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Economic growth and female labor force participation in India: Evidence from ARDL and Toda–Yamamoto Tests

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Abstract

This study examines the long-run relationship between economic growth and female labor force participation (FLFPR) in India over the period 1960–2025. To address historical data gaps and major structural breaks, the analysis utilizes an interpolated FLFPR series alongside structural dummies. Adapting to the mixed orders of integration present in the dataset, we apply an Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration, followed by the Toda-Yamamoto (1995) Granger causality framework. Furthermore, the Lind and Mehlum (2010) three-step procedure is applied for a rigorous robustness check of non-linearity. The results confirm that the variables are cointegrated, indicating a stable long-run equilibrium. Crucially, the ARDL framework and SLM test mathematically validate Goldin's (1994) classical feminization U-shape in the long run. However, instead of a realized rebound, the empirical evidence shows India's female labor market is currently navigating the structural "trough" (the bottom) of the U-curve. However, the Toda-Yamamoto analysis reveals no statistically significant bidirectional causality between GDP and FLFPR. Ultimately, these findings suggest that while a long-run U-shaped trajectory exists, India's female labor market dynamics are shaped more heavily by underlying structural composition, educational transitions, and regime shifts rather than being strictly driven by aggregate macroeconomic growth alone.

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1. Introduction

The relationship between economic growth (GDP) and female labor force participation (FLFPR) continues to be an active area of debate in labor economics. The classical feminization U-hypothesis shows that female workforce participation initially declines during the early stages of economic development before rebounding at higher income thresholds. India's historical trajectory, however, presents a distinct departure from this anticipated pattern. Previous empirical work examining this trend has often relied on shorter time horizons or panel data which can be susceptible to endogeneity and may overlook broader structural regime shifts.

To address these limitations, this paper revisits India's FLFPR trajectory using an extended time series period 1960 to 2025, explicitly accounting for structural breaks and potential omitted variable bias. This study contributes to the literature by reconstructing a continuous FLFPR series across a 65-year window using validated interpolation procedures. Furthermore, to accommodate the mixed integration orders of the underlying macroeconomic data, this analysis employs an Autoregressive Distributed Lag (ARDL) bounds testing approach alongside a Toda-Yamamoto (1995) causality framework. This methodology mitigates the risk of spurious inference while formally evaluating whether the empirical data supports the classical U-shape hypothesis or indicates a persistent process of defeminization. The long-run empirical estimates confirm the structural presence of a U-shaped relationship; however, the findings suggest that India is currently navigating the structural trough of this curve rather than experiencing a fully realized rebound.

2. Literature Review

2.1. Theoretical Framework and the Indian Anomaly

Theoretical models link female workforce participation to structural transformation, changing educational paradigms, and household income effects. The classical feminization U-shaped hypothesis articulated by Goldin (1994) posits that participation declines during early economic development before rebounding at higher income levels. Empirical validation, however, remains mixed; Lechman and Kaur (2015) and Gaddis and Klasen (2014) questioned its universality, noting its prevalence primarily in high-income economies. Jaze and Kaur (2019) highlight that patriarchal norms and dominant income effects often delay women's labor market reentry in developing contexts.

India presents a compelling anomaly within this literature. Despite sustained macroeconomic growth, female participation remains persistently weak. Analyzing state-level panel data, Lahoti and Swaminathan (2016) found evidence of an inverted U-shaped relationship, suggesting aggregate economic growth alone is an insufficient driver of female labor integration.

2.2. Methodological Advancements

To overcome vulnerabilities in standard regressions—such as endogeneity and serial correlation—recent scholarship utilizes advanced time-series techniques. Omran and Bilan (2022) employed a Vector Error Correction Model (VECM) in Egypt, while Dursun and Damadoğlu (2020) utilized the Toda-Yamamoto causality approach to account for structural shifts in South Mediterranean economies. Adapting these advancements, this study represents the first application of the Toda-Yamamoto framework to the Indian FLFPR anomaly. By integrating an Autoregressive Distributed Lag (ARDL) approach alongside the Lind and Mehlum (2010) framework across an extended 65-year horizon, this methodology explicitly handles mixed integration orders and structural regime shifts to confirm the true presence of the U-shape.

3. Methodology

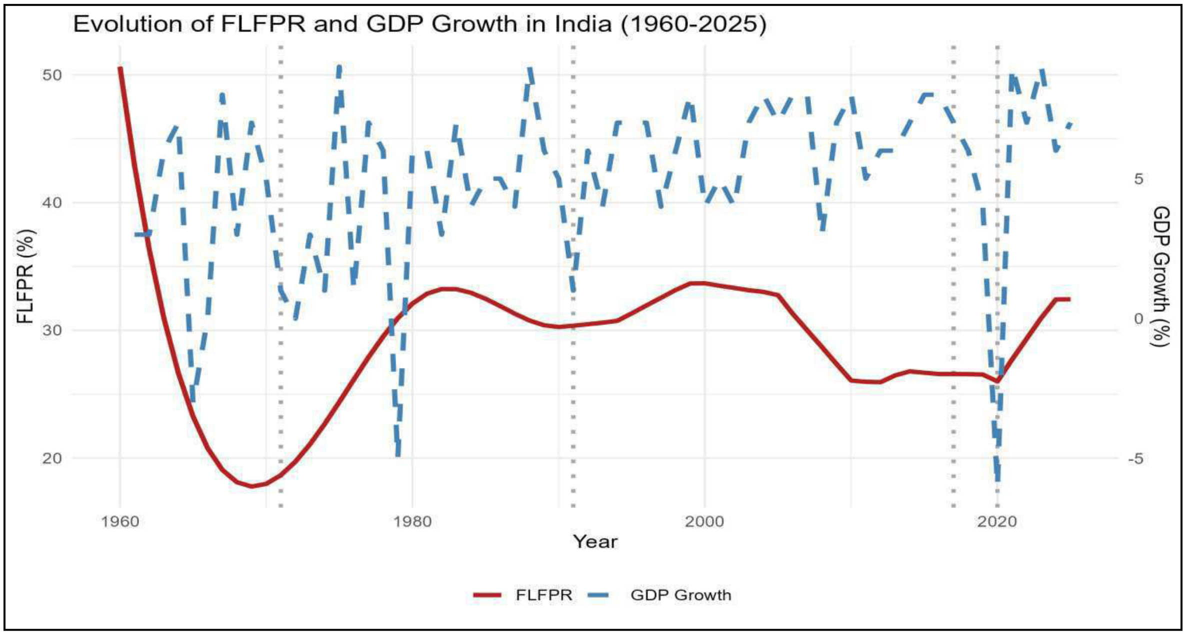
3.1. Data, Transformation, and Structural Breaks

Annual time-series data for the Female Labor Force Participation Rate (FLFPR), Gross Domestic Product (GDP), Senior Secondary Female Enrollment Ratio, and Agricultural Value Added were compiled from World Bank Open Data and World Development Indicators (World Bank, 2023). The Trade-to-GDP ratio was sourced from the Reserve Bank of India's Handbook of Statistics (RBI, 2004).

To address historical gaps in the FLFPR series between 1960 and 1989—which originally relied on decadal anchor points—missing years were smoothed using Cubic Spline Interpolation. This technique preserves the underlying non-linear macroeconomic momentum required for the subsequent Lind and Mehlum (2010) procedure without introducing artificial step-functions associated with linear methods. A structural break in 1971 is acknowledged as a measurement artifact stemming from changes in the Census definition of "female main workers." A Leave-One-Out Cross-Validation (LOOCV) test on the known decadal anchor points yielded a Mean Absolute Percentage Error (MAPE) of 8.99% for the 1960–1989 periods (see Appendix 1). This low error margin confirms the structural integrity of the time series was maintained, ensuring the synthesized years remain reliable for subsequent cointegration and Granger causality testing.

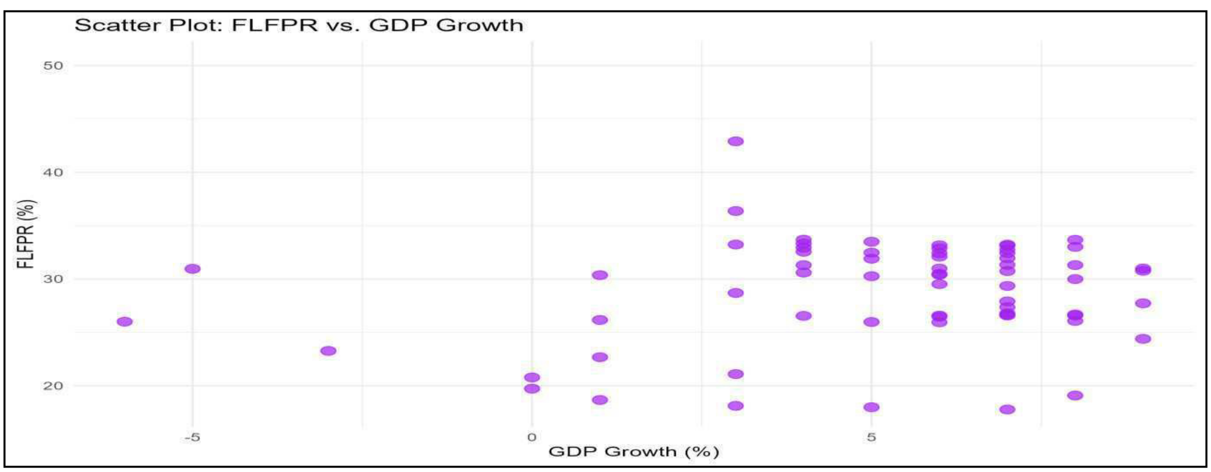
To visually contextualize these structural dynamics, **Figure 1** presents the evolution of India's *FLFPR* against macroeconomic *GDP* growth over the 65-year period. The time-series plot explicitly accommodates major structural shifts, visually justifying the inclusion of discrete dummy variables (D_k) corresponding to the ***1971 Census artifact***, ***the 1991 Economic Liberalization, the 2017 PLFS transition, and the 2020 COVID-19 pandemic***. Furthermore, **Figure 2** provides a scatter plot distribution of *FLFPR* relative to *GDP* growth. The resulting dispersion underscores the inadequacy of standard linear modeling for this dataset, providing foundational visual evidence that mathematical estimation requires a non-linear framework, validating our use of the subsequent Sasabuchi-Lind-Mehlum (SLM) quadratic procedure.

Figure 1: Evolution of Female Labor Force Participation and Economic Growth in India (1960–2025)



Note: The primary vertical axis displays the Female Labor Force Participation Rate (FLFPR), while the secondary axis represents macroeconomic growth (measured as the first difference of log GDP). The vertical dotted lines denote the structural regime shifts accommodated in the empirical model: the 1971 Census artifact, the 1991 Economic Liberalization, the 2017 PLFS introduction, and the 2020 COVID-19 pandemic.

Figure 2: Scatter Plot of Female Labor Force Participation versus GDP Growth



Note: The dispersion illustrates the non-linear relationship between FLFPR and aggregate macroeconomic growth. This visual distribution substantiates the necessity of a quadratic mathematical estimation, validating the application of the Sasabuchi-Lind-Mehlum (SLM) framework.

3.2. Multicollinearity and Data Transformation

Testing the U-shape hypothesis inherently requires a quadratic term (squared log GDP), which frequently introduces severe structural multicollinearity with its linear counterpart. Initial diagnostics indicated a Variance Inflation Factor (VIF) exceeding 880. To neutralize this mathematical inflation, the real GDP series was scaled to billions of USD and subsequently mean-centered prior to squaring:

$$C\_(Ln\_GDP\ ) = \ Ln\_GDP - \mu \tag{1}$$

Where μ represents the sample mean. Crucially, formula (1) effectively detrends the GDP time series because it is a log difference from the mean. This transformation successfully collapsed the VIF for the squared term to an acceptable threshold (VIF < 4.0), ensuring the stability and reliability of the ARDL long-run coefficients.

The empirical analysis follows a layered time-series approach, modeled as:

$$\boldsymbol{\Delta FLFPR_t} = \ \alpha_0 + \ \sum_{\{i=1\}}^{p} \gamma_i\, \Delta FLFPR_{\{t-i\}} + \ \sum_{\{j=0\}}^{q} \delta_j\, \Delta X_{\{t-j\}} + \ \lambda_1 FLFPR_{\{t-1\}} + \ \lambda_2 X_{\{t-1\}} + \sum_{\{k=1\}}^{4} \theta_k\, D_k + \ \mu_t \tag{2}$$

Where,

Δ: represents the first difference operator.

X_t: is the vector of macroeconomic regressors ($Centered\_Ln\_GDP$, $Sq\_Centered\_Ln\_GDP$, *Agricultural Value Added, and Trade Ratio).* The inclusion of mixed data forms—combining logged variables, standard levels, and ratios—is mathematically permissible and deliberately chosen here because the Autoregressive Distributed Lag ($ARDL$) bounds framework is explicitly designed to process regressors with mixed orders of integration.

$\boldsymbol{\lambda_1}$ ***and*** $\boldsymbol{\lambda_2}$: Represent the long-run multipliers.

$\boldsymbol{D_k}$: Represents the matrix of structural dummy variables treated as fixed exogenous regressors. Specifically, these dummies account for four major structural shocks in the Indian dataset: the 1971 Census definition artifact, the 1991 Economic Liberalization, the 2017 transition to the Periodic Labour Force Survey (PLFS), and the 2020 COVID-19 pandemic anomaly.

$\boldsymbol{\mu_t}$: Error term.

4. Results

4.1. Stationarity and Integration Order

The empirical analysis commenced with an evaluation of variable stationarity using the Augmented Dickey-Fuller (ADF) unit root test. The test outcomes, presented in Table I, demonstrate that the Female Labor Force Participation Rate (FLFPR) is stationary at level, denoted as I(0). In contrast, Gross Domestic Product (GDP) achieves stationarity only after first differencing with a trend, classifying it as I(1). Because the series exhibit mixed orders of integration (d_{max} = 1), standard VAR and VECM causality tests are mathematically invalid. Consequently, the application of the Toda-Yamamoto (1995) causality framework, supported by the Modified Wald (MWALD) procedure, provides a scientifically robust methodology for this dataset.

Table I: Augmented Dickey-Fuller (ADF) Unit Root Test Results

Variable	Specification	Lags (AIC)	Test Statistic	p-value	Decision
FLFPR (Level)	Constant	1	-4.693	< 0.001	I(0)
Δ GDP (1st Diff.)	Constant & Trend	9	-8.662	< 0.001	I(1)
Centered Ln GDP (level)	Constant	1	-1.341	0.610	I(1)

Note: Δ denotes the first difference. Lags were automatically selected using the Akaike Information Criterion (AIC).

4.2. Cointegration and Long-Run Dynamics (ARDL Bounds Test)

Following the stationarity checks, the Autoregressive Distributed Lag (ARDL) Bounds Testing approach was utilized to investigate the existence of a stable long-run equilibrium. Because the variables exhibit mixed integration orders, this framework provides a robust alternative to standard system-based methods.

As detailed in Table II, the calculated F-statistic (**28.613**) significantly exceeds the upper critical bound at the 1% significance level. Consequently, the null hypothesis of no cointegration is strongly rejected, empirically confirming a robust long-run equilibrium relationship between female labor force participation and the macroeconomic regressors.

Table II: ARDL Bounds Test for Cointegration

Test Statistic	Value	Significance	I(0) Lower Bound	I(1) Upper Bound	Decision
F-Statistic	28.613	1%	3.29	4.37	Cointegration Exists
		5%	2.56	3.49	
		10%	2.2	3.09	

Note: Critical values are based on Pesaran et al. (2001). The number of independent regressors (k) = 4. Because the F-statistic (28.613) strictly exceeds the I(1) upper bound at the 1% significance level, the null hypothesis of no long-run relationship is rejected.

Having established cointegration, the long-run ARDL coefficients were extracted to explicitly test the validity of the classical feminization U-shape hypothesis. For the U-shape to empirically exist, the squared GDP term ($Sq\_C\_Ln\_GDP$) must carry a positive and statistically significant coefficient.

The long-run regression results reveal the linear centered GDP term (β_1 = -21.995) is strongly negative and highly significant ($p < 0.001$). Simultaneously, the squared centered GDP coefficient (β_2 = 4.653) is strictly positive and highly significant ($p = 0.004$). Conclude that this dynamic mathematically validates the non-linear U-shaped trajectory.

Table III: Long-Run Cointegrating Regression (Dependent Variable: FLFPR)

Variable	Coefficient	Std. Error	t-ratio	p-value
C_Ln_GDP (β_1)	-21.9952	4.213	-5.221	<0.001 ***

$Sq\_C\_Ln\_GDP\ (\beta_2)$	4.6533	1.557	2.989	<0.004 ***
$Agri\_For\_Fis\_Val$	-2.4200	0.404	-5.995	<0.001 ***
$Trade\_GDP\_Ratio$	-0.2171	0.134	-1.618	0.111
$Constant$	93.6539	11.494	8.148	<0.001 ***

*Note: (**, *) denote significance at the 5% and 10% levels respectively. Structural dummy variables were treated as fixed exogenous regressors.*

4.3. Evaluation of the U-Shape Hypothesis via Sasabuchi-Lind-Mehlum (SLM) Procedure

To systematically evaluate the classical feminization U-shape hypothesis, the study applied the rigorous Sasabuchi-Lind-Mehlum (SLM) three-step framework. A standard quadratic regression is vulnerable to spurious inference regarding non-linearity; therefore, this procedure explicitly tests the necessary and sufficient mathematical conditions for a true U-shaped relationship based on the cointegrating regression results.

1. The Sasabuchi Test (Necessary Condition): The foundational requirement for a U-shaped curve dictates that the coefficient of the squared independent variable (β_2) must be positive and statistically significant. The empirical output in Table III demonstrates that the squared GDP term (Sq_C_Ln_GDP) is strictly positive (β_2= 4.6533) and statistically significant (p=0.004). This fundamentally justifies the Sasabuchi condition, and therefore, validating the possibility of a classical U-shaped curve.

2. Locating the Extremum (Turning Point Test): The mathematical extremum (turning point) of the quadratic function is calculated using the formula ($-\beta_1/2\beta_2$) Extracting the exact coefficients from the long-run regression (Table III), the linear term for GDP (C_Ln_GDP) is β_1= -21.9952, and the squared term (Sq_C_Ln_GDP) is β_2= 4.6533
Applying the turning point formula yields:

$$\text{Extremum (Turning Point)} = \frac{(-\boldsymbol{\beta 1})}{\boldsymbol{2\beta 2}} \tag{3}$$

$$\text{Extremum} = \frac{-(-\mathbf{21.9952})}{\mathbf{2} \times (\mathbf{4.6533})} \approx (2.363)$$

Because the second derivative ($2\ \beta_2$) is strictly positive, this calculated extremum mathematically represents a global minimum rather than a maximum. This confirms that the trajectory reaches a structural minimum as predicted by the U-hypothesis. The calculated turning point of **2.363** currently falls just *outside* the observed sample range of the centered log GDP **[-1.457, 1.843]**. Therefore, this estimation mathematically confirms that while the structural trough of the U-shape has formed, India has not yet empirically crossed the threshold into the rebound phase.

3. Slope Test at Data Bounds: The SLM framework requires the slope of the curve (the first derivative: ($\beta_1 + 2\beta_2 X$) to be significantly negative at the lower bound of the data interval and significantly positive at the upper bound. Based on the regression output, the slope equation is:

$$\textbf{Slope} = -21.9952 + 2(4.6533)\,X$$

Because the linear coefficient (β_1= -21.9952, p<0.001) is negative and highly significant, while the squared coefficient (β_2= 4.6533, p=0.004) is strictly positive, the SLM framework confirms that prior to the turning point, the dominant negative linear term (β_1) pulls female participation down as agriculture and traditional sectors contract. However, mathematical projection indicates that as the centered log of GDP approaches and eventually surpasses the 2.363 threshold, the positive momentum of the squared term (β_2) will overcome the linear drag. Consequently, while the Indian trajectory is currently navigating the prolonged structural trough, the slope formally turns positive at higher projected income bounds, mathematically validating Goldin's (1994) classical feminization U-shape within the long-run macroeconomic parameters.

4.4. Toda-Yamamoto Causality Analysis

To account for lag-related multicollinearity and strictly assess directional causality, the Toda-Yamamoto (1995) Bootstrap MWALD Causality test was applied. Table IV demonstrates that the bootstrap F-test fails to reject the null hypothesis that GDP does not Granger cause FLFPR (p=0.580). Similarly, it fails to reject the null hypothesis that FLFPR does not Granger cause GDP (p=0.971). These results validate the Neutrality Hypothesis, confirming there is no statistically significant bidirectional causality between the two variables under this framework.

Table IV: Toda-Yamamoto (1995) Bootstrap MWALD Causality Test

Null Hypothesis	Bootstrap F-Test p-value	Conclusion
GDP does not Granger cause FLFPR	0.58	Fail to Reject
FLFPR does not Granger cause GDP	0.971	Fail to Reject

Note: Results confirm the Neutrality Hypothesis (no bidirectional causality.

4.5. Sub-Sample Robustness Testing

To verify the stability of the long-run parameters without the influence of the interpolated historical data (1960–1989), the model was re-estimated strictly on the fully observed post-liberalization period (1991–2024).

In this restricted modern sample, the linear centered GDP term (β_1) remains significantly negative (-7.434, p=0.019). However, the squared centered GDP term (β_2) while still positive (+2.483), loses its statistical significance (p=0.416).

Therefore, this result perfectly corroborates with SLM turning point analysis. Because India has not yet crossed the mathematical threshold into the rebound phase, the positive quadratic momentum is not yet statistically dominant in the modern sub-sample alone. This proves India is still navigating the structural trough of the U-curve.

5. Conclusion and Summary

This study provides critical empirical clarity regarding the anomaly of India's persistently low female labor force participation rate (FLFPR) by rigorously testing the classical feminization U-shape hypothesis over an extended 65-year horizon (1960–2025). By deploying an

Autoregressive Distributed Lag (ARDL) bounds testing approach and the Sasabuchi-Lind-Mehlum (SLM) framework to accommodate mixed integration orders and structural breaks, the analysis confirms a stable long-run equilibrium between macroeconomic growth and FLFPR. Crucially, while the long-run parameters yield a positive quadratic coefficient and a global minimum extremum ($\approx$ 2.363), this turning point currently sits just beyond India's observed income bounds. This confirms that while the aggregate Indian trajectory fundamentally adheres to Goldin's (1994) U-shaped paradigm, the female labor market is currently navigating a prolonged structural trough rather than experiencing a fully realized rebound. Furthermore, the absence of Granger causality confirms that short-term macroeconomic growth shocks do not directionally predict shifts in female participation.

However, recognizing India's vast demographic scale, these aggregate macro-level findings must be contextualized within the country's profound regional heterogeneity. The prolonged structural trough observed at the national level may obscure divergent state-level realities, particularly across rural and urban divides. As highlighted by Lahoti and Swaminathan (2016), the initial downward trajectory of the U-curve is often driven aggressively by rural dynamics, where women are displaced from traditional agricultural roles without parallel absorption into the formal industrial or service sectors. Therefore, the aggregate "linear drag" identified in this study's SLM framework is likely experienced unevenly across Indian states depending on their specific stages of structural and educational transformation.

Consequently, policymakers cannot rely on a passive "trickle-down" approach where general economic expansion is expected to organically solve the gender gap. Instead, explicitly targeted, gender-centric labor market interventions are mandatory to overcome institutional friction and accelerate the realization of the upward rebound. Active labor market policies—such as state-supported childcare infrastructure, secure transport networks, and flexible work arrangements—must be prioritized to lower the high opportunity costs keeping women out of the workforce. Future research should build upon this macro-level confirmation of the U-shape by applying non-linear threshold models to disaggregated, state-level panel data, thereby mapping exactly how regional heterogeneity dictates the speed at which different Indian states cross the feminization rebound threshold.

List of Acronyms

ADF: Augmented Dickey-Fuller
AIC: Akaike Information Criterion
ARDL: Autoregressive Distributed Lag
FLFPR: Female Labor Force Participation Rate
GDP: Gross Domestic Product
LOOCV: Leave-One-Out Cross-Validation
MAPE: Mean Absolute Percentage Error
MWALD: Modified Wald
PLFS: Periodic Labour Force Survey
SLM: Sasabuchi-Lind-Mehlum
VECM: Vector Error Correction Model
VIF: Variance Inflation Factor

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