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Distributional Dynamics in Atal Pension Yojana (APY) Enrolments: A multi-method analysis across States and Zones of India- Period 2015-16 to 2024-25

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Distributional Dynamics in Atal Pension Yojana (APY) Enrolments: A multi-method analysis across States and Zones of India- Period 2015-16 to 2024-25

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1. Abstract

This study presents the first comprehensive multi-method distributional analysis of Atal Pension Yojana (APY) enrolment across 29 Indian states over the complete first decade of the scheme's operation, from its launch in FY 2015-16 to FY 2024-25. The study employs APY enrolments per 1,000 eligible population as the analytical metric, with the eligible population derived from Population Projections for India and States 2011–2036 (National Commission on Population, MoHFW), using linear interpolation for intermediate years.

The study deploys seven complementary analytical frameworks: Gini coefficient, Lorenz curves, Theil T decomposition, σ-convergence, β-convergence via OLS, heteroskedasticity-consistent (HC3) robust standard errors and Fixed Effects panel regression, non-parametric rank correlation tests (Spearman ρ and Kendall's τ), Wilcoxon rank-sum test, quartile mobility matrix and Gender Parity Index (GPI) analysis.

The national Gini coefficient for APY total enrolment penetration rose from 0.210 in 2015–16 to a peak of 0.359 in 2021–22 before moderating to 0.280 in 2024-25, indicating a net increase in inequality over the decade. Female enrolment penetration inequality is consistently and substantially higher than its male counterpart, peaking at 0.444. Theil T decomposition reveals a decisive structural transformation: inter-zone inequality collapsed from 31.7% to 3.3% of total inequality, while intra-zone state-level divergence now accounts for 96.7%. Sigma-convergence confirms divergence, with the national standard deviation rising from 1.72 to a peak of 38.87 (during the COVID years), before partially recovering to 13.60. Although cross-sectional OLS β-convergence was non-significant due to small sample constraints, the panel Fixed Effects regression using all year-state observations confirmed highly significant β-convergence for Total ($\beta = -0.233$, $p < 0.001$), Male ($\beta = -0.271$, $p < 0.001$) and Female ($\beta = -0.210$, $p < 0.001$). Male convergence was independently confirmed through Spearman $\rho = -0.387$ ($p = 0.039$) and HC3-corrected OLS ($p = 0.041$). The national Gender Parity Index rose from 0.689 to 1.339 over the decade, with parity crossed in 2022–23. However, substantial state-level disparities persist.

These findings collectively indicate that APY inequality has increased, shifted from inter-zonal to intra-zonal, and requires state-specific rather than zone-level policy interventions.

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1 Introduction

The shift from the traditional pension pay-as-you-go (PAYG) or the defined benefit pension system (DBPS) to the National Pension System (NPS) in 2003 was a significant reform in India (Mohanty, 2022). Initially applicable to government employees and later extended to the general public, including the informal sector, through the All Citizen model in 2009 (PFRDA, 2016). To further increase coverage, the Swavalamban Scheme was introduced in the 2010–11 Union Budget in which the government contributed Rs. 1,000 annually to NPS-Lite accounts opened during that financial year, aimed at individuals making minimum contributions of Rs. 1,000 annually (Mukherjee, 2010). Just like NPS, Swavalamban Scheme contributions were also managed by professional private pension funds and offered market-linked returns. However, despite efforts, enrolment remained low, with only 41.5 lakh enrolees by March 2015, attributed to the lack of guaranteed returns (Arora & Kundu, 2018; Vats, 2016). Responding to this, the APY was launched in 2015. APY launched by the Government of India in 2015, represents the significant attempt in independent India's history to extend contribution based defined-benefit pension coverage to the underprivileged sections of society in the unorganized sector (Budget Speech, 2015; PFRDA, 2025a). The Government of India scheme is administered by the Pension Fund Regulatory and Development Authority (PFRDA) and is anchored within the National Pension System (NPS) system architecture.

APY targets Indian citizens aged 18 to 40 years who hold a savings bank account but are not members of any statutory social security scheme. The scheme provides a guaranteed minimum monthly pension of Rs. 1,000 to Rs. 5,000 on attaining the age of 60 year, depending upon the contributions. The quantum of periodic contribution is calibrated by age of entry of the prospective subscriber and desired pension tier. The scheme has three major benefits- a guaranteed minimum pension for the life of the subscriber after attaining the age of 60 years, the continuation of the same pension to the spouse in case of subscriber's death and finally, return of the corpus to the nominee of the subscriber after the death of both the subscriber and the spouse. Contributions depend on entry age and the chosen pension level with earlier enrolment ensuring lower monthly payments, while late payments accrue interest. Subscribers can adjust their pension amount annually during the accumulation phase per PFRDA guidelines (PFRDA, 2022). Voluntary exit is allowed before age 60, refunding contributions (excluding government co-contributions for pre-2016 subscribers).

To encourage the adoption of the scheme by the populace in the initial years, the Government of India co-contributed 50 per cent of the subscriber's annual premium or Rs. 1,000, whichever was lower, for a period of five years for those enrolling on or before 31 March 2016. Notably, w.e.f. October 01st, 2022, only non-income tax payees can enrol

under APY (PFRDA, 2025a); however, subscribers enrolled by September 30th, 2022, could still continue contributions regardless of tax status (Dept of Financial Services, 2022; PFRDA, 2025a).

The scheme's aggregate performance since inception has been remarkable. Gross APY enrolments have grown from approximately 25 lakh in March 2016 to over 7.61 crore by April 2025, with cumulative corpus exceeding Rs. 44,780.49 crore till March 2025 (PFRDA, 2025a). The female enrolment share, which was approximately 38% in March 2016, crossed 52% by 2024–25 (Chatterjee & Nandan, 2025).

Although, these headline numbers project an image of broad-based and increasingly gender-equitable expansion, they conceal the non-uniform distributional reality across India's major states and union territories (Chatterjee & Nandan, 2025). The scheme having grown impressively in absolute numbers has simultaneously, become more unequally distributed across geographies and genders.

Research by (Mohanty et al., 2022a) suggests a correlation between banking infrastructure (i.e. more bank branches and PMJDY accounts), state-level per capita income, life expectancy and rural population size.

Although the gender ratio in enrolments has improved over the years, this progress has not been consistent across all zones and states in the union. (Chatterjee & Nandan, 2025) identify find that majority of the states/UTs have enrolments skewed towards males with significantly heavy skewness in states like UP, Delhi, HP, Uttarakhand, Gujarat and J&K. They further identify a statistically significant negative correlation between APY enrolment density and gender differences suggesting, that as the gender difference in coverage tends to decrease, the overall APY coverage increases and vice versa.

To address this paradox, this study investigates APY's expansion over its first ten years, tracking whether enrolment inequality across Indian states and zones has widened or narrowed. It further evaluates whether gender-based gaps in penetration are converging or diverging. We attempt to answer these questions by applying a novel, multi-method distributional analysis framework that offers a fresh methodological perspective on APY data.

Since, APY operates across all the states that differ profoundly in banking infrastructure, female literacy, governance capacity, economic structure and demographic composition no single statistical tool can characterise or analyse the full distributional picture. Thus, this study, believed to be the first of its kind to analyse APY coverage, simultaneously employs Gini coefficient analysis, Theil T decomposition, sigma-convergence, multiple beta-convergence specifications (OLS, HC3, panel Fixed Effects), non-parametric rank correlation tests, quartile mobility analysis and Gender Parity Index tracking to APY

state-wise panel data covering the scheme's full decade of operation. Each tool in the analytical framework thus, answers a policy question that the others cannot and together, they provide a comprehensive diagnostic that equips policymakers to design targeted responses rather than national-level averages. The study uses gender-disaggregated Census population projection data as denominators, ensuring that penetration rates accurately reflect policy performance relative to the eligible population rather than demographic differences across states. The complete justification for this conceptual and methodological architecture is developed under Section 3. The findings carry direct relevance for Govt. of India and PFRDA's policy design & state-level targeting priorities & approach and researchers studying financial inclusion and pension equity in emerging economies.

2 Review of Related Literature

2.1 Inequality in Social Security and Pension Coverage- Global Evidence

Deep structural inequalities are an inherent feature of social protection systems and programs worldwide. ILO World Social Protection Report 2020–22 (ILO, 2021), provides extensive and direct evidence towards this. The report confirms that as of 2020, only 46.9 per cent of the global population is effectively covered by at least one social protection benefit, thus leaving 4.1 billion people wholly unprotected. The report further highlights severe regional and geographic disparities with Europe and Central Asia boasting an 83.9% coverage, the Americas 64.3% coverage and Asia & the Pacific (including India) with mere 44.1% coverage. The report explicitly links these gaps to wider development disparities and higher spending on social protection- 16.4% of GDP for higher income countries vs 1.1% in low-income countries.

The report further finds that social protection coverage is indeed strongly correlated with employment formality and notes that workers in the informal economy become part of the "missing middle"- workers not poor enough for social assistance and simultaneously lacking the formal employment and regular income stream required to support a contributory schemes (ILO, 2021). The report confirms that major disparities remain between rural and urban areas regarding social protection access.

The World Bank monograph "Old-Age Income Support in the 21st Century" provides (Holzmann & Hinz, 2005) extensive theoretical and empirical evidence supporting the statement that pension coverage inequality is a structural feature of developing economies rather than a temporary transition problem. Resonating (ILO, 2021)'s assertion (Holzmann & Hinz, 2005) also describe how formal earnings-related systems typically cover only a small segment of the population (civil servants and large enterprises), leaving the

informal sector totally uncovered. The report notes that lower-income workers lack incentives to participate in voluntary schemes without matching contributions or tax credits, leading to a self-selection process that favours the financially integrated and wealthy.

(Holzmann & Hinz, 2005) also note the gender gap, with women systematically having less work experience, lower earnings and less pension coverage than men, makes them more vulnerable to old-age poverty. On the aspect of geographic barriers in respect of coverage inequalities, the report points out extreme the difficulty of extending services to thinly populated rural areas where infrastructure and administrative data are lacking.

However, of particular relevance is the fact that gender inequality in pension coverage is structurally distinct from geographic inequality and the two dimensions do not necessarily move together, as evidenced from the cross-country finding of the World Social Protection Report 2020–22 (ILO, 2021). The report documents that in most developing and emerging economies, women's effective coverage by contributory pension schemes is 15–25% points below men's, driven by lower female labour force participation, greater concentration of women in informal and domestic work, shorter contribution periods due to caregiving interruptions and lower average earnings reducing the attractiveness of contribution-based schemes and this structural gender disadvantage in pension access is not automatically corrected by the expansion of aggregate coverage. The report treats gender inequality as a dimension structurally distinct from geographic or regional disparities. It provides data showing that while some regions (like Latin America) have made progress in aggregate coverage, women often still lag behind in terms of the type of coverage they receive, ending up with lower effective coverage in terms of actual benefit receipt even when legal coverage exists.

The (ILO, 2021) report states that coverage and the resultant inequality, is also a downstream impact of literacy and financial access and notes that delivery mechanisms relying on digital technologies carry exclusion risks for those who lack digital literacy, access to smartphones or banking & financial services. The aforementioned findings have specific relevance and resonance in the Indian context considering informal/unorganized workers constituting approximately 88 per cent of India's total workforce (Narayana, 2023). Further, India's sharp digital divide is defined by deep geographic, literacy and gender disparities, as evidenced by (OXFAM India, 2022) in their report "Digital Divide: India Inequality Report 2022". Internet usage is more than twice as high in urban areas (67%) than in rural areas (31%), a gap mirrored in digital literacy rates (61% urban versus 25% rural), which drop even lower to 21% among Scheduled Tribes. This exclusion is further compounded by a 30 percentage point gender gap in mobile ownership, where 61% of men own a phone compared to just 31% of women, severely blocking vulnerable populations from accessing mobile-based social protection.

2.2 Inequality in Financial Inclusion- Global and Indian Evidence

APY enrolment is contingent on bank account ownership. Understanding inequality in financial inclusion access is therefore directly relevant to explaining APY penetration disparities. The World Bank's Global Findex Database 2017 (Demirgüç-Kunt et al., 2020) provides the authoritative global reference. Tracking formal account ownership across 140 countries, it shows that the gender gap in account ownership i.e. the difference in male and female formal account ownership rates, as a share of the adult population, narrowed significantly between 2011 and 2017 in South Asia, largely driven by India's PMJDY expansion. However, (Demirgüç-Kunt et al., 2020) add that, account ownership alone being taken as a parameter of assessment is an insufficient as dormant accounts and low-usage accounts are highly concentrated among women, rural populations and lower-income households. The existence of a formal account does not equate to active financial inclusion or the capacity to maintain monthly periodic contributions. The distinction between account access and active financial participation thus, can be central to understanding why coverage and inequality rates diverge so substantially.

India's financial inclusion trajectory over the study period has been shaped decisively by PMJDY, launched in August 2014. The scheme grew from 15.67 crore accounts in March 2015 to 53.14 crore accounts by August 2024, with total deposit balances crossing Rs. 2 Lakh crores. Women account for 55.6 per cent of PMJDY account holders and 66.6 per cent of accounts are held in rural and semi-urban areas (PIB, 2024). (Demirgüç-Kunt et al., 2020) further note that between 2014 and 2017 alone, India's gender gap in formal account ownership fell from 20 percentage points to 6 percentage; one of the most rapid reductions recorded globally.

However, underlying the aggregate financial inclusion improvements, lies the deep seated and persistent financial inclusion gap, as pointed out in the research of (Yadav et al., 2021). Constructing a multidimensional Financial Inclusion Index (FII) for 27 Indian states across 2004–2017, they find that financial inclusion showed only marginal improvement overall and that most northern and NE states remained in the low financial inclusion category throughout the period. PMJDY's impact was insufficient to move structurally disadvantaged states out of the low FII classification and high-HDI and high-literacy states saw substantially larger gains.

(Deaton & Drèze, 2002) documented that per capita consumption diverged strongly across Indian states during the 1990s, with the low-growth states forming a contiguous belt of eastern and BIMARU states while southern and western states grew substantially faster, thus confirming the deep-rooted structural regional disparities predating any social programme. (Drèze & Khera, 2017) subsequently document that the major social protection expansions of the 2000s exhibit striking inter-state variation in implementation quality,

with some of the poorest and weakest-governed states showing the least effective delivery. However, (Drèze & Khera, 2017) also document evidence of gradual convergence with lagging states like Chhattisgarh and Odisha being able to emulate the achievements of pioneer states over time, suggesting that the structural regional inequalities in programme delivery are not permanently fixed, even if they are slow to correct.

(Ziegler et al., 2024) studying gender patterns in health insurance enrolment in Rashtriya Swasthya Bima Yojana (RSBY) scheme across eight Indian states using a 2014 household survey and multivariate logistic regression, found that enrolment at the individual level was largely gender-neutral in the pooled sample. The researchers attributed it to mandatory spousal enrolment provisions. They further go on to state that female-headed households showed 36 per cent higher enrolment likelihood than male-headed households across most states- suggesting that household decision-making autonomy is at least as important as gender itself.

2.3 Prior Research on Measuring Inequality in Implementation of Social Programmes

The methodological framework used in this study viz. Gini coefficients, Lorenz curves, Theil T decomposition and convergence analysis applied to programme penetration rates, has deep roots in health economics and education research. This subsection documents the prior applications of these tools in social sector contexts, providing both the methodological warrant and the empirical precedent for their use in pension penetration analysis as has been envisioned in this research.

(Narayana, 2023) in his paper has applied inequality measurement to the Indira Gandhi National Old Age Pension Scheme (IGNOAPS) and used the standard Gini coefficient to ascertain age-specific and intra-generational inequalities.

(Wagstaff & Van Doorslaer, 2000) established the canonical framework for measuring horizontal inequity in health care delivery using need-standardised concentration indices. Their central contribution is the principle that equity analysis must compare like with like- a scheme that allocates services proportionally to need achieves horizontal equity, while one that over-serves accessible or higher-income populations exhibits horizontal inequity, in spite of the aggregate coverage being high. The said principle i.e. distributional equity requires adjusting for the underlying distribution of need before inequality can be meaningfully measured, directly guides this study's use of APY enrolment penetration per 1000 eligible population, rather than the raw enrolment counts. Eventually, this ensures that the Gini coefficient captures genuine differences in APY's coverage & reach across states and neutralizes the impact of differences arising out of state's population

size.

In the Indian health context, the NFHS-5 India Report (IIPS & ICF, 2022) presents Gini coefficients of the household wealth index distribution for every state and union territory in, alongside wealth quintile disaggregation of health outcomes including vaccination coverage, stunting prevalence and institutional delivery rates. The presence of Gini-based inequality measurement in India's flagship national health survey confirms that this analytical approach is not merely academic and in fact it is embedded in India's national social monitoring framework and can be directly applied to the distributional analysis of any social scheme, including APY.

(Pradhan et al., 2003) in their paper Decomposing World Health Inequality, applied the Theil entropy measure to decompose cross-country health inequality using child anthropometric outcomes as the health status indicator. The measure was specifically chosen for its decomposability property of finding the source of the inequality i.e. inter-group or intra-group and the study found that within-country inequality was the dominant component of global health inequality, substantially exceeding the between-country component. The said feature of decomposability is structurally analogous to this study's proposed Theil decomposition to ascertain within-zone or inter-zone inequality, with the finding directly guiding where policy action should be targeted.

In education research, (Ram, 1990) applied sigma-convergence analysis to track educational attainment inequality across countries and found that the spread of schooling rates across countries widened during the early expansion phase before eventually converging. He documented that educational inequality first increases as average schooling rises, reaching a peak at approximately seven years before starting to decline. To track this spread through sigma-convergence, (Ram, 1990) used standard deviation.

(Sab & Smith, 2002) in IMF Staff Papers extended this framework to human capital indicators viz. life expectancy, infant survival and schooling stocks and established that beta-convergence testing is an appropriate and well-validated tool for social indicator dynamics.

(Becker et al., 2005) documented sigma-convergence in life expectancy across countries, demonstrating that health outcomes can exhibit convergence patterns that differ from income.

In the Indian regional development context, (Nagaraj et al., 1998) in their OECD Development Centre Working Paper applied between-region and within-region decomposition alongside panel convergence analysis to per capita income across Indian states during 1970–1994. They found sigma-divergence in Indian state incomes during the 1980s despite aggregate growth. Their finding that within-state infrastructure differentials are

the dominant driver of persistent inequality has a direct parallel in our proposed study on measuring inequality in APY.

Thus, the aforementioned research provide a strong theoretical and empirical foundation for studying the sigma-convergence or divergence and panel beta-convergence in the APY enrolment coverage.

2.4 APY-Specific Research and the Indian Pension Literature

Research on APY can be grouped into three streams- first scheme design and financial feasibility, second subscriber awareness and behavioural barriers and finally enrolment trends & policy effectiveness.

On the aspect of design features, (Shankar & Asher, 2011) while exploring the micro-pensions sector in India state that it should be voluntary, portable and flexible, enabling experimentation in design and service delivery to suit the varied needs of the bottom of the pyramid populace. The further state that such a scheme should operating on the defined contribution platform and rely on voluntary, long-term savings managed by professional fund managers with options for lump sums, phased payouts or annuities at withdrawal. (Shankar & Asher, 2011) further add that to address challenges like high transaction costs and limited accessibility, micro-pensions must leverage technology, ensure low-cost operations and provide frequent, small-value contribution options through convenient collection mechanisms while maintaining simple product features to complement the comprehension of the cohort with limited financial literacy. The said features have been incorporated in the APY scheme design and rollout.

On the financial feasibility front, the research by (Arora & Kundu, 2018; Basu, 2015; Panicker & Cherian, 2021; Sudindra, 2016) highlights concerns about the low interest rates during the accumulation phase and the inadequacy of APY's guaranteed pension for ensuring retirement security. The "bottom of the pyramid" population, characterized by low formal education, faces challenges with financial literacy. (Arora & Kundu, 2018; Basu, 2015; National Centre for Financial Education, 2019) point out that APY investors may struggle with money illusion.

On the awareness side, NCFE's Financial Literacy and Inclusion in India - 2019 (NCFE, 2019) report indicates low financial literacy and awareness of APY, with account usage significantly lower than awareness levels. (Devi.S, 2020) study in Thiruvananthapuram District found a lack of awareness among individuals, leading to low enrolment in APY. (Balamurugan, 2022) identified insufficient pension amounts and lack of awareness due to inadequate advertising as major reasons for low APY adoption. (Bhattacharjee & Rengma, 2020) note differing attitudes toward APY among government and private em-

ployees, with the latter cohort seeking guaranteed and regular income. (Renugadevi & Kavya, 2023) while studying the attitude towards APY in Coimbatore, state that the scheme's effectiveness is limited by low public awareness, insufficient training of distribution channel, lack of flexibility in contributions, inadequate pension amounts and concerns about its continuity due to political changes.

On enrolment trends and policy effectiveness, (Chatterjee & Nandan, 2025) provide a comprehensive prior time-series analysis of APY. Their study documents compound annual growth rates by state and zone, female subscriber share crossing 50 per cent nationally, persistent NE zone underperformance and post-pandemic dropout rate increases in low-income states. (Rooj & Sengupta, 2025) cite NSSO and PMJDY data to suggest that SC, ST, OBC households and agricultural workers are disproportionately represented among APY subscribers, while inter-state penetration variation is better explained by banking infrastructure density than by poverty levels alone. Research by (Mohanty et al., 2022b) suggests a correlation between banking infrastructure, state-level income, life expectancy and APY enrolment, with higher enrolment observed in states with more rural populations.

2.5 Identified Research Gap

At the India-specific level, while descriptive analyses of APY enrolment trends exist (Chatterjee & Nandan, 2025) and while regional inequality in Indian social indicators has been studied in income (Deaton & Drèze, 2002) and financial inclusion (Demirgüç-Kunt et al., 2020) contexts, no study has applied a comprehensive distributional and convergence analytical framework to APY's state-wise panel data across the scheme's full decade of operation.

This study fills these gaps simultaneously by deploying a multi-method framework - Gini coefficient, Lorenz curves, Theil T decomposition, sigma-convergence, panel Fixed Effects beta-convergence, non-parametric rank tests, quartile mobility matrix and Gender Parity Index tracking to APY state-wise panel data across 29 states and 6 zones for the full decade 2015–16 to 2024–25. To the best of the authors' knowledge, this is the most methodologically comprehensive inequality analysis of any Indian pension scheme to date.

Thus, this study is structured around six specific research questions:

1. Has APY enrolment penetration inequality across states increased or decreased over the 10 year period?

2. Is the source of that inequality inter-zone or intra-zone divergence and has the balance between these sources shifted over the decade?

3. Are states converging toward similar penetration levels over time or diverging further apart?

4. Are initially laggard states catching up with early movers?

5. Is gender inequality in APY penetration narrowing or widening over the decade and which states and zones drive the gender gap?

6. Has the national Gender Parity Index in APY crossed the parity threshold? If so, how is the state-level picture beneath the national average?

3 Data, Conceptual Framework and Analytical Methodology

3.1 Data

The study draws on two primary data sources:

- **APY State-wise Enrolment Data-** Annual state-wise Total, Male and Female APY enrolment figures for fiscal years 2015–16 through 2024–25 for all states and union territories were sourced from Table A6 of the PFRDA statistical data portal (PFRDA, 2025b).

- **Population Projections 2011–2036:** Gender-disaggregated population projections were sourced from Census of India 2011: Population projections for India and states 2011–2036: Report of the Technical Group on Population Projections published by (National Commission on Population, MoHFW, 2020). For approximation of eligible population, the 15–39 age bracket population figures were used as the denominator for penetration rate computation.

3.1.1 Scope and Exclusions

The study covers 29 states and major union territories. Six small union territories viz. Andaman & Nicobar Islands, Chandigarh, Lakshadweep, Puducherry, Dadra & Nagar Haveli & Daman & Diu and Goa, were excluded from penetration rate analysis because population projections are not available for these geographies. The "Others (NRI/Defense)" row in (PFRDA, 2025b) data has also been excluded as it has no geographic eligible population base. In spite of the exclusions, the 29 included states represent over 99% of India's APY-eligible population and over 98% of total APY enrolments.

3.1.2 Penetration Rate Computation

The analytical metric is APY Enrolment Penetration Rate, defined as-

APY Enrolment Penetration Rate = (APY Enrolments / Eligible Population) × 1,000

where eligible population is the state-wise projected 15–39 age bracket (in thousands). This metric is computed separately for total, male and female dimensions, using gender-specific denominators for the latter two. The penetration rate normalisation, using gender-specific population denominators, ensures the analytical metric properly measures how equitably the scheme reaches eligible citizens regardless of state's population size. (Wagstaff & Van Doorslaer, 2000) established this normalisation principle in the context of health care concentration indices and this study applies it to APY enrolment.

3.1.3 Population Interpolation

Since the population projections provide the population estimates at 5-year intervals (i.e. 2011, 2016, 2021, 2026 etc.) Census of India 2011: Population projections for India and states 2011–2036: Report of the Technical Group on Population Projections published by (National Commission on Population, MoHFW, 2020), linear interpolation was used to prepare the projected populations for the intermediate years. This is a standard and defensible approach given the slow-moving nature of age-structure change in India.

3.1.4 Zone Classification

States are grouped into the following six zones-

- **Central-** Chhattisgarh, Madhya Pradesh, Uttar Pradesh;
- **East-** Bihar, Jharkhand, Odisha, West Bengal;
- **North-East-** Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura;
- **North-** Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Uttarakhand;
- **South-** Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Telangana; and
- **West-** Gujarat, Maharashtra, Rajasthan.

3.1.5 Analytical Software

All computations are performed in R (version 4.3.5). The script uses standard CRAN packages- readxl, dplyr, tidyr, ggplot2, patchwork, ggrepel, scales, ggridges, RColor-

Brewer, plm, sandwich and lmtest. Gini and Lorenz computations are implemented natively without external packages to ensure maximum transparency.

3.2 Conceptual Framework

This study employs seven analytical tools to measure and understand APY enrolment inequality across 29 Indian states over 10 years. Each tool is chosen to align with a specific research question. Further every tool has certain limitation which makes the deployment of the next tool necessary. Thus, the result is a logically ordered analytical sequence in which the findings of each method, motivate the next. Taken together, they build a complete analytical picture of how much inequality exists, where it comes from geographically, whether it is widening or narrowing, whether laggard states are catching up, whether gender equity is improving and how the full distribution of states has evolved over the decade.

The table below summarises the seven methods, the Core question each addresses & its alignment with the Research Questions (RQ) and the key limitation that motivates the deployment of the next method.

Table 1- Analytical Methods- Logical Sequence, RQ Alignment and Rationale

S No.	**Method**	**Core Question**	**Research Question alignment**	**Limitation of method and Decision towards choice of tool**
1	Gini Coefficient	How much inequality exists?	RQ1	A single number which cannot show shape, source or trajectory
2	Lorenz Curve	Can we see the shape of inequality?	RQ1	Cannot decompose by geographic group
3	Theil T Decompo-sition	Is inequality between geographies or within geographies?	RQ2	Static number which does not track whether inequality is growing or shrinking

Continued on next page

Table 1 continued

S No.	Method	Core Question	Research Question alignment	Limitation of method and Decision towards choice of tool
4	σ-Convergence	Is the gap between states narrowing?	RQ3 and RQ4	Cannot identify whether laggard states are driving the change
5a	β-Convergence: OLS+HC3	Are laggard states growing faster?	RQ4	Only 29 data points (i.e. Indian states) on account of which heteroskedasticity inflates standard errors
5b	Panel Fixed Effects	Does catch-up hold controlling for state traits?	RQ4	Regression-based tests assume linearity and distributional structure
5c	Non-Parametric Tests	Does convergence hold without assumptions?	RQ4	Shows average tendencies and thus, misses individual state rank changes

Continued on next page

Table 1 continued

S No.	Method	Core Question	Research Question alignment	Limitation of method and Decision towards choice of tool
5d	Quartile Mobility Matrix	Did states actually change performance rank?	RQ4	All above tools measure total/male/female but not gender parity
6	Gender Parity Index	Are women served at parity with men?	RQ5	Summary statistics miss whether distribution is unimodal or polarised
7	Ridge Density Plot	How has the full distribution evolved?	RQ6	—

3.2.1 Gini Coefficient- How Much Inequality Exists?

The Gini coefficient was introduced by Italian statistician Corrado Gini in 1912 (Gini, 1912). It has since become one of the world's most widely used summary measure of distributional inequality (Giorgi & Gigliarano, 2017) applied by the United Nations, World Bank and national statistical agencies to measure income distribution, health care access and the geographic distribution of public resources (IIPS & ICF, 2022; Kakwani, 1980).

In this study the Gini coefficient is used to measure how unequally APY enrolment penetration is distributed across India's 29 states. G = 0 means every state has identical penetration; G = 1 means high concentration of APY enrolments towards one state. For our research, Gini values below 0.20 indicate are being categorised as low inequality, 0.20–0.35 moderate inequality and above 0.35 high inequality.

Table 2- Gini Coefficient Interpretation Scale for APY enrolment

Gini Range	**Inequality Level**	**Policy Interpretation in Social Programmes**
Below 0.20	Low	Distribution broadly equitable; most states close to national average
0.20 – 0.35	Moderate	Meaningful disparities; some states significantly above or below average
Above 0.35	High	Severe disparities; a small number of states dominate scheme coverage

It may be noted that the Gini coefficient as used in this study to summarize inter-state inequality in APY penetration across states provides a single index of the extent to which enrolments are evenly or unevenly distributed. The aforementioned classification should be understood as an operational heuristic for analysis rather than a universal academic threshold (Pangariya, 2007). The Gini is computed separately for Total, Male and Female enrolment rates to capture the gender dimension of inequality and additionally on a zone-restricted basis to measure within-zone dispersion.

The Gini is a single scalar that cannot reveal where inequality originates geographically, whether it differs across the income distribution, or whether states are catching up or diverging. The Lorenz curve and Theil decomposition address these limitations in turn.

3.2.2 Lorenz Curve- Can we see the shape of inequality?

The Lorenz curve, developed by (Lorenz, 1905) is the visual counterpart of the Gini coefficient. It plots the cumulative share of APY penetration (vertical axis) against the cumulative share of states ranked from lowest to highest penetration (horizontal axis). A 45-degree diagonal line represents perfect equality. Had the total enrolment being uniform across states, the bottom 30 per cent of states would hold exactly 30 per cent of total penetration. Lorenz curves are the standard visualisation tool accompanying any Gini-based analysis in development economics. The further the curve bows below the diagonal, the more unequal the distribution. The area between the curve and the diagonal, multiplied by two, equals the Gini coefficient exactly. This means the Lorenz curve carries all the information in the Gini number while additionally showing the shape of the distribution, whether inequality is concentrated at the bottom of the ranking, uniformly spread or driven by outlier performance at the top.

The interpretation of the Lorenz curve focuses on three basic questions-

- How far does the curve bow from the diagonal at its maximum departure point?
- Has the curve moved closer to or further from the diagonal between years?
- Do the male, female and total curves show different shapes, indicating gender-specific distributional dynamics?

Although, the Lorenz curve reveals the shape of inequality and makes temporal trends visually compelling, it cannot decompose inequality by geographic group or tell us whether zone-level or state-level factors are the primary driver. The next tool, Theil T decomposition addresses this.

3.2.3 Theil T Decomposition- Is inequality between geographies or within geographies?

The Theil T index, introduced by Henri Theil in Economics and Information Theory is an inequality measure with the property of perfect additive decomposability i.e. the total index can be split exactly into a between-group component and a within-group component with no residual. In this study, the groups are PFRDA's six operational zones (Central, East, NE, North, South, West) and the units within groups are individual states.

The decomposition produces three numbers whose interpretation is as follows-

- **T_Between-** the share of total APY inequality explained by zones being at different average penetration levels. If this is high, zone-level policy targeting is appropriate.
- **T_Within-** the share of total APY inequality explained by states within the same zone diverging from each other. If this is high, state-specific interventions are required.
- **T_Total-** the sum of the two, equalling 100 per cent by construction.

The policy value lies not in the absolute Theil T value but in the percentage split between the two components. The decomposition of total variation into between-zone and within-zone components is used to assess the relative importance of structural differences across zones versus heterogeneity within zones. Higher between-zone shares indicate that a larger proportion of total disparity is explained by inter-zone differences, whereas higher within-zone shares indicate greater state-level heterogeneity within zones. For interpretive purposes, this study applies an operational classification of between-zone shares as low, mixed or high concentration. Notably, these bands are used as heuristic policy thresholds rather than universal academic cut-offs.

Although the Theil decomposition is a static snapshot at each point in time, it does not

indicate whether total inequality is growing or shrinking over time or whether states at the bottom are catching up with those at the top. Sigma and beta convergence analysis address these questions.

3.2.4 Sigma-Convergence- Is the Gap Between States Narrowing?

Sigma-convergence, introduced by (Barro & Sala-i-Martin, 1992) in the landmark study of regional income convergence, measures whether the standard deviation of penetration rates across states is falling or rising over time. Unlike the Gini coefficient, sigma-convergence is not a scale-bounded measure.

Its interpretation is directional and magnitude-based-

- The direction of change over time is the primary indicator. A rising standard deviation confirms sigma-divergence; a falling one confirms sigma-convergence.
- The magnitude of change contextualises severity. A standard deviation doubling over a decade indicates strong divergence.
- Zone-wise sigma identifies which zones are most internally polarised, guiding the geographic granularity of policy response.

Sigma-convergence tracks overall spread but cannot identify whether individual laggard states are specifically catching up with leaders. The beta-convergence analysis addresses this directly.

3.2.5 Beta-Convergence- Are laggard states growing faster?

Beta-convergence tests a specific hypothesis i.e. do states that started with lower APY penetration in 2015–16 grow proportionally faster over the decade? The theoretical basis lies in the principle of diminishing marginal returns to penetration i.e. states far below their saturation ceiling face a larger pool of readily accessible enrolments and thus, higher marginal returns to outreach effort, while high-enrolment states confront progressively harder-to-reach populations.

The key output of the test is the beta coefficient and its statistical significance:

- A negative beta coefficient indicates the catch-up direction- states that started lower grew faster.
- Statistical significance confirms that this catch-up pattern is systematic, not coincidental.
- However, a non-significant result does not necessarily mean no convergence, it may reflect insufficient statistical power, which is why multiple specifications are used.

An important conceptual distinction must be noted- sigma-divergence and beta-convergence can coexist (Barro & Sala-i-Martin, 1992). Beta-convergence captures the average tendency for laggard states to grow faster, but individual states may deviate substantially from this trend due to idiosyncratic factors viz. policy differences, administrative capacity and outreach effort and if these deviations are large enough, overall cross-sectional dispersion can rise even as the central convergence tendency holds.

This study uses four progressively robust specifications, each addressing a specific weakness of the preceding one.

3.2.5.1 OLS and HC3 Robust Standard Errors The standard cross-sectional OLS test regresses each state's total growth from 2015–16 to 2024–25 on its 2015–16 penetration level. With only 29 states, the test has limited statistical power and outlier states like Sikkim and several NE states, create heteroskedasticity that inflates standard errors and produces false non-significance. The HC3 correction recalculates standard errors without assuming uniform variance (MacKinnon & White, 1985).

3.2.5.2 Panel Fixed Effects Regression The panel Fixed Effects model uses all 261 year-state observations (29 states $\times$ 9 year-on-year periods) rather than 29, multiplying statistical power ninefold. It controls for each state's permanent, time-invariant characteristics viz. banking infrastructure, governance quality, historical financial literacy, through state-specific intercepts. The (Hausman, 1978) test confirms Fixed Effects is the correct specification ($p < 0.001$ for all three dimensions).

3.2.5.3 Non-Parametric Tests and Quartile Mobility Matrix Spearman's rank correlation (Spearman, 1904) and Kendall's tau (KENDALL, 1938) test whether states ranked lower on initial penetration tended to rank higher on growth rate, with no distributional assumptions. The (Wilcoxon, 1945) Rank-sum test directly tests whether bottom-half states grew significantly faster than top-half states. The quartile mobility matrix takes the most concrete approach- it classifies each state into a performance quartile (Q1 = bottom 25%, Q4 = top 25%) in both 2015–16 and 2024–25 and counts actual transitions.

3.2.6 Gender Parity Index- Are Women Being Served at Parity?

The GPI for each state in each year is the ratio of the female APY penetration rate (female enrolments per 1,000 female eligible population) to the male APY penetration rate (male enrolments per 1,000 male eligible population). The female share figure is misleading: it rises when male enrolment slows even if female penetration is stagnant, creating a false impression of equity improvement. The GPI with gender-specific denominators isolates

female policy performance independently of male dynamics. The key methodological choice is to use gender-specific population denominators rather than simply reporting female share of total APY enrolments.

Although, the GPI tells us whether APY is reaching women at parity with men within each state, it does not tell us whether APY's reach to women is distributed equitably across states. That we understand through the female Gini coefficient. The two measures are complementary, not interchangeable. However, neither the GPI nor Gini, reveal how the full distribution of state penetration rates has evolved in shape. Thus, to comprehend the same we use the ridge density plot.

3.2.7 Ridge Density Plot: How Has the Full Distribution Evolved?

Kernel density estimation estimates the shape of the distribution of state penetration rates without assuming any particular mathematical form. For each year, it produces a smooth curve showing where states are concentrated along the penetration rate scale. The ridge plot stacks one density curve per year vertically, creating a visual sequence of how the distribution evolved.

The key interpretive question is the shape of the distribution in each year-

- A single peak (unimodal) suggests that all states are broadly converging toward a single level and no permanent polarisation is occurring.
- Two peaks (bimodal) suggests that states are splitting into two separate groups- a high-performing cluster and a permanently lagging cluster.
- A rightward shift of the peak over time suggests average penetration is rising nationally.
- A widening of the distribution suggests sigma-divergence is present.
- A narrowing of the distribution suggests sigma-convergence is beginning.

4 Results

4.1 APY Penetration Rates: Overview

Table 3 presents the master summary of all key metrics computed in this study across the 10-year panel. Figure 6 provides a state-wise heatmap of total APY penetration across all years.

Table 3 Master Summary- Gini, Theil Decomposition, Sigma-Convergence and GPI (2015-16 to 2024-25)

Year	Gini Total	Gini Male	Gini Female	Gender Gap	Theil Total	% Between	% Within	Sigma Total	GPI Avg.
2015–16	0.2099	0.2067	0.2398	0.0331	0.0696	31.7%	68.3%	1.72	0.689
2016–17	0.2194	0.2119	0.2682	0.0563	0.0789	22.5%	77.5%	1.62	0.615
2017–18	0.2441	0.2340	0.3122	0.0782	0.1080	12.8%	87.2%	3.91	0.780
2018–19	0.2822	0.2450	0.3688	0.1238	0.1433	13.0%	87.0%	5.54	0.931
2019–20	0.2334	0.2203	0.2905	0.0702	0.0945	14.7%	85.3%	5.04	0.915
2020–21	0.2814	0.2309	0.3690	0.1381	0.2476	22.1%	77.9%	16.64	0.937
2021–22	0.3594	0.2976	0.4438	0.1461	0.4133	26.5%	73.5%	34.22	0.977
2022–23	0.3402	0.2865	0.4226	0.1361	0.3862	26.6%	73.4%	38.87	1.085
2023–24	0.2988	0.2384	0.3851	0.1467	0.2910	18.3%	81.7%	29.07	1.228
2024–25	0.2801	0.2426	0.3393	0.0967	0.1577	3.3%	96.7%	13.60	1.339

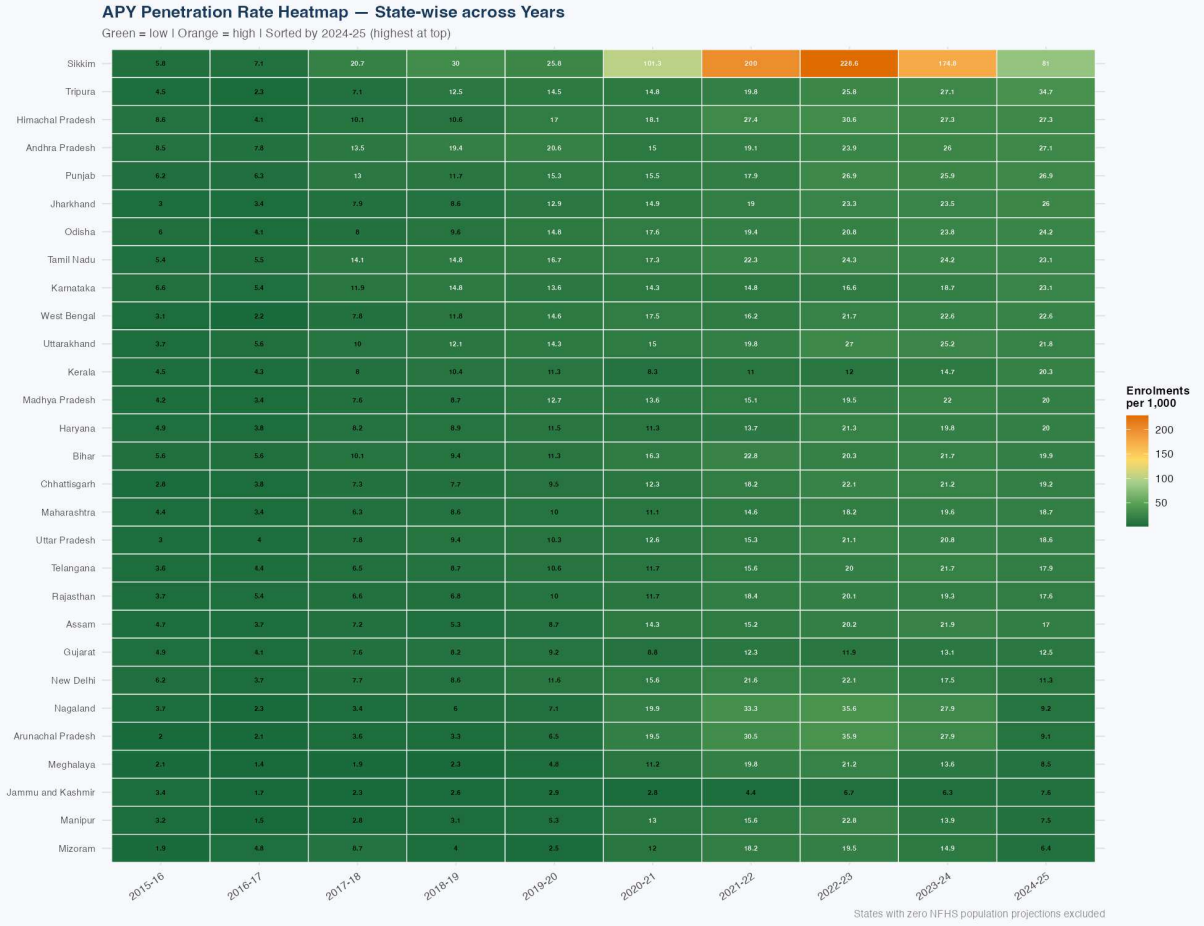


Figure 1- APY Penetration Rate Heatmap

4.2 Gini Coefficient Analysis

The national Gini coefficient for APY total enrolment penetration started at 0.210 in 2015–16, rose steadily to 0.282 by 2018–19, moderated to 0.233 in 2019–20. At the height of the Covid pandemic's disruption period, it spiked sharply to 0.359 in 2021–22, before declining to 0.280 by 2024–25. The net change over the decade is an increase of 0.070 Gini points, representing an approx. 33% increase in inequality from 2015–16 baseline.



Figure 2- APY Gini Coefficient Trend- Total, Male and Female Penetration (2015-16 to 2024-25)

Zone-wise Gini coefficients (Figure 3) reveal substantial heterogeneity. The NE zone shows the highest and worsening within-zone inequality, rising from 0.219 in 2015–16 to 0.493 in 2024–25, signalling extreme polarisation with Tripura and Assam achieving high penetration while Nagaland, Manipur and Mizoram remain at extremely low levels (Figure 1). The South zone shows the most equitable and improving picture, with its within-zone Gini declining from 0.167 to 0.077, reflecting convergence among Southern states toward high penetration levels.

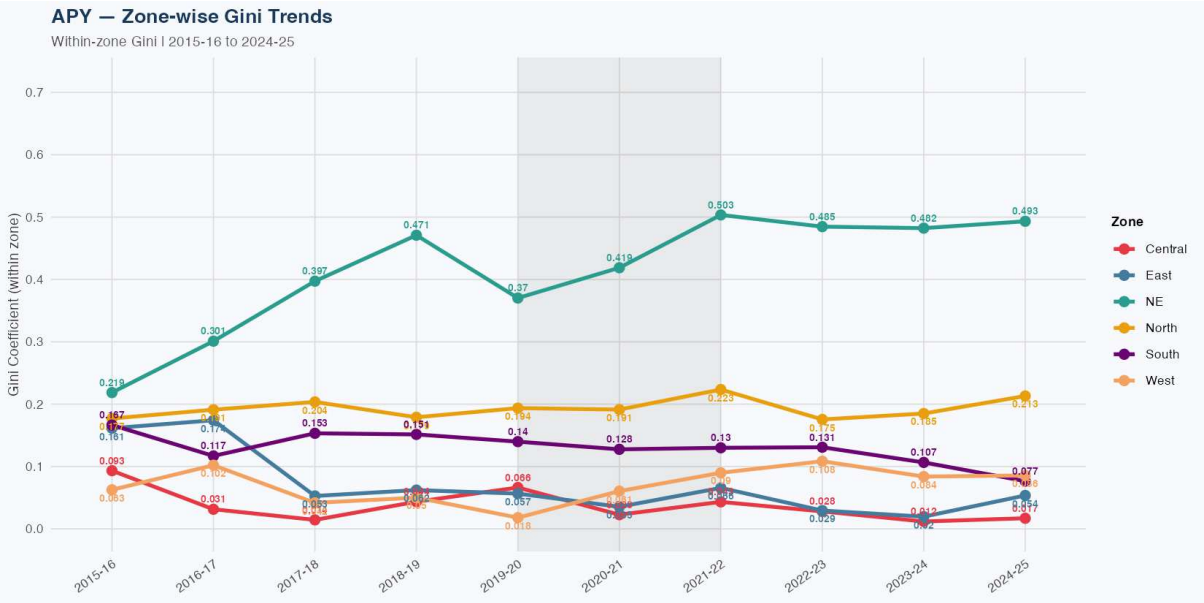


Figure 3- Zone-wise Gini Coefficient Trends (2015-16 to 2024-25)

Four phases are discernible in the Gini trajectory (Figure 2).

- The expansion phase (2015–16 to 2018–19) saw the Gini rise from 0.210 to 0.282 as early-mover states in the South and East zones grew their APY networks substantially faster than laggard states in the Central and NE zones.
- The temporary moderation phase (2018–19 to 2019–20), Gini falling to 0.233 may reflect post-PMJDY banking infrastructure improvements reaching laggard states.
- The COVID disruption phase (2019–20 to 2021–22) saw the sharpest Gini increase, rising from 0.233 to 0.359. This may have been because of the asymmetric disruptions in enrolment channels caused by the pandemic which might have disproportionately affected states with lower banking density and less robust digital infrastructure.
- The partial recovery phase (2021–22 to 2024–25) shows the Gini declining from 0.359 to 0.280. However, it remained above the pre-COVID level of 0.233.

Female Gini coefficients are consistently and substantially higher than male throughout the decade. The gender Gini gap (Female minus Male) widened from 0.033 in 2015–16 to a peak of 0.147 in 2023–24 before narrowing to 0.097 in 2024–25. This confirms that while female APY enrolments are growing nationally, growth is highly concentrated in a few high-performing states, leaving female enrolment deeply unequal across the country.

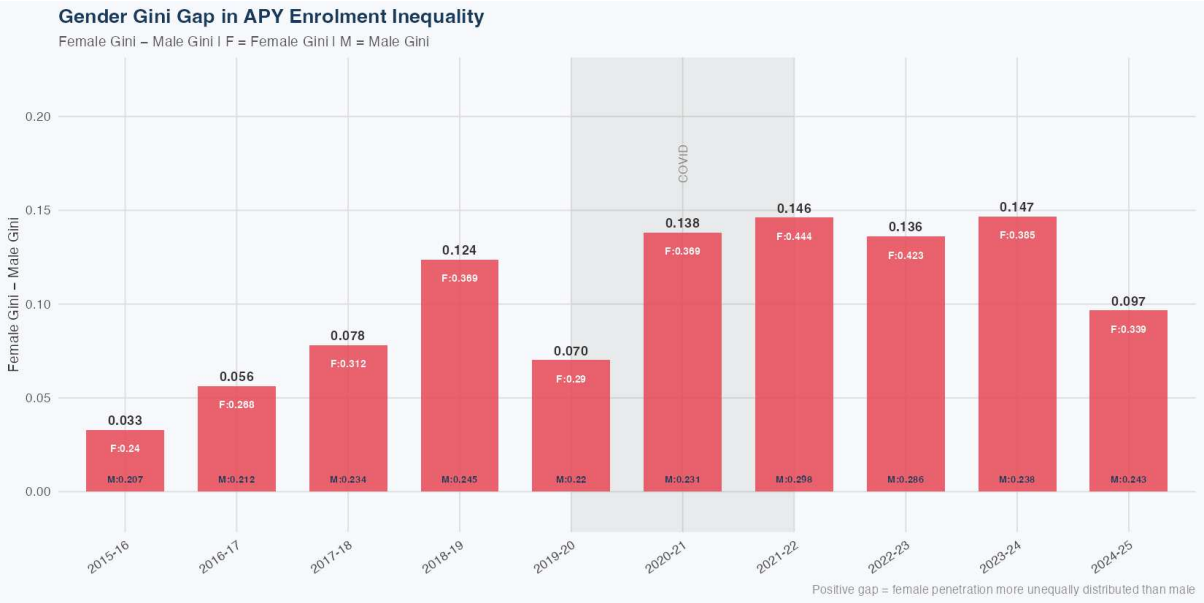


Figure 4- Gender Gini Gap

4.3 Lorenz Curve Analysis

Lorenz curves (Figure 5) for three selected years visually confirm the Gini findings. In all three panels (total, male, female), the 2019–20 and 2024–25 curves bow further below the diagonal than the 2015–16 curve, confirming increased inequality. The female panel shows substantially greater departure from the equality diagonal throughout, providing visual corroboration of the higher female Gini values.

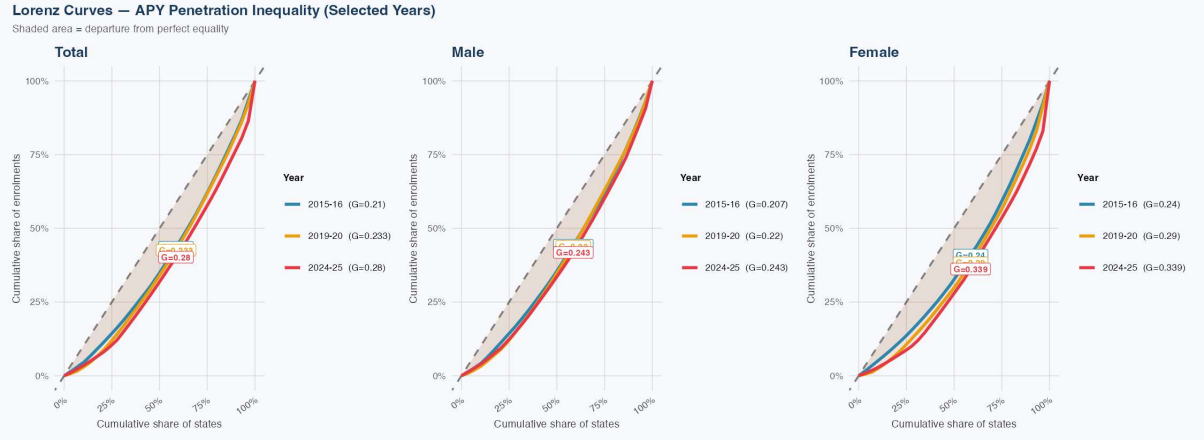


Figure 5- Lorenz Curves- Total, Male and Female APY Penetration

Figure 6 overlays all 10 annual Lorenz curves for total penetration. The colour gradient from blue (early years) to red (later years) clearly shows the progressive migration of curves away from the equality diagonal through 2021–22, followed by partial convergence back toward equality in 2022–23 through 2024–25.

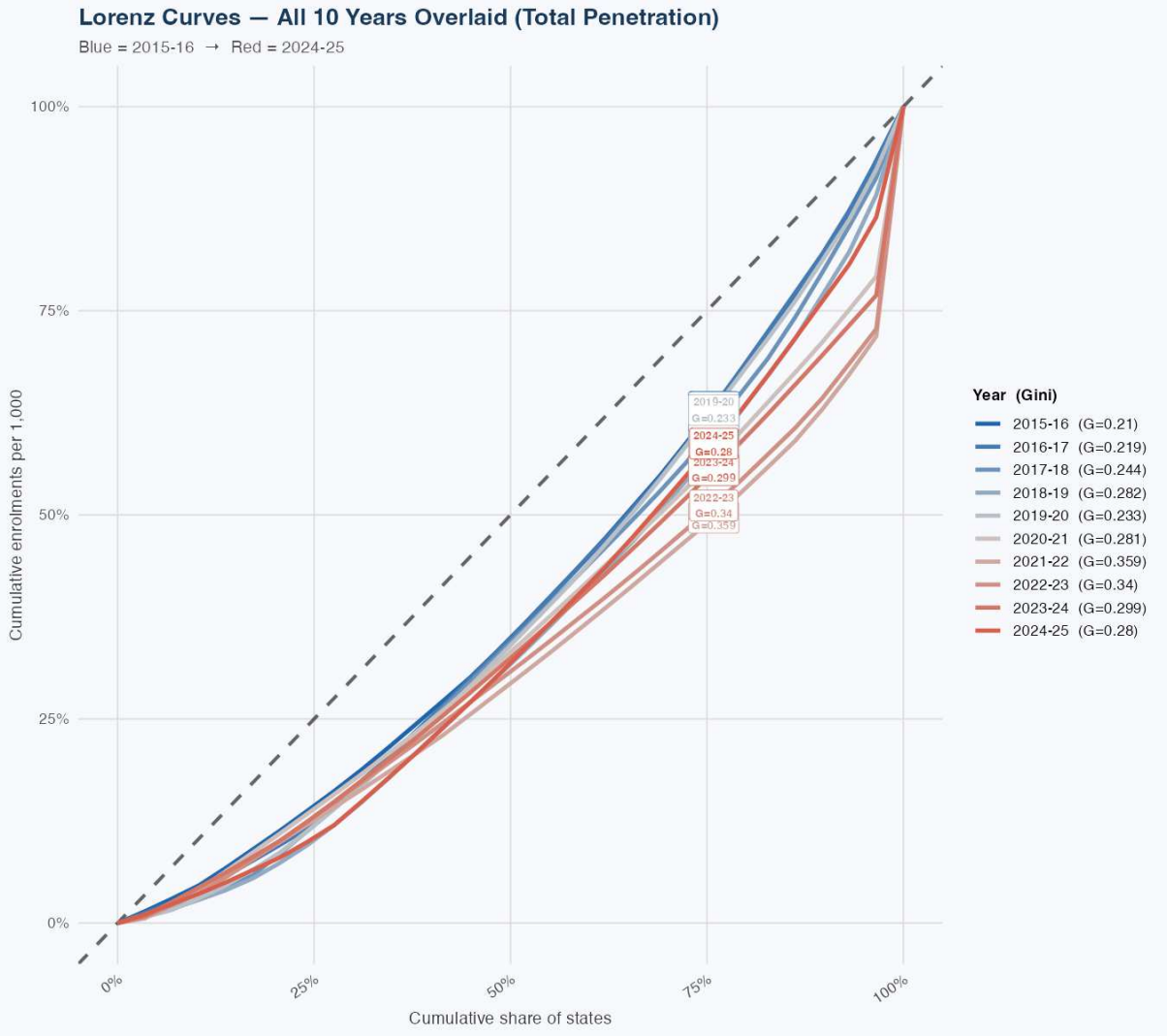


Figure 6- Lorenz Curves- All 10 Years Overlaid

4.4 Theil T Decomposition

The Theil decomposition results represent the analytically most significant finding of this study. Table 2 presents the complete decomposition. In 2015–16, between-zone inequality accounted for 31.7% of total Theil T. Zones were at genuinely different average penetration levels (South significantly higher than NE and Central). By 2017–18 the between-zone share had already fallen to 12.8%, which further collapsed to 3.3% by 2024–25.

Table 4- Theil T Decomposition

Year	Theil Total	T Between	T Within	% Between	% Within	Policy Implication
2015–16	0.0696	0.0221	0.0475	31.7%	68.3%	Zone-level factors dominant
2016–17	0.0789	0.0178	0.0611	22.5%	77.5%	State-specific dominant
2017–18	0.1080	0.0138	0.0942	12.8%	87.2%	State-specific dominant
2018–19	0.1433	0.0187	0.1246	13.0%	87.0%	State-specific dominant
2019–20	0.0945	0.0139	0.0806	14.7%	85.3%	State-specific dominant
2020–21	0.2476	0.0546	0.1930	22.1%	77.9%	State-specific dominant
2021–22	0.4133	0.1094	0.3039	26.5%	73.5%	Zone-level factors dominant
2022–23	0.3862	0.1028	0.2834	26.6%	73.4%	Zone-level factors dominant
2023–24	0.2910	0.0533	0.2377	18.3%	81.7%	State-specific dominant
2024–25	0.1577	0.0052	0.1525	3.3%	96.7%	State-specific dominant

This structural shift has a precise policy interpretation: zones have essentially converged with each other in average APY enrolment. What remains i.e. 96.7% of all APY enrolment inequality is entirely explained by states within the same zone having dramatically different penetration rates. Tripura outperforming Nagaland by a factor of 20 within the NE zone or Telangana outperforming Kerala within the South zone, exemplifying this within-zone polarisation (Figure 1). The temporary COVID reversal during the period 2019–20 to 2021–22 is noteworthy. The between-zone share rose to 26.6% in 2022–23 as the pandemic disrupted zones asymmetrically. The reversal was temporary and by 2024–25 the between-zone share reached its lowest recorded level.

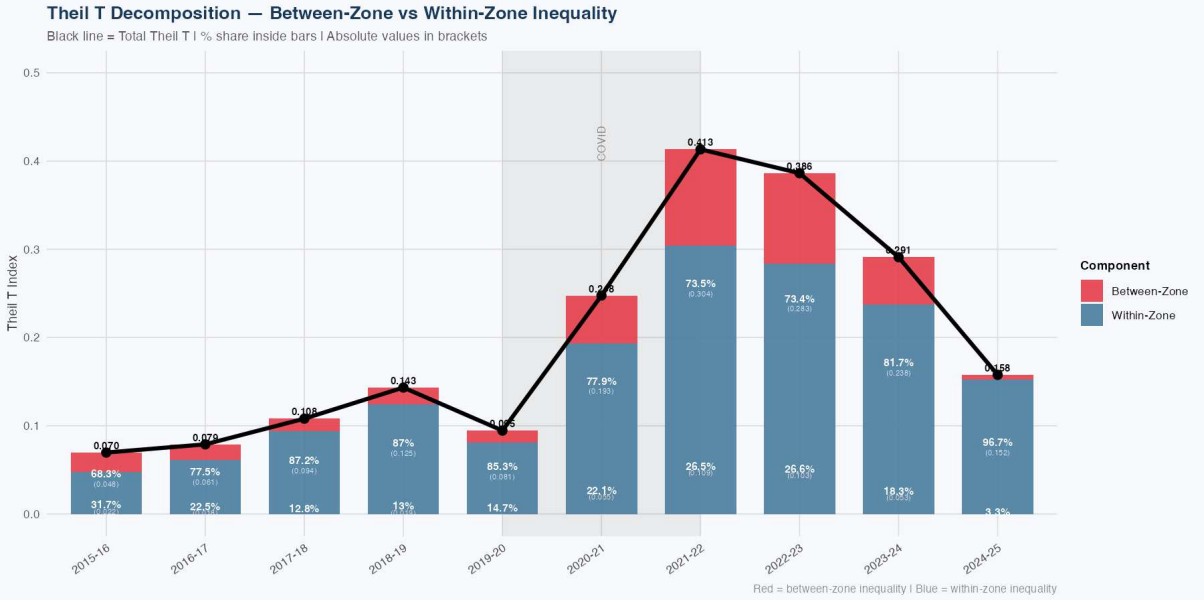


Figure 7: Theil T Decomposition

4.5 Sigma-Convergence

The national standard deviation of total penetration rates rose from 1.72 in 2015–16 to a peak of 38.87 in 2022–23, before declining to 13.60 in 2024–25 indicating sigma-divergence, with the standard deviation growing by a factor of 22.6 (Figure 8). Female sigma is consistently larger than male, peaking at 57.70 in 2022–23 compared to male's peak of 22.56, confirming that national female APY growth has been concentrated in a small number of high-performing states, thus corroborating the indications already provided by the Gini and Lorenz analysis. However, the post-2022–23 decline in sigma from 38.87 to 13.60 in just two years is encouraging. Notably, even after the decline the sigma at 13.60 for 2024–25, remains nearly 8 times its 2015–16 level, indicating that meaningful convergence is still some time away.

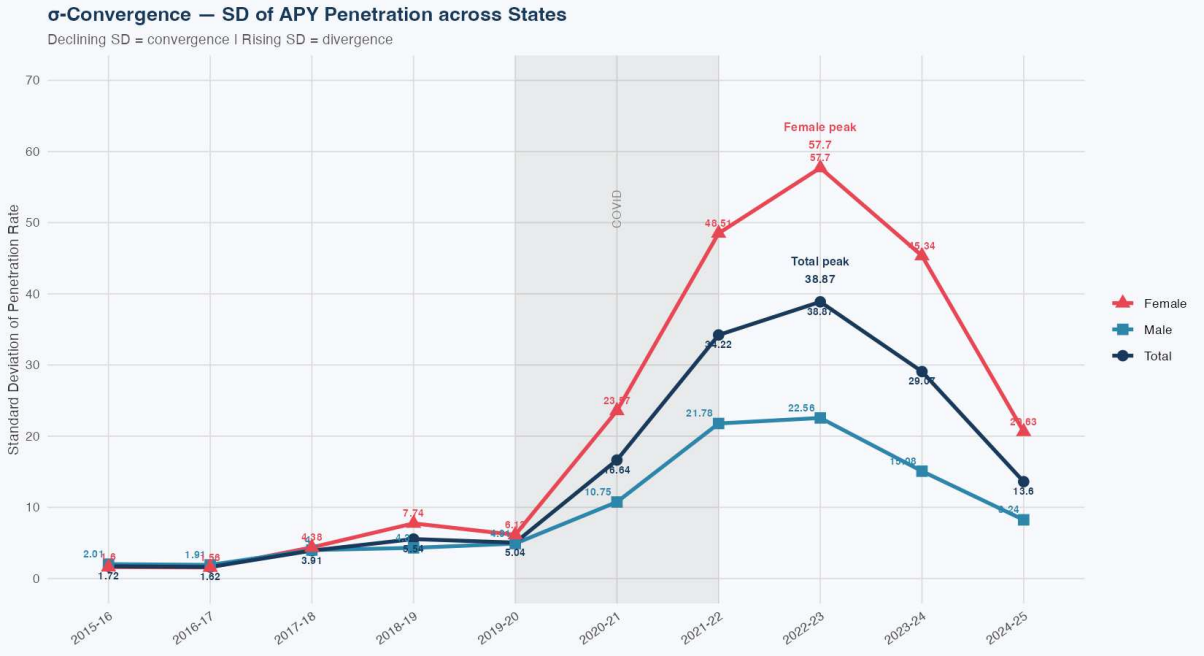


Figure 8- σ-Convergence

Zone-wise sigma (Figure 9) confirms the NE zone as the most internally polarised, with within-zone SD rising through 2022–23 without meaningful reversal. The East zone shows encouraging partial recovery from 2023–24, suggesting more vigorous catch-up within the zone. South and West zones maintain the lowest within-zone sigma throughout the 10 year period.

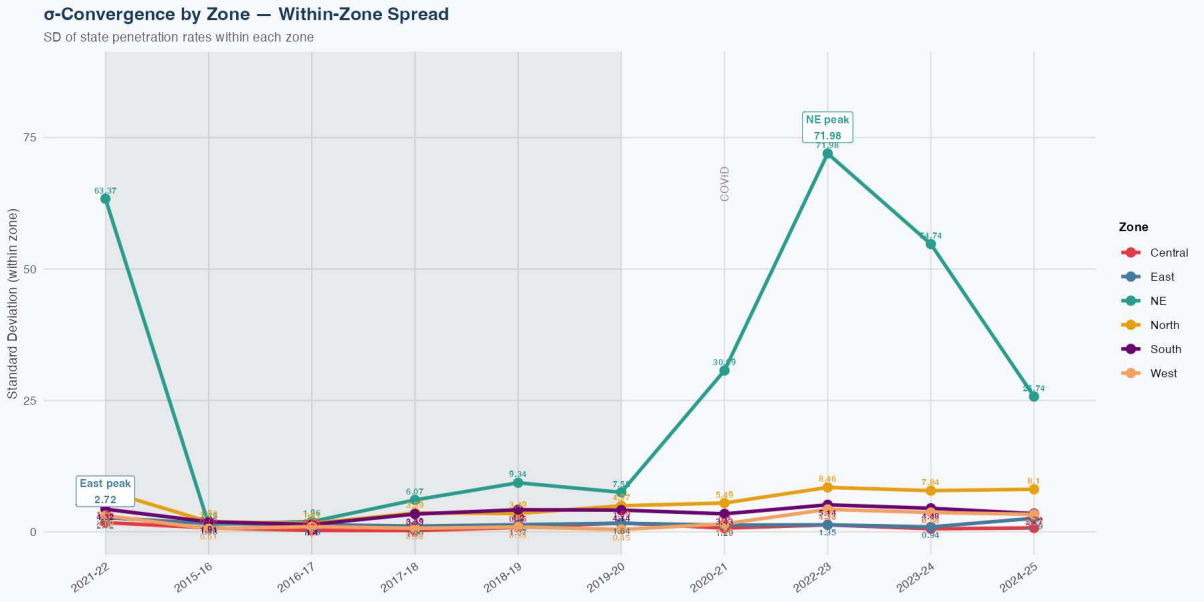


Figure 9- σ-Convergence by Zone

4.5 Beta-Convergence Analysis

4.6.1 Cross-Sectional OLS and Robust Results

Table 5 presents cross-sectional convergence test results. OLS beta coefficients are negative for all three dimensions, indicating catch-up convergence. However, none are statistically significant under standard OLS, due to heteroskedasticity and small sample constraints (29 states).

*Table 5- Cross-Sectional Beta-Convergence Results (*** p<0.05 | n=29 states | OLS = standard; HC3 = robust SE)*

Category	**OLS β**	**OLS p**	**HC3 p**	**Spearman ρ**	**Spearman p**	**Kendall τ**	**Sig?**
Total	−0.1887	0.383	0.339	−0.306	0.107	−0.237	No
Male	−0.2758	0.123	0.041***	−0.387	0.039***	−0.251	Yes (2)
Female	−0.1875	0.446	0.518	−0.157	0.415	−0.158	No

We carry out the HC3 robust correction. The correction changes the inference for Male penetration with p-value from going down to 0.041 from earlier 0.123, confirming significant Male beta-convergence.

Spearman $\rho = -0.387$ ($p = 0.039$) independently confirms this via a rank-based test. These two independent confirmations i.e. parametric (HC3) and non-parametric (Spearman), constitute reliable evidence of Male beta-convergence that OLS could not detect.

4.6.2 Panel Data Beta-Convergence

Table 6 presents panel Fixed Effects and Random Effects results using all 261 year-state observations (29 states X 9 intermediate years = 261). Panel Fixed Effects regression confirms highly significant beta-convergence for all three dimensions. The Hausman test ($p < 0.001$ in all cases) selects Fixed Effects, indicating that unobserved state-specific characteristics are correlated with penetration levels and thus, need to be controlled.

The discrepancy between cross-sectional OLS (non-significant) and panel Fixed Effects (highly significant) is in itself a revelation. The cross-sectional approach discards 8 years of intermediate dynamics and cannot control for state heterogeneity, producing a false negative that the panel approach corrects.

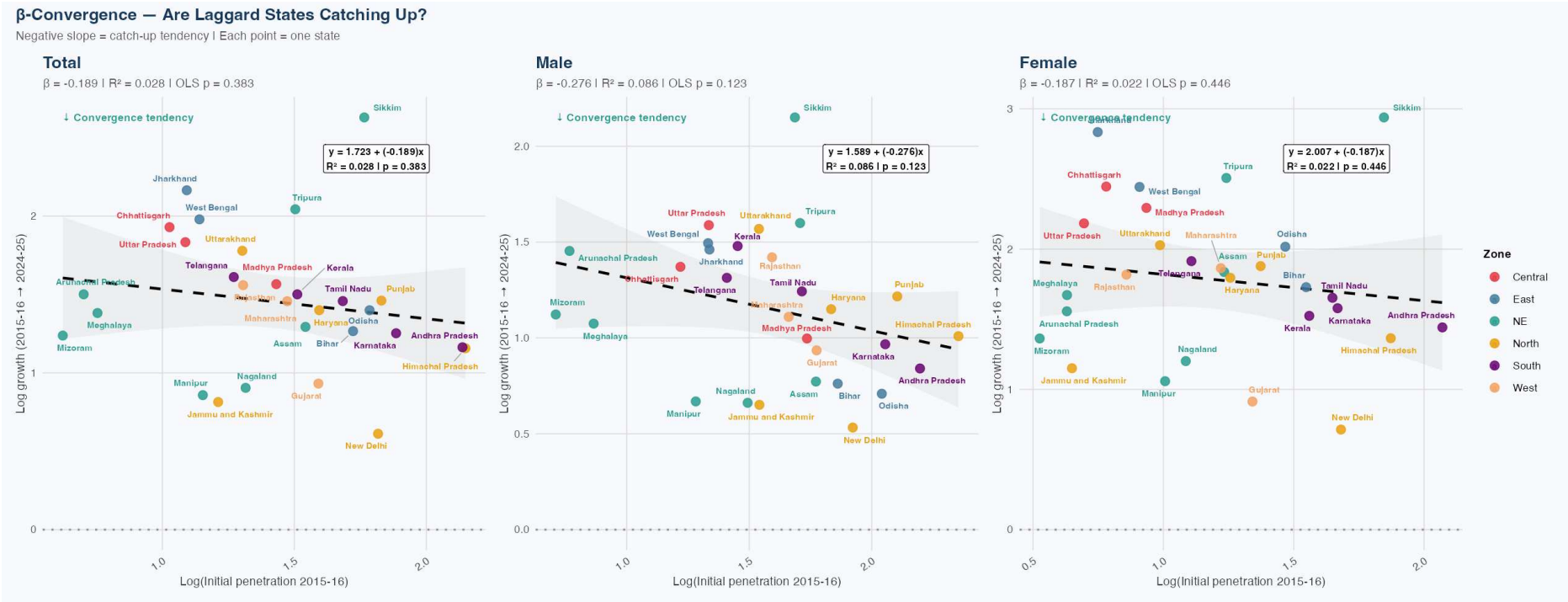


Figure 10- β-Convergence Scatter Plots

*Table 6- Panel Beta-Convergence Results- Fixed and Random Effects (Hausman test selects Fixed Effects; *** p<0.001)*

Category	**FE Beta**	**FE p-value**	**RE Beta**	**RE p-value**	**Preferred Model**
Total	−0.2333	<0.001***	−0.1589	<0.001***	Fixed Effects
Male	−0.2714	<0.001***	−0.1910	<0.001***	Fixed Effects
Female	−0.2100	<0.001***	−0.1342	<0.001***	Fixed Effects

4.6.3 Quartile Mobility Matrix

The quartile mobility matrix (Table 7) classifies each of the 29 states into a performance quartile based on total APY penetration rate in both 2015–16 (initial) and 2024–25 (final), with Q1 being the bottom 25% and Q4 the top 25%. Diagonal cells represent states that maintained their relative rank and off-diagonal cells represent upward or downward mobility. Above diagonal movement suggests that the state has moved up in performance and below diagonal movement suggests deterioration in performance.

Table 7- Quartile Mobility Matrix- APY Total Penetration 2015–16 vs 2024–25 (n=29 states; Q1=bottom quartile, Q4=top quartile)

2015–16 ↓ / 2024–25 →	**Q1 (Bottom)**	**Q2**	**Q3**	**Q4 (Top)**
Q1 (Bottom)	3: Mizoram, Arunachal Pradesh, Meghalaya	2: Chhattisgarh, Uttar Pradesh	1: West Bengal	1: Jharkhand
Q2	3: Manipur, J&K, Nagaland	2: Telangana, Rajasthan	2: Uttarakhand, Madhya Pradesh	0
Q3	0	3: Maharashtra, Assam, Gujarat	2: Kerala, Haryana	2: Tripura, Tamil Nadu
Q4 (Top)	1: New Delhi	0	2: Bihar, Karnataka	5: Sikkim, Odisha, Punjab, Andhra Pradesh, Himachal Pradesh

Of the 29 states, 12 (41.4%) remained in the same quartile. Eight states moved up (27.6%) and nine moved down (31.0%).

The most notable upward movers are Jharkhand (Q1 → Q4, from 2.98 to 26.35 per 1,000) and West Bengal (Q1 → Q3, from 3.13 to 22.55), representing genuine catch-up from the bottom quartile. Tripura (Q3 → Q4) contrasted by Sikkim's explosive growth at 81.44 per 1,000, is a standout Q4 performer. Tamil Nadu is the other mover from Q3 → Q4.

Among the seven initial Q1 states, Mizoram, Arunachal Pradesh and Meghalaya remained in Q1 throughout the decade, each still below 10 per 1,000 in 2024–25 despite 10 years of scheme operation. This evidences the structural nature of their underperformance. New Delhi's descent from Q4 to Q1 reflects the lowest 2024–25 penetration rate (11.35 per 1,000) of any initial Q4 state and the most dramatic relative rank deterioration of the decade. This is most likely on account of early market saturation in a highly urbanised, largely formally employed population where APY-eligible citizens may be a smaller share of the working-age population.

4.7 Distributional Convergence

The ridge plot (Figure 11) reveals three structural changes. First a dramatic rightward shift. This means penetration rose from 4.5 in 2015–16 to peaking at 29.0 in 2022–23, before declining to 20.7 in 2024–25. Second a substantial widening from 2019–20 onwards, with a long right tail of high-performing outlier states pulling the mean far above the median. Third, with partial narrowing in 2024–25, the SD fell from 38.87 in 2022–23 to 13.60.

Since, there is no evidence of twin peaks or convergence club formation, the distribution remains unimodal throughout. This is consistent with the panel beta-convergence finding that a genuine catch-up mechanism is in motion, albeit slowly. The persistence of right-skewness confirms that convergence is driven by catch-up from the bottom rather than reversion from the top.

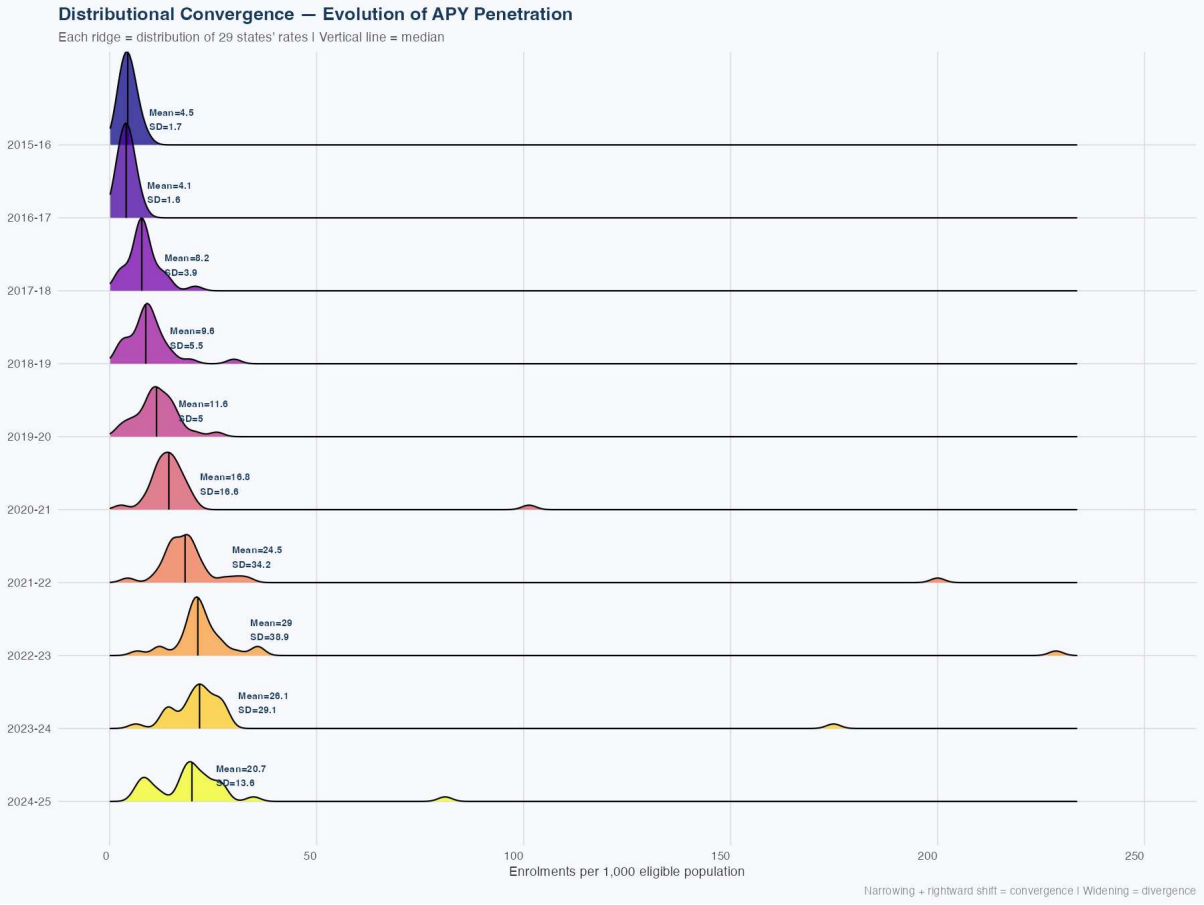


Figure 11: Distributional Convergence- Ridge Density Plot of State APY Penetration Rates (2015-16 at top, 2024-25 at bottom)

4.6 Gender Parity Index Analysis

The national average GPI rose from 0.689 in 2015–16 to 1.339 in 2024–25, crossing the parity threshold in 2022–23 as confirmed by the vertical dashed line on the heatmap. This represents a genuine and significant policy achievement.

However, the GPI heatmap reveals the heterogeneity underlying this national average. Several NE and North zone states remained below GPI = 1.0 in 2024–25, with persistent male advantage. Several East zone states developed strong female advantages (GPI above 1.5 in some cases). The range of state-level GPI values in 2024–25 (approximately 0.6 to 2.2) is wider than in 2015–16 (approximately 0.4 to 1.2), confirming that geographic inequality in gender equity is itself growing even as the national average improves.

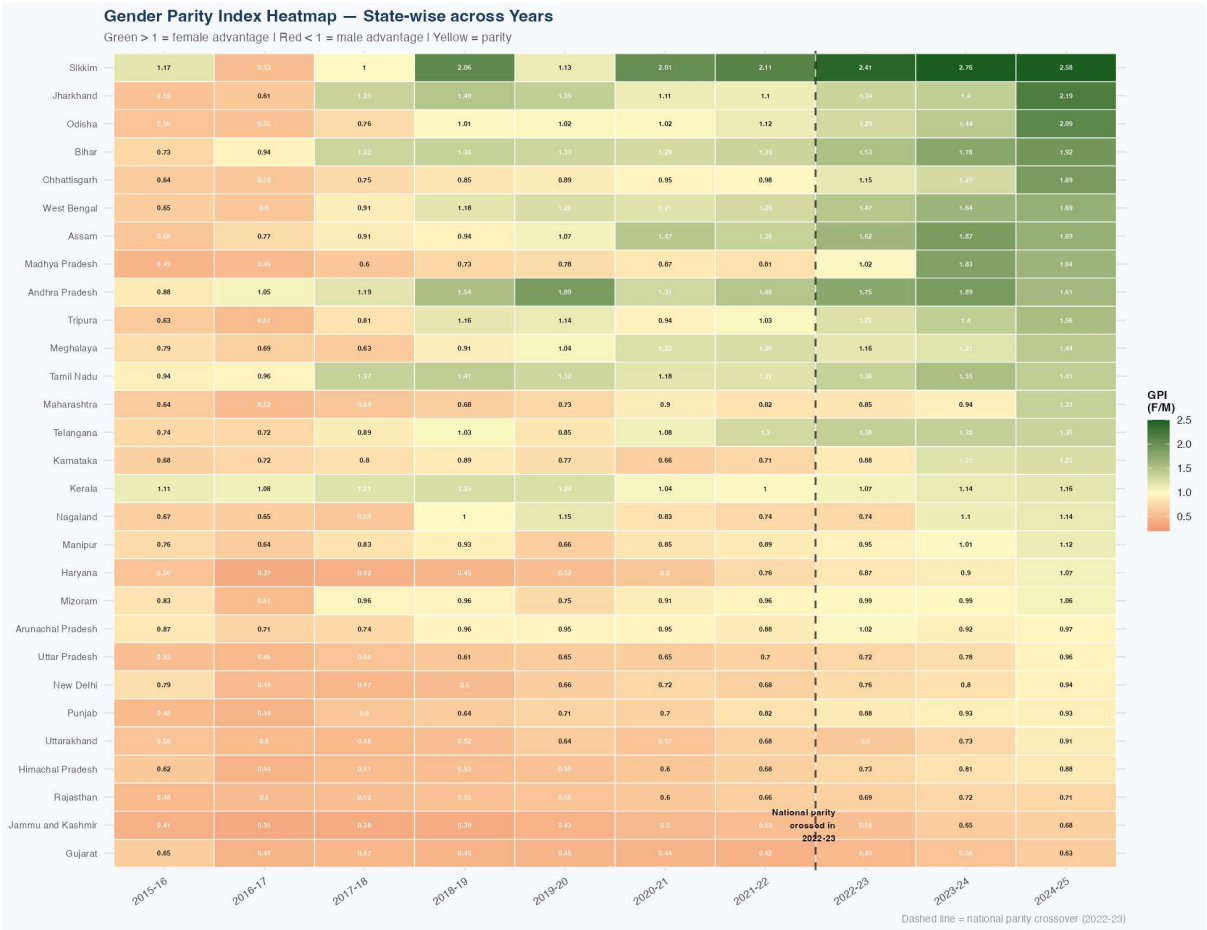


Figure 12- GPI Heatmap

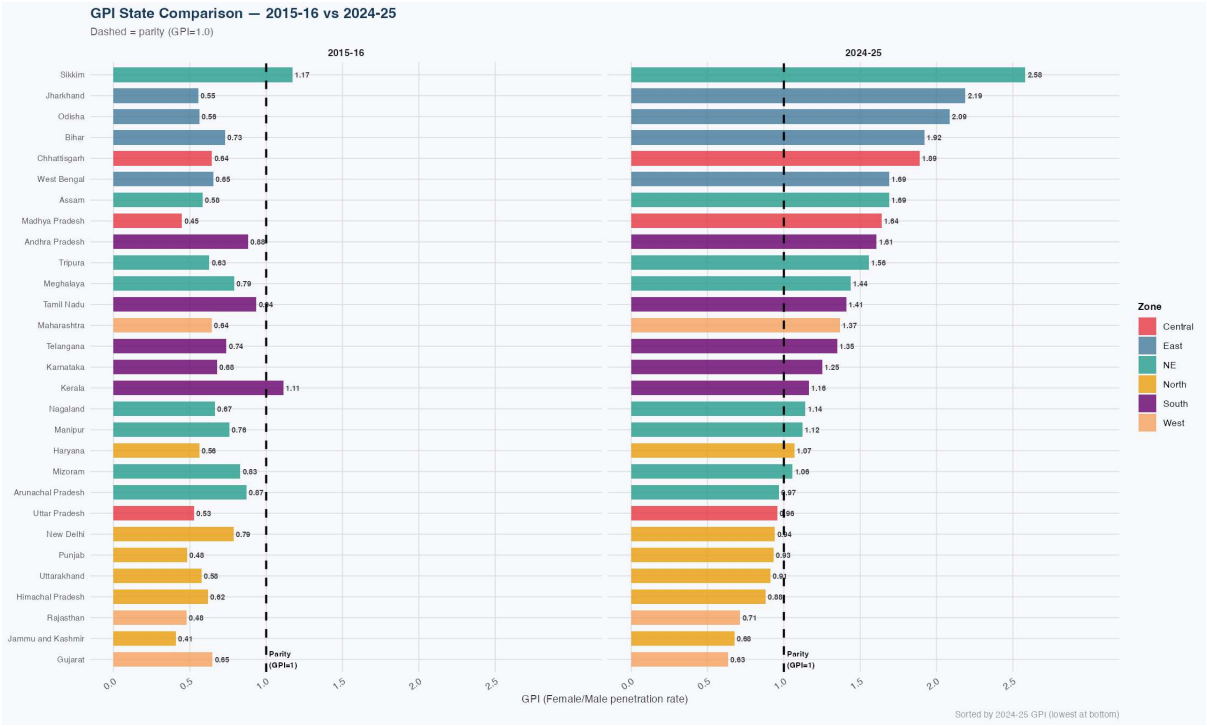


Figure 13- GPI State Comparison- 2015-16 vs 2024-25

Zone-wise GPI trends (Figure 14) show that East and South crossed parity simultaneously and earliest, both in 2017–18, East zone reaching 1.089 and the South zone reaching 1.098 in that year. The NE zone followed in 2018–19 (GPI = 1.026) and has maintained female advantage consistently since, reaching 1.635 by 2024–25. The Central zone crossed parity only in 2023–24 (GPI = 1.012), the second latest of all zones. Two zones, North (GPI = 0.941 in 2024–25) and West (GPI = 0.974 in 2024–25) have never achieved female parity at the zone-average level throughout the entire decade and both remain below 1.0 as of 2024–25.

This zone-level GPI pattern is not consistent with the broader finding that the NE zone is the most problematic region on gender equity. The NE zone is actually one of the better performing zones, with persistent female advantage since 2018–19. The North and West zones are the persistent gender equity laggards.

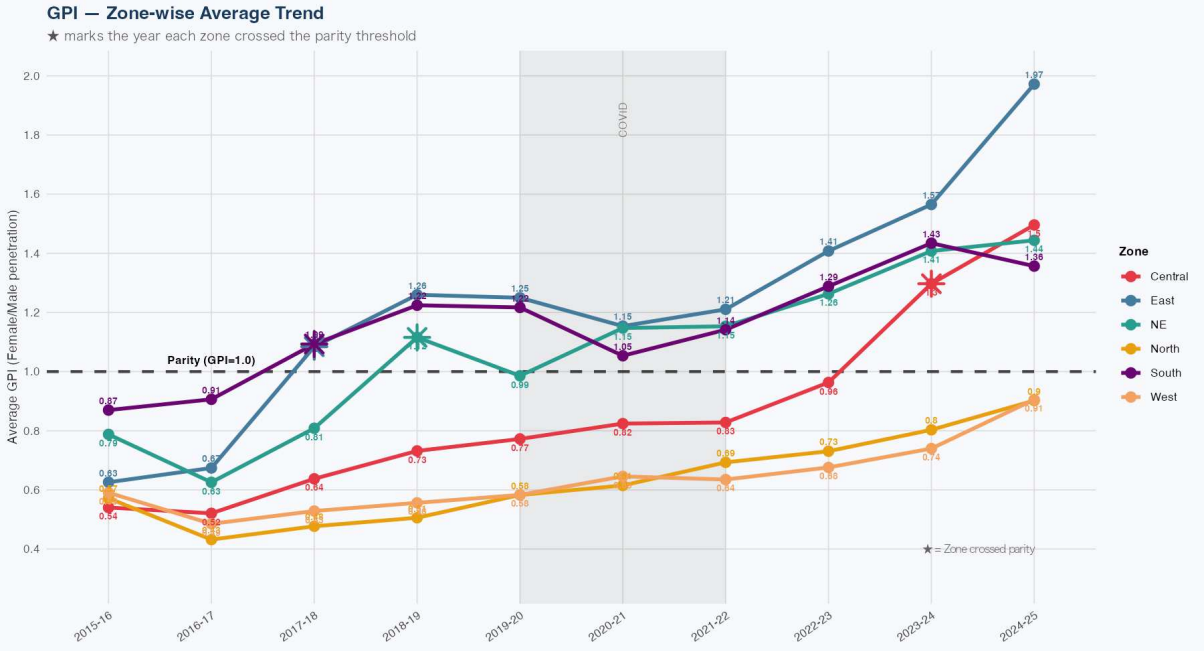


Figure 14- GPI Zone-wise Average Trend

5 Discussion

The study deploys seven complementary analytical tools, each answering a question that the other tool cannot. Cumulatively they produce a complete distribution diagnostic of APY's first decade. The findings below are presented in this order.

5.1 APY Inequality- grown over the decade, but showing signs of recovery

Although APY has grown substantially in absolute enrolment, the growth has been heavily concentrated in states that were already above-average performers at the scheme's launch. The national Gini coefficient for APY total enrolment penetration rose from 0.210 in 2015–16 to a decade peak of 0.359 by 2021–22, representing a 71% increase from baseline. By 2024–25 the Gini moderated to 0.280, representing a net increase of 33% over the full decade.

Four phases characterise the decade's inequality trajectory. The expansion phase (2015–16 to 2018–19) saw early-mover Southern and Eastern states accelerate enrolment substantially faster than Central and NE zone states, driving the Gini from 0.210 to 0.282. A brief moderation phase in 2019–20 (Gini fell to 0.233) likely reflects post-PMJDY banking infrastructure improvements beginning to reach structurally laggard states. The COVID disruption phase (2019–20 to 2021–22) produced the sharpest inequality increase. The Gini spiked to 0.359 as digital enrolment channels proved accessible only in states

with stronger digital and banking infrastructure. The partial recovery phase (2021–22 to 2024–25) shows the Gini declining to 0.280, though it remains substantially above the pre-COVID level of 0.233.

Female inequality is structurally worse and more volatile. The Female Gini peaked at 0.444 in 2021–22, which is full 25 Gini points above the Male peak of 0.298 in the same year. The gender Gini gap widened from 0.033 in 2015–16 to 0.147 in 2023–24 before narrowing to 0.097 in 2024–25, confirming that female APY growth has been geographically concentrated in a small number of high-performing states and has not spread uniformly across the country.

Zone-wise Gini analysis reveals pronounced heterogeneity. The NE zone records the highest and worsening within-zone inequality driven by Tripura and Assam achieving high penetration while Nagaland, Manipur and Mizoram remain critically underperforming. The South zone is the most equitable and improving, with its within-zone Gini declining from 0.167 to 0.077, reflecting convergence of Southern states toward uniformly high penetration levels.

These findings are fully consistent with the structural predictions of the global social protection literature (ILO, 2021) and the theoretical mechanism is provided by (Holzmann & Hinz, 2005). The rising Gini is therefore, not a failure of implementation but the expected distributional consequence of applying a voluntary scheme to a population with deeply unequal financial access, as the introduction's framing anticipates (Chatterjee & Nandan, 2025). The female Gini's higher trajectory confirms (ILO, 2021) finding that women's coverage by contributory pension schemes is structurally below men's.

5.2 Lorenz Curves- confirming increasing inequality & concentration

Lorenz curves across dimensions visually corroborate the Gini findings. In every panel i.e. total, male and female enrolment bow further below the diagonal of equality than the 2015–16 baseline, confirming increased concentration. The female panel shows substantially greater departure throughout. The all-years overlay of ten annual Lorenz curves for total penetration, provides the most compelling visual narrative i.e. the curves migrate progressively away from equality through 2021–22, evidencing increased inequality and concentration across a few major states, before a partial return toward the diagonal in 2022–23 to 2024–25. Notably, the 2024–25 curve still does not return to its 2015–16 position, thus confirming that inequality has not been reversed, only partially moderated.

5.3 Primary Source of Inequality- Intra Zonal

The Theil T decomposition produces the study's most significant finding. In 2015–16, between-zone inequality accounted for 31.7 per cent of total APY inequality suggesting that zones were at genuinely different average penetration levels. By 2024–25, the between-zone share had collapsed to 3.3 per cent indicating that the six PFRDA zones have essentially equalised with each other. However, this inter-zone compression in the inequality has been simultaneously accompanied with a gigantic leap in the within-zone inequality. States within the same zone diverge dramatically from their zonal peers and now account for 96.7 per cent of all APY inequality.

This structural shift has a direct and unambiguous policy implication. Zone-level analysis and zone-targeted policy intervention although initially justified on account of substantially higher inter-zone inequality, may be now largely an ineffective tool for addressing APY inequality. The intra-zone divergences illustrate the point starkly: within the NE zone, Tripura (34.7 per 1,000) outperforms Nagaland (9.2 per 1,000) by a factor of nearly four; within the Central zone, UP (18.6) and Jharkhand (26.0) diverge substantially despite sharing a zone; within the South zone, Telangana (17.9) and Tamil Nadu (23.1) show distinct trajectories. The relevant unit of policy intervention thus needs to be the individual state.

This finding directly parallels and extends two key literature review references from (Nagaraj et al., 1998), who while studying the inter-region and intra-region decomposition to Indian state income inequality during 1970–1994 found that within-state infrastructure differentials were the dominant driver of persistent inequality. They concluded that the individual state and not the region, should be the correct unit for policy intervention. Similarly (Pradhan et al., 2003) applying Theil entropy decomposition to global health inequality found within-country inequality substantially exceeded between-country inequality.

A temporary COVID-era reversal reflects the pandemic's asymmetric disruption of zones, possibly with weaker digital infrastructure and lack of necessary digital literacy (OXFAM India, 2022). The reversal, however, was temporary and by 2024–25 the between-zone share reached its lowest recorded level, confirming that the structural shift is secular, not cyclical. This observation finds its parallel to (Drèze & Khera, 2017) finding that social protection programmes exhibit inter-state variation in implementation quality that is amplified under stress, with the poorest-governed states most affected.

5.4 Sigma-divergence with the first convergence signal in 2024-25

The national standard deviation of total APY penetration rates rose 22.6-fold from 1.72 in 2015–16 to a peak of 38.87 in 2022–23 indicating high sigma-divergence. The only and first meaningful convergence happened in 2024–25 when it declined to 13.60. Even after the 2024–25 improvement, the national sigma remains nearly eight times its baseline level, indicating that meaningful aggregate convergence is still years away.

Female sigma divergence has been further and faster confirming that women's APY enrolment growth has been concentrated in a small number of high-performing states.

Zone-wise sigma confirms the NE zone as the most internally polarised, with within-zone standard deviation rising through 2022–23 without meaningful reversal. The East zone shows the most encouraging recovery from 2023–24, consistent with Jharkhand's performance improvement and West Bengal's sustained catch-up. South and West zones maintain the lowest within-zone sigma throughout the decade, reflecting their internally more equitable distributions.

(Ram, 1990) in his study of educational attainment inequality across countries found that the standard deviation of schooling rates widened during the early expansion phase before eventually converging. (Becker et al., 2005) also documented sigma-convergence in life expectancy across countries, confirming that social sector indicators exhibit convergence dynamics structurally analogous to income convergence. Both the studies contextualise the divergence as a structural phase of social programme expansion, not an alarm signal, provided the catch-up mechanism operates, which the recent year's beta-convergence confirms it does.

5.5 Beta-Convergence- systematic catch-up in operation, albeit slowly

The negative OLS beta coefficients, although non-significant, for all three dimensions (total, male and female enrolment) indicate the catch-up direction throughout. The HC3 robust correction changes the inference for Male penetration, confirming the significant Male catch-up. Spearman rank correlation independently corroborates this via a non-parametric approach. Panel Fixed Effects regression using all 261 state-year observations resolves the small-sample limitation- $\beta = -0.233$ ($p < 0.001$), Male $\beta = -0.271$ ($p < 0.001$), Female $\beta = -0.210$ ($p < 0.001$). The Hausman test ($p < 0.001$) confirms Fixed Effects as the correct specification.

The discrepancy between cross-sectional OLS (non-significant) and panel Fixed Effects (high statistical significance) is itself a methodological contribution. The cross-sectional approach discards eight years of intermediate dynamics and cannot control for time-

invariant state characteristics like banking infrastructure, governance quality and financial literacy levels. Its non-significant result is thus, a false negative that the panel approach corrects. Thus, a policymaker relying only on cross-sectional OLS alone would incorrectly conclude that no catch-up mechanism exists and that inter-state inequality in APY is permanent, a reading that the panel Fixed Effects result corrects.

APY replicates the pattern of coexistence of sigma-divergence and panel beta-convergence which has been observed in prior and existing literature. (Barro & Sala-i-Martin, 1992) documented this coexistence for US state incomes- beta-convergence (laggard states growing faster) was present even as sigma-divergence (overall spread widening) persisted for extended periods. (Nagaraj et al., 1998) documented the same coexistence for Indian state incomes.

5.6 Quartile Mobility- Strong rank persistence with genuine catch-up

A majority of the 29 states (41.4%) remained in the same performance quartile from 2015–16 to 2024–25, confirming strong rank persistence, which is consistent with the convergence literature. Eight states (27.6%) moved up and nine moved down (31.0%) in their performance.

Notably, at the bottom tail, three NE states viz. Mizoram, Arunachal Pradesh and Meghalaya, remained in Q1 throughout the decade, each still below 10 per 1,000 in 2024–25 despite ten years of scheme operation. Three additional states descended into Q1 (Manipur, Nagaland, J&K). It may be observed that all six are geographically remote, have relatively low banking penetration and face administrative capacity constraints. Their failure to benefit from the catch-up mechanism confirms that beta-convergence operates on average but does not reach states where structural barriers to financial access are most severe.

At the top, five states viz. Sikkim, Odisha, Punjab, Andhra Pradesh and Himachal Pradesh have the common characteristics of strong banking infrastructure, active state government APY outreach and in Sikkim's case a small eligible population, makes high penetration rates arithmetically accessible.

The persistent bottom-quartile NE states confirm (Drèze & Khera, 2017)'s observation that some states cannot access universal scheme benefits without qualitatively different, structurally targeted interventions. Drèze and Khera (Drèze & Khera, 2017; Mohanty et al., 2022a) also document banking infrastructure preconditions for financial scheme uptake. (Chatterjee & Nandan, 2025)'s identification of persistent NE zone underperformance is confirmed and deepened.

5.7 Distributional convergence without any polarisation

The ridge density plot reveals three structural changes over the decade. First, a dramatic rightward shift in the modal penetration rate. Second, a substantial widening from 2019–20 onwards, driven by high-performing outlier states pulling the mean above the median and creating a long right tail. Third, partial narrowing in 2024–25, when the standard deviation fell. The lack of twin peaks formation is perhaps structurally most encouraging finding suggesting that APY is not producing a bifurcated India of permanently high-penetration and permanently low-penetration states and all states remain on a single distribution.

5.8 Gender parity, although observed nationally but geographic inequity persists

The national average GPI rose from 0.689 in 2015–16 to 1.339 in 2024–25, crossing the parity threshold of 1.0 in 2022–23. This represents a genuine and significant policy achievement tha APY has moved from being a male-dominated scheme to one where women are nationally enrolled at higher rates relative to their eligible population than men.

The NE zone's strong gender equity performance is counterintuitive given its overall APY penetration underperformance and warrants attention. Despite having the highest and worsening within-zone APY inequality overall, the NE zone achieved and sustained female advantage 2018–19 onwards. This paradox may be symptomatic of the relatively higher share of women in informal sector economic activity in several NE states, combined with active state government women oriented financial literacy outreach programmes.

This persistent pattern of national aggregate improvement coexisting with widening sub-national dispersion is a well-documented structural feature of social programme expansion documented across the literature.

APY's gender enrolment patterns confirm the pattern revealed by (Ziegler et al., 2024), who while studying gender patterns in RSBY health insurance across eight Indian states, found that national gender equity averages conceal persistent state-level disparities. Their specific finding that UP was a state-specific exception to gender-neutral enrolment is directly confirmed in the APY enrolments as well. (Chatterjee & Nandan, 2025)'s identification of heavily male-skewed enrolments in UP, Gujarat, J&K and Delhi is confirmed and extended.

6 Policy Implications

Move from zone-level to state-level APY targeting

The Theil decomposition finding of the high intra-zone inequality is the study's most direct policy directive. Zone-level performance monitoring may no longer be an adequate intervention. Instead, the authority PFRDA should establish state-specific penetration targets with differentiated outreach strategies for each of the 29 states especially for the 7–8 states that have remained the persistent laggards and in the bottom performance quartile throughout the decade.

Prioritise the North-East with customised delivery models

NE zone shows worsening within-zone Gini, highest sigma and persistent male-dominant GPI. States like Nagaland, Manipur, Mizoram and Arunachal Pradesh have extremely low penetration despite a decade of operations. Traditional bank-branch APY enrolment is clearly ineffective in these states. Alternative channels like postal networks, tribal self-help groups, microfinance institution partnerships and mobile banking units, may be explored, piloted and scaled.

Look beyond female aggregate numbers and address female distribution inequality

The national GPI crossing 1.0 in 2022–23 is an encouraging headline. However, the female Gini (0.339) remains far above male (0.243) and the range of state-level GPI values is widening. Policy should identify which states are driving female APY success, understand the mechanisms (SHG integration, Asha/Anganwadi outreach, women's saving circles) and actively replicate those mechanisms in states with GPI persistently below 0.8.

Treat COVID-19 as a structural warning for future disruptions

The 2020–21 to 2021–22 spike in Gini, Theil and sigma confirms that APY enrolment is highly vulnerable to economic disruptions and that vulnerability is unequally distributed. PFRDA should develop resilience protocols that activate automatically during declared economic emergencies. Such protocols could be premium deferment mechanisms, digital catch-up campaigns and outreach surges in affected states.

Use GPI as a formal monitoring metric alongside aggregate enrolment

PFRDA's performance monitoring currently emphasises total enrolment numbers and female share. The GPI, computed at state level, should be added as a formal monitoring indicator and should trigger a structured gender-focused intervention review.

7 Limitations and Caveats

1. The eligible population includes organised sector workers who are ineligible for APY. States with higher formal sector employment shares will have slightly overstated denominators, marginally understating their true penetration relative to their actual eligible pool.

2. The years 2022 to 2025 are linearly extrapolated toward the population projection figures, which could have introduced marginally higher uncertainty for the most recent years.

3. With n=29 states, cross-sectional OLS has limited statistical power. Hence, results from the panel specification (n=261) should be given greater weight.

4. The Gini, Theil, and sigma metrics do not control for structural state characteristics. The inclusion of such controls is recommended for future research.

5. PFRDA data provides enrolments. Inequality in gross enrolment versus dropout rates could present a different picture. Also, future studies incorporating subscriber exit data would add an important dimension.

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