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Digital access as public health infrastructure: Evidence on maternal healthcare utilization from India

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Abstract

Background

Digital health systems are increasingly embedded in public health initiatives across low- and middle-income countries. Nevertheless, there is limited evidence on whether women's access to digital technology—especially mobile phones—serves as a facilitating public health resource or if it deepens existing inequalities in maternal healthcare.

Objectives

This research investigates whether women's access to digital tools, such as mobile phones and the Mother and Child Protection (MCP) card, serves as a foundational enabler of maternal healthcare utilization in India, with a particular focus on the adoption of four or more antenatal care visits (ANC4).

Methods

A mixed-methods approach incorporated a PRISMA-guided systematic review along with a quasi-experimental analysis of three waves of the National Family Health Survey (NFHS-3, NFHS-4, NFHS-5; from 2005 to 2021). State-level panel data were examined using Difference-in-Differences and Propensity Score Matching methods, with placebo and parallel trend tests conducted to ensure validity robustness.

Results

Throughout the country, ANC4 coverage grew between NFHS-4 and NFHS-5, especially in states with initially lower mobile ownership. Quasi-experimental data indicated that increasing mobile access was notably linked to a 9.2 percentage-point rise in ANC4 use in areas with weak digital infrastructure. Both the systematic review and empirical analysis underscore that digital access forms a vital part of health system infrastructure, shaped by governance and trust.

Conclusions

Mobile access among women should not be viewed as a standalone technology but as an integral part of public health infrastructure. Enhancing equitable digital connectivity is crucial for advancing maternal healthcare and increasing health system accountability.

Background: Digital Inclusion, Governance, and the Future of Maternal Health in India

The current digital health transformation in India is unfolding against the backdrop of significant initiatives, including the Ayushman Bharat Digital Mission (ABDM), the Health Management Information System (HMIS), and the Reproductive Child Health portal. These services are designed to improve the delivery of health services, increase accountability, and expand their reach through digital linking.[1]. However, the potential of the digital health transformation remains mismatched. The availability of digital services is deeply stratified along gender, caste, education, and geographic lines, and the assumptions of universal ownership of mobile phones, internet access, and the ability to use the government's health application have become invalid. [2]

The imbalance has been particularly severe in maternal health, where those who need services the most are the most excluded from digital services.[3]

Mobile technologies and health information systems are often praised for their efficiency and scalability, but they operate within complex sociotechnical systems.[4]. Within these systems, digital tools like the "Mother and Child Protection (MCP) Card" have evolved from individual behavior-change tools into vital components of a growing public health infrastructure.[5]. Nevertheless, there is limited empirical evidence on how these systems either promote or hinder participation in maternal healthcare.

This research study seeks to determine the extent to which basic digital access—namely, mobile phone ownership and pregnancy registration through the MCP card—is a structural enabler of maternal healthcare participation in India. The proportion of women who complete four or more antenatal care (ANC-4) visits is used as the measure of adequate maternal healthcare. The conceptualization of digital access will not be restricted to availability but will be more broadly defined through the lens of systems thinking and digital governance. By integrating empirical research and conceptual understandings of digital public service delivery, this research aims to move from discussions of digital adoption to digital architecture, demonstrating how policy regimes and platform governance shape who benefits from innovation. In this respect, maternal healthcare is highlighted in this body of literature as an extremely important case study of how ICT-enabled governance, through mobile technology integration, can be more than simply convenient.

Methods

Mixed Methods Design

This study employed a mixed-methods design, integrating a Systematic Literature Review (SLR) with an Empirical (Exploratory, Correlational, Quasi-Experimental) **a**nalysis

to examine how digital access—specifically mobile phone ownership and MCP card registration—affects maternal healthcare engagement in India. The SLR followed PRISMA 2020 guidelines and reviewed peer-reviewed studies (2010–2024) on digital health interventions in LMICs (Low- and Middle-Income Countries), with a focus on maternal care, mobile penetration, and governance. Findings informed the research framework and the selection of indicators.

Empirically, we used state-level panel data from NFHS-3, 4, and 5 to evaluate outcomes related to mobile ownership, MCP card registration, and ANC4 + uptake. States were classified into treatment and control groups based on the median level of mobile phone ownership in NFHS-4. Causal inference was drawn using Difference-in-Differences (DiD) models,[6]. Propensity Score Matching (PSM) for baseline balance[7], and Placebo tests using pre-treatment waves.[8]. Additional OLS regressions controlled for urbanization and female literacy. All analyses were performed using Python.

Conceptually, the study draws on Information Infrastructure Theory.[9] And the Public Value of ICT framework,[10]; positioning digital tools as evolving public infrastructures that mediate access, equity, and citizen–state accountability in maternal healthcare systems.

Stage 1: Systematic Literature Review

To examine how digital innovation influences maternal health in India and similar LMICs, we conducted a Systematic Literature Review (SLR) in accordance with PRISMA 2020 guidelines. This review mapped empirical, conceptual, and policy-oriented evidence on mobile-based interventions—such as SMS alerts, teleconsultations, and digital pregnancy registration—and their role in improving engagement in antenatal care. Framed by socio-technical and governance perspectives, the review identified how these tools shape access, equity, and accountability in public health systems. It reveals digital technologies as more than delivery tools—positioning them as public infrastructure critical to inclusive maternal care innovation. This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The complete PRISMA 2020 flow diagram is presented in Fig. 7. A completed PRISMA 2020 checklist is available **at ["Digital access as public health infrastructure: Evidence on maternal healthcare utilization from India", Mendeley Data, V1, doi**: 10.17632/fpssb7tjbs.1**]. Published: 5 February 2026,"** and in Supplementary File 1 for detailed information.

Search Strategy and Data Sources

To establish a conceptual foundation, we conducted a systematic literature search across Scopus, PubMed, Web of Science, and Google Scholar (2000–2024), using Boolean combinations of key terms including: *"maternal health" AND ("digital health" OR "mHealth" OR "telehealth")*; *"Internet access" AND "maternal care" AND ("India" OR "LMICs")*; *"mobile technology" AND ("antenatal care" OR "postnatal care")*; and *"digital tools" AND "maternal health outcomes" AND "governance."* Studies were included if they examined how digital interventions—such as mobile phones, SMS alerts, teleconsultations, or e-registration—impacted maternal healthcare uptake (ANC, PNC, institutional deliveries), particularly in low-resource or socially stratified contexts. Emphasis was placed on literature engaging public health governance, digital equity, and infrastructure reform. The review aimed not only to assess technological effectiveness but to understand how digital tools function within systems of access, accountability, and institutional trust.

Research Gap

While digital health systems have garnered increasing policy and research attention in India and other low- and middle-income countries, empirical understanding of how digital access—particularly mobile phone ownership and internet connectivity—shapes maternal health outcomes remains limited. Much of the existing literature frames digital tools as individual-level behavioral interventions, overlooking their integration within institutional systems and governance frameworks.[11]. The mediating role of regulatory mechanisms, such as the Ayushman Bharat Digital Mission (ABDM), data interoperability standards, and accountability structures, is poorly understood.[12] Likewise, maternal digital agency—encompassing digital literacy, language accessibility, and platform usability—has yet to be systematically theorized or operationalized.[13] Crucially, few studies interrogate how social determinants such as gender, caste, geography, and income moderate the relationship between digital access and maternal service utilization. This study addresses these gaps by conceptualizing mobile access and MCP-linked systems as embedded elements of India's evolving digital public infrastructure and by analysing their role in enabling equitable engagement with maternal healthcare within sociotechnical and institutional contexts.

Research Questions

1. **To what extent does access to digital public infrastructure**—specifically mobile phone ownership and internet connectivity—**influence maternal health service engagement**, as measured by antenatal care (ANC4+), postnatal care (PNC), and institutional delivery in India?
2. **How do governance structures and regulatory frameworks**—including data interoperability, digital health policies (ABDM), and accountability mechanisms—**mediate the relationship between digital access and maternal health outcomes**?
3. **What role do maternal digital agency and literacy** play in enabling the effective use of digital health platforms (e.g., SMS alerts, teleconsultation, MCP card systems), and how are these influenced by interface design, language accessibility, and health education?
4. **How do social determinants**—including gender, caste, income level, and geography—**moderate the impact of digital infrastructure on maternal health outcomes**, and what disparities emerge in access and use?
5. What evidence supports the view that mobile access and MCP-linked registration act as digital infrastructure components, rather than isolated behavioral tools, in enabling equitable maternal healthcare within national health systems?

Therefore, the Systematic Literature Review study emphasizes the need for a structured understanding of the impact of digital inclusion on maternal health outcomes. Out of 1,287 articles screened using the PRISMA approach, only 112 met the inclusion criteria, highlighting a notable gap in both empirical and theoretical research in this field.

From Conceptual Mapping to Empirical Analysis

The Systematic Literature Review (SLR) conducted in Stage 1 identified substantial gaps in empirical research on the connections between digital infrastructure, governance frameworks, and maternal health outcomes in stratified, resource-constrained contexts such as India. Although digital tools such as SMS reminders, MCP card registration, and teleconsultations were frequently cited, few studies examined their effects within integrated models of public service delivery and citizen engagement. This fragmentation informed the development of a multi-layered conceptual model linking digital access, maternal platforms, governance, and social determinants to key health outcomes, as illustrated in Fig. 1.

Guided by this model, Stage 2 involved an empirical analysis of NFHS panel data to test whether mobile phone ownership and MCP registration function as structural enablers of maternal care, as measured by ANC4 + visits. Thus, the SLR not only shaped the research hypotheses and variable selection but also justified the shift from conceptual mapping to causal investigation, embedding digital health tools within a broader infrastructure-of-care perspective.

Research Design: A Dual-Pronged Approach to Digital Inclusion in Maternal Health

This study adopts a mixed-method, multi-phase research design to assess how digital access—particularly mobile phone ownership and internet usage—influences maternal health engagement in India. Stage one involved a Systematic Literature Review (SLR) that integrated theoretical, empirical, and policy-oriented insights on digital health infrastructure and maternal care in low-resource settings. Findings from the SLR informed the second stage: Empirical Study (an exploratory, correlational, quasi-experimental analysis using state-level data from the National Family Health Surveys -NFHS-3, 4, and 5). Analytical methods included Difference-in-Differences (DiD), Propensity Score Matching (PSM), and spatial-temporal modeling to isolate the effects of digital access on key maternal health indicators such as ANC4 + visits and MCP registration. By bridging conceptual mapping with large-scale empirical testing, the study provides an integrated evidence base to inform policy recommendations on equity, inclusion, and digital health system design, as illustrated in Fig. 2.

Stage 2: Empirical (Exploratory, Correlational, Quasi-Experimental) Analysis

Longitudinal Analysis of Digital Access and Maternal Health Engagement

Stage 2 employs a district-level panel analysis using three rounds of India's National Family Health Survey (NFHS-3, NFHS-4, NFHS-5), covering the period 2005–2021. These nationally representative

datasets provide harmonized indicators across time, enabling spatial-temporal analysis of structural determinants of maternal health.

The study investigates whether digital access functions as an enabling infrastructure for maternal healthcare engagement.

The independent variables include:

- Mobile phone ownership and use (NFHS-4, 5),
- Internet use (NFHS-5), and
- MCP card possession (NFHS-3, 4, 5).

These proxies capture women's digital inclusion, autonomy, and integration into public health systems.

The dependent variable is ANC4 coverage—the uptake of four or more antenatal care visits—used as a benchmark for maternal service utilization and system responsiveness.

This design allows for a robust examination of how digital access influences maternal health trajectories across India’s diverse socio-geographic landscape.

Empirical Strategy: Linking Digital Access to Maternal Health Equity

The empirical analysis adopts a multi-method approach to assess how digital access influences maternal health engagement in India. Anchored in the study’s conceptual framework, it integrates exploratory, correlational, and quasi-experimental methods to examine the impact of mobile phone ownership, internet use, and MCP card registration on ANC4 uptake. The strategy leverages temporal and geographic variation across states and districts using harmonized data from NFHS-3, NFHS-4, and NFHS-5.

To estimate causal effects, the study employs a Difference-in-Differences (DiD) framework, complemented by Propensity Score Matching (PSM) to reduce baseline imbalance, parallel trend analysis to validate assumptions, and placebo tests to assess robustness. By accounting for confounders such as female literacy, urban-rural residence, and baseline health access, the analysis isolates the structural role of digital inclusion in maternal health service uptake.

Exploratory Analysis: Digital Access and Maternal Health Engagement

Before applying causal models, the study conducts an exploratory and correlational analysis to visually and descriptively examine associations between digital access and maternal healthcare utilization across 12 diverse Indian states. Using NFHS-4 and NFHS-5 data, the study includes:

1. A summary table mapping women's mobile phone ownership against maternal health indicators as shown in Table 1.

Table 1
State-Level Trends in Women's Mobile Phone Ownership, MCP Card Possession, and ANC4 Coverage (NFHS-4 and NFHS-5)

State	Mobile (4)	Mobile (5)	ANC4 (4)	ANC4 (5)	MCP (4)	MCP (5)
Andhra Pradesh	48.90%	64.00%	51.30%	74.70%	92.30%	84.90%
Bihar	20.60%	41.30%	14.40%	43.00%	89.30%	78.50%
Gujarat	53.30%	69.60%	59.10%	65.50%	93.90%	91.00%
Karnataka	57.40%	78.10%	63.60%	79.40%	94.10%	87.10%
Kerala	85.20%	92.20%	83.30%	92.50%	94.50%	87.80%
Madhya Pradesh	26.50%	49.60%	35.70%	57.70%	90.40%	77.30%
Maharashtra	65.60%	76.40%	62.50%	77.30%	95.80%	88.20%
Odisha	45.30%	66.60%	48.10%	78.90%	93.10%	84.90%
Rajasthan	30.40%	56.60%	39.10%	61.50%	88.90%	83.60%
Tamil Nadu	75.50%	85.30%	68.00%	85.90%	95.10%	88.10%
Uttar Pradesh	23.00%	42.00%	26.40%	46.90%	88.10%	77.60%
Ist Bengal	50.00%	72.10%	46.40%	79.20%	93.20%	89.70%

(This table presents comparative percentages across 12 Indian states, capturing shifts in women's mobile phone ownership, MCP card registration, and uptake of four or more antenatal care visits (ANC4) between NFHS-4 and NFHS-5. It illustrates how changes in digital access align with patterns in maternal health engagement across diverse demographic contexts.)

2. A heatmap as depicted in Fig. 3 visualizing temporal changes in MCP card registration, mobile ownership, and ANC4 coverage.
3. A comparative review of maternal care uptake in states with high vs. low digital penetration, as illustrated in Fig. 4.

This exploratory phase helps contextualize state-level disparities and assess the plausibility of the core hypothesis: that digital infrastructure functions as a structural enabler of maternal healthcare engagement. These findings lay the groundwork for the subsequent quasi-experimental models, reinforcing the empirical link between digital inclusion and health equity.

Integrating Analytical Design with Policy and Data Structures

Building on the exploratory findings and correlational framework, this section operationalizes the quasi-experimental analysis by leveraging variation in women's mobile phone ownership as a proxy for state-level digital readiness. Using NFHS-5 data, states were stratified around the national median (64%) to classify treatment (higher mobile access) and control (lower access) groups. This binary assignment reflects the differential exposure to India's post-2015 digital health initiatives, allowing us to estimate whether digitally lagging states experienced greater gains in maternal health outcomes—particularly ANC4 coverage—following the expansion of mHealth infrastructure. The classification supports a Difference-in-Differences (DiD) design augmented by Propensity Score Matching (PSM), ensuring baseline comparability. To strengthen causal inference, we harmonize data across NFHS waves, apply balance diagnostics, and validate assumptions using placebo and parallel trend tests. This integration of policy context, digital stratification, and statistical design enables robust analysis of how digital access shapes maternal health equity across India's fragmented health landscape.

Quasi-Experimental Scenario: Digital Access as a Natural Policy Shock

This study exploits a quasi-experimental setting in which differential digital access across Indian states creates a natural experiment to evaluate the effects of mobile-enabled health infrastructure on maternal care. Following the post-2015 national digital health expansion, states with low baseline mobile phone ownership—as measured by NFHS-5—are hypothesized to experience disproportionate improvements in antenatal care uptake because the marginal benefit from mHealth tools is greater. States are stratified using a national median threshold of 64% female mobile ownership, forming two groups:

- Treated states (e.g., Kerala, Tamil Nadu, Delhi) with high mobile access and digital readiness
- Control states (e.g., Bihar, Jharkhand, Assam) with lower baseline access.

This binary classification—shown in Fig. 5—serves as the foundation for a Difference-in-Differences (DiD) analysis, supplemented by Propensity Score Matching (PSM) to improve baseline comparability across states. The post-2015 rollout of India's national digital health programs is considered a time-limited policy intervention, enabling causal inference into changes in ANC4 coverage. To validate identification, pre-intervention trends from NFHS-3 and NFHS-4 are analyzed using placebo tests and parallel trends assessments. All indicators are harmonized across NFHS surveys for consistent measurement, and covariate balance is verified using standardized differences and visual tools such as Love plots, thereby ensuring the robustness of the methodology.

Estimating the Causal Impact of Digital Access on Maternal Healthcare Engagement

To assess the causal relationship between digital access and maternal health uptake, we employed a Difference-in-Differences (DiD) estimation strategy, using pooled state-level data from NFHS-4 (2015–16) and NFHS-5 (2019–21). The primary outcome variable is the proportion of women aged 15–49 who received four or more antenatal care visits (ANC4). The key independent variable—digital access—is

proxied by mobile phone ownership, and states are stratified into treatment and control groups based on whether female mobile usage is above or below the median in NFHS-5.

To strengthen causal inference and reduce selection bias, we applied Propensity Score Matching (PSM) prior to DiD estimation. Matching was performed on pre-treatment socio-demographic covariates (e.g., female literacy, urbanization rate), and balance was evaluated using Standardized Mean Differences (SMDs) and visual diagnostics (e.g., Love plots). This combined approach ensures that differences in ANC4 coverage are attributable to changes in digital exposure, not to confounding baseline disparities.

The core DiD model is specified as:

$$Y_{d,t} = \alpha + \beta_1 \text{DigitalExposure}_{d,t} + \beta_2 X_{d,t} + \mu_s + \lambda_t + \delta_d + \varepsilon_{d,t}$$

Where:

- $Y_{d,t}$: Proportion of women in the district $d$at time $t$receiving ANC4
- Digital Exposure$_{d,t}$: District-level proxy for NDHM-linked digital access (e.g., mobile phone ownership)
- $X_{d,t}$: Vector of control variables (e.g., tech access, female literacy)
- μ_s: State fixed effects
- λ_t: Time fixed effects
- δ_d: Treatment group indicator
- $\varepsilon_{d,t}$: Error term clustered at the district level

This specification allows us to isolate the differential effect of mobile phone diffusion on maternal care outcomes across districts with varying levels of digital readiness. Table 2 presents the resulting estimates, offering robust evidence that increased digital access is positively associated with improvements in ANC4 coverage, particularly in digitally underserved regions.

Table 2
Key Coefficients and Interpretation

Term	Coefficient	p-value	Interpretation
Intercept	32.47	0	Baseline ANC4 in the control group (NFHS-4)
Treated	9.23	**0.012**	Treated states had **9.2% higher** ANC4 than controls in 2015
Post	32.47	0	All states saw a **32.5% average increase** in ANC4 by 2020
Interaction	9.23	**0.012**	**Treatment effect**: digitally lagging states improved **9.2% more** than controls **because of digital access expansion**
Mobile Access	0.01	0.878	Not significant after adjusting for group-time effects

Integrated Causal Strategy: Aligning Propensity Scores with Difference-in-Differences

The combination of Propensity Score Matching (PSM) and Difference-in-Differences (DiD) estimation provides a robust empirical strategy for identifying the effect of digital access on maternal health service utilization. While the DiD model captures temporal changes in antenatal care across high- and low-access states, PSM ensures that treatment and control groups are balanced on observable baseline characteristics. This alignment minimizes confounding and approximates a quasi-experimental setting.

Figure 6 illustrates the results of covariate balance diagnostics via a **Love plot**, showing standardized mean differences (SMDs) before and after matching. Post-matching, nearly all covariates fall within ± 0.1, indicating that systematic differences between the groups have been effectively neutralized. This visual verification reinforces the assumption of conditional independence—critical for valid causal inference from observational data.

To assess covariate balance, a Love plot was used to visualize standardized mean differences (SMDs) before and after propensity score matching. The conventional ± 0.1 threshold, marked by red dashed lines, was applied to evaluate acceptable imbalance. Post-matching, nearly all covariates—spanning maternal, child, and household indicators—fell within this range, indicating strong alignment between treatment and control groups. This supports the assumption of conditional independence and reinforces the internal validity of the causal estimates by minimizing bias from baseline differences (Tomlin, 2025; Hammerton & Munafò, 2021).

Results

Systematic Review, Thematic and Theoretical Insights

Following PRISMA 2020 guidelines, the literature search retrieved 1,287 unique records across Scopus (460), PubMed (345), Web of Science (312), and Google Scholar (170). After removing 174 duplicates using Zotero, 1,113 records were screened based on titles and abstracts. Two independent reviewers applied inclusion criteria focused on digital interventions in maternal health, excluding 820 articles that lacked policy relevance, focused narrowly on clinical outcomes, or addressed general digital health rather than maternal-specific interventions. Grey literature and non-peer-reviewed studies were also excluded.

Of the 293 full-text articles assessed, 181 were removed due to limited discussion of maternal outcomes, lack of implementation insight, or weak conceptual framing. The final synthesis included 112 peer-reviewed studies, distributed as follows:

- 41 empirical studies on digital tools in antenatal and postnatal care (ANC/PNC) delivery
- 39 theoretical works on access, innovation, and patient agency
- 32 policy reviews on equity, ethics, and health system integration

The PRISMA flow diagram in Figure 7 illustrates the full screening and selection process.

Thematic analysis of the 112 peer-reviewed studies revealed three interrelated domains shaping how digital tools influence maternal health systems in low-resource contexts:

1. Digital Pathways of Engagement: Mobile phones, internet access, SMS reminders, and mHealth applications are reshaping maternal behaviors—from initiating antenatal care to maintaining continuity throughout pregnancy. These tools enhance communication, support timely decision-making, and increase adherence to antenatal protocols.
2. Governance and Equity: Access to digital health remains deeply stratified, shaped by gender, caste, geography, and education. Gaps in digital literacy, consent, and algorithmic transparency limit both uptake and trust. The promise of digital health cannot be fulfilled without addressing these structural inequities.
3. Institutional Integration: Public programs such as *Janani Suraksha Yojana* and *RMNCH+A* are being integrated with digital infrastructure to support monitoring, targeted outreach, and data-informed service delivery[14] . This evolution positions digital tools within a broader healthcare reform framework.

These themes underscore that digital health interventions must be understood not as standalone innovations, but as embedded within wider sociotechnical and institutional ecosystems.

To synthesize these insights, a theoretical model (Figure 8) was developed, offering a structured view of how digital access influences maternal health through multi-layered, context-specific processes. The model includes four interconnected layers:

- Input Layer: Material conditions of access—mobile phone ownership, internet connectivity, and device usability[15] .
- Process Layer: Mediators such as digital literacy, user trust, and interaction with health platforms. [16]
- Structural Moderators: Social determinants—gender norms, caste, geography, and language—that shape who benefits from digital access[17] .
- Output Layer: Health outcomes including ANC/PNC uptake, institutional delivery, and women's confidence in navigating the health system [18].

At the center of the model is maternal digital agency—a woman's capacity to interpret, control, and act on digital health information. The model reframes empowerment not merely as access, but as the ability to use digital tools effectively and equitably. It provides a conceptual framework for identifying exclusion points and designing policy responses that embed digital health within broader systems of equity and care.

Exploratory and Correlational Patterns Linking Digital Access to Maternal Health Engagement

Before turning to quasi-experimental estimates, exploratory visualizations reveal important correlational trends. Figure 3 (heatmap) shows consistent increases in women's mobile phone ownership and ANC4 coverage across Indian states between NFHS-4 and NFHS-5, with sharp improvements in digitally underserved states such as Bihar, Madhya Pradesh, and Uttar Pradesh. Figure 4 (line plot) further illustrates convergence in ANC4 uptake across states, particularly in areas where mobile access rose most significantly. These patterns suggest a positive association between digital inclusion and maternal healthcare engagement. Building on these observations, the subsequent causal analyses (DiD, PSM, placebo test, and parallel trends diagnostics) confirm that improved mobile access—especially among women—was significantly associated with higher ANC4 coverage. Together, the visual and inferential results underscore that digital infrastructure, when accessible and equitably distributed, plays a pivotal role in enabling maternal health service utilization.

DiD Estimates: Mobile Expansion and ANC Uptake

The DiD analysis compares ANC4 coverage between states grouped by digital access. Control states had lower-than-median levels of women's mobile ownership in NFHS-5, while treated states exceeded the median threshold (64%). Between NFHS-4 and NFHS-5:

- Control states began with an average ANC4 coverage of 32.47% ($p < 0.001$).
- A national improvement of 32.5 percentage points in ANC4 was observed across all states ($p < 0.001$).
- The DiD interaction term yielded a net treatment effect of +9.23 percentage points ($p = 0.012$), indicating higher gains in states with greater digital expansion.

Yet, when controlling for group-time interactions, the direct effect of mobile access alone was statistically insignificant (β = 0.01). This underscores that while mobile access facilitates engagement, it must be embedded within responsive governance systems to produce meaningful outcomes.

Propensity Score Matching validates digital access as a structural predictor of maternal healthcare use

To reduce selection bias and enhance causal estimates, Propensity Score Matching was applied to the NFHS-5 data. Women residing in states with mobile phone use above the national median were matched with women in states with lower access, based on observable demographic and socioeconomic factors. The average treatment effect was +19.76 for ANC4, showing significant improvements in antenatal care for those with greater digital access compared to their matched counterparts.

Post-matching diagnostics, evaluated via the Love plot (Figure 6), revealed that nearly all covariates had standardized mean differences within ±0.1, validating the quality of the matching process and suggesting that the observed treatment effect was not due to pre-existing differences between groups.

Importantly, the positive ATE from PSM corroborates the findings from the Difference-in-Differences analysis, confirming the robustness of the results. Overall, mobile phone ownership acts both as a means to improve communication and as a structural facilitator that encourages maternal involvement in maternal health within India's emerging digital health landscape.

Placebo and Parallel Trends Tests

To further strengthen causal inference, two diagnostic checks were performed.

Placebo Test: Ruling Out Spurious Effects

As shown in Table 3, a placebo regression was conducted using sex ratio—an outcome unlikely to be affected by digital access. Neither treatment status nor mobile access showed a significant relationship with the placebo outcome ($p > 0.5$), and the R^2 was negligible (0.006). This confirms that the ANC4 results are unlikely to be driven by unobserved confounding or spurious correlation.

Table 3. Placebo Test Results (NFHS-5 Cross-Sectional OLS Regression)

Variable	Coefficient	Std. Error	t-Statistic	p-Value	95% Confidence Interval
Intercept	1004.25	19.24	52.19	0	[966.11, 1042.40]
Treatment Group	10.68	17.57	0.61	0.544	[-24.14, 45.51]
Mobile Access	0.0054	0.35	0.015	0.988	[-0.69, 0.70]

Parallel Trends Analysis: Confirming DiD Validity

Parallel trends were evaluated across NFHS-3, NFHS-4, and NFHS-5, comparing states with high versus low digital access (Figure 9). Before the digital expansion (from NFHS-3 to NFHS-4), both groups followed similar trajectories, satisfying the parallel trends assumption. Post-intervention, however, low-access states exhibited steeper improvements in ANC4 coverage, suggesting that the national digital health initiatives disproportionately benefited underserved areas.

From Digital Access to Maternal Empowerment: Policy Interpretation

The convergence of results across DiD, PSM, placebo, and parallel trends methods provides robust evidence that women's digital access—particularly mobile phone ownership—enhances engagement in antenatal care. This effect was most pronounced in states with weaker health infrastructure, revealing a redistributive potential of digital inclusion. However, digital access alone is insufficient. As the insignificant direct effect in DiD models indicates, institutional capacity, trust in systems, and frontline engagement remain critical mediators.

This policy framework synthesizes key governance implications derived from the study's quasi-experimental analysis. It outlines how digital inclusion—when paired with system integration, trust-building, and equity-focused design—can serve as a structural lever to improve maternal healthcare engagement in India. Each dimension highlights actionable areas for public health policymakers, digital platform designers, and frontline implementers navigating the intersection of digital health and maternal equity as depicted in Box 1

Box 1. Policy and Governance Implications: Toward Equitable Digital Health for Maternal Care

Dimension	Policy Insight
1. Digital Infrastructure	Treat mobile phone access as essential public health infrastructure—not merely a communication tool—to strengthen maternal health engagement.
2. Targeted Inclusion	Prioritize resource allocation to digitally underserved states and districts. Address structural inequalities through tailored digital literacy and outreach programs.
3. System Integration	Embed digital tools within trusted platforms such as **HMIS**, **RCH Portal**, and **ABDM** to ensure continuity and community-level credibility.
4. Usability and Trust	Design for linguistic, cultural, and technological accessibility. Build trust through transparent governance, privacy protections, and user-centered services.
5. Equity-by-Design	Actively govern digital inclusion by integrating feedback loops, ensuring participation from marginalized groups, and adapting tools to local contexts.
6. Empowerment Beyond Access	Support women's digital agency by promoting autonomy, informed decision-making, and service navigation within digitally mediated health ecosystems.

Discussion

Digital Access, Governance, and Equity: Integrating Empirical Evidence with Systemic Implications

This study establishes a clear, empirically grounded link between women's mobile phone ownership and engagement with maternal digital platforms—such as MCP card registration—and increased utilisation of key maternal health services, particularly four or more antenatal care (ANC) visits (ANC4). Drawing on NFHS-3, NFHS-4, and NFHS-5, the analysis shows that mobile phone access functions not merely as a private asset but as a public interface through which women navigate and activate health entitlements. Although the findings are from India, they are relevant to other low- and middle-income countries, as observed effects depend less on specific technologies than on how digital access is institutionally embedded. Importantly, digital inclusion is neither uniform nor inherently equitable: women who lack digital literacy, linguistic access, or frontline mediation may remain excluded, and poorly governed digital systems risk reinforcing existing power asymmetries. These findings underscore the need for equity-oriented governance that integrates digital access within trusted public health infrastructure.

The spatial and temporal patterns highlighted in Figures 3 and 4 demonstrate that improvements in digital inclusion, especially in previously underserved states such as Bihar and Odisha, are associated with steep gains in ANC4 coverage.

Regression trends in Figure 10 further support this association. Notably, while MCP card coverage remained relatively high, mobile access was the most consistent predictor of care engagement, reinforcing theoretical insights from the Digital Pathways model that emphasize maternal digital agency.

Policy implications extend beyond health metrics to the architecture of digital governance. Mobile-enabled systems like the MCP platform enable scalable outreach, accountability via traceable health records, and targeted inclusion of digitally marginalized populations. These findings align with the broader governance agenda of India's federated digital health mission, where linking Aadhaar-based identity systems with decentralized community-level data holds promise for more equitable and responsive service delivery.

The study's findings reaffirm three critical propositions:

First, that mobile phones function as gateways to state interaction and healthcare participation; **Second,** that digital platforms such as MCP can transform paper-based maternal care into adaptive, real-time governance tools; and

Third, that regional disparities in digital infrastructure and literacy continue to reproduce inequities in access to maternal care.

The findings are consistent across various analytical approaches, including DiD, PSM, placebo, and parallel trends. However, they are limited by inherent issues in observational data, including self-report

bias and unmeasured differences between rural and urban areas. Future studies should use longitudinal microdata and administrative service logs to improve causal inference and enhance policy targeting.

Equity-Focused Digital Health: From Access to Empowerment

These findings underscore the need for digital inclusion policies that ensure mobile phones are used to advance maternal health equity. Digital health must not be a side stream running alongside existing service delivery systems; rather, the approach must be designed to integrate all aspects of health so that technology improves health.

Women need to be made active players in defining digital health services, rather than mere beneficiaries. Participatory approaches, such as community workshops, digital literacy, and feedback platforms, could help ensure the adaptation of health services to needs. In addition, trust needs to be incorporated within digital health systems through the adoption of sound data protection norms and the provision of redressal and human support mechanisms, including the use of ASHAs as digital health middlemen.

For the move from mere access to empowerment to take place, the following are some of the policies that ought to

Integrate Digital Access into Public Health Infrastructure

Mobile connectivity and digital literacy must be recognized as vital infrastructure, particularly in remote areas. Subsidies for targeted areas, Wi-Fi connectivity, and device access programs must focus on poorer and less-connected districts.

Design for Inclusion & Usability

Online platforms can be made more effective by supporting multiple languages, audiovisual formats, and options for disconnecting. User-centric design needs to be grounded in the realities of women receiving maternal care.

Train and Empower Frontline Health Workers

The ASHAs, ANMs, and other frontline personnel must be provided not only with the technological tools but also with the training necessary to serve as ‘intermediaries.’ The role of ASHAs in overcoming digital divides must be recognized and encouraged. For this reason, it's imperative that feedback systems, such as SMS polls, IVR helplines, and digital review boards, be incorporated into digital platforms for maternal healthcare. This aids in course correction. Guarantee Interoperability and Data Equity. These platforms must support open standards to interface with registries and the mother-tracking system, such as the MCP Cards. Data systems need to enable privacy, non-exclusion, and non-unintended bias in the provision of the service and the system developed. Overall, this research shifts the focus on digital maternal health from being an innovation by technology to an imperative for governance. The potential

of digital approaches in the health industry can only be harnessed if the system promotes trust-building, responsiveness, and agency. Equity in digital access must be a principle for change, not just an outcome.

Ultimately, this study positions digital access not merely as a technological fix, but as a structural determinant and governance instrument within maternal health systems. Digital inclusion, when meaningfully integrated into public service delivery, can catalyse a more participatory, accountable, and equitable health ecosystem.

Conclusion

This study demonstrates that digital inclusion, as measured by female ownership of mobile phones and MCP card registration, is an important facilitator of maternal healthcare service use in India. Utilizing quasi-experimental design methods such as Difference-in-Difference (DiD) and Propensity Score Matching (PSM) and placebo and parallel trends tests, this study reveals that access to mobile phones is not only an important technological facilitator but also an infrastructural determinant affecting female service use and interaction with public healthcare services and systems in India, especially in regions where digital penetration is relatively lower.

Thus, mobile connectivity does not merely reveal its role as a medium of communication; rather, it also reflects its role as a conduit of agency, providing access, building trust, and promoting continuity of care. Instead of being viewed as autonomous technological interventions, the systems of mobile health need to be embedded in the governance of maternal health services to promote equity, accountability, and the role of health workers in translating technological access into long-term improvements in service use. As such, digital health services also operate as a form of public infrastructure and a form of governance.

From the perspective of policymakers, the implications of the above findings would be to create a framework that enhances the quality of the maternal health system by treating digital connectivity as part of the public health infrastructure. Thus, integrating digital tools into trusted institutional platforms would be significant in promoting women's digital agency by creating a secure environment. Ultimately, applying the principles of trust would ensure the integration of the digital dimension as a policy instrument by adapting the broader rights-based approach to the health system.

Limitations:

While providing strong empirical evidence linking digital access to maternal health outcomes, several limitations should be acknowledged. Firstly, the analysis relies on aggregated state-level data from the National Family Health Surveys (NFHS), which limits the specificity of the findings. Such aggregation may conceal significant intra-state disparities and localized patterns of mobile access and maternity healthcare utilization. Secondly, despite employing robust quasi-experimental methods like Difference-in-Differences (DiD) and Propensity Score Matching (PSM), the analysis is constrained by the non-random distribution of mobile access. This introduces the possibility of residual confounding, as unobservable factors—such as governance quality, concurrent health interventions, or socio-cultural influences—may

affect the results.[19]. Lastly, although placebo tests were conducted for certain effects, the analysis did not evaluate qualitative factors such as trust in the digital tools, user experience, or adoption barriers.[20] These factors are crucial for understanding real-world applicability and impact, but are beyond this study's scope. Overall, these limitations suggest that while the study confirms a positive link between digital access and maternity health engagement, the findings should be interpreted with consideration of context, causality, and the depth of access.

Future Research and Policy Implications

This study provides robust empirical evidence that women's mobile phone ownership—a core marker of digital inclusion—is positively associated with increased utilization of maternal health services, particularly four or more antenatal care visits (ANC4). States that initially lagged in digital infrastructure saw the largest improvements between NFHS-4 and NFHS-5, as shown by Difference-in-Differences and Propensity Score Matching analyses. Supplementary robustness checks, including a placebo test using female literacy, further support the conclusion that mobile access may serve as a proxy for broader access to essential services such as education, sanitation, and financial inclusion.

These insights open several avenues for future research and offer actionable lessons for digital governance reform:

Multimethod Research for Understanding Causal Pathways

Quantitative evidence must be complemented by research that captures the mediating mechanisms between digital access and behavioral change.

Longitudinal designs, ethnographic methods, and participatory approaches can illuminate how women interact with digital health content, how trust is built over time, and how information translates into care-seeking behaviors.[21] Understanding these processes is vital for designing more responsive and inclusive digital health systems.

From Connectivity to Capability

Policy interventions must move beyond device distribution to build digital capability. This includes designing platforms that are culturally relevant, linguistically accessible, and privacy-conscious. Trust-building, user-centered design, and iterative feedback mechanisms should become foundational pillars of digital health governance—especially in maternal care, where systemic inequities intersect with new technologies.[22]

In sum, future research should embrace mixed method approaches to unpack how digital access reshapes maternal health agency. At the same time, policymakers must treat mobile connectivity as a foundational layer of public health infrastructure. Closing the digital divide is not just a technological imperative—it is a governance challenge with profound implications for health equity and maternal empowerment.

Declarations

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Author Contributions

Dr. Atantra Das Gupta: Conceptualization, Methodology, Formal analysis, Writing - original draft, Visualization.

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All authors have read and agreed to the published version of the manuscript.

Disclosure

The authors declare no conflicts of interest.

Ethics and Consent

This study used publicly available secondary data from the National Family Health Surveys (NFHS-3, NFHS-4, and NFHS-5). All datasets are anonymized and de-identified. No primary data collection or human subjects research was conducted. Ethical approval was not applicable to this secondary data analysis.

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Paper Context

Main findings

Women owning mobile phones and participating in digital maternal health registries are strongly linked to higher use of antenatal care services in India, especially in states that were previously underserved.

Added knowledge

This study demonstrates that mobile phones serve as a crucial public health infrastructure rather than merely communication tools, with their effectiveness depending on institutional integration, trusted governance, and frontline health worker interventions.

Global health impact for policy and action

Recognizing digital connectivity as a crucial part of public health infrastructure is key to strengthening maternal health services and advancing equity in low- and middle-income countries. This strategy depends on policy frameworks that integrate digital access with effective governance and active community participation.

Data Availability Statement

The data used in this study are publicly available secondary datasets. Individual-level data from the National Family Health Surveys (NFHS-3, NFHS-4, and NFHS-5) were obtained from the Demographic and Health Surveys (DHS) Program upon registration and approval (https://dhsprogram.com). All datasets are anonymised and de-identified prior to release.

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Figures

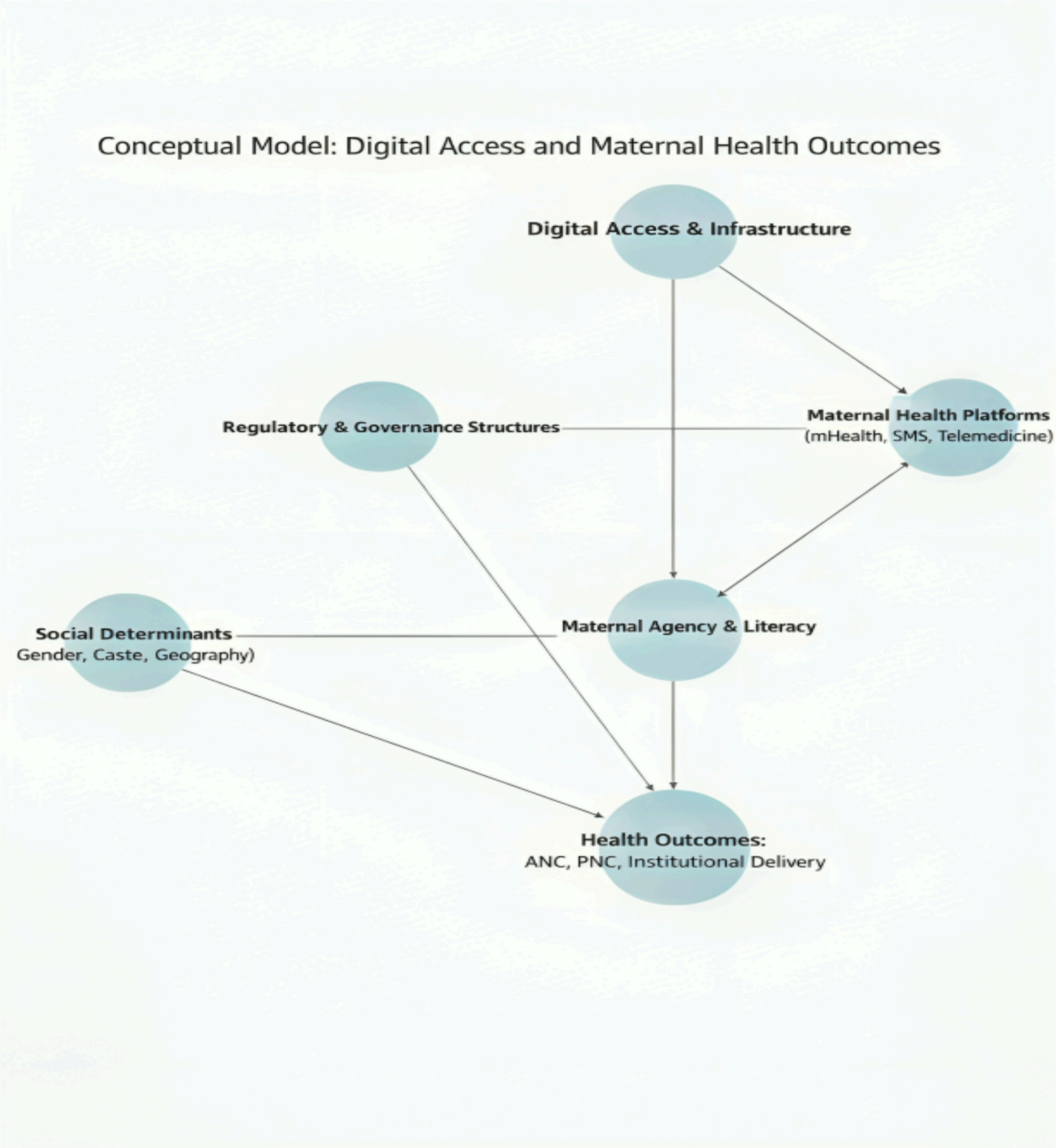


Figure 1

Conceptual Model Linking Digital Access to Maternal Health Outcomes

(This figure illustrates how digital infrastructure interacts with maternal health platforms, governance systems, and social determinants to shape maternal health outcomes.)

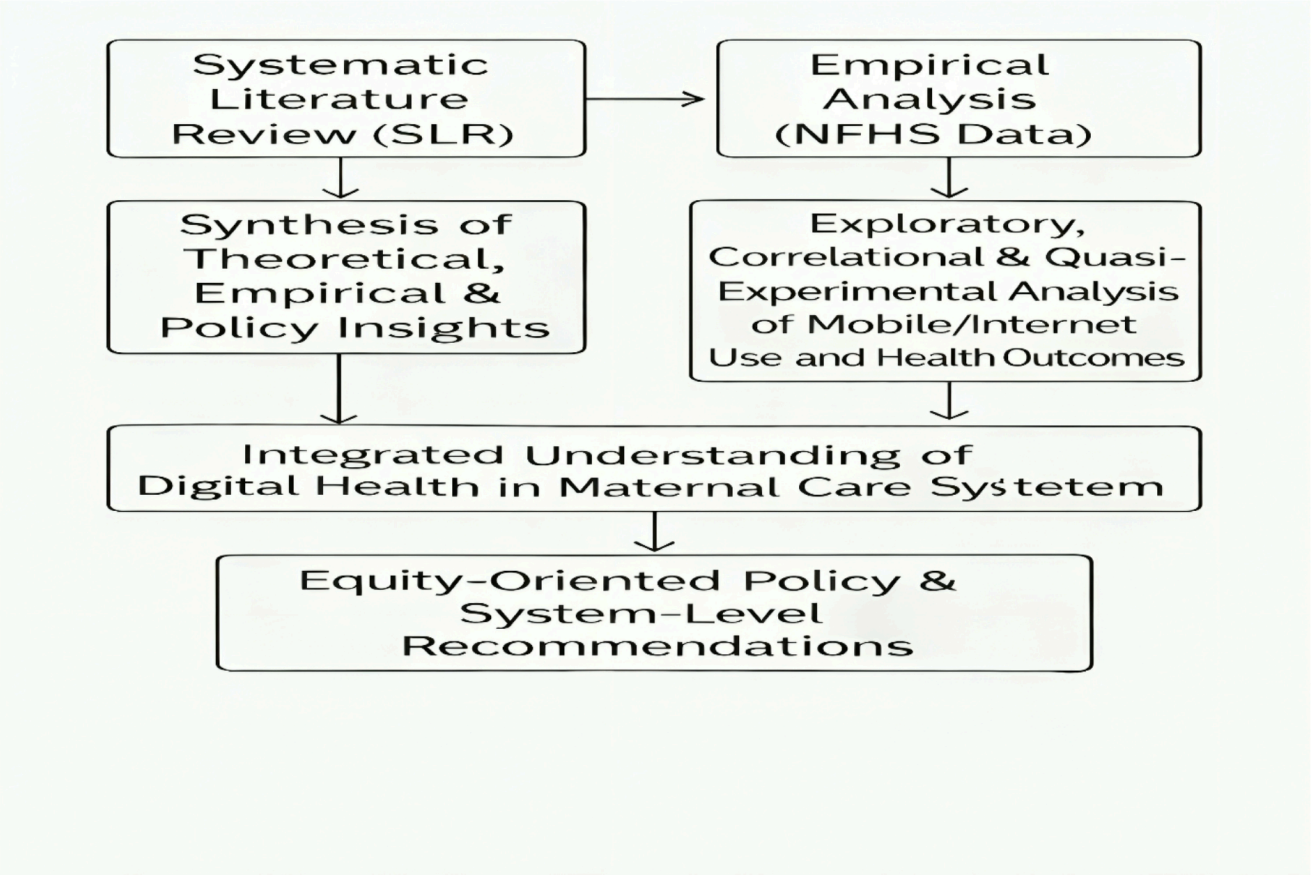


Figure 2

Integrated Research Design Linking Literature and Empirical Analysis.
(This flowchart illustrates the sequential research design combining a Systematic Literature Review (SLR) with an empirical analysis of NFHS data. It demonstrates how conceptual insights from the literature inform empirical investigation, with integrated findings used to assess the role of digital access in maternal healthcare and generate equity-oriented policy recommendations.)

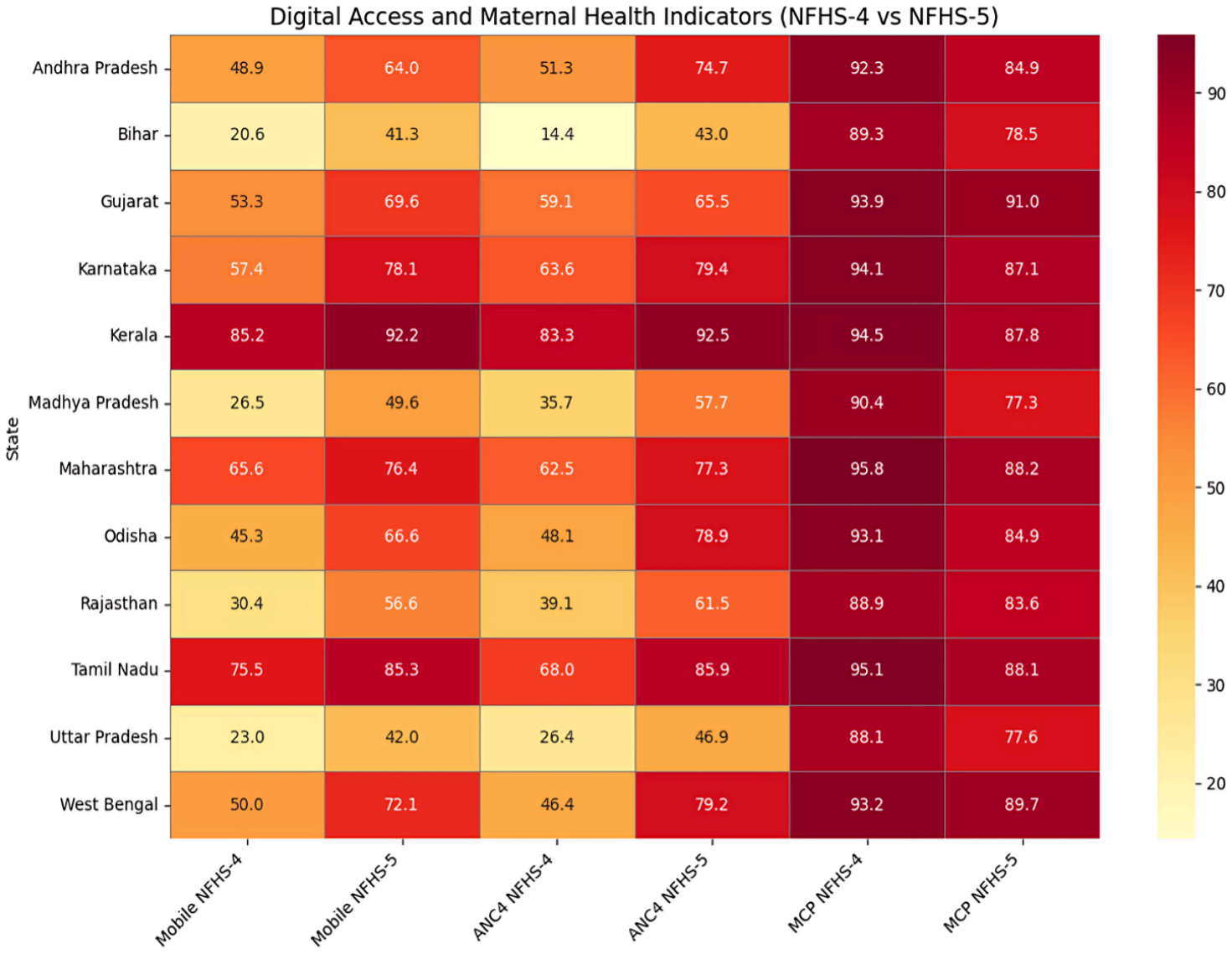


Figure 3

Heatmap of Digital Access and Maternal Health Outcomes Across 12 Indian States (NFHS-4 and NFHS-5)

(This heatmap visualizes state-level variation in women's mobile phone ownership, MCP card registration, and ANC4 coverage across two time points. By mapping changes between NFHS-4 and NFHS-5, the figure illustrates spatial and temporal patterns in digital access and maternal healthcare engagement, offering insights into the uneven diffusion of digital infrastructure and its association with service uptake.)

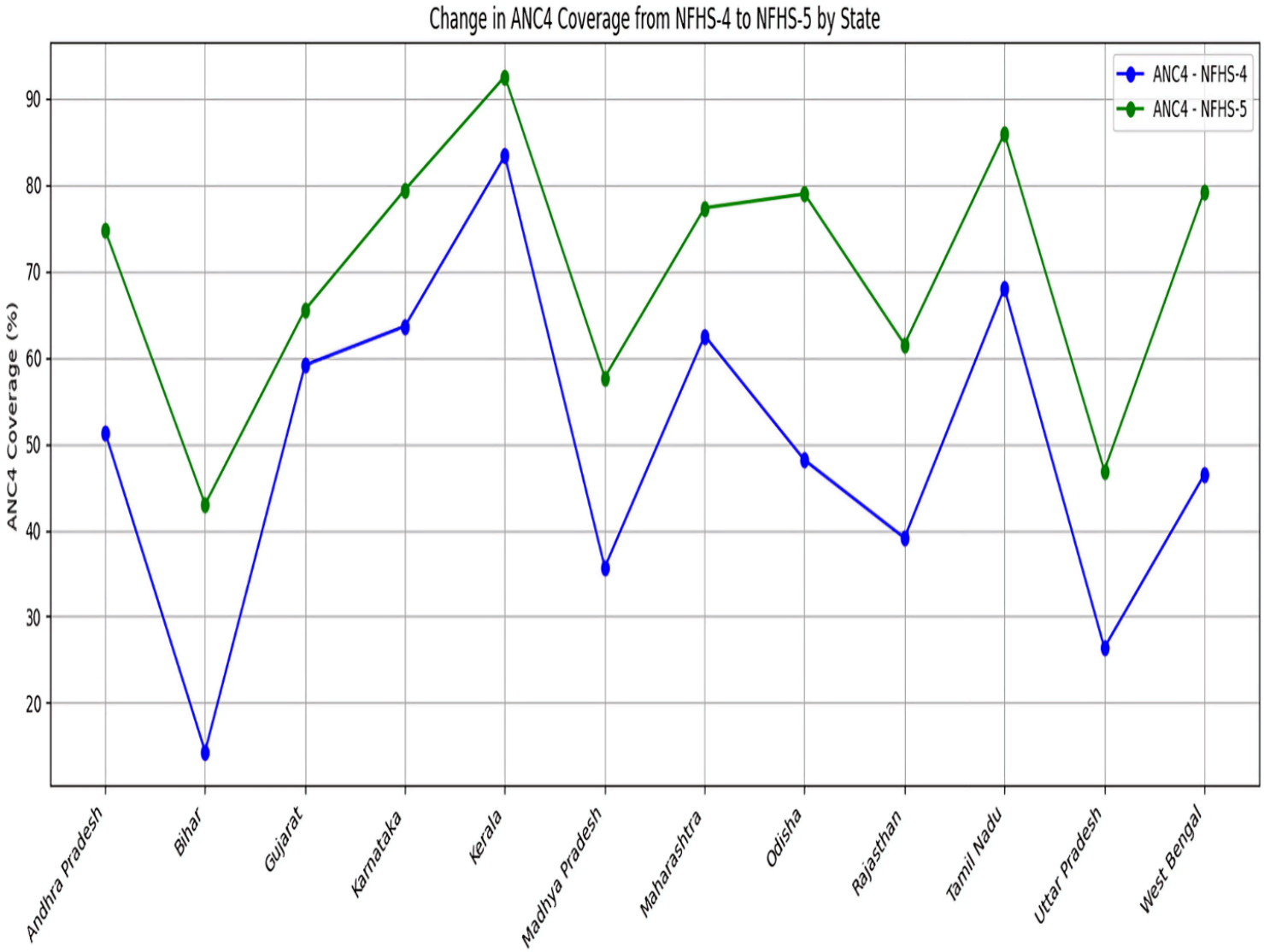


Figure 4

State-Wise Change in ANC4 Coverage Between NFHS-4 and NFHS-5

(This line chart compares the proportion of women who received four or more antenatal care (ANC4) visits across selected Indian states, using data from NFHS-4 and NFHS-5. The figure illustrates temporal trends in maternal healthcare engagement, highlighting variation in service uptake across regions during the digital expansion period.)

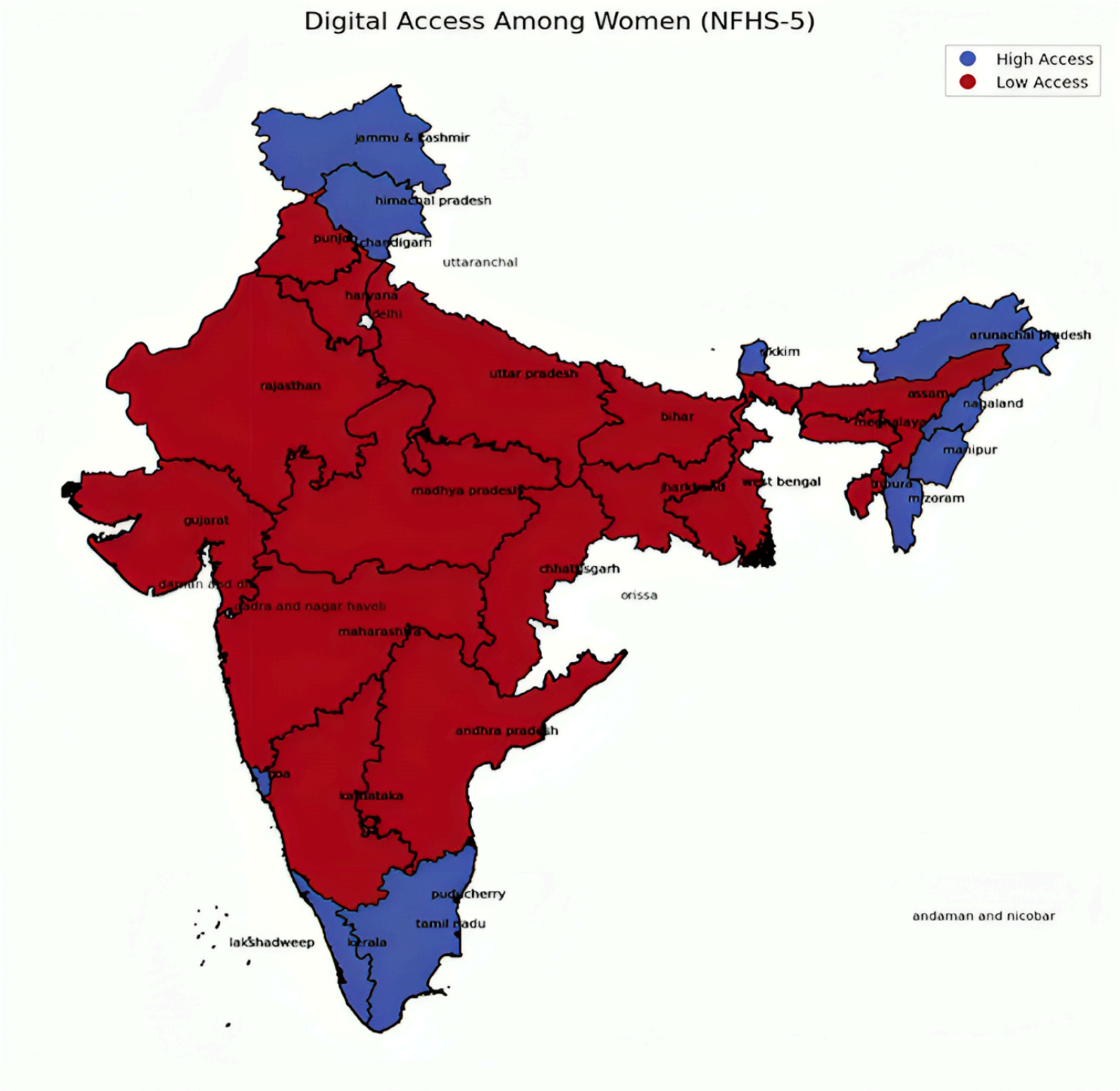


Figure 5

Classification of Indian States by Women's Mobile Phone Access (NFHS-5)

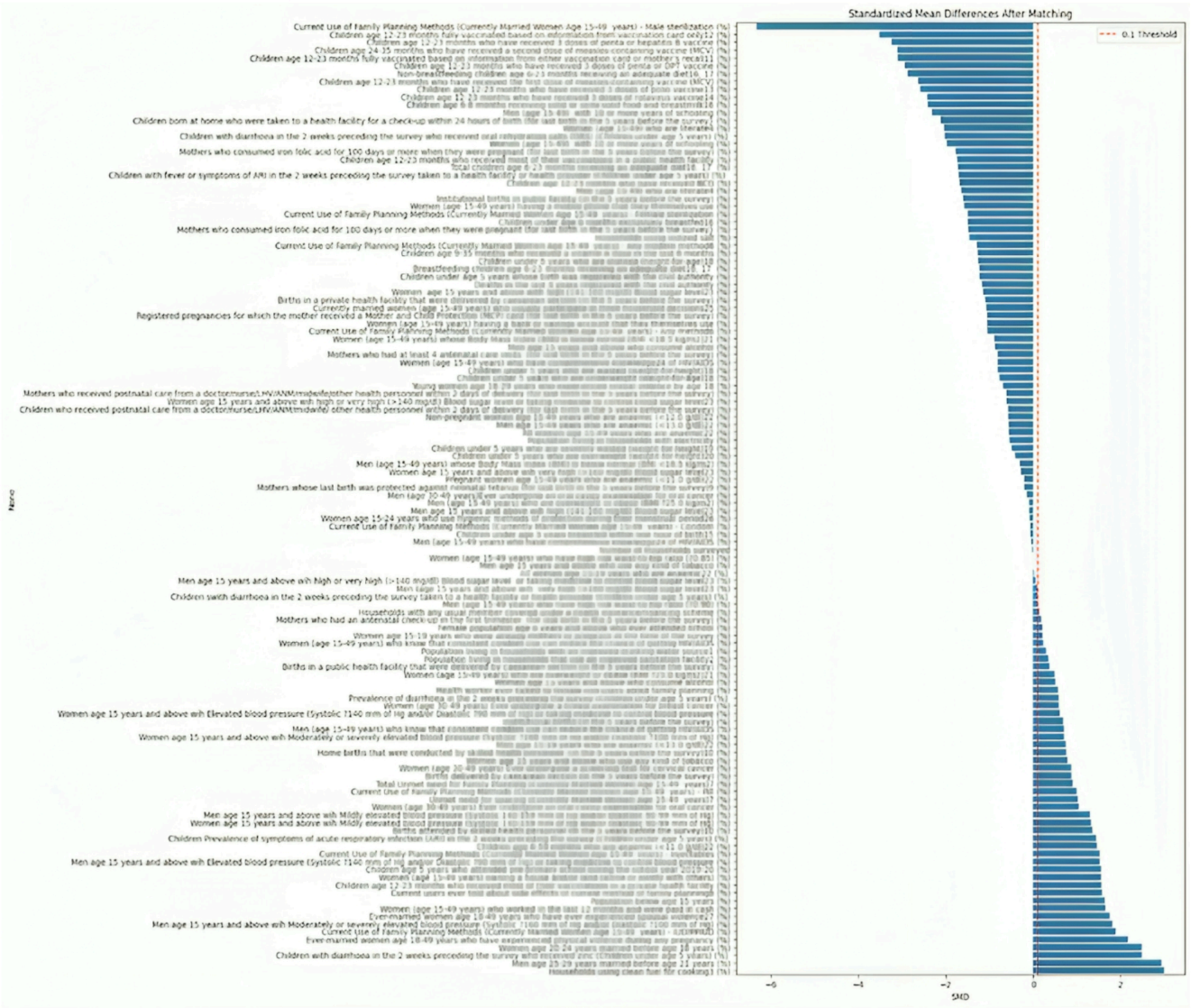


Figure 6

Covariate Balance Before and After Propensity Score Matching

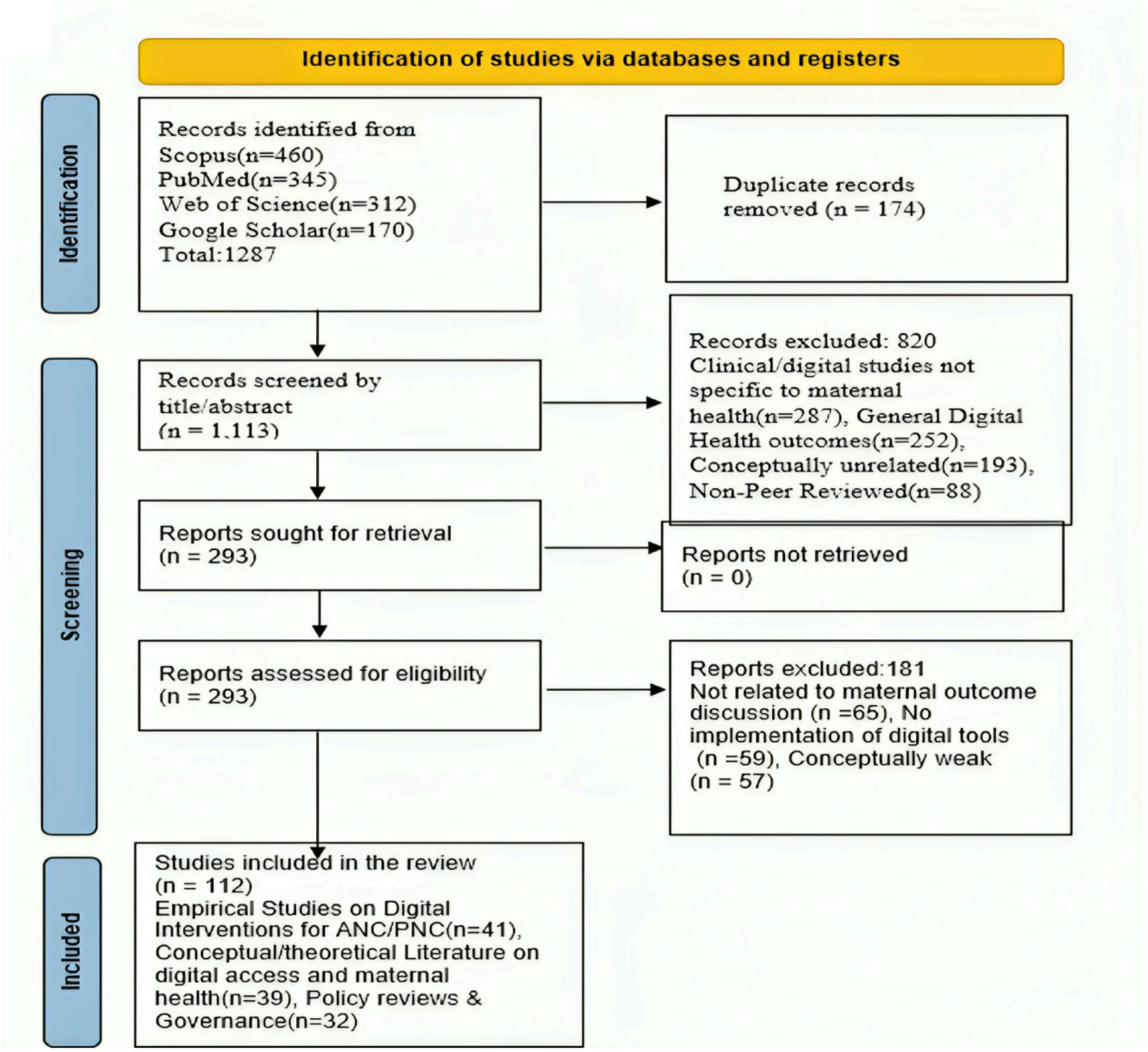


Figure 7

The PRISMA flow diagram depicts the entire screening process.

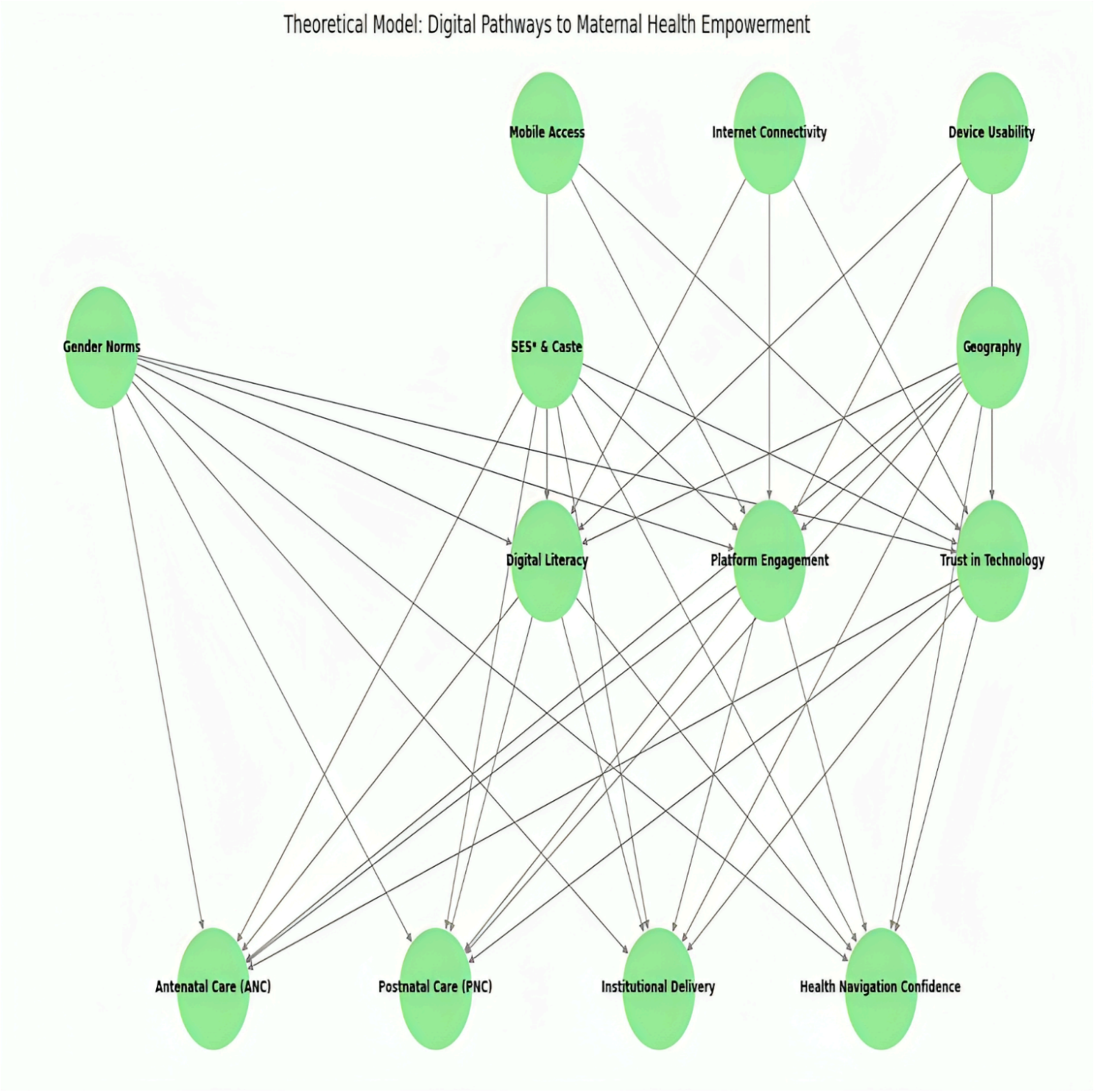


Figure 8

Digital Pathways to Maternal Health Empowerment: A Theoretical Framework

(This framework conceptualizes how digital access translates into maternal health outcomes through layered processes involving infrastructure, digital literacy, and structural moderators such as gender, caste, and geography. It centres maternal digital agency as the enabling mechanism linking access to empowerment.)

***SES-Socioeconomic Status**

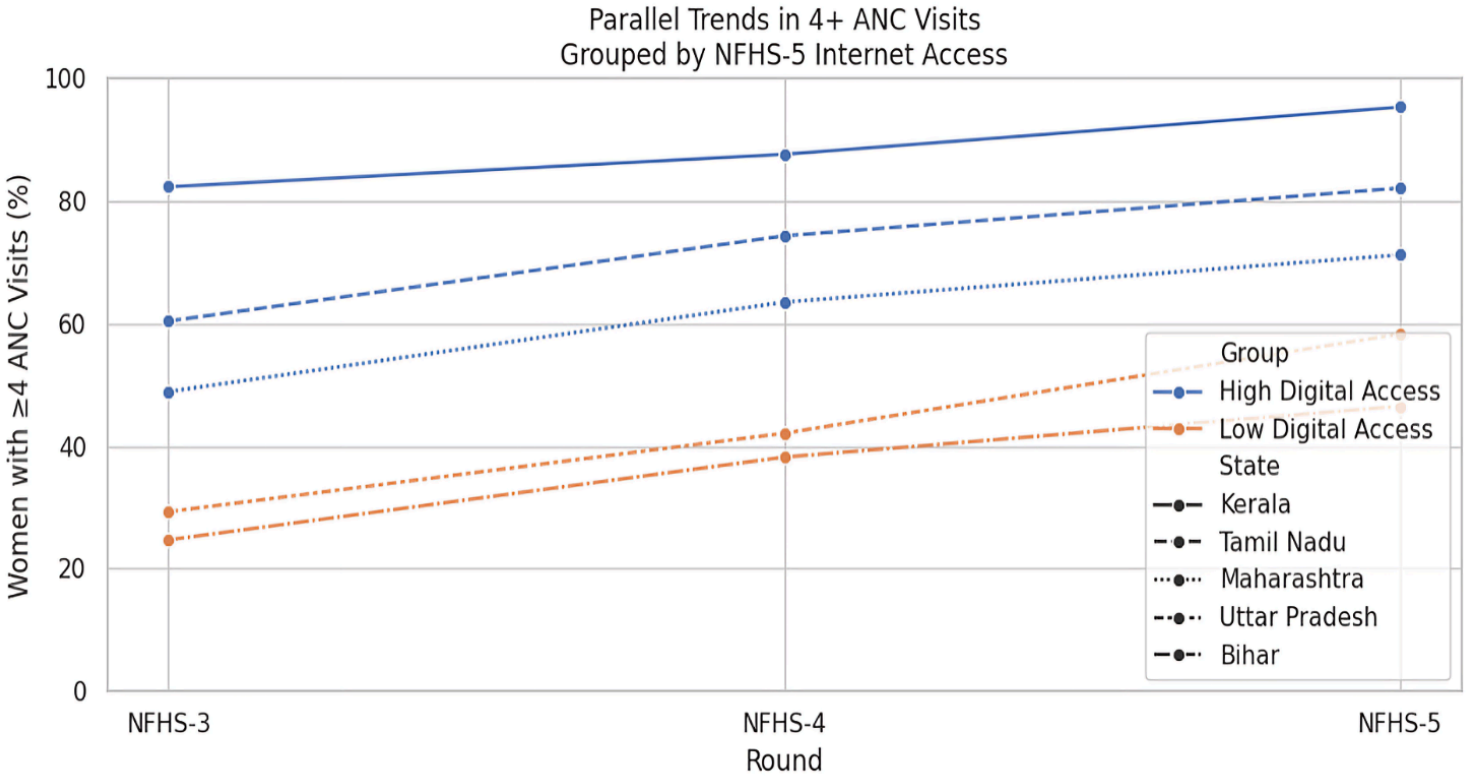


Figure 9

Parallel Trends in 4+ ANC Visits Grouped by Digital Access

(This figure plots ANC4 coverage across NFHS rounds by state-level digital access. It shows that pre-treatment trajectories were aligned, while post-2015 expansions in digital infrastructure led to faster gains in low-access states, affirming the DiD assumption of parallel trends.)

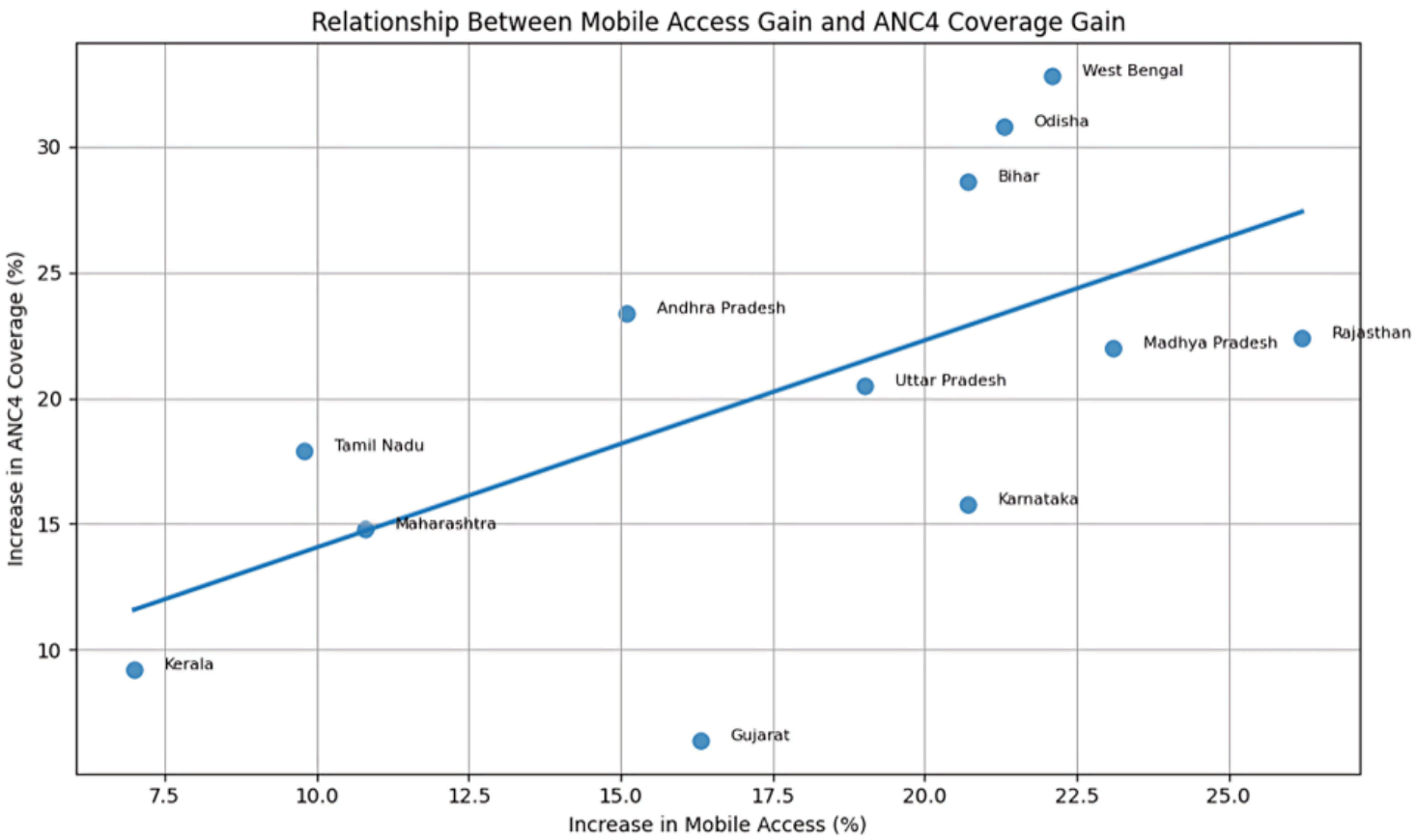


Figure 10

Association Between Change in Mobile Phone Access and ANC4 Coverage Across States (NFHS-4 to NFHS-5)

(Regression Line:

- *The blue line is a line of best fit showing the trend across all states.*
- *It has a positive slope, suggesting a positive correlation — as mobile access increases, ANC4 coverage also tends to increase.)*