International Journal of Economics, Finance and Management Sciences
2026, Vol. 14, No. 3, pp. 235–243
https://doi.org/10.11648/j.ijefm.20261403.15

Research Article

Population Ageing and Export Technological Sophistication: Nonlinear Mediation via Technological Innovation

Hongyun Kuang, Xue Li*

The School of Economics and Management, Shanghai Second University of Technology, Shanghai, China

Abstract

Consistent with the strategic emphasis of the 20th National Congress of the Communist Party of China on high-quality trade development, this paper explores the impact of population ageing on export technological sophistication. While existing literature has extensively discussed the direct effects of demographic shifts on trade performance, the specific mechanisms—particularly the nonlinear mediating pathways—remain underexplored in cross-country settings. To fill this gap, this study uses panel data from 96 economies for the period 2013–2022 and employs a two-way fixed-effects model to empirically examine the relationship between population ageing and export technological sophistication, as well as its internal transmission mechanisms. The results reveal a clear inverted U-shaped relationship: moderate population ageing significantly improves export technological sophistication, whereas excessive ageing produces inhibitory effects. Consistent with Hypothesis 1, the inflection point is identified when the population aged 65 and over reaches 9.824%. Notably, this suggests heterogeneous policy priorities across developmental stages. Supporting Hypothesis 2, mechanism tests confirm that technological innovation serves as a nonlinear mediator. More specifically, the mediating effect is conditional on the stage of ageing: it is insignificant at low ageing levels but significantly positive at moderate and high levels. Quantitatively, the marginal mediation effect in the high-ageing stage (about twice that in the moderate stage) indicates that the indirect pathway via innovation becomes increasingly important as populations grow older. Taken together, these findings suggest that technological innovation is not merely a parallel outcome but an active transmission channel through which demographic change shapes trade competitiveness. This paper provides practical policy references for China to coordinate high-quality export trade development and population ageing governance, and also offers valuable implications for global policymakers amid accelerating demographic transitions. In particular, the results underscore the need for stage-specific innovation policies that leverage the demographic window of opportunity while mitigating long-run risks.

Keywords

Population Ageing, Export Technological Sophistication, Technological Innovation, Mediating Effect

*Correspondence: Xue Li (14708084832@163.com)

Received: 20 May 2026; **Accepted:** 1 June 2026; **Published:** 18 June 2026

1. Introduction

Export technological sophistication is a comprehensive metric that captures both the technological content and production efficiency embedded in exported goods. As such, it serves as a robust indicator of a country's or region's overall manufacturing capability (Hausmann et al., 2007) [1] and its competitive position in global markets. Empirical evidence further indicates that this metric is shaped by several interrelated structural drivers—including technological innovation, digital economy development, and population ageing (Xia et al., 2022) [2]. Since the beginning of the twenty-first century, China's export trade has expanded steadily. According to data released by the General Administration of Customs, the total value of merchandise exports has increased from ¥13.72 trillion in 2013 to ¥23.77 trillion in 2024. Nevertheless, China continues to confront structural challenges, including regional disparities in economic development and a persistent gap in technology and productivity relative to advanced economies. The *Decision of the Central Committee of the Communist Party of China on Further Comprehensively Deepening Reform and Advancing Chinese Modernization*, adopted at the Third Plenary Session of the 20th Central Committee, underscores the strategic imperative of advancing high-level opening-up, fostering the high-quality trade development, and strengthening China's role within the global industrial value chain. Although the technological sophistication of China's exports has risen markedly over the past decade, a range of challenges—including constraints in core technologies, technological innovation, and institutional coordination—remain unresolved (Liu & Luo, 2016) [3]. At the same time, global population ageing continues to accelerate. According to the United Nations' *World Population Prospects 2024*, the world's population in 2024 is projected to reach approximately 8.2 billion, of whom 830 million (10.1%) are aged 65 years or older. Against this backdrop, China's State Council issued the *National Medium- and Long-Term Plan for Actively Responding to Population Ageing* in 2019, elevating proactive responses to population ageing as a national strategy. The Plan underscores three strategic priorities: enhancing scientific and technological innovation capacity; refining institutional frameworks governing ageing-related policies and services; and fostering smart elderly care communities (Hu & Sun, 2024) [4]. While a growing body of literature has examined the relatively low technological sophistication of China's exports—and identified its underlying determinants—few studies have systematically investigated the specific mechanisms through which population ageing influences Export Technological Sophistication (Chu et al., 2025) [5]. Given the accelerating pace of global demographic transitions, analyzing how key political–economic factors—particularly technological innovation—mediate the relationship between population ageing and export technological sophistication holds both theoretical significance and practical relevance. Such analysis offers actionable insights for China and other population ageing societies seeking to bolster their trade competitiveness in an increasingly knowledge-intensive global economy.

2. Literature Review

Population ageing is exerting profound effects across various industries. However, research on its relationship with export technological sophistication remains limited and inconsistent. One strand of literature finds a positive association. Most scholars argue that population ageing fosters export upgrading through technological innovation and structural transformation. Much of this research adopts a firm-level perspective (Du et al., 2024) [6]. For instance, Li et al. (2024) [7] show that industrial policies targeting ageing have increased exports of high-sophistication products. Ke et al. (2022) [8] and Kai et al. (2024) [9] further find positive effects on global value chain position and export sophistication, depending on the pace of ageing.

A second strand, though sparser, posits a negative relationship. Grounded in labor supply and innovation bottleneck theories, scholars contend that ageing constrains export upgrading by weakening innovation capacity and human capital. Fei et al. (2021) [10] show that in developing countries, ageing undermines export sophistication through reduced innovation incentives and human capital investment. Yin and Chen (2016) [11] report similar negative effects using Chinese provincial data. A third perspective emphasizes nonlinearity, albeit with limited empirical support. Gao and Li (2018) [12] propose an inverted U-shaped pattern: ageing first facilitates and then inhibits export sophistication. Li et al. (2019) [13] find that education can reverse the negative effects. In sum, despite the growing body of relevant literature, research findings remain inconsistent. A key limitation is that existing studies mainly focus on the direct associations while overlooking mediating mechanisms. Moreover, most studies rely on subnational or single-country samples, lacking cross-national representativeness [14]. This study contributes in three ways: (1) modeling technological innovation as a transmission channel; (2) using a balanced panel of 96 economies from 2013 to 2022; and (3) employing rigorous identification strategies to estimate both direct and indirect effects, offering mechanism-grounded evidence for relevant theoretical debates.

3. Theoretical Analysis and Hypothesis Formulation

According to factor endowments theory, shifts in age structure reshape labor supply. Population ageing—a sustained decline in the working-age population share (15–64 years old)—exerts countervailing effects on export technological sophistication (Li et al., 2019) [13].

On the one hand, a shrinking working-age cohort intensifies

dependency burdens, constraining savings and capital accumulation. This reduces R&D resources, weakening innovation capacity and slowing technological progress. Shortages of skilled personnel in R&D, manufacturing, and marketing erode labor-market efficiency. Firms struggle to recruit and retain talent for innovation, fostering technological conservatism—stagnation, undiversified products, and deferred upgrades. Consequently, firms rely more on low-tech, low-value-added exports, dragging down export sophistication (Dong & Song, 2023) [15].

On the other hand, erosion of the demographic dividend and rising unit labor costs undermine labor-intensive competitiveness. This pressure incentivizes a shift toward capital- and technology-intensive sectors, raising R&D intensity, automation, and output of sophisticated goods—positively affecting export sophistication. Domestic market demand also catalyzes corporate innovation (Cai, 2015) [16]. Population ageing affects consumer demand in a stage-dependent manner: early ageing may stimulate healthcare demand, while advanced ageing may suppress consumption growth due to precautionary saving and declining income mobility (Zhu, 2022) [17]. Collectively, the net effect hinges on the balance and timing of these forces, yielding an inverted U-shaped relationship: at low-to-moderate ageing levels, positive effects dominate; beyond a threshold, resource and skill constraints prevail (Gao & Li, 2018) [12]. Thus, we propose:

Hypothesis 1: Population ageing and export technological sophistication exhibit an inverted U-shaped relationship.

Regarding technological innovation—the central mediating mechanism—the literature identifies positive, negative, and nonlinear effects. Wu et al. (2023) [18] find that ageing enhances innovation via human capital and experience. Shao and Wang (2019) [19] report a negative association due to reduced dynamism and slower knowledge diffusion. Chang et al. (2022) [20] confirm an inverted U-shaped pattern. He and Huang (2020) [21] find that ageing inhibits upstream innovation but facilitates downstream commercialisation.

As a key transmission channel, technological innovation influences export sophistication through several pathways. Xu et al. (2021) [22] show that innovation inputs, outputs, and capabilities directly and indirectly raise export sophistication. Zhang and Yin (2019) [23] distinguish explicit channels (e.g., technology adoption, new products) from implicit ones (e.g., structural shifts, innovation-friendly institutions). Thus, we propose:

Hypothesis 2: Technological innovation mediates the relationship between population ageing and export technological sophistication in a nonlinear (inverted U-shaped) manner.

4. Research Design

4.1. Variable Measurement and Data Sources

Dependent variable: Export technological sophistication (EXPY). Following the methodology of Hausmann et al. (2007) [1], this study constructs country-level EXPY indices for the period 2013–2022 using export product data from the United Nations Conference on Trade and Development (UNCTAD) database. The data cover 10 broad categories and 63 commodity chapters classified under the Standard International Trade Classification (SITC) Revision 4.

Key explanatory variable: Population ageing (POE). Consistent with Tan et al. (2024) [24], we measure population ageing using the old-age dependency ratio—the share of the population aged 65 years and older of the total population. Data are drawn from the World Bank's World Development Indicators.

Mediating variable: Technological innovation (RD). Building on Liu and Zhong (2023) [25], we proxy technological innovation with Technological innovation intensity, defined as the ratio of a country's gross domestic expenditure on research and development (GERD) to its GDP. This metric captures national investment in knowledge creation and technological advancements. As posited by endogenous growth theory, sustained R&D investment fosters cumulative knowledge accumulation and frontier-pushing technological innovations, thereby enhancing firms' capacity to develop and export more technologically sophisticated goods.

Control variables: Trade openness (OPEN), capital formation (GC), human capital (EDU), net migration (MIG), female labor force participation (FL), foreign direct investment inflows (FDI), education expenditure (ES), labor productivity (LP), and inflation rate (IR). Trade openness is expressed as the ratio of total imports and exports to GDP; capital formation is the ratio of total capital formation to GDP; human capital is measured by the higher education enrolment rate; net migration is calculated as immigrants minus emigrants; female labor force participation refers to the proportion of women aged 15 and above in the labor force; FDI inflows are measured as the ratio of inward FDI stock to GDP; education expenditure is the ratio of public education expenditure to GDP; labor productivity is the ratio of real GDP to the number of employed persons; and the inflation rate is the annual percentage change in consumer prices (Tan et al., 2024) [24].

Table 1. *Descriptive Statistics of Variables.*

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
EXPY	960	2.264	0.031	2.083	2.334

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
POE	960	1.899	0.755	0.050	3.175
OPEN	960	4.369	0.508	2.846	5.853
GC	960	24.867	7.820	1.225	48.268
EDU	960	41.922	27.492	2.237	112.706
MIG	960	-1.835	29.693	-569.945	59.234
FL	960	50.534	13.745	12.283	83.329
FDI	960	5.364	27.432	-440.131	184.054
LP	960	2.389	2.983	0.059	20.715
ES	960	2.441	2.344	0	7.083
IR	960	5.001	8.713	-25.958	54.013

Due to missing data, this study selects 96 countries from 2013 to 2022 as the research sample. Data primarily originated from the World Bank, the Institute of Finance and Banking at the Chinese Academy of Social Sciences, and the Heritage Foundation. Missing values were imputed using trend-based interpolation (Xiao Zhouyan and Zhang Yafei, 2024) [26]. To obtain scientifically valid estimates, logarithmic transformation was applied to some variables, which reduces heteroscedasticity and mitigates multicollinearity without altering the underlying data relationships (Deng Yue et al., 2023) [27].

4.2. Model Construction

4.2.1. Baseline Model

To investigate the impact of population ageing on export technological sophistication and to test for nonlinear effects, a squared term for population ageing is introduced (Gao Yue and Li Ronglin, 2018) [12]. The baseline model is specified as:

$$EXPY_{it} = \alpha_1 + \beta_1 POE_{it} + \gamma_1 POE_{it}^2 + \delta_1 \sum_{j=1}^{9} y_i control_{it}^{j} + \varphi_i + \tau_t + \mu_{1it} \quad (1)$$

Where i denotes country, t denotes year, and j indexes the control variables. POE is population ageing, EXPY is export technological sophistication, and Control represents the set of control variables. α、β、γ、δ are coefficients to be estimated. φ_i denotes individual fixed effects, τ_t denotes time fixed effects, and μ_{it} is the random disturbance term.

4.2.2. Mediation Model

To test whether technological innovation mediates the relationship between population ageing and export technological sophistication, a nonlinear mediation model is constructed based on Lin Weipeng and Feng Baoyi (2022) [28]:

$$RD_{it} = \alpha_2 + \beta_2 POE_{it} + \gamma_2 POE_{it}^2 + \delta_2 \sum_{j=1}^{9} y_i control_{it}^{j} + \varphi_i + \tau_t + \mu_{2it} \quad (2)$$

$$EXPY_{it} = \alpha_3 + \beta_3 POE_{it} + \gamma_3 POE_{it}^2 + g_i RD_{it} + \delta_3 \sum_{j=1}^{9} y_i control_{it}^{j} + \varphi_i + \tau_t + \mu_{3it} \quad (3)$$

Given the nonlinear relationship between population ageing and technological innovation, the mediation effect θ varies with the level of population ageing and is calculated as:

$$\theta = (\beta_2 + 2\ \gamma_2\ X)\ g_i \quad (4)$$

RD refers to technological innovation. β_2 and γ_2 are respectively the coefficients of the linear and quadratic terms of population ageing on the mediating variable. The expression in parentheses stands for the marginal effect of population ageing on technological innovation at a specific level, and its product with g_i is the mediation effect.

5. Empirical Analysis

5.1. Baseline Regression Analysis

As shown in Table 2, the coefficients of the linear term for population ageing in columns (1) through (4) are all significantly positive, indicating that when the proportion of elderly people is relatively low, population ageing significantly promotes export technological sophistication. The coefficients of the quadratic term for population ageing in columns (3) and

(4) are significantly negative at the 0.01 level, indicating that as the proportion of elderly people continues to rise, population ageing significantly inhibits Export Technological Sophistication. This confirms an inverted U-shaped relationship—initially promoting, then inhibiting. The calculated inflection point is 9.824% of the population aged 65+.

Table 2. BAseline Regression Results.

Variable	(1)	(2)	(3)	(4)
POE	0.013**	0.014**	0.040***	0.054***
	(2.26)	(2.28)	(3.42)	(3.98)
POE^2			-0.008***	-0.012***
			(-2.65)	(-3.31)
Constant	YES	YES	YES	YES
Control variables	NO	YES	NO	YES
Year FE	NO	YES	NO	YES
Individual FE	NO	YES	NO	YES
N	960	960	960	960
R^2	0.928	0.928	0.928	0.929

Note: ***p < 0.01, **p < 0.05, *p < 0.1; t-values in parentheses. The same applies below.

5.2. Robustness and Endogeneity Tests

Robustness checks were conducted using alternative measures, exclusion of outlier years, and data truncation. Specifically, given the limitation that the proportion of the population aged 65 and over does not account for the labour force, the old-age dependency ratio (LN) was used as an alternative measure of population ageing.

The pandemic year 2020 was removed, and the dataset was trimmed at the 1% level (Xiao Zhouyan and Zhang Yafei, 2024) [26]. As shown in Table 3, the coefficients of the linear term for population ageing in columns (1) to (3) are all significantly positive at the 0.01 level, while the quadratic term coefficients are significantly negative at the 0.01 level, confirming the inverted U-shaped relationship and the robustness of the findings.

To mitigate potential endogeneity, a two-stage least squares (2SLS) regression was conducted using one-period lagged population ageing as an instrumental variable. Population ageing is a persistent long-term trend and highly exogenous. Its one-period lagged value is strongly correlated with its current level. Since the past demographic structure is free from the reverse influence of the dependent variable, the endogeneity arising from reverse causality is effectively mitigated. Relevant tests verify the validity of this lagged instrumental variable. The regression results are shown in column (5) of Table 3. The Kleibergen–Paap rk LM statistic and the Kleibergen–Paap rk Wald F-statistic (below column 5) both pass the relevant tests, confirming the appropriateness of the instrumental variable and the reliability of the results.

Table 3. RObustness and Endogeneity Tests.

Variable	Robust			Endogeneity	
	(1)	(2)	(3)	(4)	(5)
POE	0.046***	0.062***	0.054***		0.056***
	(3.52)	(4.12)	(3.97)		(3.09)
	-0.011***	-0.014***	-0.012***	0.089**	-0.013***

Variable	Robust			Endogeneity	
	(1)	(2)	(3)	(4)	(5)
POE^2	(-2.94)	(-3.49)	(-3.29)	(3.13)	(-3.17)
L. POE				0.653***	
				(5.67)	
Kleibergen-Paap rk LM					61.790
					[0.000]
Kleibergen-Paap rk Wald F					880.210
					[16.38]
Constant	YES	YES	YES	YES	YES
Control variables	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Individual FE	YES	YES	YES	YES	YES
N	960	864	960	864	864
R^2	0.929	0.925	0.929		0.937

5.3. Mediating Effect Analysis

The indirect effect parameter (IND) is calculated by multiplying the coefficient of the quadratic term of population ageing on the mediating variable by the coefficient of the mediating variable on Export Technological Sophistication. This can be used to test for a mediating effect (Lin Weipeng and Feng Baoyi, 2022) [28]. The results in Table 4 show that the coefficient of the quadratic term of population ageing on technological innovation is significant, indicating the presence of a mediating effect. However, given that the distribution of the variables is non-normal, the regression results may be biased (P. D. M. et al., 2007) [29].

To obtain more accurate estimates and further test the nonlinear mediating effect, this study draws on Ye Baosheng et al. (2023) [30]. After standardising the independent variables, a bias-corrected bootstrap test was conducted using the Medcurve macro in SPSS 27.0 with 5,000 repetitions. The results are shown in Table 5.

Table 5 presents the strength and significance of the mediating effect of technological innovation when population ageing takes three typical values: -1 (M – 1SD), 0 (M), and +1 (M + 1SD). From the perspective of the technological innovation pathway, when population ageing is at a moderate (x = 0) or high (x = +1) level, the confidence interval does not include zero, and the mediating effect is significant. However, when population ageing is at a low level (x = –1), the confidence interval includes zero, and the mediating effect is not significant. Therefore, moderate levels of population ageing promote the enhancement of Export Technological Sophistication through the indirect effect of technological innovation, but when the level of population ageing is too low, this indirect effect is not present.

Table 4. *Regression Results for Testing Nonlinear Mediation Effects.*

Variable	RD	
	(1)	(2)
	RD	EXPY
POE	-1.180**	0.056***
	(-3.73)	(4.18)
	0.268***	-0.013***

Variable	RD (1) RD	 (2) EXPY
POE^2	(3.19)	(-3.46)
RD		0.003* (1.92)
Constant	YES	YES
Control variables	YES	YES
Year FE	YES	YES
Individual FE	YES	YES
N	960	960
R^2	0.935	0.938

Table 5. Bootstrap Test Results for Nonlinear Mediating Effects.

Variable	Variable Value	Nonlinear Mediating Effect	95% Bias-Corrected CI (5,000 reps)	
RD	-1 (M-1SD)	0.003	-0.001	0.001
	0 (M)	0.004	0.003`	0.005
	1 (M+1SD)	0.007	0.005	0.009

6. Research Implications

First, leverage technological innovation as a driver to promote collaborative gains from technological upgrading. Policy support systems should be improved by providing financial backing for technological innovation through measures such as establishing special funds and increasing R&D subsidies. Talent support should be strengthened by specifically cultivating high-calibre talent capable of meeting the demands of technological innovation. Furthermore, the alignment of research outcomes with practical needs should be promoted, encouraging research institutions and universities to integrate their work with the actual requirements of export trade. Generous financial rewards and honours should be conferred upon individuals or teams that successfully collaborate with enterprises, achieve significant results in technological innovation, and successfully enhance the technological sophistication of export products.

Second, improve targeted policy supervision, dynamic feedback, and collaborative evaluation mechanisms to enhance policy implementation effectiveness. A dynamic supervision system covering core areas should be established. For key areas such as carbon emission control, incentives for technological innovation, progress of industrial upgrading, implementation of institutional optimisation, effectiveness of urbanisation coordination, and level of financial support, a multi-stakeholder information feedback network should be established to regularly collect policy implementation data and frontline feedback, ensuring that policies are effectively implemented.

Abbreviations

EXPY	Export Technological Sophistication
POE	Population Ageing
RD	Technological Innovation
OPEN	Trade Openness
GC	Capital Formation
EDU	Human Capital
MIG	Net Migration
FL	Female Labor Force Participation
FDI	Foreign Direct Investment INFLOWS
ES	Education Expenditure
LP	Labor Productivity
IR	Inflation Rate

Author Contributions

Hongyun Kuang: Conceptualization, Funding acquisition, Supervision, Writing – review & editing

Xue Li: Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft

Data Availability Statement

The data that support the findings of this study can be found at: https://databank.worldbank.org/reports.aspx?source=world-development-indicators (a publicly available repository url).

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. Journal of Economic Growth, 12(1), 1–25. https://doi.org/10.1007/s10887-006-9009-4

[2] Xia, J. C., Xu, Z. Y., & Yao, Z. Q. (2022). A study on the impact of the digital economy on the technological complexity of China's exports. Social Sciences Frontline, (2), 65–75.

[3] Liu, Y., & Luo, T. (2016). Analysis of the technological level of China's manufacturing exports and influencing factors. Review of Industrial Economics, (1), 30–43. https://doi.org/10.19313/j.cnki.cn10-1223/f.2016.01.004

[4] Hu, Z., & Sun, X. (2024). "Why strategy" and "what strategy": National strategies for proactively addressing population ageing in the process of Chinese-style modernization. Population Research, 48(5), 3–16.

[5] Chu, M., Lü, F. H., & Yang, L. (2025). Has inter-provincial trade driven the quality improvement and upgrading of China's manufacturing sector? A perspective based on export technological sophistication. Issues in International Trade, (4), 158–174. https://doi.org/10.13510/j.cnki.jit.2025.04.010

[6] Du, Y., Zhang, W., & Qi, B. L. (2024). Population ageing, changes in factor costs and corporate product market performance. Journal of Shanxi University of Finance and Economics, 46(12), 120–134. https://doi.org/10.13781/j.cnki.1007-9556.2024.12.010

[7] Li, J. J., Jiang, M. X., & Zhang, C. S. (2024). How does the development of the digital economy affect urban export technology complexity? A theoretical model and empirical evidence. International Economic and Trade Exploration, 40(11), 57–73. https://doi.org/10.13687/j.cnki.gjjmts.2024.11.004

[8] Ke, X. W., Zhi, W. T., & Long, P. Z. (2022). Population ageing, industrial intelligence and export technology complexity. Sustainability, 14(20), 13600. https://doi.org/10.3390/SU142013600

[9] Kai, Y. W., Chen, F., Anwar, S., et al. (2024). The impact of population ageing on a country's global value chain position: Unraveling the dynamics and mechanisms. Emerging Markets Finance and Trade, 60. https://doi.org/10.1080/1540496X.2023.2300636

[10] Fei, F. W., Hong, N. Y., & Bo, G. (2021). Old, not yet rich? The impact of population ageing on export upgrading in developing countries. China Economic Review, 70. https://doi.org/10.1016/J.CHIECO.2021.101707

[11] Yin, M., & Chen, Z. F. (2016). Population age structure, human capital and export technological sophistication. Contemporary Economic Management, 38(12), 40–45. https://doi.org/10.13253/j.cnki.ddjjgl.2016.12.007

[12] Gao, Y., & Li, R. L. (2018). How population ageing affects export technological sophistication. Contemporary Finance and Economics, (6), 92–101. https://doi.org/10.13676/j.cnki.cn36-1030/f.2018.06.009

[13] Li, G. C., Wei, S. J., & Gao, X. (2019). Population ageing, educational attainment and technological complexity of agricultural exports: Empirical evidence from China and countries along the Belt and Road. Journal of Huazhong University of Science and Technology (Social Sciences Edition), 33(2), 56–64. https://doi.org/10.19648/j.cnki.jhustss1980.2019.02.08

[14] Peng, Y., Yang, B. Z., & Zeng, H. Z. (2025). Has international cooperation under the "Silk Road E-commerce" initiative enhanced the complexity of digital service exports? A perspective from signatory countries. International Trade Issues, (5), 67–83. https://doi.org/10.13510/j.cnki.jit.2025.05.005

[15] Dong, Y. D., & Song, G. H. (2023). Population agglomeration, exports of Chinese manufacturing enterprises and technological complexity. Shanghai Economic Research, (10), 63–73. https://doi.org/10.19626/j.cnki.cn31-1163/f.2023.10.006

[16] Cai, X. (2015). Life expectancy, the development of pension insurance and Chinese household consumption. Economic Review, (6), 81–91, 107. https://doi.org/10.19361/j.er.2015.06.006

[17] Zhu, J. Y. (2022). Population ageing, consumer demand and employment in the tertiary sector. Research on Financial and Economic Issues, (12), 117–127. https://doi.org/10.19654/j.cnki.cjwtyj.2022.12.011

[18] Wu, J. F., Han, C., Zhang, W. Y., et al. (2023). A study on the impact of population ageing on technological innovation and economic growth: A re-examination from the perspective of factor endowments. East China Journal of Economics and Management, 37(2), 103–110. https://doi.org/10.19629/j.cnki.34-1014/f.210818006

[19] Shao, H. H., & Wang, Y. S. (2019). Demographic structure and technological innovation. Studies in Science of Science, 37(4), 739–749. https://doi.org/10.16192/j.cnki.1003-2053.2019.04.018

[20] Chang, Z. Z., Jiang, K., & Wei, S. Y. (2022). A study on the impact of population ageing on technological innovation. Research on Finance and Trade, 33(11), 55–68. https://doi.org/10.19337/j.cnki.34-1093/f.2022.11.005

[21] He, Y. J., & Huang, Y. (2020). Analysis of the mechanism of the impact of population ageing on technological innovation from a value chain perspective. Northwest Population Journal, 41(3), 92–103. https://doi.org/10.15884/j.cnki.issn.1007-0672.2020.03.009

[22] Xu, Z. Y., Yao, Z. Q., & Xia, J. C. (2021). A study on the impact of synergistic agglomeration on the technological complexity of exports: An examination of the mediating effect of regional innovation. Economic Review, (9), 43–52. https://doi.org/10.16528/j.cnki.22-1054/f.202109043

[23] Zhang, A. L., & Yin, M. L. (2019). Technological innovation, demographic structure and the complexity of China's manufacturing exports. Soft Science, 33(5), 29–34. https://doi.org/10.13956/j.ss.1001-8409.2019.05.06

[24] Tan, N., Liang, X., & Chang, L. (2024). Growing older and growing technologically backward? Population ageing and high-technology exports of 171 countries. The Journal of the Economics of Ageing, 29, 100530. https://doi.org/10.1016/j.jeoa.2024.100530

[25] Liu, H. Y., & Zhong, H. M. (2023). A study on the impact of industrial robot applications on the enhancement of technological complexity in manufacturing exports. Asia-Pacific Economy, (4), 49–59. https://doi.org/10.16407/j.cnki.1000-6052.2023.04.006

[26] Xiao, Z. Y., & Zhang, Y. F. (2024). Population ageing, the digital economy and the structure of employment skills. China Population, Resources and Environment, 34(7), 170–183.

[27] Deng, Y., Wu, Z. B., & Luo, L. F. (2023). Has agricultural mechanisation boosted farmers' incomes? An analysis based on the moderating effect of rural human capital. Journal of Nanjing Agricultural University (Social Sciences Edition), 23(1), 169–180. https://doi.org/10.19714/j.cnki.1671-7465.2023.0017

[28] Lin, W. P., & Feng, B. Y. (2022). The curve effect and statistical testing methods in the field of management. Nankai Business Review International, 25(1), 155–166.

[29] P. D. M., S. M. F., Jason, W., et al. (2007). Distribution of the product confidence limits for the indirect effect: Program PRODCLIN. Behavior Research Methods, 39(3), 384–389. https://doi.org/10.3758/BF03193007

[30] Ye, B. S., Yu, C. P., Lin, C. P., et al. (2023). Management innovation and competitive advantage of small and medium-sized enterprises: The nonlinear mediating role of resource patching ability and the moderating role of cognitive consistency between leaders and subordinates. Business and Management Review, 35(2), 94–105. https://doi.org/10.14120/j.cnki.cn11-5057/f.2023.02.022