984](#)) extends this logic to outcomes: structural conditions shape proximate biological mechanisms through which care quality, nutrition, and disease exposure determine survival.

Applied to the continuum-of-care framework, these perspectives suggest that the social distribution of maternal care quality is not simply a matter of unequal access at the entry point of the continuum. Rather, social disadvantage may compound across the continuum: women who enter the system with constrained predisposing or enabling factors may also experience lower-quality care at each stage and weaker continuity between stages. The Indian context provides specific reasons to expect such patterning. Caste-based stratification, region-specific health system capacity, and the well-documented inequalities in institutional delivery and postnatal coverage ([Dandona et al., 2020](#); [Contractor et al., 2018](#); [Meitei and Singh, 2024](#)) point to mechanisms through which the continuum could fracture along social lines, and where in the continuum those fractures are likely to be most pronounced.

For women from lower caste groups, particularly Scheduled tribes, geographic isolation,

limited transport access, and structural barriers to emergency obstetric services suggest that delivery care may be the stage at which discontinuity is sharpest, even where outreach-based antenatal and postnatal services are reaching tribal communities through ASHA workers and community health programmes (Contractor et al., 2018; Chawla et al., 2025). This pattern, if observed, would indicate that the continuum operates not as a smooth pathway but as a structurally fractured system whose breakpoints are themselves socially located. We therefore propose:

H4 (Social distribution of the continuum).

The quality and continuity of maternal care vary systematically across socioeconomic and social-group lines, with discontinuities in the care continuum, particularly at the delivery-to-postnatal transition, concentrated among disadvantaged populations.

2.4 Conceptual Model

The four hypotheses can be expressed compactly within a health production framework Figure 1. Let H_i denote the health outcome for individual i , which may represent infant survival or birth weight, produced by maternal care received across the three stages of the continuum:

$$H_i = f(Q_i^A, Q_i^D, Q_i^P, X_i, \epsilon_i) \quad (1)$$

where Q_i^A , Q_i^D , and Q_i^P denote the quality of antenatal, delivery, and postnatal care, respectively. X_i represents individual, household, and regional characteristics, and ϵ_i captures unobserved factors. Equation (1) is the structural statement of H1: outcomes depend on stage-specific care quality, conditional on social and contextual covariates.

Care quality is not realised independently across stages. The quality of care a woman receives at later stages depends on the quality of care she received earlier, mediated by socioeconomic

and institutional factors that condition access to and engagement with the health system:

$$Q_i^D = g(Q_i^A, Z_i) \quad (2)$$

$$Q_i^P = h(Q_i^D, Q_i^A, Z_i) \quad (3)$$

where Z_i includes the social and institutional factors that shape continuity of care. Equation (3) is the structural statement of H2 (earlier-stage quality conditions later-stage quality) and H3 (postnatal care receives the cumulative influence of both antenatal and delivery care, making it the integrating node through which earlier care reaches outcomes).

Substituting Equation (3) into Equation (1) shows that health outcomes depend not only on stage-specific care inputs, but also on the continuity of care across stages, and that this continuity is conditioned by Z_i . H4 follows: because Z_i varies systematically across social groups, the realised continuity of care, and the location of breaks in the continuum, is itself socially distributed.

3 Data and Variables

3.1 Data and Analytical Sample

We use data from the fifth round of the National Family Health Survey (NFHS-5), conducted in India during 2019–21. NFHS-5 is a nationally representative household survey covering all states and union territories that provides detailed information on fertility, maternal and child health, healthcare utilisation, nutrition, and mortality. The survey collects retrospective birth histories and health-related information from women aged 15–49 years, making it well suited for analysing maternal care trajectories and early-life health outcomes.

The analytical sample is constructed using the Children Recode file, which contains child-

level information on survival, birth characteristics, and maternal healthcare utilisation, supplemented with household-level socioeconomic characteristics from the Household Recode file. The analysis is restricted to women’s most recent live birth prior to the survey, as detailed information on antenatal, delivery, and postnatal care is collected only for the latest birth in NFHS-5. Focusing on recent births also reduces recall bias and improves the temporal consistency of reported maternal healthcare utilisation across the continuum.

Although this restriction underrepresents higher-parity women, who contribute fewer observed births proportionally, we control for birth order, total children ever born, and verify robustness using first births only (see Table C1 in the Appendix). The final analytical sample consists of 132,172 women’s most recent live births with complete information on maternal care quality indicators and outcome variables. Figure 2 summarises the sample construction.

3.2 Outcome Variables

Two outcome variables are examined. The primary outcome is infant mortality, analysed as a time-to-event outcome measured by the duration (in months) from birth until death within the first 12 months of life. Infants who die before reaching their first birthday are classified as experiencing the event of interest, whereas those who survive beyond 12 months or are alive at the time of the survey are treated as right-censored observations. Neonatal deaths occurring on the day of birth are recorded as occurring on the first day of life to ensure a positive survival time for survival analysis.

The second outcome is Birth weight is classified into three clinically standard categories: low birth weight (less than 2.5 kg), normal birth weight (2.5–4.0 kg), and high birth weight or macrosomia (above 4.0 kg). This classification follows established clinical and epidemiological literature, recognising that low birth weight and macrosomia reflect distinct biological mechanisms and neonatal health risks (Shen et al., 2021; Mengesha et al., 2017; Liu et al., 2022).

3.3 Covariates

The selection of covariates follows the conceptual framework and standard practice in maternal and child health research. Socioeconomic covariates include caste, religion, household wealth quintile, household size, and maternal educational attainment. Maternal demographic and biological covariates include maternal age, age at first birth, and birth order. Child-level covariates include sex of the child. These capture the structural, biological, and demographic determinants of maternal and child health outcomes ([Mosley and Chen, 1984](#); [Andersen, 1995](#); [Nadella et al., 2021](#); [Agarwal et al., 2019](#); [Powell-Jackson et al., 2015](#)). Summary statistics for the analytical sample are presented in Table 2.

3.4 The Maternal Continuum of Care Quality Index

The principal explanatory variable is the Maternal Continuum of Care Quality Index (MCCQI), a composite measure designed to capture the quality, content, and intensity of maternal healthcare received across the antenatal, delivery, and postnatal continuum.

The MCCQI is constructed from fifteen binary indicators describing the services received during a woman’s most recent pregnancy, informed by the World Health Organization’s recommendations on maternal and newborn care and the existing literature on quality-of-care measurement ([World Health Organization, 2014, 2025](#)). The indicators are grouped into three domains corresponding to the major stages of the maternal care continuum. The antenatal care domain captures the content and quality of pregnancy care, including the adequacy of antenatal contacts, recommended clinical examinations, diagnostic tests, and counselling services. The delivery care domain reflects the quality of childbirth care through indicators of skilled attendance, institutional delivery, and medically indicated obstetric intervention. The postnatal care domain measures essential maternal and newborn care immediately after delivery, including newborn assessment, thermal care, breastfeeding support, and counselling on neonatal danger signs. The complete list of indicators and their coding is presented in

Table 3.

Following the SWPER approach of Ewerling et al. (2017), we employ principal component analysis (PCA) with promax rotation to construct three stage-specific quality scores from the joint indicator matrix. PCA is preferable to simple additive indexing because it assigns data-driven weights to indicators based on their shared variation, reduces redundancy across correlated measures, and accommodates the integrated nature of care received across stages. The rotated solution identifies three latent components corresponding to antenatal, delivery, and postnatal care quality, with each indicator loading predominantly on its corresponding domain.

The three stage-specific scores (Q_{ij}) are computed as standardised linear combinations of the indicators using the rotated loading matrix:

$$Q_{ij} = \frac{\sum_{v=1}^V \lambda_{vj}(x_{iv} - \bar{x}_v)}{\sigma_j} \quad (4)$$

where λ_{vj} is the loading of indicator v on component j , x_{iv} is the observed value of indicator v for individual i , $\bar{x}_v$ is a centring constant, and σ_j is the standard deviation of component j in the pooled sample. Although each domain score is computed from the full set of fifteen indicators using the rotated loading matrix, the cross-domain weights are small in magnitude. The dominant contribution to each score originates from indicators loading on the corresponding component, while preserving information about modest cross-stage correlations consistent with the interconnected nature of the maternal care continuum.

Internal consistency of the MCCQI is acceptable, with Cronbach’s alpha of 0.80 for the full index and domain-specific reliability reported in Appendix A. The Kaiser–Meyer–Olkin statistic of 0.85 confirms sampling adequacy. External validity is assessed by correlating state-level MCCQI scores with the Health Management Information System maternal mortality ratio and the NITI Aayog Health Index; correlations are strong and in the expected

direction (Appendix A). The three stage-specific scores correspond to Q_A , Q_D , and Q_P in the conceptual model (Equations 1 and 2).

4 Empirical Strategy

We estimate the conceptual framework laid out in Section 2 using three sets of empirical specifications: discrete-time survival models for infant mortality, multinomial logistic models for birth weight, and spatial econometric models for district-level patterns. Equations (1) and (2) in Section 2.4 motivate the estimation: Equation (1) is operationalised through stage-specific quality indices entering models of health outcomes (testing H1), while Equation (2) is operationalised through regressions of later-stage quality on earlier-stage quality (testing H2 and H3).

4.1 Infant Survival

Infant mortality is analysed using a discrete-time complementary log-log (cloglog) specification, the discrete-time analogue of the Cox proportional hazards model. The cloglog specification is appropriate for data that are continuous in nature but observed in grouped time intervals (NFHS records survival time in months), and it accommodates the heavy concentration of deaths in the neonatal period that produces tied event times in continuous-time models. The discrete-time hazard for infant i in month j is specified as:

$$\log [-\log (1-h(t_{ij} \mid X_{ij}))]=\alpha_{t_j}+X_{ij} \beta \quad (5)$$

where $h(t_{ij} \mid X_{ij})$ denotes the probability that infant i experiences death in month j , conditional on survival up to that month, α_{t_j} captures duration dependence, and X_{ij} is a vector of covariates. Coefficients are interpreted as log hazard ratios; exponentiated coefficients give proportional changes in the risk of infant death. The data are organised in person-month format, with each infant contributing one observation for every month at risk.

The antenatal, delivery, and postnatal care indices enter the model separately to estimate their total effects on infant survival without conditioning on downstream mediators (Schisterman et al., 2009). To test H3, we estimate a regression-based pathway decomposition in which postnatal care quality is included as a mediator linking antenatal and delivery care to infant survival; the full specification is presented in Appendix C.

$$Q_{D_i} = \gamma_0 + \gamma_1 Q_{A_i} + Z_i \gamma + \varepsilon_i \quad (6)$$

$$Q_{P_i} = \delta_0 + \delta_1 Q_{D_i} + \delta_2 Q_{A_i} + Z_i \delta + \nu_i \quad (7)$$

$$\log[-\log(1 - h(t_{ij} | X_{ij}))] = \alpha_{t_j} + \beta_1 Q_{A_i} + \beta_2 Q_{D_i} + \beta_3 Q_{P_i} + Z_i \beta + u_i \quad (8)$$

4.2 Birth Weight

Birth weight is analysed using multinomial logistic regression with three outcome categories (low, normal, and high birth weight), with normal birth weight as the reference category. Stage-specific quality indices and covariates enter the model as in Equation (4). Coefficients are reported as relative risk ratios for low birth weight and macrosomia relative to normal birth weight.

4.3 Heterogeneity and Spatial Analysis

To test H4, we examine how the associations between maternal care quality and health outcomes vary across socioeconomic and social-group lines through interactions of the stage-specific quality indices with household wealth quintile and caste category. The geographic dimension of H4 is examined using district-level spatial econometric models.

Spatial autocorrelation in maternal care quality, socioeconomic conditions, and birth out-

comes is first assessed using univariate and bivariate Moran’s I statistics. We then estimate a Spatial Durbin Model (SDM) that allows both outcome and explanatory variables to exhibit spatial dependence. The SDM specification, model selection criteria, and LeSage–Pace direct, indirect, and total impact decomposition are described in Appendix C. All descriptive statistics and regression analyses account for the complex survey design of NFHS-5.¹

5 Results

We begin with descriptive patterns in maternal care quality across the population (Section 5.1), then test the four hypotheses developed in Section 2 in turn. Subsection 5.2 reports the association between stage-specific care quality and child health outcomes, testing H1. Subsection 5.3 examines the sequential structure of the continuum, testing H2 and H3. Subsection 5.4 presents the central discontinuity finding. Subsections 5.5 and 5.6 examine the social and geographic distribution of the continuum, testing H4. Subsection 5.7 reports robustness checks.

5.1 Descriptive Patterns in Maternal Care Quality

Maternal care quality varies substantially across India along both geographic and social lines. Figure 3 shows zonal mean MCCQI scores by stages of care. The South zone records the highest scores across all three stages, while the East zone consistently lags, with the largest gaps observed in delivery and postnatal care. The relatively weaker performance of the East is consistent with longstanding healthcare constraints in Bihar, Jharkhand, and Uttar Pradesh, where shortages of skilled healthcare personnel, weaker public health systems, and lower access to quality maternal services have been documented (Pal et al., 2020; Kumar and R.S., 2022; International Institute for Population Sciences (IIPS) and ICF, 2021).

¹All analyses apply the sampling weights provided by NFHS-5 and adjust standard errors for the survey’s stratified, two-stage sampling design using Stata’s `svy` estimation procedures. Primary sampling units and sampling strata are incorporated in all estimations to obtain design-corrected standard errors and confidence intervals.

Figure 4 disaggregates maternal care quality by caste group and reveals a pattern that motivates the analysis that follows. The Scheduled Tribe population documents relatively higher antenatal care quality but lower delivery and postnatal care quality, indicating discontinuity rather than uniform disadvantage. Table 1 shows four standard coverage indicators with MCCQI quality scores for ST and non-ST populations. Panel A shows that coverage gaps are modest: ST and non-ST women report statistically identical antenatal visit rates (58.1 percent, $p = 0.985$), and gaps in institutional delivery (-11.3 pp) and skilled birth attendance (-4.4 pp) remain relatively contained. Panel B tells a different story: the delivery quality score reveals a gap of -0.300 standard deviations ($p < 0.001$), the largest disparity across all seven indicators, which is entirely invisible in the coverage metrics of Panel A. Panel B shows positive postnatal quality gap for ST women ($+ 0.050$ SD) despite lower postnatal coverage ($- 4.2$ pp) likely reflects the composition of ST women’s postnatal contacts: ASHA-led home visits, which predominate in tribal areas, score systematically higher on the MCCQI’s postnatal indicators (cord examination, breastfeeding counselling) than cursory facility check-outs more common among non-ST women.

More advantaged groups show more consistent quality across stages. Socioeconomic gradients in care quality (by wealth quintile, maternal education, and fertility characteristics) are reported in Appendix Table A7; these gradients are clear and in the expected direction but are not the focus of the main analysis.

Two preliminary observations emerge. First, disparities in maternal care are both geographic and social, and they persist across the continuum rather than being confined to a single stage. Second, the pattern for Scheduled Tribe women—high antenatal and postnatal utilisation but low delivery quality—suggests that the continuum operates differently across social groups, a pattern we examine formally in Subsections 5.4 and 5.5.

5.2 Stage-specific Care Quality and Health Outcomes

Table 4 reports the association between stage-specific maternal care quality and health outcomes. Higher quality maternal care is consistently associated with improved infant survival and birth weight outcomes, supporting H1 with small variation across stages and outcomes.

For infant mortality, all three components are protective. Antenatal care quality is associated with a modest reduction in mortality risk ($HR = 0.958$, 95% CI: 0.920–0.997), delivery care with a larger reduction ($HR = 0.921$, 95% CI: 0.879–0.964), and postnatal care with the strongest protective association of the three ($HR = 0.595$, 95% CI: 0.570–0.620). The composite MCCQI is associated with a 13 per cent reduction in infant mortality risk ($HR = 0.868$, 95% CI: 0.853–0.883). The dominance of the postnatal association is consistent with H1: neonatal mortality risk concentrates in the early postnatal period, and postnatal care is the stage at which that risk is most directly addressed.

The relationship between care quality and birth weight varies across outcome categories. Higher antenatal care quality is associated with lower relative risks of both low birth weight ($RRR = 0.970$, 95% CI: 0.950–0.989) and macrosomia ($RRR = 0.742$, 95% CI: 0.729–0.754) relative to normal birth weight, reflecting the role of prenatal screening, nutritional supplementation, and early risk identification during pregnancy. Delivery care, by contrast, shows no statistically significant association with low birth weight, which is biologically plausible given that fetal growth restriction is primarily determined during pregnancy rather than at the point of delivery. Additional specifications examining macrosomia are reported in Appendix D. These estimates are interpreted cautiously, given the potential for reverse causality and differential measurement of birth weight across institutional and non-institutional delivery settings.

5.3 Sequential Structure of the Maternal Care Continuum (H2 and H3)

We examine whether maternal care operates as a sequential process in which care at earlier stages is associated with care at subsequent stages, and whether the protective association of antenatal and delivery care with infant survival operates partly through postnatal care. Because the data are observational, the pathway decomposition is interpreted descriptively, as a characterisation of dominant pathways linking maternal care to infant survival, not as a causal mediation analysis. Methodological details are reported in Appendix B.

Earlier-stage care quality is positively associated with later-stage care quality, supporting H2. ANC is strongly associated with improved delivery care ($\beta = 0.117$, $p < 0.001$), and both ANC ($\beta = 0.198$, $p < 0.001$) and DC ($\beta = 0.091$, $p < 0.001$) are associated with postnatal care quality. The sequential and reinforcing structure posited by the continuum-of-care framework is clearly evident in the data.

Pathway decomposition (Figure 5) supports H3: postnatal care operates as an integrating node through which earlier-stage care reaches infant survival. The direct association between postnatal care quality and infant survival is large and statistically significant (HR = 0.595, $p < 0.001$), corresponding to a 40.5 per cent reduction in infant mortality risk. Beyond this direct effect, postnatal care also carries an indirect share of the upstream protective effect of antenatal care. Multiplying the antenatal–postnatal care coefficient ($\beta = 0.198$) by the log-hazard of postnatal care yields an indirect log-hazard of approximately -0.103 , implying an indirect hazard ratio of 0.902, a 9.8 per cent reduction in mortality risk operating via the antenatal–postnatal pathway.

The pathway from antenatal care to infant survival operating through delivery care is, by contrast, modest. Combining the antenatal–delivery coefficient ($\beta = 0.117$) with the delivery care hazard ratio yields an indirect log-hazard of approximately -0.010 , implying only a 1 per

cent indirect effect. Delivery care’s protective association with infant survival ($HR = 0.921$, equivalent to an 8 per cent reduction) is therefore largely direct, reflecting skilled birth attendance and timely management of obstetric complications, rather than serving as a conduit for upstream antenatal investments.

A parallel pathway structure emerges for birth weight (Figure 6), with one difference. The indirect pathway operating through delivery care is negligible for low birth weight (consistent with fetal growth restriction being a pregnancy-stage phenomenon), but delivery care has a meaningful share of the association between antenatal care and macrosomia: improved antenatal care reduces macrosomia risk partly through increased utilization of skilled and institutional delivery. As noted in Subsection 5.2, the macrosomia results should be interpreted with caution given likely reverse causality.

5.4 Discontinuity in the Maternal Care Continuum

The pathway decomposition characterises the average association between earlier-stage and later-stage care quality, but it does not show what happens to individual women as they move through the continuum. To address this, we examine transitions across quality tiers, classifying women into low, moderate, and high-quality categories at each stage and tracing the flows between stages. Figure 7 presents three chord diagrams: antenatal to delivery, antenatal to postnatal, and delivery to postnatal. The visualisation reveals a pattern that the average effects in Subsection 5.3 cannot capture.

The transition from antenatal to delivery care shows partial persistence: women receiving high or moderate-quality antenatal care are more likely to access comparable levels of delivery care. But a sizeable share, particularly women who began with low-quality antenatal care, remain in low-quality delivery services, indicating limited upward mobility within the system. Discontinuities intensify in the antenatal-to-postnatal transition, where even women who received moderate or high-quality antenatal services frequently fail to reach high-quality postnatal care.

The sharpest attrition is at the delivery-to-postnatal transition. A large share of women who receive moderate or even high-quality delivery care subsequently move into low-quality postnatal care. This is the weakest link in the continuum, and it is structurally distinctive: women have reached the formal health system at the highest-acuity stage and received quality care there, yet the system loses them in the immediate postpartum period when neonatal mortality risk is highest. Across all three transitions, flows originating from low-quality care overwhelmingly terminate in low-quality subsequent stages, suggesting path dependence and cumulative disadvantage within the continuum.

Together, the pathway decomposition and these transition patterns underscore a distinctive structural feature of maternal care in India. The continuum is not a smooth pathway in which contact at each stage builds on the previous one. It is a fractured system in which contact at one stage does not guarantee comparable quality at the next, and in which the largest break occurs precisely where the protective association with infant survival is strongest. Strengthening postnatal outreach and follow-up, rather than expanding contact at the antenatal or delivery stages, therefore emerges as the policy lever most directly aligned with the structure of the problem.

5.5 Social Distribution of the Continuum (H4)

The fracture in the continuum is not uniformly distributed across the population. We examine social patterning along two dimensions: caste and household wealth. The most important finding is for Scheduled Tribe households, where the social-distributional logic of H4 is most clearly visible.

Scheduled Tribe women document a distinct pattern across the maternal care continuum: relatively higher utilisation of antenatal care and postnatal care, but substantially lower delivery care quality compared with socially advantaged groups (Figure 4 and Figure 9). This is not a uniform deficit in access. ST women are reaching the health system at the antenatal stage, and they are being followed up postpartum. The fracture occurs precisely

at the delivery stage. To examine whether this delivery-stage fracture is primarily driven by poorer geographic access to health facilities, we estimated additional survey-weighted regression models relating caste, distance to the nearest Community Health Centre (CHC) or District Hospital (DH), and delivery care quality (Table 5). Scheduled Tribe women reside significantly farther from delivery-capable facilities than women in the other caste group ($\beta = 0.468$, $p < 0.001$), and greater distance is itself associated with significantly lower delivery care quality ($\beta = -0.0107$, $p < 0.001$). However, controlling for distance explains only a small proportion of the observed disparity. The coefficient for Scheduled Tribe women changes only marginally, from -0.223 to -0.218 , after adjusting for geographic accessibility, representing an attenuation of approximately two percent. Details of the GIS procedure used to construct the distance measure are provided in Appendix B.6.

This evidence suggests that geographic accessibility alone cannot account for the delivery care deficit among Scheduled Tribe women. The persistence of the disparity after controlling for distance is consistent with broader structural features of maternal healthcare delivery in tribal regions. Outreach-based services delivered through Accredited Social Health Activists (ASHAs) and community health workers extend antenatal monitoring and postnatal follow-up into geographically isolated areas (Chawla et al., 2025). By contrast, high-quality delivery care depends on timely access to adequately equipped health facilities, skilled obstetric personnel, emergency referral systems, and respectful maternity care, all of which remain more limited in many tribal regions (Contractor et al., 2018; Maity, 2016). Outreach, therefore, succeeds at the stages where community-based services can substitute for facility-based care, but is less able to overcome structural barriers surrounding institutional delivery.

Wealth-based heterogeneity shows a different pattern. The protective association between antenatal care quality and infant survival is strongest among women from wealthier households, while estimates for poorer and middle-wealth groups are smaller and in some cases statistically indistinguishable from zero (Figure 8). This is consistent with antenatal care quality varying considerably with household resources: wealthier women receive more com-

prehensive screening and earlier registration, allowing antenatal inputs to translate more effectively into survival benefits. Patterns for delivery and postnatal care are less monotonic across wealth groups (Figure 9 and 10), reflecting the near-universalisation of institutional delivery under Janani Suraksha Yojana and JSSK, which has substantially reduced wealth-based disparities in facility-based childbirth. Marginal improvements in delivery or postnatal care yield larger survival gains among poorer households with higher baseline mortality risk. Taken together, the heterogeneity results support H4: the quality and continuity of maternal care are systematically distributed across social and economic lines. The Scheduled Tribe pattern is the clearest illustration—the fracture in the continuum at the delivery stage is concentrated among precisely the population for whom geographic and structural barriers to facility-based care are most acute.

5.6 Geographic Dimension of the Continuum (H4)

The social patterning examined in Subsection 5.5 has a spatial counterpart. District-level analysis reveals strong geographic clustering in maternal care quality and birth outcomes, indicating that the social distribution of the continuum operates at both group and place levels.

Univariate Moran’s I statistics show significant spatial autocorrelation in antenatal and delivery care quality and in the district-level prevalence of normal birth weight Table 6. Bivariate Moran’s I results confirm statistically significant spatial associations between maternal care quality and birth outcomes: districts with higher-quality antenatal and delivery care tend to be surrounded by districts with better neonatal outcomes, while spatial clustering of poverty is associated with poorer neighbouring birth weight outcomes. Maternal care quality and child health outcomes are not randomly distributed across Indian districts.

We estimate a Spatial Durbin Model (SDM) to characterise direct and spillover effects, with full specification and the LeSage–Pace impact decomposition reported in Appendix B.

Table 7 reports direct, indirect, and total impacts. Higher-quality antenatal and delivery care within districts is significantly associated with higher proportions of normal birth weight, and the spatial autoregressive parameter is large and statistically significant ($\rho \approx 0.6$), indicating substantial inter-district dependence. The direct effects of antenatal and delivery care on local birth weight outcomes are positive and significant; indirect effects through neighbouring districts are mixed in sign, reflecting heterogeneity in the spatial structure of healthcare access and care-seeking behaviour across regions.

These spatial patterns reinforce the social-distribution finding from Subsection 5.5. The continuum of care operates within a broader geographic structure in which maternal healthcare quality and birth outcomes cluster at the district level, with implications for how social and place-based disadvantages compound across the maternal care pathway. The interpretation of negative indirect effects—whether they reflect cross-district care-seeking, regional concentration of obstetric infrastructure, or unobserved spatial confounding—cannot be resolved from these data alone and is taken up in the Discussion.

5.7 Robustness Checks

We conducted a series of robustness analyses to assess the sensitivity of the main findings to alternative methods of index construction, sample restrictions, and potential unobserved confounding.

First, because the Maternal Continuum of Care Quality Index (MCCQI) is constructed from fifteen binary indicators, the baseline principal component analysis (PCA) based on Pearson correlations may underestimate associations among dichotomous variables. To assess whether the factor structure depends on the choice of correlation matrix, we re-estimated the index using PCA based on a tetrachoric correlation matrix, which assumes that the observed binary indicators arise from underlying continuous latent variables.

The tetrachoric PCA reproduced the same three latent dimensions identified in the baseline

analysis. Three factors with eigenvalues greater than one were retained, jointly explaining 76.0% of the total variance. Following Promax rotation, antenatal care indicators loaded strongly on the first component (0.49–0.96), postnatal care indicators on the second (0.91–0.98), and delivery care indicators on the third (0.68–0.92). The factor structure, ordering of components, and substantive interpretation were virtually identical to those obtained from the baseline PCA, indicating that the MCCQI is robust to the choice of correlation matrix. Complete factor loadings are reported in Appendix Table C1.

Second, the discrete-time complementary log-log models for infant mortality were re-estimated using only first births to address the possibility that parity may confound the relationship between maternal healthcare quality and infant survival. The estimated hazard ratios remained substantively unchanged, with postnatal care continuing to exhibit the strongest protective association with infant mortality (see Appendix Table C2).

Third, we assessed the sensitivity of the principal estimates to unmeasured confounding using E-value analysis. The estimated E-value for postnatal care indicates that a relatively strong unmeasured confounder would be required to fully explain the observed association with infant survival, suggesting that the main findings are reasonably robust to omitted variable bias (see Appendix Table C3).

Finally, we constructed an alternative maternal healthcare quality index using the DHS-SPA Quality of Care framework proposed by [Mallick et al. \(2020\)](#). Re-estimating the infant mortality models using this alternative index yielded substantively similar results. Higher maternal healthcare quality remained significantly associated with improved infant survival, and postnatal care continued to exhibit the strongest protective association. Collectively, these robustness analyses indicate that the principal findings are not sensitive to alternative methods of index construction, sample composition, or plausible levels of unmeasured confounding (see Appendix Table C4).

6 Discussion

The findings of this study point toward a conclusion that extends beyond the established proposition that maternal healthcare quality improves birth outcomes. The more fundamental contribution lies in what the analysis reveals about the structural architecture of the maternal healthcare system itself. Coverage-based metrics, the dominant tool of health system monitoring in India and globally, measure whether women access individual services but remain insensitive to whether those services form a coherent continuum of care. A woman counted as having received antenatal care may never transition to high-quality delivery care, and a woman without institutional delivery may fall into a postnatal vacuum. The analysis shows that this is not a rare failure mode; it is a structural feature of maternal healthcare in India that current monitoring systems are not designed to detect.

At the individual level, the four hypotheses developed in Section 2 are supported. Stage-specific care quality is consistently associated with improved infant survival and birth weight outcomes (H1), with postnatal care showing the strongest protective association, consistent with the concentration of neonatal mortality risk in the early postnatal period ([Lawn and Sadoo, 2018](#); [Lee et al., 2022](#)). Earlier-stage care quality is associated with later-stage care quality (H2), indicating that the continuum operates sequentially rather than as a set of independent contacts. The pathway decomposition supports H3: a meaningful share of the protective association of antenatal and delivery care with infant survival operates through postnatal care, identifying postnatal care as the integrating node through which earlier-stage investments reach survival outcomes.

The strongest finding, however, concerns the social distribution of the continuum (H4). The chord diagrams show substantial fragmentation at the delivery-to-postnatal transition: a sizeable share of women who receive moderate or high-quality delivery care subsequently move into low-quality postnatal care. This discontinuity is not uniformly distributed. Scheduled Tribe women, in particular, show relatively high antenatal and postnatal utilisation

but markedly lower delivery care quality. The pattern is the social-distributional logic of H4 made concrete: outreach-based services delivered through Accredited Social Health Activists and community health workers extend antenatal monitoring and postnatal follow-up into geographically isolated tribal communities ([Chawla et al., 2025](#)), but institutional delivery requires transportation, nearby facilities, and access to emergency obstetric services that remain limited in remote regions ([Contractor et al., 2018](#)). The continuum reaches ST women at the stages where outreach can substitute for facility-based care and fails them at the stage where it cannot. A coverage-based monitoring system would record these women as relatively well-served at two of three stages; the chord diagrams reveal a systematic fracture that utilisation data alone cannot detect.

Spatial analysis adds a geographic dimension to the social-distributional finding. District-level patterns in maternal care quality and birth outcomes are not randomly distributed across India; they cluster spatially in ways that compound the social inequalities documented at the individual level. The negative spatial spillover estimates in the Spatial Durbin Model are significant: improvements in maternal care quality in neighbouring districts are not always associated with improvements in local outcomes. One plausible interpretation is that maternal healthcare infrastructure remains unevenly distributed across districts, with higher-quality delivery and obstetric services concentrated in a limited number of regional centres. Households in underserved districts may travel across district boundaries to access institutional care, generating competitive rather than complementary spatial dynamics ([Kruk et al., 2009](#); [Contractor et al., 2018](#)). This interpretation cannot be definitively resolved from the data, but it points toward the importance of regional rather than purely district-level health system planning.

Several limitations of this study should be acknowledged. First, the analysis relies on observational cross-sectional survey data and therefore identifies statistical associations rather than causal effects. Women who utilise institutional delivery and skilled birth attendance are likely to differ systematically from those who do not, not only in observed socioeco-

nomie and demographic characteristics controlled for in the models, but also in unobserved dimensions such as health literacy, risk perception, and health-seeking propensity. These unobserved characteristics are independently and positively associated with both healthcare utilisation and better maternal and infant outcomes. Their omission therefore biases the estimated protective associations upward: the estimated hazard ratios overstate the true causal reduction in infant mortality risk attributable to each stage of care. Our estimates should accordingly be read as upper bounds on the true protective associations rather than as unbiased causal effects. This upward bias is likely most pronounced for the antenatal and delivery care estimates, which depend more heavily on women’s health-seeking propensity; the postnatal care association, which the E-value analysis (Appendix C3) indicates is robust to moderate unobserved confounding, is less sensitive to this concern.

Maternal healthcare utilisation measures are self-reported and may be affected by recall bias, though restricting the analysis to recent births reduces this concern. The MCCQI captures multiple dimensions of maternal care content and intensity but does not fully reflect provider competence, clinical effectiveness, or interpersonal aspects of care. Spatial estimates depend on the chosen weights matrix and may be sensitive to alternative geographic specifications. Finally, restricting the sample to women’s most recent live birth underrepresents higher-parity women; first-birth robustness analysis (Appendix C2) indicates that the substantive findings are not driven by this restriction.

Three policy implications follow. First, the delivery-to-postnatal transition emerges as the weakest link in the continuum and the point at which policy attention should concentrate. Strengthening postnatal follow-up, through expanded implementation of Janani Shishu Suraksha Karyakram, sustained ASHA-led postnatal home visits, and better integration of facility-based delivery with community-based postnatal care, addresses the stage at which the protective association with infant survival is strongest and the structural break in the continuum is sharpest. Second, the Scheduled Tribe pattern suggests that expanding outreach alone is insufficient to close the continuum where geographic and structural bar-

riers to facility-based care persist. Targeted investments in transportation infrastructure, emergency obstetric services, and reductions in social barriers within healthcare facilities are needed alongside outreach. Third, the spatial findings indicate that district-level improvements may not generate uniformly positive regional gains if obstetric infrastructure remains concentrated. Regional coordination across district boundaries, rather than isolated district-level investment, is required to address the geographic patterning of maternal care quality.

Beyond these specific recommendations, the findings have broader implications for how maternal health systems are monitored. Coverage-based indicators (antenatal visits attended, institutional deliveries conducted, postnatal contacts recorded) were designed for an era in which the primary challenge was extending access to maternal care. They remain useful for that purpose. But where access has expanded substantially, as in India, the binding constraint on further improvement in maternal and child health outcomes is no longer whether women contact the health system at each stage but whether the contacts they have add up to a coherent continuum of care. Monitoring systems that track transitions across stages, and that disaggregate quality by social group and geography, would provide visibility into the structural fractures this analysis identifies. Such monitoring is a precondition for the policy responses required to address them.

7 Conclusion

This study examines maternal healthcare in India as a quality-adjusted continuum rather than as a set of disconnected service contacts. Three contributions emerge. The Maternal Continuum of Care Quality Index, constructed using nationally representative NFHS-5 data, provides a quality-adjusted measure of care received across antenatal, delivery, and postnatal stages. The pathway decomposition documents that the continuum operates sequentially, with postnatal care serving as the integrating node through which earlier-stage care reaches

infant survival outcomes. And the social-distributional analysis reveals that the continuum is fractured, most sharply at the delivery-to-postnatal transition, and most acutely among Scheduled Tribe women, in ways that coverage-based monitoring cannot detect.

These findings suggest that further gains in maternal and child health in India will require attention not only to whether women access care but to the quality and continuity of care across stages, and to the social and geographic distribution of fractures in the continuum. The delivery-to-postnatal transition emerges as the weakest link and the most consequential point for policy intervention. The Scheduled Tribe pattern indicates that outreach-based services alone cannot close the continuum where structural barriers to institutional delivery remain. And the geographic clustering of maternal care quality suggests that regional rather than district-level coordination is needed to address the spatial concentration of obstetric infrastructure.

More broadly, the analysis contributes to a growing recognition that coverage-based metrics, while indispensable for tracking access, are insufficient for understanding why expansions in healthcare reach do not always translate into proportionate improvements in health outcomes. The quality-adjusted continuum-of-care framework developed here, combined with attention to the social distribution of discontinuities, offers one approach to closing this measurement gap. Strengthening transitions across the maternal care continuum and monitoring those transitions across social groups may provide a more effective pathway for improving maternal and child health outcomes in India than expanding individual service contacts alone.

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Figures

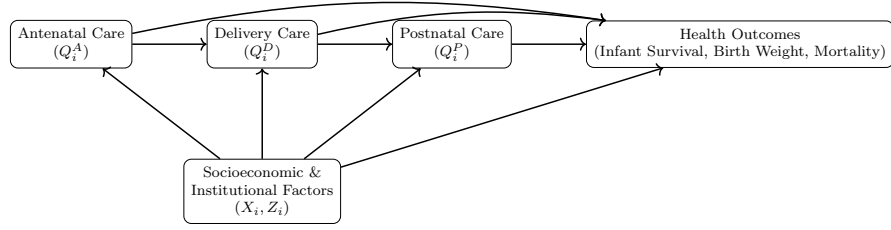


Figure 1: Conceptual framework: maternal care as a sequential health production process

Notes: The framework integrates the life-course model, Andersen’s behavioural model, and the Mosley–Chen child survival framework to illustrate how socioeconomic, behavioural, and health system factors jointly shape maternal and child health outcomes.

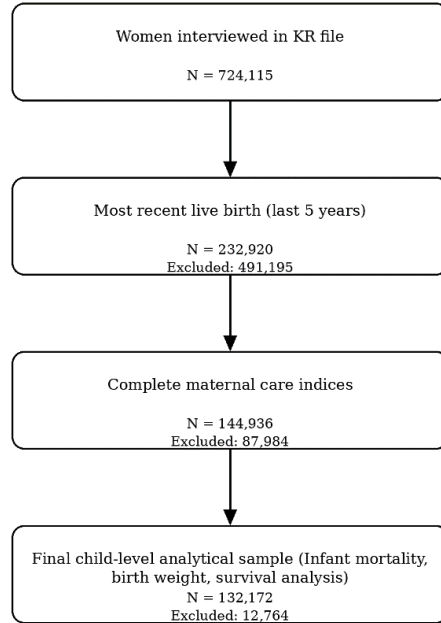


Figure 2: Construction of analytical samples for child-level analyses using NFHS-5

Notes: The analytical sample is constructed from the NFHS-5 Children Recode (KR) file. The analysis is restricted to women’s most recent live birth within five years prior to the survey and observations with complete information on maternal care quality indicators and outcome variables.

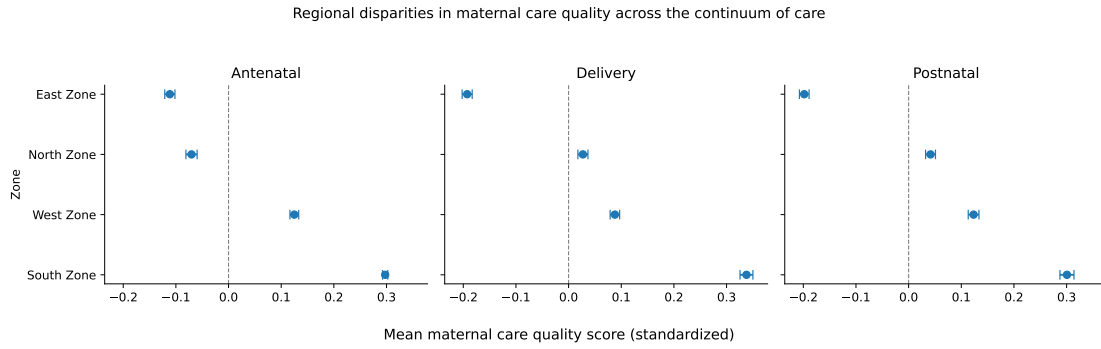


Figure 3: Regional variation in maternal care quality across stages.

Notes: Zonal mean MCCQI scores for antenatal, delivery, and postnatal care. Scores are standardised to a national mean of zero.

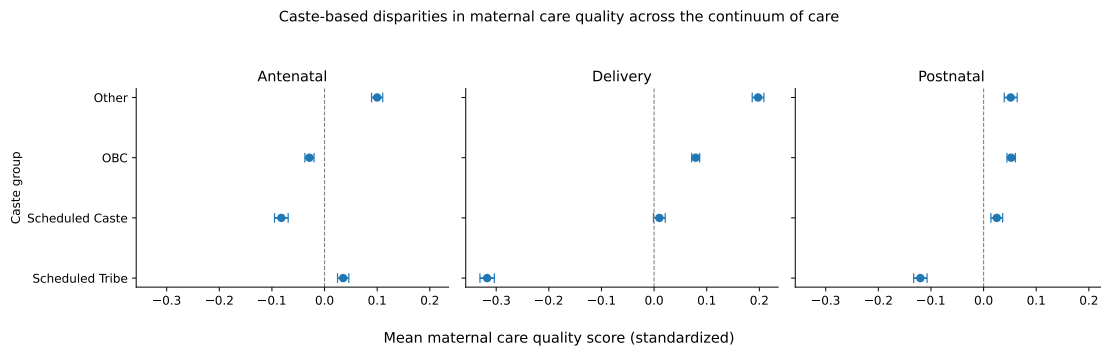


Figure 4: Maternal care quality across caste groups.

Notes: Mean MCCQI scores for antenatal, delivery, and postnatal care across caste groups. Scores are standardised to a national mean of zero.

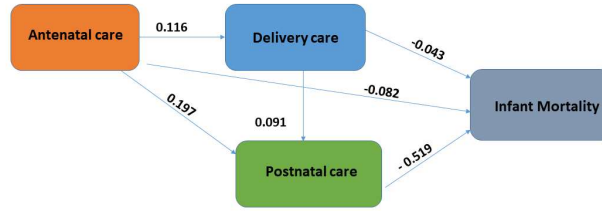


Figure 5: Sequential pathway associations: antenatal and delivery care, postnatal care, and infant survival

Notes: Coefficients reported along the arrows represent estimated associations from sequential regression models linking antenatal care (ANC), delivery care (DC), postnatal care (PNC), and infant mortality. Negative coefficients indicate reductions in infant mortality risk. All models control for maternal, child, household, socioeconomic, and regional characteristics and account for the complex survey design of NFHS-5 using sampling weights, stratification, and clustering adjustments.

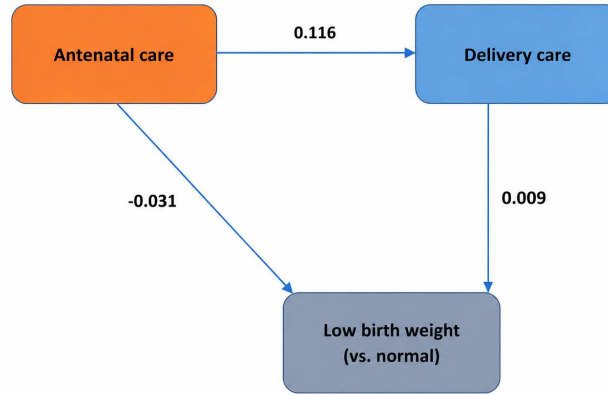


Figure 6: Sequential pathway analysis for birth weight outcomes

Notes: The figure presents sequential pathway associations between antenatal care (ANC), delivery care (DC), and low birth weight relative to normal birth weight. Coefficients reported along the arrows represent estimated log-coefficients derived from multinomial logistic regression models within the pathway-based decomposition framework. Negative coefficients indicate lower relative risks of low birth weight relative to normal birth weight. Model control for maternal, child, household, socioeconomic, and regional characteristics and account for the complex survey design of NFHS-5 using sampling weights, stratification, and clustering adjustments.

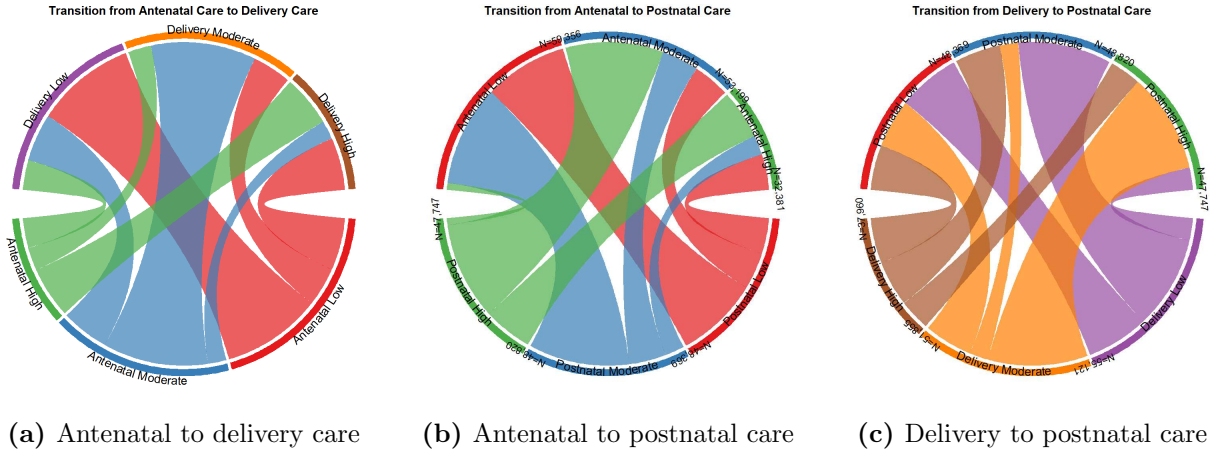


Figure 7: Transitions across the maternal health care continuum

Notes: Chord diagrams illustrate transitions between low, moderate, and high tiers of maternal care quality across antenatal, delivery, and postnatal stages. Arc widths represent the number of women in each care category, while chord thickness indicates the volume of transitions between stages. Persistent flows within low-quality tiers and sharp drop-offs into low-quality postnatal care highlight fragmentation in continuity of maternal health services.

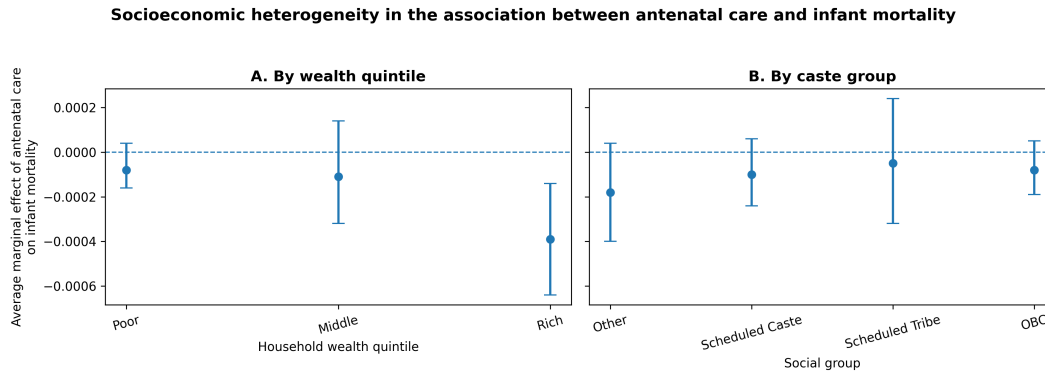


Figure 8: Socioeconomic heterogeneity in the association between antenatal care and infant mortality.

Notes: Panel A shows average marginal effects by household wealth quintile, and Panel B by caste group. Points represent marginal effects estimated from discrete-time complementary log-log models, with vertical bars indicating 95% confidence intervals. Confidence intervals are based on robust standard errors. All specifications include the full set of controls used in the baseline models.

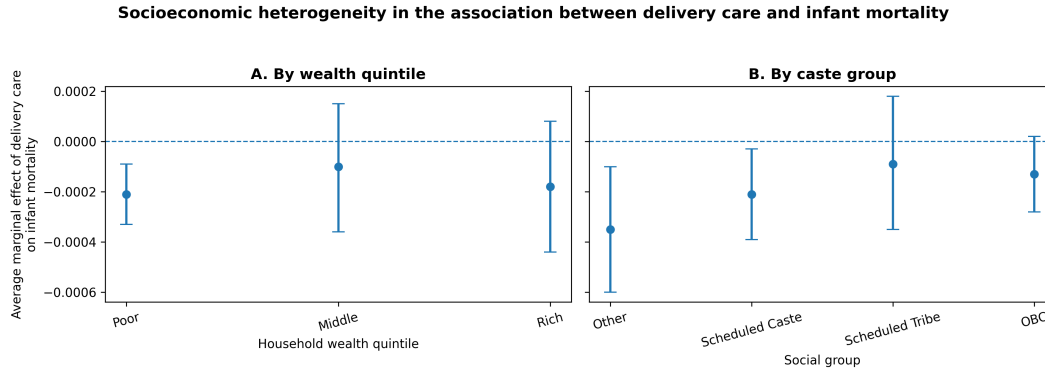


Figure 9: Socioeconomic heterogeneity in the association between delivery care and infant mortality.

Notes: Panel A presents wealth-based heterogeneity, while Panel B reports caste-based differences. Delivery care effects capture variation in facility-based and skilled birth attendance quality. Estimates are average marginal effects from complementary log-log survival models. Confidence intervals are based on robust standard errors. All specifications include the full set of controls used in the baseline models.

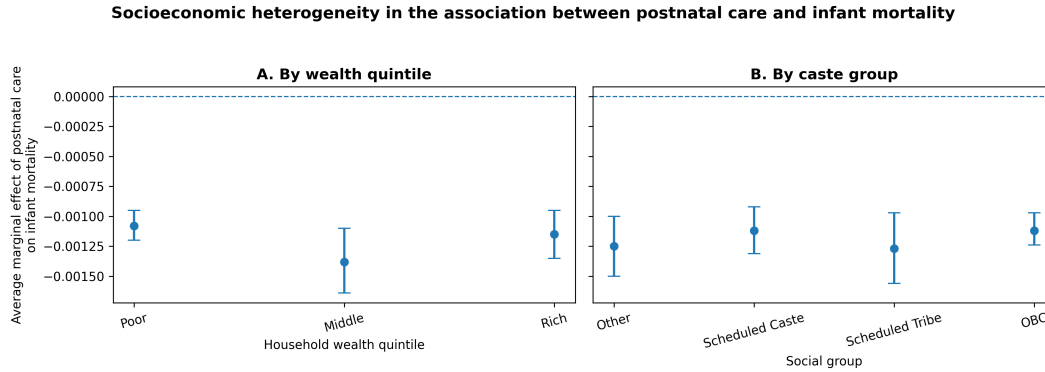


Figure 10: Socioeconomic heterogeneity in the association between postnatal care and infant mortality.

Notes: Panel A shows heterogeneity by wealth quintile and Panel B by caste group, highlighting differential returns to postnatal care across socioeconomic strata. Marginal effects are derived from discrete-time survival models with complementary log-log links. Confidence intervals are based on robust standard errors. All specifications include the full set of controls used in the baseline models.

Table 1: Coverage Indicators and Maternal Care Quality Scores among Scheduled Tribe and Non-Scheduled Tribe Populations

Indicator	Non-ST	ST	Difference (ST – Non-ST)	<i>p</i> -value
<i>Panel A: Coverage Indicators (%)</i>				
Four or More ANC Visits	58.1	58.1	-0.0	0.985
Institutional Delivery	85.6	74.3	-11.3	< 0.001
Skilled Birth Attendance	91.6	87.2	-4.4	< 0.001
Postnatal Care within 24 Hours	75.8	71.6	-4.2	< 0.001
<i>Panel B: Maternal Continuum of Care Quality Index (Standardised Scores)</i>				
Antenatal Care Quality	-0.035	0.039	0.074	< 0.001
Delivery Care Quality	0.100	-0.200	-0.300	< 0.001
Postnatal Care Quality	0.017	0.068	0.051	< 0.001

Notes: Panel A reports survey-weighted coverage rates for standard maternal healthcare contact indicators. Panel B reports mean values of the Maternal Continuum of Care Quality Index (MCCQI), standardised to have a mean of zero and a standard deviation of one in the full sample. Differences are calculated as Scheduled Tribe (ST) minus Non-Scheduled Tribe (Non-ST) values. *p*-values are based on design-adjusted tests accounting for the complex survey design of NFHS-5.

Table 2: Summary statistics of the analytical sample

	Mean / % (SE)
<i>Outcome variables</i>	
Infant mortality	2.31 (0.0005)
Low birth weight	15.51 (0.0010)
Normal birth weight	75.76 (0.0011)
High birth weight	8.73 (0.0007)
<i>Maternal care quality indices</i>	
Antenatal care score	-0.042 (0.0037)
Delivery care score	0.059 (0.0033)
Postnatal care score	0.025 (0.0036)
Overall quality-of-care index	0.041 (0.0070)
<i>Socioeconomic characteristics</i>	
<i>Religion</i>	
Hindu (%)	82.55 (0.0014)
Non-Hindu (%)	17.45 (0.0014)
<i>Caste</i>	
Scheduled caste (%)	24.30 (0.0016)
Scheduled tribe (%)	10.38 (0.0010)
Other backward classes (%)	45.61 (0.0018)
Other caste (%)	19.70 (0.0016)
<i>Wealth</i>	
Poor household (%)	44.42 (0.0016)
Middle household (%)	19.78 (0.0015)
Rich household (%)	35.80 (0.0017)
<i>Maternal education</i>	
No education (%)	20.06 (0.14)
Primary education (%)	12.01 (0.12)
Secondary education (%)	51.03 (0.19)
Higher education (%)	16.90 (0.16)
<i>Household characteristics</i>	
Household size	6.25 (0.010)
Male household head (%)	84.89 (0.0013)
<i>Child characteristics</i>	
Number of children	1.50 (0.003)
Male child (%)	54.03 (0.19)
<i>Reproductive characteristics</i>	
Age at first birth ≥ 21 (%)	54.43 (0.18)
Current age ≤ 35 (%)	90.91 (0.11)
Birth interval ≥ 24 months (%)	83.36 (0.14)
Birth order ≤ 2 (%)	96.62 (0.06)
<i>Geographic characteristics</i>	
West zone (%)	25.29 (0.0011)
South zone (%)	14.31 (0.0008)
North zone (%)	30.06 (0.0008)
East zone (%)	30.33 (0.0009)
Observations	132,172

Notes: All statistics are weighted using NFHS-5 sampling weights and account for the complex survey design. Continuous variables are reported as means with standard errors in parentheses, and categorical variables are reported as percentages with standard errors in parentheses. Maternal care indices are standardised with mean zero.

Table 3: Items used to construct the Maternal Continuum of Care Quality Index (MCCQI)

Domain	Variable description	Coding
Antenatal care domain		
	Mother weighted during pregnancy	Yes = 1, No = 0
	Blood pressure measured during pregnancy	Yes = 1, No = 0
	Urine sample taken during pregnancy	Yes = 1, No = 0
	Blood sample taken during pregnancy	Yes = 1, No = 0
	Abdomen examined during pregnancy	Yes = 1, No = 0
	Number of antenatal care visits	≥ 4 visits = 1, otherwise = 0
	Counselled about pregnancy complications	Yes = 1, No = 0
Delivery care domain		
	Type of delivery assistance	Skilled = 1, Unskilled = 0
	Place of delivery	Institutional = 1, Other = 0
	Caesarean section performed if required	Yes = 1, No = 0
Postnatal care domain		
	Cord examined within first two days after birth	Yes = 1, No = 0
	Newborn temperature measured within first two days	Yes = 1, No = 0
	Counselled on newborn danger signs within first two days	Yes = 1, No = 0
	Counselled on breastfeeding within first two days	Yes = 1, No = 0
	Breastfeeding observed by provider within first two days	Yes = 1, No = 0

Notes: All variables are binary indicators. Higher values indicate better quality of care. The index is constructed using principal component analysis across antenatal, delivery, and postnatal care domains.

Table 4: Association between maternal care quality and maternal and child health outcomes

Outcome	Model	ANC	DC	PNC	Overall quality
Infant mortality (HR)	Cloglog	0.958* (0.020)	0.921*** (0.022)	0.595*** (0.013)	0.868*** (0.008)
<i>Birth weight categories (reference: normal birth weight)</i>					
Low birth weight (RRR)	Multinomial logit	0.970** (0.010)	1.009 (0.013)	—	0.985** (0.006)

Notes: Hazard ratios (HR) are reported for infant mortality, and relative risk ratios (RRR) for multinomial birth weight models. Normal birth weight (2.5–4.0 kg) serves as the reference category. Standard errors are shown in parentheses. All models control for maternal, household, socioeconomic, and regional characteristics and apply NFHS-5 sampling weights with clustering and stratification adjustments. Dashes (—) indicate that postnatal care was excluded from birth weight models because it occurs after delivery. Additional macrosomia specifications are reported in Appendix D. ANC = antenatal care; DC = delivery care; PNC = postnatal care. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5: Geographic Access to Delivery-Capable Facilities and Scheduled Tribe Disparities in Delivery Care Quality

Variables	(1) Distance (km)	(2) Delivery QoC	(3) Delivery QoC
Distance to nearest CHC/DH (km)		−0.0107***	(0.0006)
Scheduled Caste	−0.146** (0.071)	−0.055*** (0.010)	−0.057*** (0.010)
Scheduled Tribe	0.468*** (0.089)	−0.223*** (0.013)	−0.218*** (0.013)
Other Backward Class	0.306*** (0.062)	−0.065*** (0.009)	−0.062*** (0.009)
Observations	132,172	132,172	132,172

Notes: Model (1) estimates the association between caste and the straight-line distance from the NFHS cluster to the nearest Community Health Centre (CHC) or District Hospital (DH). Model (2) estimates caste differences in delivery care quality. Model (3) additionally controls for geographic accessibility. All regressions are estimated using NFHS-5 sampling weights and include the full set of covariates used throughout the paper, including religion, household wealth, maternal education, household characteristics, maternal characteristics, and state fixed effects. Robust standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 6: Global Moran’s I : spatial autocorrelation (Queen contiguity, $n = 707$)

Variable	Moran’s I	p -value	Interpretation
Normal birth-weight	0.5422	0.001	Strong positive clustering
Antenatal score	0.7481	0.001	Very strong positive clustering
Delivery score	0.6679	0.001	Strong positive clustering
Quality of care	0.7538	0.001	Very strong positive clustering

Notes: Permutation-based p -values are based on 999 permutations. All statistics are significant at $p < 0.001$. Bivariate correlations between normal birth-weight and spatially lagged care scores range from $r = 0.45$ (delivery) to $r = 0.53$ (antenatal), further confirming spatial linkages between care quality and birth outcomes in neighbouring districts.

Table 7: SDM direct, indirect and total impacts (LeSage & Pace 2009)

Variable	ANC model			Delivery model			Quality model		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Care score (main)	0.143	−0.013	0.131	0.088	0.032	0.120	0.067	−0.012	0.055
Middle income	0.052	0.118	0.171	0.070	0.049	0.119	0.094	0.092	0.186
Higher education	0.143	−0.109	0.034	0.106	−0.128	−0.022	0.133	−0.132	0.000
Secondary education	0.087	−0.017	0.070	0.076	0.079	0.155	0.048	0.098	0.145
No. of children	0.070	−0.177	−0.107	0.105	−0.110	−0.005	0.100	−0.128	−0.028
Birth order (< 2)	0.431	0.560	0.991	0.663	0.844	1.508	0.332	0.651	0.983
Mother’s age (> 21)	−0.063	−0.052	−0.114	−0.043	−0.121	−0.164	−0.036	−0.269	−0.305

Notes: Direct = own-district effect; Indirect = spillover to/from neighbouring districts; Total = Direct + Indirect. Bold values in the “Total” columns indicate the largest effects. Impacts are computed using the “simple” method with simulation-based standard error estimation.

Appendix

A MCCQI Construction Details and Validation

This appendix details the construction and validation of the Maternal Continuum of Care Quality Index (MCCQI) introduced in Section 3.4 of the main text. Five components are reported: content validity (A1), construct validity and the principal component analysis (A2), external validity against independent benchmarks (A3), internal consistency and sampling adequacy (A4), and the full score equations and weight matrix used in the construction (A5). Section A6 reports socioeconomic correlates of the MCCQI scores, which informs the descriptive analysis in Section 5.1 of the main text.

A.1 Content validity and indicator selection

The MCCQI is constructed from fifteen binary indicators of services received during the most recent pregnancy, drawn from standard WHO guidelines and prior empirical literature on maternal care quality measurement ([World Health Organization, 2015, 2025, 2014](#)). Indicators span the three stages of the maternal care continuum and capture the content of services received rather than mere utilisation.

The quality of antenatal care is measured using seven binary indicators capturing services received during pregnancy: whether the mother was weighed, whether blood pressure was measured, whether urine and blood samples were taken, whether an abdominal examination was conducted, whether at least four antenatal visits were completed, and whether the woman was counselled on potential pregnancy-related complications ([Nadella et al., 2021](#)).

The quality of delivery care is captured using three binary indicators: whether delivery assistance was provided by a skilled health professional, whether delivery occurred in an institutional setting, and whether a caesarean section was performed among women who reported pregnancy or labour-related complications. The caesarean indicator is intended to capture

access to medically indicated obstetric intervention rather than all surgical deliveries. We interpret this measure with caution in the Indian context, where elective and provider-driven caesarean rates have increased substantially, particularly in private healthcare facilities (Bhatta et al., 2021; World Health Organization, 2015). The measure may therefore not perfectly distinguish medically necessary procedures from non-essential caesarean deliveries.

The quality of postnatal care is measured using five binary indicators capturing care provided to the mother and newborn within the first two days after delivery: whether a healthcare provider examined the umbilical cord, measured the newborn’s temperature, counselled the mother on newborn danger signs, counselled the mother on breastfeeding, and observed breastfeeding practices (Usman et al., 2021b). All indicators are coded as binary variables, with higher values representing better quality of care. The full set of fifteen indicators and their coding is reported in Table 3 of the main text.

A.2 Construct validity, principal component analysis, and loading structure

Following the SWPER methodology of Ewerling et al. (2017), principal component analysis (PCA) was jointly estimated across all fifteen maternal care indicators to identify the latent dimensions underlying care quality across the antenatal, delivery, and postnatal continuum. Joint estimation allows correlated dimensions of maternal healthcare utilisation to be represented as distinct but interconnected components, rather than imposing strict separation between domains.

Because components of maternal care are likely to be correlated rather than independent, we employed oblique rotation (promax) following standard practice for related latent constructs (Costello and Osborne, 2005). The rotation allows factors to correlate while preserving interpretability. Factor loadings with absolute values greater than or equal to 0.30 ($|\phi_{vj}| \geq 0.30$) were considered meaningful and retained within each domain.

The rotated loading structure demonstrated clear domain separation. Postnatal care indicators loaded predominantly on Component 1 (loadings between 0.41 and 0.46), antenatal care indicators on Component 2 (loadings between 0.13 and 0.46), and delivery care indicators on Component 3 (loadings between 0.34 and 0.67). Cross-domain loadings were comparatively small relative to the dominant loadings, indicating limited overlap across the three maternal care dimensions. The full rotated loading matrix is reported in Table A1.

Table A1: Estimated domain-specific weights (λ_{vj}) for components of the MCCQI index

Indicator	Comp 1	Comp 2	Comp 3	Unexplained
<i>During pregnancy</i>				
Weighted ANC index	-0.014	0.396	-0.028	0.552
Blood pressure measured	-0.026	0.461	-0.025	0.398
Urine sample taken	-0.004	0.458	0.008	0.379
Blood sample taken	-0.012	0.463	0.021	0.367
Abdominal examination	0.026	0.407	0.000	0.492
Number of ANC visits	0.036	0.130	0.158	0.877
Counselling on pregnancy complications	0.181	0.153	-0.077	0.778
<i>Postnatal care (first two days)</i>				
Cord examination	0.407	-0.013	0.003	0.393
Temperature measured	0.439	0.004	0.029	0.268
Counselled on newborn danger signs	0.452	-0.004	-0.017	0.249
Counselled on breastfeeding	0.459	-0.021	-0.001	0.232
Observed breastfeeding	0.437	-0.005	-0.001	0.293
<i>Delivery care</i>				
Skilled delivery assistance	0.001	0.010	0.337	0.819
Place of delivery	0.011	0.012	0.635	0.354
Caesarean section if needed	-0.008	-0.016	0.671	0.306

Notes: Reported values are estimated weights (λ_{vj}) obtained from principal component analysis used to construct the Maternal Continuum of Care Quality Index (MCCQI). Components correspond to antenatal, postnatal, and delivery-care dimensions. The unexplained column reports the proportion of variance not captured by the first three components. Higher absolute loadings indicate greater contribution to the respective domain.

Although each domain score is computed from the full set of fifteen indicators using the rotated loading matrix, the cross-domain weights are small in magnitude. The dominant contribution to each score originates from indicators loading on the corresponding component (antenatal indicators contribute primarily to the antenatal score, and so on), while the construction preserves information about modest cross-stage correlations consistent with

the interconnected nature of the maternal care continuum.

A.3 External validity

External validity of the MCCQI was assessed by comparing state-level scores against two independent benchmarks: (i) the Maternal Mortality Ratio (MMR) obtained from the Health Management Information System (HMIS, averaged over 2017–2020) and (ii) the Health Index published by NITI Aayog (2019–2020). Although NFHS-5 was conducted during 2019–21, maternal mortality information in the survey is collected retrospectively and reflects deaths occurring during the years preceding the survey. The NFHS-5 reference period therefore overlaps substantially with the HMIS MMR estimates, with a small temporal mismatch that should be considered when interpreting the validation results. The complete state-level scores in Tables A2.

Spearman rank correlation coefficients were used to assess concordance in state rankings rather than linear associations. State-level MCCQI scores correlate strongly with the NITI Aayog Health Index (ρ between 0.34 and 0.56 across the three stage-specific scores) and negatively with the HMIS MMR (ρ between -0.47 and -0.56). All correlations are in the expected direction and significant at conventional levels. The correlation matrices are reported in Table A3.

A.4 Internal consistency and sampling adequacy

Internal consistency of the MCCQI was assessed using Cronbach’s alpha:

$$\alpha = \left(\frac{k}{k-1} \right) \left[1 - \left(\frac{\sum \sigma_{\text{item}}^2}{\sigma_{\text{total}}^2} \right) \right] \quad (9)$$

where k is the number of items, $\sum \sigma_{\text{item}}^2$ is the sum of item variances, and σ_{total}^2 is the variance of the total scale score. The full-scale Cronbach’s alpha for the MCCQI is 0.796, indicating acceptable reliability. Domain-specific alphas vary across the three stages: postnatal care

Table A2: State-level maternal reproductive care index scores, maternal mortality, and health index

State / UT	Postnatal	Antenatal	Delivery	MMR	Health Index
Jammu & Kashmir	-0.000	0.266	0.384	151	48.28
Himachal Pradesh	0.223	0.246	0.076	127	68.77
Punjab	0.338	0.236	0.428	143	61.56
Chandigarh	0.535	0.346	0.396	15	48.94
Uttarakhand	0.011	0.035	-0.043	107	42.87
Haryana	0.277	0.187	0.233	90	46.41
NCT of Delhi	0.167	0.162	0.310	162	34.50
Rajasthan	0.016	0.031	0.112	162	46.41
Uttar Pradesh	-0.082	-0.286	-0.112	208	25.64
Bihar	-0.473	-0.775	-0.269	164	30.80
Sikkim	-0.195	0.168	0.285	228	66.01
Arunachal Pradesh	-0.499	0.050	-0.117	284	35.67
Nagaland	-1.365	-0.217	-0.836	143	31.99
Manipur	-0.836	0.104	0.014	282	38.52
Mizoram	-0.118	-0.023	-0.038	131	83.49
Tripura	-0.352	0.114	0.182	119	85.01
Meghalaya	-0.394	0.047	-0.667	266	44.42
Assam	-0.278	0.066	-0.213	209	45.84
West Bengal	-0.069	0.204	0.354	100	58.25
Jharkhand	0.012	-0.247	-0.250	78	58.55
Odisha	0.273	0.244	0.151	138	40.82
Chhattisgarh	0.455	0.197	-0.115	144	48.94
Madhya Pradesh	0.244	0.099	0.001	179	34.55
Gujarat	0.062	0.255	0.192	76	60.97
Maharashtra	0.382	0.315	0.336	40	73.31
Andhra Pradesh	0.079	0.221	0.245	64	71.68
Karnataka	0.372	0.275	0.257	85	63.35
Goa	0.137	0.257	0.215	91	55.36
Lakshadweep	0.399	0.372	0.531	208	65.40
Kerala	0.222	0.310	0.485	44	85.97
Tamil Nadu	0.023	0.263	0.599	56	72.73
Puducherry	0.579	0.363	0.451	41	60.04
Andaman & Nicobar Islands	0.576	0.357	0.490	275	51.09
Telangana	0.287	0.369	0.219	53	73.06
Ladakh	0.310	0.265	0.497	48.21	—
Dadra & Nagar Haveli and Daman & Diu	0.127	0.284	0.350	61	67.42

Notes: Antenatal, delivery, and postnatal scores are components of the Maternal Continuum of Care Quality Index (MCCQI) constructed using NFHS-5 data. Maternal mortality ratio (MMR) is taken from the Health Management Information System (HMIS), averaged over 2017–2019. Health Index scores are from NITI Aayog (2019–20). Higher MCCQI scores indicate better quality of care. Health Index values are unavailable for Ladakh.

Table A3: Spearman rank correlations among maternal care scores, health index, and maternal mortality

	Delivery	Postnatal	Antenatal	Health index	MMR
Delivery score	1.000				
Postnatal score	0.622	1.000			
Antenatal score	0.628	0.709	1.000		
Health index	0.552	0.506	0.342	1.000	
Maternal mortality rate (MMR)	-0.517	-0.557	-0.473	-0.587	1.000

Notes: Entries report Spearman rank correlation coefficients calculated at the state level. Positive correlations indicate complementarity across stages of maternal care, while negative correlations with maternal mortality confirm the external validity of the MCCQI index.

exhibits high internal consistency ($\alpha = 0.901$), antenatal care shows moderate internal consistency ($\alpha = 0.649$), and delivery care exhibits comparatively lower internal consistency ($\alpha = 0.491$).

The lower delivery-care alpha is a mechanical artefact of having only three binary indicators and of the clinically heterogeneous role that caesarean section plays relative to institutional delivery and skilled birth attendance. As a robustness check, we re-estimated the baseline infant mortality models using each delivery-care indicator separately alongside the composite delivery-care score (see Table A4).

Table A4: Robustness check — Individual delivery-care indicators and infant survival

	(1) C-Section	(2) Skilled Assistance	(3) Institutional Delivery
Delivery-care indicator	1.104 (0.078)	0.763*** (0.055)	0.867** (0.052)
Controls ^a	Yes	Yes	Yes
Observations	1,333,955	1,333,955	1,333,955

Notes: Hazard ratios from survey-adjusted complementary log-log regression models. Each column introduces one delivery-care indicator at a time in place of the composite delivery-care score. Institutional delivery and skilled birth attendance produce statistically significant protective associations consistent with the composite index. The non-significant caesarean coefficient reflects its role as a response to pre-existing obstetric risk rather than as a preventive care input. Standard errors in parentheses. *** $p < 0.001$, ** $p < 0.05$, * $p < 0.10$.

^a Controls include religion, caste, wealth, education, household size, household head sex, number of children, child sex, age at first birth, birth order, maternal age, birth interval, and region.

Institutional delivery and skilled birth attendance each show statistically significant associ-

ations with infant survival, consistent in direction and magnitude with the composite index. Caesarean section does not produce an independently significant association, which is substantively expected: caesarean procedures are performed in response to pre-existing obstetric complications or fetal distress rather than as routine preventive inputs, and their inclusion in the composite index therefore introduces clinical heterogeneity that reduces measured alpha without undermining the validity of the composite. Removing the caesarean indicator raises the KR-20 from 0.491 to 0.633 (Table A5), meeting the conventional threshold of ≥ 0.60 . These results confirm that the low full-scale alpha reflects the clinical role of one indicator rather than any incoherence among the core delivery-care items.

Table A5: Item-Level Diagnostics: Delivery-Care Domain (KR-20)

Indicator	Item-Test r	Item-Rest r	KR-20 if Deleted
Institutional Delivery	0.788	0.409	0.197
Skilled Birth Attendance	0.702	0.388	0.289
Caesarean Delivery	0.630	0.167	0.633
<i>Full Scale</i>	—	—	0.491

Notes: KR-20 is reported for binary indicators. Removing caesarean delivery raises scale reliability from 0.491 to **0.633**, meeting the conventional threshold of ≥ 0.60 (Nunnally, 1978), consistent with its heterogeneous clinical role relative to the other two indicators.

Sampling adequacy was evaluated using the Kaiser–Meyer–Olkin (KMO) statistic:

$$\text{KMO} = \frac{\sum \sum r_{ij}^2}{\sum \sum r_{ij}^2 + \sum \sum p_{ij}^2} \quad (10)$$

where r_{ij}^2 denotes the squared correlation between variables i and j , and p_{ij}^2 represents the squared partial correlation. The resulting KMO value of 0.851 exceeds the recommended threshold of 0.80 and confirms the suitability of the data for principal component analysis.

A.5 Detailed score equations and weight matrix

Stage-specific scores are computed as standardised linear combinations of the fifteen indicators using the rotated loading matrix. Let λ_{vj} denote the weight assigned to indicator v in component j , computed as the product of the factor loading and the standard deviation of the indicator in the pooled national sample:

$$\lambda_{vj} = \phi_{vj} / \sigma_v \quad (11)$$

The standardised score for individual i in domain j is then computed as:

$$S_{ij} = \frac{-\sum_{v=1}^{15} \lambda_{vj} \bar{X}_v + \sum_{v=1}^{15} \lambda_{vj} X_{vi}}{\sigma_j} \quad (12)$$

where X_{vi} denotes the observed value of indicator v for individual i , $\bar{X}_v$ is the national mean of indicator v in the pooled sample, and σ_j is the standard deviation of the predicted component scores for domain j .

The three domain-specific standardised scores, with intercepts and divisors estimated from the pooled national sample, are:

$$\text{Antenatal care score} = \frac{-9.9849 + \sum_{v=1}^{15} \lambda_{vj} X_{vi}}{1.7194} \quad (13)$$

$$\text{Delivery care score} = \frac{-3.3749 + \sum_{v=1}^{15} \lambda_{vj} X_{vi}}{1.2530} \quad (14)$$

$$\text{Postnatal care score} = \frac{-4.1110 + \sum_{v=1}^{15} \lambda_{vj} X_{vi}}{1.9282} \quad (15)$$

The full weight matrix (λ_{vj} values) is reported in Table [A6](#). These standardised scores

constitute the Maternal Continuum of Care Quality Index and are used in the survival, regression, and spatial analyses reported in the main text.

Table A6: Full weight matrix (λ_{vj}) for MCCQI score computation

Indicator	Antenatal	Delivery	Postnatal
m42a	-0.08535	2.380921	-0.16710
m42c	-0.13964	2.454288	-0.13164
m42d	-0.01438	1.830197	0.03316
m42e	-0.05207	1.943948	0.08903
s419e	0.09605	1.525180	0.00038
visits	0.07202	0.263183	0.31962
m43	0.43294	0.367456	-0.18421
s494a	0.91890	-0.03141	0.00655
s494b	1.02750	0.00867	0.06886
s494c	1.01836	-0.00923	-0.03782
s494d	1.15882	-0.05327	-0.00303
s494e	1.02383	-0.01241	-0.00141
c.delivery	0.00134	0.02707	0.90206
deliv_assis	0.03657	0.03890	2.10961
delivery_p	-0.02058	-0.04272	1.74794

Notes: Entries report the rotated weight matrix (λ_{vj} values) used in the construction of the Maternal Continuum of Care Quality Index (MCCQI). Weights are computed as the product of the rotated factor loading and the standard deviation of each indicator in the pooled NFHS-5 sample. The three columns correspond to the antenatal, delivery, and postnatal care components, respectively. The table is provided for reproducibility and allows reconstruction of the standardised MCCQI scores from the raw NFHS-5 indicators.

A.6 Socioeconomic correlates of maternal care quality

Table A7 examines the association between socioeconomic characteristics and stage-specific MCCQI scores. Clear gradients emerge across all stages. Women from wealthier households and those with higher levels of education receive significantly higher-quality care, highlighting the role of economic resources and health literacy in facilitating access to services.

Fertility-related characteristics also show systematic associations with care quality: higher age at first birth, longer birth intervals, and lower birth order are linked to better care, consistent with greater experience and sustained engagement with the health system. Caste-based disparities persist across all dimensions, with Scheduled Tribe women exhibiting relatively higher antenatal scores but substantially lower delivery scores – a pattern that motivates the

heterogeneity analysis in Section 5.5 of the main text. Regional gradients are pronounced, with the South Zone exhibiting consistently higher care quality and the East Zone lagging across all three stages.

Table A7: Association between socioeconomic factors and Maternal Continuum of Care Quality Index (MCCQI) components

	MCCQI index components			
	Antenatal	Delivery	Postnatal	Overall quality
<i>Religion</i>				
Hindu (ref.)	1.000	1.000	1.000	1.000
Non-Hindu	1.070***	0.978*	0.968**	1.014
<i>Caste</i>				
Other (ref.)	1.000	1.000	1.000	1.000
Scheduled caste	0.935***	0.942***	1.005	0.886***
Scheduled tribe	1.137***	0.794***	1.120***	1.011
OBC	0.920***	0.932***	0.996	0.855***
<i>Household wealth</i>				
Poor (ref.)	1.000	1.000	1.000	1.000
Middle	1.142***	1.182***	1.050***	1.417***
Rich	1.200***	1.297***	1.068***	1.663***
<i>Education</i>				
Illiterate (ref.)	1.000	1.000	1.000	1.000
Primary	1.218***	1.200***	1.055***	1.542***
Secondary	1.371***	1.383***	1.133***	2.149***
Higher	1.354***	1.497***	1.104***	2.238***
<i>Household characteristics</i>				
Female household head (ref.)	1.000	1.000	1.000	1.000
Male household head	1.078***	1.043***	1.044***	1.174***
Household size	0.987***	0.995***	0.986***	0.968***
Number of children	0.987*	0.966***	1.020***	0.972**
<i>Reproductive characteristics</i>				
Age at first birth <21 (ref.)	1.000	1.000	1.000	1.000
Age at first birth ≥21	1.058***	1.109***	1.061***	1.246***
Birth interval <24 months (ref.)	1.000	1.000	1.000	1.000
Birth interval ≥24 months	1.082***	1.111***	1.055***	1.268***
Birth order >2 (ref.)	1.000	1.000	1.000	1.000
Birth order ≤2	1.152***	1.064**	1.129***	1.383***
<i>Region (zone)</i>				
North zone (ref.)	1.000	1.000	1.000	1.000
West zone	1.271***	1.153***	1.072***	1.571***
South zone	1.359***	1.253***	1.289***	2.196***
East zone	0.974*	1.085***	0.868***	0.918***
Observations	132,172	132,172	132,172	132,172

Notes: Marginal effects are reported. Reference categories are normalised to 1.000. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

B Statistical Methods: Detailed Specifications

This appendix provides full specifications for the statistical methods summarised in Section 4 of the main text. Section B1 provides the complete derivation of the discrete-time

complementary log-log survival model used for infant mortality analysis. Section B2 details the person-month transformation. Section B3 sets out the rationale for estimating stage-specific care effects separately rather than jointly. Section B4 specifies the Spatial Durbin Model and the LeSage–Pace impact decomposition. Section B5 details the regression-based pathway decomposition methodology.

B.1 Discrete-time complementary log-log survival model

The primary outcome of interest is infant survival within the first year of life. Because the National Family Health Survey records survival time in discrete units (months) rather than continuous time, and because infant deaths are heavily concentrated in the neonatal period, we employ a discrete-time survival analysis framework. This approach is suited to interval-censored data and accommodates the large number of tied event times that characterise infant mortality, for which continuous-time models such as the Cox proportional hazards model may yield biased estimates ([Singer and Willett, 2003](#)).

Let Y_{it} denote an indicator equal to one if infant i dies in month t , conditional on survival up to that month, and zero otherwise. The discrete-time hazard is defined as the conditional probability of death in month t given survival until the beginning of that interval. We estimate this hazard using a complementary log-log (cloglog) specification, the discrete-time analogue of the Cox proportional hazards model, appropriate when the underlying event process is continuous but observed in grouped intervals:

$$\log [-\log (1-h(t_{ij} \mid X_{ij}))] = \alpha_{tj} + X'_{ij}\beta \quad (16)$$

where $h(t_{ij} \mid X_{ij})$ denotes the probability that infant i experiences death in month j , conditional on survival up to that month, α_{tj} captures duration dependence, and X_{ij} is a vector of covariates.

The implied discrete-time hazard function is:

$$h(t_{ij} \mid X_{ij}) = 1 - \exp(-\exp(\alpha_{tj} + X'_{ij}\beta)) \quad (17)$$

which represents the probability of event occurrence during interval j , conditional on survival up to that interval.

Estimation proceeds via maximum likelihood. Let δ_{ij} be an indicator equal to one if infant i dies in month j and zero otherwise. The log-likelihood for the sample is:

$$\ell(\beta) = \sum_{i=1}^n \sum_{j=1}^{T_i} [\delta_{ij} \log h(t_{ij} \mid X_{ij}) + (1 - \delta_{ij}) \log(1 - h(t_{ij} \mid X_{ij}))] \quad (18)$$

following [Singer and Willett \(2003\)](#). Coefficients from the cloglog model are interpreted as log hazard ratios; exponentiating the estimated coefficients yields hazard ratios, which indicate the proportional change in the risk of infant death associated with a one-unit change in the covariate. Hazard ratios below one imply a protective association, while values above one indicate increased risk.

To account for duration dependence in infant mortality risk, we allow the baseline hazard to vary with time. Alternative functional forms (linear, quadratic, cubic, and logarithmic specifications of time) were evaluated using the Akaike Information Criterion. A logarithmic specification of time provided the best fit (AIC = 29,464.13 versus 31,109.15 for quadratic and 32,307.55 for cubic) and is therefore adopted in the main analysis. Table [B1](#) reports the model fit comparison.

B.2 Person-month transformation and estimation sample

Prior to estimation, the data are transformed into a person-period (person-month) format. Each infant contributes one observation for every month during which they are at risk of death, yielding an unbalanced panel. As a result of this person-month expansion, the final estimation sample used in the discrete-time survival analysis consists of 1,333,955 observations

Table B1: Model fit comparison for alternative functional forms of time

Time specification	AIC
Linear time	29,464.13
Quadratic time (t^2)	31,109.15
Cubic time (t^3)	32,307.55

Notes: Akaike Information Criterion (AIC) values from discrete-time hazard models. Lower values indicate better model fit, supporting the use of a linear duration specification.

from 132,172 unique births.

For infants who survive through the observation window (12 months), all person-months are coded as zero on the outcome variable. For infants who die within the first year, the outcome variable is coded as zero in all months prior to death and one in the month of death. This transformation preserves the temporal ordering of events while allowing estimation using standard binary-response models.

Table B2 reports the discrete-time life table for the analytical sample, showing the number of infants at risk, deaths, censoring, and cumulative survival probability by month.

Table B2: Life table showing infant survival, deaths, and censoring by interval

Interval (months)	At risk	Deaths	Censored	Survival	SE	95% CI
1–2	144,936	2,594	6,186	0.9817	0.0004	[0.9810, 0.9824]
2–3	136,156	169	3,309	0.9805	0.0004	[0.9797, 0.9812]
3–4	132,678	142	3,224	0.9794	0.0004	[0.9787, 0.9801]
4–5	129,312	88	3,326	0.9787	0.0004	[0.9780, 0.9795]
5–6	125,898	55	3,049	0.9783	0.0004	[0.9775, 0.9791]
6–7	122,794	89	3,183	0.9776	0.0004	[0.9768, 0.9784]
7–8	119,522	39	2,945	0.9773	0.0004	[0.9765, 0.9780]
8–9	116,538	42	2,821	0.9769	0.0004	[0.9761, 0.9777]
9–10	113,675	43	2,934	0.9765	0.0004	[0.9757, 0.9773]
10–11	110,698	21	2,878	0.9763	0.0004	[0.9755, 0.9771]
11–12	107,799	24	2,988	0.9761	0.0004	[0.9753, 0.9769]
12–13	104,787	12	104,775	0.9759	0.0004	[0.9751, 0.9767]

Notes: Life table constructed from NFHS-5 child histories. Survival probabilities refer to cumulative survival up to the end of each interval. Censoring reflects children alive at survey.

B.3 Justification for stage-separate estimation

Consistent with the conceptual framework, maternal care is modelled as a sequence of stage-specific inputs. The antenatal, delivery, and postnatal care indices (Q^A , Q^D , Q^P) are introduced separately in the survival and birth weight models to estimate their total effects on outcomes.

Estimating these components jointly in a single specification would condition on downstream mediators and potentially attenuate the effects of earlier-stage care — a form of overadjustment bias documented by [Schisterman et al. \(2009\)](#). Separate models therefore preserve the temporal ordering of care (antenatal $\rightarrow$ delivery $\rightarrow$ postnatal) and yield policy-relevant estimates of total stage-specific effects.

The pathway decomposition in Section 5.3 of the main text complements this approach by characterising indirect effects operating through later stages.

B.4 Spatial Durbin Model: specification and impact decomposition

To examine geographic patterning in maternal care quality and birth outcomes, we estimate spatial econometric models at the district level. Spatial autocorrelation is first assessed using univariate and bivariate Moran’s I statistics. We then estimate alternative specifications (spatial lag, spatial error, and Spatial Durbin Model) and select between them using log-likelihood ratio tests and the Akaike Information Criterion. The Spatial Durbin Model provides the best fit and is reported in the main text.

The Spatial Durbin Model is specified as:

$$y = \rho W y + X\beta + W X\theta + \varepsilon \tag{19}$$

where y is the dependent variable (the proportion of normal birth weight at the district level), X is a matrix of district-level explanatory variables (MCCQI components, reproductive characteristics, socioeconomic variables), W is a row-standardised spatial weights matrix based on contiguity, ρ is the spatial autoregressive parameter capturing dependence in the outcome, θ is the vector of spatial lag coefficients on explanatory variables, β is the vector of direct coefficients, and ε is the error term. The model allows both the outcome and the explanatory variables to exhibit spatial dependence, accommodating the possibility that maternal care quality and outcomes in one district are influenced by conditions in neighbouring districts.

Following [LeSage and Pace \(2009\)](#), the partial derivatives of the dependent variable with respect to changes in an explanatory variable are decomposed into direct, indirect, and total impacts:

$$\frac{\partial y}{\partial X_k} = (I - \rho W)^{-1}(\beta_k I + \theta_k W) \quad (20)$$

Direct impacts capture within-district associations between an explanatory variable and the outcome. Indirect impacts capture spillover effects to neighbouring districts. Total impacts are the sum. We report all three for the main specifications in Table 5 of the main text. Tables [B3](#), [B4](#), and [B5](#) report the underlying SDM coefficients and the model selection diagnostics.

B.5 Regression-based pathway decomposition

To characterise the sequential structure of the maternal care continuum, we estimate a regression-based pathway decomposition linking antenatal care, delivery care, and postnatal care to infant survival. Because the data are observational and nonlinear models are involved (cloglog for the survival outcome), we interpret the decomposition descriptively – as a characterisation of dominant pathways linking maternal care to outcomes – rather than as

a causal mediation analysis. The decomposition uses sequential regression equations:

$$DC = b_1 ANC + Z' \gamma_1 + \varepsilon_1 \quad (21)$$

$$PNC = b_2 DC + b_3 ANC + Z' \gamma_2 + \varepsilon_2 \quad (22)$$

$$\text{cloglog hazard} = b_4 PNC + b_5 DC + b_6 ANC + Z' \gamma_3 + \varepsilon_3 \quad (23)$$

where ANC , DC , and PNC denote the standardised antenatal, delivery, and postnatal care scores, and Z denotes the vector of socioeconomic, demographic, and regional controls.

Table B3: Model fit comparison: log-likelihood, AIC and Schwarz criterion

Model	Log-Lik.	AIC	BIC	$\Delta\text{AIC vs OLS}$
Antenatal care specification				
OLS	976.9	−1927.9	−1868.6	ref.
Spatial Lag (SAR)	1012.1	−1996.2	−1932.3	−68.3
Spatial Error (SEM)	1073.5	−2121.1	−2061.8	−193.2
Spatial Durbin (SDM)*	1081.2	−2110.5	−1991.9	−182.6
Delivery care specification				
OLS	955.6	−1885.2	−1825.9	ref.
Spatial Lag (SAR)	993.3	−1958.5	−1894.7	−73.3
Spatial Error (SEM)	1037.8	−2049.6	−1990.3	−164.4
Spatial Durbin (SDM)*	1046.6	−2041.3	−1922.7	−156.1
Quality of care specification				
OLS	1012.0	−1998.0	−1938.7	ref.
Spatial Lag (SAR)	1044.1	−2060.2	−1996.3	−62.2
Spatial Error (SEM)	1101.8	−2177.6	−2118.3	−179.6
Spatial Durbin (SDM)*	1118.5	−2184.9	−2066.3	−186.9

Notes: Bold values indicate the best log-likelihood within each specification. *SDM is the preferred model based on highest log-likelihood and theoretical justification. ΔAIC values are calculated relative to the OLS baseline. All spatial models are estimated by full maximum likelihood using **spreg**.

The indirect association of antenatal care with infant mortality operating through postnatal care is computed using the product-of-coefficients approach:

$$\text{Indirect (ANC} \rightarrow \text{PNC} \rightarrow \text{mortality)} = (b_1 \times b_2 \times b_4) + (b_3 \times b_4) \quad (24)$$

Standard errors are obtained using the delta method via the `nlcom` command in Stata. Given the nonlinear outcome model, these estimates are interpreted as pathway-based associations rather than causal mediation effects. The total association of antenatal care with infant mortality is decomposed into a direct component (b_6 in equation 23) and an indirect component (equation 24), and analogously for delivery care.

Table B4: OLS regression diagnostics

Test	ANC spec.	Delivery spec.	Quality spec.
Goodness of fit			
R^2	0.440	0.406	0.493
Adjusted R^2	0.431	0.395	0.485
Normality of errors			
Jarque–Bera (df = 2)	63.40***	12.65***	9.05**
Heteroskedasticity			
Breusch–Pagan (df = 12)	95.95***	115.33***	52.07***
Koenker–Bassett (df = 12)	65.11***	103.08***	51.72***
Spatial dependence (SARERR)			
LM-lag (df = 1)	79.72***	85.45***	72.00***
Robust LM-lag (df = 1)	0.61	3.98*	1.80
LM-error (df = 1)	256.87***	203.83***	221.75***
Robust LM-error (df = 1)	177.76***	122.36***	151.54***
Spatial Durbin tests			
LM-WX (df = 12)	35.66***	35.11***	58.50***
Joint SDM test (df = 13)	291.36***	244.51***	279.00***
Multicollinearity			
Condition number	360.4	350.3	358.3

Notes: $^{\dagger}p < 0.10$; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$. Robust LM-error dominates robust LM-lag in all specifications, indicating SEM/SDM models are preferred over SAR models. Condition numbers above 100 indicate potential multicollinearity, though variance inflation was not severe enough to alter substantive conclusions.

Table B5: Spatial Durbin Model (SDM)

Variable	ANC		Delivery		Quality	
	Coef.	SE	Coef.	SE	Coef.	SE
Care quality (main exposure)						
Antenatal score	0.143***	0.013	—	—	—	—
Delivery score	—	—	0.088***	0.012	—	—
Quality of care	—	—	—	—	0.067***	0.005
Socioeconomic status						
Poor (wealth)	−0.005	0.021	0.031	0.023	0.028	0.021
Middle wealth	0.052	0.034	0.070 [†]	0.036	0.094**	0.033
Maternal education						
Higher education	0.143***	0.043	0.106*	0.046	0.133**	0.041
Secondary education	0.087**	0.029	0.076*	0.031	0.048	0.028
Household and child factors						
Household size	−0.003	0.006	−0.007	0.006	−0.002	0.005
Male household head	0.007	0.038	−0.004	0.040	0.005	0.036
Number of children	0.070**	0.027	0.105***	0.029	0.100***	0.026
Male child	0.015	0.048	−0.024	0.050	−0.007	0.045
Birth-related factors						
Low birth order	0.431**	0.153	0.663***	0.159	0.332*	0.146
Younger mother	−0.063	0.055	−0.043	0.058	−0.036	0.053
Adequate birth interval	0.021	0.057	0.072	0.060	0.050	0.054
Spatial parameter						
Rho – W (normal BW)	0.565***	0.040	0.542***	0.041	0.540***	0.041
Model fit						
Pseudo R^2	0.614		0.572		0.650	
AIC	−2110.5		−2041.3		−2184.9	
n	707		707		707	

Notes: [†] $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. ρ denotes the spatial autoregressive parameter on the spatially lagged dependent variable. Standard errors are asymptotic. Common Factor Hypothesis tests: ANC $\chi^2(12) = 17.6$, $p = 0.128$; Delivery $\chi^2(12) = 17.9$, $p = 0.118$; Quality $\chi^2(12) = 33.9$, $p = 0.001$.

B.6 Construction of the Geographic Accessibility Measure

To examine whether geographic accessibility explains disparities in delivery care quality, we constructed a cluster-level measure of distance to the nearest delivery-capable public health facility using geographic information system (GIS) methods.

The geographic coordinates of NFHS-5 survey clusters were obtained from the NFHS-5 Geographic (GE) file, while the locations of public health facilities were obtained from the

national Health Facility Geocode Database. The facility database contains the geographic coordinates and facility type for public health institutions, including Sub-Centres, Primary Health Centres (PHCs), Community Health Centres (CHCs), Sub-district Hospitals, and District Hospitals. Before distance calculation, the facility database was cleaned by removing facilities with missing or invalid geographic coordinates, excluding inactive facilities, removing observations outside the geographic boundaries of India, and deleting placeholder coordinates located at (0,0). Facility type labels were standardised to ensure consistent classification across observations.

Distances were calculated using the Haversine (great-circle) distance between each NFHS-5 cluster centroid and the nearest health facility. Nearest-neighbour searches were implemented using the BallTree algorithm, which efficiently identifies the closest facility on the Earth’s spherical surface. Distances were converted to kilometres using the mean Earth radius of 6,371 km. Our primary measure of geographic accessibility is the minimum distance from each NFHS cluster to the nearest delivery-capable facility, defined as the nearest Community Health Centre (CHC), Sub-district Hospital, or District Hospital.

The resulting cluster-level distance measures were merged with the individual-level NFHS-5 data using the unique cluster identifier. These merged data were subsequently used in the regression models reported in Section 5.5 to assess whether geographic accessibility explains the observed caste disparities in delivery care quality.

C Robustness Checks

This appendix reports four robustness exercises that assess the sensitivity of the main findings to alternative measurement strategies, sample restrictions, and potential unobserved confounding. Section C1 presents an alternative construction of the Maternal Continuum of Care Quality Index (MCCQI) using principal component analysis based on a tetrachoric correlation matrix. Section C2 reports the first-birth sensitivity analysis. Section C3 presents

E-value estimates for unobserved confounding, and Section C4 reports results using an alternative maternal healthcare quality index constructed following the DHS-SPA Quality of Care framework. Across all specifications, the substantive conclusions of the main analysis remain unchanged.

C.1 Tetrachoric Principal Component Analysis

Because the Maternal Continuum of Care Quality Index (MCCQI) is constructed from fifteen binary indicators, we re-estimated the factor structure using principal component analysis based on a tetrachoric correlation matrix, which is more appropriate for dichotomous variables. The tetrachoric PCA reproduced the same three latent dimensions identified in the baseline analysis. Three factors with eigenvalues greater than one were retained, jointly explaining 76.0% of the total variance. Following Promax rotation, the factor loading pattern remained virtually identical to that obtained from the baseline PCA, confirming that the construction of the MCCQI is robust to the choice of correlation matrix. Table C1 reports the complete factor loading matrix.

C.2 First-births sensitivity analysis

The analysis in the main text restricts the sample to women’s most recent live birth prior to the survey, because detailed information on antenatal, delivery, and postnatal care is collected only for the latest birth in NFHS-5. This restriction may introduce sample selection bias, since women with higher parity contribute proportionally fewer observed births to the analysis. To assess the sensitivity of our findings to this restriction, we re-estimated the discrete-time complementary log-log hazard models for infant mortality on the subsample of first births only.

The pattern of stage-specific hazard ratios remains substantively similar to the main results. Postnatal care continues to exhibit the strongest protective association with infant survival, followed by delivery care and then antenatal care. The composite MCCQI is associated

with a reduction in infant mortality risk of comparable magnitude to the main estimate. Coefficients on socioeconomic and demographic controls are also similar in direction and magnitude. These findings indicate that the substantive conclusions of the main analysis are not driven by sample selection on parity. Table C2 reports the full first-births estimates alongside the main specification for comparison.

Table C1: Robustness Check: Tetrachoric Principal Component Analysis of the Maternal Continuum of Care Quality Index

Variable	Antenatal Care	Postnatal Care	Delivery Care
Blood pressure measured	0.886		
Urine sample taken	0.957		
Blood sample taken	0.926		
Iron-folic acid supplementation	0.926		
Tetanus immunization	0.867		
Four or more ANC visits	0.487		
Postnatal care within recommended period		0.913	
Newborn examined		0.927	
Cord examined		0.964	
Temperature checked		0.982	
Breastfeeding counselling		0.933	
Caesarean delivery			0.681
Skilled birth attendance			0.826
Institutional delivery			0.924
Eigenvalue	7.005	2.702	1.696
Variance explained (%)	46.7	18.0	11.3
Cumulative variance explained (%)	46.7	64.7	76.0

Notes: Principal component analysis was estimated using a tetrachoric correlation matrix with Promax (oblique) rotation. Only primary factor loadings greater than or equal to 0.30 are reported; cross-loadings are suppressed for clarity. Three factors with eigenvalues greater than one were retained. The tetrachoric PCA reproduced the same three latent dimensions (antenatal care, delivery care, and postnatal care) identified in the baseline principal component analysis, indicating that the construction of the Maternal Continuum of Care Quality Index is robust to the use of a correlation matrix appropriate for binary indicators.

Table C2: Complementary log-log regression estimates for mothers with one child

	(1)	(2)	(3)	(4)
	ANC	Delivery	Postnatal	Overall QoC
<i>Maternal care quality</i>				
Antenatal score	0.898** (0.034)			
Delivery score		0.815*** (0.037)		
Postnatal score			0.560*** (0.020)	
Overall quality-of-care index				0.801*** (0.012)
<i>Social group</i>				
Other (ref.)	1.000	1.000	1.000	1.000
Scheduled caste	1.322* (0.187)	1.336* (0.189)	1.282 (0.176)	1.312 (0.184)
Scheduled tribe	1.526* (0.256)	1.474* (0.248)	1.569** (0.252)	1.521* (0.255)
OBC	1.111 (0.147)	1.114 (0.148)	1.115 (0.143)	1.110 (0.146)
<i>Household wealth</i>				
Poor (ref.)	1.000	1.000	1.000	1.000
Middle	0.986 (0.115)	1.006 (0.118)	1.001 (0.115)	1.029 (0.121)
Rich	1.052 (0.118)	1.086 (0.123)	1.107 (0.123)	1.164 (0.131)
<i>Maternal education</i>				
No education (ref.)	1.000	1.000	1.000	1.000
Primary	0.945 (0.145)	0.958 (0.147)	0.916 (0.141)	1.066 (0.167)
Secondary	0.691*** (0.077)	0.709** (0.079)	0.718** (0.081)	0.831 (0.096)
Higher	0.395*** (0.068)	0.413*** (0.071)	0.401*** (0.069)	0.493*** (0.087)
<i>Household characteristics</i>				
Number of household members	0.858*** (0.030)	0.860*** (0.030)	0.857*** (0.029)	0.855*** (0.029)
Female-headed household	1.413** (0.187)	1.403* (0.185)	1.265 (0.163)	1.373* (0.178)
Children under age 5 in household	0.026*** (0.004)	0.026*** (0.004)	0.027*** (0.004)	0.026*** (0.004)

Continued on next page

Table C2 continued

	(1)	(2)	(3)	(4)
	ANC	Delivery	Postnatal	Overall QoC
Male child	1.246*	1.235*	1.221*	1.243*
	(0.110)	(0.109)	(0.108)	(0.110)
<i>Reproductive characteristics</i>				
Age at first birth	1.015	1.012	1.062	1.078
	(0.095)	(0.095)	(0.101)	(0.102)
Current age	1.002	1.006	1.006	1.053
	(0.218)	(0.216)	(0.242)	(0.269)
<i>Region</i>				
North zone (ref.)	1.000	1.000	1.000	1.000
West zone	0.590***	0.586***	0.664**	0.669**
	(0.077)	(0.076)	(0.083)	(0.085)
South zone	0.456***	0.463***	0.560***	0.560***
	(0.073)	(0.075)	(0.090)	(0.090)
East zone	0.628***	0.637***	0.595***	0.620***
	(0.064)	(0.065)	(0.061)	(0.064)
Observations	433,699	433,699	433,699	433,699

Notes: Hazard ratios from complementary log-log regression models are reported with standard errors in parentheses. Each column estimates a separate maternal care component to assess stage-specific associations with infant mortality risk. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

C.3 E-values for unobserved confounding

To quantify the sensitivity of our principal regression estimates to potential unmeasured confounding, we computed E-values following the approach of [VanderWeele \(2015\)](#). The E-value is the minimum strength of association (on the risk-ratio scale) that an unmeasured confounder would need to have with both the exposure and the outcome, above and beyond the measured covariates, to fully explain away the observed association. Larger E-values indicate greater robustness to unobserved confounding.

For the principal infant mortality estimates, the E-value for the postnatal care index is 2.75, indicating that a relatively strong unmeasured confounder would be required to fully explain

the observed protective association. The E-value for delivery care is smaller (1.42), indicating greater sensitivity to unobserved confounding for this stage. The E-value for antenatal care is 1.30. The composite MCCQI produces an E-value of 1.75.

These values suggest that the postnatal care association is the most robust to unobserved confounding among the stage-specific results, consistent with its dominant role in the pathway decomposition.

Table C3: Sensitivity analysis of maternal healthcare associations using E-values

Exposure variable	Outcome variable	Estimate	E-value
Antenatal care	Infant mortality	HR = 0.958	1.29
Delivery care	Infant mortality	HR = 0.921	1.43
Postnatal care	Infant mortality	HR = 0.595	2.75
Overall quality of care	Infant mortality	HR = 0.868	1.57
Antenatal care	Low birth weight	RRR = 0.970	1.28
Overall quality of care	Low birth weight	RRR = 0.985	1.16
Antenatal care	Macrosomia/high birth weight	RRR = 0.742	2.04
Delivery care	Macrosomia/high birth weight	RRR = 0.426	4.13
Overall quality of care	Macrosomia/high birth weight	RRR = 0.678	2.31

Notes: HR = hazard ratio; RRR = relative risk ratio. E-values indicate the minimum strength of association that an unmeasured confounder would need to have with both the exposure and outcome, conditional on observed covariates, to fully explain away the estimated association. Larger E-values indicate greater robustness to potential unobserved confounding. Normal birth weight (2.5–4.0 kg) is used as the reference category in the multinomial logistic regression models.

C.4 Alternative quality index: DHS-SPA framework

To verify that the substantive findings are not artefacts of the particular index construction methodology, we constructed an alternative maternal healthcare quality index using a Demographic and Health Surveys Service Provision Assessment (DHS-SPA) framework (Mallick et al., 2020). The DHS-SPA approach aggregates indicators of healthcare readiness and service provision into composite measures of structural and process quality, conceptually distinct from the PCA-based MCCQI used in the main text.

Specifically, we constructed a DHS-SPA-style index using the same fifteen indicators used in the MCCQI but aggregated using simple additive weights rather than PCA-derived weights.

Each indicator is coded zero or one, and the alternative index is the unweighted sum of indicators within each domain, standardised to mean zero and unit variance. The three stage-specific DHS-SPA indices are then used in place of the MCCQI scores in the discrete-time cloglog models for infant mortality.

Re-estimating the infant mortality models with the alternative DHS-SPA index yields substantively similar findings. Higher maternal healthcare quality at each stage is associated with lower infant mortality risk, and postnatal care remains the strongest protective component. Hazard ratios are slightly attenuated relative to the PCA-based index, consistent with the PCA approach producing more efficient weights, but the pattern of stage-specific protection and the relative ordering of antenatal, delivery, and postnatal effects is preserved. Table C4 reports the full alternative-index estimates.

D Supplementary Descriptive Tables and Figures

This appendix reports descriptive material that complements the main analysis. Section D1 disaggregates maternal care quality by place of residence (urban versus rural) and type of health institution (public versus private). Section D2 reports state-level patterns. Section D3 reports caste-disaggregated patterns within geographic zones.

D.1 Disaggregation by residence and facility type

Maternal care quality differs systematically between urban and rural areas across all three stages of the continuum (Figure 11). Urban areas exhibit higher MCCQI scores in antenatal, delivery, and postnatal care, while rural areas remain systematically disadvantaged. The gap is largest in delivery care, reflecting the geographic concentration of skilled birth attendants and emergency obstetric services in urban centres. These patterns are consistent with the broader literature on urban–rural disparities in maternal healthcare in India ([International Institute for Population Sciences \(IIPS\) and ICF, 2021](#)).

Table C4: Complementary Log–Log Regression Estimates for Infant Mortality Using Alternative DHS–SPA Quality of Care Index

Variables	Hazard Ratio (HR)	Standard Error	95% Confidence Interval	
			Lower	Upper
Quality care	0.894***	0.005	0.885	0.904
Time	0.480***	0.014	0.453	0.509
Hindu religion (Ref: Non-Hindu)	1.071	0.076	0.933	1.230
Caste (Ref: Other caste)				
Scheduled Caste	1.127	0.091	0.962	1.320
Scheduled Tribe	1.338***	0.121	1.122	1.597
OBC	1.090	0.079	0.945	1.257
Wealth Status (Ref: Poor households)				
Middle	1.058	0.072	0.927	1.208
Rich	0.983	0.067	0.859	1.124
Maternal Education (Ref: No education)				
Primary education	0.897	0.070	0.771	1.045
Secondary education	0.717***	0.043	0.637	0.808
Higher education	0.451***	0.048	0.366	0.555
Household size	0.875***	0.015	0.845	0.905
Male-headed household (Ref: Female-headed)	1.290***	0.091	1.124	1.480
Number of children	0.140***	0.009	0.123	0.159
Male child (Ref: Female child)	1.084	0.053	0.985	1.193
Age at first birth	1.001	0.053	0.903	1.109
Low birth order (Ref: High birth order)	0.161***	0.021	0.125	0.208
Current maternal age	0.890	0.067	0.768	1.032
Adequate birth interval	0.631***	0.045	0.549	0.726
Region (Ref: North Zone)				
West Zone	0.715***	0.048	0.627	0.816
South Zone	0.536***	0.057	0.435	0.661
East Zone	0.597***	0.036	0.530	0.671
Constant	25.634***	5.755	16.508	39.804

Notes: Hazard ratios (HR) are reported from survey-adjusted complementary log–log regression models. The dependent variable is infant mortality. Estimates are based on NFHS-5 sampling weights and account for survey stratification and clustering. Standard errors are reported in the second column. The maternal healthcare quality index was constructed using a modified DHS–Service Provision Assessment (SPA) Quality of Care Index framework following [Mallick et al. \(2020\)](#). *** $p < 0.001$, ** $p < 0.05$, * $p < 0.10$.

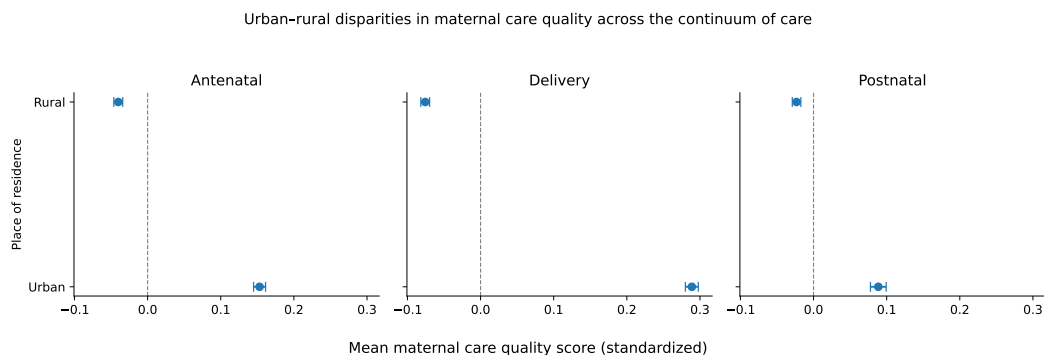


Figure 11: Mean MCCQI scores by place of residence, India (NFHS 2019–20).

Notes: The figure reports mean values of MCCQI index for antenatal, delivery, and postnatal care, disaggregated by place of residence (urban vs. rural). MCCQI scores are standardised to a national mean of zero; positive (negative) values indicate higher (lower) quality of care relative to the national average.

Differences by facility type reveal complementary patterns (Figure 12). Private facilities exhibit higher quality scores in antenatal and delivery care, consistent with their concentration in urban areas and their typical clientele. Public facilities exhibit comparatively stronger performance in postnatal care, consistent with the emphasis of government programmes (Janani Suraksha Yojana and Janani Shishu Suraksha Karyakram) on postnatal outreach and follow-up. These patterns inform the policy implications discussed in Section 6 of the main text.

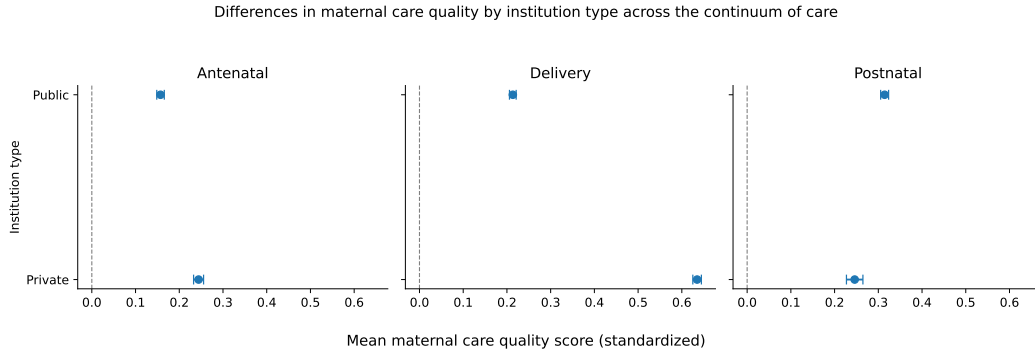


Figure 12: Mean MCCQI index scores by type of health institution, India (NFHS 2019–20)

Notes: The figure displays mean values of MCCQI for antenatal, delivery, and postnatal care, disaggregated by type of health institution (public vs. private). Higher values indicate better quality of care relative to the national average.

D.2 State-level descriptive patterns

Table A2 (Appendix A3) reports state-level MCCQI scores alongside HMIS maternal mortality and the NITI Aayog Health Index. Substantial inter-state variation is evident across all three stages. South Indian states (Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, and Telangana) and several union territories (Puducherry, Lakshadweep, and Chandigarh) consistently rank among the highest performers across all three stages.

States in the East Zone (Bihar, Jharkhand, and Uttar Pradesh) and parts of the North East (Nagaland, Meghalaya, and Manipur) consistently rank lowest. These rankings inform the regional analysis presented in Section 5.1 of the main text and provide the basis for the

external validity correlations reported in Appendix A3.

D.3 Caste-disaggregated zonal patterns

Figures 13 through 15 disaggregate antenatal, delivery, and postnatal care quality by caste group within each geographic zone. The patterns reveal that caste-based disparities in maternal care quality are not uniform across India.

In the South Zone, where average care quality is highest, caste-based gaps are relatively compressed. In the East and North Zones, where average care quality is lower, caste-based gaps are more pronounced, with Scheduled Tribe women experiencing the largest disadvantage in delivery care. These patterns inform the H4 analysis in Section 5.5 of the main text.

Additional disaggregations by wealth quintile and caste are reported in Figures 16 through 18, complementing the heterogeneity analysis in the main text.

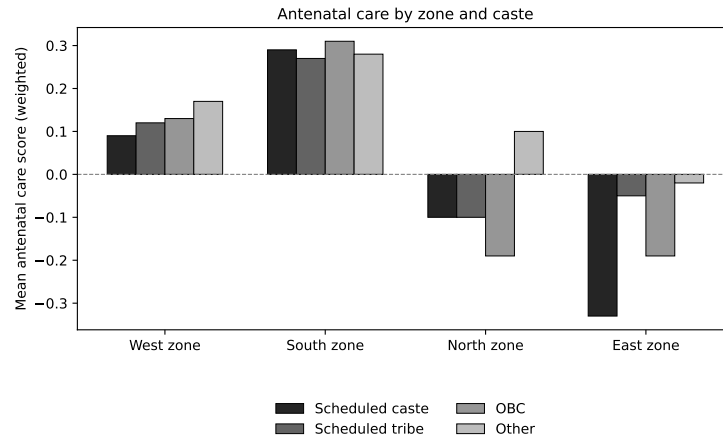


Figure 13: Antenatal care by zone and caste

Notes: Bars represent weighted mean antenatal care scores by caste across geographic zones. Antenatal care scores are standardized indices constructed from pregnancy check-ups, clinical examinations, diagnostic tests, and counseling services. Higher values indicate better quality of antenatal care.

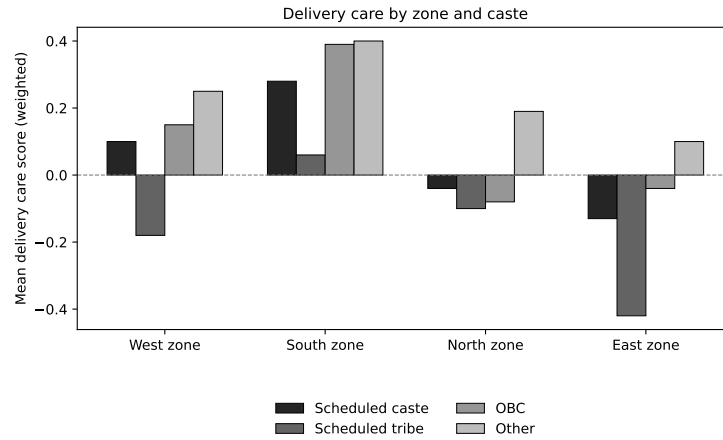


Figure 14: Delivery care by zone and caste

Notes: Bars represent weighted mean delivery care scores by caste across geographic zones. Delivery care scores are standardized indices capturing institutional delivery, skilled birth attendance, and emergency obstetric services. Higher values indicate better quality of delivery care.

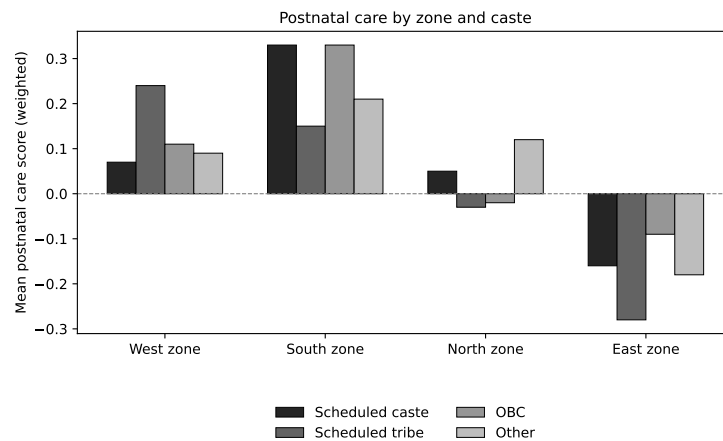


Figure 15: Postnatal care by zone and caste

Notes: Bars represent weighted mean postnatal care scores by caste across geographic zones. Postnatal care scores are standardized indices constructed from newborn examinations, breastfeeding counseling, and early postnatal follow-up. Higher values indicate better quality of postnatal care.

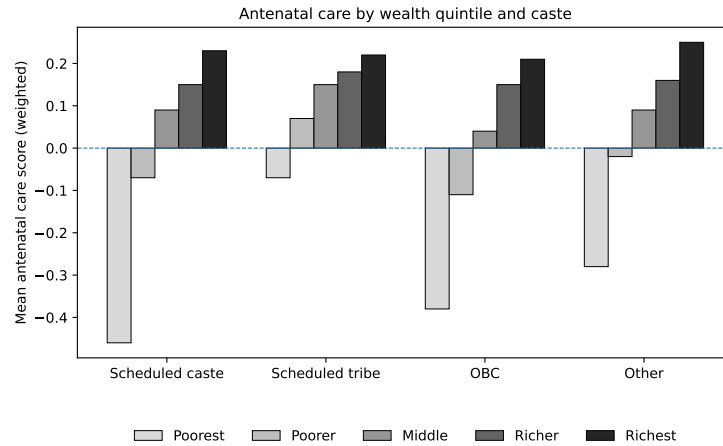


Figure 16: Antenatal care by wealth quintile and caste

Notes: Bars represent weighted mean antenatal care scores by caste and household wealth quintile. Antenatal care scores are standardized indices constructed using information on pregnancy check-ups, clinical examinations, diagnostic tests, and counseling services. Higher values indicate better quality of care.

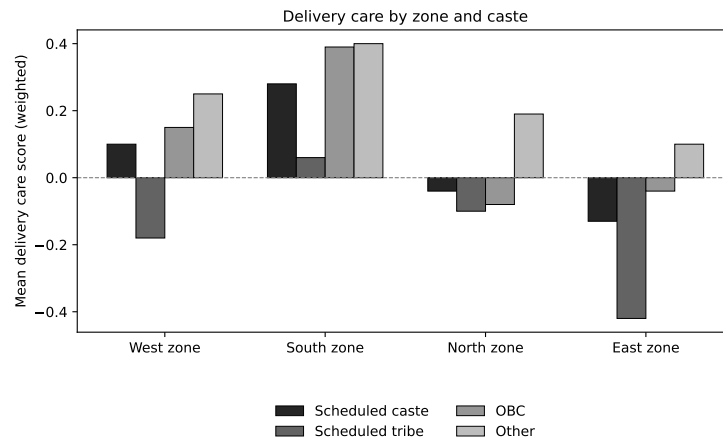


Figure 17: Delivery care by wealth quintile and caste

Notes: Bars represent weighted mean delivery care scores by caste and household wealth quintile. Delivery care scores are standardized indices capturing institutional delivery, skilled birth attendance, and emergency obstetric interventions. Higher values reflect better quality of delivery care.

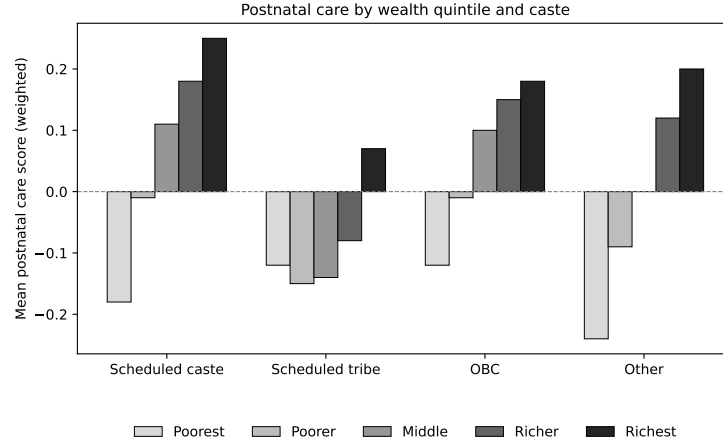


Figure 18: Postnatal care by wealth quintile and caste

Notes: Bars represent weighted mean postnatal care scores by caste and household wealth quintile.

Postnatal care scores are standardized indices constructed from information on newborn examinations, breastfeeding counseling, and postnatal follow-up within the first days after delivery. Higher values indicate better care.

D.4 Full complementary log–log regression estimates

Table D1 reports the full complementary log–log discrete-time survival estimates underlying the main infant mortality analysis. The table includes the complete set of socioeconomic, demographic, and regional control variables used in the preferred specifications. Consistent with the main findings, higher maternal healthcare quality is associated with lower infant mortality risk across all stages of the continuum, with postnatal care exhibiting the strongest protective association. Socioeconomic gradients remain substantial: higher maternal education and household wealth are associated with significantly lower infant mortality risk, while Scheduled Tribe households exhibit persistently elevated mortality risk. Regional disparities are also pronounced, with the South and West zones exhibiting substantially lower infant mortality risk relative to the North Zone.

Table D1: Discrete-Time Complementary Log–Log Models of Infant Mortality

Variables	(1) ANC	(2) DC	(3) PNC	(4) Overall QoC
<i>Maternal Care Quality</i>				
Antenatal care score	0.958* (0.020)			
Delivery care score		0.921*** (0.022)		
Postnatal care score			0.595*** (0.013)	
Overall quality-of-care index				0.868*** (0.008)
<i>Duration Dependence</i>				
Time (log)	0.479*** (0.014)	0.479*** (0.014)	0.483*** (0.014)	0.480*** (0.014)
<i>Religion (Ref: Hindu)</i>				
Non-Hindu	1.073 (0.076)	1.068 (0.076)	1.067 (0.076)	1.078 (0.077)
<i>Caste (Ref: Other caste)</i>				
Scheduled caste	1.176* (0.095)	1.176* (0.095)	1.142 (0.095)	1.141 (0.093)
Scheduled tribe	1.364*** (0.125)	1.331** (0.122)	1.445*** (0.131)	1.354*** (0.124)
OBC	1.118 (0.083)	1.115 (0.082)	1.119 (0.083)	1.095 (0.081)
<i>Household Wealth (Ref: Poor households)</i>				
Middle	0.966 (0.066)	0.971 (0.066)	1.000 (0.068)	1.025 (0.071)
Rich	0.862* (0.060)	0.869* (0.060)	0.912 (0.063)	0.945 (0.066)
<i>Maternal Education (Ref: No education)</i>				
Primary education	0.841* (0.065)	0.846* (0.065)	0.864 (0.067)	0.894 (0.070)
Secondary education	0.629*** (0.037)	0.639*** (0.038)	0.663*** (0.040)	0.709*** (0.043)
Higher education	0.390*** (0.041)	0.400*** (0.043)	0.407*** (0.044)	0.448*** (0.048)
<i>Household Characteristics</i>				

Continued on next page

Table D1 continued

Variables	(1) ANC	(2) DC	(3) PNC	(4) Overall QoC
Household size	0.885*** (0.016)	0.884*** (0.016)	0.879*** (0.015)	0.880*** (0.015)
Male household head (Ref: Female-headed)	1.262** (0.090)	1.264** (0.090)	1.251** (0.089)	1.285*** (0.091)
<i>Region (Ref: North Zone)</i>				
West zone	0.650*** (0.044)	0.651*** (0.044)	0.675*** (0.047)	0.709*** (0.048)
South zone	0.430*** (0.046)	0.433*** (0.046)	0.523*** (0.056)	0.503*** (0.054)
East zone	0.602*** (0.037)	0.605*** (0.037)	0.556*** (0.034)	0.598*** (0.036)
Observations	1,333,955	1,333,955	1,333,955	1,333,955

Notes: Hazard ratios from complementary log–log discrete-time survival models are reported, with robust standard errors in parentheses. Each column estimates a separate maternal care component to preserve the sequential structure of the maternal healthcare continuum and avoid overadjustment bias. All models include the full set of socioeconomic, demographic, reproductive, and regional controls used in the main analysis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

D.5 Birth Weight Specifications

The main analysis focuses on low birth weight as the primary adverse birth outcome. Additional multinomial logistic regression models examining macrosomia/high birth weight are presented here as supplementary specifications. These estimates should be interpreted cautiously. In particular, the estimated association between delivery-care quality and macrosomia may partly reflect reverse causality, since pregnancies involving suspected fetal overgrowth are more likely to require institutional delivery, skilled obstetric management, or caesarean intervention. Differential measurement may also contribute to the observed association, as birth weights recorded in institutional settings are more likely to be measured using standardised procedures than those occurring outside health facilities. The appendix results are therefore interpreted as descriptive associations rather than causal effects.

Table D2: Additional specifications: Maternal care quality and macrosomia/high birth weight

Outcome	Model	ANC	DC	PNC	Overall quality
Macrosomia / high birth weight (RRR)	Multinomial logit	0.742*** (0.006)	0.426*** (0.005)	—	0.678*** (0.004)
Controls included		Yes	Yes	—	Yes
Observations		1,333,955	1,333,955	—	1,333,955

Notes: Relative risk ratios (RRR) are reported from multinomial logistic regression models with normal birth weight (2.5–4.0 kg) as the reference category. Macrosomia/high birth weight refers to birth weight above 4.0 kg. Standard errors are shown in parentheses. All models control for maternal, household, socioeconomic, and regional characteristics and apply NFHS-5 sampling weights with clustering and stratification adjustments. Dashes (—) indicate that postnatal care was excluded because it occurs after delivery and therefore cannot plausibly influence birth weight outcomes. ANC = antenatal care; DC = delivery care; PNC = postnatal care. *** $p < 0.001$.