DOI: https://doi.org/10.62985/j.huit_ojs.vol26.no3E.567

INNOVATION INVESTMENT AND HIGH-TECHNOLOGY EXPORTS: EVIDENCE FROM ASIAN ECONOMIES

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Received: 19 March 2026; Revised: 24 April 2026; Accepted: 18 May 2026

ABSTRACT

This study investigates the effects of innovation investment, proxied by research and development expenditure, on high-technology exports in Asian economies. Drawing on a panel dataset of nine Asian countries over the period 2010–2024 and employing quantile regression techniques, the analysis captures the heterogeneous impacts of innovation investment across different levels of high-technology export performance, thereby moving beyond the average-effect focus prevalent in the existing literature. The empirical results demonstrate that innovation investment exerts a robust and statistically significant positive effect on high-technology exports across all estimated quantiles. In addition, trade openness, labor, and foreign direct investment are found to play critical roles in facilitating the expansion of high-technology exports. From an academic standpoint, this study advances the innovation–trade nexus by providing novel evidence from Asian economies using a long-horizon panel dataset and a distribution-sensitive empirical approach. From a policy and managerial perspective, the findings underscore the importance of strengthening research and development investment. They also highlight the need to deepen trade liberalization, attract high-quality foreign direct investment, and enhance human capital. These factors serve as key strategic levers for upgrading export structures and improving the global competitiveness of Asian economies within global value chains.

Keywords: Asian economies, high-technology exports, innovation investment, quantile regression, research and development.

1. INTRODUCTION

In the context of globalization and the transition toward knowledge-based economies, high-technology exports have become a crucial indicator of a country's innovation capacity and international competitiveness. Economies that successfully expand high-technology exports tend to achieve stronger productivity growth, deeper participation in global value chains, and sustained structural transformation. Understanding the determinants of high-technology exports is therefore of central importance for both economic theory and policy design.

The relationship between research and development (R&D) expenditure and export performance is grounded in several major theoretical frameworks. Endogenous growth theory emphasizes that knowledge accumulation and innovation are fundamental drivers of long-term growth and technological progress [1, 2]. Early technology-gap and product life-cycle theories [3, 4] highlight the role of innovation in shaping temporary technological advantages, while endogenous growth and innovation-based trade models [5] provide a formal framework linking R&D investment to sustained comparative advantage and high-technology export

performance. In addition, absorptive capacity theory argues that the effectiveness of R&D investment depends on the existing knowledge base and institutional environment, implying that returns to innovation may differ across countries [6].

Empirical evidence largely supports the positive role of R&D in enhancing high-technology exports. For example, Sandu and Ciocanel [7] document significant effects of R&D intensity on high-tech exports in European Union countries, while Navarro Zapata, Arrazola and de Hevia [8] provide similar evidence for OECD economies. Evidence from developing countries, such as Sepehrdoust, Tartar and Davarikish [9], also confirms the importance of R&D in promoting export sophistication. However, most prior studies rely on mean-based estimation methods such as ordinary least squares (OLS) or fixed-effects models, implicitly assuming homogeneous effects across countries.

This assumption may be restrictive given substantial cross-country differences in technological capabilities, innovation systems, and export maturity. Moreover, mixed findings reported in the literature [10] suggest that the effectiveness of R&D investment may depend on countries' structural conditions and levels of technological development. Despite these indications, limited attention has been paid to examining whether the impact of R&D varies along different points of the export distribution. By focusing primarily on average effects, existing research may overlook important distributional heterogeneity between low- and high-performing exporters.

Against this backdrop, this study seeks to address the following research questions. First, to what extent does R&D expenditure influence high-technology exports in Asian economies? Second, does the impact of R&D vary across different levels of high-technology export performance? Third, is there evidence of an amplification effect, whereby the contribution of R&D becomes stronger among countries with higher export performance?

To address this gap, the present study combines mean-based estimation with quantile regression techniques to examine the impact of R&D expenditure on high-technology exports using panel data for the period 2010–2024. This study contributes to the existing literature in three important respects: (i) it provides updated empirical evidence on the relationship between innovation investment and high-technology exports in Asian economies over the period 2010–2024, thereby extending the geographical and temporal scope of prior studies; (ii) it applies a panel quantile regression approach to uncover distributional heterogeneity in the innovation–export nexus, moving beyond conventional mean-based estimations; (iii) the study identifies an amplification effect of R&D, whereby its impact on high-technology exports becomes stronger at higher levels of export performance, offering nuanced insights into the role of absorptive capacity and structural conditions.

2. THEORY AND LITERATURE REVIEW

2.1. Theory

In traditional growth models, economic growth is primarily determined by physical capital accumulation, labor, and exogenous technological progress [11, 12]. However, this approach does not adequately explain the endogenous sources of innovation or the mechanisms sustaining long-run growth. Endogenous growth theory addresses these limitations by emphasizing the central role of R&D, human capital, and innovation as the principal drivers of sustained economic growth [1, 2].

Within this framework, R&D promotes knowledge accumulation and technological progress, thereby enhancing productivity and generating increasing returns through cross-sectoral spillovers. Knowledge is characterized as a non-rival and partially excludable good; consequently, R&D investment not only improves firm-level performance but also

strengthens economy-wide competitiveness [5]. Nevertheless, the effectiveness of R&D critically depends on a country's absorptive capacity, which is shaped by the quality of human capital, institutional efficiency, and the strength of linkages between research institutions and firms [6, 13].

In an increasingly integrated global economy, R&D also provides the foundation for the expansion of high-technology exports. By fostering product innovation and increasing technological intensity, R&D enables the formation of dynamic comparative advantages, enhances international competitiveness, and supports the growth of high-tech exports. At the same time, the expansion of high-technology exports reinforces incentives for further R&D investment, creating a positive feedback loop between innovation, high-tech exports, and long-run economic growth [1, 2].

This perspective offers a coherent theoretical basis for empirical models in which R&D is treated as a core input, high-technology exports serve as a key transmission channel of innovation, and economic growth represents the ultimate outcome of knowledge accumulation and enhanced national competitiveness.

2.2. Empirical studies

High-tech exports are widely regarded as one of the key drivers of long-term economic growth and an essential source of national competitiveness. In this context, a substantial body of empirical literature has emphasized the central role of innovation—most commonly proxied by R&D expenditure as a share of GDP—in fostering both the scale and the technological sophistication of exports.

At the level of developed regions, the study by Sandu and Ciocanel [7] focuses on European Union countries and demonstrates that medium- and high-technology exports exhibit a strong causal relationship with key determinants of innovation, among which total R&D expenditure—encompassing both public and private components—plays a pivotal role. The econometric results reveal a clear positive correlation between R&D expenditure and the level of high-tech exports, while also highlighting that private-sector R&D exerts a stronger impact than public R&D. These findings suggest that increasing the R&D-to-GDP ratio may substantially enhance high-tech exports and national competitiveness.

Extending the analysis to OECD countries, Navarro Zapata, Arrazola and de Hevia [8] employ panel data from 35 countries over the period 2004–2018 and provide robust empirical evidence that R&D expenditure as a percentage of GDP constitutes one of the most important determinants of high-technology manufacturing exports. In addition, factors such as physical capital, human capital, foreign direct investment (FDI), imports of high-tech manufactures, and institutional quality play complementary roles, indicating that innovation affects high-tech exports not only directly but also through channels of technological spillovers and international integration.

Another strand of the literature approaches innovation through the lens of human capital and education, which are widely regarded as foundational inputs to R&D activities. Using a sample of 27 European countries, Mulliqi [14] confirms a positive and statistically significant relationship between the share of the population with tertiary education and the proportion of medium-high- and high-technology exports, with a stronger effect observed for the high-technology category. These results indirectly reinforce the role of R&D, as high-quality human capital represents a critical input for research and innovation processes.

Nevertheless, the empirical evidence on the impact of R&D on high-tech exports is not entirely uniform. Drapkin et al. [10], examining Central and Eastern European countries and the Commonwealth of Independent States over the period 1995–2018, do not find empirical support for a positive effect of R&D expenditure on high-tech export performance. Instead,

factors such as wages, resource prices, trade openness, tax regimes, and the quality of human capital are identified as the main drivers. These findings suggest that the effectiveness of R&D investment may depend heavily on institutional contexts and the overall level of economic development.

For developing economies, Sepehrdoust, Tartar and Davarikish [9] conceptualize innovation through scientific productivity and analyze its impact on high-tech exports in selected G15 countries during the period 1996–2017. Results derived from a panel vector autoregressive model indicate that positive shocks to scientific productivity lead to sustained increases in high-tech exports over the long run, thereby reinforcing the argument that innovation and scientific knowledge constitute fundamental pillars for the export of technology-intensive products.

Finally, Sara, Jackson and Upchurch [15] emphasize the role of a country's overall innovative capability in increasing the share of high-technology products in total manufactured exports. Their empirical findings show that innovative capacity exerts a positive and statistically significant effect on high-tech exports, further supporting the view that investment in innovation, including R&D, is a necessary condition for upgrading export technological intensity.

Taken together, the existing literature indicates that, despite certain differences across national contexts and study periods, the majority of empirical evidence supports a positive relationship between innovation—measured by R&D expenditure as a share of GDP—and high-technology exports. However, most existing studies focus on European or OECD countries and largely rely on conventional mean-based estimation techniques, while the heterogeneous effects of R&D across different levels of high-technology export performance remain underexplored. From an economic perspective, the impact of R&D investment on high-technology exports is unlikely to be uniform across countries, as differences in technological capabilities, absorptive capacity, and positions within global value chains may generate heterogeneous responses to innovation inputs; ignoring such heterogeneity may obscure important distributional effects and lead to incomplete or even misleading policy conclusions. Given the highly skewed distribution of high-technology exports across countries, quantile regression provides an appropriate empirical framework to capture differential effects of R&D investment across the entire distribution rather than focusing solely on average outcomes. This issue is particularly salient for Asian economies, many of which are characterized by late industrialization and technology-catching-up processes, where the effectiveness of R&D investment may vary substantially across stages of export upgrading. Against this backdrop, an empirical investigation of the role of R&D in shaping high-technology exports in Asian countries over the period 2010–2024, employing quantile regression methods, is warranted to fill this research gap and to derive relevant policy implications for the region.

3. MODEL AND DATA

Building on endogenous growth theory [1, 2] and the mixed empirical evidence discussed above—including the findings of Navarro Zapata, Arrazola and de Hevia [8] and the contrasting results reported by Drapkin et al. [10]—this study develops a research framework to systematically examine the role of innovation investment in shaping high-technology exports across selected Asian economies.

Within this framework, innovation investment, proxied by R&D expenditure (LnR&D), is hypothesized to positively influence high-technology exports (LnHT) by enhancing firms' technological capabilities and facilitating product upgrading. Trade openness (TO) is expected to promote high-technology exports through greater integration into global value chains and access to foreign markets. Labor input (LnL) captures production capacity effects, while

foreign direct investment (LnFDI) is assumed to contribute through technology spillovers and knowledge transfer. Accordingly, the empirical model is specified as follows:

$$LnHT_{it} = \beta_0 + \beta_1 LnR\&D_{it} + \beta_2 TO_{it} + \beta_3 LnL_{it} + \beta_4 LnFDI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where i denotes country (including 9 nations: China, Vietnam, Thailand, Indonesia, India, Cambodia, Malaysia, Iran, Kazakhstan); t denotes time (2010-2024); μ_i, λ_t represent country-specific and time-specific effects, respectively; ε it is the error term.

The model adopts a semi-log specification in which most explanatory variables are expressed in logarithmic form. This transformation serves three purposes: (i) reducing potential skewness in the data distribution, (ii) mitigating heteroskedasticity, and (iii) allowing coefficients to be interpreted as elasticities. Trade openness (TO) is retained in level form because it is already expressed as a ratio, and logarithmic transformation does not materially improve its distributional properties.

Table 1. The specification of variables and data sources

Variable	Specification	Data sources	Reference
HT	High-technology exports	The World Bank	Navarro Zapata, Arrazola and de Hevia [8], Sepehrdoust, Tartar and Davarikish [9]
R&D	Research and development expenditure		Navarro Zapata, Arrazola and de Hevia [8], Drapkin et al. [10]
L	Labor force		Navarro Zapata, Arrazola and de Hevia [8]
TO	Trade		Drapkin et al. [10]
FDI	Foreign direct investment		Navarro Zapata, Arrazola and de Hevia [8], Drapkin et al. [10]

The selection of explanatory variables is grounded in both theoretical and empirical considerations. R&D expenditure is included as the primary proxy for innovation investment, consistent with endogenous growth theory, which emphasizes knowledge accumulation as a key driver of productivity and export competitiveness. TO captures the extent of integration into global markets and facilitates technology diffusion through international trade. FDI is incorporated to reflect technology spillovers and managerial know-how transferred from multinational enterprises. Finally, L represents the scale of human resources and serves as a proxy for absorptive capacity, which is essential for effectively utilizing innovation inputs.

This study employs the fixed-effects panel quantile regression approach proposed by Koenker [16], which allows for heterogeneous slope coefficients across different quantiles while controlling for unobserved country-specific effects. Specifically, the quantile regression model at quantile $\tau \in (0,1)$ is specified as:

$$Q_\tau(lnHT_{it}|X_{it}) = \beta_0(\tau) + \beta_1(\tau)\, LnR\&D_{it} + \beta_2(\tau)\, TO_{it} + \beta_3(\tau)\, LnL_{it} + \beta_4(\tau)\, LnFDI_{it} \quad (2)$$

where $Q_\tau(\cdot)$ denotes the conditional quantile function of high-technology exports ($lnHT_{it}$) at quantile τ.

Unlike conventional mean-based estimators such as ordinary least squares or fixed-effects models, panel quantile regression allows the estimated coefficients to vary across different points of the conditional distribution of high-technology exports. This feature enables the analysis to capture distributional heterogeneity in the innovation–export relationship and to assess whether the impact of R&D investment differs between countries with lower export

performance and those located at the upper tail of the export distribution. Consequently, this approach provides more nuanced empirical insights and supports the derivation of differentiated and context-specific policy implications. The pooled OLS estimation is first employed to provide a benchmark for comparison with quantile regression results.

4. EMPIRICAL RESULTS

4.1. Descriptive statistics

Table 2. Summary of statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LnHT	135	23.281	2.400	18.381	27.565
LnR&D	135	-0.676	0.875	-2.469	1.036
TO	135	76.777	45.578	32.972	186.676
LnL	135	17.925	1.444	16.009	20.476
LnFDI	135	23.382	1.271	19.683	26.564

The descriptive statistics indicate considerable heterogeneity among Asian countries over the study period. The variable LnHT, representing high-technology exports, has a mean of 23.281 and a standard deviation of 2.4, with values ranging from 18.381 to 27.565. This wide dispersion reflects substantial cross-country differences in technological export performance, suggesting the coexistence of economies at different stages of high-tech development.

Similarly, LnR&D records a mean of –0.676 and a relatively large standard deviation of 0.875, indicating uneven investment in research and development across countries and highlighting disparities in innovation capacity. TO, measured as a percentage of GDP, has a mean of 76.777 and exhibits considerable variability, pointing to notable differences in the degree of integration into global markets. Meanwhile, LnL and LnFDI also show meaningful dispersion, reflecting cross-country variation in labor force size and the ability to attract foreign direct investment.

Overall, the observed variability across variables confirms the heterogeneous nature of the sample and provides empirical support for employing quantile regression to capture potential distributional differences in the determinants of high-technology exports.

Table 3. Correlation matrix of the variables used in the model

Variables	(1)	(2)	(3)	(4)	(5)
(1) LnHT	1.000				
(2) LnR&D	0.631	1.000			
(3) TO	0.419	0.117	1.000		
(4) LnL	0.524	0.506	-0.358	1.000	
(5) LnFDI	0.678	0.478	-0.190	0.773	1.000

The correlation matrix indicates mostly moderate relationships among the variables, with all coefficients remaining below the conventional multicollinearity threshold of 0.8. LnHT shows relatively strong positive correlations with LnFDI and LnR&D, suggesting that foreign investment and innovation activities are closely associated with export performance. LnHT is also moderately correlated with LnL and TO, implying supportive but less pronounced roles.

Among the explanatory variables, LnR&D is positively related to LnL and LnFDI, which may reflect that economies with larger labor forces and stronger capital inflows tend to invest more in innovation. TO exhibits generally weak correlations with the other variables, including modest negative associations with LnL and LnFDI. The highest correlation appears between LnL and LnFDI; although relatively high, it remains below the warning threshold.

To further examine the potential multicollinearity among explanatory variables, the variance inflation factor (VIF) test is conducted. The results indicate that all VIF values are below 3, which is well under the commonly accepted threshold of 10 and even the more conservative threshold of 5. This finding confirms that multicollinearity is not a serious concern in the estimated model and suggests that the regression coefficients are stable and reliable for subsequent empirical analysis. Therefore, all explanatory variables are retained for further estimation.

Panel unit root test results indicate that the variables in the model are integrated of mixed orders, namely I(0) and I(1). Therefore, the Pedroni panel cointegration test is employed to examine the long-run relationship among the variables. The results show that the Modified Phillips–Perron, Phillips–Perron, and Augmented Dickey–Fuller statistics are all statistically significant at the 1% level, leading to the rejection of the null hypothesis of no cointegration. This finding confirms the existence of a long-run equilibrium relationship among the variables, indicating that they move together over time in the long run. Consequently, the regression model can be estimated in levels without encountering the problem of spurious regression.

The results of the Pesaran CD test reveal no evidence of cross-sectional dependence among the panel units, indicating that country-specific shocks are largely independent. This supports the validity of conventional panel estimation techniques and suggests that the empirical results are not biased by cross-sectional correlations.

4.2. Empirical results

Table 4. Result from pooled OLS estimation

LnHT	Coef.	Robust St.Err.	t-value	[95% Conf	Interval]
LnR&D	0.551***	0.127	4.330	0.300	0.803
TO	0.030***	0.002	15.840	0.027	0.034
LnL	0.388***	0.111	3.490	0.168	0.607
LnFDI	0.965***	0.156	6.190	0.657	1.274
Constant	-8.198***	2.606	-3.150	-13.352	-3.043
Mean dependent var	23.281		SD dependent var		2.400
R-squared	0.837		Number of obs		135
F-test	118.795		Prob > F		0.000
Akaike crit. (AIC)	383.501		Bayesian crit. (BIC)		398.027

*** $p<0.01$

The pooled OLS results indicate that all explanatory variables exert positive and statistically significant effects on high-technology exports. In economic terms, the estimated elasticity of 0.551 for R&D suggests a moderately strong relationship, implying that increases in innovation investment are associated with meaningful improvements in export performance. Notably, foreign direct investment exhibits the largest elasticity (0.965), highlighting its dominant role in promoting high-technology exports, likely through channels of technology transfer and productivity spillovers. Trade openness and labor force also contribute positively,

though their magnitudes are comparatively smaller, indicating supporting but less dominant roles in the export upgrading process.

The quantile regression results reveal substantial heterogeneity in the impact of innovation investment across the distribution of high-technology exports. A key finding is the presence of an amplification effect of R&D, whereby its estimated coefficient increases toward the upper quantiles. This pattern suggests that countries with higher levels of export performance are able to extract greater returns from innovation investment, likely due to stronger absorptive capacity, more advanced innovation systems, and better integration into global value chains.

In contrast, the effect of trade openness exhibits a diminishing pattern across quantiles, indicating decreasing marginal benefits as countries move to higher levels of export performance. This finding implies that while openness is crucial in early stages of export development, its relative importance declines as economies become more technologically advanced.

Table 5. Result from the quantile regression (robust)

Variable	$Q_{0.10}$	$Q_{0.25}$	$Q_{0.50}$	$Q_{0.75}$	$Q_{0.90}$
LnR&D	0.809***	0.699***	0.420**	0.933***	1.138***
TO	0.032***	0.033***	0.028***	0.018***	0.013***
LnL	0.292***	0.296***	0.043	0.266*	0.472***
LnFDI	1.236***	1.247***	1.428***	0.665**	0.160
Constant	-13.771***	-13.940***	-12.945***	2.976	12.162***

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Similarly, the impact of foreign direct investment is strongest at lower and middle quantiles but weakens at the upper tail, suggesting that FDI-driven spillovers are more relevant for countries in earlier stages of technological upgrading. For more advanced economies, domestic innovation capacity appears to play a more central role.

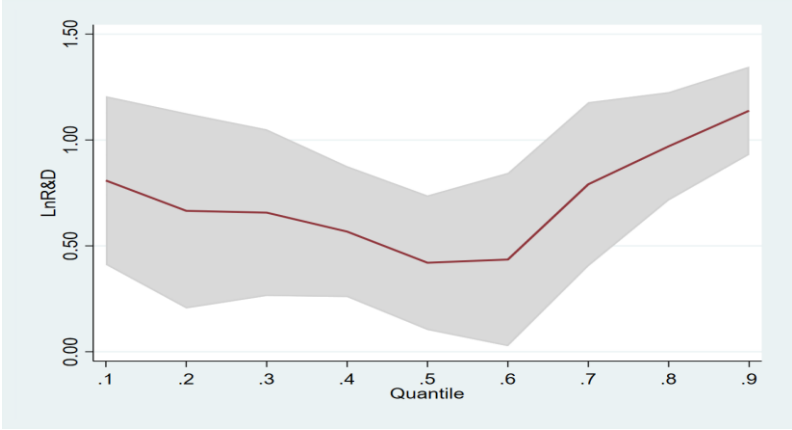

Figure 1. Heterogeneous effects of R&D on high-technology exports across quantiles

Figure 1 illustrates the heterogeneous impact of R&D on high-technology exports across conditional quantiles. The coefficient of LnR&D remains positive throughout the distribution, confirming the consistently favorable role of innovation investment. However, the magnitude of the effect varies substantially across quantiles. The estimated coefficient declines from the lower quantiles to the median, reaching its minimum around the 0.5 quantile, before increasing

sharply toward the upper quantiles. Notably, the effect becomes considerably stronger beyond the 0.7 quantile and reaches its highest level at the 0.9 quantile. This pattern suggests that R&D generates larger returns in countries with relatively higher levels of high-technology exports, indicating the presence of an amplification effect. Overall, the figure provides clear visual evidence of heterogeneity that cannot be captured by mean-based estimators such as OLS.

The Wald test results indicate that the null hypothesis of coefficient equality across quantiles is rejected for R&D ($p = 0.029$), trade openness ($p = 0.000$), and foreign direct investment ($p = 0.000$), suggesting significant heterogeneous effects across the distribution of high-technology exports. In contrast, the effect of labor (LnL) does not differ significantly across quantiles ($p = 0.806$), indicating a relatively stable impact. These findings further justify the use of quantile regression to capture distributional heterogeneity. Overall, the Wald test provides statistical evidence supporting the presence of heterogeneous effects, thereby reinforcing the appropriateness of using panel quantile regression instead of relying solely on mean-based estimators.

The empirical findings provide robust evidence supporting the positive role of innovation investment in promoting high-technology exports, while also uncovering substantial heterogeneity across the export distribution that cannot be captured by conventional mean-based estimators. A key contribution of this study lies in identifying an amplification effect of R&D, whereby its marginal impact becomes significantly stronger at higher quantiles of the high-technology export distribution. In practical terms, this implies that countries already performing well in high-technology exports are able to convert additional R&D investment into export gains more efficiently. This pattern likely reflects the presence of complementary factors—such as skilled human capital, advanced infrastructure, and well-developed innovation systems—that enhance the productivity of innovation efforts. While previous studies (e.g., Sandu and Ciocanel [7]; Navarro Zapata, Arrazola and de Hevia [8]) document a positive average effect of R&D, the present findings extend this literature by showing that such effects are not uniform but instead concentrated among higher-performing economies.

From a theoretical perspective, this result can be more precisely explained by the concept of absorptive capacity [6]. Countries with stronger technological capabilities are better equipped not only to generate new knowledge through R&D, but also to internalize, adapt, and commercialize that knowledge into exportable high-technology products. This suggests that the returns to innovation investment are conditional on underlying structural characteristics, rather than homogeneous across countries, thereby refining the predictions of endogenous growth theory in an international trade context.

The analysis also reveals a diminishing marginal effect of trade openness, with its impact declining toward higher quantiles of the export distribution. Economically, this indicates that trade integration plays a more critical role in the earlier stages of export development, where access to foreign markets and imported technologies helps build initial capabilities. This finding is consistent with prior studies such as Drapkin et al. [10], which emphasize the importance of trade-related channels in less advanced economies. However, the present results add nuance by showing that, as countries move up the technological ladder, the relative importance of trade openness decreases, and export performance becomes increasingly driven by domestic innovation capacity rather than external exposure alone.

Similarly, the role of foreign direct investment appears to be stage-dependent. The stronger effects observed at lower and middle quantiles suggest that FDI serves as an important channel for technology transfer, managerial know-how, and capability building in developing and transitioning economies. This interpretation aligns with existing evidence (e.g., Sepehrdoust, Tartar and Davarikish [9]) highlighting the role of external knowledge inflows in facilitating export upgrading. However, the weakening impact of FDI at higher quantiles

indicates that, beyond a certain level of development, countries rely less on external sources of technology and more on internally generated innovation. In other words, once a critical threshold of technological capability is reached, domestic R&D systems become the primary drivers of high-technology export performance.

Taken together, these findings suggest that the relationship between innovation and high-technology exports is inherently non-linear and context-dependent. By adopting a distributional perspective, this study not only confirms the positive role of innovation investment but also demonstrates that its effectiveness depends on countries' positions along the development and technological capability spectrum. This more nuanced understanding helps reconcile mixed findings in the existing literature and highlights the importance of tailoring policy strategies to different stages of economic development.

5. CONCLUSION AND POLICY IMPLICATIONS

This study provides new empirical evidence on the relationship between innovation investment and high-technology exports in Asian economies, highlighting the importance of moving beyond average effects to account for distributional heterogeneity. The findings demonstrate that while R&D investment consistently promotes high-technology exports, its impact is significantly stronger among countries with higher levels of export performance, revealing an amplification effect that has important theoretical and policy implications.

More broadly, the results suggest that the innovation–export relationship is inherently conditional on structural factors, including absorptive capacity, institutional quality, and integration into global value chains. As such, policies aimed at fostering innovation should not be designed in isolation but rather embedded within a broader development strategy that strengthens complementary capabilities.

While the study provides robust empirical insights, the findings should be interpreted with caution, as the estimated relationships reflect conditional associations rather than strict causal effects. Future research may extend this analysis by incorporating more granular measures of innovation and employing identification strategies that better address potential endogeneity concerns.

From a policy perspective, the findings suggest that increasing R&D expenditure remains a fundamental strategy for enhancing technological competitiveness and expanding high-technology exports. However, the effectiveness of such investment depends on the presence of complementary conditions. For countries at lower levels of technological development, policies should prioritize strengthening human capital, improving institutional quality, and enhancing absorptive capacity in order to fully leverage innovation efforts. In addition, fostering stronger linkages between domestic firms, research institutions, and global value chains can facilitate knowledge spillovers and accelerate capability building.

For more advanced economies, policy efforts may focus on supporting frontier innovation, promoting advanced manufacturing, and strengthening intellectual property protection to sustain export growth. In contrast, middle- and lower-performing countries may benefit more from policies aimed at technology adoption, industrial upgrading, and gradual capability accumulation. Overall, the results indicate that a one-size-fits-all innovation policy is unlikely to be effective; instead, tailored strategies aligned with each country's position in the high-technology export distribution are essential for achieving sustainable long-term competitiveness.

Despite these contributions, several limitations should be acknowledged. The sample size remains relatively small, covering only nine Asian economies, which may limit the generalizability of the findings. In addition, potential endogeneity between R&D and high-

technology exports cannot be fully addressed within the current empirical framework. Future research could extend the analysis by incorporating additional control variables, such as institutional quality and human capital, or by applying alternative estimation techniques to further strengthen causal inference.

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