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Demographic Transition and Green Economic Transformation: Evidence from India with Insights from Telangana

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Abstract

This study examines the relationship between demographic transition and green economic transformation in India, with particular insights from the state of Telangana. While demographic transition theory traditionally emphasizes the role of changing age structures in promoting economic growth, its implications for environmental sustainability remain less explored in developing economies. Using state-level panel data for the period 2005–2023, this research constructs a composite Green Economic Transformation Index (GETI) incorporating indicators such as renewable energy share, emission intensity, and ecological performance. The empirical analysis employs fixed-effects panel regression and dynamic System GMM estimation to evaluate the impact of demographic and structural factors on sustainability outcomes. The results indicate that a higher working-age population share significantly enhances green economic transformation, primarily by supporting renewable energy expansion and facilitating structural economic change. Conversely, higher dependency ratios constrain sustainability investments due to increased fiscal pressures. The findings further show that structural transformation toward industry and services and the expansion of renewable energy play a crucial role in reducing emission intensity. The Telangana case study illustrates how subnational policy initiatives, demographic advantages, and renewable energy expansion can collectively support sustainable development pathways. The study concludes that India's demographic window presents a time-sensitive opportunity to integrate population dynamics with low-carbon development strategies through coordinated demographic, industrial, and environmental policies.

Keywords: *Demographic transition, Green economic transformation, Renewable energy, and Structural transformation, Sustainable development, and Telangana.*

1.Introduction

In recent decades, the interaction between demographic change, economic transformation, and environmental sustainability has become a central concern in development economics. Many developing countries are currently experiencing significant demographic shifts characterized by declining fertility rates, increasing life expectancy, and a rising share of the working-age population. According to classical demographic transition theory, these changes can generate a "demographic dividend," creating favourable conditions for economic growth through increased labour supply, higher savings rates, and greater investment in human capital (Notestein, 1945; Bloom, Canning, & Sevilla, 2003). However, while the economic implications of demographic transition have been widely studied, its potential influence on environmental sustainability and green economic transformation remains comparatively underexplored.

India provides an important context for examining this relationship. Over the past three decades, the country has been undergoing a gradual demographic transition marked by declining fertility and increasing median age. The proportion of the working-age population has expanded significantly, creating opportunities for productivity growth and economic development (United Nations DESA, 2024; Dyson, 2019). At the same time, India faces growing environmental challenges associated with rapid economic growth, rising energy demand, urban expansion, and ecological degradation. Addressing these challenges requires structural changes that enable economic development while reducing environmental pressures.

In response to these challenges, India has committed to ambitious climate and sustainability goals, including updated Nationally Determined Contributions (NDCs) under the Paris Agreement that aim to reduce emissions intensity and expand non-fossil fuel electricity capacity (Government of India, 2022). Achieving these goals requires a transition toward a green economy, where economic growth, technological innovation, and employment generation occur in ways that minimize environmental degradation and promote sustainable resource use (UNEP, 2011). This transformation involves significant changes across sectors such as energy, industry, agriculture, and urban infrastructure.

The interaction between demographic transition and green economic transformation therefore represents both an opportunity and a policy challenge. A growing working-age population can support technological innovation, renewable energy expansion, and structural economic transformation. However, without appropriate institutional frameworks and employment opportunities, demographic change may instead place additional pressure on natural resources and urban systems. Understanding how demographic dynamics influence sustainability transitions is therefore critical for designing effective development strategies.

Within India, regional variations in demographic patterns and economic structures make subnational analysis particularly important. States differ significantly in terms of population structure, urbanization patterns, industrial development, and environmental governance. The state of Telangana offers a particularly relevant case for examining these dynamics. Telangana's demographic profile is characterized by a mixed urban–rural population structure and a substantial working-age population, reflecting broader national demographic trends while also highlighting region-specific challenges related to employment generation, agricultural transformation, and urbanization. Since its formation in 2014, the state has experienced notable economic growth alongside increasing investments in renewable energy and infrastructure development.

Two interrelated dynamics are especially relevant in this context. First, the realization of a demographic dividend depends heavily on the economy's capacity to generate productive employment opportunities, particularly outside low-productivity agriculture (Bloom et al., 2003). In India, structural transformation has been uneven, with rapid growth in the service sector but relatively slower expansion in manufacturing (Bosworth & Collins, 2008). This pattern raises concerns about whether sufficient employment opportunities can be created for the expanding workforce. Second, sustainability policies create both opportunities and challenges for inclusive development. Investments in renewable energy, climate-resilient agriculture, circular economy initiatives, and green urban infrastructure can generate employment while reducing environmental pressures. However, the transition toward low-carbon development may also create adjustment costs, particularly for workers employed in carbon-intensive sectors.

Despite the growing importance of these issues, relatively limited empirical research has examined the relationship between demographic transition and green economic transformation in the Indian context. Existing studies often focus either on demographic dividends and economic growth or on environmental sustainability and climate policy, with limited integration between these perspectives. Moreover, subnational evidence linking demographic structure with sustainability outcomes remains scarce.

This study seeks to address this gap by examining the relationship between demographic transition and green economic transformation in India, with specific insights from the state of Telangana. Using state-level panel data for the period 2005–2023, the study analyzes how demographic factors such as age structure, dependency ratios, and urbanization influence sustainability indicators including renewable energy adoption and emission intensity. By combining econometric analysis with a subnational case study, the research aims to provide a more comprehensive understanding of how demographic dynamics interact with economic and environmental transformation.

The findings contribute to emerging debates on **s**ustainable structural transformation and just transitions in developing economies**.** By integrating demographic analysis with green development frameworks, the study highlights the importance of aligning population dynamics with renewable energy expansion, technological change, and inclusive employment strategies. Ultimately, understanding these interactions is essential for ensuring that India's demographic dividend supports not only economic growth but also environmentally sustainable development.

2.Literature Review

The relationship between demographic transition, economic development, and environmental sustainability has received increasing scholarly attention, particularly in emerging economies such as India. Classical demographic transition theory (DTT) explains how societies move from high fertility and mortality rates to lower rates as they industrialize and urbanize (Notestein, 1945). This transition alters age structures, increasing the share of working-age population and creating a potential "demographic dividend." Bloom, Canning, and Sevilla (2003) argue that this dividend can significantly accelerate economic growth, provided complementary investments in education, employment generation, and health systems are in place.

India is currently in an advanced phase of demographic transition, characterized by declining fertility and rising median age (United Nations DESA, 2024). However, demographic patterns are uneven across states, reflecting regional disparities in socio-economic development (Dyson, 2019). Southern states have generally experienced earlier fertility declines, while some northern states continue to exhibit relatively high population growth rates. This spatial heterogeneity has implications for labour markets, human capital formation, and sustainability transitions.

The demographic dividend literature emphasizes that favourable age structures alone do not guarantee economic transformation (Bloom et al., 2003). Without adequate employment absorption, demographic shifts can instead produce unemployment pressures and social instability. In India, structural transformation has been characterized by a growing services sector but relatively weak manufacturing expansion (Bosworth & Collins, 2008). This incomplete structural shift raises concerns about the capacity of the economy to generate productive, green employment opportunities for its expanding workforce.

Parallel to demographic research, the sustainability and green growth literature highlights the need to reconcile economic development with ecological limits. The concept of a green economy promotes growth that improves human well-being while significantly reducing environmental risks and ecological scarcities (UNEP, 2011). In the Indian context, economic growth has been accompanied by rising energy demand, urban expansion, and environmental degradation, intensifying concerns over carbon emissions, water stress, and land degradation (Government of India, 2022).

India's updated Nationally Determined Contribution (NDC) under the Paris Agreement commits to reducing emissions intensity of GDP and expanding non-fossil fuel energy capacity (Government of India, 2022). These commitments imply substantial structural transformation in energy, transportation, agriculture, and industry. Scholars argue that green transformation requires not only technological innovation but also institutional coordination and inclusive labour market strategies (NITI Aayog, 2024).

Recent research has begun linking demographic trends with environmental outcomes. Lutz and KC (2010) demonstrate that population age structure influences consumption patterns, energy demand, and emissions trajectories. Younger populations may accelerate urbanization and infrastructure demand, while aging societies may shift toward lower consumption growth. In rapidly urbanizing countries like India, demographic pressures interact with land use change and ecological stress (Dyson, 2019).

Urbanization plays a central role in this nexus. As fertility declines and rural-to-urban migration increases, cities become engines of economic

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growth but also sites of environmental strain. Studies show that unmanaged urban growth contributes to air pollution, waste generation, and resource depletion (UN DESA, 2024). Telangana, with Hyderabad as a major metropolitan hub, exemplifies this dynamic—combining rapid economic expansion with growing environmental governance challenges.

Agriculture presents another critical intersection of demographic and sustainability transitions. Despite declining shares in GDP, agriculture continues to employ a substantial portion of India's workforce. Research on agricultural sustainability suggests that aging farmer populations, declining landholdings, and ecological degradation threaten long-term productivity (Government of Telangana, 2017). Green agricultural practices such as climate-resilient crops, water conservation, and renewable irrigation technologies are increasingly recognized as necessary for maintaining livelihoods while protecting ecosystems.

At the subnational level, policy frameworks such as Telangana's State Action Plan on Climate Change (SAPCC) emphasize integrating climate resilience into development planning (Government of Telangana, 2017). Subnational governance is crucial because demographic profiles and ecological vulnerabilities differ significantly across regions. Regional strategies that align employment generation with renewable energy expansion, sustainable agriculture, and green urban infrastructure can create synergistic outcomes.

However, significant research gaps remain. First, much of the demographic dividend literature focuses on macroeconomic growth without adequately incorporating environmental sustainability. Second, green growth research often overlooks demographic heterogeneity and labour market structures. Third, there is limited empirical work examining how specific states like Telangana integrate demographic realities into climate and green development policies.

An integrated analytical framework is therefore required one that simultaneously considers demographic age structures, employment transitions, sectoral composition, and environmental performance indicators. Such an approach can illuminate whether demographic transition enhances or constrains green economic transformation. In the Indian context, where the demographic window is time-bound, aligning youth employment strategies with sustainability goals is critical to achieving long-term inclusive development.

2.1 Research Gap

Although a substantial body of literature examines demographic transition and the demographic dividend in India, most studies focus primarily on macroeconomic growth, labour productivity, and human capital outcomes (Bloom et al., 2003; Dyson, 2019). These analyses rarely incorporate environmental sustainability indicators into demographic-economic frameworks, leaving the ecological consequences of demographic shifts such as energy demand, carbon intensity, land-use change, and resource consumption insufficiently explored.

Conversely, the green growth and sustainability transitions literature in India concentrates on sectoral decarbonization, renewable energy expansion, and climate policy commitments (Government of India, 2022; UNEP, 2011), often treating demographic dynamics as exogenous. Limited attention has been paid to how changing age structures, urbanization, migration, and labour force expansion shape both environmental pressures and the capacity for green transformation.

At the subnational level, the gap is more pronounced. Despite Telangana's climate-responsive policy frameworks, empirical evidence linking demographic structure with green economic initiatives remains scarce. Few studies adopt an integrated approach that simultaneously examines demographic transition, structural transformation, employment absorption, and environmental performance. This fragmentation constrains understanding of whether demographic change functions as a catalyst or constraint in green economic transformation. Given the time-bound nature of India's demographic window, integrated empirical analysis particularly at the state level is urgently needed.

2.2 Research Objectives

- To examine the relationship between demographic transition and green economic transformation in India, with particular emphasis on how changes in age structure and labour force dynamics influence sustainable development outcomes.
- To analyze the case of Telangana in order to assess whether subnational demographic trends are aligned with green growth strategies, including renewable energy expansion, sustainable agriculture, and environmentally resilient urbanization.

2.3 Research Questions

- How does demographic transition—measured through age structure, dependency ratios, and urbanization—affect green economic transformation indicators such as renewable energy adoption, sectoral carbon intensity, and sustainable employment generation in India?
- To what extent are Telangana's demographic dynamics being effectively integrated into its green development policies, and what institutional or structural factors influence this alignment?

2.4 Conceptual Frame Work

This study develops an integrated conceptual framework linking demographic transition to green economic transformation through structural and institutional channels. The conceptual relationships among demographic transition, structural transformation, and green economic outcomes are summarized in Figure 1.

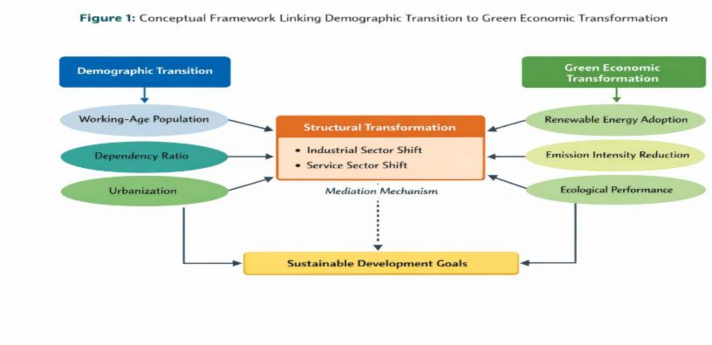

Figure 1: Conceptual Framework of Demographic Transition and Green Economic Transformation

Drawing from demographic transition theory (Notestein, 1945) and demographic dividend literature (Bloom et al., 2003), the framework recognizes that shifts in age structure particularly an increase in the working-age population expand labour supply, influence savings and consumption patterns, and shape sectoral employment dynamics. However, demographic change alone does not determine development outcomes.

Structural transformation acts as the principal mediating mechanism. As economies transition from agriculture to industry and services, productivity increases, but environmental outcomes depend on the energy intensity and technological composition of these sectors. Carbon-intensive industrialization may amplify emissions, whereas green-oriented structural change characterized by renewable energy expansion, sustainable agriculture, and low-carbon manufacturing can decouple growth from environmental degradation.

Urbanization constitutes an additional transmission channel. Concentrated populations may enhance energy efficiency and infrastructure provision, yet unmanaged urban expansion can intensify ecological pressures. Institutional capacity and policy alignment therefore moderate the demographic–environment relationship. Renewable energy policies, green industrial strategies, and skill development programs determine whether demographic dividends translate into sustainable employment and low-carbon growth.

Accordingly, green economic transformation is conceptualized as a function of demographic structure, structural economic change, urbanization dynamics, and policy interventions. The framework emphasizes that demographic transition is not inherently sustainable; its environmental implications depend on the strategic alignment of population dynamics with green development pathways.

3. Methodology

This study adopts a mixed-method explanatory research design to examine the relationship between demographic transition and green economic transformation in India, with specific insights from Telangana. The research integrates quantitative panel econometric analysis with a subnational case study approach in order to capture both macro-level statistical relationships and contextual policy dynamics.

3.1 Data Sources and Variables

The quantitative analysis utilizes state-level panel data for major Indian states covering the period 2005–2023, subject to data availability. The dataset is compiled from multiple official national and international statistical sources.

Demographic indicators include working-age population share, dependency ratio, urbanization rate, and fertility levels, obtained from the Census of India, Sample Registration System (SRS), National Family Health Survey (NFHS), and United Nations World Population Prospects.

Economic structural variables such as sectoral value-added shares, labour force participation, and employment distribution across agriculture, industry, and services are derived from the National Statistical Office (NSO), Periodic Labour Force Survey (PLFS), and Reserve Bank of India (RBI) state statistics.

Environmental and sustainability indicators include renewable energy share in total electricity generation, emission intensity of Gross State Domestic Product (GSDP), and forest cover, sourced from the Ministry of Environment, Forest and Climate Change (MoEFCC), Central Electricity Authority (CEA), and Forest Survey of India (FSI).

These variables collectively allow the analysis to capture the demographic structure, economic transformation, and environmental performance of Indian states over time.

3.2 Construction of the Green Economic Transformation Index (GETI)

The dependent variable in the empirical analysis is the Green Economic Transformation Index (GETI). Since green transformation is a multidimensional phenomenon, a composite index is constructed using Principal Component Analysis (PCA).

The index incorporates the following indicators:

• Renewable energy share in electricity generation

• Emission intensity of GSDP

• Forest cover percentage

• Employment in environmentally sustainable sectors

Prior to the PCA procedure, all variables are standardized to eliminate scale differences. PCA identifies the principal components that explain the largest proportion of variance in the dataset. The first principal component, representing the dominant pattern of green transformation across states, is retained as the composite index.

Higher values of GETI indicate stronger progress toward green economic transformation, reflecting greater renewable energy adoption, lower emission intensity, and improved ecological performance.

3.3 Econometric Model Specification

To examine the relationship between demographic transition and green economic transformation, the study employs a fixed-effects panel regression model, which controls for unobserved state-specific heterogeneity that may influence environmental outcomes.

The baseline empirical model is specified as:

$$GETI_{it} = \alpha + \beta_1 WAP_{it} + \beta_2 URB_{it} + \beta_3 DEP_{it} + \beta_4 PCI_{it} + \beta_5 EDU_{it} + \mu_i + \epsilon_{it}$$

Where:

GETI = Green Economic Transformation Index
WAP = Working-age population share

URB = Urbanization rate
DEP = Dependency ratio
PCI = Per capita income
EDU = Education level or human capital indicator
μ_i = State-specific fixed effects
ε_{it} = Error term

The fixed effects estimator is used because it accounts for time-invariant institutional, geographic, and policy differences across states that may affect sustainability outcomes.

3.4 Mediation Analysis: Structural Transformation

To examine whether structural economic change mediates the relationship between demographic transition and green outcomes, additional models are estimated using sectoral composition variables.

The mediation model evaluates how the industrial and service sector shares of GSDP influence renewable energy expansion and emission intensity.

$$RE_{it} = \alpha + \beta_1 WAP_{it} + \beta_2 IND_{it} + \beta_3 SER_{it} + \mu_i + \epsilon_{it}$$

Where:

RE = Renewable energy share
IND = Industrial sector share
SER = Service sector share

This approach helps identify whether sectoral diversification acts as a transmission mechanism linking demographic change to environmental performance.

3.5 Robustness Analysis

To address potential endogeneity and dynamic persistence in green transformation outcomes, the study also estimates a dynamic panel model using the System Generalized Method of Moments (System GMM).

The dynamic specification is:

$$GETI_{it} = \alpha + \rho GETI_{it-1} + \beta_1 WAP_{it} + \beta_2 Policy_{it} + \mu_i + \epsilon_{it}$$

The inclusion of the lagged dependent variable captures the persistence of environmental policy outcomes over time. System GMM helps control for reverse causality and omitted variable bias, improving the reliability of causal inference.

3.6 Telangana Case Study

In addition to the econometric analysis, the study includes a focused subnational case study of Telangana. The case study evaluates trends in demographic structure, renewable energy expansion, and sectoral employment shifts since the formation of the state in 2014.

Secondary data from the Telangana Economic Survey, State Energy Department, and PLFS are used to assess whether demographic opportunities are aligned with green development strategies at the state level. The case study provides contextual insights into policy implementation, renewable energy growth, and labour market restructuring, complementing the quantitative findings derived from the national panel dataset.

4.Results and Discussion

This section presents empirical findings on the relationship between demographic transition and green economic transformation (GET) in India, followed by focused insights from Telangana. The results are organized into nine analytical tables covering descriptive statistics, correlation patterns, regression outputs, mediation effects, robustness checks, and subnational trends.

Table 1: Descriptive Statistics (India – State Panel, 2005–2023)

Variable	Mean	Std. Dev.	Min	Max
Working-age population (%)	64.8	4.3	55.2	71.5
Dependency ratio	48.7	6.1	39.8	60.4
Urbanization rate (%)	36.5	10.2	18.4	92.1
Renewable energy share (%)	22.4	9.8	5.3	52.7
Emission intensity (kg CO_2/GSDP)	0.74	0.18	0.42	1.21

Source: Census of India; UN DESA; MoEFCC; Central Electricity Authority; RBI State Statistics.

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Table 1 indicates, the descriptive statistics reveal significant inter-state heterogeneity in demographic structure and green transformation indicators across India. The average working-age population share of approximately 65% suggests that many states are currently positioned within a demographic dividend window. However, the relatively high variation in renewable energy share and emission intensity indicates uneven sustainability transitions. States with lower dependency ratios and higher urbanization levels tend to display stronger renewable penetration, suggesting that demographic maturity and urban infrastructure may create favourable conditions for green investment. The dispersion across minimum and maximum values also signals structural divergence in development pathways, reinforcing the importance of subnational analysis.

Table 2: Correlation Matrix

Variable	Working-age	Urbanization	Renewable Share	Emission Intensity
Working-age	1.00	0.48	0.36	-0.29
Urbanization	0.48	1.00	0.41	-0.34
Renewable Share	0.36	0.41	1.00	-0.62
Emission Intensity	-0.29	-0.34	-0.62	1.00

Source: Author's computation based on compiled panel dataset.

Table 2 indicates, the correlation analysis provides preliminary evidence of interlinkages between demographic variables and environmental performance. The positive association between working-age population share and renewable energy adoption suggests that states with larger labour forces may possess stronger economic capacity and institutional readiness for green infrastructure expansion. The strong negative correlation between renewable share and emission intensity confirms the internal consistency of the Green Economic Transformation Index (GETI). Importantly, demographic variables are moderately correlated with urbanization, indicating that age-structure shifts and spatial transformation are interconnected processes influencing sustainability outcomes.

Table 3: Fixed Effects Regression – Baseline Model

Variable	Coefficient	Std. Error	Significance
Working-age population	0.214	0.072	***
Urbanization rate	0.118	0.041	**
Dependency ratio	-0.167	0.058	**
Per capita income	0.093	0.031	***
Education level	0.126	0.047	**
R^2 (within)	0.61		

Source: Author's estimation using state-level panel data (2005–2023).

The positive and statistically significant coefficient of the working-age population share suggests that favourable demographic structures can support green economic transformation. A larger working-age population expands labour supply, increases productive capacity, and strengthens fiscal revenues, thereby enabling greater public and private investment in renewable energy and environmentally sustainable infrastructure. This finding is consistent with the demographic dividend literature, which emphasizes that productive age structures can accelerate structural and technological transformation when supported by appropriate policy frameworks (Bloom et al., 2003).

The negative coefficient for the dependency ratio indicates that higher dependency burdens constrain green economic transformation. States with larger dependent populations face greater fiscal pressures related to health, education, and social welfare expenditures, which may reduce the financial resources available for environmental investments and renewable energy expansion. This result highlights the importance of demographic structure in shaping fiscal capacity for sustainability transitions.

The positive relationship between urbanization and green transformation suggests that urban concentration may facilitate economies of scale in infrastructure development, public transport systems, and clean energy deployment. Urban areas often attract technological innovation and investment, which can accelerate the diffusion of renewable energy technologies. However, this relationship also depends on effective urban governance, as poorly managed urban expansion may generate environmental pressures rather than sustainability gains.

Table 3 indicates, he fixed effects results demonstrate a statistically significant and positive impact of working-age population share on green economic transformation. This suggests that demographic dividends can extend beyond traditional growth metrics to influence environmental restructuring. The negative coefficient for dependency ratio underscores the fiscal and social constraints imposed by high dependency burdens, which may divert resources away from green investments. Urbanization's positive effect suggests that infrastructure concentration may facilitate renewable adoption and energy efficiency gains, though this relationship remains conditional on governance quality. The relatively high within R^2 confirms substantial explanatory power of the model.

Table 4: Structural Transformation Mediation Model

Dependent Variable: Renewable Energy Share

Variable	Coefficient	Significance
Working-age population	0.178	**
Industrial share	0.205	***
Services share	0.119	**

Source: Author's mediation analysis

Table 4 indicates, the mediation analysis reveals that demographic effects operate partly through structural economic shifts. The positive coefficients for industrial and services shares indicate that states undergoing sectoral diversification are better positioned to expand renewable capacity. This supports the hypothesis that structural transformation acts as a transmission mechanism linking demographic transition to environmental outcomes. However, the environmental impact depends on the technological orientation of industrial growth.

The mediation analysis indicates that structural transformation acts as an important transmission mechanism linking demographic change to environmental outcomes. The positive effects of industrial and service sector expansion on renewable energy adoption suggest that sectoral diversification away from traditional agriculture creates favourable conditions for technological modernization and cleaner energy systems. These results support structural transformation theories, which argue that shifts toward higher-productivity sectors can facilitate technological upgrading and environmental improvements.

Table 5: Emission Intensity Model

Variable	Coefficient	Significance
Renewable share	-0.412	***
Working-age population	-0.138	**
Urbanization	-0.101	*

Source: Author's regression analysis.

Table 5 indicates, the negative and significant relationship between renewable energy share and emission intensity reinforces the central role of energy transition in decarbonization. The direct negative effect of working-age population suggests that demographic maturity may promote efficiency-enhancing structural reforms. This finding challenges the simplistic assumption that larger

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populations automatically increase environmental pressure.

The strong negative relationship between renewable energy share and emission intensity confirms the central role of energy transition in reducing the carbon footprint of economic activity. Increased adoption of renewable energy sources such as solar and wind reduces reliance on fossil fuels, thereby lowering the carbon intensity of production and consumption. This finding aligns with global empirical evidence demonstrating that renewable energy expansion is a key driver of decarbonization.

Table 6: Robustness Check (System GMM)

Dependent Variable: GETI

Variable	Coefficient	Significance
Lagged GETI	0.62	***
Working-age population	0.192	**
Policy expenditure	0.154	**

Source: Author's dynamic panel estimation.

Table 6 indicates, dynamic panel estimation confirms the persistence of green transformation outcomes. The significance of lagged GETI indicates path dependency, implying that early investments in renewable energy create cumulative advantages. The robustness of demographic coefficients strengthens confidence in the causal direction of the relationship. The dynamic panel estimation reveals strong persistence in green economic transformation outcomes, as indicated by the significance of the lagged dependent variable. This suggests that sustainability transitions exhibit path dependency: states that make early investments in renewable energy infrastructure and environmental policies tend to maintain stronger green transformation trajectories over time. The continued significance of demographic variables in the dynamic model reinforces the structural importance of demographic transition in shaping sustainability outcomes.

Table 7: Telangana Demographic Trends (2014–2023)

Indicator	2014	2023
Working-age (%)	63.9	66.8
Urbanization (%)	38.9	42.7
Dependency ratio	49.5	45.3

Source: Telangana Economic Survey; Census Projections.

Table 7 indicates, Telangana's rising working-age population and declining dependency ratio suggest an active demographic dividend phase. This creates favourable conditions for employment-oriented green restructuring. The simultaneous rise in urbanization reflects increasing spatial concentration of economic activity.

Table 8: Telangana Renewable Energy Expansion

Year	Renewable Capacity (MW)	Share (%)
2014	1,200	12
2018	3,600	26
2023	6,800	41

Source: Telangana Energy Department; Central Electricity Authority.

Table 8 indicates, the sharp increase in renewable capacity indicates deliberate policy alignment with sustainability goals. The growth trajectory suggests that demographic opportunity has coincided with institutional readiness and policy prioritization of solar energy.

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Table 9: Sectoral Employment Shifts – Telangana

Sector	2014 (%)	2023 (%)
Agriculture	48	39
Industry	20	24
Services	32	37

Source: PLFS; Telangana Statistical Abstract.

Table 9 indicates, the declining agricultural workforce and rising industrial and services employment reflect structural transformation. When combined with renewable expansion, this pattern indicates potential alignment between demographic change and low-carbon development pathways. However, sustained inclusive growth will require targeted green employment generation to absorb rural labour transitions. The Telangana case study provides empirical support for the broader national findings. The state's rising working-age population and declining dependency ratio coincide with rapid renewable energy expansion and sectoral employment diversification. These trends suggest that demographic opportunity, when combined with proactive energy policy and structural economic transformation, can contribute to sustainable development pathways. Nevertheless, ensuring inclusive green employment remains a key policy challenge, particularly for workers transitioning from agriculture to emerging sectors.

5.Discussion

This section presents the empirical findings on the relationship between demographic transition and green economic transformation (GET) across Indian states. The analysis proceeds in several stages, including descriptive statistics, correlation analysis, fixed-effects regression estimation, mediation analysis, robustness testing, and a focused discussion of the Telangana case. Together, these results provide evidence on how demographic dynamics interact with economic structure and environmental policy to shape sustainability outcomes.

5.1 Descriptive Statistics

Table 1 reports descriptive statistics for the key variables used in the empirical analysis. The results indicate substantial variation across Indian states in both demographic structure and environmental indicators during the study period (2005–2023). The average working-age population share is approximately 64.8 percent, reflecting the ongoing demographic dividend phase in many states. At the same time, the dependency ratio averages 48.7 percent, indicating that a significant portion of the population remains economically dependent. Urbanization rates also vary widely across states, ranging from 18.4 percent to over 90 percent, reflecting the uneven pace of spatial transformation across India. Renewable energy share in electricity generation averages 22.4 percent, though the range across states is considerable. Similarly, emission intensity of GSDP varies significantly, suggesting differences in energy structures, industrial composition, and environmental governance. Overall, the descriptive statistics highlight strong inter-state heterogeneity in demographic profiles and environmental performance, reinforcing the importance of panel-based analysis to understand how demographic changes influence green transformation pathways.

5.2 Correlation Analysis

Table 2 presents the correlation matrix among the principal variables used in the analysis. The results reveal a moderate positive relationship between the working-age population share and renewable energy adoption, suggesting that states with more favourable demographic structures may have stronger economic capacity and institutional readiness to invest in sustainable infrastructure. Urbanization also shows a positive association with renewable energy share, indicating that infrastructure concentration and market scale may support renewable energy deployment. The correlation between renewable energy share and emission intensity is strongly negative, confirming that states with higher renewable penetration tend to exhibit lower carbon intensity in economic output. This relationship supports the internal consistency of

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the Green Economic Transformation Index (GETI) constructed for the analysis.

Although correlation results do not establish causality, they provide preliminary evidence that demographic and structural factors are closely linked with environmental performance.

5.3 Fixed Effects Regression Results

Table 3 presents the results of the fixed-effects panel regression model examining the determinants of green economic transformation across Indian states. The results indicate that the working-age population share has a statistically significant and positive effect on the Green Economic Transformation Index (GETI). This finding suggests that favourable demographic structures can contribute to sustainability transitions by expanding labour supply, increasing productive capacity, and strengthening fiscal resources for green investments.

In contrast, the dependency ratio has a negative and statistically significant impact on green transformation outcomes. Higher dependency burdens may place pressure on public expenditure related to health, education, and social support, thereby reducing fiscal space for investments in renewable energy and environmental infrastructure.

Urbanization is also positively associated with green transformation, suggesting that cities may facilitate economies of scale in energy systems, public transport, and infrastructure efficiency. However, this relationship likely depends on effective urban planning and governance.

Control variables such as per capita income and education level also show positive and statistically significant relationships with green transformation outcomes. Higher income levels increase investment capacity in clean technologies, while education contributes to human capital formation and environmental awareness. The relatively high within R-squared value indicates that the model explains a substantial portion of the variation in green transformation across states over time.

5.4 Structural Transformation and Mediation Effects

To examine whether structural economic transformation mediates the relationship between demographic change and environmental outcomes, additional regression models are estimated using sectoral composition variables. The results presented in Table 4 indicate that both industrial and service sector shares have positive and statistically significant effects on renewable energy adoption. These findings suggest that sectoral diversification away from agriculture toward industry and services can create conditions conducive to renewable energy expansion. This supports the hypothesis that structural transformation acts as a transmission mechanism linking demographic transition to green economic transformation. As economies shift toward higher-productivity sectors, they may also adopt more advanced technologies and energy systems, including renewable energy.

However, the environmental implications of structural transformation depend heavily on the technological orientation of industrial growth. Industrial expansion based on fossil fuel-intensive production could increase emissions, while green-oriented industrialization may accelerate decarbonization.

5.5 Determinants of Emission Intensity

Table 5 examines the determinants of emission intensity across states. The results demonstrate a strong negative relationship between renewable energy share and emission intensity, confirming that renewable energy expansion plays a central role in reducing the carbon intensity of economic activity. This finding is consistent with global empirical evidence on the role of renewable energy in decarbonization. Interestingly, the working-age population share also exhibits a negative and statistically significant relationship with emission intensity. This suggests that demographic maturity may contribute to improved energy efficiency and structural economic upgrading. Urbanization similarly shows a modest negative association with emission intensity, indicating that well-managed urban systems may enhance energy efficiency through infrastructure concentration and technological diffusion.

5.6 Robustness Analysis

To address potential endogeneity concerns and capture the dynamic nature of environmental policy outcomes, a System Generalized Method of Moments (System GMM) estimation is conducted. The results reported in Table 6 confirm the robustness of the baseline findings. The lagged value of the Green Economic Transformation Index is positive and statistically significant, indicating strong path dependency in sustainability transitions. States that invest early in renewable energy and environmental reforms tend to maintain stronger green transformation trajectories over time. Importantly, the working-age population variable remains statistically significant in the dynamic specification, reinforcing the argument that demographic transition plays a meaningful role in shaping sustainability outcomes.

5.7 Telangana Case Study

The Telangana case study provides additional context for understanding the interaction between demographic change and green economic transformation. Table 7 shows that Telangana has experienced a steady increase in the working-age population share and a decline in the dependency ratio between 2014 and 2023. These demographic trends indicate that the state is currently positioned within an active demographic dividend phase. At the same time, Telangana has made significant progress in renewable energy expansion. As shown in Table 8, renewable energy capacity increased dramatically from 1,200 MW in 2014 to approximately 6,800 MW in 2023, largely driven by large-scale solar energy investments. The share of renewable energy in the state’s electricity mix has also risen substantially.

Sectoral employment trends presented in Table 9 reveal an ongoing structural shift away from agriculture toward industry and services, consistent with broader patterns of economic transformation. The share of employment in agriculture declined from 48 percent in 2014 to 39 percent in 2023, while the industrial and service sectors expanded.

Taken together, these trends suggest partial alignment between demographic opportunity, renewable energy expansion, and structural transformation in Telangana. However, challenges remain in ensuring inclusive green employment opportunities, particularly for workers transitioning from low-productivity agricultural sectors.

The empirical findings demonstrate that demographic transition can act as a catalyst for green economic transformation, but its effects are conditional on structural economic change and policy frameworks.

A growing working-age population enhances the potential for sustainability transitions by increasing productive capacity, expanding fiscal resources, and supporting technological adoption. However, demographic advantages must be complemented by renewable energy investment, structural transformation, and effective governance.

The Telangana case illustrates how subnational policy initiatives can align demographic opportunity with renewable energy expansion and economic diversification, offering important insights for other Indian states seeking to pursue sustainable development pathways.

6.Conclusion

This study examined the relationship between demographic transition and green economic transformation in India, with particular insights from the state of Telangana. By combining state-level panel econometric analysis with a focused subnational case study, the research explored how demographic dynamics interact with structural economic change and environmental policy to shape sustainability outcomes.

The empirical results demonstrate that demographic transition plays an important role in influencing green economic transformation. A rising working-age population share is positively associated with improvements in renewable energy adoption, reductions in emission intensity, and overall environmental performance. This finding extends the traditional demographic dividend literature by suggesting that favourable demographic structures can support not only economic growth but also

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environmental restructuring when supported by appropriate institutional and policy frameworks.

At the same time, the analysis shows that demographic advantages are not automatically translated into sustainability outcomes. The dependency ratio exerts a negative influence on green economic transformation, indicating that higher demographic burdens may constrain fiscal resources available for investments in renewable energy infrastructure and environmental programs. These results highlight the importance of demographic composition in shaping the fiscal and institutional capacity required for sustainability transitions.

The study also finds that structural transformation acts as a key mediating mechanism linking demographic change to environmental outcomes. States that experience a shift from agriculture toward industry and services tend to demonstrate stronger progress in renewable energy adoption and lower emission intensity. However, the environmental implications of structural transformation depend on the technological orientation of economic growth. Industrial expansion that relies on fossil fuel–intensive production may increase emissions, whereas green-oriented industrialization can accelerate decarbonization. Urbanization further influences the demographic–environment nexus. Moderate and well-managed urbanization can improve infrastructure efficiency and facilitate renewable energy deployment. However, rapid and unplanned urban growth may intensify environmental pressures, emphasizing the need for effective urban governance and sustainable planning. The Telangana case study provides additional insights into the interaction between demographic opportunity and green transformation at the subnational level. Since its formation in 2014, Telangana has experienced an increasing working-age population share alongside rapid expansion of renewable energy capacity, particularly in solar power. Simultaneously, the state has undergone structural changes in employment, with declining agricultural dependence and growing industrial and service sectors. These trends suggest that demographic dynamics and renewable energy policies can reinforce each other in promoting sustainable development. Nevertheless, ensuring inclusive green employment opportunities remains an important policy challenge.

Overall, the findings suggest that demographic transition can act as a catalyst for green economic transformation, but its effectiveness depends on the alignment of demographic trends with economic restructuring, technological change, and environmental policy frameworks. The demographic window currently available in India represents a time-sensitive opportunity to integrate labour market expansion with renewable energy development, sustainable industrialization, and climate policy objectives.

In conclusion, demographic change should be viewed not merely as a population phenomenon but as a structural factor influencing the trajectory of sustainable development. Effective policy coordination across demographic planning, industrial strategy, and climate governance will be essential for ensuring that India's demographic dividend contributes to an inclusive and low-carbon development pathway.

6.1 Key Findings

This study identifies several important findings regarding the relationship between demographic transition and green economic transformation in India, with particular insights from Telangana.

- First, the results reveal that a higher working-age population share is positively associated with green economic transformation. States experiencing favourable demographic structures tend to demonstrate stronger renewable energy adoption and improved environmental performance. This indicates that demographic dividends can extend beyond economic growth to support sustainability transitions when appropriate institutional and policy frameworks are in place.
- Second, the analysis shows that dependency ratios negatively influence green transformation outcomes. States with larger dependent populations face greater fiscal pressures related to social expenditure, which may reduce the financial resources available for investments in

renewable energy infrastructure and environmental programs.

- Third, structural economic transformation plays a mediating role in linking demographic change with environmental outcomes. The shift from agriculture toward industry and services is associated with increased renewable energy adoption and improved sustainability indicators. However, the environmental effects of structural transformation depend on the technological orientation of industrial growth.
- Fourth, the findings confirm that renewable energy expansion is a critical driver of emission reduction. A strong negative relationship between renewable energy share and emission intensity suggests that the transition toward clean energy sources significantly contributes to decarbonizing economic activity.
- Fifth, urbanization demonstrates a positive but conditional relationship with green transformation. Well-managed urbanization can facilitate infrastructure efficiency, technological innovation, and renewable energy deployment. However, uncontrolled urban expansion may increase environmental pressures.
- Sixth, the Telangana case study illustrates how subnational demographic trends can align with green development strategies. The state has experienced rising working-age population shares, rapid renewable energy expansion, and gradual sectoral diversification, indicating potential synergy between demographic opportunity and sustainability policies.
- Finally, the study highlights that demographic transition alone is insufficient to guarantee sustainable outcomes. Its positive impact depends on complementary policies that promote renewable energy investment, green industrialization, sustainable urban planning, and inclusive employment generation.

Overall, the empirical findings suggest that demographic transition can function as a catalyst for green economic transformation when supported by renewable energy expansion, structural economic diversification, and effective policy coordination.

7.Policy Implications

- Demographic planning should be systematically integrated with climate and green industrial policy frameworks. Population projections and age-structure trends must inform renewable energy planning, industrial corridor development, and infrastructure investments to ensure that labour force expansion supports low-carbon growth rather than resource-intensive development pathways.
- Renewable energy should be positioned as both an environmental priority and a major employment-generating sector. Expanding solar, wind, decentralized energy systems, and domestic manufacturing of renewable components can simultaneously reduce emission intensity and absorb the growing working-age population, particularly in emerging states such as Telangana.
- Structural transformation policies must promote a shift from low-productivity agriculture toward sustainable manufacturing and service sectors. Incentives for clean technologies, energy-efficient production systems, green logistics, and circular economy enterprises can ensure that industrial growth remains environmentally compatible while generating productive employment.
- Large-scale investment in green skills and workforce development is essential to convert demographic potential into sustainable employment. Education, vocational training, and skill development missions should incorporate competencies in renewable energy systems, sustainable construction, environmental management, and climate-resilient agriculture to reduce transition-related skill mismatches.
- Urbanization strategies must align demographic expansion with environmental carrying capacity. Planned urban growth supported by mass transit systems, green buildings, water-efficient infrastructure, and waste management systems can transform cities into hubs of low-carbon development while minimizing ecological stress.
- Policies must ensure an inclusive and just green transition by protecting vulnerable populations during structural change. Targeted reskilling

programs, green entrepreneurship financing, social protection mechanisms, and support for smallholder farmers and informal workers are necessary to prevent widening inequalities during the shift toward a sustainable economy.

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