



**CONSTRAINING EFFECTS OF POPULATION DECLINE AND
POPULATION AGEING ON RURAL AGRICULTURAL INDUSTRIAL
PROSPERITY: EVIDENCE FROM PROVINCIAL PANEL DATA IN
CHINA, 2008–2023**

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Abstract

Rural revitalization evaluation has expanded rapidly in China, yet increasingly large indicator systems can reduce interpretability and weaken policy operability. To address this issue, this study focuses on rural agricultural industrial prosperity (AIP) and measures it using observable agricultural and production-condition indicators from statistical yearbooks. Using provincial panel data for 31 provinces from 2008 to 2023 (excluding Hong Kong, Macao, and Taiwan), this study estimates a two-way fixed effects model to examine the relationship between rural population decline, rural ageing, and AIP. It also tests whether human capital, proxied by the average years of schooling of rural residents, conditions these demographic effects. The results show that population decline is negatively and robustly associated with AIP across alternative index construction methods, ageing measures, lagged specifications, and treatments for census-year or breakpoint shocks and outliers. In contrast, the direct effect of ageing is unstable and mostly insignificant. Moderation results show that the interaction between ageing and education is negative and significant, whereas the interaction between population decline and education is not significant. Regional interaction models further show stronger negative effects in specific regions. Overall, population decline is the more consistently supported demographic correlate of lower AIP, whereas the relationship between ageing and AIP appears to be more conditional. By focusing on AIP within a unified framework, this study provides more interpretable evidence for rural planning and governance under demographic change.

Keywords: Population Decline, Population Ageing, Agricultural Industrial Prosperity, Regional Heterogeneity

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INTRODUCTION

Since the 19th National Congress proposed the Rural Revitalization Strategy, related evaluation studies have expanded rapidly in China. At the same time, increasingly large indicator systems have raised interpretive complexity and weakened policy operability (Sarfo et al., 2024; Cai et al., 2024). In response, some studies have argued for a “key goals–key levers” approach that prioritises core policy orientations, such as agricultural labour productivity, the urban–rural income gap, and the equalisation of basic public services, rather than relying on overly composite indicators that may blur policy logic (Liu et al., 2020; Tang & Han, 2023).

Demographic change is one of the key structural factors shaping rural revitalization. Population decline, population ageing, and labour out-migration may reshape factor supply and local development conditions (Liu et al., 2020). Their implications, however, appear to vary across contexts, and existing studies suggest that migration ties, place attachment, counter-urbanisation, digital infrastructure, and broader regional conditions may reshape demographic pressures under specific circumstances (Wu et al., 2022; Guo et al., 2023; Yu et al., 2024; Wang et al., 2025; Lichter & Johnson, 2025).

Against this background, this study focuses on rural agricultural industrial prosperity (AIP), which is measured through observable agricultural and production-condition indicators from statistical yearbooks. This narrower focus is intended to reduce disputes over measurement scope and to improve consistency between concept and measurement (Zhang et al., 2020; Tang & Han, 2023). Using provincial panel data for 2008–2023, this study examines the relationship between population decline, population ageing, and AIP, and tests the conditional role of human capital (Wang, Zheng, et al., 2024). This focus helps provide more interpretable evidence for rural planning and governance.

LITERATURE REVIEW

Rural Revitalization Evaluation and the Need for a More Bounded Target

Rural revitalization research has expanded rapidly and produced a large number of indicator-based evaluations and reviews (Sarfo et al., 2024; Cai et al., 2024). At the same time, this literature has increasingly emphasised the population–land–industry nexus in rural transformation and governance. However, increasingly large indicator systems may reduce interpretability and blur the link between empirical findings and policy levers, especially for broad dimensions such as “industrial prosperity” (Tang & Han, 2023). Against this background, focusing on AIP through observable agricultural-sector indicators offers a more clearly bounded target for empirical analysis.

Population Decline, Ageing, and Their Possible Constraints on Agricultural Industrial Prosperity

Existing studies suggest that population decline, ageing, and labour out-migration may constrain rural development by weakening factor supply and local development foundations. Areas with revitalization potential may still face labour shortages, limited technical support, and uneven institutional conditions (Bai et al., 2021; Tao & Wu, 2023; Hu et al., 2023). International research reports similar concerns, linking population loss and ageing to poverty, deprivation, regional divergence, and barriers to generational renewal in agriculture (Gkatsikos et al., 2022; Murtagh et al., 2023; Pollnow et al., 2023; Consentino et al., 2023; Lichter & Johnson, 2025). Overall, the literature suggests that population decline and ageing may be associated with lower AIP through labour constraints, weaker innovation adoption, and lower organisational capacity.

Conditional Factors and the Role of Human Capital

Demographic constraints are not necessarily deterministic. Migration ties, place attachment, counter-urbanisation, digital infrastructure, and spatial governance tools may partly offset or reshape these effects under specific conditions (Wu et al., 2022; Yuan et al., 2022; Guo et al., 2023; Wang et al., 2025). Human capital may improve rural revitalization performance, but its effects vary across regions and may not automatically translate into local agricultural productivity or organisational capacity (Hu et al., 2023; Wang, Zheng, et al., 2024). This suggests that the relationship between population decline, ageing, and AIP, as well as the conditional role of human capital, should be examined empirically within a unified panel framework.

Hypotheses

H1: Population decline constraint. Higher population decline is associated with lower rural AIP.

H2: Ageing constraint. Greater population ageing is associated with lower rural AIP.

H3: Conditional role of human capital. Human capital conditions the effects of population decline and ageing; the direction of this moderation is an empirical question.

RESEARCH METHODOLOGY

Research Design and Data

This study uses provincial panel data for China from 2008 to 2023, covering 31 provincial-level administrative units and excluding Hong Kong, Macao, and Taiwan. The dataset is organised as a province–year panel. The analysis focuses

on AIP as the dependent variable and treats it as a more clearly bounded outcome than broader rural revitalization composite indices. Within a two-way fixed effects framework, the study examines the relationship between population decline, population ageing, and AIP, while also testing the conditional role of human capital and exploring regional heterogeneity. This strategy improves comparability and reduces time-invariant omitted bias, although the results should still be interpreted as association rather than definitive causal identification. The number of observations varies across specifications due to data availability for the population-decline series and the use of smoothing and lag constructions.

Variables and Measurement

As shown in Table 1, the dependent variable is the level of agricultural industrial prosperity (AIP), denoted as IP_{it} . AIP is constructed from observable agricultural performance and production-condition indicators reported in statistical yearbooks. Before aggregation, the indicators are aligned in direction and standardised to improve comparability across provinces and years. The baseline AIP measure is constructed using the entropy-weighted method, while a PCA-based score is used in the robustness analysis as an alternative measure.

The core explanatory variables are rural population decline, denoted as $PCS_pos_adj_{it}$ and rural ageing, denoted as $Aging_{it}$. Population decline is measured as the negative change in rural population size; specifically, it is constructed from the first difference of the logarithm of rural population multiplied by -1 , so that larger values indicate stronger decline. $Aging_{it}$ is measured by the share of the rural population aged 65 and above and is alternatively proxied in the robustness analysis by the old-age dependency ratio, denoted as $OADR_{it}$.

The moderating variable is human capital, denoted as HC_{it} . In this study, it is proxied by education-related indicators of rural educational attainment. This specification is used to assess whether the association between demographic constraints and AIP varies with human capital conditions. The control variable set, denoted as X_{it} , includes key contextual factors related to economic development, industrial structure, and fiscal support for agriculture, so as to reduce confounding bias.

Table 1. Variable Definitions, Index Construction, and Data Sources (2008–2023)

Variable	Dimension	Indicator	Code	Source
Dependent variable	Industrial output scale	Value added of the primary industry	X1(+)	Fiúza et al. (2023); Wang, Wu, et al., (2024); Chen and Wang (2025)
		Gross output value of agriculture, forestry, animal husbandry and	X2(+)	Wang, Zhang, et al. (2023); Wang, Zheng, et al. (2024)

Variable	Dimension	Indicator	Code	Source	
Independent variable	Industrial efficiency and productivity	fishery			
		Total agricultural machinery power	X3(+)	Liu et al. (2022); Tao and Wu (2023); Chen and Wang (2025)	
		Share of effectively irrigated area	X4(+)	Wang, Zhang, et al. (2023)	
	Industrial upgrading and factor input	Share of agriculture, forestry and water expenditure	X5(+)	Tao and Wu (2023)	
	Population shrinkage	Population growth rate	PCS (+)	Wang, Xu, et al. (2023); Wang and Li (2024); Wang, Wu, et al., (2024); Qi et al. (2025)	
		Intensity of population shrinkage	PCS_pos adj (-)		
	Population ageing	Share of population aged 65 and above	Aging (-)	Li et al. (2022); Osanai and Yu (2023); Cai et al. (2024)	
		Old-age dependency ratio	OADR (-)	Zhang and Wang (2022)	
	Control variable	Economic development level	Income–expenditure ratio	X6(+)	Gao et al. (2022)
		Industrial structure	Share of secondary and tertiary industry value added in provincial GDP	X7(+)	Shi and Yang (2022); Wang, Wu, et al., (2024); Chen and Wang (2025)
Fiscal support for agriculture		Per capita fiscal expenditure	X8(+)	Wang, Zhang, et al. (2023)	
Resource–environment and ecological constraints		Fertilizer application amount	X9(-)	Shi and Yang (2022); Wang, Zheng, et al. (2024); Chen and Wang (2025)	
Moderating variable		Human resources	Average years of schooling of rural residents	HC (+)	Tao and Wu (2023); Wang, Zheng, et al. (2024)

Source: Data and Author's Table

Models

Baseline Two-Way Fixed Effects Model

To assess the average relationship between population decline, ageing, and agricultural industrial prosperity, this study uses a two-way fixed effects (TWFE) model. The model controls for time-invariant provincial differences, and common year shocks. Although this framework helps reduce bias from time-invariant unobserved heterogeneity, the estimates should still be interpreted as panel-based evidence of association rather than strict causal effects. Standard errors are cluster-robust at the provincial level.

$$IP_{it} = \alpha + \beta_1 PCS_pos_adj_{it} + \beta_2 Aging_{it} + \gamma X_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

Interaction Tests for the Conditional Role of Human Capital

To test H3, this study examines whether the relationship between demographic constraints and agricultural industrial prosperity varies with human capital conditions. Human capital is proxied by rural educational attainment. Interaction terms are added to assess the conditional role of human capital.

$$IP_{it} = \alpha + \beta_1 PCS_pos_adj_{it} + \beta_2 Aging_{it} + \beta_3 HC_{it} \\ + \beta_4 (PCS_pos_adj_{it} \times HC_{it}) + \beta_5 (Aging_{it} \times HC_{it}) + \gamma X_{it} \\ + \mu_i + \tau_t + \varepsilon_{it}$$

To improve interpretability, this study reports marginal effects at selected levels of human capital, including representative quantiles and the mean plus or minus one standard deviation. These estimates help show whether the relationship varies across human capital conditions.

Robustness and Heterogeneity Tests

To examine whether the main findings depend on specific indicators or model settings, this study conducts robustness checks in three ways. First, the ageing variable $Aging_{it}$ is replaced by the old-age dependency ratio $OADR_{it}$, and the dependent variable is re-measured using an alternative index-construction method for agricultural industrial prosperity. Second, lagged specifications are estimated to examine whether the main associations remain stable when explanatory variables are shifted by one period. Third, regional heterogeneity is examined using region-based analyses to assess whether the relationship between demographic constraints and agricultural industrial prosperity differs across major regions of China. The provincial composition of each region is reported separately for transparency and replication.

Together, these tests assess whether the main findings remain stable across alternative measures, specifications, and regional contexts (Tang & Han, 2023; Luo et al., 2023).

ANALYSIS AND DISCUSSION

Baseline Effects (H1–H2)

The baseline TWFE results (Table 2) show a significant negative association between population decline and AIP. With controls and two-way fixed effects, the smoothed population-decline indicator $PCS_pos_adj_{it}$ remains significant at the 5% level with a negative coefficient. The estimated coefficient is about -0.246 ($p < 0.05$), suggesting lower AIP in provinces with stronger population decline under the current specification.

Table 2. Baseline Model Results (Dependent Variable: Entropy-Weighted AIP Index)

Variable	PCS_pos_adj	Aging	PCS_pos_adj + Aging	PCS_pos_adj + Aging + Controls
PCS_pos_adj	-0.4026** (0.1923)		-0.4116** (0.1887)	-0.2463** (0.1061)
Aging		0.2068 (0.3154)	0.1671 (0.2880)	-0.2052 (0.2607)
X6				-0.0646** (0.0238)

Variable	PCS_pos_adj_Aging	PCS_pos_adj + Aging	PCS_pos_adj + Aging + Controls
X7			-0.4037 (0.4448)
X8			-0.0334*** (0.0108)
X9			-0.00009 (0.00027)
Constant	0.2917*** (0.0022)	0.2549*** (0.0401)	0.2702*** (0.0373)
Observations	465	496	465
R-squared	0.9611	0.9531	0.9614
Province fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes

Notes: Standard errors in parentheses. Standard errors are clustered at the provincial level. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Authors' calculation based on the data.

This result is broadly consistent with H1. Population decline may be associated with reduced labour supply, weaker local demand, and lower factor allocation efficiency. These should be understood as plausible channels rather than directly identified mechanisms in the present model. Among the control variables, X6 and X8 remain negative and statistically significant, whereas X7 and X9 do not show robust significance. Taken together, these results suggest that AIP is related not only to demographic structure but also to broader contextual conditions.

By contrast, the coefficient on $Aging_{it}$ changes sign across specifications and is mostly insignificant. Accordingly, the baseline results do not provide robust evidence of a direct net association between ageing and AIP, and H2 is therefore not robustly supported. One possible interpretation is that the relationship between ageing and AIP may operate through indirect or context-dependent channels, such as fiscal structure, population decline, or industrial restructuring. In addition, offsetting supply- and demand-side adjustments, together with limited within-province variation in ageing, may weaken statistical significance in a fixed-effects framework.

Conditionality: Human Capital (H3)

To test H3, this study examines the conditional role of human capital, proxied by the average years of rural schooling. Two interaction terms are included in the baseline model: “ $PCS_pos_adj_{it} \times HC_{it}$ ” and “ $Aging_{it} \times HC_{it}$ ”. As shown in Table 3, the interaction between population declines and human capital is not statistically significant, whereas the interaction between ageing and human capital is negative and significant.

Table 3. Moderation Results: Human Capital and Demographic Constraints

Variable	Coefficient	Standard Error	p-value
PCS_pos_adj	-0.1842	0.0960	0.064
HC_c	0.0490	0.0277	0.087
PCS_pos_adj × HC_c	-0.0184	0.0310	0.558
Aging	0.0629	0.2976	0.834
Aging × HC_c	-0.4190	0.1583	0.013
X6	-0.0542**	0.0222	0.021
X7	-0.3282	0.4531	0.474
X8	-0.0338***	0.0080	<0.001
X9	-0.00009	0.00027	0.743
Constant	0.7552*	0.4425	0.098
Model Diagnostics			
Province fixed effects	Yes		
Year fixed effects	Yes		
Observations	465		
Joint Significance Test (Interaction Terms)			
F-statistic	3.61		
p-value	0.0393		

Source: Authors' calculation based on the data.

To improve interpretation, this study further reports marginal effects at selected levels of human capital. The marginal effects of population decline remain negative across education levels, but the non-significant interaction term does not support a stable moderating role of human capital in the relationship between population decline and AIP (Table 4). By contrast, the negative interaction coefficient for ageing suggests that the relationship between ageing and AIP may vary with human capital conditions, although the marginal effects reported in Table 5 are not consistently statistically significant.

Table 4. Marginal Effects of Population Decline across Human-Capital Levels

HC_c	Marginal effect	Standard error	p-value
25th percentile (-0.2775)	-0.1791	0.0963	0.063
50th percentile (0.1564)	-0.1871	0.0961	0.052
75th percentile (0.4428)	-0.1923	0.097	0.047

Source: Authors' calculation based on the data.

Table 5. Marginal Effects of Ageing across Human-Capital Levels

HC_c	Marginal effect	Standard error	p-value
25th percentile (-0.2775)	0.1792	0.3125	0.566
50th percentile (0.1564)	-0.0026	0.2918	0.993
75th percentile (0.4428)	-0.1226	0.2864	0.669

Notes: HC_c denotes the centred human-capital variable.

Source: Authors' calculation based on the data.

Overall, H3 is better understood as evidence of a conditional role of human capital rather than as support for a simple buffering mechanism. The results do not support a stable moderating effect of human capital in the case of

population decline, but they provide tentative evidence that the relationship between ageing and AIP may vary across human-capital conditions.

Robustness Checks

This study conducts robustness checks using alternative index construction, alternative variable measurement, lagged specifications, and adjustments for possible data-definition shocks. First, when the entropy-weighted AIP index is replaced by a PCA-based score and ageing is alternatively measured by the old-age dependency ratio, the negative association between population decline and AIP remains stable, whereas ageing remains mostly insignificant (Table 6).

Second, lagged specifications show that the lagged population-decline measure remains negatively associated with current AIP, while ageing does not show robust significance in either contemporaneous or lagged terms (Table 7).

Third, additional checks for census-year and breakpoint shocks, as well as winsorisation and trimming, remain broadly consistent with the baseline model (Table 8 and Table 9).

Table 6. Robustness Checks: Alternative AIP Measure (PCA) and Alternative Ageing Measure (OADR)

Variable	PCA: PCS_pos_adj	PCA: OADR	PCA: PCS_pos_adj + OADR	PCA: PCS_pos_adj + OADR+Controls
PCS_pos_adj	-4.5697** (1.8526)		-4.6389** (1.8447)	-2.5298** (1.0013)
OADR		0.0121 (0.0093)	0.0101 (0.0084)	-0.0030 (0.0060)
X6				-0.6299*** (0.2218)
X7				-0.2203 (0.4074)
X8				-0.3411*** (0.1116)
X9				-0.00236 (0.00267)
Observations	465	496	465	465
R-squared	0.9614	0.9534	0.9619	0.9700
Province fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Source: Authors' calculation based on the data.

Table 7. Robustness Checks: One-Period Lagged Explanatory Variables

Variable	PCS_pos_adj _{i,t-1}	PCS_pos_adj _{i,t-1} +Controls	PCS_pos_adj _{i,t-1} + Aging _{i,t-1}	PCS_pos_adj _{i,t-1} + Aging _{i,t-1} + Controls
PCS_pos_adj _{i,t-1}	-0.3910** (0.1748)	-0.2148 (0.1212)	-0.3932** (0.1753)	-0.2095 (0.1197)
Aging _{i,t-1}			0.1604 (0.2776)	-0.2453 (0.2351)

Variable	PCS_pos_adj _{i,t-1}	PCS_pos_adj _{i,t-1} +Controls	PCS_pos_adj _{i,t-1} + Aging _{i,t-1}	PCS_pos_adj _{i,t-1} + Aging _{i,t-1} + Controls
Aging _{i,t}	0.1111 (0.2755)	-0.1972 (0.2595)		
X6		-0.0634*** (0.0222)		-0.0663*** (0.0212)
X7		-0.3926 (0.3860)		-0.4076 (0.3830)
X8		-0.0274*** (0.0083)		-0.0280*** (0.0080)
X9		-0.00017 (0.00028)		-0.00018 (0.00029)
Observations	465	496	465	465
R-squared	0.9678	0.9736	0.9679	0.9737
Province fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Source: Authors' calculation based on the data.

Table 8. Robustness Checks A: Census-Year and 2015 Breakpoint Adjustments

Variable	Coefficient	Standard error	p-value
PCS_pos_adj (raw)	-0.2135*	0.1220	0.090
Aging	-0.2275	0.2857	0.432
X6	-0.0689***	0.0259	0.013
X7	-0.4190	0.4802	0.390
X8	-0.0333***	0.0111	0.005
X9	-0.0001	0.0003	0.666
Fixed Effects & Controls			
Province FE × Census Shock	Yes		
Province FE × 2015 Break	Yes		
Province fixed effects	Yes		
Year fixed effects	Yes		
Observations	465		

Source: Authors' calculation based on the data.

Table 9: Robustness Checks B: Winsorisation and Trimming versus the Baseline Model

Model	Contraction Measure	Coefficient	Standard error	p-value	Observations
Winsorised model	PCS_pos w	-0.1454**	0.0657	0.035	465
Trimmed-sample model	PCS_pos	-0.1655**	0.0710	0.027	457
Main Model	PCS_pos adj	-0.2667**	0.1105	0.022	465

Source: Authors' calculation based on the data.

Taken together, the robustness checks reinforce the main empirical pattern of the study: population decline is consistently associated with lower AIP, whereas the relationship between ageing and AIP does not exhibit stable

statistical significance. Although these checks cannot fully eliminate endogeneity concerns, they show that the main findings remain stable across alternative specifications.

Heterogeneity Tests

This study examines whether the relationship between population decline and AIP varies across regions. The 31 provinces are grouped into six regions (Region1–Region6). Because some regional subsamples contain few provinces and limited clusters, group-wise regressions may weaken statistical inference. For this reason, this study estimates a full-sample TWFE model with interaction terms, in which region dummies are interacted with population-decline intensity, to assess regional heterogeneity within a unified framework.

As shown in Table 10, the interaction terms for Region4 and Region5 are negative and statistically significant relative to the baseline region (Region1), suggesting a stronger negative association in these two regions. The marginal effects reported in Table 11 are significantly negative in Region5 and marginally significant in Region4, whereas the remaining regions are also negative but not well supported statistically.

Table 10. Heterogeneity Analysis: Regional Differences in the Association between Population Decline and AIP

Model	Coefficient	Standard error	p-value
PCS_pos_adj (Baseline:Region1)	-0.0353	0.1329	0.792
Region2×PCS_pos_adj	-0.1102	0.2021	0.59
Region3×PCS_pos_adj	-0.1057	0.0905	0.252
Region4×PCS_pos_adj	-0.2457**	0.0913	0.012
Region5×PCS_pos_adj	-0.2849**	0.115	0.019
Region6×PCS_pos_adj	-0.0627	0.087	0.477
Control variables included	Yes		
Observations / Province clusters	465 / 31		

Notes: Standard errors are clustered at the provincial level. Region1 is the baseline region. The six regional groupings are defined as follows: Region1 = North China; Region2 = Northeast China; Region3 = East China; Region4 = Central and South China; Region5 = Southwest China; and Region6 = Northwest China.

Source: Authors' calculation based on the data.

Table 12. Regional Marginal Effects of Population Decline (lincom)

Region	lincom	Standard error	p-value	95% CI	Interpretation
Region1	-0.0353	0.1329	0.792	[-0.3068, 0.2362]	Not significant
Region2	-0.1455	0.2623	0.583	[-0.6812, 0.3902]	Not significant
Region3	-0.141	0.1198	0.248	[-0.3858, 0.1037]	Not significant
Region4	-0.2810*	0.1433	0.059	[-0.5737, 0.0117]	Marginally significant (p < 0.10)
Region5	-0.3202**	0.1318	0.021	[-0.5894, -0.0510]	Significant (negative)
Region6	-0.0981	0.1496	0.517	[-0.4036, 0.2075]	Not significant

Source: Authors' calculation based on the data.

Taken together, these results suggest that the relationship between population decline and AIP varies across regional contexts rather than operating uniformly across space.

CONCLUSION

Key Findings

Based on panel data for 31 provinces in China from 2008 to 2023, this study uses a two-way fixed effects (TWFE) model to examine how rural population decline, ageing, and human capital are associated with agricultural industrial prosperity (AIP). It provides a structured assessment of demographic constraints under a unified framework.

First, population decline shows a significant and robust negative association with AIP, which is consistent with H1. This result remains stable across alternative measures, lagged specifications, and different data treatments. Population decline appears to be the more stable demographic correlate of lower AIP.

Second, the effect of ageing is unstable and mostly insignificant across specifications, so H2 is not robustly supported. Ageing may therefore be linked to AIP through indirect or context-dependent channels rather than through a stable direct net association.

Third, the interaction between population decline and education is not significant, while the interaction between ageing and education is significantly negative. H3 is therefore better understood as evidence of conditionality rather than support for a simple buffering mechanism. The results do not support a stable moderating role of human capital for population decline but provide tentative evidence that the relationship between ageing and AIP may vary across human-capital conditions.

Fourth, the regional interaction results show that the relationship between population decline and AIP is not spatially uniform, with more negative associations in some regions than in others. Demographic constraints therefore vary across regional contexts rather than operating uniformly across space.

Overall, the results suggest that population decline is the more consistently supported demographic constraint on AIP in this study, whereas ageing appears to be more conditional in its relationship with AIP. This study provides more interpretable evidence on demographic constraints and their relevance for planning under demographic change.

Policy Implications

The findings suggest that rural industrial planning should treat demographic change, especially population decline, as a practical constraint rather than

assuming continued growth by default. In planning terms, agricultural development strategies need to be aligned with changing population capacity, service thresholds, and spatial demand.

First, policy responses should focus on measures closely related to AIP, including agricultural organization, processing and circulation systems, value-chain linkages, and infrastructure efficiency. In areas with sustained out-migration, labour-saving and moderately scaled approaches may be more realistic than expansion-oriented strategies. Rural spatial planning may prioritise agricultural service nodes, storage and cold-chain facilities, irrigation and mechanisation infrastructure, and land consolidation arrangements that support moderate-scale and labour-saving production.

Second, human capital policy should not focus only on raising education levels. It should also consider whether education can be converted into local employment, industrial upgrading, and talent retention. Otherwise, higher education may coexist with continued out-migration. Planning and governance should therefore pay greater attention to the local conversion of human capital through employment platforms, entrepreneurship support, and public-service improvement in rural areas.

Third, because demographic constraints differ across regions, rural industrial governance should adopt more differentiated strategies. For more constrained areas, planning may need to focus on maintaining key functions, improving networks, and strengthening important nodes. Differentiated regional strategies may include adjusting village-system layouts, concentrating selected services in viable centres, and coordinating industrial land, service facilities, and infrastructure according to local demographic conditions.

Limitations and Future Research

This study has several limitations. First, the direct effect of ageing is not stable in the present models, so future research should further examine its indirect channels.

Second, although the interaction analysis shows a conditional relationship between education and demographic constraints, this study does not distinguish human capital stock, mobility, and return. Finer-scale data may help clarify these processes.

Third, the heterogeneity analysis is based on broad regional groupings. Future studies may extend the analysis to smaller spatial units to improve local relevance. More explicit regional classifications and finer spatial comparisons may also help connect demographic analysis with planning practice.

In sum, the findings suggest that demographic change is associated with AIP in differentiated ways. Population decline appears to be the more consistently

supported constraint, while the relationship between ageing and AIP appears to be more conditional.

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