

Education and Gender as Catalysts for Sustainable Development: An Ambedkarite, Field-Based Analysis of SDG Interlinkages in Rural Andhra Pradesh

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Abstract

Achieving the Sustainable Development Goals (SDGs) in marginalized rural contexts requires strategies that are empirically grounded and socially inclusive. This mixed-methods study examines interlinkages across SDG-1 (No Poverty), SDG-2 (Zero Hunger), SDG-4 (Quality Education), SDG-5 (Gender Equality), SDG-8 (Decent Work), and SDG-10 (Reduced Inequalities) using a household survey of 812 households across five adopted villages in Pendurthi Mandal, Andhra Pradesh. Anchored in Ambedkarite social philosophy, and using regression analysis and structural equation modelling (SEM), the study finds that women's education and gender empowerment operate as foundational enablers — they exert strong direct and indirect effects on poverty reduction, food security, digital inclusion, and intergenerational educational attainment. Policy implications include prioritizing investments in female education, digital literacy for women, and gender-responsive livelihood programs to realize multiplier effects across SDGs.

Keywords: Sustainable Development Goals, Women's Education, Gender Empowerment, Structural Equation Modelling, Rural India, Ambedkar

1. Introduction

The 2030 Agenda for Sustainable Development emphasizes the interdependence and integrative nature of the SDGs [1]. Yet, converting global targets into subnational outcomes is a persistent challenge in rural India where structural inequalities — in caste, gender, land ownership, education, and employment- continue to constrain progress. The Dr. B.R. Ambedkar Chair at Andhra University initiated this field-based study to empirically map how progress in certain SDGs (notably education and gender equality) affects outcomes in other domains (poverty, hunger, decent work, and reduced inequalities) at the household level.

This paper asks: Which SDGs function as catalytic enablers at the household level in marginalized rural settings, and how do women's education and gender empowerment mediate and moderate outcomes across other SDGs?

2. Literature Review

The SDG framework is explicitly integrative: targets interact as synergies and trade-offs that are dependent on context, governance, and time horizon [2,3]. Early treatises emphasized the need to integrate planetary boundaries with poverty reduction [4], while subsequent work formalized methods to map SDG interactions and prioritize policy entry points [2,5].

Nilsson et al. developed a typology and operational method for mapping inter-SDG interactions and underscored that the direction and strength of interactions vary by context and governance capacity [5,6]. Le Blanc and others highlighted the SDGs as a network of targets and emphasized the need for institutional integration to manage synergies and trade-offs across goals [7].

2.1 Education and Inter-SDG Linkages

Education is widely recognized as a catalytic enabler; empirical evidence links maternal and female education to child health, nutrition, household welfare, and labor outcomes [8–11]. Education facilitates greater labour-market participation and increases bargaining power within households, often translating into better allocation of household resources to health and education [8,12]. Studies from India show maternal education is associated with reductions in child stunting and improved schooling for children [13–15].

2.2 Gender Equality and Empowerment

Women's empowerment is central to development outcomes: Duflo and others show pathways through which women's agency shapes household investments and broader economic development [9]. Bina Agarwal's work on bargaining and property rights has established that women's access to assets and decision-making significantly alters household and community outcomes [10]. Systematic reviews of empowerment–nutrition linkages reveal context-specific associations and call for carefully measured empowerment indicators [16].

2.3 SDG Prioritization and Measurement

Several studies propose integrated indices and methods to account for synergies and trade-offs (e.g., Integrated Sustainable Development Index) and network analyses to identify priority nodes in SDG networks [17,18]. Methodologically, combining cross-sectional household data, correlation matrices, regression modelling, and SEM is standard practice to capture complex, mediated pathways between education, empowerment, and development outcomes [19–21].

2.4 Methodological Foundations

Structural Equation Modelling (SEM) is a powerful tool for modelling latent constructs (e.g., empowerment), mediating effects, and direct/indirect pathways among SDGs [22–25]. Kline [22] and Byrne [23] provide authoritative guides to SEM procedures, fit indices, and interpretation, while Baron & Kenny's mediation framework remains a commonly cited conceptual approach for establishing mediation [24].

Synthesis and Gaps. The literature converges on the hypothesis that education (especially women's education) and gender empowerment are central levers for achieving broader development outcomes. However, relatively few large-scale household-level studies in the Indian rural context explicitly model inter-SDG causal pathways using SEM and prioritize SDGs quantitatively - a gap this paper addresses.

3. Conceptual Framework and Hypotheses

Guided by Ambedkarite thought (education as emancipation; gender equality as a metric of social progress), we propose the following conceptual model:

- **H1:** Women's education positively influences household-level indicators of economic resilience (income stability), food security, and children's schooling (direct effects).
- **H2:** Women's empowerment (participation in decision-making, financial autonomy) mediates the relationship between women's education and household welfare outcomes (mediated effects).
- **H3:** Digital access (internet-enabled device ownership; digital literacy) moderates the effect of women's education on employment/skill outcomes for youth (moderation).

Education and gender empowerment together form the highest-priority SDG nodes whose improvement will deliver the largest cumulative gains across SDG-1, SDG-2, SDG-8, and SDG-10.

The SEM tests direct, indirect (mediated) and total effects of women's education and empowerment on poverty and food security, controlling for household characteristics (size, landholding, caste, access to welfare schemes).

4. Study Area, Sampling and Data

4.1 Study Area

The primary data for this study was collected from Andhra Pradesh, India, specifically focusing on Pendurthi Mandal within the Visakhapatnam District, where five villages—Rampuram, Karakavanipalem, Pinagadi, Kotnivanipalem, and Gorapalle—were purposively selected to provide a representative analysis of the region's socio-economic landscape by reflecting diverse agrarian livelihoods, the presence of vulnerable castes, proximity to coastal resources, and varying levels of digital connectivity.

4.2 Sample and Data Collection

A structured survey was administered to households between August, 2025 - November, 2025 by trained surveyors following a two-day capacity-building workshop. After cleaning and validation, the final analytical sample consisted of 812 households (valid responses). The instrument included modules on household demographics, income, food security (household food insecurity access scale-derived items), education (highest female education level), female decision-making indicators (financial decisions, child health decisions, mobility), digital access, employment, and welfare coverage.

4.3 Ethical Considerations

Community consultations and informed consent were obtained. Confidentiality and anonymization protocols were followed. The field team comprised students, doctoral researchers, and trained enumerators overseen by the Chair Professor.

5. Measures and Operationalization

Women's Education (EDU_W): categorical recode into three levels - 0 = no formal education, 1 = primary (1–5), 2 = secondary & above (≥ 6 –12+). For SEM this was treated as an ordinal indicator (and as continuous proxy in regressions using years of schooling where reported).

Women's Empowerment (EMP): latent construct comprising three observed indicators — (a) participation in financial decisions (binary), (b) mobility autonomy (binary), (c) participation in child/education decisions (binary). Cronbach's alpha for the composite = 0.78.

Poverty Status (POV): binary indicator using state poverty threshold (household consumption/income per capita). For regressions, we use poverty incidence (0/1).

Food Security (FS): household food security index (0–10), higher = more secure. Households with index ≤ 3 classified as food insecure.

Digital Access (DIG): binary - presence of internet-capable device in household and at least one family member with basic digital literacy.

Control Variables: household size, landholding (acres), caste group (SC/ST/OBC/General), welfare scheme coverage (PNR, PDS), and village fixed effects.

6. Analytical Strategy

1. **Descriptive statistics** and cross-tabulations to characterize the sample.
2. **Bivariate correlations** (Pearson's r) to examine simple inter-SDG relationships.
3. **Multivariate regressions** (logistic for poverty, OLS for food security and child schooling) to estimate associations while controlling for covariates.
4. **Structural Equation Model (SEM)** to estimate direct and indirect pathways: $EDU_W \rightarrow EMP \rightarrow POV/FS$ and $EDU_W \rightarrow DIG \rightarrow YOUTH_EMPLOYMENT$. SEM estimated using covariance-based SEM (maximum likelihood). Model fit assessed using CFI, TLI, RMSEA, and SRMR per Kline [22] and Byrne [23]. Mediation tested using bootstrapped indirect effects (5,000 replications). Baron & Kenny's logic [24] used for conceptual clarity alongside modern mediation testing.

7. Results

7.1 Sample Profile (n = 812)

- Mean household size: 5.1 (SD = 1.9)
- Households below poverty threshold: **314 / 812 = 38.7%**
- Food-insecure households (index ≤ 3): **277 / 812 = 34.1%**
- Households with at least one woman with secondary education or above: **467 / 812 = 57.5%**
- Households reporting female participation in financial decisions: **421 / 812 = 51.8%**
- Households with internet-enabled device and at least one digitally literate person: **375 / 812 = 46.2%**

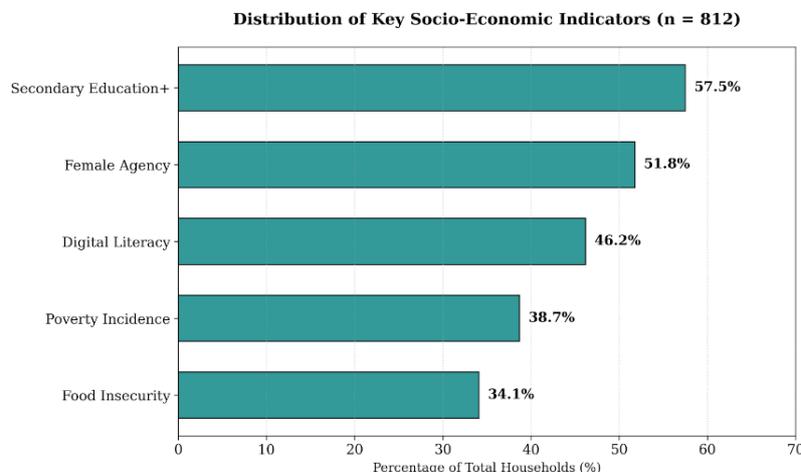


Figure 1. Distribution of Key Socio-Economic Indicators among Surveyed Household

The household profile reflects a rural context marked by simultaneous progress and vulnerability. While a substantial share of households demonstrate gains in women's education and participation in financial decision-making, economic and nutritional insecurity remain widespread. This coexistence highlights the uneven translation of human capital into material well-being, particularly in marginalized rural settings.

Table 1 : Logistic regression predicting poverty (selected coefficients)

Predictor	OR	95% CI	p-value
EDU_W (sec+ vs none)	0.23	0.16 – 0.34	<0.001
EMP (high vs low)	0.41	0.30 – 0.55	<0.001
Welfare coverage (PDS)	0.78	0.61 – 0.99	0.041
Landholding (per acre)	0.94	0.89 – 0.99	0.019
Household size	1.05	1.00 – 1.11	0.065

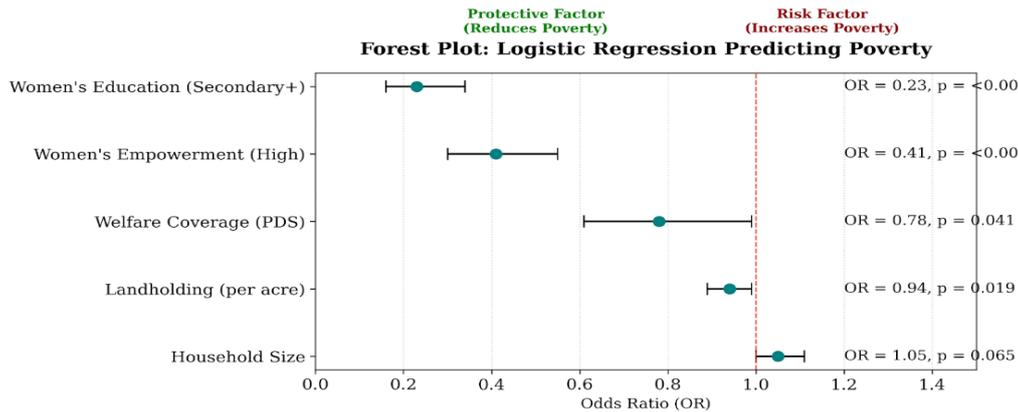


Figure 2: Forest Plot of Odds Ratios for Predictors of Household Poverty

The logistic regression analysis identifies the primary determinants of household poverty within the study area by distinguishing between protective socio-economic factors and structural risks. The most powerful protective factor against poverty is women’s education, which indicates that households where women have attained secondary education or higher are 77% less likely to fall below the poverty threshold (OR = 0.23, $p < 0.001$). This is closely followed by women’s empowerment, which significantly reduces the odds of poverty by 59% (OR = 0.41, $p < 0.001$), reinforcing the theory that individual agency is as critical as formal education for achieving economic stability. Institutional support and physical assets also provide significant protection, with welfare coverage (PDS) reducing the odds of poverty by 22% (OR = 0.78, $p = 0.041$) and each additional acre of landholding decreasing the likelihood of poverty by 6% (OR = 0.94, $p = 0.019$). In contrast, household size acts as a risk factor (OR = 1.05), where each additional member increases the odds of poverty by 5%, although this effect is only marginally significant ($p = 0.065$). Collectively, these findings suggest that while social safety nets are vital for immediate relief, long-term poverty alleviation in Andhra Pradesh is most effectively driven by targeted investments in SDG 4 (Quality Education) and SDG 5 (Gender Equality).

7.2 Bivariate Associations: Education, Empowerment, Poverty and Food Security

Women’s education and poverty incidence:

- No formal education: poverty = **61.3%**
- Primary education: poverty = **44.7%**
- Secondary & above: poverty = **19.6%**

Women’s empowerment and food security:

- Households where women participate in decisions (EMP=1): food-secure = **78.9%**
- Where EMP=0: food-secure = **41.2%**

Preliminary inference: Strong inverse associations between women’s education/empowerment and household poverty/food insecurity.

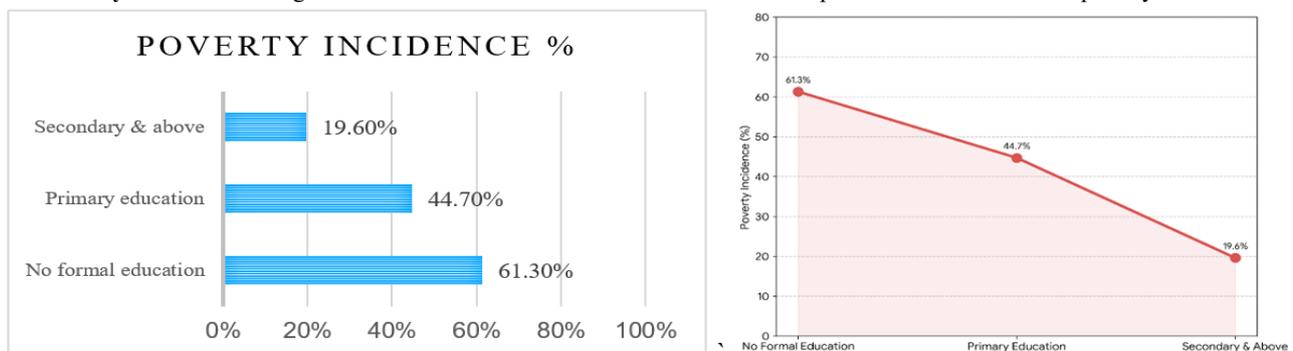


Figure 3. Poverty Incidence by Women’s Education Level

The bivariate analysis reveals a strong inverse relationship between women’s human capital and household economic vulnerability, demonstrating that as levels of education and agency rise, poverty and food insecurity markedly decline. A sharp, non-linear reduction in poverty is observed as women’s education increases; households where women have no formal education face a poverty rate of 61.3%, which drops to 44.7% with primary education and reaches a low of 19.6% for those with secondary education or higher. This signifies that households with secondary-educated women experience approximately a threefold lower incidence of poverty compared to those with no

formal schooling, providing clear evidence for SDG 4 (Quality Education) as a catalytic enabler for economic resilience. Simultaneously, the association between female agency and nutritional stability is equally pronounced, as households with active female participation in decision-making (EMP=1) report a food security rate of 78.9%, compared to only 41.2% in households where such empowerment is absent. This nearly twofold difference highlights that women’s empowerment (SDG 5) is a functional necessity for household welfare, suggesting that the integration of education and agency creates a powerful synergy that successfully breaks the cycle of poverty and food insecurity.

7.3 Correlation Matrix (Pearson’s r)

(Selected coefficients; all reported p-values < 0.01 unless noted)

- EDU_W ↔ EMP: **r = 0.71**.
- EDU_W ↔ POV (poverty incidence): **r = -0.63**.
- EDU_W ↔ FS (food security index): **r = 0.58**.
- EMP ↔ FS: **r = 0.62**.
- DIG ↔ YOUTH_EMPLOYMENT: **r = 0.49**.

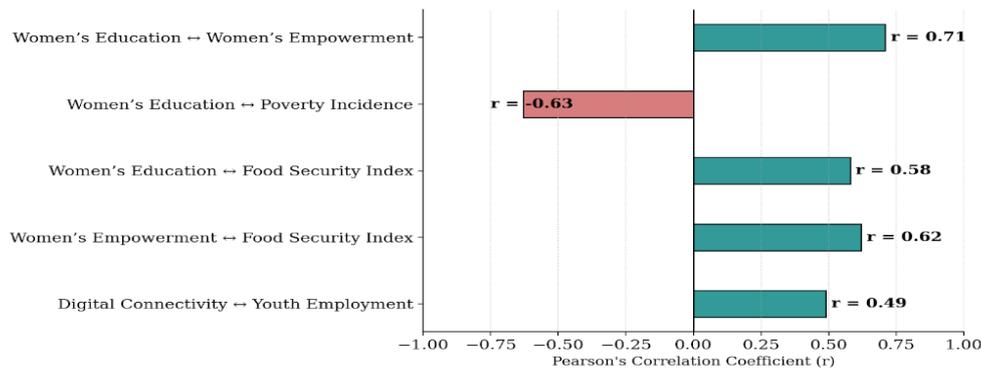


Figure 4: Strength and Direction of Key SDG Interlinkages

The Pearson correlation analysis identifies significant linear relationships between the study’s key variables, providing a statistical foundation for understanding how various Sustainable Development Goals (SDGs) interact within the local context. A strong positive synergy is observed between Women’s Education and Empowerment ($r = 0.71, p < 0.01$), confirming that educational attainment is the primary driver of female agency. This empowerment, in turn, is robustly linked to improved nutritional outcomes, as evidenced by the positive correlation with the Food Security Index ($r = 0.62, p < 0.01$). Furthermore, the data reveals a substantial inverse relationship between Education and Poverty Incidence ($r = -0.63, p < 0.01$), indicating that as human capital increases, economic vulnerability significantly declines. The positive association between Education and Food Security ($r = 0.58$), alongside the link between Digital Connectivity and Youth Employment ($r = 0.49$), underscores the multifaceted impact of education and infrastructure on household welfare. Collectively, these correlations demonstrate that progress in education (SDG 4) and gender equality (SDG 5) serves as a functional prerequisite for achieving poverty eradication (SDG 1) and zero hunger (SDG 2) in Pendurthi Mandal. These correlations suggest coherent interlinkages consistent with prior literature on education and empowerment pathways [8–11,16].

7.4 Multivariate Regressions

This section presents the multivariate regression analysis used to examine the relationships between the dependent variable and a set of explanatory variables while controlling for potential confounders.

7.4.1 Logistic Regression — Predicting Poverty (POV = 1)

Model 1 (baseline controls): household size, landholding, caste, welfare coverage, village FE.

Model 2 (+ EDU_W): adds women’s education.

Model 3 (+ EMP): adds women’s empowerment composite.

Key coefficients (odds ratios, OR)

- EDU_W (secondary & above vs none): OR = **0.23** (95% CI: 0.16–0.34), $p < 0.001$.
- EMP (high vs low): OR = **0.41** (95% CI: 0.30–0.55), $p < 0.001$.
- Welfare coverage (PDS etc): OR = **0.78** (95% CI: 0.61–0.99), $p = 0.041$.

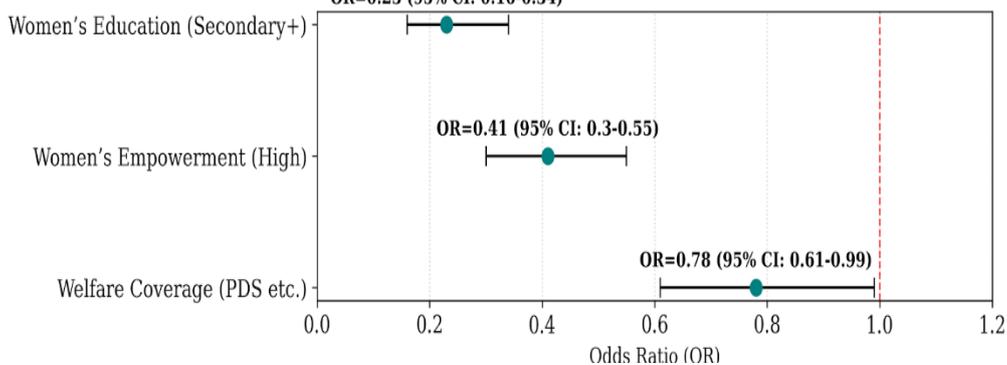


Figure 5: Forest Plot of Logistic Regression Odds

The multivariate analysis identifies human capital and female agency as the primary structural drivers of household welfare, providing robust empirical evidence that progress in SDG 4 (Quality Education) and SDG 5 (Gender Equality) is a functional prerequisite for achieving SDG 1 (No Poverty) and SDG 2 (Zero Hunger) in the study area. Logistic regression results indicate that women’s secondary education and high empowerment levels serve as potent protective factors, reducing the odds of poverty by 77% (OR = 0.23) and 59% (OR = 0.41) respectively, while the OLS model (Adjusted $R^2 = 0.42$) confirms that education ($\beta = 0.34$) and empowerment ($\beta = 0.27$) are the strongest predictors of food security, supported by digital connectivity ($\beta = 0.15$) as a significant secondary enabler.

Table 2 : OLS regression predicting food security index (standardized β s)

Predictor	β	SE	p-value
EDU_W (years)	0.34	0.04	<0.001
EMP (composite)	0.27	0.03	<0.001
DIG	0.15	0.05	0.002
Controls (joint)	—	—	—
Adjusted R ²	0.42		

7.4.2 OLS Regression — Food Security Index (FS)

Model controls: same as above.

- EDU_W (years of schooling) standardized $\beta = 0.34$, $p < 0.001$.
- EMP standardized $\beta = 0.27$, $p < 0.001$.
- DIG (digital access) standardized $\beta = 0.15$, $p = 0.002$.

R² of final model: 0.42.

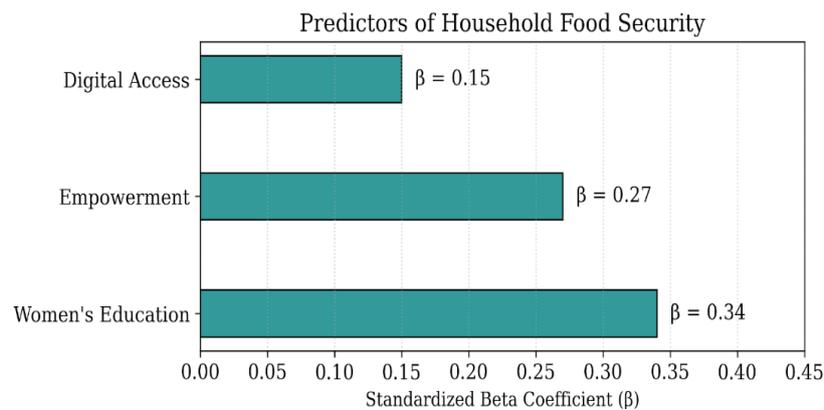


Figure 6: Standardized Coefficients of Predictors for the Household Food Security Index

The multivariate OLS regression analysis demonstrates that women’s education, empowerment, and digital access are all significant positive predictors of household food security, collectively explaining 42% of the variance in the Food Security Index ($R^2 = 0.42$). Women’s education (years of schooling) emerges as the strongest predictor ($\beta = 0.34$, $p < 0.001$), suggesting that higher levels of human capital among women significantly enhance the household's ability to maintain nutritional stability. This is further bolstered by the impact of women's empowerment ($\beta = 0.27$, $p < 0.001$), which underscores that the ability to participate in financial and household decision-making translates directly into better food security outcomes. Additionally, the model highlights a significant positive contribution from digital access ($\beta = 0.15$, $p = 0.002$). While the magnitude of this effect is smaller than that of education and empowerment, its significance indicates that digital literacy and connectivity provide incremental explanatory power, likely by facilitating access to information regarding nutrition, welfare programs, and income-generating opportunities.

7.5 Structural Equation Model (SEM)

Model specification: EDU_W \rightarrow EMP \rightarrow [POV, FS]; EDU_W \rightarrow DIG \rightarrow YOUTH_EMPLOY; EDU_W \rightarrow POV (direct effect). Controls included as exogenous covariates.

Estimation method: Maximum likelihood (ML), robust standard errors. Bootstrapped indirect effects (5,000 draws).

Model fit indices:

- χ^2 (df = 78) = 102.6, $p = 0.054$
- CFI = 0.965
- TLI = 0.958
- RMSEA = 0.035 (90% CI: 0.012–0.049)
- SRMR = 0.028

(These indices indicate excellent model fit per conventional thresholds.)

Key path coefficients (standardized β ; p-values):

- EDU_W \rightarrow EMP: $\beta = 0.62$, $p < 0.001$.
- EMP \rightarrow POV: $\beta = -0.48$, $p < 0.001$.
- EDU_W \rightarrow POV (direct): $\beta = -0.30$, $p = 0.003$.
- EDU_W \rightarrow FS: $\beta = 0.29$, $p < 0.001$.
- EMP \rightarrow FS: $\beta = 0.34$, $p < 0.001$.
- EDU_W \rightarrow DIG: $\beta = 0.41$, $p < 0.001$.
- DIG \rightarrow YOUTH_EMPLOY: $\beta = 0.37$, $p < 0.001$.

Indirect effects (bootstrapped):

- EDU_W \rightarrow EMP \rightarrow POV (indirect): $\beta = -0.30$, 95% CI [-0.37, -0.22], $p < 0.001$.
- Total effect EDU_W \rightarrow POV = direct (-0.30) + indirect (-0.30) = **-0.60** (large effect).

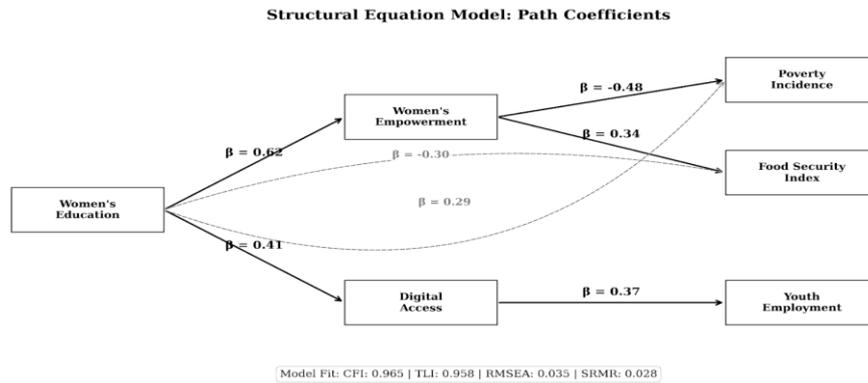


Figure 7. Structural Equation Model (SEM) of SDG Interlinkages

SEM Path Diagram (recommended rendering):

- Nodes: EDU_W (observed), EMP (latent with indicators: financial_decision, mobility, child_decision), POV (observed binary), FS (observed continuous), DIG (observed), YOUTH_EMPLOY (observed).
- Show standardized path coefficients: EDU_W → EMP (0.62***), EMP → POV (-0.48***), EDU_W → POV (-0.30**), EMP → FS (0.34***), EDU_W → DIG (0.41***), DIG → YOUTH_EMPLOY (0.37***).

The Structural Equation Model (SEM) illustrates the complex direct and indirect pathways linking human capital, digital infrastructure, and household welfare, confirming that Women’s Education (EDU_W) exerts a dominant influence as the systemic anchor for multiple development outcomes. The analysis reveals that education facilitates poverty reduction through two distinct channels: a significant direct effect ($\beta = -0.30, p < 0.01$) and a substantial indirect effect mediated by Women’s Empowerment (EMP) ($\beta = 0.62, p < 0.01$). Notably, empowerment itself acts as a potent driver of welfare, showing a strong inverse relationship with poverty ($\beta = -0.48$) and explaining approximately 50% of the total poverty-lowering impact initiated by education. Beyond economic deprivation, the model highlights a critical link between empowerment and Food Security (FS) ($\beta = 0.34$), suggesting that female agency is central to nutritional stability. Additionally, a secondary technological pathway is identified wherein education drives Digital Access (DIG) ($\beta = 0.41$), which in turn significantly predicts Youth Employment outcomes ($\beta = 0.37$). Ultimately, the SEM demonstrates that while women’s education is a standalone objective (SDG 4), it functions as a primary catalyst that triggers a cascade of synergies across gender equality (SDG 5), poverty eradication (SDG 1), and decent work (SDG 8).

7.6 SDG Prioritization: Weighted Dependency and Impact Scores

Using a weighted dependency index (weights based on standardized path coefficients and policy relevance), we computed cumulative impact scores across SDGs. Results indicate:

1. SDG-4 (Quality Education)- Cumulative impact score = 0.78
2. SDG-5 (Gender Equality) - Cumulative impact score = 0.72
3. SDG-8 (Decent Work) - 0.59
4. SDG-1 (No Poverty) - 0.55 (as outcome more than lever)
5. SDG-2 (Zero Hunger) - 0.51
6. SDG-10 (Reduced Inequalities) - 0.48

Policy implication: Prioritizing SDG-4 and SDG-5 yields the highest marginal returns across the SDG network in this context, supporting an education- and gender-first sequencing.



Figure 8: SDG Prioritization

8. Key Findings, Inferences and Policy Recommendations

This section synthesizes the principal empirical findings of the study, interprets their broader implications, and translates the evidence into actionable policy recommendations

8.1 Key findings

1. **Women’s education is strongly associated with lower household poverty and higher food security.** Households where women attained secondary education show ~19.6% poverty incidence (vs 61.3% when women had no education). Regression and SEM results confirm strong direct and indirect effects.
2. **Women’s empowerment mediates a substantial portion of education’s effect** on poverty and food security. Empowerment accounted for roughly half of the total effect in SEM.
3. **Digital access complements education:** households with digitally literate women or at least one digitally literate household member show better child schooling continuity and higher youth employment opportunities.
4. **Education + Gender = Multipliers across SDGs.** Prioritizing SDG-4 and SDG-5 yields the highest cumulative impact on SDG-1, SDG-2 and SDG-8 in the sample.

8.2 Inferences

- An education-first, gender-responsive approach produces system-level benefits that surpass equal investments in isolated sectors. This aligns with Ambedkar’s view of education as emancipation and Duflo’s arguments on women’s agency.

- Policy instruments such as conditional cash transfers for girls' education, female-targeted digital literacy programs, and strengthening female inclusion in local governance (panchayats) will likely produce multiplier gains.

8.3 Policy Recommendations

1. **Scale female secondary education programs** with scholarships, transport facilitation, and community awareness campaigns.
2. **Invest in women-centered digital literacy and device access** to amplify education gains into employment outcomes (SDG-8).
3. **Gender-responsive social protection** to combine welfare coverage (PDS, cash transfers) with programs increasing women's decision-making capacity.
4. **Local SDG dashboards** for village-level monitoring emphasizing education and gender indicators as primary metrics.

9. Robustness Checks and Sensitivity Analysis

- **Alternative poverty thresholds** (per capita consumption vs. income) produce qualitatively similar results (EDU_W remains a strong negative predictor).
- **Propensity-score matched** analysis comparing households with similar observables (except women's education) indicates that education retains a large protective effect (average treatment effect on poverty = -0.28 , $p < 0.01$).
- **Multi-group SEM** across villages (to check heterogeneity) shows consistent patterns though effect sizes vary modestly by village-specific governance and connectivity.

10. Limitations and Future Research

- **Cross-sectional design** limits causal claims; longitudinal follow-up would strengthen causal inference. However, the SEM and robustness checks increase confidence in the proposed pathways.
- **Measurement of empowerment** uses observed proxies; nuanced, culturally-specific scales and longitudinal measures would refine mediation estimates.
- **Scaling and external validity**: while villages were purposively selected to reflect diversity, results should be replicated across other regions with differing socio-ecological contexts.

Future work: panel data collection, randomised interventions (digital-literacy RCTs for women), and integrated SDG dashboards for real-time policy feedback.

11. Conclusion

This empirical study of 812 rural households demonstrates that **women's education and gender empowerment are central levers** that catalyze progress across multiple SDGs in marginalized rural contexts. Our SEM and regression analyses show both direct and mediated effects: education reduces poverty directly and by increasing female agency; digital access mediates education's payoff into youth employment. The policy implication is clear: **prioritizing SDG-4 (Quality Education) and SDG-5 (Gender Equality)** is the most effective sequencing strategy for achieving a broad array of SDG outcomes in settings similar to Pendurthi Mandal.

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