

RESEARCH ARTICLE

Migration and spatial distribution of the demographic dividend: Regional effects of the interprovincial working-age population flows in China

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Abstract

Interprovincial migration in China has redistributed the working-age population at an unprecedented scale, yet its spatial demographic consequences remain underquantified. This study constructs a Net Demographic Dividend Transfer index to capture the provincial balance of working-age inflows and outflows across 31 Chinese provinces from 2000 to 2023, and applies two-way fixed effects panel models and a spatial Durbin model to decompose direct and indirect spillover effects on provincial old-age dependency ratios, with instrumental variable estimation addressing endogeneity concerns. Results show that net inflows of working-age population significantly reduce provincial old-age dependency ratios while net outflows accelerate demographic ageing in sending regions. Spatial spillover effects are significant and asymmetric: eastern provinces generate positive demographic externalities for neighbouring regions, while central, western, and northeastern provinces impose negative spillovers on surrounding areas. Regional heterogeneity analysis further reveals that western and central provinces exhibit substantially greater sensitivity to working-age outflows than eastern provinces, reflecting the compounding vulnerability of smaller, higher-dependency origin regions. These findings collectively indicate that interprovincial migration operates as a spatial redistribution mechanism for the demographic dividend, deepening regional demographic divergence rather than moderating it. Compensatory policy measures for sending provinces are warranted to address the structural asymmetry in demographic costs generated by market-driven labour mobility.

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1. Introduction

Interprovincial migration in China has been recognised as one of the most significant shifts in human population distribution in recent demographic history, with a floating population figure exceeding 376 million by 2020 (Wen *et al.*, 2025). This pattern of interprovincial flows not only has significant implications for regional human resource allocation but also has led to significant shifts in population age composition, both

at sending and receiving places, beyond what could be explained by natural population trends. While younger, working-age populations are being concentrated in coastal urban clusters, inland areas are left with ageing and declining populations, resulting in a spatial split in population composition that continues to increase with each census cycle (Gu *et al.*, 2025). This spatial divergence has unfolded against a broader backdrop of national population decline, as China entered a phase of sustained negative natural growth characterised by persistently sub-replacement fertility and an accelerating shift in the national age structure (D. Peng, 2023). The age-selective nature of these flows has been further documented through census-based analyses showing that migration intensity has surged across all age cohorts over the past two decades, yet the peak concentration among young working-age adults has remained remarkably stable, reinforcing the directional persistence of demographic redistribution (H. Zhou & Chen, 2023).

The fundamental factor underlying this divergence is the demographic dividend, the potential for economic growth associated with the ratio of the working-age population to dependents. Prior studies have established a significant relationship between the provincial structure of the age distribution and the provincial economy, with differences in provincial age composition accounting for a significant proportion of interprovincial income inequality (Liang *et al.*, 2023). Recent studies have also established the effects of age-selective migration, where it has been found to reduce the dependency ratio in the destination regions while increasing the rate of ageing in the origin regions, thus having implications for growth, not only for labour supply but also for long-term growth (Du *et al.*, 2025). A parallel line of inquiry has demonstrated that the conventional understanding of the demographic dividend as a function of age structure alone is increasingly insufficient. Recent evidence from Chinese city-level data suggests that the dividend has undergone a qualitative transformation, shifting from an extensive reliance on the size of the working-age population to an intensive dependence on the skill composition and quality of the labour force's human capital (Gu *et al.*, 2026). This transition implies that the redistributive consequences of migration may extend beyond headcount transfers to encompass the spatial reallocation of productive capacity itself. These effects are further exacerbated by the spatial concentration of migrants in dynamically evolving regions, thereby polarising them rather than converging them (Ge & Yang, 2025).

Yet, despite the clear relevance of migration to demographic dividend distribution, the two bodies of

literature have engaged only to a limited extent. Research on migration patterns and determinants has treated demographic outcomes largely as context rather than as measurable results of mobility (H. Zhang *et al.*, 2025), a tendency that persists even as the scale and complexity of internal flows have continued to grow (Xia *et al.*, 2022). Studies of population ageing, meanwhile, have attributed provincial age structure primarily to fertility and mortality trends (S. Wang *et al.*, 2022), leaving migration as a secondary and often uncontrolled consideration in demographic accounting frameworks (L. Guo & Wang, 2024). This analytical separation is compounded by a tendency to treat provinces as demographically self-contained units, despite mounting evidence that internal migration operates through spatially interconnected networks that transmit demographic pressures across regional boundaries (Gao *et al.*, 2024). A broader comparative literature on urbanisation trajectories in developing countries further confirms that internal migration generates systematic spatial externalities that reshape demographic structures at both origin and destination, yet these spillover channels remain poorly integrated into subnational demographic models (Lerch, 2025). As a result, the net transfer of demographic dividend between provinces through working-age population flows has not been formally quantified, and the spatial spillover dimension of this redistribution process remains underexplored.

Existing studies have examined the spatial determinants of migration or the correlates of population ageing separately, but few have integrated these into a spatial econometric framework that treats migration as a mechanism for redistributing the demographic dividend. The cross-boundary spillover channel through which migration reshapes neighbouring provinces' age structures, and the regional variation in the sensitivity of dependency ratios to these flows, remain underexplored.

This study attempts to fill these gaps by developing a Net Demographic Dividend Transfer (NDDT) index to measure the provincial balance of working-age population inflows and outflows and utilising a spatial Durbin panel model to differentiate direct and indirect spillover effects on provincial dependency ratios across 31 provincial units in China from 2000 to 2023. Regional heterogeneity across eastern, central, western, and northeastern China is also examined to test whether migration reinforces or mitigates existing demographic disparities in these regions. The findings of this article will not only contribute to the replicable measurement of dividend redistribution but also inform the practical implications of labour migration reform and regional development planning in an ageing society.

2. Data and methods

2.1. Theoretical framework and research hypotheses

The theoretical base of this research draws upon two related but distinct literatures: the economics of demographic change and the spatial theory of internal migration. The former provides the conceptual basis for examining the impact of interprovincial labour migration on the geographic distribution of the demographic dividend, as depicted in Figure 1.

The theoretical underpinning of the concept of a demographic dividend is that, rather than population size, population structure is critical for explaining cross-country differences in economic performance. Specifically, an increase in the share of the working-age population relative to dependents leads to higher savings rates, a larger labour force, and higher economic output per capita (Bloom *et al.*, 2008). Indeed, cross-country data have confirmed that this structural effect is an important contributor to long-run income levels (Zelity, 2025), and at the subnational level, age structure is an important determinant of regional economic divergence over time, as the coupling between population ageing and economic growth has been shown to exhibit significant spatial-temporal variation across Chinese provinces (Wang *et al.*, 2022). The relationship between age structure and economic performance, however, is not mechanistically determined by the size of the working-age population alone. Simulation-based projections for China have demonstrated that even under conditions of very low fertility, productivity-weighted measures of dependency

that account for educational attainment present a substantially more favourable economic outlook than conventional age-based indicators (Lutz *et al.*, 2021). This finding raises the question of whether migration-induced changes in provincial age structure translate linearly into economic outcomes, or whether the human capital content of migrant flows mediates the magnitude of the transfer of the demographic dividend. The structural effect of a demographic dividend is not immutable; rather, it can be enhanced through investment in human capital and savings accumulation (Mason *et al.*, 2016), but it may be reduced through out-migration of working-age populations from a region. Previous evidence on China has shown that education interacts with age structure to determine how effectively provinces translate their demographic potential into economic output (J. Zhou *et al.*, 2023), suggesting that not only the size but also the quality of the working-age population is important for realising a demographic dividend.

On the migration side, the aspirations-capabilities framework offers a useful lens for understanding why labour flows are age-selective and directionally persistent (de Haas, 2021). Younger working-age individuals possess both the motivation and the capacity to relocate in response to wage differentials, while older residents face higher mobility costs. This selectivity is well documented in the Chinese context, where institutional factors such as hukou restrictions continue to mediate the volume and direction of flows (Gu *et al.*, 2020), and where skill composition has been shown to shape the spatial structure of interprovincial

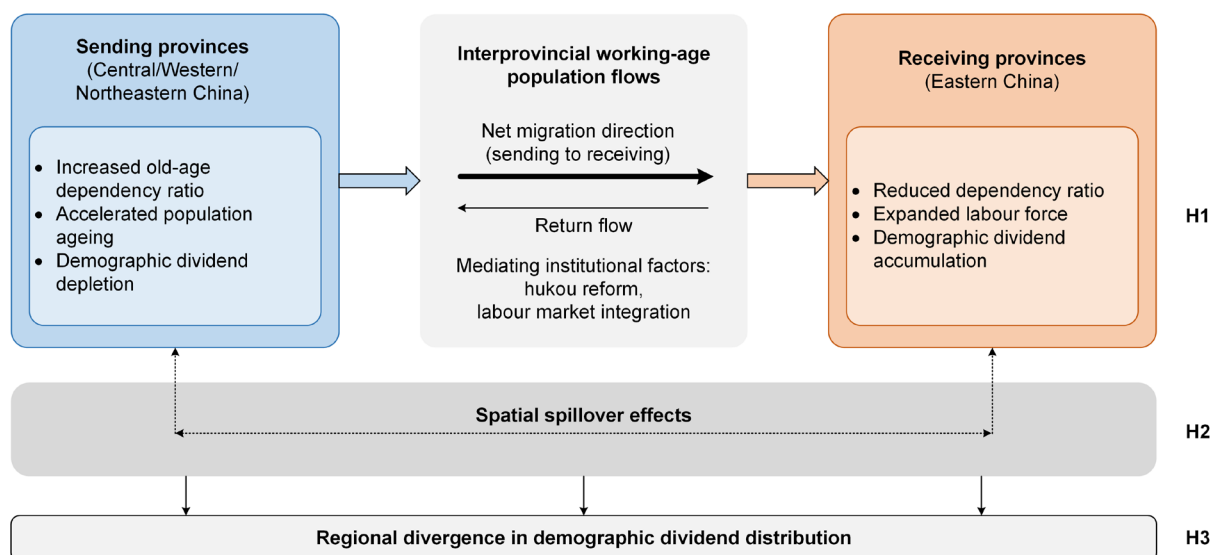


Figure 1. Theoretical framework of interprovincial working-age population flows and spatial redistribution of the demographic dividend

flows in important ways (Gu & Shen, 2021), with the spatial heterogeneity of migration determinants growing more pronounced as regional labour markets have deepened (S. Li *et al.*, 2023). The heterogeneity of migration drivers across the urban hierarchy has been further substantiated by evidence on the spatial concentration patterns of floating populations under different agglomeration regimes, suggesting that the direction and intensity of migration are jointly conditioned by urban economic structure and local policy environments (Cao *et al.*, 2023). The migration behaviour of older adults, though smaller in scale, follows a broadly similar spatial gradient from central and western regions toward the eastern seaboard, indicating that age-selective out-migration compounds the demographic depletion of sending regions across the full age spectrum rather than operating exclusively through the working-age channel (Qin *et al.*, 2024). Recent evidence further reveals that demographic ageing itself feeds back into migration policy, as localities facing labour shortages have progressively relaxed settlement restrictions to attract working-age residents (Chen *et al.*, 2026). The mass migration documented over recent decades thus reflects a dynamic interplay among economic incentives, institutional constraints, and evolving demographic pressures (R. Guo *et al.*, 2024), a process this study frames as a spatial mechanism for redistributing the demographic dividend. The institutional dimension of this process has been further clarified by recent empirical work on the labour market effects of hukou liberalisation, which demonstrates that the relaxation of settlement restrictions generates measurable adjustments in local labour supply and demand structures in both origin and destination regions (W. Zhang *et al.*, 2024). Such findings suggest that the institutional architecture governing internal mobility is not merely a background condition but an active determinant of the scale, direction, and demographic consequences of interprovincial flows.

Building on this framework, three hypotheses guide the empirical analysis:

- (i) H1: The magnitude of net working-age population flows is sufficient to widen the demographic gap between receiving and sending provinces over successive census periods.
- (ii) H2: The demographic spillover effects of working-age flows are spatially asymmetric, varying in sign and magnitude between net-receiving and net-sending provincial clusters.
- (iii) H3: Provincial dependency ratios are disproportionately sensitive to working-age outflows in regions with smaller population bases and higher baseline dependency.

2.2. Data sources and variable measurement

This study drew on three major data sources covering 31 provincial-level units in mainland China between 2000 and 2023. The provincial-level age-structure indicators of total dependency ratio, old-age dependency ratio, and youth dependency ratio were sourced from the China Statistical Yearbook (National Bureau of Statistics of China, 2001–2024a) and the China Population and Employment Statistics Yearbook (National Bureau of Statistics of China, 2001–2024b) published annually by the National Bureau of Statistics of China. The interprovincial working-age population flows were calculated from the fifth, sixth, and seventh national censuses conducted in 2000, 2010, and 2020, respectively, and supplemented by the annual China Population Sample Survey for intercensal years, the results of which are incorporated in the China Statistical Yearbook (National Bureau of Statistics of China, 2001–2024a) for intercensal years. The socioeconomic control variables of provincial-level GDP per capita, urbanisation rates, and average wages were sourced from the China Statistical Yearbook for the entire period of interest (Mi & Zheng, 2025).

The dependent variable of interest was the provincial old-age dependency ratio, defined as the number of people aged 65 and above divided by the working-age population aged 15–64 years. This directly measures the age structure conditions that affect the demographic dividend at the provincial level (Lu *et al.*, 2024). At the national level, the old-age dependency ratio has risen from 10.1% in 2000 to 20.7% in 2023, while at the provincial level, it has varied, reaching 38.2% in Heilongjiang and exceeding 54% in Guizhou in 2023 (National Bureau of Statistics of China, 2024).

The major independent variable was the NDDT index, which is defined as the net inflow of the working-age population relative to the total provincial population. A positive NDDT index represents net demographic accumulation in the recipient province, while a negative NDDT index represents net demographic depletion in the sending province. In 2020, the total floating population was 375.8 million, of which 124.8 million individuals had crossed the provincial boundary and formed the largest interprovincial mobility stock ever recorded in China (Wen *et al.*, 2025). The control variables included the provincial Gross Domestic Product (GDP) per capita, the urbanisation rate, and the mean wage level, which have been proven to affect the migration and demographic patterns in China (Chen *et al.*, 2024). Trade openness and foreign direct investment were not control variables in the model due to their demographic nature. However, previous literature proves the importance of these factors

as structural factors in the interprovincial labour flow in China (X. Li & Pan, 2023). Table 1 lists the definitions and sources of the variables.

2.3. Construction of the demographic dividend indicators

2.3.1. Effective dependency ratio

The effective dependency ratio was utilised as the main outcome variable to measure the structural burden on the working-age population imposed by dependents at the extremes of the age distribution. In conformity with demographic norms, the working-age population is defined as individuals aged 15 to 64 years, while the youth dependents range from 0 to 14 years, and the elderly dependents range from 65 years and beyond (Mi & Zheng, 2025). The total dependency ratio was defined as Equation 1:

$$DR_{it} = \frac{P_{dep,it}}{P_{wap,it}} \times 100 \quad (1)$$

where DR_{it} denotes the total dependency ratio of province i in year t , $P_{dep,it}$ is the combined youth and elderly population, and $P_{wap,it}$ is the working-age population. Lower values indicate a more favourable age structure. The old-age dependency ratio is additionally retained as a separate outcome variable to isolate the ageing-driven component of demographic change (Lu *et al.*, 2024).

2.3.2. Net Demographic Dividend Transfer index

To quantify the redistribution of the demographic dividend through interprovincial labour flows, this study constructed a provincial-level NDDT index. The index was defined as Equation 2:

$$NDDT_{it} = \frac{M_{in,it}^{wap} - M_{out,it}^{wap}}{P_{it}} \times 100 \quad (2)$$

where $M_{in,it}^{wap}$ and $M_{out,it}^{wap}$ denote the inflow and outflow of working-age migrants in province i in period t , and P_{it} is the total provincial population. Positive values indicate net demographic accumulation in receiving provinces, while negative values signal depletion in sending provinces. By normalising flows against the total population, the index enables comparable measurement across provinces of varying sizes and directly links mobility to the demographic dividend rather than to overall population change.

Since complete migration matrices were available only for census years (2000, 2010, and 2020), intercensal annual estimates were derived through linear interpolation between adjacent benchmarks. This method was chosen for its parsimony and transparency, imposing only a constant rate of change between observed endpoints, consistent with the broadly monotonic intercensal trends in interprovincial flow patterns.

2.4. Econometric model specification

2.4.1. Baseline panel model

This study first established a two-way fixed effects panel model as the baseline specification, controlling for unobserved provincial heterogeneity and common time trends. The model is expressed as Equation 3:

$$DR_{it} = \alpha + \beta_1 NDDT_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where DR_{it} is the dependency ratio of province i in year t , $NDDT_{it}$ is the NDDT index, X_{it} is a vector of control variables including GDP per capita, urbanisation rate, and average wage, μ_i and λ_t represent province

Table 1. Variable definitions and data sources

Variable	Definition	Source
Old-age dependency ratio (%)	Population aged 65+/Population aged 15–64 × 100	China Statistical Yearbook
Total dependency ratio (%)	Population aged 0–14 and 65+ / Population aged 15–64 × 100	China Statistical Yearbook
Net Demographic Dividend Transfer (%)	Net working-age inflow / Total provincial population × 100	National Population Census; Annual Population Survey
Gross Domestic Product (GDP) per capita (ln)	Log of provincial GDP per capita (CNY)	China Statistical Yearbook
Urbanisation rate (%)	Urban population / Total population × 100	China Statistical Yearbook
Average wage (ln)	Log of average annual wage (CNY)	China Statistical Yearbook

Notes: Working-age population is defined as individuals aged 15 to 64. Data cover 31 provincial-level units in mainland China from 2000 to 2023.

and year fixed effects, respectively, and ε_{it} is the error term. The coefficient β_1 captures the direct effect of working-age population flows on provincial dependency ratios. Instrumental variable estimation was additionally employed to address potential endogeneity between migration flows and local demographic conditions.

The instrumental variable was constructed from the stock of interprovincial migrants recorded in the 1990 national population census, predating the study period. Origin-province migrant stocks from 1990 were interacted with national-level changes in migration push factors over time, following a shift-share approach. This Bartik-type instrument exploits the persistence of historical migration corridors to generate exogenous variation in current working-age population flows, on the assumption that 1990 migration patterns reflect established bilateral linkages rather than responses to contemporaneous provincial demographic conditions. The first-stage F -statistic is reported to confirm instrument relevance. A Hausman specification test was additionally conducted to formally assess the presence of endogeneity between NDDT and provincial dependency ratios. Under the null hypothesis, both the fixed effects and instrumental variable estimators were consistent and yielded similar estimates; rejection of the null indicates systematic endogeneity and supports the adoption of instrumental variable estimation over the fixed effects specification alone.

2.4.2. Spatial Durbin model

The baseline model assumes independence across provinces, which is unrealistic given the interconnected nature of regional labour markets. Moran's I tests were first used to assess the presence of spatial autocorrelation in the dependent variable. Once the presence of substantial spatial dependence was established, the spatial Durbin model was applied, which accounts for the spatial lag of both the dependent and independent variables simultaneously (LeSage & Pace, 2021) (Equation 4):

$$DR_{it} = \rho WDR_{it} + \beta_1 NDDT_{it} + \gamma X_{it} + \theta W \cdot NDDT_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

where Y is the vector of provincial old-age dependency ratios, X includes the NDDT index and controls (GDP per capita, urbanisation rate, and average wage), and W is a row-standardised queen contiguity matrix. The coefficient ρ captures spatial clustering of ageing across neighbouring provinces. The parameter θ measures the cross-border effect of neighbouring provinces' NDDT on a given province's dependency ratio. For example, a significant negative θ would imply that large-scale out-migration from Anhui erodes the demographic base of

its neighbouring provinces as well. The total effects were decomposed into direct and indirect components to distinguish within-province impacts from cross-province spillovers (R. Peng *et al.*, 2023), providing the empirical basis for testing H2. This decomposition approach has been widely adopted in spatial demographic studies of China (Y. Guo & Zhong, 2025). The appropriateness of spatial econometric approaches for analysing demographic phenomena at the provincial level is reinforced by recent work documenting significant multiscale spatial heterogeneity in the determinants of population ageing across Chinese regions, where the strength and direction of explanatory variables vary markedly depending on geographic scale (Long *et al.*, 2025). Such evidence underscores the importance of modelling spatial dependence explicitly rather than treating cross-provincial demographic linkages as residual noise.

3. Results

3.1. Spatial evolution of interprovincial working-age population flows

Given that complete interprovincial migration matrices were only available in census years, the spatial pattern analysis drew on three benchmark periods (2000, 2010, and 2020), while annual panel data across the full study period were employed in the econometric analysis that follows.

Figure 2 reveals a persistent and deepening pattern of demographic polarisation across China's 31 provincial units. In 2000, spatial differentiation was relatively modest. Eastern coastal provinces recorded positive NDDT values, with Guangdong at +13.3%, Shanghai at +21.2%, and Zhejiang at +10.1%, reflecting net accumulation of working-age population. Central and northeastern provinces exhibited moderate but consistent outflows, with Henan at -4.4%, Anhui at -3.6%, and Heilongjiang at -1.8%. Most provinces remained within a comparatively narrow range, suggesting that migration had not yet generated pronounced structural divergence.

By 2010, the pattern had intensified at both ends. Shanghai rose to +25.2% and Zhejiang to +15.3%, while sending provinces deepened their depletion, with Anhui at -4.2% and Henan at -3.5%. Northeastern provinces began exhibiting more pronounced outflows, foreshadowing the deterioration that would accelerate over the following decade.

The 2020 distribution marks a qualitative shift. Eastern provinces further consolidated their advantage, with Shanghai at +34.3%, Zhejiang at +21.4%, and Guangdong at +21.2%. Sending provinces experienced sharply

accelerated depletion across all major origin regions, with Henan at -14.5% , Anhui at -15.1% , Heilongjiang at -12.9% , and Guizhou recording the steepest decline at -19.7% . These patterns suggest that migration has progressively reinforced spatial demographic divergence, providing initial descriptive support for H1 and H3.

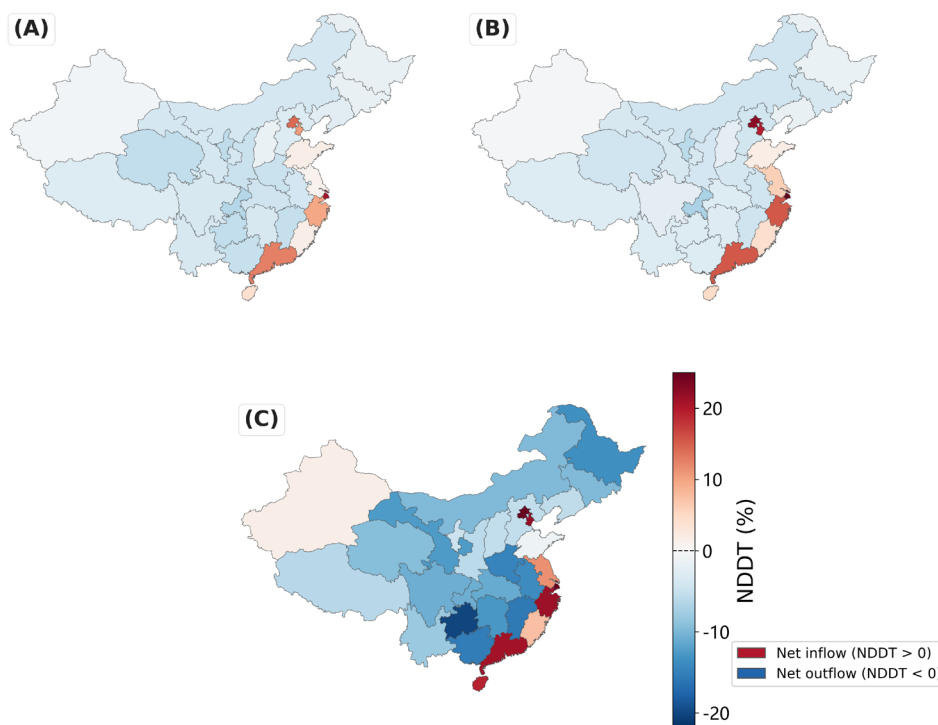
3.2. Descriptive characteristics of the demographic dividend spatial distribution

Figure 3 presents the temporal evolution of two key indicators across the study period. As shown in Figure 3A, a persistent and widening gap in old-age dependency ratios was observed between net inflow and net outflow provincial groups. In 2000, net outflow provinces already had a higher mean old-age dependency ratio (10.1%) than net inflow provinces (8.2%), reflecting the early-stage demographic consequences of age-selective out-migration. By 2020, this gap had widened substantially, with net outflow provinces reaching 19.3% compared to 14.6% in net inflow provinces, and the divergence continued to expand through 2023. Figure 3B further illustrates the regional heterogeneity in NDDT trajectories. Eastern

provinces maintained persistently positive NDDT values throughout the period, rising from approximately $+8.2\%$ in 2000 to $+16.1\%$ by 2020. Central provinces experienced the sharpest decline, falling from -4.2% to -13.6% , while western and northeastern provinces also recorded accelerating depletion at somewhat more moderate magnitudes.

Table 2 presents the descriptive statistics for all key variables. The mean old-age dependency ratio across all provincial-year observations was 13.42% , masking substantial variation between net inflow provinces (mean 11.83%) and net outflow provinces (mean 14.61%). The NDDT index ranged from -19.74% to $+34.30\%$, with an overall negative mean of -1.83% , reflecting the structural dominance of net outflow provinces in the sample.

Table 3 reports the results of Moran's I spatial autocorrelation test. Statistics for both the old-age dependency ratio and NDDT were positive and statistically significant across all three census years, confirming positive spatial autocorrelation in both variables. The degree of spatial dependence increases over



Data source: National Population Census 2000, 2010, 2020.

Figure 2. Spatial distribution of the Net Demographic Dividend Transfer (NDDT) across 31 Chinese provinces, 2000–2020
Data source: National Population Census 2000, 2010, 2020.

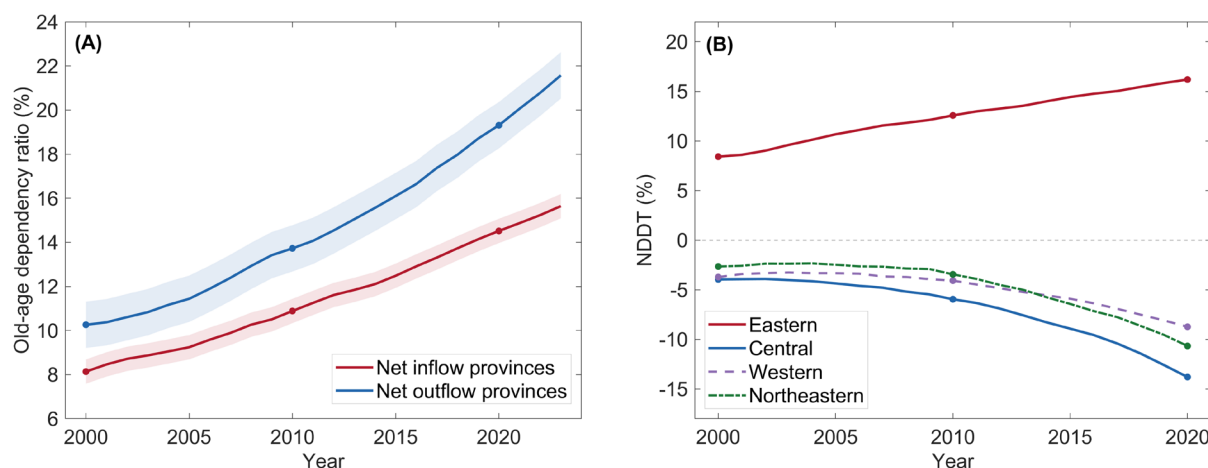


Figure 3. Temporal trends in demographic dividend indicators across provincial groups. (A) Old-age dependency ratio by net inflow and net outflow provinces, 2000–2023. (B) Mean Net Demographic Dividend Transfer (NDDT) index by four regional groupings, 2000–2020 (census benchmark years).

time, with Moran's I for the old-age dependency ratio rising from 0.312 in 2000 to 0.441 in 2020, suggesting that spatial clustering of demographic outcomes has intensified alongside migration-driven redistribution. The consistently significant Moran's I statistics confirm spatial autocorrelation in both the dependent and independent variables, justifying the adoption of spatial econometric models in the subsequent analysis.

3.3. Baseline regression results

Table 4 presents the baseline panel regression results examining the effect of the NDDT Index on provincial old-age dependency ratios. Across all four specifications, the coefficient on NDDT was negative and statistically significant, indicating that net inflows of the working-age population are associated with lower old-age dependency

ratios, whereas net outflows accelerate increases in dependency ratios. This finding is consistent with H1.

In the pooled ordinary least squares specification (Column 1), the NDDT coefficient was -0.187 , suggesting that a one percentage point increase in NDDT was associated with a 0.187 percentage point reduction in the old-age dependency ratio. The magnitude remained stable after the inclusion of control variables in Column 2 (-0.174), while GDP per capita and the urbanisation rate also exhibited significant negative associations with old-age dependency, reflecting the broader demographic effects of economic development. The two-way fixed effects specification in Column 3 absorbed unobserved provincial heterogeneity and common time trends, yielding a somewhat smaller but still significant coefficient of -0.143 . This attenuation is expected, as fixed effects remove time-

Table 2. Descriptive statistics of key variables for 31 Chinese provinces (2000–2023), with separate means for net inflow and net outflow province groups

Variable	Mean	SD	Min	Max	Inflow provinces	Outflow provinces
Old-age dependency ratio (%)	13.42	3.86	6.80	22.10	11.83	14.61
Total dependency ratio (%)	42.31	6.24	26.50	57.80	36.42	46.18
NDDT (%)	-1.83	8.64	-19.74	34.30	+14.26	-10.38
GDP per capita (ln)	10.24	0.74	8.31	11.84	10.87	9.84
Urbanisation rate (%)	54.62	14.83	22.67	89.60	68.34	46.21
Average wage (ln)	10.41	0.49	9.18	11.62	10.79	10.18

Note: Inflow and outflow province groups are defined by the sign of NDDT averaged across the study period.

Data source: China Statistical Yearbook (2001–2024); National Population Census.

Abbreviations: GDP: Gross Domestic Product; NDDT: Net Demographic Dividend Transfer; SD: Standard deviation.

invariant provincial characteristics that may correlate with both migration patterns and age structure.

Table 3. Moran's I spatial autocorrelation test results

Variable	Year	Moran's I	Z-value	p-value
Old-age dependency ratio	2000	0.312	3.847	0.001
	2010	0.378	4.623	0.000
	2020	0.441	5.218	0.000
Net Demographic Dividend Transfer	2000	0.284	3.512	0.002
	2010	0.326	4.018	0.001
	2020	0.403	4.876	0.000

Notes: Spatial weight matrix based on queen contiguity, row-standardised. All Moran's I statistics are significant at the 1% level.

Column 4 addresses potential endogeneity between migration flows and local demographic conditions by using historical migration networks as an instrumental variable. The instrumental variable estimate of -0.162 falls between the ordinary least squares and fixed effects estimates, and the first-stage F -statistic of 24.37 comfortably exceeded the conventional threshold of 10, confirming instrument relevance. The Hausman test further supports the presence of endogeneity, justifying the instrumental variable approach. Among control variables, GDP per capita consistently showed a negative and significant association

with old-age dependency, while the average wage coefficient was positive in some specifications, reflecting the tendency of high-wage regions to attract migrants who may also bring dependent family members. Urbanisation rate exhibited a negative but marginally significant effect across specifications.

3.4. Spatial spillover effects: Direct and indirect effect decomposition

Table 5 presents the decomposition of total effects from the spatial Durbin model into direct and indirect components. The direct effect of NDDT on provincial old-age dependency ratios was -0.156 and statistically significant at the 1% level, confirming that working-age population inflows reduce local dependency ratios after accounting for spatial feedback. The indirect effect, capturing the spillover of migration-induced demographic changes across provincial boundaries, was estimated at -0.089 and significant at the 5% level, providing direct evidence in support of H2. The total effect of -0.245 indicates that the aggregate demographic impact of interprovincial migration extends meaningfully beyond the receiving or sending province itself.

Figure 4 illustrates the heterogeneity of indirect effects across all 31 provincial units. A clear spatial gradient emerges from east to west and from northeast to southwest. Eastern provinces, including Shanghai (0.31), Beijing

Table 4. Baseline panel regression results: Effects of NDDT on old-age dependency ratio

Variables	(1) OLS	(2) Controls	(3) Two-way FE	(4) IV
NDDT	-0.187^{***} (0.031)	-0.174^{***} (0.028)	-0.143^{***} (0.024)	-0.162^{***} (0.037)
GDP per capita (ln)	-	-1.842^{***} (0.412)	-1.263^{**} (0.498)	-1.591^{***} (0.443)
Urbanisation rate	-	-0.063^* (0.034)	-0.041 (0.038)	-0.058^* (0.033)
Average wage (ln)	-	0.724^* (0.389)	0.381 (0.412)	0.612^* (0.356)
Province FE	No	No	Yes	Yes
Year FE	No	No	Yes	Yes
First-stage F	-	-	-	24.37
Observations	744	744	744	744
R^2	0.312	0.468	0.631	-

Notes: Robust standard errors clustered at the provincial level in parentheses. $*p < 0.1$, $**p < 0.05$, $***p < 0.01$. The instrumental variable in Column 4 is the historical interprovincial migration network constructed from the 1990 census. The dependent variable is the provincial old-age dependency ratio (%). Abbreviations: FE: Fixed effects; GDP: Gross Domestic Product; IV: Instrumental variable; NDDT: Net Demographic Dividend Transfer; OLS: Ordinary least squares.

(0.30), Zhejiang (0.26), and Guangdong (0.20), exhibited significant positive spillover effects, indicating that working-age inflows into these provinces generate positive demographic externalities for neighbouring regions. This finding reflects the role of eastern urban agglomerations as demographic anchors whose attractiveness partially sustains the labour supply of adjacent provinces.

Table 5. Spatial Durbin model effect decomposition: Direct, indirect, and total effects of NDDT on old-age dependency ratio

Effect	Coefficient	Standard error	p-value
Direct effect	-0.156***	0.029	0.000
Indirect effect	-0.089**	0.041	0.031
Total effect	-0.245***	0.058	0.000

Notes: Effects estimated from spatial Durbin model with two-way fixed effects and queen contiguity spatial weight matrix (row-standardised).

** $p < 0.05$, *** $p < 0.01$.

Abbreviation: NDDT: Net Demographic Dividend Transfer.

In contrast, central and western provinces displayed significant negative indirect effects. Henan (-0.28), Anhui (-0.32), Guizhou (-0.35), and Guangxi (-0.26) recorded among the largest negative spillovers, suggesting that out-migration from these provinces not only depletes local working-age populations but also erodes the demographic dividend of neighbouring sending provinces through

cascading labour supply effects. The transition zone, comprising Shandong, Xinjiang, Tibet, and Qinghai, exhibited statistically insignificant indirect effects, reflecting their intermediate position in the national migration system.

The northeastern provinces registered the most severe negative spillovers. Liaoning (-0.43), Jilin (-0.40), and Heilongjiang (-0.47) all exhibited large and significant negative indirect effects, consistent with the region's structural demographic collapse driven by persistent out-migration over the past two decades. These results collectively confirm that the spatial redistribution of the demographic dividend operates through both direct and indirect channels, generating a self-reinforcing pattern of demographic divergence that cannot be fully captured by standard non-spatial panel models.

3.5. Regional heterogeneity in the demographic effects of migration

Table 6 presents the results of subsample regressions stratified by four regional groupings, allowing for direct comparison of the demographic effects of working-age population flows across eastern, central, western, and northeastern China. The NDDT coefficient was negative and statistically significant across all four subsamples, confirming that the negative relationship between net

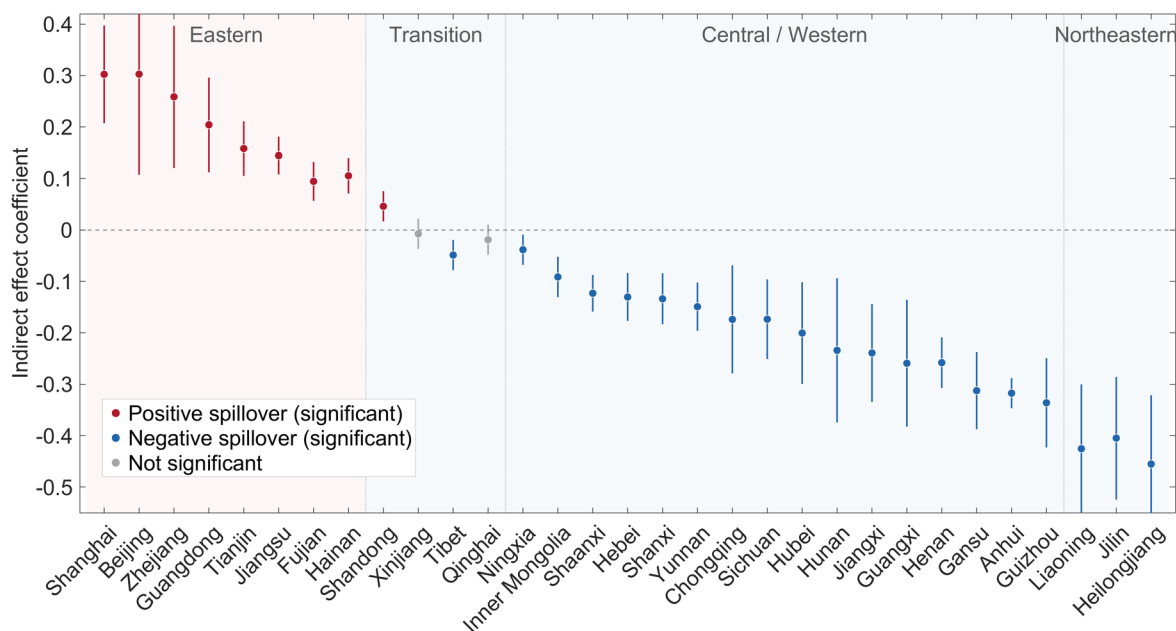


Figure 4. Provincial indirect effects of Net Demographic Dividend Transfer index on old-age dependency ratio from the spatial Durbin model. Error bars represent 95% confidence intervals. Provinces are ordered by indirect effect magnitude.

working-age outflows and old-age dependency ratios holds regardless of regional context. However, the magnitude and precision of the estimates vary substantially across regions, providing evidence for H3.

Table 6. Regional heterogeneity in the effect of NDDT on old-age dependency ratio: Subsample two-way fixed effects regression results by region

Variables	(1) Eastern	(2) Central	(3) Western	(4) Northeastern
NDDT	−0.098*** (0.021)	−0.187*** (0.034)	−0.213*** (0.041)	−0.176*** (0.048)
GDP per capita (ln)	−1.124** (0.468)	−1.487*** (0.412)	−1.832*** (0.524)	−1.263** (0.587)
Urbanisation rate	−0.058* (0.031)	−0.071** (0.029)	−0.049 (0.036)	−0.038 (0.042)
Average wage (ln)	0.412 (0.341)	0.687* (0.378)	0.834** (0.412)	0.521 (0.463)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	240	144	288	72
R ²	0.548	0.673	0.701	0.634

Notes: Robust standard errors clustered at the provincial level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Eastern region: 10 provinces; central region: 6 provinces; western region: 12 provinces; northeastern region: 3 provinces.

Abbreviations: FE: Fixed effects; GDP: Gross Domestic Product; NDDT: Net Demographic Dividend Transfer.

The eastern region yielded the smallest NDDT coefficient in absolute terms (−0.098), reflecting the relatively moderate sensitivity of old-age dependency ratios to migration flows in provinces that already maintain favourable age structures. Despite hosting the largest absolute inflows, the demographic base of eastern provinces was sufficiently large that marginal changes in NDDT produced comparatively modest effects on dependency ratios. In contrast, the central region exhibited a substantially larger coefficient (−0.187), consistent with the structural vulnerability of provinces such as Henan and Anhui, where sustained outflows have progressively hollowed out the working-age population base, making dependency ratios increasingly sensitive to further migration shocks.

The western region produced the largest coefficient in absolute terms (−0.213), suggesting that migration-induced demographic depletion is most acute in provinces characterised by smaller population bases and higher baseline dependency ratios. The northeastern subsample

yielded a coefficient of −0.176, significant at the 1% level, reflecting the compounding effect of both economic out-migration and low natural population growth that has characterised the region since the early 2000s. The substantially higher R -squared values in the central and western subsamples further indicate that NDDT explains a greater share of the variation in the dependency ratio in sending regions than in receiving regions, consistent with the asymmetric nature of migration-driven demographic redistribution documented throughout this study.

4. Discussion

4.1. Migration-driven polarisation of the demographic dividend

The results suggest that interprovincial migration has facilitated the transfer of demographic dividends rather than driven convergence. The NDDT coefficient remains negative and statistically significant across all regressions, and the two-way fixed-effects estimate of −0.143 provides the most conservative characterisation of the within-province relationship between working-age inflows and the decline in the dependency ratio. The widening gap in the disparity between the provinces experiencing net inflows and those experiencing net outflows, rising from 1.9 percentage points in 2000 to 4.7 percentage points in 2020, also suggests that two decades of age-selective migration have served to accentuate existing regional disparities in age structure, as previous evidence on the demographic impact of directionally persistent migration suggested (Du *et al.*, 2025).

This finding carries implications beyond demographic accounting. Prior research has established that age structure differences account for a meaningful share of persistent interprovincial income inequality (Liang *et al.*, 2023) and that the growth contribution of the demographic dividend operates through labour supply and savings channels that are sensitive to age composition (Mason *et al.*, 2016). If migration continues to concentrate working-age population in eastern provinces while accelerating ageing in origin regions, the fiscal and welfare consequences for sending provinces will compound over time in ways that provincial-level policy instruments are ill-equipped to address. The Moran's I evidence, showing rising spatial autocorrelation in both old-age dependency ratios and NDDT values across successive census periods, indicates that these demographic trajectories are interconnected through the same migration networks that drive the redistribution process. Any analytical framework that treats provinces as independent demographic units will systematically underestimate the scale and persistence of migration-induced divergence (Ge & Yang, 2025). The

spatiotemporal co-evolution of population ageing and socioeconomic indicators across Chinese provinces lends additional support to this interpretation, as prior research has documented a persistent east–west gradient in ageing intensity that mirrors the spatial structure of economic development and internal migration flows (M. Wang *et al.*, 2021). The implication is that demographic divergence and economic divergence operate as mutually reinforcing processes, with migration serving as the primary transmission channel between them.

4.2. Structural mechanisms underlying dividend siphoning

The decomposition of indirect effects reveals that the demographic effects of migration systematically spill over across provincial borders. The eastern provinces generate positive demographic spillovers, whereas the central, western, and northeastern provinces impose negative externalities. This spatial asymmetry suggests the operation of a dividend-siphoning effect arising from the interaction of institutional, infrastructural, and demographic feedback effects.

From an institutional perspective, the hukou system has traditionally guided the working-age population towards existing eastern destinations. Previous research suggests that institutional factors continue to influence the scale and direction of migration, with a bias towards economically advanced regions (Gu *et al.*, 2020), and that the spatial variation in migration determinants has increased with the differentiation of local labour markets (Li *et al.*, 2023). The complex interaction of economic opportunities, institutional barriers, and demographic pressures also supports the directional persistence of migration towards eastern agglomerations (L. Guo *et al.*, 2024). In terms of infrastructure, the development of transportation infrastructure has reduced the cost of inter-provincial migration without affecting its directional nature, thus reinforcing rather than relieving the spatial concentration of the working-age population. The demographic feedback loop forms the third force. As the sending provinces' populations age, the future migrant supply diminishes, thereby reducing the labour available for redistribution. Prior studies suggest that demographic ageing has a feedback effect into migration policies, where areas facing labour shortages increasingly liberalise their settlement policies (Chen *et al.*, 2026). Such a process might alleviate the effects of marginal siphoning but is unlikely to reverse the gradient effect found here.

The structural persistence of this siphoning mechanism is consistent with the observation that the old-age dependency ratio exerts a measurable drag on secular

economic growth trajectories, creating a feedback loop in which demographic depletion reduces the fiscal capacity of sending provinces to invest in the retention and attraction of working-age residents (Emerson *et al.*, 2024). The fact that even low-skilled migrant inflows have been shown to generate significant productivity effects in destination firms further suggests that the economic returns to migration accrue disproportionately to receiving regions, widening rather than narrowing the structural asymmetry documented in this study (Kong *et al.*, 2024). Labour segmentation between hukou and non-hukou populations in destination cities limits the potential of receiving regions to integrate migrants and reinforces the circular nature of migration (Chen *et al.*, 2024).

4.3. Compensation pathways for sending provinces

The differences in indirect effect estimates for sending provinces suggest that demographic depletion is channelled by structural factors that offer potential policy levers for intervention. The larger population-based provinces have slightly lower indirect effect coefficients, implying that provincial scale provides partial protection against the impact of migration-induced erosion, while smaller western provinces such as Guizhou and Qinghai are doubly vulnerable.

Three compensation mechanisms are consistent with the empirical evidence. Human capital deepening among the residual working-age population represents the first pathway. Prior research demonstrates that the demographic dividend can be extended through investments in education and training that raise the productivity of a smaller working-age cohort (Mason *et al.*, 2016), and that the interaction between education and age structure is particularly consequential for provincial economic performance in China (J. Zhou *et al.*, 2023). The viability of this pathway is reinforced by the broader finding that the sustainability of demographic dividends depends less on the absolute size of the working-age population than on the capacity to translate improvements in human capital quality into productivity gains, a process that is itself conditioned by local institutional and market environments (Lutz *et al.*, 2021). For sending provinces where the residual working-age population is comparatively small, targeted investment in educational quality and vocational training may therefore offer a more effective compensation strategy than attempts to directly reverse migration flows.

The second pathway involves institutional reform targeted at sending regions. Prior research has shown that relaxing migration barriers can stimulate local entrepreneurship and economic activity in origin areas

(Liu *et al.*, 2024), and that well-designed hukou reform can generate growth dividends in origin as well as destination regions (X. Guo & Xu, 2025). Reforms to disassociate public service entitlements from hukou registration in destination provinces would reduce one of the principal incentives for permanent relocation, since migrants currently face restricted access to healthcare and education in cities where they lack local hukou. If equivalent services become accessible regardless of registration status, the benefits of permanent settlement decline relative to circular migration, encouraging more workers to maintain a demographic presence in their origin provinces. Recent evidence on the comprehensive liberalisation of household registration further indicates that the removal of settlement barriers can stimulate rural labour reallocation in ways that partially counterbalance the demographic losses associated with outward migration, although the magnitude of this effect varies considerably across regional contexts (Hu & Jia, 2025). Complementary research on the labour market consequences of internal migration in settings with non-wage compensation structures suggests that institutional reforms must address not only the formal barriers to mobility but also the informal mechanisms through which destination regions attract and retain working-age populations (Corbi *et al.*, 2025).

The third mechanism concerns transport-mediated circular migration. Existing studies have suggested that increased market access is related to the composition of the labour force (Y. Wang *et al.*, 2024), which might induce patterns of circular rather than permanent migration and maintain economic ties to destination cities while preserving demographic presence in the provinces of origin. Fiscal redistribution to compensate provinces for the demographic costs of labour export is another fiscal instrument that remains inadequately addressed in current regional development policy frameworks.

4.4. Limitations

Several limitations must be acknowledged. The calculation of the NDDT index requires migration matrices by census year to achieve the most accurate estimates, with intercensal estimates derived through interpolation. This results in a degree of estimation error in the annual estimates of the panel. In addition, future research with access to annual administrative migration data will allow for more precise estimates of the annual NDDT. The spatial weight matrix derived through queen contiguity imposed a binary and geographically proximate concept of spatial interaction that may not accurately reflect the nature of interprovincial demographic spillovers, which will likely be related to economic rather than geographic gradients (LeSage & Pace, 2021). Specifications of weight matrices based on

migration flow intensities or economic distances provide a theoretically sound foundation for spillover estimation. Finally, this study considered only the quantitative aspect of population redistribution among the working-age population and did not account for variations in the skill composition or the quality of migrants' human capital. This creates a gap between the theoretical framework, which emphasises human capital as a mediator of the demographic dividend, and the empirical model, which captures only the quantity of working-age redistribution. Provincial average years of schooling would serve as an appropriate proxy in future extensions, enabling tests of whether the economic impact of changes in age structure varies with the educational profile of migrant flows. Future studies that include the educational and occupational attributes of interprovincial flows will provide a richer analysis of how migration contributes to the overall demographic dividend of China's regional system.

The study period encompassed the 2008 financial crisis and the COVID-19 pandemic, both of which temporarily altered migration flows, yet the model did not include explicit controls for these shocks. The geographic contiguity weight matrix also did not capture economic distance or migration corridor intensity; flows between Sichuan and Guangdong, for instance, far exceed those between Sichuan and its physical neighbours. Alternative matrices based on flow volumes may yield different spillover estimates. More broadly, provincial-level quantitative models cannot fully capture migration decisions shaped by household circumstances, cultural ties, and informal information networks.

5. Conclusions

This study constructed an NDDT index to quantify the provincial balance of working-age population flows across 31 Chinese provinces from 2000 to 2023, and applied a spatial Durbin model to decompose the direct and indirect demographic effects of interprovincial migration. Three principal findings emerge. Net inflows of working-age population significantly reduced provincial old-age dependency ratios while net outflows accelerated ageing in sending regions, confirming that migration redistributes rather than neutrally reallocates the demographic dividend. Spatial spillover analysis further revealed that these effects extend beyond provincial boundaries, with eastern provinces generating positive demographic externalities while central, western, and northeastern provinces imposed negative spillovers on surrounding areas. Regional heterogeneity analysis confirms that the sensitivity of dependency ratios to working-age outflows was substantially greater in western and central provinces, reflecting the compounding vulnerability of smaller, higher-dependency origin regions.

Such findings have important policy implications for regional development and labour mobility policies. The diversion of dividend revenues revealed in this paper confirms that unregulated market-based migration will continue to exacerbate the demographic gap between the coastal and inland provinces. Labour mobility policies that merely ease the movement of people without considering the structural differences in the demographic costs of labour outward movement for the sending and receiving provinces are likely to exacerbate the problem of demographic divergence. Fiscal transfers that take into account the demographic costs of labour outward movement, investments in human capital in the sending provinces, and institutional strengthening of public services in these provinces are policy priority areas. The case of the northeastern region is of particular policy concern because natural population growth cannot counterbalance structural ageing.

Future studies can also build on the framework developed here by incorporating annual administrative migration data, experimenting with different specifications of the spatial weight matrix, and analysing the human capital content of interprovincial migration. Such extensions would provide a more detailed picture of the effects of migration on the distribution of demographic dividends within the regional system of China.

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Author contributions

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Writing—review & editing: All authors

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Availability of data

Data will be made available upon request to the corresponding author.

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