

An Age-Structured Multi-Regional Projection of India's Population: A Leslie Matrix Model for Internal Migration

Ramesh Singh¹ & Dr. Pratima Singh²

Research Scholar¹, Assistant Professor²

^{1,2}P.G. College Ghazipur (U.P.), Veer Bahadur Singh Purvanchal University, Jaunpur (U.P.) 222002

Abstract

This paper extends previous analyses of India's population dynamics by developing a multi-regional, age-structured projection model based on the Leslie matrix framework. Standard cohort-component models often assume closed populations, which is untenable in the Indian context due to its vast internal migration flows driven by profound regional demographic and economic disparities. This study formulates and parameterizes a two-region (North-South) Leslie-type model, incorporating age-specific fertility, mortality, and inter-regional migration rates derived from Census and National Sample Survey data. We conduct comparative simulations to quantify the demographic impact of migration on the long-term population size, growth rate (λ), and stable age distribution of both sending and receiving regions. The findings reveal that migration acts as a significant demographic rebalancing mechanism, accelerating population aging in the destination states of the South while slowing the youth bulge in the source states of the North. These results have critical implications for the trajectory of the demographic dividend, future labor markets, and the strategic allocation of social sector investments across the nation. The paper concludes with policy recommendations for creating a migrant-inclusive framework for sustainable and equitable development.

Keywords: India's population, Leslie matrix framework, age-structured projection model, regional demographic, age-specific fertility, mortality, and inter-regional migration rates.

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I. Introduction

1.1 Recapitulation and Research Gap

Previous studies on India's demographic trends have confirmed that age-structured models, such as the cohort-component method, are more accurate than basic non-age-specific models like exponential or logistic approaches (Mahaffy, n.d.). These models offer a detailed and dynamic view of the population by analyzing vital rates across different age groups, effectively capturing phenomena like population momentum and aging (Mahaffy, n.d.). The Leslie matrix, a discrete-time, age-based model, is especially effective and widely used in ecology and human demography for projecting population changes (Leslie, 1945; Monagan, n.d.).

Nevertheless, a fundamental assumption inherent to the classical Leslie matrix model, as well as many conventional cohort-component projection methods, is that the population under examination remains closed to migration (Arriaza, 2024; Leslie, 1945; Monagan, n.d.). While this premise simplifies the mathematical formulation, it presents significant theoretical and practical limitations when applied to the analysis of sub-national population dynamics within India. India is not a homogeneous entity but rather a mosaic of states at markedly different stages of demographic transition, interconnected by substantial and rapidly increasing flows of internal migration (Bhagat, 2021; Government of India, 2017; James, 2011). Between 2001 and 2011 alone, internal migration in India rose by 45%, reaching 45.6 crore, with an estimated 5 to 6 million individuals relocating annually between states for employment-related purposes (Government of India, 2017; James & Goli, 2024). The application of a closed-population model to individual states or regions in such a context neglects a primary component of their demographic change, thereby resulting in systematically biased projections. Such models tend to consistently overestimate the future youth population in sending regions and underestimate the rate of population aging and the size of the future workforce in receiving regions. This study aims to address this critical research gap by explicitly integrating internal migration within a formal, age-structured projection framework.

1.2 The North-South Demographic Divide as a Migration Driver

The imperative to model internal migration in India is driven by a profound and deepening demographic and economic divide between its northern and southern states. This "North-South divide" is a defining feature of India's contemporary development landscape (James & Goli, 2024). The large northern states, including Uttar Pradesh, Bihar, Madhya Pradesh, and Rajasthan, are characterized by historically higher fertility rates, which, despite recent declines, have resulted in a younger age structure and significant population momentum (James, 2011; James & Goli, 2024; Singh & Kumar, 2024). In 2011, the median age in Bihar was just 19.9 years, and these states collectively account for a disproportionate share of India's youth population (James & Goli, 2024). In contrast, the southern states, such as Kerala, Tamil Nadu, Karnataka, and Maharashtra, led the nation's demographic transition, achieving low mortality and low fertility regimes much earlier (James & Goli, 2024). Consequently, these states have older populations and are experiencing rapid aging; the median age in Tamil Nadu in 2011 was 29.9 years, a full decade older than in Bihar (James & Goli, 2024).

An economic one mirrors this demographic divergence. Economic growth, investment, and employment opportunities have become increasingly concentrated in the more developed southern and western states, while the populous northern states lag (Bhagat, 2021; James & Goli, 2024). This creates a powerful gradient that fuels a central migration corridor. Young, working-age individuals from the employment-scarce, demographically "young" North move in vast numbers to the economically dynamic, demographically "aging" South to fill labor demands (James & Goli, 2024; Ministry of Statistics and Programme Implementation, 2023). This movement can be conceptualized as a form of "demographic arbitrage," where the surplus of young labor in one region flows to meet the deficit in another, exploiting the differential in wages and opportunities. This paper hypothesizes that this migration is not a peripheral demographic event but a central mechanism of demographic redistribution. It actively reshapes the age structures of both sending and receiving regions, with profound long-term consequences for the national trajectory of the demographic dividend, fiscal federalism, and social development.

The primary objective of this research is to formulate, parameterize, and analyze a mathematical model capable of quantifying the long-term demographic impact of India's North-South internal migration. To achieve this, this study employs the Leslie matrix model as its foundational framework. The classical single-region model is extended to a multi-regional, Leslie-type projection system, an approach pioneered by Andrei Rogers and others to analyze interconnected populations (Rogers, 1975; Schmidbauer et al., 2012; Wiśniowski & Raymer, 2025). This extension allows for the explicit modeling of population exchange between two distinct regional blocs, representing the "North" (source region) and the "South" (destination region).

The multi-regional model will be parameterized using the most recent comprehensive demographic data available for India, primarily the 2011 Census of India and data from the National Sample Survey (NSS) and Periodic Labour Force Survey (PLFS) (Census of India, 2011; National Sample Survey Office, 2012). By constructing a projection matrix that integrates age-specific rates of fertility, mortality, and inter-regional migration, this study will conduct comparative simulations to 2061. A baseline "no migration" scenario will be contrasted with a complete model incorporating migration flows. This comparative analysis will allow for the isolation and quantification of migration's net effect on the future population size, growth rate, age structure, and dependency ratios of each region. The ultimate goal is to move beyond static descriptions of migration and provide a dynamic, forward-looking assessment of its role as a transformative force in India's demographic future.

II. Theoretical Framework: The Leslie Matrix and Its Extension for Open Populations

2.1 Mathematical Foundations of the Leslie Matrix Model

The Leslie matrix model is a discrete, age-structured model that projects a population's size and age distribution over time (Leslie, 1945). It is typically applied to the female population, as female fertility is the primary driver of reproduction (Leslie, 1945; Schmidbauer et al., 2012). The state of the population at time t , disaggregated into n discrete age classes of equal duration, is represented by a column vector, $N(t)$:

$$N(t) = [n_1(t) \ n_2(t) \ n_3(t) \ \dots \ n_n(t)]$$

Where $n_i(t)$ is the number of females in age class i at time t . The population vector at the next time step, $t+1$, is obtained through a linear transformation governed by the Leslie matrix, L (Arriaza, 2024; Monagan, n.d.; Wiśniowski & Raymer, 2025):

$$N(t+1) = LN(t)$$

The Leslie matrix L is an $n \times n$ square matrix whose elements represent the age-specific vital rates of the population. Its structure is particular:

$$L = \begin{bmatrix} F_1 & F_2 & \dots & F_n & P_1 & 0 & \dots & 0 & 0 & 0 & \dots & P_n \end{bmatrix}$$

The elements of L are defined as follows:

- F_i (Fecundity): The elements of the first row represent the average number of female offspring born to a female in age class i during one time step who survive to be counted in the first age class at the next time step

(Mahaffy, n.d.; Monagan, n.d.). In a "pre-breeding census" model, where the population is counted just before reproduction, this term is a composite value. It is calculated as the age-specific birth rate (b_i) multiplied by the probability of survival of a newborn to enter the first age class (P_0) (Mahaffy, n.d.; Wiśniowski & Raymer, 2025).

Thus, $F_i = b_i \cdot P_0$.

- P_i (Survival Probability): The elements on the sub-diagonal represent the probability that a female in age class i at time t will survive to be in age class $i+1$ at time $t+1$ (Leslie, 1945; Mahaffy, n.d.). All other elements of the matrix are zero, as individuals can only survive into the next age class or die; they cannot skip age classes or revert to younger ones.

2.2 Asymptotic Dynamics: Stable Growth and Age Distribution

A powerful property of the Leslie matrix model is its long-term convergence to a stable state, a result mathematically guaranteed by the Perron-Frobenius theorem for non-negative, irreducible, and primitive matrices (Arriaza, 2024; Schmidbauer et al., 2012). After a sufficient number of time steps, regardless of the initial age distribution $N(0)$, the population's growth pattern and structure stabilize. This stable state is fully described by the dominant eigenvalue of the Leslie matrix L and its corresponding eigenvector (Monagan, n.d.; Montgomery, n.d.).

- Dominant Eigenvalue (λ_1): The Leslie matrix L has a unique, positive, real eigenvalue, known as the dominant eigenvalue or Perron root, which is larger in magnitude than any other eigenvalue (Arriaza, 2024). This value, denoted as λ_1 , represents the asymptotic or intrinsic rate of population growth (Arriaza, 2024; Monagan, n.d.). The total population size $N_{\text{total}}(t)$ eventually grows by a factor of λ_1 in each time step, such that $N_{\text{total}}(t+1) \approx \lambda_1 N_{\text{total}}(t)$.
 - If $\lambda_1 > 1$, the population experiences exponential growth.
 - If $\lambda_1 < 1$, the population experiences exponential decline.
 - If $\lambda_1 = 1$, the population is stationary, achieving zero population growth (Mahaffy, n.d.; Montgomery, n.d.).
- Right Eigenvector (w): Associated with the dominant eigenvalue λ_1 is a unique, positive right eigenvector, w , which satisfies the equation $Lw = \lambda_1 w$ (Arriaza, 2024). This eigenvector, when normalized so its elements sum to 1, represents the Stable Age Distribution (SAD) (Monagan, n.d.; Montgomery, n.d.). The SAD is the proportional distribution of the population across age classes that remains constant over time once the population has stabilized (Mahaffy, n.d.; Monagan, n.d.). Even as the total population size changes (governed by λ_1), the percentage of individuals in each age class becomes fixed.

2.3 Formulating a Multi-regional Leslie-Type Model

To incorporate migration, the classical Leslie model must be extended from a single-region to a multi-regional framework (Rogers, 1975). For this study's two-region system, designated as North (N) and South (S), the population vector is augmented to include the age structures of both regions:

$$N(t) = [N_N(t) \ N_S(t)]$$

Where $N_N(t)$ and $N_S(t)$ are the population vectors for the North and South regions, respectively. The projection is now governed by a larger, partitioned matrix M , such that $N(t+1) = MN(t)$ (Rogers, 1975). The matrix M takes a block structure:

$$M = \begin{bmatrix} L_{NN} & L_{SN} \\ L_{NS} & L_{SS} \end{bmatrix}$$

The four sub-matrices, or blocks, represent all possible transitions within and between the two regions:

- L_{NN} and L_{SS} (Diagonal Blocks): These are modified Leslie matrices for individuals who *remain* in their region of origin (stayers). The fecundity elements in the first row remain the same, representing births within each region. However, the sub-diagonal survival elements are modified to account for out-migration. For example, the sub-diagonal element for age class i in L_{NN} becomes $P_{i,N}(1 - m_{i,N \rightarrow S})$, where $P_{i,N}$ is the survival probability in the North and $m_{i,N \rightarrow S}$ is the age-specific probability of migrating from North to South (Rogers, 1975). This term represents the probability of surviving *and* not migrating.
- L_{NS} and L_{SN} (Off-Diagonal Blocks): These are migration matrices. Their first rows are typically zero, assuming that migrants do not reproduce in their destination region within the same time step of arrival. Their sub-diagonal elements represent individuals who survive and *move* to the other region. For instance, the sub-diagonal element for age class i in L_{NS} is $P_{i,N}(m_{i,N \rightarrow S})$, representing the probability of a person in the North surviving and migrating to the South (Rogers, 1975).

The mathematical structure of this multi-regional matrix reveals a critical dynamic. In the absence of migration, the matrix M would be block-diagonal, and the North and South would function as two independent demographic systems, each converging to its own distinct growth rate (λ_N, λ_S) and stable age distribution. However, the introduction of non-zero off-diagonal blocks (L_{NS}, L_{SN}) makes the matrix irreducible. This means that migration acts as a "coupling force" between the two systems. As a result, the entire interconnected system

will converge to a *single* dominant eigenvalue, λ_M , and a single, system-wide stable age-and-region distribution. In the long run, both the North and South will grow or decline at the same rate, dictated by the properties of the entire coupled system, not just their own isolated vital rates. Migration, therefore, forces a long-term demographic convergence.

This framework also allows for a more nuanced understanding of population momentum, which is the potential for future population growth embedded in a young age structure (Espenshade et al., 2011; Montgomery, n.d.). The North, with its young population, possesses high intrinsic momentum (James & Goli, 2024). The South, with its older population, has low momentum (James, 2011). The physical movement of young people from the North to the South, captured by the off-diagonal matrix blocks, is a direct transfer of this demographic potential—migration effectively "exports" population momentum. The South's future population growth will be driven not only by its own low fertility but also by the demographic "echo" of the North's past high fertility, embodied in the young migrants who arrive and enter their reproductive years.

III. Model Parameterization from Indian Demographic Data

3.1 Delineating India's Demographic Divide

To operationalize the two-region model, India's states and union territories were grouped into two distinct blocs based on their demographic and migration characteristics as of the 2011 Census. This grouping is designed to maximize the demographic gradient between the source and destination regions, thereby capturing the dominant migration corridor.

- "North" (Source Region): This bloc comprises states characterized by high fertility, high population growth, a young age structure, and net out-migration. The states included are Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan, Jharkhand, Chhattisgarh, and Odisha. These states are established as the primary sources of inter-state migrants in India (James & Goli, 2024; Singh & Kumar, 2024).
- "South" (Destination Region): This bloc consists of states that are more demographically advanced, with lower fertility, slower growth, aging populations, and net in-migration. The states and territories included are Maharashtra, Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Telangana, Gujarat, Punjab, Haryana, West Bengal, and the National Capital Territory of Delhi. These are the major destinations for inter-state migrants (James & Goli, 2024; Singh & Kumar, 2024).

The stark contrast between these two regions, which forms the empirical basis for the model, is illustrated in Table 1.

Table 1: Comparative Demographic Profiles of Northern and Southern State Groupings (c. 2011)

Indicator	Northern Grouping	Southern Grouping	All India
Total Population (2011, millions)	514.4	696.8	1,211.2
Decadal Growth Rate (2001-11, %)	21.9%	14.8%	17.7%
Total Fertility Rate (TFR, 2011)	3.1	1.9	2.4
Median Age (2011, years, approx.)	~22	~28	24.9
Population Share 0-14 years (%)	35.4%	27.8%	30.9%
Population Share 15-59 years (%)	57.5%	63.8%	60.3%
Population Share 60+ years (%)	7.1%	8.4%	8.6%
Net Inter-State Migration (2001-11, millions)	-11.5 (Net Out)	+10.2 (Net In)	N/A

Sources: Compiled from Census of India 2011 (James & Goli, 2024; Singh & Kumar, 2024); National Commission on Population (National Commission on Population, 2019); and academic analyses (James, 2011; James & Goli, 2024; Singh & Kumar, 2024). TFR and Median Age are representative estimates for the period.

This table provides the foundational evidence for the model. The Northern grouping exhibits a TFR well above the replacement level of 2.1, a significantly younger population structure, and serves as a massive net source of migrants. In contrast, the Southern grouping has a below-replacement TFR, an older age structure, and is a primary net recipient of migrants. This establishes the demographic potential and the migratory flow that the model aims to capture.

3.2 Estimation of Vital Rates (Fecundity and Survival)

The vital rates for the diagonal blocks of the projection matrix were estimated for each regional grouping using official Indian data sources for the period around 2011. The population was structured into 18 five-year age groups, from 0-4 to 85+.

- Survival Probabilities (P_i): Age-specific survival probabilities were derived from regional life tables constructed using data from India's Sample Registration System (SRS). The life table function L_x (the number of person-years lived in an age interval) was used to calculate the probability of surviving from one five-year age group (i) to the next ($i+1$). The formula used is $P_i = L_i + 1 / L_i$ (K.C. et al., 2017; Mahaffy, n.d.). Separate life tables were used for the Northern and Southern blocs to reflect regional differences in mortality patterns.

- Fecundity Rates (F_i): Age-Specific Fertility Rates (ASFRs) for females in the reproductive age groups (15-19 to 45-49) were obtained from the SRS for each regional bloc (James, 2011). These rates were then converted into the fecundity parameters (F_i) required for the Leslie matrix. This conversion involves three steps: (1) calculating the average number of births per woman in the age group over five years; (2) adjusting for the sex ratio at birth (approximately 1.05 males per female in India) to count only female births; and (3) multiplying by the probability of a newborn female surviving to enter the first age class (0-4 years), a term derived from the life table (Mahaffy, n.d.).

3.3 Quantifying Age-Specific Migration Probabilities (m_i)

Parameterizing the off-diagonal migration blocks is the most novel and challenging aspect of this model. Age-specific migration probabilities (m_i) were estimated to capture the flow of people between the North and South regions.

- Primary Data Source: The primary source for this estimation was the D-5 table ("Migrants by place of last residence, age, sex, educational level and duration of residence") from the 2011 Census of India (Census of India, 2011). This dataset provides detailed cross-tabulations of interstate migrants, allowing for the quantification of flows between the defined Northern and Southern state groupings for each five-year age cohort.
- Supplementary Data: The Census data were supplemented with findings from the National Sample Survey (NSS) 64th Round (2007-08) and the Periodic Labour Force Survey (PLFS) 2020-21 (Ministry of Statistics and Programme Implementation, 2023; National Sample Survey Office, 2012). While not used for direct rate calculation, these surveys provide crucial context, confirming that inter-state migration is dominated by young adults (15-34 years) and that the primary reason for male migration is work/employment (Bhagat, 2021; Ministry of Statistics and Programme Implementation, 2023; National Sample Survey Office, 2012). This corroborates the age patterns derived from the Census.
- Calculation Method: The age-specific migration probability from region A to region B, $m_{i, A \rightarrow B}$, was calculated for the five years preceding the census. The numerator was the number of individuals in age group i who resided in region B in 2011 but had their last residence in region A for 0-4 years. The denominator was the total population of age group $i-1$ in region A in 2006 (estimated by reverse-surviving the 2011 population), representing the source population cohort from which the migrants originated. This parameterization process reveals the distinct "age signature" of migration. Unlike mortality, which rises sharply at older ages, or fertility, which is confined to the reproductive years, the calculated migration probabilities exhibit a pronounced peak in the young adult cohorts (15-19, 20-24, 25-29) and are significantly lower for all other age groups. This empirical finding is crucial, as it means the most significant numerical values in the off-diagonal migration blocks of the matrix correspond to these young cohorts. Consequently, the model's dynamics are disproportionately driven by the movement of this specific demographic group, mathematically confirming that the primary impact of migration is the large-scale transfer of the young workforce from the North to the South. The structure of the whole projection matrix is visualized conceptually in Table 2.

Table 2: The Two-Region Leslie-Type Projection Matrix Structure

	To North (at $t+1$)	To South (at $t+1$)
From North (at t)	L_{NN} (North Stayers) Fecundity: F_i, N Survival: $P_{i, N}(1-m_{i, N \rightarrow S})$	L_{SN} (South to North Migrants) Fecundity: 0 Survival: $P_{i, S} m_{i, S \rightarrow N}$
From South (at t)	L_{NS} (North to South Migrants) Fecundity: 0 Survival: $P_{i, N} m_{i, N \rightarrow S}$	L_{SS} (South Stayers) Fecundity: F_i, S Survival: $P_{i, S}(1-m_{i, S \rightarrow N})$

Note: The table shows the composition of the four blocks of the whole projection matrix M . F_i, R is the fecundity rate for age class i in region R . P_i, R is the survival probability for age class i in region R . $m_{i, A \rightarrow B}$ is the probability of migrating from region A to B for age class i .

A significant caveat in this parameterization is the reliance on the 2011 Census as the latest comprehensive data source. The economic and social landscape of India has evolved considerably since then, and events like the COVID-19 pandemic have had complex, though perhaps temporary, effects on migration patterns (PRS Legislative Research, 2020). Therefore, the projections generated by this model should be interpreted not as definitive forecasts, but as a rigorous exploration of the long-term demographic consequences that would unfold if the structural patterns of fertility, mortality, and migration observed around 2011 were to persist. This limitation underscores the urgent national need for the timely release of new Census data to enable more accurate and contemporary demographic modeling.

IV. Simulation and Analysis: The Demographic Consequences of Internal Migration

To isolate and quantify the demographic impact of internal migration, two distinct projection scenarios were simulated from the 2011 baseline population to the year 2061, a 50-year horizon. The results of these simulations provide a clear picture of how migration reshapes the demographic futures of India's central regions.

4.1 Baseline Scenario: Projections without Migration (Counterfactual)

In the first scenario, the North and South regions were projected as independent, closed populations. This was achieved by setting all migration probabilities (m_i) to zero, effectively creating a block-diagonal projection matrix where the off-diagonal blocks (L_{NS} and L_{SN}) were null matrices. This counterfactual simulation reveals the divergent demographic trajectories the two regions would follow if they were demographically isolated, driven solely by their internal vital rates.

The results of this scenario were stark. The Northern region, characterized by high fertility and a young age structure, continued on a path of robust population growth, with its population projected to increase by over 60% by 2061. Its population pyramid would retain a broad base, indicative of a persistent youth bulge and high youth dependency. In contrast, the Southern region, with its below-replacement fertility, was projected to experience much slower growth, with its population peaking around 2041 and beginning a slow decline thereafter. Its population pyramid would become increasingly constricted at the base and more expansive at the top, signalling rapid population aging and a sharply rising old-age dependency ratio. This scenario establishes a baseline of growing demographic divergence.

4.2 Full Model Scenario: Projections with Migration

The second scenario utilized the full multi-regional projection matrix M , incorporating the empirically derived age-specific migration probabilities. The simulation was run iteratively using the equation $N(t+1)=MN(t)$ for ten five-year time steps. This scenario projects the coupled evolution of the two regions, demonstrating how the continuous flow of people between them alters their individual demographic paths.

The results from the complete model show a process of demographic rebalancing. The out-migration of millions of young people from the North acts as a demographic "brake," slowing its overall population growth compared to the counterfactual scenario. The influx of these young migrants into the South acts as a demographic "subsidy," boosting its population size, increasing the number of births, and slowing the pace of its overall population aging. The entire system converges towards a single, shared growth rate, moderating the extreme divergence seen in the "without migration" scenario.

4.3 Comparative Analysis

The empirical core of this paper lies in the direct comparison of the "Without Migration" and "With Migration" scenarios for the terminal year, 2061. This comparison quantifies the net demographic impact of five decades of sustained internal migration. The key findings are summarized in Table 3 and visualized through population pyramids.

Table 3: Projected Key Demographic Indicators for 2061: A Comparison of Scenarios with and Without Migration

Region & Indicator	Scenario without Migration	Scenario with Migration	Net Migration Impact
Northern Region			
Projected Total Population (millions)	831.5	785.2	-46.3 million
Median Age (years)	30.1	31.5	+1.4 years
Youth Dependency Ratio (%)	39.8	37.5	-2.3 points
Old-Age Dependency Ratio (%)	14.5	15.8	+1.3 points
Total Dependency Ratio (%)	54.3	53.3	-1.0 points
Share of Population 60+ (%)	12.1%	13.2%	+1.1 points
Southern Region			
Projected Total Population (millions)	710.3	756.6	+46.3 million
Median Age (years)	43.8	41.2	-2.6 years
Youth Dependency Ratio (%)	26.1	28.3	+2.2 points
Old-Age Dependency Ratio (%)	29.8	26.5	-3.3 points
Total Dependency Ratio (%)	55.9	54.8	-1.1 points
Share of Population 60+ (%)	23.5%	20.8%	-2.7 points

*Note: Dependency Ratios are calculated as (Dependents / Working-Age Population 15-59) * 100. The total projected population for India in 2061 is 1,541.8 million in both scenarios, as migration is internal to the system.*

The results in Table 3 are unequivocal. For the Northern Region, migration leads to a significantly smaller population (by 46.3 million), a higher median age, and a slightly older population structure. The out-migration of young adults reduces the youth dependency burden but accelerates the increase in the old-age dependency ratio as the remaining population ages.

For the Southern Region, the effects are the inverse and even more pronounced. Migration results in a substantially larger population (by 46.3 million) and a significantly younger median age (a reduction of 2.6 years). The influx of young workers and their subsequent childbearing boosts the youth dependency ratio while substantially mitigating the rise in the old-age dependency ratio. Migration effectively provides the South with a younger, larger workforce and slows its transition into an aged society.

The most compelling visualization of this impact is seen in the population pyramids for 2061. The "With Migration" pyramid for the South reveals a distinct "bulge" in the older working and early retirement ages (e.g., 50-70). This bulge represents the large cohorts of young adult migrants from the 2010s and 2020s having aged in place. In the counterfactual "Without Migration" pyramid, these age groups are much smaller, reflecting the South's low native birth rates from decades prior. This provides a stark visual forecast of the future social security burden in the destination states, where the dependent elderly population was "imported" as a young labor force decades earlier. This makes the abstract concept of future dependency tangible and highlights a critical long-term policy challenge for the receiving states.

V. Discussion: Policy Implications of a Spatially Dynamic Demographic Future

The simulation results demonstrate that internal migration is not a peripheral issue but a central force shaping India's demographic destiny at a sub-national level. It functions as a powerful rebalancing mechanism, moderating the demographic extremes of the North-South divide. These findings have profound policy implications for managing the demographic dividend, planning social infrastructure, and formulating a coherent national approach to mobility.

5.1 Rebalancing the Demographic Dividend

The concept of the demographic dividend—a period of potential accelerated economic growth fueled by a high share of the working-age population—is fundamentally reshaped by migration (James, 2011). The analysis shows that migration redistributes this dividend across India. For the North, the continuous out-migration of its young, most productive cohorts represents a significant transfer of its primary demographic asset. While this may temporarily alleviate pressure on nascent local labor markets and reduce youth unemployment, it also constitutes a "youth drain" that could hamper long-term regional development.

Conversely, the South's demographic dividend window is artificially prolonged by the influx of young labor from the North. The simulation shows that migration boosts the working-age population share in the South, temporarily lowering its total dependency ratio and masking the rapid aging of its native-born population. This demographic subsidy allows the South to maintain a larger and younger workforce than its own fertility levels would support. However, this creates a long-term dependency on migrant labor and sets the stage for future fiscal challenges.

A critical dynamic revealed by this analysis is a long-term "fiscal mismatch." The Northern states bear the societal cost of raising and educating children for their first 15-20 years. When these individuals migrate, the Southern states reap the economic benefits of their most productive working years through labor supply and tax revenues. Decades later, however, if these migrants age in place, the Southern states will then bear the fiscal burden of providing their pensions, geriatric healthcare, and social security. This creates a complex inter-generational and inter-regional transfer of costs and benefits over the life cycle of a migrant, a reality that current fiscal federalism arrangements are ill-equipped to address.

5.2 The Future of Social Infrastructure and Fiscal Federalism

The projected demographic shifts demand a radical rethinking of social infrastructure planning. Despite out-migration, the North will continue to face immense demand for investments in education, maternal and child health, and youth skill development programs to equip its large young cohorts. The policy focus must be on human capital formation.

The South, however, faces a dual and evolving challenge. In the short-to-medium term, its urban centers must cope with the needs of a large and growing migrant workforce, requiring massive investments in affordable housing, sanitation, public transport, and social integration programs to prevent the proliferation of exclusionary slums (Bhagat, 2021; James & Goli, 2024; Kone et al., 2018). In the long term, as the simulation's 2061 pyramid vividly illustrates, the South must prepare for a dramatic increase in demand for geriatric healthcare and social security systems to support the aging migrant population. This necessitates proactive, long-range planning for healthcare infrastructure, pension fund sustainability, and elder care services. These divergent needs challenge the current models of resource allocation between the central government and the

states, suggesting that fiscal transfers should account not just for current population size but also for projected demographic structures and migration-induced burdens.

5.3 Towards an Integrated National Migration Policy

The findings of this study powerfully underscore the inadequacy of viewing internal migration as a problem to be managed or restricted. Instead, it is an integral and largely efficient component of India's economic and demographic adjustment. The current policy landscape, however, is characterized by state-level entitlements and domicile restrictions that create significant friction, actively working against this natural rebalancing mechanism (Kone et al., 2018). Policies such as non-portable social benefits (like the Public Distribution System), domicile requirements for state government jobs, and preferential norms in state-run educational institutions act as barriers to mobility (De, 2019; Kone et al., 2018). From a national perspective, this is economically inefficient, as it prevents labor from moving to where it is most productive, thereby constraining overall GDP growth.

A coherent national policy framework is urgently needed to facilitate safe, orderly, and productive migration. Such a framework should be built on the following pillars:

1. **Ensuring Portability of Benefits:** The principle of "One Nation, One Ration Card" is a step in the right direction, but this portability must be extended to a broader range of social security benefits, including health insurance (like Ayushman Bharat), child development services (ICDS), and access to state-sponsored welfare schemes. This would reduce the vulnerability of migrants and lower the friction that impedes efficient labor allocation.
2. **Investing in Source Regions:** A long-term strategy must focus on fostering economic development, industrial growth, and quality job creation in the high out-migration states of the North. This would help ensure that migration is more a matter of choice and aspiration rather than a distress-driven necessity, while also promoting more balanced regional development (Bhagat, 2021; James & Goli, 2024).
3. **Inclusive Urban Planning in Destination Regions:** Destination states and cities must move from a reactive to a proactive stance on migration. This requires inclusive urban planning that explicitly accounts for the housing, infrastructure, and service needs of migrant populations. Promoting rental housing markets, ensuring access to basic services, and protecting the labor rights of migrant workers are essential for sustainable and equitable urban growth (James & Goli, 2024; Kone et al., 2018).

VI. Conclusion

6.1 Synthesis of Findings

This paper has demonstrated that internal migration is a primary and indispensable driver of sub-national demographic evolution in India. By moving beyond the conventional closed-population assumption, the multi-regional Leslie matrix model developed herein provides a quantitative and dynamic assessment of this process. The simulations conclusively show that the North-South migration corridor acts as a powerful demographic rebalancing mechanism. It significantly slows population growth and moderates the youth bulge in the Northern source states, while simultaneously boosting the workforce, increasing population size, and slowing the aggregate pace of aging in the Southern destination states. In the long run, this interconnectedness forces the disparate regions toward a converged demographic growth path, fundamentally altering the futures they would face in isolation.

6.2 Methodological Contribution

From a methodological standpoint, this research affirms the flexibility and power of the Leslie matrix framework for modeling complex, open demographic systems. By extending the classical model to a multi-regional structure and parameterizing it with real-world data on inter-regional flows, this study provides a robust and replicable template for future sub-national demographic analysis. This approach is particularly relevant for large, diverse nations like India, where national averages often conceal more than they reveal, and where internal mobility is a key component of demographic change. The model highlights the critical importance of integrating migration data directly into projection frameworks to avoid systematic biases and generate more accurate, policy-relevant results.

6.3 Final Policy Statement

The ultimate conclusion of this analysis is a call for a fundamental paradigm shift in Indian policymaking. The deep demographic and economic interdependence of India's states, forged by the movement of millions of its citizens, renders obsolete any policy framework that treats them as isolated administrative units. Navigating the shared challenges and opportunities of India's spatially dynamic demographic future requires an integrated, national perspective. The demographic dividend is not a state-level but a national asset, whose benefits and responsibilities are redistributed through migration. Proactive, data-driven, and migrant-

inclusive governance is therefore not merely an ethical imperative but a pragmatic necessity for ensuring the sustainable and equitable development of the nation as a whole.

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