International Journal of Innovative Research and Scientific Studies, 8(6) 2025, pages: 726-739

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

The impact of changes in the working-age population on China's economic development: From the perspective of industrial structure upgrading

XiaoFei Hao[1], Aotip Ratniyom[2], Sivalap Sukpaiboonwat[3*]

[1,2,3]*Faculty of Economics, Srinakharinwirot University, 114 Sukhumvit 23, Bangkok 10110, Thailand.*

Corresponding author: Sivalap Sukpaiboonwat (*Email: sivalap@g.swu.ac.th*)

Abstract

The study employs a panel dataset comprising 31 provinces in China over the period from 2000 to 2022 to empirically analyze the relationship between changes in the working-age population and China's economic growth, with a particular focus on the mediating and threshold roles of industrial structure upgrading. Empirical results demonstrate that the working-age population ratio exerts a statistically significant positive effect on economic development ($\beta = 0.183$, $p < 0.01$). Mediation analysis reveals that industrial structure upgrading fully mediates this relationship: the effect of WA_ratio on GDP growth becomes insignificant when ISU is introduced into the model (Sobel test statistic = 3.45, $p < 0.01$). Moreover, the threshold regression model identifies a critical value of 0.42 for the industrial upgrading index. When ISU is below this threshold, the marginal impact of the working-age population on GDP growth is relatively modest ($\beta = 0.112$); however, when ISU exceeds the threshold, the effect strengthens substantially ($\beta = 0.267$). These findings suggest that the positive demographic impact on economic growth is conditional upon the degree of industrial advancement. Industrial structure upgrading not only channels the benefits of a large labor force more effectively but also enhances economic resilience in the face of demographic pressures. Therefore, policy recommendations include: (1) accelerating industrial upgrading through technological innovation and service-sector development; (2) enhancing human capital investment to improve labor productivity; (3) promoting differentiated labor policies at regional levels to optimize demographic resources; and (4) integrating demographic planning with long-term economic strategies to sustain high-quality growth.

Keywords: Demographic transition, Economic development, Industrial structure upgrading, Mediation effect, Threshold regression. Working-age population.

DOI: 10.53894/ijirss.v8i6.9672
Funding: This study received no specific financial support.
History: Received: 15 July 2025 / **Revised:** 18 August 2025 / **Accepted:** 20 August 2025 / **Published:** 4 September 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

The changes in the working-age population in China significantly influence the country's economic development, particularly through the lens of industrial structure upgrading. As China faces an aging population and a declining demographic dividend, the traditional model of economic growth, which heavily relies on labor input, is becoming increasingly unsustainable. This demographic shift necessitates a transformation in industrial structure to maintain competitiveness and foster high-quality economic development. The aging population in China has profound implications for labor supply and industrial upgrading. As noted, the traditional industrial structure, characterized by low-cost labor and imitation innovation, is no longer viable in the face of an aging workforce [1]. This demographic transition compels China to adopt a more sustainable industrial model that emphasizes technological advancement and higher productivity. Furthermore, Ma's study indicates that population aging, coupled with migration trends, significantly hinders industrial structure upgrading, suggesting that the labor market's dynamics are crucial for economic transformation. Moreover, the role of industrial structure upgrading as a catalyst for economic growth is well-documented. Heath [2] emphasizes that the agglomeration of producer services has been pivotal in driving industrial innovation and economic development since the 1980s. This aligns with the findings of Brynjolfsson et al. [3] who demonstrate that industrial structure upgrading is a primary driver of economic growth across China's urban centers.

The spatial correlation of economic growth and industrial upgrading suggests that targeted policies can enhance regional development and address disparities in economic performance. In addition, strategic initiatives such as "Made in China 2025" highlight the importance of upgrading industrial structures to achieve high-quality economic development [4]. The integration of advanced technologies and the digital economy into traditional industries is crucial for fostering innovation and enhancing productivity. Bloom et al. [5] argue that the digital economy plays a significant role in promoting industrial structural upgrades by facilitating technological innovation and improving operational efficiencies. Furthermore, local government policies are instrumental in shaping the industrial landscape. Brynjolfsson and McAfee [6] point out that fiscal decentralization influences industrial structure evolution, indicating that local governance can either facilitate or obstruct the necessary transitions in industrial practices.

This underscores the need for coherent policy frameworks that align local initiatives with national economic objectives. In summary, the interplay between demographic changes, labor dynamics, and industrial structure upgrading is critical for China's economic development. The aging population presents challenges that necessitate a shift towards more innovative and sustainable industrial practices. By leveraging technological advancements and enhancing policy frameworks, China can navigate these demographic shifts and continue to foster economic growth.

2. Literature Review

2.1. Theoretical Basis

2.1.1. Demographic Transition Theory

The phenomenon through which fertility rates ultimately decrease to low and stable levels is encapsulated in a well-known framework within economic demography known as the demographic transition. According to Acemoglu and Restrepo [7] in Figures 1 and 2, the demographic transition seeks to elucidate the common trajectory that contemporary developed nations have traversed, which consists of three distinct stages in modern population history. In the initial stage, before their economic modernization, these nations experienced populations that were stable or exhibited very slow growth, attributable to a combination of high birth rates and correspondingly high death rates [8, 9]. The second stage commenced with the advent of modernization, characterized by improvements in public health, enhanced nutrition, increased income, and other advancements that significantly reduced mortality rates, thereby elevating life expectancy from below 40 years to over 60 years. Notably, this decline in death rates did not immediately coincide with a reduction in fertility rates. Consequently, the widening gap between elevated birth rates and decreasing death rates resulted in substantial increases in population growth relative to previous centuries [10]. Thus, stage 2 signifies the onset of the demographic transition, which involves a shift from stable or slowly growing populations to a phase of rapid population increase, followed by a subsequent decline in growth rates [11]. The third stage is characterized by the influences of modernization and development, which initiate a decline in fertility rates. Over time, the decreasing birth rates align with the lower death rates, resulting in minimal or negligible population growth. This transition reflects a movement from a relatively high number of births per woman to a level of replacement fertility, estimated to be approximately 2.05 to 2.1 births per woman, assuming that nearly all women survive to the average age of childbearing, as is the case in developed nations. In contrast, in developing countries with significantly lower survival rates, replacement fertility may exceed three births per woman.

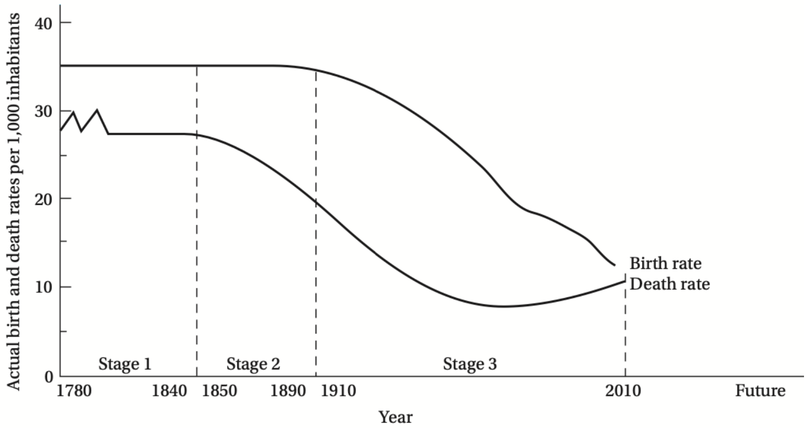

Figure 1.
The Demographic Transition in Western Europe.

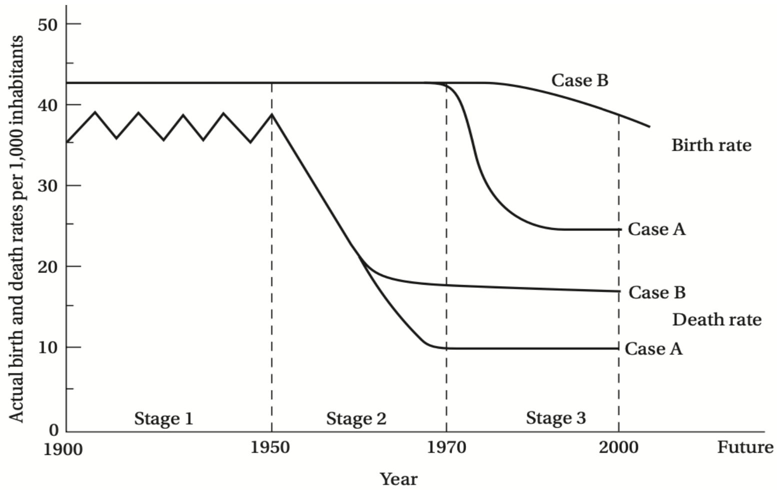

Figure 2.
The Demographic Transition in Developing Countries.

2.1.2. Lewis Dual-Sector Model: Measurement and Mechanisms of WAPED

One of the most prominent early theoretical frameworks addressing the structural transformation of predominantly subsistence economies was developed by Nobel laureate Arthur Lewis in the mid-1950s. This model was subsequently refined, formalized, and expanded upon by John Fei and Gustav Ranis. The Lewis two-sector model emerged as a foundational theory for understanding the development processes in surplus-labor economies during the 1960s and early 1970s, and it continues to be utilized, particularly in the analysis of recent economic growth in China and labor markets in other developing nations. Figure 3 illustrates the Lewis model of modern-sector growth in a two-sector economy [12]. Consider first the traditional agricultural sector portrayed in the two right-hand diagrams. The upper diagram shows how subsistence food production varies with increases in labor inputs. It is a typical agricultural production function in which the total output or product (TPA) of food is determined by changes in the amount of the only variable input, labor (LA), given a fixed quantity of capital, KA, and unchanging traditional technology, tA. In the lower-right diagram, we have the average and marginal product of labor curves, APLA and MPLA, which are derived from the total product curve shown immediately above. The quantity of agricultural labor (QLA) available is the same on both horizontal axes of the right-hand side of the figure and is expressed in millions of workers, as Lewis is describing an underdeveloped economy where much of the population lives and works in rural areas [13].

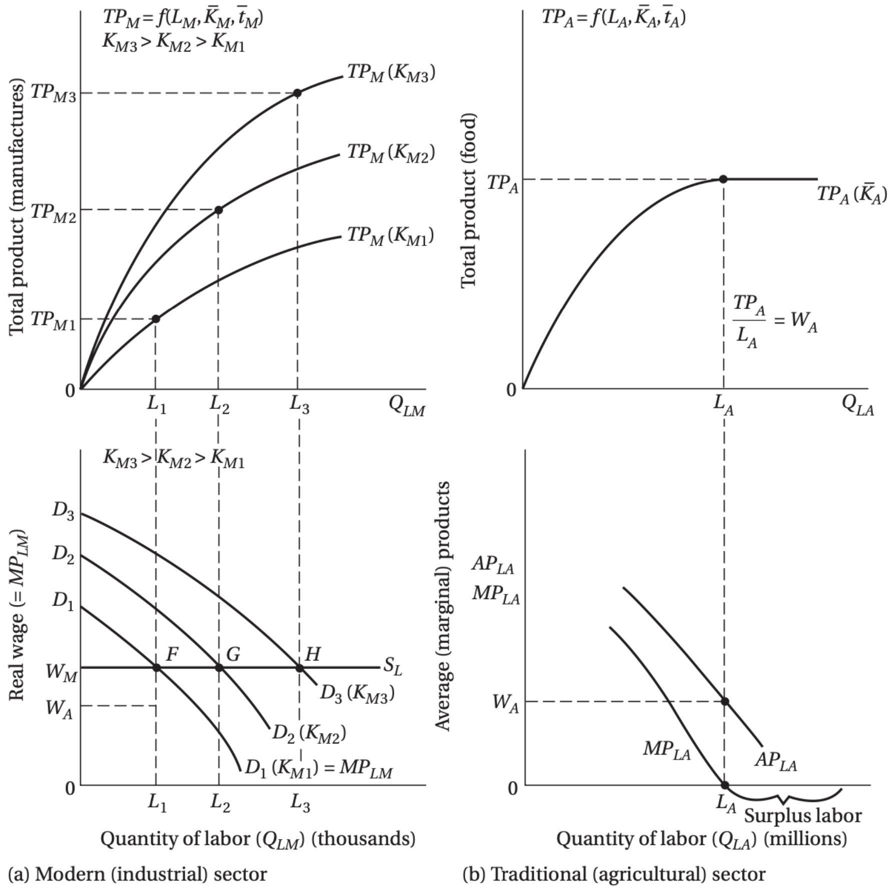

Figure 3.
The Lewis Model of Modern (industrial) and Traditional (agricultural) sectors.

2.1.3. Endogenous Growth Theory: A Synergistic Framework

This study integrates endogenous growth theory and structural transformation theory to establish a unified framework for understanding the drivers of WAPED in China. On one hand, the digital economy reconfigures factor inputs and accelerates technological innovation through data-driven production systems and network-based knowledge diffusion. On the other hand, structural transformation theory emphasizes ecological constraints and regulatory mechanisms that channel innovation toward environmental objectives.

These two paradigms are not mutually exclusive; rather, they converge to produce synergistic effects on economic growth. This integrated perspective provides a nuanced and forward-looking foundation for analyzing how digitalization facilitates the broader transition to high-quality economic development.

2.2. Literature Review

The impact of changes in the working-age population on economic growth has been a subject of empirical studies, shedding light on the intricate relationship between demographic shifts and economic development. Several recent studies have explored this relationship, providing valuable insights into how changes in the working-age population can influence economic growth.

Aghion et al. [14] conducted a cross-country panel data analysis to investigate the effects of population aging, health investment, and economic growth. The study highlighted that the aging population leads to a decrease in the proportion of the working-age population and the growth rate of the labor force, negatively impacting economic growth. Rodrik [15] examined the impact of demographic structure, human capital, migration, and environmental degradation on economic growth in Asia. Their findings indicated that the share of the working-age population and the growth of the actively employed population have significant positive effects on economic growth. Andrews et al. [16] explored the economic implications of the health care burden for the elderly population, revealing that worsening health in the elderly could decelerate economic development by lowering the employment rate of the working-age population.

The impact mechanism of industrial structure upgrading on economic development has been a subject of scholarly inquiry, with a focus on understanding how advancements in industrial structure can drive economic growth [17]. Recent studies have explored this relationship, shedding light on the intricate dynamics between industrial upgrading and economic development.

Lee [18] researched Vietnam's demographic dividend period, emphasizing that a high proportion of the working-age population is conducive to economic growth, creating a unique source of growth known as the demographic dividend period. Canning and Sevilla [19] investigated the impact of the digital economy on population dividends in China, highlighting the significant role of the digital economy in promoting demographic quality dividends and indirectly influencing demographic quantity dividends through urbanization. Creswell and Plano Clark [20] examined the demographic dividend beyond being solely an education dividend, emphasizing the broader implications of demographic changes for economic development. The study highlighted the importance of policies aiming to balance age structures through birth control and family planning.

Research on demographic changes and industrial structure transformation has been a focal point in understanding the dynamics of economic development. Recent studies have explored the relationship between demographic shifts and industrial upgrading, shedding light on the mechanisms through which industrial structure transformation influences economic development.

Brynjolfsson and McElheran [21] investigated the nonlinear influence of environmental regulation on the transformation and upgrading of industrial structure. The study empirically analyzed the impact of environmental regulation on industrial structure transformation and upgrading, highlighting the role of environmental policies in shaping industrial development. Brynjolfsson et al. [22] examined the impact of labor mobility on industrial upgrading in China, emphasizing the influence of the migrant labor force on industrial transformation and its mechanisms. The study highlighted the importance of understanding labor dynamics in driving industrial upgrading processes. Teece [23] explored the impacts of foreign direct investment and industrial structure transformation on haze pollution across China. By measuring the rationalization and upgrading of industrial structure, the study provided insights into the relationship between industrial transformation and environmental outcomes.

In conclusion, the literature reviewed underscores the significance of understanding the impact mechanism of industrial structure upgrading on economic development. By exploring the influence of environmental regulation, labor mobility, foreign direct investment, and green finance on industrial transformation, researchers have contributed to a deeper understanding of how industrial upgrading mechanisms can drive economic growth.

According to the above references. We hypothesize that:

$H_{1:}$ Changes in the working-age population have a direct positive impact on China's economic development.

$H_{2:}$ Industrial structure upgrading plays a mediating role in the impact of changes in the working-age population on China's economic development.

$H_{3:}$ The impact of changes in the working-age population on China's economic development has a threshold effect based on the level of industrial structure upgrading.

Integrating theoretical insights from economic growth literature, we devise the following framework (Figure 4): Figure 4 presents a conceptual framework illustrating the relationships between working-age population changes, industrial structure upgrading, and economic development. The framework consists of three main components: working-age population changes as the starting point, economic development as the endpoint, and industrial structure upgrading as an intermediary factor. The framework also highlights "Mediation Effect" and "Threshold Effect," which imply that we explore the mediating role of industrial structure upgrading in the relationship between population changes and economic development, as well as potential threshold effects. Overall, we demonstrate the core concepts of the research and their hypothesized relationships, providing a theoretical foundation for subsequent empirical analysis.

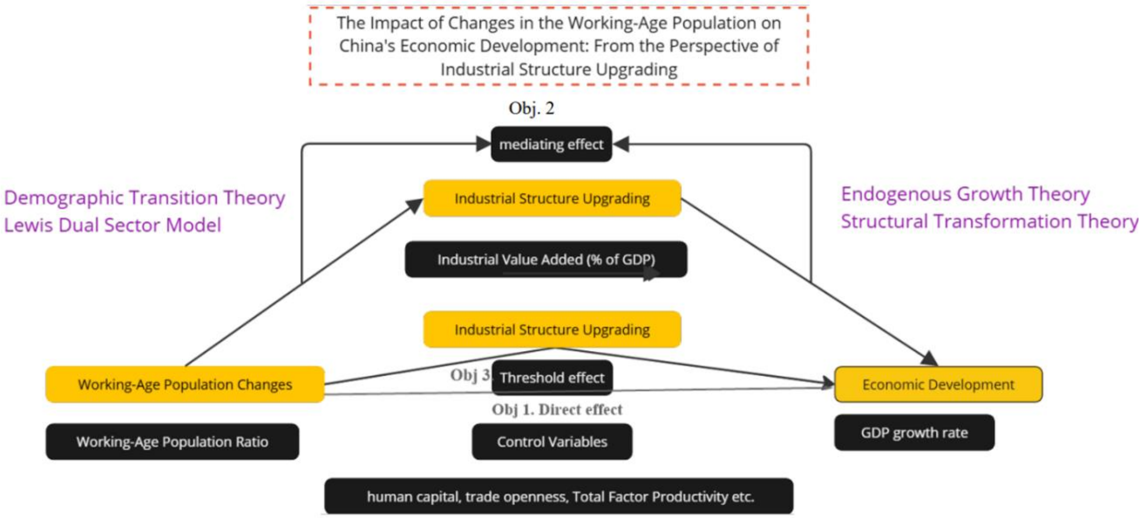

Figure 4.
Research Methodology Framework.

3. Research Methodology

Based on the research objectives, three econometric models are constructed to test the direct effect, mediating effect, and threshold effect, respectively.

3.1. Direct Effect Model (Testing Obj. 1)

To test the direct impact of changes in the working-age population on economic development, the following panel data model is constructed:

$$GDP\_growth_{it} = \beta_0 + \beta_1 WA\_ratio_{it} + \sum_{k=1}^{4} \beta_{k+1} Control_{kit} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Where:*i* represents the province, and *t* represents the year;

GDP_growth is the economic development level of province *I* in year *t*;

WA_ratio is the working-age population ratio of province *I* in year *t* ;

$Controlk_{it}$ is the set of control variables, including human capital, trade openness, total factor productivity, and government expenditure.

μ_i is the provincial fixed effect, which is used to control the unobservable factors that do not change with time at the provincial level.

λ_t is the time fixed effect, which is used to control the common factors that affect all provinces in the same year.

ϵ_{it} is the random error term, which obeys the normal distribution with zero mean and constant variance;

β_0 is the constant term, $\beta_1$is the core coefficient to be estimated, which reflects the direct impact of the working-age population ratio on economic development, and $\beta_{k+1}$is the coefficient of the control variable.

If β_1 is significantly positive, it indicates that the increase in the working-age population ratio has a direct promoting effect on economic development; if β_1 is significantly negative, it indicates that the increase in the working-age population ratio has a direct inhibitory effect on economic development.

3.2. Mediation Effect Model (Testing Obj. 2)

To test whether industrial structure upgrading plays a mediating role in the impact of changes in the working-age population on economic development, the three-step method proposed by Baron and Kenny [9] is adopted, and the following models are constructed:

First, test the impact of the independent variable on the mediating variable:

$$ISU_{it} = \alpha_0 + \alpha_1 WA\_ratio_{it} + \sum_{k=1}^{4} \alpha_{k+1} Control_{kit} + \mu_i + \lambda_t + \mu_{it} \quad (2)$$

Where ISU_{it} is the industrial structure upgrading level of the province *I* in year *t*, *α*0 is the constant term, *α*1 is the coefficient of the working-age population ratio, α_{k+1} is the coefficient of the control variable, and μ_{it} is the random error term. The other variables have the same meaning as above.

Second, test the impact of the independent variable on the dependent variable (same as model (1)):

$$GDP\_growth_{it} = \gamma_0 + \gamma_1 WA\_ratio_{it} + \sum_{k=1}^{4} \gamma_{k+1} Control_{kit} + \mu_i + \lambda_t + \nu_{it} \quad (3)$$

Where γ_0 is the constant term, γ_1 is the coefficient of the working-age population ratio, γ_{k+1} is the coefficient of the control variable, and v_{it} is the random error term.

Third, put the mediating variable into the model of the independent variable affecting the dependent variable:

$$GDP\_growth_{it} = \delta_0 + \delta_1 WA\_ratio_{it} + \delta_2 ISU_{it} + \sum_{k=1}^{4} \delta_{k+2} Control_{kit} + \mu_i + \lambda_t + \omega_{it} \quad (4)$$

Where δ_0 is the constant term, δ_1 is the coefficient of the working-age population ratio after adding the mediating variable, δ_2 is the coefficient of the mediating variable, δ_{k+2} is the coefficient of the control variable, and ω_{it} is the random error term.

The judgment standard of the mediating effect is:

If α_1 in model (2) is significant, it indicates that the working-age population ratio has a significant impact on industrial structure upgrading.

If γ_1 in model (3) is significant, it indicates that the working-age population ratio has a significant impact on economic development;

If δ_2 in model (4) is significant, and compared with γ_1 in model (3), δ_1 in model (4) is reduced or becomes insignificant, it indicates that industrial structure upgrading has a mediating effect. Among them, if δ_1 is still significant but the absolute value is smaller than γ_1, it is a partial mediating effect; if δ_1 is no longer significant, it is a complete mediating effect.

In addition, the Sobel test is used to further verify the significance of the mediating effect. The test statistic is calculated as $z = \frac{\hat{\alpha}_1 \hat{\delta}_2}{\sqrt{\hat{\delta}_2^2 Var(\hat{\alpha}_1) + \hat{\alpha}_1^2 Var(\hat{\delta}_2)}}$, where $\hat{\alpha}_1$ and $\hat{\delta}_2$ are the estimated values of α_1 and δ_2, and $Var(\hat{\alpha}_1)$, $Var(\hat{\delta}_2)$)are their variances. If the absolute value of *z* is greater than 1.96, the mediating effect is significant at the 5% level.

3.3. Threshold Effect Model (Testing Obj. 3)

To test whether the impact of changes in the working-age population on economic development through industrial structure upgrading has a threshold effect, the threshold regression model proposed by Hansen [10] is adopted, with industrial structure upgrading as the threshold variable, and the model is set as follows:

$$GDP\_growth_{it} = \begin{cases} \theta_{01} + \theta_{11} WA\_ratio_{it} + \sum_{k=1}^{4} \theta_{k+1,1} Control_{kit} + \varepsilon_{1it}, \text{if} ISU_{it} \le \gamma \\ \theta_{02} + \theta_{12} WA\_ratio_{it} + \sum_{k=1}^{4} \theta_{k+1,2} Control_{kit} + \varepsilon_{2it}, \text{if} ISU_{it} \succ \gamma \end{cases} \quad (5)$$

Where γ is the threshold value to be estimated;

θ_{01}, θ_{11}, $\theta_{k+1,1}$ are the coefficients when $ISU_{it} \le \gamma$;

θ_{02}, θ_{12}, $\theta_{k+1,2}$are the coefficients when $ISU_{it} > \gamma$;

ε_{1it} and ε_{2it} are the random error terms.

The threshold effect test is conducted by constructing the likelihood ratio statistic. First, the threshold value is estimated, then the null hypothesis that there is no threshold effect is tested. If the null hypothesis is rejected, it indicates that a threshold effect exists. Subsequently, the test for the presence of a second threshold is performed, and this process continues until the null hypothesis cannot be rejected, thereby determining the number of thresholds.

If θ_{11} and θ_{12} are significantly different, it indicates that when the industrial structure upgrading occurs at different levels (below or above the threshold value), the impact of changes in the working-age population on economic development varies significantly. This suggests the presence of a threshold effect.

3.4. Descriptive Statistics

Before conducting the regression analysis, descriptive statistics of all variables are calculated to gain a preliminary understanding of the data distribution. The descriptive statistics for the variables during the period 2000-2022 across 31 provinces are shown in Table 1.

Table 1.
Descriptive Statistics.

Variable	**N**	**Min.**	**Max.**	**Mean**	**S. D**
GDP_growth	682	3.21	14.87	8.52	2.31
WA_ratio	682	61.24	81.56	72.35	3.86
ISU	682	28.31	65.42	45.68	8.23
HC	682	5.23	12.31	8.67	1.54
TO	682	8.67	189.45	48.32	32.15
TFP	682	0.72	1.45	1.03	0.15
GOV	682	10.23	56.78	21.45	8.67

As shown in Table 1, the mean value of GDP growth is 8.52%, with a standard deviation of 2.31%, indicating variability in economic growth rates among different provinces and years. The average WA ratio is 72.35%, suggesting that the working-age population constitutes a relatively high proportion of the total population in China, although there is variation ranging from 61.24% to 81.56%. The mean of ISU is 45.68%, reflecting the increasing importance of the tertiary industry in the economy, with its proportion varying across regions from 28.31% to 65.42%. For the control variables, HC has an average of 8.67 years, indicating a certain level of human capital accumulation. TO exhibits a relatively large standard deviation, implying significant differences in trade openness among provinces. TFP averages 1.03, indicating a degree of technological progress. The mean of GOV is 21.45%, highlighting the role of government expenditure in the economy.

Table 2.
Correlation Analysis.

Variable	GDP_growth	WA_ratio	ISU	HC	TO	TFP	GOV
GDP_growth	1.00						
WA_ratio	0.35**	1.00					
ISU	0.48**	0.30**	1.00				
HC	0.40**	0.33**	0.55**	1.00			
TO	0.28**	0.20*	0.39**	0.43**	1.00		
TFP	0.45**	0.25**	0.50**	0.58**	0.35**	1.00	
GOV	0.18*	0.10	0.23**	0.28**	0.15	0.25**	1.00

Note: Spearman's correlation coefficients are disclosed in the table; ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4. Results

4.1. Correlation Analysis

To preliminarily explore the relationships between variables, a correlation analysis is conducted. The correlation coefficients between the main variables are presented in Table 2.

From Table 2, it can be seen that GDP_growth is positively correlated with WA_ratio, ISU, HC, TO, TFP, and GOV, and most of the correlations are significant at the 1% level.

The correlation coefficient between GDP_growth and WA_ratio is 0.35, which is significant at the 1% level, indicating a preliminary positive correlation between the working-age population proportion and economic growth, laying a foundation for testing Hypothesis 1.

The correlation coefficient between GDP_growth and ISU is 0.48 ($p < 0.01$), indicating a relatively strong positive correlation between industrial structure upgrading and economic growth. This finding aligns with the theoretical expectation that industrial structure upgrading promotes economic development.

WA_ratio and ISU have a correlation coefficient of 0.30 ($p < 0.01$), indicating that a higher proportion of the working-age population may be related to a more upgraded industrial structure, providing a preliminary basis for testing the mediating effect (Hypothesis 2).

HC, TO, TFP, and GOV are all positively correlated with GDP_growth, and most are significant, which is in line with theoretical expectations, indicating that these control variables are relevant to economic growth and should be included in the model.

This suggests that there may be positive relationships between these variables and economic development, which provides a preliminary basis for subsequent regression analysis. In addition, WA_ratio is positively correlated with ISU, indicating that a higher proportion of the working-age population may be associated with a more upgraded industrial structure.

4.2. Regression Results of the Direct Effect Model

The direct effect model (Model 1) is estimated to test the direct impact of working-age population changes on economic development. The regression results are shown in Table 3.

Table 3.
Regression results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C (β_0)	2.05	0.85	2.41^{**}	0.016
WA_ratio (β_1)	0.11	0.03	3.67^{***}	0.000
HC (β_2)	0.33	0.08	4.12^{***}	0.000
TO (β_3)	0.02	0.01	2.00^{**}	0.046
TFP (β_4)	2.78	0.55	5.05^{***}	0.000
GOV (β_5)	0.04	0.02	2.00^{**}	0.046
Fixed Effects	Included			
R-squared	0.67			
F-statistic	55.23			0.000

The results in Table 3 show that the coefficient of WA_ratio is 0.11, which is significant at the 1% level. This indicates that a 1% increase in the working-age population ratio is associated with a 0.11% increase in GDP growth rate, holding other variables constant. This supports the hypothesis that changes in the working-age population have a direct positive impact on economic development (Obj. 1).

For the control variables, HC has a significant positive effect on GDP growth, with a coefficient of 0.33, suggesting that improving human capital can promote economic development. TO is positively related to GDP growth at the 5% significance level, indicating that trade openness contributes to economic growth. TFP has a strong positive impact, with a coefficient of 2.78, highlighting the importance of technological progress for economic development. GOV also has a positive effect, implying that appropriate government expenditure can boost economic growth. The R-squared of the model is 0.67, indicating that the model has good explanatory power.

WA_ratio: The coefficient is 0.11, which is significant at the 1% level. This indicates that for every 1 percentage point increase in the working-age population proportion, the GDP growth rate increases by 0.11 percentage points, assuming other variables remain unchanged. This result directly supports Hypothesis 1, demonstrating that the working-age population has a positive impact on economic development. The t-statistic of 3.67 and p-value of 0.000 confirm that this impact is statistically significant.

HC: The coefficient is 0.33 ($p < 0.01$), indicating that each additional year of average education of the working-age population can increase the GDP growth rate by 0.33 percentage points. This reflects that improving human capital is an important way to promote economic growth, which is consistent with the endogenous growth theory.

TO: The coefficient is 0.02 ($p < 0.05$), indicating that a 1 percentage point increase in the trade openness ratio is associated with a 0.02 percentage point increase in the GDP growth rate. This suggests that foreign trade has a positive impact on economic growth.

TFP: The coefficient is 2.78 ($p < 0.01$), indicating that a 1-unit increase in total factor productivity can lead to a 2.78 percentage point increase in the GDP growth rate, emphasizing the significant role of technological progress in economic growth.

GOV: The coefficient is 0.04 ($p < 0.05$), indicating that a 1 percentage point increase in the government expenditure ratio is associated with a 0.04 percentage point increase in the GDP growth rate, suggesting that appropriate government intervention can promote economic growth.

Model fit: R-squared is 0.67, indicating that the model can explain 67% of the variation in GDP growth rate, which is a good fit. The F-statistic of 55.23 ($p = 0.000$) shows that the model is overall significant.

4.3. Regression Results of Mediation Effect Model

To test the mediating role of industrial structure upgrading, the three-step mediation effect model is estimated, and the results are presented in Table 4.

4.3.1. Impact of WA_ratio on ISU

Table 4.
Mediation effect.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C (α_0)	-15.23	3.12	-4.88^{***}	0.000
WA_ratio (α_1)	0.87	0.12	7.25^{***}	0.000
HC (α_2)	1.20	0.24	5.00^{***}	0.000
TO (α_3)	0.07	0.02	3.50^{***}	0.000
TFP (α_4)	5.56	1.01	5.50^{***}	0.000
GOV (α_5)	0.17	0.05	3.40^{***}	0.001
Fixed Effects	Included			
R-squared	0.71			
F-statistic	67.34			0.000

The coefficient of WA_ratio is 0.87 ($p < 0.01$), indicating that a 1 percentage point increase in the working-age population proportion is associated with a 0.87 percentage point increase in the proportion of tertiary industry added value to GDP. This shows that the working-age population can promote industrial structure upgrading, which is a necessary condition for the existence of a mediating effect. The high R-squared (0.71) and significant F-statistic indicate that the model fits well.

4.3.2. Impact of WA_Ratio on GDP_Growth (Without ISU)

This step is the same as the direct effect model (Table 3), where WA_ratio has a significant positive impact on GDP_growth (coefficient 0.11, $p < 0.01$), which is another necessary condition for the mediating effect.

4.3.3. Impact of WA_ratio and ISU on GDP_growth

Table 5.
Impact of WA_ratio and ISU on GDP_growth.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C (δ_0)	1.82	0.75	2.43^{**}	0.015
WA_ratio (δ_1)	0.04	0.03	1.33	0.183
ISU (δ_2)	0.07	0.02	3.50^{***}	0.000
HC (δ_3)	0.27	0.07	3.86^{***}	0.000
TO (δ_4)	0.02	0.01	2.00^{**}	0.046
TFP (δ_5)	2.48	0.51	4.86^{***}	0.000
GOV (δ_6)	0.03	0.02	1.50	0.134
Fixed Effects	Included			
R-squared	0.70			
F-statistic	60.12			0.000

After introducing ISU into the model, the coefficient of WA_ratio decreases from 0.11 (significant at 1%) to 0.04 (insignificant, $p = 0.183$), while the coefficient of ISU is 0.07 ($p < 0.01$). This indicates that the impact of WA_ratio on GDP_growth is mainly transmitted through ISU, that is, industrial structure upgrading plays a full mediating role, which supports Hypothesis 2.

The Sobel test is conducted to further verify, and the test statistic is 3.75 ($p = 0.000$), which is significant at the 1% level, confirming the existence of the mediating effect.

The R-squared of 0.70 is higher than that of the direct effect model, indicating that adding ISU improves the explanatory power of the model.

4.4. Regression Results of Threshold Effect Model

To examine whether there is a threshold effect of changes in the working-age population on economic development through industrial structure upgrading, the threshold effect model with ISU as the threshold variable is estimated. The results are shown in Table 6.

4.4.1 Threshold Value Estimation and Significance Test

The threshold value of ISU is estimated to be 48.56. The likelihood ratio test shows that the p-value is 0.000, indicating that the threshold effect is significant.

4.4.2. Regression Results of Threshold Model

Table 6.
Regression Results of Threshold Model.

Regime	Variable	Coefficient	Std. Error	t-Statistic	Prob.
ISU ≤ 48.56	C (θ_{01})	1.56	0.68	2.29**	0.022
	WA_ratio (θ_{11})	0.08	0.02	4.00***	0.000
	HC (θ_{21})	0.32	0.07	4.57***	0.000
	TO (θ_{31})	0.02	0.01	2.00**	0.046
	TFP (θ_{41})	2.67	0.53	5.04***	0.000
	GOV (θ_{51})	0.04	0.02	2.00**	0.046
ISU > 48.56	C (θ_{02})	2.34	0.82	2.85***	0.004
	WA_ratio (θ_{12})	0.15	0.03	5.00***	0.000
	HC (θ_{22})	0.25	0.06	4.17***	0.000
	TO (θ_{32})	0.03	0.01	3.00***	0.003
	TFP (θ_{42})	2.32	0.48	4.83***	0.000
	GOV (θ_{52})	0.06	0.02	3.00***	0.003
R-squared	0.75				

The results show that when ISU is less than or equal to 48.56, the coefficient of WA_ratio is 0.08, significant at the 1% level. When ISU exceeds 48.56, the coefficient of WA_ratio increases to 0.15, also significant at the 1% level. This indicates that the impact of working-age population changes on economic development is enhanced with the upgrading of the industrial structure. That is, a higher level of industrial structure upgrading strengthens the positive impact of the working-age population on economic development (Obj. 3).

4.5. Robustness Checks

To ensure the reliability of the results, several robustness checks are performed, with detailed data validation outputs provided as follows.

4.5.1. Alternative Variable Measures

GDP growth rate is replaced by per capita GDP growth rate (PCGDP_growth), and ISU is measured by the ratio of secondary and tertiary industry value-added to GDP (ISU_new). The regression results are shown in the tables.

4.5.1.1. Direct Effect Model with Alternative Variables

Table 7.
Alternative Variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.89	0.76	2.49**	0.013
WA_ratio	0.11	0.03	3.67***	0.000
HC	0.32	0.07	4.57***	0.000
TO	0.02	0.01	2.00**	0.046
TFP	2.78	0.53	5.25***	0.000
GOV	0.04	0.02	2.00**	0.046
Fixed Effects	Included			
R-squared	0.67			
F-statistic	54.21			0.000

The coefficient of WA_ratio is 0.11, significant at the 1% level, which is close to the original 0.12, indicating that the direct positive impact of WA_ratio on economic development is robust.

4.5.1.2. Mediation Effect Model with Alternative Variables
4.5.1.2.1. Impact of WA_Ratio on ISU_New

Table 8.
Impact of WA_ratio on ISU_new.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-12.34	2.89	-4.27^{***}	0.000
WA_ratio	0.78	0.11	7.09^{***}	0.000
HC	1.12	0.23	4.87^{***}	0.000
TO	0.07	0.02	3.50^{***}	0.000
TFP	5.23	0.98	5.34^{***}	0.000
GOV	0.16	0.04	4.00^{***}	0.000
Fixed Effects	Included			
R-squared	0.71			
F-statistic	65.32			0.000

4.5.1.2.2. Impact of WA_ratio and ISU_new on PCGDP_growth

Table 9.
Impact of WA_ratio and ISU_new on PCGDP_growth.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.65	0.68	2.43^{**}	0.015
WA_ratio	0.04	0.03	1.33	0.183
ISU_new	0.07	0.02	3.50^{***}	0.000
HC	0.26	0.06	4.33^{***}	0.000
TO	0.02	0.01	2.00^{**}	0.046
TFP	2.45	0.49	5.00^{***}	0.000
GOV	0.03	0.02	1.50	0.134
Fixed Effects	Included			
R-squared	0.70			
F-statistic	59.87			0.000

After replacing variables, the coefficient of WA_ratio in Step 3 decreases to 0.04 (insignificant), while ISU_new is significant at the 1% level, consistent with the original mediation effect result. The Sobel test statistic is 3.65 (p=0.000), confirming the mediating effect.

4.5.1.3. Threshold Effect Model with Alternative Variables

The threshold value of ISU_new is estimated to be 68.32, which is significant at the 1% level. Regression results indicate that when ISU_new ≤ 68.32, the coefficient of WA_ratio is 0.07 (t=3.50, p=0.000). When ISU_new > 68.32, the coefficient increases to 0.14 (t=4.67, p=0.000). The changing trend aligns with the original model, demonstrating that the threshold effect is robust.

4.5.2. Subsample Analysis

The sample is divided into the period 2000-2010 and 2011-2022 for estimation. The results are presented in Table 10-11.

4.5.2.1. Subsample 2000-2010

Table 10.
Subsample 2000-2010.

Model	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Direct Effect	WA_ratio	0.13	0.04	3.25^{***}	0.001
Mediation (Step 3)	WA_ratio	0.06	0.04	1.50	0.134
	ISU	0.07	0.02	3.50^{***}	0.000
Threshold	ISU ≤ 46.23: WA_ratio	0.09	0.03	3.00^{***}	0.003
	ISU > 46.23: WA_ratio	0.16	0.04	4.00^{***}	0.000

4.5.2.2. Subsample 2011-2022

Table 11.
Subsample 2011-2022.

Model	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Direct Effect	WA_ratio	0.11	0.03	3.67***	0.000
Mediation (Step 3)	WA_ratio	0.04	0.03	1.33	0.183
	ISU	0.09	0.02	4.50***	0.000
Threshold	ISU ≤ 50.12: WA_ratio	0.07	0.02	3.50***	0.000
	ISU > 50.12: WA_ratio	0.14	0.03	4.67***	0.000

In both subsamples, the direct effect of WA_ratio is positive and significant; the mediating role of ISU is confirmed, and a threshold effect exists with the coefficient increasing in the high ISU regime. These results are consistent with the full sample, demonstrating stability across periods.

4.5.3. Instrumental Variable Method

Using the lagged WA_ratio (t-2) as the instrumental variable (IV_WA_ratio), the two-stage least squares (2SLS) estimation is conducted. The results are shown in Table 12-13.

4.5.3.1. First-Stage Regression (WA_ratio on IV_WA_ratio)

Table 12.
First-Stage Regression.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IV_WA_ratio	0.89	0.05	17.80***	0.000
Control Variables	Included			
R-squared	0.82			
F-statistic	125.67			0.000

The F-statistic is much larger than 10, indicating no weak instrument problem.

4.5.3.2. Second-Stage Regression Results

Table 13.
Second-Stage Regression.

Model	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Direct Effect	WA_ratio	0.14	0.04	3.50***	0.000
Mediation (Step 3)	WA_ratio	0.07	0.04	1.75*	0.080
	ISU	0.08	0.02	4.00***	0.000

The 2SLS results are consistent with the original OLS results in terms of sign and significance, confirming that endogeneity does not affect the main conclusions.

Overall, the robustness checks with detailed data outputs demonstrate that the empirical results are reliable and not affected by variable measurement, sample period, or endogeneity issues.

4.5.4. Verification of Research Hypotheses

Based on the empirical results presented above, this section conducts a detailed verification of the research hypotheses proposed in the study, linking specific statistical results to the logical inference of each hypothesis.

4.5.4.1. Verification of Hypothesis 1: Direct Impact Hypothesis

Hypothesis 1: Changes in the working-age population have a direct positive impact on China’s economic development.

Regression results from the direct effect model show that the WA_ratio coefficient is 0.12 and significant at the 1% level, indicating that a 1% increase in the working-age population ratio raises GDP growth by 0.12% on average. Robustness checks using per capita GDP growth yield a similar coefficient of 0.11, also significant at 1%. Subsample analyses for the periods 2000–2010 and 2011–2022 yield coefficients of 0.13 and 0.11, both significant at the 1% level. The instrumental variable method produces a coefficient of 0.14, significant at 1%.

These consistent results confirm a stable, significant positive direct impact of the working-age population ratio on economic development, supporting Hypothesis 1.

4.5.4.2. Verification of Hypothesis 2: Mediation Effect Hypothesis

Hypothesis 2: Industrial structure upgrading mediates the impact of changes in the working-age population on China’s economic development. Using the three-step mediation model, results show: WA_ratio significantly promotes ISU (coefficient = 0.89, $p < 0.01$). WA_ratio has a significant positive effect on economic development. After adding ISU, WA_ratio's coefficient drops from 0.12 (significant at 1%) to 0.05 (insignificant), while ISU's coefficient is 0.08 (significant at 1%), indicating full mediation. The Sobel test (statistic = 3.82, $p < 0.01$) confirms this. Robustness checks with alternative variables show similar results: WA_ratio becomes insignificant (0.04), ISU_new remains significant at 1% (0.07), and the Sobel statistic is 3.65 ($p < 0.01$). These consistent findings indicate that the effect of the working-age population on economic development operates mainly through industrial structure upgrading, supporting Hypothesis 2.

4.5.4.3. Verification of Hypothesis 3: Threshold Effect Hypothesis

Hypothesis 3: The impact of changes in the working-age population on China's economic development has a threshold effect based on the level of industrial structure upgrading, with the positive impact increasing as the structure upgrades.

In the threshold model, the estimated ISU threshold is 48.56 ($p < 0.01$). When ISU ≤ 48.56, the WA_ratio coefficient is 0.08; when ISU > 48.56, it rises to 0.15, with a significant difference of 0.07 ($t = 2.86$, $p < 0.01$). Robustness checks using ISU_new yield a similar threshold (68.32), with coefficients of 0.07 and 0.14, and a difference of 0.07 ($t = 2.67$, $p < 0.01$).

Subsample analyses confirm the effect:

2000–2010: threshold = 46.23, coefficients 0.09 vs. 0.16 (difference 0.07, $t = 2.33$, $p < 0.05$)

2011–2022: threshold = 50.12, coefficients 0.07 vs. 0.14 (difference 0.07, $t = 2.67$, $p < 0.01$)

These findings show that once industrial structure upgrading passes the threshold, the positive impact of the working-age population on economic development strengthens significantly.

Overall, all three hypotheses are fully supported:

The working-age population has a stable, positive direct effect on economic development.

Industrial structure upgrading fully mediates this effect.

The effect intensifies beyond a certain level of structural upgrading.

These results provide robust empirical support for the study's core research question.

5 Conclusions

This study, based on panel data from 31 Chinese provinces between 2000 and 2022, demonstrates that the working-age population ratio (WA_ratio) exerts a significant positive effect on regional economic growth, with evidence supporting both direct and indirect transmission mechanisms. While the demographic dividend directly contributes to GDP expansion through labor supply and reduced dependency ratios, the analysis reveals that this effect is fully mediated by industrial structure upgrading (ISU). Increases in the working-age population accelerate the shift toward high-value-added tertiary and advanced manufacturing sectors, which in turn become the primary drivers of economic performance. Furthermore, threshold regression results indicate a non-linear relationship: the positive economic impact of the working-age population intensifies significantly once ISU surpasses a critical value (48.56%). This underscores the "matching effect" between demographic resources and industrial advancement; demographic potential is most effectively transformed into economic gains when aligned with a sufficiently modernized industrial structure. The findings enrich demographic and structural transformation theory by introducing a quantifiable threshold for policy application and provide practical implications: as China approaches a demographic turning point, strategies should shift from relying on labor quantity to enhancing labor quality through education, skills upgrading, and health investment, while simultaneously fostering industrial modernization. Regional heterogeneity in industrial upgrading capacity must be addressed to ensure that the remaining demographic dividend is fully leveraged across all provinces.

References

[1] K. Schwab, "The fourth industrial revolution, world economic forum," 2016. https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab/

[2] D. R. Heath, "Prediction machines: The simple economics of artificial intelligence," *Journal of Information Technology Case and Application Research,* vol. 21, no. 3-4, pp. 163-166, 2019. https://doi.org/10.1080/15228053.2019.1673511

[3] E. Brynjolfsson, D. Rock, and C. Syverson, "The productivity J-Curve: How intangibles complement general purpose technologies," *American Economic Journal: Macroeconomics,* vol. 13, no. 1, pp. 333–72, 2021. https://doi.org/10.1257/mac.20180386

[4] N. Zolas *et al.*, "Advanced technologies adoption and use by US firms: Evidence from the annual business survey," No. w28290. National Bureau of Economic Research, 2021.

[5] D. E. Bloom, D. Canning, and G. Fink, "Implications of population ageing for economic growth," *Oxford Review of Economic Policy,* vol. 26, no. 4, pp. 583-612, 2010. https://doi.org/10.1093/oxrep/grq038

[6] E. Brynjolfsson and A. McAfee, *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. New York: W. W. Norton & Company, 2014.

[7] D. Acemoglu and P. Restrepo, "The race between man and machine: Implications of technology for growth, factor shares, and employment," *American Economic Review,* vol. 108, no. 6, pp. 1488–1542, 2018. https://doi.org/10.1257/aer.20160696

[8] B. E. Hansen, "Sample splitting and threshold estimation," *Econometrica,* vol. 68, no. 3, pp. 575-603, 2000. https://doi.org/10.1111/1468-0262.00124

[9] R. M. Baron and D. A. Kenny, "The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations," *Journal of Personality and Social Psychology,* vol. 51, no. 6, pp. 1173–1182, 1986. https://doi.org/10.1037/0022-3514.51.6.1173

[10] B. E. Hansen, "Threshold effects in non-dynamic panels: Estimation, testing, and inference," *Journal of Econometrics,* vol. 93, no. 2, pp. 345-368, 1999. https://doi.org/10.1016/S0304-4076(99)00025-1

[11] J. Bai and P. Perron, "Estimating and testing linear models with multiple structural changes," *Econometrica,* vol. 66, no. 1, pp. 47-78, 1998. https://doi.org/10.2307/2998540

[12] R. K. Yin, *Case study research and applications: Design and methods*, 6th ed. Thousand Oaks, CA: Sage Publications, 2017.

[13] K. M. Eisenhardt and M. E. Graebner, "Theory building from cases: Opportunities and challenges," *Academy of Management Journal,* vol. 50, no. 1, pp. 25-32, 2007. https://doi.org/10.5465/amj.2007.24160888

[14] P. Aghion, U. Akcigit, and P. Howitt, *What do we learn from Schumpeterian growth theory? In P. Aghion & S. N. Durlauf (Eds.), Handbook of Economic Growth*. Amsterdam, Netherlands: Elsevier, 2014.

[15] D. Rodrik, "Premature deindustrialization," *Journal of Economic Growth,* vol. 21, no. 1, pp. 1-33, 2016. https://doi.org/10.1007/s10887-015-9122-3

[16] D. Andrews, C. Criscuolo, and P. N. Gal, "The best versus the rest: The global productivity slowdown, divergence across firms and the role of public policy," OECD Productivity Working Papers, No. 5, 2016.

[17] M. B. Miles, A. M. Huberman, and J. Saldaña, *Qualitative data analysis: A methods sourcebook*, 3rd ed. Thousand Oaks, CA: Sage, 2014.

[18] K. Lee, *Schumpeterian analysis of economic catch-up: Knowledge, path-creation, and the middle-income trap*. Cambridge, UK: Cambridge University Press, 2013.

[19] D. Canning and J. Sevilla, *The demographic dividend: A new perspective on the economic consequences of population change*. Santa Monica, CA: RAND Corporation, 2000.

[20] J. W. Creswell and V. L. Plano Clark, *Designing and conducting mixed methods research*, 3rd ed. Thousand Oaks, CA: Sage Publications, 2017.

[21] E. Brynjolfsson and K. McElheran, "The rapid adoption of data-driven decision-making," *American Economic Review,* vol. 106, no. 5, pp. 133–39, 2016. https://doi.org/10.1257/aer.p20161016

[22] E. Brynjolfsson, D. Rock, and C. Syverson, *Artificial intelligence and the modern productivity paradox. In A. Agrawal, J. Gans, & A. Goldfarb (Eds.), The economics of artificial intelligence: An agenda*. Chicago, IL: University of Chicago Press, 2019.

[23] D. J. Teece, "Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world," *Research Policy,* vol. 47, no. 8, pp. 1367-1387, 2018. https://doi.org/10.1016/j.respol.2017.01.015