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ABOUT THE COLLEGE

Hansraj College is one of the largest constituent colleges of the University of Delhi. The college was founded by the D.A.V. College Managing Committee on 26th July, 1948 in the sacred memories of Maharshi Dayanand Saraswati and Mahatma Hansraj who spent their magnificent lives emphasizing the importance of knowledge. It is one of the leading lights in the D.A.V. family of over 700 institutions.

Hansraj College is a premier institution dedicated to teaching and research. It has highly qualified academicians who impart education in Science, Commerce, and Arts at undergraduate and graduate levels to more than 5000 students. The college has consistently demonstrated outstanding performance in academics, sports, and extracurricular activities.

The college has completed 76 years in the realm of imparting higher education. It has made significant and unparalleled contributions in terms of producing scholars, bureaucrats, intellectuals, and sportsperson serving in different domains not only in our own country but even at international levels.

Hansraj College stands at the cusp between the past and the future today. While it retains inspiring facets of its proud history, with an equally sharp gaze it looks ahead, assimilating the exciting world of new knowledge as it unfolds in front of it, holding the promise of an experience seeped with exhilarating learning and holistic growth for all those who enter its portals.

About the Journal

The *HRC Journal of Economics and Finance* is a **double-blind peer-reviewed academic journal** for students, researchers, and faculty to showcase their research pertaining to the discipline of economics and business. It is an international journal. Our mission is to provide a platform through which scholars can publish their scholarly findings to showcase them with the research community at large. We invite research papers and articles on topics related to the field of economics, business and management for its quarterly journal publication.

Message from the Principal

The launch of the *HRC Journal of Economics and Finance* is a milestone that marks our dedication towards providing a platform to young researchers in the field of economics and finance. It is even more fortuitous that the launch has been manifested in the Platinum jubilee year of the college, the Centenary year of the University of Delhi and the 75th year of India's independence.

The New Education Policy, 2020 has launched a paradigm shift that encourages research both at the faculty and student level. Accordingly there is a growing need to provide credible platforms to present research outputs at all levels. This journal fills a significant gap and will contribute to fostering a research ecosystem thereby advancing the objectives of the NEP 2020. This journal will provide an opportunity to students, teachers and scholars, around the world to come together and showcase the links between classroom teaching and their practical training.

I congratulate the authors whose papers/articles have been published in the journal and encourage others to contribute to future issues. Appreciation is due to the Editor In-Chief of this journal, Dr. Apoorva Gupta who has worked tirelessly for the successful launch of this issue of the journal. My best wishes for the success of this venture.

Prof. (Dr.) Rama
Principal
Hansraj College

From the Editor's Desk

Dear Readers,

It is my great pleasure and privilege to present the next issue of the Journal of Hansraj College, the *HRC Journal of Economics and Finance*. The journal provides a platform to young researchers in the field of economics, business, social sciences, finance and management to publish their scholarly articles. Our inclusive nature ensures that we cover the wide range of issues in the field. This issue features a diverse range of articles that provide insightful analyses and innovative perspectives on various contemporary economic topics.

We have received around thirty papers relevant to the field of development economics, political economy, macroeconomic policy, financial markets, international trade, and behavioral economics. All the papers went through three rounds of review process, first by the editors and then by the review board. All the papers have gone through double blind peer review process. The authors were communicated with the revisions. The papers were accepted only after the satisfactory revisions were being made. We strictly follow the research ethics and do not tolerate plagiarism. All the selected papers were tested for plagiarism before publication. We have worked tirelessly to bring out the fourth issue of the journal with high quality research work.

Writing quality research papers takes a lot of time and effort, and the authors must be congratulated for writing their research papers for the journal, which is launched in the Platinum Jubilee year of the college, the Centenary year of the University of Delhi and the 75th year of India's independence. We also take this opportunity to congratulate the review board of this issue for their constant academic support for the timely release of the journal. We also thank the support received from the Principal of the college, Prof. (Dr.) Rama, the Advisory Board and the Editorial Board.

We hope that readers find the articles interesting, informative and engaging, and enjoy reading it. We believe that this effort of ours will stimulate further research and discussion in the field of economics and finance, and encourage readers to write for further issues of the journal. We look forward to receiving your feedback and suggestions for future issues.

Disclaimer: The opinions expressed in this journal belong to the contributors and do not necessarily reflect the viewpoints of the college, the editors, the Advisory Board, the Editorial Board, and the Review Board of the *HRC Journal of Economics and Finance*.

Dr. Apoorva Gupta

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CONTENTS

S. No.	Title and Authors	Page No.
1.	Three Decades of Women's Employment in Rajasthan: Trends, Determinants, and Structural Shifts (1993–2023) <i>Ajad Singh, Rakesh Kumar and Sandeep</i>	1
2.	Renewable Energy Transition in Odisha: Opportunities and Challenge <i>Richika Rana</i>	23
3.	A Critical Analysis of Population Growth: Through the Lens of Economic Growth <i>Mangal Sing Kro</i>	45
4.	Key Concepts in Measuring Productivity and a Review of Estimation Techniques for India <i>Pooja Khanna</i>	57
5.	Monetary Policy Transmission in India: Evidence from Liquidity, Interest Rates, and Inflation Dynamics <i>Tushar Sen</i>	79

Three Decades of Women's Employment in Rajasthan: Trends, Determinants, and Structural Shifts (1993–2023)

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Abstract

This paper examines trends and determinants of female labour force participation rate (FLFPR) in Rajasthan over three decades, from 1993–94 to 2023–24, using unit-level data from the National Sample Survey Organisation's Employment and Unemployment Surveys (NSSO EUS) and the Periodic Labour Force Surveys (PLFS). Rural FLFPR followed a non-linear path: it fell from a peak of 702.6 per 1,000 women in 1993–94 to a low of 325.7 in 2017–18, and then rose sharply to 620.0 by 2023–24. Urban female participation stayed below rural levels across the entire period. A regression analysis for 2023–24 identifies household job count, age (particularly the 30–44 cohort), and graduate-level education as the strongest predictors of participation. The results also point to an education–employment paradox: women with secondary education participate less than both those with sub-middle-level education and graduates, suggesting that intermediate education creates a “reserve force” of women who are neither absorbed into the labour market nor content to remain outside it. Caste-based patterns show higher participation among SC/ST women than among OBC and General Category women, pointing to participation driven by economic necessity rather than opportunity among marginalized groups. The paper recommends targeted investment in infrastructure and

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market-aligned skill development, with emphasis on the needs of rural and SC/ST women.

Keywords: Female Labour Force Participation; Rajasthan; NSSO; PLFS; Logistic Regression; Caste; Rural-Urban Divide

1. Introduction

Female labour force participation (FLFP) is one of the most debated fields of the development economics. Across developing countries, the relationship between women's participation in labour force and processes of economic transformation, demographic transition, and social change is very complex. India, as a very important country of South Asia, comes across with a very interesting paradox. Though India has made significant stride in the field of female education and had achieved significant decline in fertility rates, female LFPR has remained strikingly low and exhibits a persistent downward trend (World Bank, 2023; International Labour Organization [ILO], 2022).

Within this narrative in India, Rajasthan as India's largest state by area, characterised by a predominantly agrarian economy, seasonality of agricultural employment and a heavy reliance on unpaid family labour, occupies a position that extends well beyond its sheer demographic weight. Simultaneously, the state is also characterised by deep-rooted patriarchal norms, practice of female seclusion in the form of *purdah*, child marriage, and spatial mobility restrictions that have suppressed women's participation in the formal labour market (Olsen & Mehta, 2006; Jeffery & Basu, 1996).

The literature on FLFPR in India is huge and has grown considerably since 1991, yet it is disproportionately focused at the national level and is limited to high-growth states such as Maharashtra, Tamil Nadu, and Gujarat. State-level analyses encompassing FLFP dynamics over three decades — and that integrate the granular household survey data now made available through the Periodic Labour Force Survey (PLFS) — remain comparatively rare. This gap is consequential for policy, given that the determinants and structural barriers to female employment differ markedly across India's agro-climatic, cultural, and economic regions.

The present study addresses this gap directly. Using unit-level data from six rounds of the NSSO Employment and Unemployment Surveys (1993-94 to 2011-12) and PLFS (2017-18 and 2023-24), covering women aged 15–64, it pursues four interrelated objectives: first, to document and analyse temporal trends in female LFPR across rural and urban Rajasthan; second, to examine the changing structure of female employment by job type and informality status; third, to assess socio-economic and educational differentials in participation by caste and education level; and fourth, to identify the key determinants of female LFPR in 2023-24 using binary logistic regression models estimated separately for rural and urban sub-samples. Together, these analyses provide a longitudinal, multi-dimensional perspective on women's employment in Rajasthan that is, to the authors' knowledge, without precise precedent in the existing literature.

The remainder of this paper is structured as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 describes the data sources and econometric methodology. Section 4 analyses trends in LFPR and employment structure. Section 5 discusses and interprets the regression results. Section 6 explains the findings in broader literature and structural context. Section 7 recommends policy implications, and Section 8 concludes the paper.

2. Review of Literature

The literature related to determinants of female labour force participation has grown significantly both at theoretical and empirical level. At the theoretical level, neoclassical economists puts labour supply decision as a function of the reservation wage which itself depends upon the household income, the marginal utility of leisure, and the opportunity cost of unpaid work at household level (Mincer, 1962; Becker, 1965). As household incomes rise, the income effect of greater wealth reduces the necessity of paid employment outweighing the substitution effect of higher wages that incentivises work. This is the famous 'backward-bending' labour supply curve (Mincer, 1962). Neoclassical theory framework when applied to female employment in developing economies generates the hypothesis that FLFP declines in the initial stages of economic development with the rise in male income, and recovers at higher income levels when labour-saving

technologies and formal childcare reduce the cost of female employment (Goldin, 1995; Mammen & Paxson, 2000).

The empirical literature on India has engaged intensively with the U-shaped hypothesis. Kapsos, Silberman, and Bourmpoula (2014) and Mehrotra and Parida (2017) provide evidence consistent with this pattern at the national level, documenting that declining FLFP between 2004-05 and 2011-12 reflected, in part, rising male incomes in agricultural households enabling women to withdraw from distress-driven self-employment. However, Himanshu (2011) and Ghosh (2009) emphasize that such withdrawals frequently represent a shift from paid to unpaid household labour rather than a genuine improvement in welfare or autonomy. The period from 2011-12 to 2017-18, is characterised by a steep decline in both national and Rajasthan-specific FLFP, and has generated a vibrant debate regarding the relative contributions of measurement methods versus genuine structural changes (Abraham, 2017; Deshpande & Singh, 2021).

The intersection of caste and gender in shaping labour market participation has also received increasing attention and is widely analysed by various scholars. Thorat and Attewell (2007) have studied the role of social discrimination in regulating upward occupational mobility for Dalit workers of both sexes, while Jodhka (2014) highlights the heterogeneous economic path of different Scheduled Caste communities. The empirical evidence suggests that Scheduled Caste and Scheduled tribe (SC/ST) women participation in the labour force is significantly higher than General category women. This cannot be attributed to superior opportunity but to greater economic compulsion of lower average household incomes of SC/ST (Klasen & Pieters, 2015; Borooah, 2005). This compulsion-driven participation has important implications, and complicates straightforward interpretations of high LFPR as an indicator of empowerment.

The relationship between female education and employment is theoretically ambiguous and empirically complex. Human capital theory predicts a positive monotonic relationship: higher education increases productivity, reduces information asymmetries in the labour market, and raises the opportunity cost of non-participation (Becker, 1964). However, in the Indian context, multiple studies have documented a non-linear, U-shaped relationship between education and FLFP: participation is high among illiterate women (who are often constrained to take up unskilled agricultural or domestic work), declines at

intermediate education levels (when educated women — and their families — hold higher occupational aspirations but face limited suitable formal employment opportunities), and rises again at graduate and post-graduate levels (Klasen & Pieters, 2015; Mehrotra & Parida, 2017). Chatterjee, Murgai, and Rama (2015) term this the “education-employment mismatch”, a structural feature of Indian labour markets particularly acute in conservative social contexts such as Rajasthan.

State-level studies on Rajasthan’s female labour market remain relatively sparse. Olsen and Mehta (2006) provide a richly contextualised analysis of gender, work, and caste in rural Rajasthan, emphasising the role of mobility constraints and social norms in deterring formal-sector participation. More recent analyses using PLFS data (Drèze & Khera, 2021; NSO, 2023) confirm the state’s persistently low urban female LFPR but offer limited longitudinal or multivariate analysis. The present paper advances beyond this literature by providing a systematic multi-decade, multi-method analysis that integrates the 2023-24 PLFS round — the most current nationally representative employment survey available at the time of writing.

3. Data and Methodology

3.1 Data Sources

This study draws upon six rounds of nationally representative household survey data. The first four rounds — 1993-94 (50th Round), 1999-2000 (55th Round), 2004-05 (61st Round), and 2011-12 (68th Round) — are sourced from the Employment and Unemployment Surveys (EUS) conducted by the National Sample Survey Organisation (NSSO). The latter two rounds — 2017-18 and 2023-24 — utilise data from the Periodic Labour Force Survey (PLFS) conducted by the National Statistical Office (NSO). All six surveys employ stratified multi-stage sampling designs and provide unit-level (household and individual) microdata, enabling a consistent longitudinal analysis across three decades. For our study, we have restricted the sample to women between the age of 15–64 years, residing in Rajasthan, comprising, in both rural and urban areas.

3.2 Variable Construction

Labour Force Participation is taken as dependent variable and is defined as a categorical binary indicator dummy equal to unity if the woman reports being either currently employed or actively seeking employment (unemployed) during the reference week, and zero otherwise. The FLFP definition is consistent with the standard International Labour Organization (ILO definition adopted in NSSO/PLFS surveys).

Key independent variables are: (i) educational attainment— Illiterate/Middle, Secondary / Senior Secondary, and Graduate and Above. Secondary/Senior Secondary is treated as the reference category) (ii) caste category, SC/ST taken as reference category, OBC, and General; (iii) age group, 15–29 years as reference category, 30–44 years, and 45–64 years; (iv) marital status, Currently Married (reference category), Unmarried, and Widow/Divorced; and (v) residential sector, Rural as reference category and Urban sector.

Household-level economic status is measured through Monthly Per Capita Consumption Expenditure (MPCE), and is constructed by dividing total monthly household consumption expenditure (MHCE) by household size: $(MPCE = MHCE \div \text{Household Size})$. This transformation ensures comparability of welfare standards across households of varying sizes. Given the complex stratified sampling design of NSSO/PLFS surveys, MPCE quintile thresholds are computed using household weights (hhwt), analogous to weighted percentile estimation. Individuals are then divided into three socio-economic groups: the Bottom 40%, the Middle 40% which is used as the reference category, and the Top 20% (above the 80th percentile). A household job count variable is constructed, that captures the number of currently employed members, to account for intra-household employment dynamics.

3.3 Econometric Model

To analyse the determinants of female labour force participation, a binary logistic regression model is estimated using unit-level data from PLFS 2023–24. The dependent variable takes the value 1 if a woman participates in the labour force and 0 otherwise. The

logit models estimates the log-odds of participation as a linear function of socio-economic and demographic covariates, allowing estimation of the probability of labour force participation conditional on individual and household characteristics.

$$\log[P_i / (1 - P_i)] = \alpha + \sum \beta_j X_{ij} \quad (1)$$

where P_i is the probability that woman i participates in the labour force, α is the intercept, X_{ij} is the j -th explanatory variable, and β_j is the corresponding coefficient. Results are reported as Odds Ratios, which indicate the multiplicative change in the odds of participation in labour force associated with a unit change in the predictor, keeping all other variables constant. We have estimated three models: 1) a pooled model (both rural-urban combined sample), 2) a rural sub-sample model, and 3) an urban sub-sample model. This helps us in comparison of determinants across the residential sectors.

4. Results and Analysis

4.1 Trends in Female LFPR and the Gender Gap

Table 1 presents female and male LFPR and unemployment rates for females aged 15–64 across six survey rounds and is disaggregated at rural and urban sector level. It captures the trends of female LFPR in Rajasthan over the study period. The first phase (1993-94 to 2004-05) is relatively stable with high levels of LFPR: rural female LFPR fluctuates between 625 and 703 per 1,000, reflecting the dominance of agricultural self-employment and unpaid family labour. During this period, the overall gender gap in LFPR was substantial.

The second phase (2004-05 to 2017-18) is dramatic and registers decline in FLFPR. Rural female LFPR fell from 668.1 in 2004-05 to just 325.7 in 2017-18, a decline of more than 50% within thirteen years. The decline in urban female LFPR was even more pronounced. It declined from 302.3 to a historic low of 154.6 per 1,000. The rural gender gap widened to an extreme 452.0 per 1,000 in 2017-18. This period also coincides with the implementation of MGNREGS (Mahatma Gandhi National Rural Employment Guarantee Scheme) that was instrumental in raising agricultural wages. Rise in household income because of increased wages in agriculture sector may have pulled some women to

withdraw from distress-driven employment. Methodological differences between the PLFS and the earlier EUS are also likely contributors to the apparent magnitude of this decline (Abraham, 2017).

Table 1: Labour Force Participation and Unemployment Rates by Gender and Sector (Per 1,000), Age Group 15–64

Survey Year	LFPR – Male	LFPR – Female	LFPR – Overall	Gender Gap (LFPR)	UR – Male	UR – Female	UR – Overall	Gender Gap (UR)
A. Rural								
1993-94	897	702.6	799.8	194.4	4.1	1.2	2.7	2.9
1999-2000	875.2	625.9	750.6	249.3	6.4	1.3	3.9	5.1
2004-05	873.9	668.1	771	205.8	12.6	0.9	6.7	11.7
2011-12	794.3	531.3	662.8	263.1	8.9	3.5	6.2	5.3
2017-18	777.6	325.7	551.6	452	68.2	12.3	40.2	55.9
2023-24	830.2	620	725.1	210.2	43.7	31.5	37.6	12.2
B. Urban								
1993-94	804.7	251.9	528.3	552.8	17.7	5	11.3	12.7
1999-2000	785.8	218.7	502.2	567.1	27.7	28.7	28.2	-1
2004-05	804.4	302.3	553.3	502.1	29.5	30.5	30	-1
2011-12	745.7	209.3	477.5	536.4	32.2	25.2	28.7	7.1
2017-18	751.7	154.6	453.1	597.1	70.1	102	86	-32
2023-24	768	319.2	543.6	448.9	71.7	113.6	92.7	-41.9
C. Overall								
1993-94	874.3	597.3	735.8	277	7.2	1.6	4.4	5.6
1999-2000	852.4	531.7	692	320.7	11.4	3.9	7.7	7.5
2004-05	855.9	579.5	717.7	276.4	16.7	4.6	10.7	12.1
2011-12	781.6	451.9	616.8	329.7	14.7	6	10.4	8.7
2017-18	771	285	528	486	68.6	23.8	46.2	44.8
2023-24	811.3	536.8	674.1	274.5	51.8	45	48.4	6.7

Note: Authors' calculation based on NSSO EUS and PLFS unit-level data. Gender Gap = Male LFPR – Female LFPR. For OBC, data was not collected as a separate category in 1993-94.

The third phase (2017-18 to 2023-24) is marked by recovery in female LFPR. Rural female LFPR rebounded to 620.0 per 1,000 by 2023-24, and the rural gender gap narrowed significantly to 210.2 per 1,000. This was the smallest recorded during the study period. Urban female LFPR also recovered to 319.2 per 1,000, though the urban gender gap remained at high levels at 448.9. The unemployment rate among urban women rose to 113.6 per 1,000 in 2023-24, exceeding that of urban men (71.7 per 1,000).

This development indicates a substantial mismatch between demand and available opportunities in urban labour markets.

4.2 Social and Educational Differentials in Female LFPR

Table 2 discusses female LFPR by social group and by educational attainment across survey rounds and residential sectors.

Table 2: Female LFPR (per 1,000) by Social Group and Educational Category, Age Group 15–64

Survey Year	SC/ST	OBC	General	Overall	Primary Level	Secondary Level	Graduate Level
A. Rural							
1993-94	782.9	—	662.2	702.6	717.9	324.2	718.6
1999-2000	700.6	662.9	490.6	625.9	650.5	288	338.3
2004-05	723.3	695.7	464.9	668.1	697.2	400.3	548.1
2011-12	609.7	511.5	398.4	531.3	595.8	258.8	432.4
2017-18	368.5	311	249.8	325.7	393.6	142.7	224.2
2023-24	652.3	628.6	498.6	620	774	393.3	573.9
B. Urban							
1993-94	338.2	—	232.6	251.9	294.3	114.9	356
1999-2000	336.2	241.1	160.4	218.7	264.4	114	282.7
2004-05	404.6	302.1	243.4	302.3	371	160	336.3
2011-12	262.6	256.8	122.4	209.3	260.1	105.5	289.3
2017-18	191.3	164.3	117.7	154.6	172.5	87.1	247.1
2023-24	341.1	338.5	262.8	319.2	428.2	162.2	419.1
C. Overall							
1993-94	719.3	—	545.1	597.3	642.8	184.3	403.1
1999-2000	642.7	592.6	372.4	531.7	588.7	185.2	287.6
2004-05	666.9	623.1	364.8	579.5	640.4	278.4	361.6
2011-12	554.9	455.2	272.4	451.9	538.1	198.4	342.1
2017-18	340.8	279.5	189.8	285	358.8	124.5	237.5
2023-24	583.5	553.2	396.1	536.8	703	324	496.9

Note: Authors' calculation based on NSSO EUS and PLFS unit-level data. OBC data is unavailable for 1993-94 as the category was not identified separately in the 50th Round.

An analysis of Table 2 shows that social category-based differences in female LFPR are visible across all survey rounds and residential sectors. SC/ST women exhibit systematically higher LFPR rates than OBC and General Category women throughout the study period. In rural areas in 2023-24, SC/ST LFPR stood at 652.3 per 1,000, compared to 628.6 for OBC and 498.6 for General category women. In urban areas, differential is even steeper: SC/ST LFPR (341.1) significantly exceeded General category LFPR (262.8). This pattern reflects the compulsion-driven character of employment among economically marginalised groups. Non-participation in the labour force causes significant welfare costs to the marginalised groups.

The educational differentials in Table 2 reveal the “education-employment paradox” which is a special characteristic of Rajasthan’s female labour market. Women with Primary-level education consistently record the highest LFPR throughout survey period. In 2023-24, their overall LFPR was 703.0 per 1,000, compared to 324.0 for Secondary-educated women and 496.9 for Graduate-level women. This U-shaped pattern with the lowest participation rates observed at intermediate education levels is a consistent feature across rural and urban areas throughout the entire study period. The withdrawal of females from labor force at the Secondary education level suggests that secondary schooling generates aspirations for formal, white-collar employment without matching qualifications required to access formal and white-collar employment.

4.3 Structure and Quality of Female Employment

Table 3 reveals the most striking feature of the employment structure that is the overwhelming and persistent dominance of unpaid family labour throughout the study period. In 1993-94, 57.0% of employed women in Rajasthan were engaged as unpaid family workers, which rose to 64.2% by 1999-2000 before declining to 53.2% in 2023-24. This pattern reflects labour force participation of involuntary and remuneration-free character. Regular salaried employment, the employment category most associated with job security and social protection, has expanded from just 3.0% in 1993-94 to 8.8% in 2023-24. While this near-trebling of the regular employment share reflects progress, the absolute level of employment remains very low. The vast majority of employed women

are engaged in informal, insecure, or unpaid work. The casual labour share has remained stable, and has fluctuated between approximately 10% and 20%. Self-employment has also oscillated between 21.7% and 28.1%, reflecting the expansion of home-based informal enterprises observed in post-pandemic surveys.

**Table 3: Distribution of Female Workers by Employment Type
(%), Age Group 15–64**

Year	Casual Jobs (%)	Self - Employed (%)	Regular Jobs (%)	Unpaid Work (%)
1993-94	11.9	28.1	3	57
1999-2000	10.7	22.2	2.9	64.2
2004-05	11.4	22	3.6	62.9
2011-12	20.2	26.4	5.4	48
2017-18	11.6	21.7	8.9	57.7
2023-24	10.6	27.3	8.8	53.2

Note: Authors' calculation based on NSSO EUS and PLFS unit-level data. Population: employed females aged 15–64 years.

4.4 Educational Expansion and Its Employment Implications

Tables 4 and 5 together examine commensurate gains in labour market participation due to improvement in female educational attainment. The transformation journey in the educational profile of Rajasthan's female population between 1993-94 and 2023-24 is in table 4. The share of women in LFPR with only Primary-level education declined from 89.3% to 50.5%. While those with Secondary education increased from 9.0% to 37.1%, and the Graduate share rose from 1.7% to 12.4% during the same time period. These structural changes, reflects the cumulative effects of school enrolment efforts, the *Sarva Shiksha Abhiyan*, and initiatives to promote female education.

Table 5 reveals that these educational gains have not translated proportionately into enhanced labour market participation. Overall female LFPR across all educational groups in 2023-24 remains below the 1993-94 baseline only in the aggregate sense. Within educational categories, the persistent U-shape is notable.

**Table 4: Educational Distribution of Female Population
(%), Age Group 15–64**

Year	Primary Level (%)	Secondary Level (%)	Graduate Level (%)	Total (%)
1993-94	89.3	9	1.7	100
1999-2000	85.3	12.3	2.4	100
2004-05	82.6	14.8	2.6	100
2011-12	72.3	22.2	5.5	100
2017-18	64.7	27.4	7.9	100
2023-24	50.5	37.1	12.4	100

Note: Authors' calculation based on NSSO EUS and PLFS unit-level data.
Age group: 15- 64 years

**Table 5: Female LFPR (per 1,000) by Educational
Attainment, Age Group 15–64**

Year	LFPR – Primary (per 1000)	LFPR – Secondary (per 1000)	LFPR – Graduate (per 1000)	LFPR – Total (per 1000)
1993-94	643	184	403	410
1999-2000	589	185	288	354
2004-05	640	278	362	427
2011-12	538	198	342	359
2017-18	359	124	238	240
2023-24	703	324	497	508

Note: Authors' calculation based on NSSO EUS and PLFS unit-level data. Age group: 15–64 years

The structural diagnosis found earlier is reinforced by the pattern of participation. The labour market has expanded educational opportunities without a commensurate expansion of formal employment that meets the aspirations of secondary-educated women. This is reflected in the growing pool of educated women who are neither in the labour force nor in formal employment.

5. Logistic Regression Analysis: Determinants of Female LFPR

5.1 Pooled and Sector-Specific Results (2023-24)

The results of binary logistic regression models are estimated and presented for all workers in Table 6 and for female workers in Table 7. Odds Ratios are reported throughout and significance levels are indicated by asterisks. The models account for household size, household job count, MPCE group, educational attainment, age group, marital status, caste category, and residential sector.

Table 6: Logistic Regression Results — Determinants of Labour Force Participation, PLFS 2023-24 (All Workers)

Explanatory Variable	All (1)	Rural (2)	Urban (3)
Constant Term	4.977***	3.415***	3.702***
Household Size	0.667***	0.650***	0.665***
Household Job Count	3.237***	3.441***	3.417***
MPCE: Lowest 40% (vs Middle 40%)	1.079	1.139*	0.981
MPCE: Top 20% (vs Middle 40%)	0.899	0.871	0.871
Primary Level (vs Secondary Level)	2.051***	1.776***	1.741***
Graduate Level (vs Secondary Level)	3.504***	3.614***	3.693***
Age 30–44 (vs 15–29)	4.930***	7.356***	4.306***
Age 45+ (vs 15–29)	1.733***	2.447***	1.468***
Unmarried (vs Currently Married)	0.166***	0.109***	0.304***
Widow/Divorced (vs Currently Married)	0.905	0.763	1.225
OBC (vs SC/ST)	0.813***	0.802***	0.778**
General (vs SC/ST)	0.668***	0.652***	0.633***
Urban Sector (vs Rural)	0.564***	—	—
Gender Female	0.081***	0.153***	0.042***
Gender 3rd Gender	0	0	—
No. of Observations	13,383	7,971	5,412
Log Likelihood	-5179	-2703	-2239
Pseudo R-squared	0.398	0.422	0.398

Note: Odds ratios are reported. *** p<0.01, ** p<0.05, * p<0.1. Reference groups: Age 15-29, Currently Married, SC/ST, Rural Sector, Female, MPCE Middle 40%, Education: Secondary Level

The results in Table 6 largely follow expected patterns, though some warrant closer contextual reading. Household job count is the strongest positive predictor of labour force participation, with an Odds Ratio of 3.237 in the pooled model — each additional employed household member nearly triples the odds that a given individual is also employed. This likely reflects intra-household employment pressures and networks, complementary skill deployment within family enterprises, and shared knowledge of labour market opportunities. The rural model shows an even higher Odds Ratio of 3.441, consistent with the prevalence of family-based agricultural enterprises in rural areas. The gender coefficient is strikingly low at 0.081: women's odds of labour force participation are roughly twelve times lower than men's. This gap persists even after controlling for observed individual and household characteristics, pointing to unobserved social norms, safety concerns, and structural labour market barriers as underlying causes. Household size shows that individuals in larger households are less likely to participate in the labour force, net of other factors. This finding is consistent with the substitutability of household members in unpaid domestic and care work. In larger households, some members are released from the imperative of market employment through the informal provision of domestic labour by others.

Table 7 presents determinants of female labour force participation, and enables a more focused examination of the factors shaping women's employment decisions. The Household Job Count coefficient of 3.734, confirms the strong positive association between intra-household employment and female participation. The Urban Sector coefficient is 0.294, indicates that the odds of an urban woman being in the labour force are less than one-third of those of her rural counterpart. This rural-urban differential in female participation reflects both the concentration of informal agricultural employment in rural areas and the paucity of suitable formal employment for women in urban settings.

The education Odds Ratios in Table 7 confirm and quantify the U-shaped relationship between education and female LFPR. Relative to the reference category (Secondary level), illiterate/Primary-educated women have substantially higher odds of participation at 2.496 in the pooled model; 2.948 in the urban model, and Graduate-educated women have the highest odds of participation (OR = 3.843 pooled; 4.108 urban). The urban graduate Odds-Ratio of 4.108 is particularly striking and confirms that in urban areas, graduate qualifications provide a decisive advantage in accessing employment.

Table 7: Logistic Regression Results — Determinants of Female Labour Force Participation, PLFS 2023-24

Explanatory Variable	All (1)	Rural (2)	Urban (3)
Constant Term	0.438***	0.481***	0.120***
Household Size	0.607***	0.614***	0.578***
Household Job Count	3.734***	3.759***	4.119***
MPCE: Lowest 40% (vs Middle 40%)	1.113	1.183*	0.999
MPCE: Top 20% (vs Middle 40%)	0.91	0.84	0.939
Primary Level (vs Secondary Level)	2.496***	1.873***	2.948***
Graduate Level (vs Secondary Level)	3.843***	2.984***	4.108***
Age 30–44 (vs 15–29)	5.851***	8.157***	4.709***
Age 45+ (vs 15–29)	2.045***	2.831***	1.564**
Unmarried (vs Currently Married)	0.507***	0.213***	2.058***
Widow/Divorced (vs Currently Married)	1.169	0.874	1.700***
OBC (vs SC/ST)	0.796***	0.820**	0.709**
General (vs SC/ST)	0.575***	0.498***	0.585***
Urban Sector (vs Rural)	0.294***	—	—
No. of Observations	6,775	4,114	2,661
Log Likelihood	-2961	-1662	-1181
Pseudo R-squared	0.369	0.382	0.285

Note: Odds Ratios reported. *** p<0.01, ** p<0.05, * p<0.1. Reference groups: Age 15–29, Currently Married, SC/ST, Rural Sector, MPCE Middle 40%, Education: Secondary Level. N = 6,775 (All); 4,114 (Rural); 2,661 (Urban)

Age group effects are also prominent, women aged 30–44 have odds of participation nearly six times (OR = 5.851) those of women aged 15–29, and the rural coefficient (8.157) exceeds the urban one (4.709) substantially. This age-participation profile can be due to marriage and early childbearing employment in agrarian economies, which interrupts formal employment. These women re-enter into agricultural or family enterprise work once their children grow older and economic pressures intensify. Unmarried women exhibit lower odds of participation than married women in the pooled and rural models, reflecting the role of economic necessity in driving married women with families into the labour force. In urban areas, however, the pattern reverses, unmarried urban women have significantly higher odds of participation consistent with

the greater prevalence of formal sector employment among educated young women prior to marriage in urban contexts.

Caste effects remain significant and directionally consistent across all models: OBC women with OR equal to 0.796 and General category women with OR equal to 0.575 exhibit lower odds of participation than SC/ST women, this residual caste effect, net of all observable socio-economic characteristics, confirms that compulsion-driven participation remains a structural feature of employment among marginalised social groups. Social norms around acceptable female employment continue to differentiate participation by caste even within income-controlled analyses.

6. Discussion

The findings reported above covers empirical, structural, and normative aspects of women's employment in Rajasthan. At the empirical level, the most consequential finding is the recovery of female LFPR in Rajasthan between 2017-18 and 2023-24, with the historic nadir of the PLFS 2017-18 estimates. Two competing explanations need attention. The first is structural. The recovery reflects genuine re-entry of women into employment, driven by post-pandemic economic recovery, the expansion of self-help group-linked livelihoods under the National Rural Livelihoods Mission, and increasing demand for casual and home-based labour in both rural and urban areas. The second explanation requires methodological differences. The PLFS 2023-24 adopted a revised activity status classification and a modified household schedule that may have improved the capture of short-duration or subsidiary employment, among women in rural areas, who were previously undercounted in the 2017-18 PLFS round (Abraham, 2017; Deshpande & Singh, 2021). Both explanations are partially correct, and disaggregating their respective contributions requires time-series consistency that is currently unavailable.

The persistent and structural nature of the rural–urban divide in female LFPR is a second major finding. Even after exhaustive statistical control for individual and household characteristics, urban women in Rajasthan participate in the labour force at lower rates than their rural counterparts. This residual effect is attributable to a combination of

factors. First, the greater prevalence of unpaid agricultural labour as a default employment category in rural areas; second, the concentration of *pardah* norms and spatial mobility constraints in urban Rajasthan's middle-class households; third, the limited availability of suitable formal employment for women in secondary cities and small towns and fourth, the higher reservation wages associated with secondary education in urban settings. The urban unemployment rate among women exceeding that of men is commonly associated with labour market failure which underscores the severity of the mismatch between educated women's aspirations and available opportunities and skill sets.

The “education-employment paradox” documented above constitutes a structural challenge of the first order. Rajasthan has invested substantially in female education over the past three decades, and these investments are in terms of enrolment and attainment. Yet the labour market has not kept pace with this educational transformation. Secondary-educated women face a structural void in which they are neither willing nor able to take up the employment that is available. The result is a large and growing cohort of educated women outside the formal economy, a serious waste of human capital, with implications for both individual welfare and aggregate productivity.

The caste dimension adds further complexity to the female LFPR picture. SC/ST women participate at higher rates than General category women even after controlling for observable characteristics, which challenges any simple narrative equating higher participation with empowerment. The regression results instead suggest that SC/ST women face lower barriers to entering the workforce — reflecting less social stigma around visible female employment, greater household reliance on female earnings, and different occupational structures within predominantly SC/ST communities. Policies should therefore focus as much on improving the quality of SC/ST women's employment as on raising participation rates among General category women.

7. Policy Implications

The findings of this study can be used to suggest few policy recommendations. First, the expansion of child care infrastructure is an urgent priority. The regression results and the

employment structure data jointly confirm that household size is a significant negative predictor of female participation. Investment in subsidised community-managed crèches, Anganwadi centres and elderly care facilities would reduce the domestic care burden that limits women's participation in market employment, particularly in rural areas where such services are deficient.

Second, skill development programmes shall align with actual labour market demand. The education-employment paradox documented in this study reflects a failure of coordination between the educational system and the labour market. Secondary-educated women's qualifications do not match with available employment skill requirements. Focus shall shift to targeted vocational training programmes, linked to skill sets required by industries in sectors such as healthcare, education, Information Technology Enabled Services (ITES), agro-processing etc.

Third, the formalisation of informal and home-based work deserves sustained policy attention. As the vast majority of employed women in Rajasthan is in informal, or unpaid work, policies extending social security coverage, statutory minimum wages, and occupational health protections to home-based workers shall be implemented.

Fourth, targeted support for SC/ST women should address the quality dimension of their employment. Given that SC/ST women already participate at high rates, the priority for this demographic is improving wages by re-skilling and retraining them for the better paid jobs, improve their working conditions, and occupational mobility rather than increasing participation per se. Reservation policies in government employment, intervention in terms of targeted microcredit access, and community-level support for productive self-employment in non-agricultural activities are some of the policy suggestions.

Fifth, urban female unemployment demands urgent and specific policy attention. The 2023-24 data reveal urban female unemployment rates exceeding 11%, substantially higher than urban male rates. This suggests a supply-demand mismatch in urban Rajasthan's formal labour market that cannot be addressed by supply-side interventions alone. Demand-side measures — including gender-responsive industrial policy, targeted incentives for firms employing women in formal roles, and the expansion of urban public employment in services are necessary complements to education and skill development.

8. Conclusion

This paper has focused on a comprehensive and longitudinal analysis of female labour force participation in Rajasthan from 1993-94 to 2023-24. The analysis confirms a non-linear trend in female LFP, a period of relative stability through 2004-05, a secular decline to 2017-18, and a significant recovery in 2023-24. The recovery is encouraging but must be interpreted with caution.

The regression analysis confirms that household job count, age, and graduate education are the strongest positive predictors of female participation, whilst urban residence, unmarried status (in rural areas), and General caste category are associated with substantially lower odds. These findings are robust across multiple models and highlight the multi-dimensional nature of the constraints facing female employment in Rajasthan. The study's key theoretical contribution lies in its rigorous empirical documentation of the education-employment paradox and the compulsion-driven nature of SC/ST female employment, findings that complicate standard human capital and empowerment narratives and call for more nuanced policy responses.

Several limitations of the present study merit acknowledgement. The NSSO EUS and PLFS surveys are cross-sectional at each round, precluding the tracking of individual employment transitions over time. The absence of time-use data prevents a precise measurement of unpaid care and domestic work, which is central to understanding why women are outside the labour force. The surveys' unit of analysis is the household rather than the workplace, limiting the analysis of demand-side factors such as employer discrimination and occupational segregation. Finally, methodological discontinuities between the EUS and PLFS rounds introduce uncertainty into inter-round comparisons, particularly around the 2011-12 to 2017-18 transition.

Future research should address these limitations through longitudinal panel designs, qualitative methods capable of capturing social norm dynamics and intra-household bargaining, and explicit modelling of labour demand conditions including firm-level and sector-level data. Policy evaluations of specific interventions like Mahatma Gandhi National Rural Employment Guarantee Scheme— MGNREGS, *Beti Bachao Beti Padhao*, the National Rural Livelihoods Mission, and others, — using quasi-experimental

methods would also substantially advance the evidence base for targeted gender employment policy in Rajasthan and comparable states.

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Renewable Energy Transition in Odisha: Opportunities and Challenge

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Abstract

The transition towards renewable energy has become a key component of India's strategy to achieve sustainable economic growth, energy security, and climate resilience. As one of India's major energy-producing states, Odisha occupies a strategic position due to its abundant coal reserves, expanding industrial base, and significant renewable energy potential. This study examines the opportunities and challenges associated with Odisha's renewable energy transition through a descriptive policy analysis based on secondary data obtained from government reports, policy documents, statistical publications, and institutional databases. The analysis reveals that Odisha possesses substantial renewable energy potential, particularly in solar, hydropower, biomass, and floating solar resources; however, much of this potential remains underutilized. Although renewable energy capacity has expanded steadily over the past decade, coal continues to dominate the state's electricity mix. The study identifies key challenges, including inadequate transmission infrastructure, limited energy storage, financing constraints, land acquisition issues, policy implementation gaps, and the need for a just transition in coal-dependent regions. At the same time, renewable energy development offers significant opportunities to strengthen energy security, reduce greenhouse gas emissions, attract investment, generate employment, and promote sustainable industrial and rural development. The study recommends strengthening grid infrastructure, expanding energy storage, promoting private investment, improving institutional coordination, and implementing

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just transition policies to accelerate Odisha's transition towards a cleaner, more resilient, and inclusive energy system.

Keywords: Renewable energy, Odisha, India, energy transition, solar power, coal dependence, sustainable development, just transition, energy policy, clean energy.

1. Introduction

India's growing energy demand, rapid industrialization, and increasing environmental concerns have accelerated the transition towards cleaner and more sustainable energy systems (International Energy Agency [IEA], 2021; NITI Aayog, 2023). As the world's third-largest energy consumer, India has committed to expanding renewable energy capacity to strengthen energy security, reduce greenhouse gas emissions, and fulfil its climate commitments under the Paris Agreement, including the target of achieving 500 GW of non-fossil fuel installed electricity capacity by 2030 (Government of India, 2022; United Nations Framework Convention on Climate Change [UNFCCC], 2015).

Within this national transition, Odisha occupies a strategically important position owing to its abundant mineral resources, coal-based industrial economy, and growing electricity demand (Government of Odisha, 2022; Ministry of Power, Government of India, 2024). The state is one of India's leading energy-producing regions, supported by extensive coal reserves, thermal power generation capacity, and energy-intensive industries such as steel, aluminium, mining, and manufacturing (Central Electricity Authority [CEA], 2024). While this coal-based energy system has played a vital role in supporting economic growth and industrialization, it has also contributed to greenhouse gas emissions, air pollution, and environmental degradation, increasing the need for a transition towards cleaner and more sustainable sources of energy (IEA, 2021; Intergovernmental Panel on Climate Change [IPCC], 2023).

The urgency of this transition has grown as Odisha faces increasing climate-related risks, including cyclones, floods, rising temperatures, and coastal vulnerability, alongside rising electricity demand and the need for sustainable industrial development (Government of Odisha, 2022; IPCC, 2023). At the same time, the state possesses considerable renewable

energy potential, particularly in solar energy, hydropower, biomass, and emerging technologies such as floating solar and green hydrogen, providing significant opportunities to diversify its energy mix, strengthen energy security, attract investment, generate employment, and support low-carbon economic growth (Government of Odisha, 2022; International Renewable Energy Agency [IRENA], 2024; Ministry of New and Renewable Energy [MNRE], 2024).

Recognizing these opportunities, both the Government of India and the Government of Odisha have introduced several policy initiatives to accelerate renewable energy deployment. National programmes, including the Jawaharlal Nehru National Solar Mission, Green Energy Corridor Programme, PM-KUSUM, and the National Green Hydrogen Mission, have established an enabling framework for renewable energy expansion across the country. Complementing these initiatives, the Odisha Renewable Energy Policy, 2022 seeks to promote private investment, strengthen renewable energy infrastructure, improve energy security, and position the state as a renewable energy hub in eastern India (Government of India, 2022; Government of Odisha, 2022; MNRE, 2024).

Despite these policy initiatives and abundant renewable resources, Odisha's energy transition continues to face significant structural, infrastructural, financial, environmental, and institutional challenges. Continued dependence on coal-based industries, transmission bottlenecks, financing constraints, land acquisition issues, and implementation gaps has slowed the pace of renewable energy deployment (Government of Odisha, 2022; IEA, 2021; NITI Aayog, 2023). While a growing body of literature has examined India's renewable energy transition, relatively few studies have comprehensively analysed Odisha's transition by integrating renewable resource potential, policy initiatives, opportunities, and implementation challenges within a single framework.

Against this backdrop, the present study examines the opportunities and challenges associated with Odisha's renewable energy transition. Specifically, the study (i) assesses the state's renewable energy potential across major renewable resources, (ii) evaluates the policy and institutional framework supporting renewable energy development, (iii) analyses the key opportunities associated with renewable energy expansion, including environmental sustainability, energy security, employment generation, and investment

potential, (iv) identifies the major economic, infrastructural, environmental, and institutional barriers affecting the transition, and (v) proposes policy measures to support a faster, more inclusive, and sustainable renewable energy transition in Odisha. By providing a comprehensive assessment of Odisha's renewable energy landscape, the study contributes to the growing literature on sub-national energy transitions and offers policy-relevant insights for achieving sustainable and resilient energy development in India.

The remainder of the paper is organized as follows. Section 2 reviews the existing literature on renewable energy transition, with particular emphasis on policy, institutional, and state-level perspectives. Section 3 outlines the research methodology and data sources used in the study. Section 4 assesses Odisha's renewable energy resource potential and analyses trends in installed capacity and the current energy mix. Section 5 examines the policy and institutional framework supporting renewable energy development in the state. Sections 6 and 7 discuss the major opportunities and challenges associated with Odisha's renewable energy transition. Finally, Section 8 presents the conclusions and policy recommendations for accelerating a sustainable, resilient, and inclusive renewable energy transition in Odisha.

2. Literature Review

The renewable energy transition has become a major area of research in India due to growing concerns over climate change, energy security, environmental sustainability, and rising energy demand. Existing studies broadly examine renewable energy from four perspectives: (i) its contribution to economic growth and sustainable development, (ii) the effectiveness of policy and institutional frameworks, (iii) barriers to renewable energy deployment, and (iv) regional disparities in renewable energy development (Bhattacharya et al., 2016; International Energy Agency [IEA], 2021; International Renewable Energy Agency [IRENA], 2023).

2.1 Renewable Energy and Sustainable Development

A substantial body of literature suggests that renewable energy contributes to sustainable economic development by improving energy security, reducing greenhouse gas emissions, attracting investment, and creating employment opportunities. Bhattacharya et al. (2016) found that renewable energy consumption positively influences economic growth in developing countries, while IRENA (2023) highlighted its role in employment generation and industrial development. Similarly, the IEA (2021) emphasized that expanding renewable energy is essential for reducing dependence on fossil fuels and supporting long-term climate and energy security objectives.

2.2 Policy and Institutional Framework

Several studies emphasize that supportive policy and institutional frameworks are critical for accelerating renewable energy deployment. National initiatives such as the Jawaharlal Nehru National Solar Mission, Renewable Purchase Obligations (RPOs), competitive bidding mechanisms, and more recent programmes including PM-KUSUM and the National Green Hydrogen Mission have significantly expanded renewable energy capacity in India (Bhattacharya & Kojima, 2012; Ministry of New and Renewable Energy [MNRE], 2024; Shukla et al., 2019). However, effective implementation depends on institutional capacity, regulatory stability, and coordinated policy support across different levels of government (IEA, 2021).

2.3 Barriers to Renewable Energy Deployment

Despite significant policy progress, the literature identifies several barriers that continue to constrain renewable energy development. Financial constraints, inadequate transmission infrastructure, technological limitations, regulatory uncertainty, and land acquisition issues remain among the most frequently cited challenges (Painuly, 2001; Shrimali & Aggarwal, 2014). Recent studies further emphasize that strengthening grid infrastructure, improving access to finance, and expanding energy storage systems are

essential for integrating higher shares of renewable energy into electricity networks (CEA, 2024; IEA, 2021).

2.4 Regional Disparities in Renewable Energy Development

Renewable energy development in India exhibits considerable regional variation, reflecting differences in resource availability, infrastructure, investment climate, and policy implementation. States such as Gujarat, Rajasthan, Karnataka, and Tamil Nadu have emerged as leaders in renewable energy deployment due to favourable policy environments, stronger transmission infrastructure, and greater private sector participation. In contrast, several coal-dependent states continue to face difficulties in balancing industrial growth with environmental sustainability (Bhattacharyya & Palit, 2014; IEA, 2021; MNRE, 2024; NITI Aayog, 2023).

2.5 Renewable Energy Transition in Odisha

Existing research on Odisha has primarily focused on its coal-based economy, thermal power generation, mining activities, and associated environmental challenges (CEA, 2024). Although the state possesses considerable renewable energy potential in solar, biomass, hydropower, and offshore wind, renewable energy deployment has progressed relatively slowly. The literature attributes this to transmission constraints, financing gaps, policy implementation challenges, land acquisition issues, and the continued dependence of the state's economy on coal-based industries (Government of Odisha, 2022; IEA, 2021; MNRE, 2024).

Researchers have also highlighted the important role of the Odisha Renewable Energy Development Agency (OREDA) in promoting decentralized renewable energy, rural electrification, and solar energy programmes. Nevertheless, greater institutional coordination, improved grid connectivity, enhanced private sector participation, and stronger policy implementation are considered necessary to accelerate renewable energy adoption in the state (Government of Odisha, 2022; MNRE, 2024). Furthermore, Odisha's

high vulnerability to cyclones, floods, and other climate-related disasters reinforces the need for resilient and decentralized renewable energy systems (IPCC, 2023).

2.6 Research Gap

Although the literature provides extensive evidence on India's renewable energy transition, relatively few studies examine Odisha from a comprehensive policy perspective. Most existing research focuses either on India's national renewable energy transition or on Odisha's coal-based industrial economy. Limited attention has been paid to evaluating the state's renewable energy transition by integrating its resource potential, policy framework, institutional mechanisms, opportunities, and implementation challenges within a single analytical framework. This study addresses this gap by providing a comprehensive assessment of Odisha's renewable energy transition and identifying policy measures required to support a sustainable, secure, and inclusive energy future.

3. Methodology

This study employs a descriptive policy analysis using secondary data obtained from government reports, policy documents, statistical publications, and peer-reviewed literature. The primary sources include the Ministry of New and Renewable Energy (MNRE), Central Electricity Authority (CEA), National Power Portal (NPP), Government of Odisha, Odisha Renewable Energy Development Agency (OREDA), International Energy Agency (IEA), International Renewable Energy Agency (IRENA), and NITI Aayog (Government of Odisha, 2022; IEA, 2021; MNRE, 2024; NITI Aayog, 2023).

Trend analysis is used to examine changes in Odisha's installed electricity capacity between 2015–16 and 2025–26, while comparative and qualitative analyses are employed to assess renewable energy potential, policy initiatives, and the key opportunities and challenges influencing the state's renewable energy transition.

4. Renewable Energy Potential in Odisha

Odisha possesses considerable renewable energy resources owing to its favourable geographical conditions, diverse natural resource base, and growing demand for clean and reliable electricity. Although the state's electricity sector has historically depended on coal-based thermal power generation, increasing concerns over climate change, environmental sustainability, and energy security have strengthened the emphasis on renewable energy development. Supported by national and state policy initiatives, renewable energy is expected to play an increasingly important role in diversifying Odisha's energy mix and supporting sustainable economic development (Government of Odisha, 2022; International Energy Agency [IEA], 2021; Ministry of New and Renewable Energy [MNRE], 2024).

Table 1: Renewable Energy Potential in Odisha by Source.

Renewable Energy Source	Resource Potential (MW)	Utilization of Resource Potential (%)
Hydro (including Pumped Storage)	7,620	28.27
Solar	1,39,470	0.66
Small Hydro	286.22	49.13
Bio-Power	299	21.48

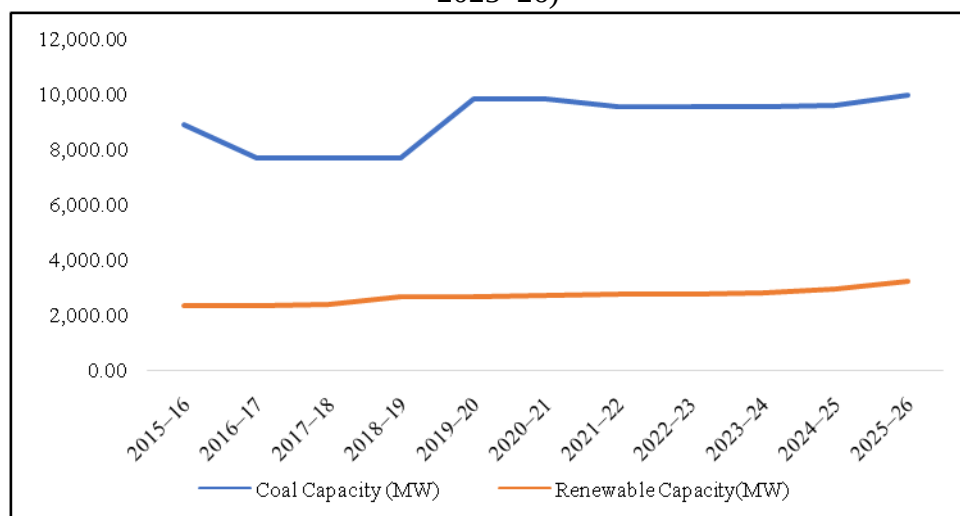
Source: NITI Aayog. (2025). India Climate & Energy Dashboard (ICED): Odisha State Report

Table 1 indicates that Odisha possesses substantial renewable energy resources, although much of this potential remains underutilized. Solar energy represents the largest resource, with an estimated potential of 139,470 MW, yet only 0.66% has been developed, highlighting significant opportunities for utility-scale and distributed solar deployment. Among the currently exploited resources, small hydropower records the highest utilization rate (49.13%), followed by hydropower including pumped storage (28.27%) and bio-power (21.48%). Although Odisha has a long coastline and recognised wind resource potential, commercial wind power development remains negligible, indicating scope for future investment as resource assessment and technology continue to improve

(Ministry of New and Renewable Energy [MNRE], 2024; National Institute of Wind Energy [NIWE], 2023).

Figures 1 and 2 collectively illustrate the evolution and current composition of Odisha's installed electricity generation capacity. Figure 1 shows that coal remained the dominant source of electricity generation throughout 2015–16 to 2025–26, with installed capacity increasing from 8,880 MW to 9,950 MW, despite minor fluctuations. Over the same period, renewable energy capacity grew steadily from approximately 2,336 MW to more than 3,240 MW, representing an increase of nearly 39%, primarily driven by the expansion of solar power. This trend reflects Odisha's progress in promoting renewable energy in line with national and state policy initiatives (Ministry of New and Renewable Energy [MNRE], 2024).

Figure 1: Installed Capacity by Energy Source in Odisha (2015–16 to 2025–26)

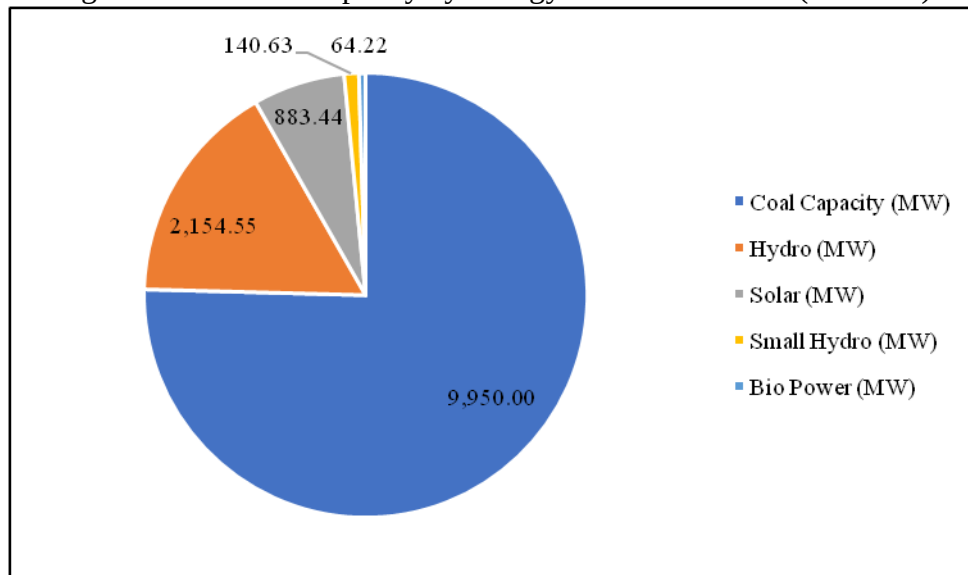


Source: NITI Aayog. (2025). India Climate & Energy Dashboard (ICED): Odisha State Report

Figure 2 further highlights the state's current energy mix in 2025–26, revealing that coal-based power accounts for 9,950 MW, or approximately 75.4% of the total installed capacity of 13,192.84 MW. Among renewable energy sources, hydropower contributes the largest share (2,154.55 MW), followed by solar power (883.44 MW), while small hydropower and bio-power account for relatively modest capacities. Although renewable

energy has expanded steadily over the past decade, it still contributes less than one-quarter of Odisha's installed capacity. Overall, the figures suggest that renewable energy is currently complementing rather than replacing conventional coal-based generation. Odisha's energy transition is therefore progressing gradually, and realizing the state's substantial untapped renewable resource potential will require continued investments in renewable energy deployment, grid modernization, energy storage, and supporting infrastructure to reduce long-term dependence on coal and promote a more sustainable energy system (International Energy Agency [IEA], 2021; Central Electricity Authority [CEA], 2024; NITI Aayog, 2023).

Figure 2: Installed Capacity by Energy Source in Odisha (2025–26)



Source: NITI Aayog. (2025). India Climate & Energy Dashboard (ICED); Odisha State Report

5. Policy Perspective

The renewable energy transition in Odisha is guided by a combination of national clean energy policies and state-level initiatives that seek to accelerate renewable energy deployment, strengthen energy security, attract private investment, and promote sustainable industrial development. Over the past decade, India has introduced several policy interventions to expand renewable energy capacity and achieve its climate commitments. Complementing these efforts, the Government of Odisha has adopted state-

specific policies that leverage the state's abundant renewable energy resources while supporting economic growth and industrial competitiveness (Government of Odisha, 2022; Ministry of New and Renewable Energy [MNRE], 2024).

5.1 National Renewable Energy Policy Framework

India's renewable energy transition has been driven by several flagship national initiatives. The Jawaharlal Nehru National Solar Mission (JNNSM) laid the foundation for India's large-scale solar expansion by promoting utility-scale and rooftop solar projects. Since its launch, the mission has contributed significantly to India's emergence as the world's third-largest solar market, with cumulative installed solar capacity exceeding 110 GW by 2025 (International Renewable Energy Agency [IRENA], 2025; MNRE, 2025).

Similarly, the Green Energy Corridor Programme has strengthened interstate and intrastate transmission infrastructure to facilitate renewable energy integration, although further transmission expansion remains necessary in renewable-rich states such as Odisha (Central Electricity Authority [CEA], 2024). The PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) scheme has promoted decentralized renewable energy through solar-powered irrigation pumps and small solar power plants, improving rural energy access while creating additional income opportunities for farmers (MNRE, 2024).

Another important initiative is the National Green Hydrogen Mission, launched in 2023 to establish India as a global hub for green hydrogen production. The mission encourages investments in electrolyser manufacturing, renewable energy capacity, and green industrial development, creating significant opportunities for industrial states such as Odisha (Government of India, 2023; MNRE, 2024).

India has also made substantial progress towards its broader climate commitments. By 2025, the country had installed approximately 262 GW of non-fossil fuel electricity capacity, accounting for more than half of its total installed electricity capacity. These achievements indicate that India remains broadly on track to achieve its target of 500 GW

of non-fossil fuel installed electricity capacity by 2030 (Government of India, 2022; MNRE, 2025).

5.2 Odisha Renewable Energy Policy, 2022

To complement national initiatives, the Government of Odisha introduced the Odisha Renewable Energy Policy, 2022, which serves as the state's primary policy framework for renewable energy development. The policy seeks to accelerate investments in solar, biomass, small hydropower, floating solar, green hydrogen, and energy storage technologies while promoting private sector participation and enhancing energy security (Government of Odisha, 2022).

Since its introduction, Odisha has recorded steady growth in renewable energy capacity, particularly in solar power. Several utility-scale solar parks, floating solar projects and pumped storage initiatives have entered various stages of planning and implementation. The policy also emphasizes decentralized renewable energy systems, industrial decarbonization, and renewable energy-based manufacturing to support sustainable economic development (Government of Odisha, 2023).

5.3 Institutional Framework and Investment Promotion

The implementation of renewable energy programmes in Odisha is coordinated primarily by the Odisha Renewable Energy Development Agency (OREDA), the state's nodal agency for renewable energy and energy efficiency. OREDA has expanded rooftop solar installations, solar street lighting, solar irrigation pumps, decentralized renewable energy systems, and rural electrification programmes, particularly in remote and tribal regions.

To encourage investment, the state government provides land facilitation, electricity duty exemptions, support for grid connectivity, and investment promotion measures for renewable energy developers. The policy framework also promotes public-private partnerships and seeks to attract domestic and foreign investment in renewable energy infrastructure (Government of Odisha, 2022; MNRE, 2024).

5.4 Alignment with India's Clean Energy and Climate Goals

Odisha's renewable energy strategy is closely aligned with India's broader commitments to sustainable development, energy security, and climate change mitigation. The state's emphasis on renewable energy expansion, green hydrogen production, pumped storage, and energy storage technologies supports national objectives of reducing fossil fuel dependence and decarbonizing energy-intensive industries such as steel, aluminium, and mining (Government of India, 2022; NITI Aayog, 2023).

By leveraging its abundant renewable resources and industrial strengths, Odisha has the potential to become an important renewable energy hub in eastern India while contributing significantly to India's clean energy transition.

5.5 Policy Implementation Challenges

Despite considerable policy progress, several implementation challenges continue to constrain renewable energy development in Odisha. Land acquisition issues, financing constraints, transmission bottlenecks, inadequate energy storage infrastructure, and administrative delays remain major barriers to large-scale renewable energy deployment. In addition, the state's continued dependence on coal-based industries presents challenges for balancing industrial growth with long-term decarbonization objectives (International Energy Agency [IEA], 2021; NITI Aayog, 2023).

Strengthening institutional coordination, accelerating transmission and storage investments, simplifying regulatory procedures, and encouraging greater private sector participation will therefore be essential for achieving Odisha's renewable energy targets.

6. Opportunities

Odisha's renewable energy transition presents significant opportunities to advance economic development, environmental sustainability, industrial competitiveness, and energy security. With abundant renewable resources, a strong industrial base, and supportive policy initiatives, the state is well positioned to become a major renewable

energy hub in eastern India while contributing to India's clean energy and climate objectives (Government of Odisha, 2022; International Energy Agency [IEA], 2021; NITI Aayog, 2023).

6.1 Lower Carbon Emissions and Environmental Sustainability

Expanding renewable energy can substantially reduce greenhouse gas emissions and local air pollution by decreasing reliance on coal-based power generation. Greater deployment of solar, biomass, small hydropower, and future wind energy can help Odisha meet India's climate commitments while improving air quality in industrial and mining regions. Reduced emissions of carbon dioxide, sulphur dioxide, nitrogen oxides, and particulate matter can also lower pollution-related health risks and enhance environmental sustainability (IEA, 2021; Ministry of New and Renewable Energy [MNRE], 2024; World Health Organization [WHO], 2021).

6.2 Strengthening Energy Security

Renewable energy provides an opportunity to diversify Odisha's electricity mix and strengthen long-term energy security. Expanding decentralized renewable energy systems—including solar photovoltaic, biomass, and small hydropower—can improve electricity access in rural and tribal areas while reducing dependence on fossil fuels and increasing resilience to fuel price volatility and climate-related disruptions (Government of Odisha, 2022; IEA, 2021; NITI Aayog, 2023).

6.3 Employment Generation and Green Investment

Renewable energy can generate employment across manufacturing, installation, operation, maintenance, and research while attracting investment into solar manufacturing, battery storage, electrolyzers, and green hydrogen industries. Odisha's industrial base, ports, and manufacturing ecosystem provide favourable conditions for developing renewable energy value chains, thereby supporting industrial diversification,

technological innovation, and regional economic growth (Government of Odisha, 2023; International Renewable Energy Agency [IRENA], 2023).

6.4 Rural Development and Industrial Competitiveness

Decentralized renewable energy systems, including solar mini-grids, rooftop solar, biomass-based generation, and solar-powered irrigation, can improve electricity access, agricultural productivity, and livelihood opportunities in rural and tribal communities. At the same time, greater use of renewable energy can help energy-intensive industries such as steel, aluminium, and mining reduce carbon emissions, improve energy efficiency, and enhance competitiveness in an increasingly low-carbon global economy (IEA, 2021; MNRE, 2024).

6.5 Green Hydrogen and Energy Storage

Emerging technologies such as green hydrogen and energy storage present new opportunities for Odisha's energy transition. The state's industrial base, renewable energy resources, and port infrastructure provide favourable conditions for green hydrogen production, particularly for decarbonizing steel, fertilisers, and other energy-intensive industries. Similarly, investments in battery energy storage systems and pumped hydro storage can enhance grid flexibility, improve renewable energy integration, and support a more reliable and resilient electricity system (Central Electricity Authority [CEA], 2024; MNRE, 2023).

7. Challenges

Despite Odisha's considerable renewable energy potential, the transition towards a cleaner energy system faces several structural, infrastructural, financial, environmental, and institutional challenges. The state's long-standing dependence on coal-based industries, combined with transmission constraints, financing gaps, land-use conflicts, and implementation bottlenecks, continues to slow renewable energy deployment. Addressing

these barriers will be essential for achieving a balanced, secure, and socially inclusive energy transition (Government of Odisha, 2022; International Energy Agency [IEA], 2021; Ministry of New and Renewable Energy [MNRE], 2024; NITI Aayog, 2023).

7.1 Coal Dependence and Just Transition

Odisha's continued dependence on coal remains one of the most significant barriers to its renewable energy transition. As one of India's largest coal-producing states, Odisha has developed an extensive coal-based electricity and industrial system that supports major sectors such as steel, aluminium, mining, and manufacturing, contributing substantially to employment, exports, and state revenues (Central Electricity Authority [CEA], 2024; Ministry of Coal, 2024). While this industrial structure has supported economic growth, it also creates strong path dependency, making the transition to renewable energy economically and politically complex (Government of Odisha, 2023; IEA, 2021).

The transition also raises important social and equity concerns. A rapid shift away from coal could affect workers, coal-dependent communities, and regional economies unless accompanied by workforce reskilling, livelihood diversification, and social protection measures. At the same time, renewable energy projects may create new social challenges related to land acquisition and benefit sharing. Therefore, adopting a just transition approach that combines economic diversification, stakeholder participation, and inclusive policy planning will be essential for ensuring that the benefits of clean energy are shared equitably (International Labour Organization [ILO], 2022; Government of Odisha, 2022; NITI Aayog, 2023).

7.2 Land Acquisition and Environmental Constraints

Land acquisition remains a major challenge for renewable energy development in Odisha. Utility-scale solar parks, wind projects, and associated transmission infrastructure require substantial land resources, often competing with agriculture, forests, industrial development, and human settlements. In forested and tribal regions, renewable energy

projects may encounter resistance due to concerns regarding land rights, livelihood displacement, and ecological conservation (Government of Odisha, 2022; MNRE, 2024).

Furthermore, project siting is constrained by environmental regulations, forest clearance requirements, and biodiversity considerations. Inadequate planning may result in habitat fragmentation and adverse impacts on ecologically sensitive areas, highlighting the need for environmentally responsible site selection and stakeholder engagement (Intergovernmental Panel on Climate Change [IPCC], 2022; Ministry of Environment, Forest and Climate Change [MoEFCC], 2023).

7.3 Grid Integration and Infrastructure Constraints

Renewable energy expansion in Odisha is constrained by inadequate transmission infrastructure, limited grid flexibility, and insufficient energy storage capacity. Although the state possesses significant renewable energy resources, transmission bottlenecks and limited evacuation infrastructure restrict the efficient integration of renewable electricity, particularly in resource-rich but remote regions (Central Electricity Authority [CEA], 2024; IEA, 2021).

In addition, the limited deployment of smart grid technologies, battery energy storage systems, and pumped storage facilities reduces the power system's ability to integrate variable renewable energy. Strengthening transmission networks, expanding storage capacity, and modernizing grid infrastructure will therefore be essential for ensuring reliable and secure renewable energy integration (Ministry of Power, 2024; NITI Aayog, 2023).

7.4 Financing and Policy Implementation

Financial and institutional constraints continue to hinder renewable energy development in Odisha. Renewable energy projects require substantial upfront investment, while high financing costs, limited access to affordable credit, and delays in subsidies, regulatory

approvals, and power purchase agreements increase project risks and discourage private investment (International Renewable Energy Agency [IRENA], 2023; IEA, 2021).

Although both the central and state governments have introduced supportive policies and financial incentives, implementation challenges—including administrative delays, fragmented institutional coordination, regulatory complexity, and limited monitoring capacity—continue to slow project execution. Strengthening institutional capacity, improving policy coordination, and creating a more predictable investment environment will therefore be essential for accelerating renewable energy deployment (Government of Odisha, 2022; NITI Aayog, 2023; World Bank, 2022).

8. Conclusion and Policy Recommendations

The renewable energy transition presents Odisha with a significant opportunity to achieve sustainable economic growth while improving energy security and reducing environmental impacts. The analysis indicates that the state possesses abundant renewable energy resources, particularly in solar energy, complemented by considerable potential in hydropower, biomass, floating solar and emerging technologies such as green hydrogen. Despite steady growth in renewable energy capacity over the past decade, coal continues to dominate the state's electricity generation, reflecting Odisha's historical dependence on coal-based industries and thermal power infrastructure. Consequently, the state's energy transition remains gradual, with renewable energy currently complementing rather than replacing conventional sources (Government of Odisha, 2022; International Energy Agency [IEA], 2021; Ministry of New and Renewable Energy [MNRE], 2024).

The study further shows that while Odisha has established a supportive policy framework through the Odisha Renewable Energy Policy, 2022, several structural constraints continue to limit renewable energy deployment. These include dependence on coal, inadequate transmission infrastructure, financing constraints, land-use challenges, and implementation bottlenecks. Addressing these issues will be critical for enabling a secure, resilient, and inclusive transition that aligns with India's renewable energy and climate commitments (NITI Aayog, 2023).

To accelerate this transition, several policy measures merit priority. First, Odisha should invest in transmission corridors, smart grids, battery energy storage systems, and pumped hydro projects to facilitate the large-scale integration of renewable energy into the electricity network (Central Electricity Authority [CEA], 2024; IEA, 2021). Second, renewable energy deployment should be supported through integrated land-use planning, environmentally responsible project sitting, and effective stakeholder consultation to minimize ecological impacts and social conflicts (Intergovernmental Panel on Climate Change [IPCC], 2022; MNRE, 2024). Third, strengthening the investment climate through stable policies, streamlined approval procedures, public-private partnerships, and greater access to green finance can encourage private investment and accelerate the deployment of both utility-scale and decentralized renewable energy systems (International Renewable Energy Agency [IRENA], 2023; World Bank, 2022).

The transition should also be guided by the principles of a just transition. Workforce reskilling, livelihood diversification, social protection measures, and investments in renewable energy manufacturing and green industries will be essential for supporting coal-dependent communities while ensuring that the socioeconomic benefits of the clean energy transition are shared equitably (International Labour Organization [ILO], 2022; IRENA, 2023). Finally, strengthening institutional coordination, improving policy implementation, and enhancing regulatory efficiency will be crucial for translating policy objectives into timely project execution and sustained renewable energy growth (Government of Odisha, 2022; NITI Aayog, 2023).

Overall, Odisha possesses the natural resources, industrial capabilities, and policy foundations necessary to emerge as a leading renewable energy hub in eastern India. Realizing this potential will require sustained investments in renewable energy infrastructure, supportive governance, technological innovation, and inclusive development policies. By adopting an integrated approach that balances economic growth, environmental sustainability, and social equity, Odisha can make a significant contribution to India's long-term energy security and low-carbon development objectives (Government of India, 2022; IEA, 2021).

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A Critical Analysis of Population Growth: Through the Lens of Economic Growth

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Abstract

Various social scientists, philosophers, and economists believe that high population growth is an obstacle to economic growth. Population growth is often viewed negatively in the context of economic growth in developing countries. However, the alarming decline in total fertility rate (TFR) and ageing population in developed countries have changed the perspectives of nations' leaders and economists on the relationship between population growth and economic growth. At present, population growth is essential for developed countries to maintain their existing status. In these countries, many leaders and economists have advocated for increasing population growth to protect their economic security. Based on the data from the World Bank and the Population Reference Bureau, this paper critically analyses population growth through the lens of economic growth. It is found that countries with large populations are experiencing steady economic growth, and developed countries are experiencing concerning economic growth due to a decline in total fertility rates.

Keywords: Total Fertility Rate, Population Growth, Economic Growth and Macroeconomic Issues.

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1. Introduction

The relationship between population and economic growth, as explained by economists, social scientists, and others, has not been concluded in a unanimous answer. Their views on the relationship found dissimilarity in many aspects. Robert Malthus (1798) delineated the relationship between population growth and food supply. He stated that the population grows at an exponential rate and the food supply grows at a linear rate. In the 19th century, the Neo-Malthusians supported his theory. Neo-Malthusians are a group of thinkers and academicians who believe in the Malthusian proposition but disagree with his ideas on controlling measures. Neo-Malthusian warned that the depletion of fertile agricultural land, coal and iron would create a crisis for future generations (Alier & Masjuan, 2004). Jane Goodall, a renowned primatologist, opined that the environmental problem would not be a problem if the present population size were equal to the population size of 500 years ago (Follett, 2020). Malthus' population theory has various practical implications in the world. For instance, China adopted the one-child policy in 1979 to control its population growth, and India adopted the National Population Policy 2000 regarding responsible family planning, improving reproductive and child health care and ensuring access to contraception. Malthusian population theory postulated population growth in a negative sense. David Ricardo (1815) also stated that the marginal productivity of labour decreases with the increase in the number of labourers employed. He applied the law of diminishing returns, particularly to the determination of rent. Today, the world is experiencing different situations as far as the relationship between population and economic growth is concerned. The Demographic Transitions Theory (Thompson, 1929; Notestein, 1945) relates birth rate and death rate with time, and it brings the connection between population growth and developmental stages. The Optimum Population Theory (Cannan, 1924) polished Malthusian Population Theory and was later popularised by Robbins, Carr-Saunders and Dalton. According to Dalton, "the population with the highest per head income is the optimum population". The theory elucidates the overpopulation, which reduces income per head in society. Both Malthus and Ricardo have pessimistic views on the growing population. The Optimum Population Theory advances an optimistic view up to a certain level of population. Still, after the optimum population, it turns towards a pessimistic view on the growth of the population. The Demographic Transitions Theory clearly states that the developed stage of economies

always has low population growth. However, it doesn't argue for the requirements of population growth after reaching the developed stage.

Economic growth needs a sizeable population to raise aggregate demand. A higher population with high per capita income can drive the growth wheel by boosting aggregate demand. Economic growth requires a workforce that can work with capital. Joseph Schumpeter (1911) advocated for innovation to boost economic growth. Innovation originates from a skilled workforce or human capital. Sufficient human capital leads to innovation, and this innovation drives economic growth. Countries with larger working-age populations have greater potential for economic growth. The Mercantilists (16th to 18th century in Europe) were in favour of population growth for the development of trade. The Physiocrats, 18th-century French Enlightenment thinkers, also believed that the population was a source of strength (Lokanathan, 2009). However, they also relate the growth of the population to the growth of misery. Greek Philosophers, Plato and Aristotle (Lianos, 2022), believed that there is a direct relationship between population and poverty. Both of them agree that a limited population is essential for a happy life in society. The researchers have interpreted the relationship between population growth and economic growth in different ways. But the existing literature has not discussed on the concerning decline in total fertility rate of developed countries; therefore, this study delves into the relationship between population and economic growth through a critical lens.

Given this background, the objective of this paper is to analyse population growth alongside economic growth and to examine the population scenario in developed countries. It is descriptive and explores the past evidence through the literature in connection with population growth and economic progress, by highlighting different population theories. The paper's arguments are supported by statistical tools, such as line graphs and bar diagrams, with data taken from secondary sources, such as the World Bank and the Population Reference Bureau.

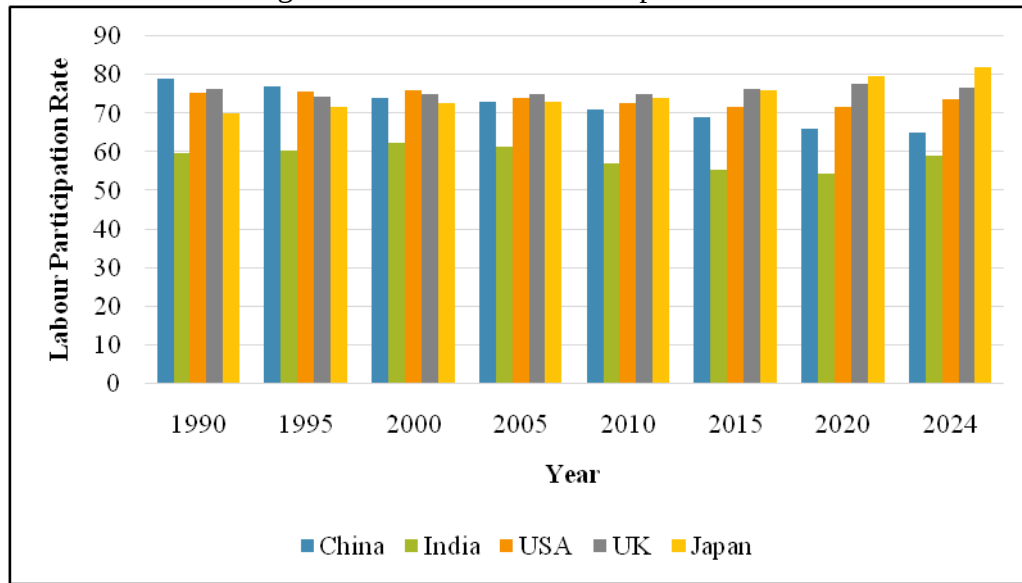
2. Population in the Journey of Economic Growth

A sizable population is crucial for economic growth. To some extent, the large size of the population can be considered as strength for economic growth. The large size of the population supplies cheap labourers to firms on the one hand, and they boost aggregate demand on the other hand. A larger population leads to economies of scale, specialisation and a younger demographic structure (Atanda et al. 2012). China, the most populous country in the world before 2023, has experienced a large population size in its development journey. Likewise, India, the most populous country in the world, 145.09 crore as per the World Bank data (2024), has witnessed its large population size on its development trajectory. The large size of the labour force contributes to the growth of GDP, which has been witnessed in many countries, including China and India. Even in the United States of America, the economic strength depends on the skilled labour force migrated from other developing countries through the H-1B visa. Immigration through the H-1B visa has lowered prices, increased the IT output and substantially increased the profits of firms (Bound et al., 2017).

Labour force participation is crucial for economic growth. The developed countries have a high labour participation rate, which indicates the necessity of the population in the economic growth journey. Figure 1 shows the labour force participation rate of India, China, Japan, the UK and the USA. The labour force participation rates of China, the USA, the UK and Japan are high, and it clearly indicates how developed countries are using their population in productive activities for economic growth. More labour force participation means more economic contribution to the nation.

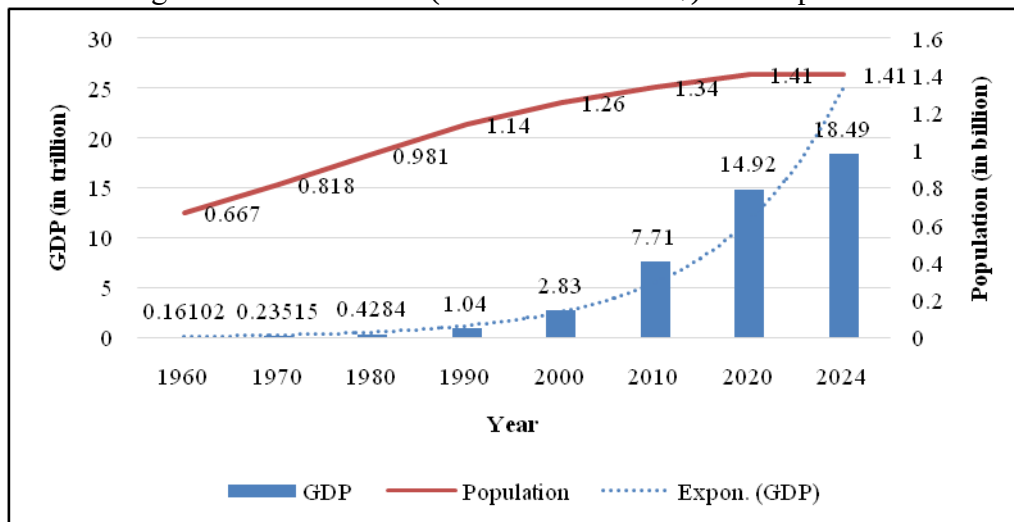
The world's two most populous countries, China and India, are the second and the fifth largest economies in the world in 2025. Both countries have great potential to surpass other developed countries in the coming year. Figure 2 shows China's GDP and the size of its population since 1960. The left vertical axis measures its GDP, and the right vertical axis measures population size. It is shown that China's GDP was 18.49 trillion dollars in 2024. China could use its human resources along with technological advancement. Its growth rate has changed drastically since the 1990s. During the period 1978-2008, its human capital stock increased by 7.6% annually and it contributed 33.2% to its economic growth (Whalley & Zhao, 2010).

Figure 1: Labour Force Participation Rate



Sources: World Bank (n.d.), World Bank Open Data, 2025

Figure 2: China's GDP (Constant 2015 US\$) and Population

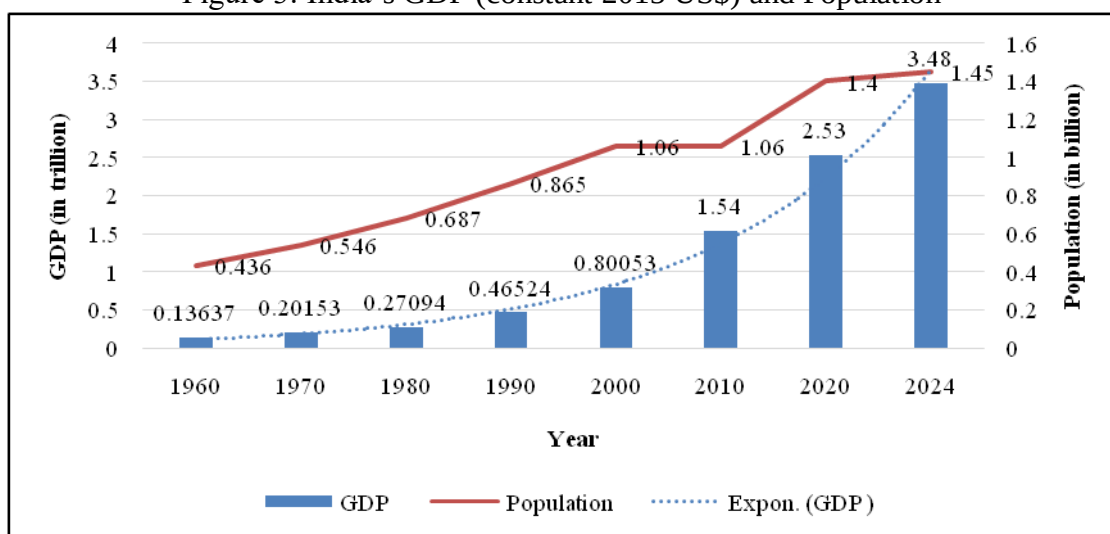


Source: World Bank (n.d.), World Bank Open Data, 2025

China's GDP has increased exponentially since its economic reforms, and its large population has witnessed this growth journey. In China, the population size was seen increasing until 2020, even though it has not moved in parallel with GDP growth. Figure 3 shows India's GDP and population since 1960. India's GDP is 3.48 trillion dollars in 2024, and it is one of the fastest-growing economies in recent times. Its GDP growth rate has increased speedily since the implementation of its economic reforms in 1991. The policies of Liberalisation, Privatisation and Globalisation (LPG) adopted in 1991 have had a good impact on its economic health (Uppal, 1993; Aiyar, 2016; Monga & Batra,

2019). According to World Bank data, India is the most populous country in the world, and like China, its population has witnessed steady GDP growth. Hence, even though much of the existing literature viewed the population as an obstacle to economic growth, its undeniable positive role cannot be ignored. It might be true that high population growth can be an obstacle to economic growth, but it is also true that a sizable population is needed for a country to maintain growth and national security.

Figure 3: India's GDP (constant 2015 US\$) and Population



Source: World Bank (n.d.), World Bank Open Data, 2025

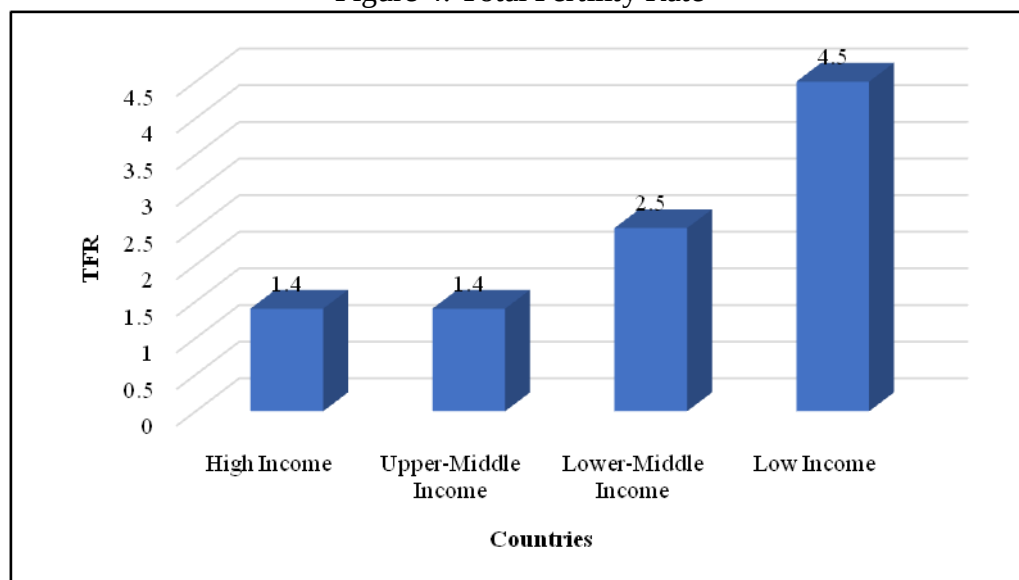
3. Scenario of Population in Developed Countries

The population fertility rate indicates the population growth scenario of a country. A high total fertility rate indicates a high population growth rate, while a low fertility rate indicates an ageing population, which reduces the labour force for productive activities. As per the Population Reference Bureau, 2024 data, the total fertility rate (TFR) of high-income (developed) and upper-middle-income countries is 1.4 per woman, which is much lower than the replacement level fertility rate of 2.1 per woman. The fertility rate of high-income or developed and upper-middle-income countries has become a concern. Because of an ageing population, these countries are obliged to depend on migrant labour forces for expanding and maintaining their economic activities. The total fertility rate of low-income countries is high, that is, 4.5 per woman (World Reference Bureau, 2024). Figure

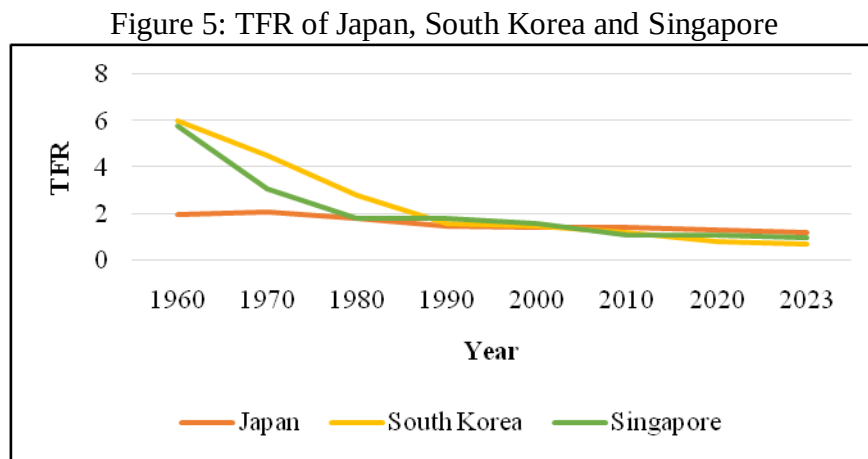
4 shows the Total Fertility Rate of High Income, Upper-Middle Income, Lower-Middle Income and Low-Income countries.

The TFR of some of the developed countries is much lower than the average TFR of developed countries. For instance, Japan's TFR was 1.15 per woman in 2024, and its decreasing fertility rate seems a worry for the nation. Japan's population is the world's oldest, with its median age 48.4 years (IMF, 2020). Japan's Ex-Prime Minister, Shigeru Ishiba, described Japan's ageing population as a "quiet emergency" (BBC News, 2025). The TFR of Singapore was 5.8 per woman in 1960, and it decreased sharply till 1980. According to the Dept of Statistics, Singapore, its TFR is 0.97 live births per woman in 2024, which is lower than Japan's TFR. One of the advanced or developed countries, South Korea, is also facing a demographic crisis, with a TFR of 0.65 live births per woman in 2023, and it is the lowest globally (Kin, J. K., 2025). Its TFR was 6 per woman in 1960, and since then it has been fallen gradually. Figure 5 shows the TFR of three developed countries of Asia. All these three developed countries have been experiencing depopulation.

Figure 4: Total Fertility Rate



Source: Population Reference Bureau, 2024



Source: World Bank (n.d.), World Bank Open Data, 2025

Depopulation in advanced countries is now a major challenge to the economic and social health of nations. “Fewer births and smaller populations naturally mean fewer workers, fewer savers and spenders, potentially sending an economy into contraction” (Bloom, Kuhn & Prettnner, 2025). Myrdal & Myrdal (1934) argued that “Sweden is faced with a population crisis due to declining birth rates”. The declining fertility rate in high-income and upper-middle-income countries is a big macroeconomic concern. Bloom et al. (2023) stated that the fertility decline has both demand and supply effects at the macroeconomic level. The shortage of labour supply on the supply side and the reduction of consumption expenditure on the demand side will have repercussions on investment expenditure. China, which has experienced rapid population growth during its economic growth, is also facing challenges in recent years. Its TFR is only 1.0 per woman. Muir et al. (2024) stated that a declining workforce is projected to lower potential growth sustainability in the long run.

4. Conclusion

In the growing stage of nations, many social scientists, philosophers and economists argued for the control of population growth. Population growth is viewed in a negative sense as far as economic growth is concerned. Many countries have adopted population control measures to stabilise economic growth. Population growth is considered a major macroeconomic problem in the developing stages of nations. However, recently, the

shrinking population in developed countries has been seen as a threat to the nations. The threat is perceived in social, economic and defence security. Many nations' leaders, economists and social scientists have advocated for increasing family members. Some developed countries have already taken some initiatives to have more children. For instance, Finland, Greece, Hungary, South Korea, Japan, etc. have taken pro-natalist policies to have more children (Fleming, 2020; Choo & Jales, 2021; King, 2026). The decreasing fertility rate and ageing population have created concerns in many developed countries like shortage of labour supply, dependence on migrant labourers, security of the aged population, etc.

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Key Concepts in Measuring Productivity and a Review of Estimation Techniques for India

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Abstract

Productivity measures relate an index of output to an index of inputs. Measuring total factor productivity (TFP), however, is a complex exercise. Because it is important to understand these complexities, this paper sets out some key concepts in defining and measuring productivity, together with the various methodologies that have been used in the literature to measure it. Further, since the estimation of TFP is itself a complex process, the paper presents an extensive review of the methodologies employed in estimating TFP. It emerges from the review that there is no clear-cut and straightforward way to measure productivity. While there is ambiguity relating to the labour measure, the perpetual inventory method is the most commonly used way of measuring capital. For firm-level studies, semi-parametric techniques emerge as the most popular techniques for estimating TFP.

Keywords: Review, Total Factor Productivity, estimation techniques

1. Introduction

A well-acknowledged fact is that economic growth is the result of higher and better resource and technical progress. It is believed by many scholars that improving productivity can lead to a higher standard of living, and hence to improved welfare, in the long run (Balakrishnan and Pushpangadan, 1998; Krugman, 1990). Measuring

productivity has therefore drawn a great deal of attention from researchers, yet the concept remains plagued with issues. This may be because of the existence of a multitude of methods and techniques for measuring productivity.

Given the complexities involved in measuring total factor productivity (TFP), this paper presents some key concepts in defining and measuring productivity and the various methodologies that have been used in the literature to measure it. The paper also presents an extensive review of the methodologies employed in estimating TFP, which has not been attempted in previous literature.

The remainder of the paper is organised as follows. Section 2 discusses the various productivity concepts. Section 3 sets out the alternative approaches and techniques for measuring TFP and TFP growth (TFPG). Section 4 reviews the methodologies used to estimate TFP and TFPG in India. Section 5 discusses the issues involved in measuring output and inputs and reviews the Indian literature on the measurement of these variables. Section 6 summarises the review and concludes.

2. Defining Productivity

2.1 Single Factor Productivity and Total Factor Productivity

Single factor productivity can be defined as an index of output over a single measure of input. Input can be labour- to measure Labour productivity or capital- to measure Capital Productivity. (Multi) Total factor productivity is defined as an aggregate index of output over an aggregate index of inputs. Productivity measures are further classified according to the output measure used, which may be Gross output or value added. Table 1 summarises the various measures of productivity.

The most frequently computed productivity measures are the value-added-based concept of labour productivity, K–L MFP and KLEMS (Krishna et al., 2018). Single or partial measures of productivity provide a powerful tool for measuring factor productivity, especially labour productivity within and across countries. They are, however, sometimes criticised for limitations arising from their sensitivity to changes in factor intensities and to economies of scale.

Table 1: Various Measures of Productivity

Inputs → Measure of output ↓	Labour (L)	Capital (K)	Capital and Labour (K, L)	Capital, Labour, Energy, Materials and Services (KLEMS)
Gross output (GO)	Labour productivity	Capital productivity	Capital-labour multifactor productivity, or K-L MFP	KLEMS multifactor productivity
Value added (VA)	Labour productivity	Capital productivity	Capital-labour multifactor productivity, or K-L MFP (VA)	–
	Single factor productivity measures		Multi (total) factor productivity measures	

Source: Schreyer and Pilat (2001)

Total factor productivity, seeks to overcome the problem of changing factor intensities by measuring productivity as an index of aggregate output over an index of inputs used in production. As stated in Kathuria et al., 2013, “TFP is a broader measure of productivity, as it decomposes changes in production into changes in the quantity of inputs used and changes in all other factors such as technology, quality of factors of production and capacity utilisation”.

Total factor productivity may be measured in levels and in growth terms. TFP is analysed as an increase in output which is not due to an increase in inputs. Similarly, total factor productivity growth (TFPG) can be analysed as growth in output that is not accounted for by growth in inputs.

2.2 Technical Change-Embodied and Disembodied

Defining and measuring TFP and TFPG have been subjects of extensive discussion and debate in the past. The terms technical change or efficiency and technological change or progress are often used to describe TFP and TFPG. Following Mahadevan (2003), TFP and TFPG can be defined as:

$$\begin{aligned}
 TFP / TFPG &= \text{technical or technological change (progress)} \\
 &= \text{embodied technical change} + \text{disembodied technical change} \\
 &= \text{technical efficiency} + \text{technological progress}
 \end{aligned}
 \tag{1}$$

Embodied technical change refers to the improvements in productivity that arises from the adoption of new technologies and efficient capital utilisation. This concept is considered endogenous because it is influenced by internal factors such as the following.

- **Learning by doing:** as producers gain experience, they become more proficient, leading to enhanced productivity.
- **Advances in applied technology:** innovations in technology can lead to better tools and processes, allowing for more efficient production methods.
- **Managerial efficiency:** improved management practices can optimise resource allocation and enhance productivity.
- **Industrial organisation:** changes in organisational structure can lead to better coordination and efficiency within production processes.

The primary outcome of embodied technical change is that it enables producers either to increase output with the same level of inputs or to maintain output while reducing the quantity of inputs required. This shift results in a movement towards the production frontier, which represents the maximum output achievable with a given set of resources. Embodied technical change is therefore crucial for economic growth and for enhancing competitiveness across industries.

Disembodied technical change, by contrast, is not embodied in factor inputs. It is exogenous and leads to an expansion of the production frontier itself, owing to technological progress arising from increases in knowledge in the art of production, which may occur through research, innovation and development (Mahadevan, 2003).

There was a debate in the earlier literature over whether total factor productivity should be defined as embodied or disembodied technological progress. While Tinbergen (1942) and Solow (1957) characterised total factor productivity as disembodied technical change, Solow (1960) interpreted TFP as embodied technical change.

2.3 Origins of the Concept

The origin of the concept of TFP goes back to the 1940s and was based on the circular income flow model. The growth accounting technique was largely used in the early literature to estimate some index of TFP (Stigler, 1947; Abramovitz, 1956). Solow, however, made the technique popular by linking it and index numbers with the production function.

3. Approaches to Measuring TFP and TFPG

There are two primary methods to measure TFP and TFPG: the frontier and the non-frontier method. Each is discussed in turn below.

3.1 The Frontier Method

The frontier method focuses on the best-performing firms or units, using them as a benchmark for efficiency. It identifies the production frontier and measures how far other firms lie from that frontier. The frontier measure of TFP or TFPG is therefore the sum of technological progress, represented by outward shifts of the production frontier, and technical efficiency, as reflected in movements towards the production frontier. Techniques used in the frontier method are as follows.

- **Parametric techniques.** These methods assume a specific functional form for the production function.
 - **Stochastic frontier analysis (SFA):** incorporates random errors as well as inefficiencies, allowing for statistical noise in the estimation.
 - **Deterministic frontier analysis:** assumes no statistical noise, focusing solely on inefficiencies.
- **Non-parametric techniques.** These methods do not assume a specific functional form.

- **Data envelopment analysis (DEA):** a linear programming approach which uses the input–output ratios to calculate the relative efficiency of decision-making units.

3.2 The Non-Frontier Approach

The non-frontier method does not focus solely on the best performers but instead examines average productivity and its changes over time. It assumes that firms are technically efficient and hence considers only shifts of the production frontier, or technological progress, as a measure of total factor productivity growth. Techniques used in non-frontier method are as follows.

- **Parametric techniques.** These methods also assume a specific functional form but do not focus on the frontier. Examples include the Cobb–Douglas production function and the translog production function.
- **Semi-parametric techniques.** These methods combine parametric and non-parametric approaches, allowing for greater flexibility. An example is the Levinsohn–Petrin (LP) methodology.
- **Non-parametric techniques.** These are similar to those used in the frontier approach but focus on average rather than best-practice productivity.

The frontier method was used for industry- and firm-level studies, whereas the non-frontier method was used to measure productivity at the economy level in the early literature. However, as disaggregated data have become available, non-frontier techniques are increasingly being used for sectoral and industrial studies. Indian studies have mainly used growth accounting techniques for productivity estimation in the past, with the recent focus now shifting to semi-parametric techniques (Mahadevan, 2003).

3.3 Explaining the Three techniques of Estimation

Both the frontier and the non-frontier approaches allow for parametric as well as non-parametric estimation. The parametric technique estimates a specific model econometrically and, because it assumes underlying statistical properties of the parameters, it permits statistical testing of the selected model. Choosing correct functional model is therefore important in parametric estimation, as model mis-specification can lead to errors in the findings.

Parametric estimations technique require that the in OLS regressions, variables on the right containing the inputs be exogenously determined, that is, not dependent on the productivity level of the firm. Inputs however, are not independently determined, as they are generally chosen by producers on the basis of the firm's level of productivity. This leads to the problem of simultaneity bias, which arises from the endogeneity between productivity (unobserved productivity shocks) and the choice of inputs by producers.

Traditional methods like fixed effects and instrumental variable estimation help solve the endogeneity issue. Both these techniques have, however, been plagued with problems such as finding appropriate instruments (Van Beveren, 2012). As an alternative, Olley and Pakes (1996) introduced the semi-parametric technique. It was subsequently modified by Levinsohn and Petrin (2003) and Akerberg, Caves and Frazer (2006) and Wooldridge (2009). LP estimation involves two stages: first, identifying the labour coefficient; and second, identifying the capital and materials coefficients. This technique removes the simultaneity bias by introducing a proxy variable to substitute for unobserved productivity (Van Beveren, 2012). Wooldridge introduces a modification to the LP estimator (W-LP) that addresses collinearity through joint generalised method of moments (GMM) estimation. This approach allows for efficient estimation of the parameters of variable inputs such as labour, and for the handling of Auto-correlation and heteroscedasticity of error terms, improving the robustness of the estimates.

Non-parametric methods like DEA and growth accounting techniques have a significant advantage of not imposing any functional form on the model. At the same time they also have the disadvantage that they cannot be validated by statistical tests. More recently, some newer techniques to estimate stochastic frontiers have been developed. These

include techniques such as stochastic DEA and the Bayesian approach that can help overcome a few of the issues relating to statistical testing. The use of these techniques requires extensive computational and programming skills, and hence they have been confined largely to operations research rather than to estimating productivity or productivity growth (Mahadevan, 2003). A few studies have employed the DEA technique for TFP estimation in India, like Raj (2011) and Ray (2002) for the manufacturing sector; Sahoo (2013) for the services (software) sector.

Among the non-frontier techniques, the growth accounting approach is sometimes referred to as the deterministic approach, as the estimator obtained from it does not contain a stochastic term. Statistical estimation of this model is therefore not possible, and usual econometrics techniques cannot be used for the growth accounting model. The non-frontier parametric techniques constitute the econometric approach to measuring productivity. The commonality between the two is that both use a production function as their starting point (Mahadevan, 2003).

3.4 Sensitivity of Estimates to Technique and Data

Despite the multitude of estimators and estimation techniques available for computing productivity, the literature remains inconclusive regarding the best choice of TFP or TFPG measure. There is no single measure that is appropriate or best suited to all situations, and TFP estimates can be sensitive to model specification and measurement error.

Van Biesebroeck (2004), using Monte Carlo simulations, compares the sensitivity of commonly used parametric, semi-parametric and non-parametric techniques for measuring firm productivity to measurement and specification errors. Results show that the GMM estimator is robust in the presence of some technological heterogeneity and high measurement error. With low measurement error, however, the GMM estimator can yield downwardly biased input coefficients. He finds techniques such as DEA and index numbers (non parametric) are robust in the presence of small measurement error, heterogeneous technology and non-constant returns to scale. Van Beveren (2012), in a study of the Belgian food and beverages sector, finds that semi-parametric estimators

perform better than parametric ones, though she also supports the view that the choice of TFP estimator is data sensitive.

4. Review of Methods Used in Estimating Productivity in India

Measuring productivity broadly involves two categories of issue: the methodology used to estimate productivity, and the measurement of output and inputs. The former pertains to selecting a suitable estimation technique. First, the researcher has a choice between frontier and non-frontier techniques. Second, there is a choice between the production function (stochastic frontier or econometric) approach, the non-parametric (deterministic) approach involving the traditional techniques of growth accounting and data envelopment analysis, and the more recent semi-parametric approach. Each technique is itself associated with issues such as sensitivity to measurement error, sample size and the functional form of the production function chosen.¹

Further, parametric techniques are associated with simultaneity bias, and growth accounting techniques rest on the strong assumptions discussed in the previous section. The existence of a multitude of techniques is perhaps the reason behind the inconclusive empirical evidence on productivity estimates. This section reviews the methodologies used to estimate TFP and TFPG in India; Section 5 discusses the issues involved in measuring outputs and inputs and presents a brief review of the Indian studies in this context.

4.1 Methodologies Used in Measuring TFP and TFPG

Productivity in India has been measured extensively at the industry and plant level as well as at the firm level. Typically, the former category of studies has used the Annual Survey of Industries (ASI) database, whereas the latter has used the Prowess database of the Centre for Monitoring Indian Economy (CMIE). A commonly used technique for measuring productivity at the industrial level has been the traditional growth accounting

¹ Kathuria et al. (2011) provide a comparison of the sensitivity of parametric, semi-parametric and non-parametric techniques to these problems.

approach, using index numbers such as the Törnqvist–Theil index (Balakrishnan and Pushpangadan, 2000; Goldar and Kumari, 2003; Tata Services Limited, 2003; Unel, 2003; Das, 2004; Goldar, 2004). Many studies have also applied the DEA approach using the Malmquist index at the industrial and firm level (Ray, 2002; Raj, 2011; Sahoo, 2013).

More recently, the semi-parametric LP approach has been used by many studies at the industrial as well as the firm level, owing to its ability to overcome simultaneity bias and its suitability for panel data estimation (Sivadasan, 2006; Kathuria et al., 2010; Nagraj, 2014; Topalova and Khandelwal, 2011; Kathuria et al., 2013; Goldar et al., 2020, among others). The stochastic frontier approach, though suitable for cross-sectional data, has been modified by Battese and Coelli (1992, 1995) for panel data estimation. Kathuria (2001), Goldar et al. (2004) and Kathuria et al. (2013) apply the stochastic frontier approach to estimate productivity using panel data.

Largely, the focus of these studies has been the formal manufacturing sector, though some recent studies have measured productivity in the informal manufacturing sector (Kathuria et al., 2010, 2013; Raj, 2011; Krishna et al., 2018). Very few studies have attempted to measure productivity for the services sector (Bhattacharya et al., 2012; Sahoo, 2013; Chawla, 2017; Goswami and Narayanan, 2022), employing different methodologies such as the Levinsohn–Petrin method used by Goswami and Narayanan (2022), the DEA technique used by Sahoo (2013) and the stochastic frontier technique used by Bhattacharya et al. (2012).

5. Issues in Measuring TFP and TFPG

Issues pertaining to the measurement of TFP and TFPG fall broadly into two categories: the measurement of output and the measurement of inputs.

5.1 Measurement of Output

Measuring productivity involves creating an index of output. This can be done following two approaches: the gross output approach and the value-added approach. Further, if the

output measure is value added, it needs to be deflated by price indices, which can also be done in two ways: single deflation and double deflation.

5.1.1 Gross Output versus Value Added

Two approaches may be used to derive the output measure: gross-output approach and the value-added approach. The total goods and services produced within a production unit (firm, industry, sector or the entire economy) available for final use are called gross output. Gross output includes the sum of total sales and net additions to inventories.

From the gross output value, if we deduct the value of intermediate inputs purchased, we derive the value added measure. The concept of separability in production functions is crucial for this measure when estimating productivity (Balakrishnan and Pushpangadan, 1998).

Value-added method is preferred over gross output as it prevents double counting of intermediate inputs, and, particularly for inter-industry studies, the estimates obtained from this approach are meaningful indicators of the value added by industries to productivity growth (Schreyer and Pilat, 2001). In addition, inter-firm comparison becomes meaningful in the case of firms using heterogeneous raw materials (Griliches and Ringstad, 1971).

On the other hand, the implicitly maintained hypothesis of separability of the production function has been questioned by many scholars stressing on the meaningfulness of a production function only if material inputs could be separated from the primary ones; their studies employ gross output as the index of output (Balakrishnan and Pushpangadan, 2000; Ray, 2002). Moreover, productivity growth estimates obtained from the value-added measure tend to be higher than those obtained from the gross output approach, as dropping intermediate inputs creates an upward bias.

5.1.2 Single and Double Deflation of Value Added

Value added as the measure of output will be credible only if we can define and derive a measure of real value added. There are two ways of obtaining the same. First when output price index is used to deflate both nominal output and nominal inputs. This is the single deflation method. Alternatively, when output price index is used to deflate the nominal

output while input price index is used as a deflator for nominal inputs, it gives the double deflation method.

The study by Balakrishnan and Pushpangadan (1994) highlighted the importance of, the double deflation method on account of changing relative prices for the Indian manufacturing sector. Since then, many studies have used the double deflation method (Dougherty et al., 2009; Sharma, 2010; Goldar et al., 2020). Owing to the difficulty of compiling a material inputs price deflator index, however, many studies have employed the single deflation method (Unel, 2003; Kathuria et al., 2013).

5.1.3 Measuring Output in the Services Sector

Measuring output for the services sector poses a further challenge to the researcher. Since this sector includes highly diversified services and activities, the nature of its output is not easy to characterise. The problem of simultaneity in production and consumption in services sector, leads to difficulties in measuring output. The issue of measuring output in services thus remains contested (Griliches, 1992). For most Indian studies on the services sector, gross output has been used for measuring TFP (Bhattacharya et al., 2012; Sahoo, 2013; Goswami and Narayanan, 2022).

5.2 Measurement of Inputs

Labour and capital are the two inputs to be estimated. The estimation of both, however, is far from straightforward.

5.2.1 Labour

There are two commonly used methods of measuring labour input. It can be measured in two ways- as the quality-adjusted number of hours actually worked or as a head count of jobs or employees. The former method is deemed the more appropriate measure of labour input, as it accounts for differences in the quality of labour by incorporating characteristics such as sex, education and employment status. One of the major limitations in obtaining this measure is the lack of accurate and consistent data on labour

employment in India.² Krishna et al. (2018) is one of the few studies to classify labour on the basis of education in order to estimate TFPG.

The second measure, the number of employees, has mostly been used in studies of productivity in India, even though it has been criticised on the grounds that it does not include changes in average working time for an employee, self-employment and the quality of labour. The main data source for these studies has been the Annual Survey of Industries (ASI), processed by the Labour Bureau, which provides data on working days, person-days worked, person-hours worked, absenteeism, earnings and social security benefits. However, as the primary unit of enumeration in the survey is the factory (for manufacturing industries) it cannot be used directly for firm-level studies in the absence of firm-level identifiers.

Company-level databases such as Prowess, developed by the Centre for Monitoring Indian Economy, also do not give complete data on the number of employees in a firm. Since disclosure of employment figures is not mandatory for companies in this database, the percentage of companies reporting their number of employees is extremely low; Chawla (2012) reports it to be about 10 per cent. Research on firm-level productivity therefore uses one of three approaches to impute labour: the ASI/CMIE-based approach, the compensation-to-employees approach, and the more recent Lancheros and Girma (2009) approach (Chawla, 2012). As a direct measure of employment is not available for firms, these approaches only suggest substitutes for it. The three measures, as discussed in Chawla (2012), are as follows.

(a) ASI/CMIE-based approach. Obtaining this measure involves two computational steps. First, data on total emoluments and total persons engaged for the relevant year or years at the appropriate two-digit or three-digit level of industry classification are taken from the ASI database, and an average wage rate is computed as emoluments per employee. Second, each firm-year observation on the total wage bill obtained from the

² The India KLEMS research project is a significant initiative aimed at enhancing understanding of the Indian economy through detailed data collection and analysis. The project is supported financially by the Reserve Bank of India and focuses on gathering comprehensive data related to various aspects of labour and productivity, including employment by education level, the wage share in GDP with estimates for self-employed workers, and indicators of labour productivity growth and total factor productivity growth. The data are available for 27 industries of the Indian economy over the period 1980–2011 (Krishna et al., 2018). However, a major gap still exists in employment statistics for firm-level studies in India.

company database is divided by the average wage calculated above to obtain a measure of the firm's employment (the ASI measure). A drawback of this approach is that it cannot be applied to the services industry, as the ASI database is restricted to registered manufacturing industries. Following Chawla (2012), a further measure, referred to here as the CMIE measure, is suggested for the computation of labour; its advantage is that it can be employed to measure labour in the services sector. It also involves two steps. First, compensation to employees is divided by the number of employees for those firms that report them, and an average wage rate is computed from the firm-specific wage rates so obtained. Second, a measure of labour is derived for the remaining firms by dividing compensation to employees by this computed average wage rate.

(b) Compensation-to-employees approach. This approach does not yield the number of employees. Real values of compensation to employees, a measure of labour productivity or quality, are used as a proxy for labour input. Firms' wages and salaries are divided by the respective industries' price index (WPI or CPI). This gives real values which are used as a proxy for labour input (the CPE measure).

(c) Lancheros–Girma approach. A relatively new technique has been proposed by Lancheros and Girma (2009). The elasticity of employment with respect to total assets is calculated by regressing the logarithm of employment on the logarithm of total assets for those firms in Prowess that report the number of employees. This elasticity is then used to estimate employment (the LG measure) for firms that do not report the data. The applicability of this approach is, however, limited in the literature.

Most studies at the industry level use the number of employees from the ASI data. For firm-level studies, both the ASI measure and the CPE measure are employed to impute labour. Prominent studies using the CPE measure include Topalova and Khandelwal (2011), Dougherty et al. (2009) and Topalova (2004). Studies that employ the ASI measure include Balakrishnan and Pushpangadan (2000), Hasan (2002) and Goldar et al. (2020). Nagraj (2014) is one of the few studies to have employed both.

The ASI measure, though the most popular, has the disadvantage that it cannot be applied to the services sector. The CPE measure can be used for both manufacturing and services, but it is at best a substitute measure of labour, reflecting its productivity. Similarly, the

LG measure is an approximation of labour based on the elasticity of employment. Given the advantages and disadvantages of all three measures, none can be considered superior or inferior to the others. Chawla (2012) reviews the ASI, CMIE and LG measures but remains inconclusive as to the best measure for imputing labour.

5.2.2 Capital

Measuring capital is a complex challenge for researchers, primarily because of the nature of capital goods and their services. Capital goods, whether purchased or rented, provide services that contribute to production. However, these services do not always correspond to observable market transactions. When capital goods provide services to their owners, no direct market transaction is recorded, and this lack of market data complicates the estimation of the value of capital services.

To measure capital services, researchers must assign prices to these implicit transactions. Since the actual flows of services are not directly observable, researchers often approximate them which can introduce inaccuracies.

The challenges of measuring capital in the services sector, particularly in relation to intangible capital for which data on depreciation are rare, also present unique difficulties for researchers (Goswami and Narayanan, 2022).

Measuring capital remains one of the most complex issues in productivity analysis, and there is no single universally acceptable way of estimating it. Researchers have applied different techniques to estimate the capital stock. One of the most popular measures is the perpetual inventory method (PIM), which accumulates past capital formation and deducts the value of assets (“scrapping”) that have reached the end of their service lives³. Many studies, including Balakrishnan and Pushpangadan (2000), Goldar et al. (2004) and Goldar et al. (2020), apply PIM to estimate the capital stock.

Alternative method of estimating capital as a stock is by taking book value of fixed assets. However, the book value may not accurately represent the actual physical stock of capital (machines and other equipment). Ray (2002) employs this technique to measure capital,

³ Capital formation and scrapping of assets are re-valued either at current-year prices or at constant prices (OECD, 2001).

acknowledging its imperfections. A summary of the review is presented in Tables 2 and 3.

6. Summary and Conclusion

It emerges from the above review that there is no clear-cut and straightforward way to measure productivity. Both parametric and non-parametric approaches have their own advantages and disadvantages as estimation techniques. Whereas parametric techniques impose a functional form on the model and face the simultaneity issue, non-parametric techniques do not assume underlying statistical properties for the model; unlike parametric techniques, however, non-parametric estimates cannot be validated by statistical testing. TFP estimates are also found to be data sensitive.

In the Indian case, industry-level studies have mainly used the traditional growth accounting techniques based on index numbers, along with DEA and LP techniques. For firm-level studies, semi-parametric techniques, and LP in particular, have emerged as the most popular, which may be due to their advantage in resolving the simultaneity bias between unobserved productivity shocks and input levels that other techniques lack.

Both gross output and value added have been used as measures of output for the Gross output measure scores over the value-added measure as it does not require the assumption of separability of the production function and is hence a more effective measure of output (Balakrishnan and Pushpangadan, 2000).

For estimating labour, industry-level studies have used ASI data, whereas firm-level studies have used both the CPE and the ASI methods. As ASI is a database for industry, it is more suitable for industry and aggregate-level studies, while CPE may be considered the preferred measure of labour for firm-level studies. The perpetual inventory method is used most widely in the literature and is a more robust way of estimating the capital input than the book value of fixed assets.

Table 2: Literature Summary on the Estimation of TFP for India – Industry- and State-Level Studies

Study	Output index	Method to estimate capital	Measure of labour	Estimation approach	Period of study	Sector
Balakrishnan and Pushpangadan (1994)	VA (SD & DD)	PIM	No. of employees (ASI)	GAA (TLI)	1970–89	Formal Mfg
Ray (2002)	GO	BVFA	No. of employees (ASI)	DEA (TLI, MI)	1991–2001	Formal Mfg
Goldar and Kumari (2003)	GO	PIM	No. of employees (ASI)	GAA (TLI)	1981–98	Formal Mfg
Unel (2003)	VA (SD)	PIM	No. of employees (ASI)	GAA (TLI); PFA	1979–98	Formal Mfg
TSL (2003)	GO	PIM	No. of employees (ASI)	GAA (TLI)	1981–2000	Formal Mfg
Goldar (2004)	GO, VA (DD)	PIM	No. of employees (ASI)	GAA (TLI); PFA	1979–2000	Formal Mfg
Das (2004)	GO	PIM	No. of employees (ASI)	GAA (TLI)	1980–2000	Formal Mfg
Sivadasan (2006)	VA (DD)	PIM	No. of employees (ASI)	LP	1986–87 to 1994–95	Formal Mfg
Banga and Goldar (2007)	GO	PIM	No. of employees (ASI)	PFA	1980–81 to 1999–2000 (agg.); 1980–81 to 1997–98 (disagg.)	Formal Mfg
Kathuria et al. (2010)	VA (SD)	Total fixed assets (ASI & NSSO)	No. of employees (ASI & NSSO)	LP	2000–01 to 2004–05	Formal & informal Mfg
Kathuria et al. (2013)	VA (SD)	Total fixed assets (ASI & NSSO)	No. of employees (ASI & NSSO)	SFA; GAA (TLI); LP	1994–95 to 2001–05	Formal & informal Mfg
Raj (2011)	VA (SD)	BVFA	No. of employees (NSSO)	DEA (MI)	1978–2001	Informal Mfg
Goldar (2015)	GO	PIM	No. of employees (ASI)	LP	1999–2000 to 2011–12	Formal Mfg
Krishna et al. (2018)	GO, VA (SD, DD, TI)	PIM	No. of employees (ASI & NSSO)	GAA (TLI)	1980–2011	Formal & informal Mfg

Source: Compiled by the authors. Notes: VA – value added; SD – single deflated value added; DD – double deflated value added; GO – gross output; PFA – production function approach ; GAA – growth accounting approach;; LP – Levinsohn and Petrin methodology; W-LP – Wooldridge-modified LP methodology; TLI – Theil–Törnqvist (translog-Divisia) index; MI – Malmquist index; TI – Törnqvist index; BVFA – book value of fixed assets; PIM – perpetual inventory method; SFA – stochastic frontier analysis; DEA – data envelopment analysis; GMM – generalised method of moments. ASI, CPE, CMIE and LG are methods of imputing labour described in Section 5.2.1.

Table 3: Literature Summary on the Estimation of TFP for India – Firm-Level Studies

Study	Output index	Method to estimate capital	Measure of labour	Estimation approach	Period of study	Sector
Krishna and Mitra (1998)	GO	Net fixed assets	CPE (public sector employee wage rate)	PFA	1986–93	Formal Mfg
Balakrishnan et al. (2000)	GO	PIM	ASI	PFA	1988–98	Formal Mfg
Kathuria (2001)	VA (SD)	PIM	ASI	SFA	1975–76 to 1988–89	Formal Mfg
Hasan (2002)	GO	PIM	ASI	PFA (GMM)	1975–76 to 1986–87	Formal Mfg
Goldar et al. (2004)	VA (SD)	PIM	ASI	SFA	1990–91 to 2000–01	Formal – engineering
Topalova (2004)	GO	PIM	CPE (WPI)	LP	1989–2001	Formal Mfg
Dougherty et al. (2009)	VA (DD)	BVFA	CPE (CPI)	PFA	2004–05	Formal Mfg
Kato (2009)	VA (SD)	PIM	ASI	PFA	1991–92 to 2001–02	Formal Mfg
Lancheros and Girma (2009)	GO	BVFA	LG	LP	1997–2007	Software services & pharmaceutical firms
Sharma (2010)	VA (DD)	PIM	Labour employed	LP	2000–09	Formal Mfg
Das (2011)	GO	Capital employed	Labour employed	LP	2000–08	Formal Mfg
Topalova and Khandelwal (2011)	GO	Capital employed	CPE (WPI)	LP	1987–2001	Formal Mfg
Bhattacharya et al. (2012)	GO	Gross fixed assets net of land and building assets	CPE	SFA	2000–08	Services – software
Das (2013)	GO	PIM	No. of employees (Prowess)	LP; PFA	2008–09 to 2011–12	Formal Mfg
Sahoo (2013)	GO	Expenditure on computer and electronics + operating expenses	LG	DEA (MI)	1999–2000 to 2007–08	Services – software
Nagraj (2014)	GO, VA	PIM	ASI, CPE (CPI)	LP	1989–2008	Formal Mfg
Chawla (2017)	GO (LP), VA (DD, W–LP)	PIM	ASI/CMIE	LP; W–LP	1995–2012	Formal Mfg; services (information & communication); mining and construction
Goldar et al. (2020)	GO, VA (DD)	PIM	ASI	LP	1995–2010	Formal Mfg
Goswami and Narayanan (2022)	GO	PIM	CMIE	LP	2000–14	Services – information technology

Source: Compiled by the authors. Notes: VA – value added; SD – single deflated value added; DD – double deflated value added; GO – gross output; PFA – production function approach; GAA – growth accounting approach; LP – Levinsohn and Petrin methodology; W–LP – Wooldridge-modified LP methodology; TLI – Theil–Törnqvist (translog-Divisia) index; MI – Malmquist index; TI – Törnqvist index; BVFA – book value of fixed assets; PIM – perpetual inventory method; SFA – stochastic frontier analysis; DEA – data envelopment analysis; GMM – generalised method of moments. ASI, CPE, CMIE and LG are methods of imputing labour described in Section 5.2.1.

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Monetary Policy Transmission in India: Evidence from Liquidity, Interest Rates, and Inflation Dynamics

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Abstract

This paper examines the monetary policy transmission mechanism in India using a monthly dataset covering the period from January 2013 to December 2025. The analysis integrates Reserve Bank of India (RBI) liquidity measures, policy rates, government bond yields, crude oil prices, exchange rates, and Consumer Price Index (CPI) data within a unified empirical framework. Augmented Dickey–Fuller tests indicate that all variables are integrated of order one, while residual-based cointegration tests confirm the existence of a stable long-run equilibrium relationship. A sequence of heteroskedasticity-robust regression models is estimated to evaluate the relative importance of alternative transmission channels. The results show that bond yields, oil prices, and exchange-rate movements are significant determinants of inflation, whereas liquidity conditions and repo-rate adjustments exhibit limited direct explanatory power. The findings suggest that monetary policy transmission in India operates primarily through financial-market conditions and external-sector channels rather than through direct policy instruments, highlighting the importance of market-based indicators in assessing inflation dynamics.

Keywords: Monetary Policy Transmission, Bond Yields, Repo Rate, Liquidity Conditions, Exchange Rate Pass-Through, Oil Price Shocks, Inflation Dynamics, India

JEL Classification: E31, E43, E52, E58, C22

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1. Introduction

Monetary policy plays a fundamental role in modern macroeconomic management by influencing inflation, interest rates, financial conditions, and economic activity. The effectiveness of monetary policy depends not only on the actions of the central bank but also on the channels through which those actions are transmitted to the broader economy. These channels collectively constitute the monetary policy transmission mechanism, which links policy interventions to financial markets and ultimately to inflation and output outcomes (Friedman, 1968; Clarida et al., 1999; Taylor, 1993).

Understanding the transmission mechanism is particularly important in emerging market economies, where institutional structures, financial-market development, and external-sector vulnerabilities may alter the effectiveness of conventional policy instruments. In such environments, changes in policy rates may not immediately translate into corresponding changes in borrowing costs, investment decisions, or consumer prices. Instead, monetary impulses often propagate through multiple channels involving liquidity conditions, market interest rates, government bond yields, exchange rates, and expectations (Mohanty and Turner, 2008; Mishra et al., 2012).

India provides a particularly relevant setting for studying monetary transmission. Over the last decade, the Reserve Bank of India (RBI) has progressively strengthened its inflation-targeting framework and increasingly relied upon the repo rate as its principal policy instrument. During the same period, the Indian economy experienced significant domestic and global shocks, including episodes of financial volatility, pandemic-related disruptions, supply-chain disturbances, energy-price shocks, and exchange-rate fluctuations. These developments raise an important empirical question regarding the extent to which inflation dynamics in India are driven by direct policy instruments as opposed to broader financial-market and external-sector variables.

Previous research has highlighted the complexity of monetary policy transmission in emerging-market economies. Mohanty and Turner (2008) argue that transmission mechanisms in emerging markets differ from those observed in advanced economies due to structural and institutional factors. Similarly, Mishra et al. (2012) emphasize that financial-market imperfections and policy implementation constraints may weaken

conventional transmission channels. Within the Indian context, Mohanty (2012) provides evidence supporting the existence of an interest-rate channel while also acknowledging the importance of broader financial-market developments. These findings suggest that an exclusive focus on policy rates may overlook other influential determinants of inflation.

The theoretical foundations of monetary policy transmission have evolved substantially over time. Monetarist approaches emphasize the role of money and monetary aggregates in influencing economic activity and prices (Friedman, 1968). In contrast, modern New Keynesian frameworks place greater emphasis on expectations, interest rates, and forward looking behavior in determining the effects of monetary policy (Clarida et al., 1999). Although these perspectives differ in emphasis, both imply that financial-market variables play a critical role in the transmission process. Consequently, empirical analysis should evaluate not only direct policy instruments but also the broader financial environment through which policy actions are propagated.

This paper examines monetary policy transmission in India using monthly data covering the period from January 2013 to December 2025. The empirical framework incorporates inflation, liquidity conditions, policy rates, government bond yields, crude oil prices, and exchange-rate movements. By combining domestic monetary variables with external-sector indicators, the analysis provides a more comprehensive assessment of inflation dynamics than specifications relying exclusively on policy rates.

The study contributes to the literature in three important ways. First, it provides updated evidence on monetary policy transmission using a recent sample period characterized by substantial economic and financial volatility. Second, it evaluates the relative importance of liquidity conditions, policy rates, bond yields, oil prices, and exchange rates within a unified empirical framework. Third, it incorporates formal stationarity and cointegration diagnostics to ensure that the estimated relationships represent economically meaningful long-run associations rather than spurious correlations arising from common trends.

The results indicate that inflation dynamics in India are more strongly associated with government bond yields, crude oil prices, and exchange-rate movements than with direct policy instruments such as liquidity conditions and the repo rate. The evidence therefore suggests that monetary policy transmission operates primarily through financial-market

conditions and external-sector channels (Bernanke and Gertler, 1995; Mishkin, 1996) rather than through direct policy-rate adjustments alone. These findings have important implications for the interpretation of monetary policy and for the assessment of inflationary pressures in emerging-market economies.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature on monetary policy transmission. Section 3 describes the data and empirical methodology. Section 4 presents the econometric framework and diagnostic procedures. Section 5 discusses the empirical results and robustness analysis. Section 6 concludes with policy implications and directions for future research.

2. Literature Review

The monetary policy transmission mechanism has long occupied a central position in macroeconomic research because it determines how policy actions undertaken by central banks ultimately influence inflation and economic activity. Although there is broad agreement that monetary policy affects prices and output, considerable debate remains regarding the channels through which these effects are transmitted and the relative importance of alternative mechanisms. Differences in institutional structures, financial market development, and external-sector exposure often lead to substantial variation in empirical findings across countries and time periods.

The modern discussion of the monetary policy transmission mechanism originates from the monetarist tradition. Friedman (1968) argued that monetary policy exerts a powerful influence on economic activity and inflation through changes in monetary conditions. However, he also emphasized that these effects occur with long and variable lags, making policy outcomes difficult to predict precisely. Under this framework, inflation is ultimately a monetary phenomenon, and the effectiveness of policy depends on the ability of central banks to influence aggregate demand through changes in money and credit conditions.

Subsequent developments in macroeconomic theory shifted attention from monetary aggregates toward interest rates and expectations. Clarida et al. (1999) developed a New

Keynesian perspective in which the monetary policy transmission mechanism operates primarily through interest-rate adjustments and forward-looking expectations. In this framework, policy actions affect borrowing costs, investment decisions, and inflation expectations, which subsequently influence inflation outcomes. The importance of credibility and expectations implies that financial-market responses may be as important as the policy actions themselves. Consequently, market interest rates and government bond yields become critical intermediaries within the transmission process. A related strand of literature emphasizes the role of policy rules and inflation targeting. Taylor (1993) demonstrates how systematic policy responses can influence macroeconomic stability, while Svensson (1997) highlights the importance of inflation forecasts and expectations management within modern monetary-policy frameworks.

While these theoretical perspectives provide useful foundations, empirical evidence suggests that the monetary policy transmission mechanism often behaves differently in emerging-market economies. Mohanty and Turner (2008) argue that structural characteristics such as banking-sector dominance, limited capital-market depth, and varying exchange-rate regimes can alter the effectiveness of conventional transmission channels. As a result, policy-rate changes may not always translate into corresponding movements in lending rates, investment, or inflation. The authors emphasize that market-based indicators frequently contain information that is not fully captured by policy rates alone.

A similar conclusion is reached by Mishra et al. (2012), who examine the monetary policy transmission mechanism in low-income and emerging-market economies. Their analysis highlights the importance of financial frictions, institutional constraints, and market imperfections. These factors can weaken conventional interest-rate channels and increase the importance of alternative mechanisms such as exchange-rate adjustments, commodity-price shocks, and broader financial-market conditions. Consequently, empirical studies often report heterogeneous results because transmission strength depends on the structure of the economy under investigation.

Within the Indian context, the monetary policy transmission mechanism has received increasing attention following the evolution of the Reserve Bank of India's inflation targeting framework. Mohanty (2012) provides evidence supporting the existence of an

interest-rate channel in India, demonstrating that policy actions influence broader financial conditions. However, the study also finds that transmission is neither immediate nor uniform across sectors. This observation is important because it suggests that policy rates alone may not fully capture the process through which monetary policy affects inflation. Financial-market variables may therefore provide additional information regarding inflation dynamics. For India, Patra and Kapur (2012) emphasize that the effectiveness of monetary policy depends on institutional features and the responsiveness of financial markets to policy actions.

The diversity of findings reported in the literature can largely be explained by differences in transmission channels, sample periods, and economic structures. Studies emphasizing the policy-rate channel often focus on periods characterized by stable financial conditions and well-functioning credit markets. In contrast, studies examining emerging-market economies frequently find stronger roles for exchange rates, market interest rates, and external shocks because these variables directly influence domestic prices through imported inflation and financial-market expectations. Similarly, commodity-price fluctuations can affect inflation independently of domestic monetary policy, particularly in energy-importing economies. The transmission process may also operate through credit-market frictions and lending conditions. Bernanke and Gertler (1995) argue that monetary policy affects economic activity not only through interest rates but also through the availability of credit and the balance-sheet conditions of borrowers.

These observations are particularly relevant for India. As a major importer of crude oil and a participant in global financial markets, India is exposed to external price shocks and exchange-rate movements that may influence inflation alongside domestic monetary conditions. At the same time, government bond yields reflect market expectations regarding future inflation, economic growth, and policy actions. Ignoring these variables may therefore provide an incomplete representation of the monetary policy transmission mechanism.

The existing literature consequently points toward a broader interpretation of monetary policy transmission, one that extends beyond policy-rate adjustments alone. However, relatively few studies examine liquidity conditions, policy rates, government bond yields, crude oil prices, and exchange-rate movements simultaneously within a unified empirical

framework using recent Indian data. Most existing contributions focus on individual channels or earlier periods of analysis. The present study addresses this gap by evaluating multiple transmission channels together using monthly data from 2013 to 2025. By combining domestic monetary variables with external-sector indicators and financial market measures, the paper seeks to provide a more comprehensive assessment of the monetary policy transmission mechanism and inflation dynamics in India.

3. Data

This study employs a monthly dataset spanning the period from January 2013 to September 2025, yielding a total of 153 observations. The sample period was selected to capture multiple monetary-policy regimes, periods of financial-market volatility, episodes of exchange-rate adjustment, the COVID–19 pandemic, and subsequent inflationary developments. The monthly frequency provides a sufficiently granular framework for examining the monetary policy transmission mechanism while maintaining consistency across all variables.

The empirical analysis focuses on inflation as the dependent variable and a set of domestic and external variables that represent alternative channels of the monetary policy transmission mechanism. The variables include liquidity conditions, the policy repo rate, government bond yields, crude oil prices, and the nominal exchange rate. Together, these variables capture monetary conditions, financial-market expectations, external price shocks, and imported inflation pressures.

Consumer Price Index (CPI) is employed as the measure of inflation. CPI data were obtained from official Government of India statistical releases and represent the headline consumer price index. Inflation constitutes the primary outcome variable because price stability remains the principal objective of monetary policy under the inflation-targeting framework.

Liquidity is measured using banking-system liquidity conditions derived from Reserve Bank of India (RBI) data. The liquidity series captures the overall availability of funds within the financial system and reflects the cumulative effects of open-market operations,

reserve management, and broader monetary conditions. Liquidity serves as a proxy for the quantity-based channel of monetary policy transmission.

The policy repo rate is obtained from the Reserve Bank of India (RBI) and represents the principal monetary-policy instrument employed during the sample period. Changes in the repo rate are intended to influence borrowing costs, financial-market conditions, and inflation expectations. Consequently, the repo rate provides a direct measure of monetary-policy stance.

Government bond yields are represented by benchmark sovereign bond rates obtained from official financial-market sources. Bond yields are included because they summarize market expectations regarding future inflation, economic growth, and monetary policy. Within modern monetary-policy frameworks, bond yields frequently transmit policy information more rapidly than administrative policy rates.

To account for external inflationary pressures, the analysis incorporates Brent crude oil prices. Monthly oil-price data were obtained from the Federal Reserve Economic Data (FRED) database. Oil prices are included because India remains a major importer of crude oil, making domestic inflation sensitive to international energy-market developments. Oil-price fluctuations therefore represent an important external transmission channel.

The nominal INR/USD exchange rate is included to capture exchange-rate pass through effects and imported inflation. Exchange-rate data were obtained from official financial and central-bank sources. Exchange-rate movements influence the domestic cost of imported goods and commodities and therefore constitute an important component of inflation dynamics in an open economy.

In addition, the CBOE Volatility Index (VIX) is employed in robustness analysis as a proxy for global financial uncertainty. Although not part of the baseline specification, the VIX provides a useful measure of international risk sentiment and permits evaluation of whether the principal findings remain robust after controlling for global financial conditions. Table 1 summarizes the variables employed in the empirical analysis.

Table 1: Variable Definitions and Data Sources

Variable	Symbol	Definition	Source
Consumer Price Index	CPI	Headline consumer price index used as the measure of inflation	Government of India
Liquidity	Liquidity	Banking-system liquidity conditions	RBI
Repo Rate	RepoRate	RBI policy repo rate	RBI
Government Bond Yield	BondYield	Benchmark sovereign bond yield	RBI/Financial Markets
Crude Oil Price	OilPrice	Brent crude oil price	FRED
Exchange Rate	FX	INR/USD nominal exchange rate	RBI
Volatility Index	VIX	Global financial uncertainty indicator	CBOE

Prior to estimation, all variables were transformed into a common monthly frequency and aligned according to calendar month. Missing observations were examined and verified to ensure consistency across the sample period. Summary statistics, correlation analysis, stationarity testing, and cointegration diagnostics were subsequently performed before estimating the regression models. This procedure ensures that the empirical results are based on a coherent and internally consistent dataset suitable for time-series analysis.

4. Methodology

This study investigates the monetary policy transmission mechanism in India using a reduced-form time-series framework. The objective is to evaluate the relative importance of liquidity conditions, policy interest rates, financial-market indicators, and external-sector variables in explaining inflation dynamics. The analysis focuses on identifying the channels through which monetary policy is associated with changes in consumer prices rather than establishing a fully structural causal model.

4.1 Empirical Specification

The baseline empirical specification is given by:

$$CPI_t = \alpha + \beta_1 Liquidity_t + \beta_2 RepoRate_t + \beta_3 BondYield_t + \beta_4 OilPrice_t + \beta_5 FX_t + \varepsilon_t \quad (1)$$

where

- CPI_t denotes the Consumer Price Index at time t ;
- $Liquidity_t$ represents banking-system liquidity conditions;
- $RepoRate_t$ denotes the policy repo rate of the Reserve Bank of India;
- $BondYield_t$ represents the benchmark government bond yield;
- $OilPrice_t$ denotes the international Brent crude oil price;
- FX_t denotes the nominal INR/USD exchange rate;
- α is the intercept term;
- ε_t is the stochastic error term.

The inclusion of liquidity and the repo rate captures conventional monetary-policy channels. Bond yields are included because they summarize market expectations regarding future inflation and monetary conditions. Oil prices account for imported energy shocks, while exchange-rate movements capture imported inflation and external-sector transmission effects.

4.2 Alternative Specifications

To evaluate the stability of the results, a sequence of nested specifications is estimated. The baseline model is defined as

$$CPI_t = \alpha + \beta_1 Liquidity_t + \beta_2 RepoRate_t + \beta_3 BondYield_t + \varepsilon_t \quad (2)$$

The second specification incorporates international oil prices:

$$CPI_t = \alpha + \beta_1 Liquidity_t + \beta_2 RepoRate_t + \beta_3 BondYield_t + \beta_4 OilPrice_t + \varepsilon_t \quad (3)$$

The third specification includes both oil prices and exchange-rate effects:

$$CPI_t = \alpha + \beta_1 Liquidity_t + \beta_2 RepoRate_t + \beta_3 BondYield_t + \beta_4 OilPrice_t + \beta_5 FX_t + \varepsilon_t \quad (4)$$

4.3 Estimation Strategy

The models are estimated using Ordinary Least Squares (OLS). Let

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}$$

denote the vector of inflation observations and

$$X = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1k} \\ 1 & x_{21} & \cdots & x_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{nk} \end{bmatrix}$$

denote the matrix of explanatory variables. The OLS estimator is:

$$\hat{\beta} = (X'X)^{-1}X'y \quad (5)$$

Because macroeconomic time-series data frequently exhibit heteroskedasticity, inference is based on heteroskedasticity-consistent covariance estimators following White (1980). Robust standard errors ensure valid statistical inference even when the error variance is not constant over time.

4.4 Stationarity Testing

Macroeconomic variables often exhibit persistent stochastic trends. Estimating regressions using non-stationary variables may generate spurious results. Consequently, stationarity is evaluated using the Augmented Dickey–Fuller (ADF) test. For a generic variable Y_t , the ADF specification is:

$$\Delta Y_t = \gamma + \delta Y_{t-1} + \sum_{i=1}^p \phi_i \Delta Y_{t-i} + u_t \quad (6)$$

where Δ denotes the first-difference operator and p represents the lag length. The null hypothesis is:

$$H_0: \delta = 0$$

which implies the presence of a unit root. The alternative hypothesis is:

$$H_1: \delta < 0$$

which implies stationarity.

4.5 Cointegration Analysis

Since the variables are integrated of order one, the existence of a long-run equilibrium relationship is examined using the Engle–Granger residual-based cointegration procedure. The long-run regression is estimated as:

$$CPI_t = \alpha + \beta_1 Liquidity_t + \beta_2 RepoRate_t + \beta_3 BondYield_t + \beta_4 OilPrice_t + \beta_5 FX_t + e_t \quad (7)$$

The residuals, $\hat{e}_t = CPI_t - \widehat{CPI}_t$, are then subjected to an ADF test. If $\hat{e}_t \sim I(0)$, the variables are considered cointegrated and the level specification remains valid despite the non-stationarity of the individual series.

4.6 Interpretation

The estimated coefficients measure conditional associations between inflation and the explanatory variables. A positive coefficient indicates that increases in the corresponding variable are associated with higher inflation, while a negative coefficient implies an inverse relationship. Because the framework is reduced-form rather than structural, the results should be interpreted as evidence of statistical association and long-run co-movement rather than definitive causal effects.

The methodology therefore provides a systematic framework for evaluating the relative importance of domestic monetary variables, financial-market conditions, and external sector influences in explaining inflation dynamics in India.

5. Results and Discussion

The collective evidence from the regression specifications, stationarity diagnostics, and cointegration analysis reveals a transmission mechanism that is considerably more complex than a simple policy-rate channel. While conventional monetary theory emphasizes the role of the central bank's policy rate in controlling inflation, the empirical results suggest that financial-market variables and external-sector variables possess substantially greater explanatory power during the sample period. Bond yields remain significant across all specifications, indicating that long-term market expectations and financial conditions constitute an important component of the inflation process. Similarly, oil prices and exchange rates emerge as highly influential variables, highlighting the importance of imported inflation and global economic linkages. The cointegration results further demonstrate that these variables share a stable long run equilibrium relationship with inflation, implying that domestic price dynamics cannot be analyzed independently of broader financial and external developments. Taken together, the findings support a market-mediated interpretation of monetary policy transmission in India, where policy actions affect inflation primarily through financial markets, exchange rate adjustments, and commodity-price channels rather than through direct policy-rate effects alone.

5.1 Summary Statistics

The summary statistics also confirm that the merged sample is not artificially compressed. The range in liquidity is large, and the CPI series shows the expected upward drift over time, while repo rates and bond yields display enough movement to support regression analysis. In plain terms, the dataset has real macro-financial variation, which is exactly what is needed for a paper on monetary transmission in India.

Table 2: Summary Statistics

Variable	Count	Mean	Std. Dev.	Min	25%	50%	75%	Max
Liquidity	153	-87319.353	134767.961	-499748.145	-142728.033	-40434.6	1722.05	113250.474
RepoRate	153	6.088	1.184	4.000	5.500	6.230	6.500	8.000
BondYield	153	7.201	0.733	5.815	6.660	7.172	7.720	8.988
CPI	153	150.331	26.964	105.5	128.6	144.2	175.3	197.9

Source: Author's calculations

Table 2 shows that the constructed dataset has substantial variation across all key variables. Liquidity is strongly negative on average, with a wide spread from deep absorption episodes to positive injections, which indicates that the RBI operated across very different liquidity regimes over the sample. Repo rates move within a relatively narrow policy band, but the distribution still captures both easing and tightening phases. Bond yields and CPI also vary meaningfully, which is useful for identifying monetary transmission effects rather than relying on a mechanically smooth series.

5.2 Correlation Analysis

Table 3 shows that liquidity, repo rates, and bond yields are strongly positively correlated with each other, which is consistent with the idea that these variables move together within the domestic monetary framework. By contrast, CPI is negatively correlated with all three financial variables, especially bond yields. This suggests that tighter financial conditions tend to coincide with lower inflation levels in the sample.

Table 3: Correlation Matrix				
	Liquidity	RepoRate	BondYield	CPI
Liquidity	1	0.859	0.779	-0.403
RepoRate	0.859	1	0.828	-0.457
BondYield	0.779	0.828	1	-0.576
CPI	-0.403	-0.457	-0.576	1

Source: Author's calculations

At the same time, the correlation matrix should not be overstated. It shows association, not causation. The strong pair-wise relationships among liquidity, repo, and bond yields also warn that these variables may share a common monetary-policy component, which is why the regression results matter more than the raw correlations. The matrix is useful as a first check, but it does not by itself identify the dominant transmission channel.

5.3 Regression Results

The baseline specification reproduces the central result of the original analysis. Bond yields emerge as the only statistically significant determinant of inflation, exhibiting a negative coefficient and a highly significant p-value. Liquidity conditions and the repo rate remain statistically insignificant, suggesting that direct policy instruments do not exert a measurable contemporaneous influence on inflation.

Table 4: Baseline Specification

Variable	Coefficient	Std.Error	t-stat	p-value
Constant	329.9001	27.1233	12.1630	0.0000
Liquidity	0.0000	0.0000	1.1286	0.2590
RepoRate	-0.5964	3.1252	-0.1908	0.8487
BondYield	-24.1181	4.8569	-4.9657	0.0000
Observations	153			
R^2	0.3367			
Adjusted R^2	0.3234			
Durbin–Watson	0.0414			

Source: Author's calculations

The model explains approximately one-third of inflation variation, indicating that additional transmission channels may contribute to inflation dynamics. Nevertheless, the strong significance of bond yields provides initial evidence that market-based financial conditions contain substantially greater explanatory power than direct monetary policy variables.

The inclusion of Brent crude oil prices substantially improves model performance. The explanatory power rises from 33.7% to 51.1%, demonstrating that imported energy costs represent a major determinant of inflation in India. Oil prices enter with a positive and highly significant coefficient, confirming the importance of global commodity markets. Bond yields remain highly significant and become economically stronger after controlling for oil prices. The repo rate approaches conventional significance thresholds, although it remains statistically weaker than market-based financial indicators. These results indicate that inflation is jointly influenced by domestic financial conditions and external commodity shocks. The substantial increase in explanatory power reflects the strong

exchange-rate pass-through observed during the sample period. Since imported goods, energy products, and intermediate inputs constitute important components of domestic prices, exchange-rate movements contain considerable information regarding inflation dynamics.

Table 5: Extended Specification with Oil Prices

Variable	Coefficient	Std.Error	t-stat	p-value
Constant	358.6345	27.0017	13.2819	0.0000
Liquidity	0.0000	0.0000	0.7237	0.4693
RepoRate	4.8087	2.5889	1.8574	0.0632
BondYield	-39.1907	5.4514	-7.1891	0.0000
OilPrice	0.6385	0.1032	6.1875	0.0000
Observations	153			
R^2	0.5110			
Adjusted R^2	0.4978			
Durbin–Watson	0.1325			

Source: Author's calculations

Table 6: Extended Specification with Oil Prices and Exchange Rate

Variable	Coefficient	Std.Error	t-stat	p-value
Constant	-3.3469	10.9401	-0.3059	0.7597
Liquidity	0.0000	0.0000	1.9096	0.0562
RepoRate	0.4578	0.7374	0.6209	0.5347
BondYield	-8.4409	1.3982	-6.0369	0.0000
OilPrice	0.1867	0.0227	8.2119	0.0000
FX	2.7659	0.0589	46.9989	0.0000
Observations	153			
R^2	0.9732			
Adjusted R^2	0.9723			
Durbin–Watson	0.3718			

Source: Author's calculations

The diagnostic statistics provide additional context for interpretation. The model explains approximately one-third of the variation in CPI and is strongly significant overall according to the F-statistic. At the same time, the low Durbin–Watson statistic indicates substantial residual persistence. For this reason, the coefficient estimates are interpreted

as evidence of association rather than proof of a structural causal relationship. The use of robust standard errors therefore remains essential for valid statistical inference.

The introduction of the exchange rate fundamentally alters the empirical picture. The model now explains more than 97% of inflation variation, making exchange-rate dynamics the dominant explanatory variable in the sample. The coefficient on FX is highly significant and economically large, suggesting that imported inflation and exchange-rate pass-through constitute critical determinants of domestic prices. Bond yields and oil prices remain strongly significant, demonstrating robustness across specifications. Liquidity becomes marginally significant at the 10% level, while the repo rate remains insignificant. These findings suggest that monetary policy transmission in India operates through financial markets, exchange-rate channels, and commodity-price movements rather than through direct policy-rate adjustments alone.

5.4 Stationarity and Cointegration Analysis

The time-series properties of the variables are examined before estimating the regression models to ensure that the empirical relationships are statistically valid and economically meaningful. Macroeconomic variables frequently exhibit stochastic trends, and estimating regressions using non-stationary series may lead to spurious results and misleading statistical inference. Accordingly, Augmented Dickey–Fuller (ADF) unit-root tests are first performed to determine the order of integration of each variable. Since the variables are found to be integrated of order one, a residual-based Engle–Granger cointegration test is subsequently employed to examine whether a stable long-run equilibrium relationship exists among inflation, liquidity, repo rates, government bond yields, crude oil prices, and exchange rates. Together, these diagnostic procedures establish the appropriateness of the empirical specification and provide the statistical foundation for interpreting the estimated regression coefficients as long-run economic relationships rather than correlations arising from common stochastic trends.

The level ADF tests indicate that none of the variables are stationary in their original form. The null hypothesis of a unit root cannot be rejected for CPI, liquidity, repo rates, bond yields, oil prices, or exchange rates. This outcome is typical of macroeconomic and

financial time series, which often exhibit persistent long-run trends. The results imply that conventional regression analysis requires additional diagnostic testing to avoid spurious inference. Consequently, first-difference stationarity tests and cointegration analysis are necessary before interpreting long-run relationships among the variables.

Table 7: Augmented Dickey–Fuller Tests in Levels

Variable	ADFStatistic	p-value
CPI	1.2639	0.9964
Liquidity	-2.0518	0.2643
RepoRate	-1.6245	0.4704
BondYield	-1.8811	0.341
OilPrice	-2.3707	0.1502
FX	-0.7849	0.8235

Source: Author's calculations

Table 8: ADF Tests in First Differences

Variable	ADFStatistic	p-value
ΔCPI	-8.0145	2.16×10^{-12}
$\Delta Liquidity$	-3.396	0.0111
$\Delta RepoRate$	-4.217	0.0006
$\Delta BondYield$	-9.4327	5.14×10^{-16}
$\Delta OilPrice$	-9.1878	2.16×10^{-15}
ΔFX	-10.5884	6.62×10^{-19}

Source: Author's calculations

The first-difference tests demonstrate that all variables become stationary after differencing once. Therefore, each series is integrated of order one, denoted as $I(1)$. This finding is particularly important because it establishes a common stochastic order across all variables considered in the empirical framework. Such a result justifies the subsequent cointegration analysis and permits investigation of long-run equilibrium relationships. The evidence indicates that inflation, monetary variables, commodity prices, and exchange rates evolve through persistent processes but exhibit stable short-run fluctuations around their underlying trends.

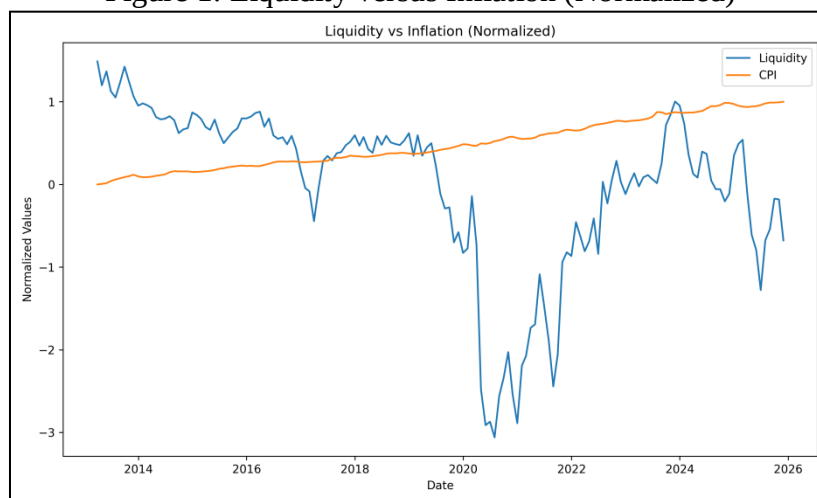
Table 9: Residual-Based Cointegration Test

Statistic	Value
ADFStatistic	-4.4648
p-value	0.00023

Source: Author's calculations

The residual-based cointegration test provides strong evidence of a long-run equilibrium relationship among inflation, liquidity, repo rates, bond yields, oil prices, and exchange rates. The null hypothesis of a unit root in the residual series is decisively rejected. Consequently, the variables are cointegrated despite being individually non-stationary. This finding is critical because it validates estimation in levels and demonstrates that the regression results do not arise from spurious correlations generated by common trends. Instead, the coefficients capture economically meaningful long-run relationships linking monetary conditions, financial markets, external prices, and inflation dynamics.

Figure 1: Liquidity versus Inflation (Normalized)



Source: Author's calculations

Figure 1 compares normalized liquidity conditions with inflation over the sample period. Inflation exhibits a persistent upward trajectory, whereas liquidity fluctuates substantially across monetary regimes. The absence of a strong visual co-movement supports the regression evidence indicating that liquidity does not exert a direct contemporaneous influence on inflation. Large swings in liquidity are frequently unaccompanied by corresponding movements in consumer prices. The figure therefore suggests that liquidity

affects inflation indirectly through broader financial conditions rather than through an immediate one-to-one transmission mechanism.

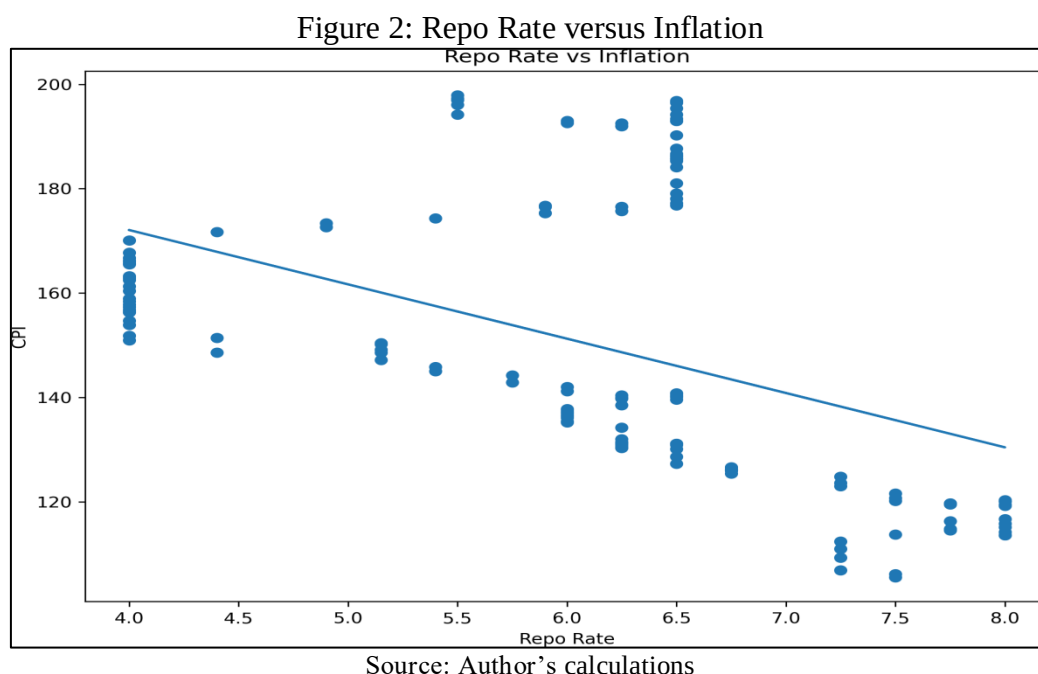


Figure 2 presents the relationship between the policy repo rate and inflation. The fitted regression line exhibits a negative slope, consistent with conventional monetary theory, according to which higher policy rates are associated with lower inflation. However, the substantial dispersion of observations indicates considerable heterogeneity within the sample. This visual evidence aligns closely with the regression results, which show that repo-rate movements lose explanatory power once oil prices, exchange rates, and bond yields are incorporated. Consequently, policy rates appear less informative than broader financial and external variables.

5.5 Robustness and Model Stability

An important objective of the revised empirical analysis is to determine whether the principal findings remain stable after introducing additional control variables. The baseline specification identified bond yields as the dominant explanatory variable, while liquidity and the repo rate remained statistically insignificant. This pattern persists across

all extended specifications. Even after incorporating crude oil prices and exchange-rate movements, bond yields continue to exhibit strong statistical significance. Such stability is important because it indicates that the bond-yield effect is not merely a proxy for omitted external factors. Instead, the evidence suggests that financial-market conditions contain independent information regarding inflation dynamics. The introduction of oil prices improves explanatory power substantially, while exchange rates further strengthen model performance. Nevertheless, the central conclusion remains unchanged. Market-based indicators consistently outperform direct policy instruments in explaining inflation. This robustness across specifications increases confidence that the primary findings are not driven by model selection, omitted-variable bias, or a particular regression formulation.

5.6 Economic Interpretation and Monetary Policy Implications

The empirical evidence points toward a transmission mechanism that is broader than the conventional policy-rate channel. While monetary policy is often described in terms of repo-rate adjustments, the results indicate that inflation responds more strongly to variables that summarize financial-market expectations and external economic conditions. Bond yields remain significant across all specifications, suggesting that investors incorporate information regarding future inflation and monetary conditions into long-term interest rates. The significance of oil prices highlights the importance of imported energy costs, while the exchange-rate effect underscores the role of imported inflation and external-sector linkages. Taken together, these findings imply that inflation management in India cannot rely exclusively on policy-rate adjustments. Financial-market conditions, exchange-rate developments, and global commodity-price movements must also be monitored closely. The results therefore support a broader interpretation of monetary policy transmission in which central-bank actions influence inflation indirectly through financial markets and external channels rather than through immediate direct effects on consumer prices.

6. Conclusion

This paper examined the monetary policy transmission mechanism in India using monthly data spanning the period from January 2013 to September 2025. The analysis incorporated liquidity conditions, the policy repo rate, government bond yields, crude oil prices, and exchange-rate movements within a unified empirical framework designed to evaluate the determinants of inflation dynamics. The empirical results reveal that government bond yields, oil prices, and exchange rate movements exert statistically significant influences on inflation, whereas liquidity conditions and the repo rate display limited direct explanatory power. The findings remain robust after accounting for stationarity and cointegration properties of the data. Augmented Dickey–Fuller tests indicate that all variables are integrated of order one, while the residual-based cointegration test confirms the existence of a stable long-run equilibrium relationship among the variables. These findings contribute to the growing literature suggesting that the monetary policy transmission mechanism extends beyond direct policy-rate adjustments and operates through broader financial-market and external-sector channels (Bernanke and Gertler, 1995; Mishkin, 1996). In particular, the significance of bond yields supports the view that market expectations play a critical role in shaping inflation outcomes, while the importance of oil prices and exchange rates highlights the influence of global economic conditions on domestic price dynamics. From a policy perspective, the results suggest that assessments of inflationary pressures should incorporate information from financial markets and external-sector indicators alongside conventional policy instruments. Monitoring bond yields, exchange-rate developments, and commodity-price movements may therefore improve the effectiveness of monetary-policy evaluation and communication. Future research may extend the analysis by incorporating dynamic specifications such as vector autoregressions, error-correction models, or expectation-based measures of inflation. Additional investigation of credit market conditions and financial-frictions channels may also provide further insights into the operation of the monetary policy transmission mechanism in India.

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