International Journal of Business & Economic Studies
Year: 2025, Vol: 7, No: 4, pp.258-271
https://doi.org/10.54821/uiecd.1786964

Artificial Intelligence and Export Performance: Insights from OECD Countries

Yapay Zeka ve İhracat Performansı: OECD Ülkelerinden Görüşler

Hafidha LAHMERI
Dr., University of Mascara, Algeria
hafidhalahmeri@univ-mascara.dz
https://orcid.org/0009-0003-3380-3213

Received : 19.09.2025
Revised : 26.12.2025
Accepted : 29.12.2025
Type of Article : Research

Keywords:
OECD Countries, Research and Development, Artificial Intelligence, International Trade, Exports

Jel Codes:
C23, F14, O33

ABSTRACT

This study investigates the effects of artificial intelligence (AI) investments and research and development (R&D) expenditures on export performance across 15 OECD countries. The analysis is conducted using a panel dataset covering the period from 2013 to 2023 and employs the Method of Moments Quantile Regression (MMQR) approach. This method allows for examining how the impacts of AI and R&D expenditures on export performance vary across different quantiles of the conditional distribution, rather than focusing solely on average effects. The findings reveal that the relationship between AI investments and export performance is neither linear nor homogeneous and differs depending on countries' export performance levels. In particular, AI investments are found to exert a suppressing effect on exports in the short run, while simultaneously reducing volatility and playing a stabilizing role in export performance. The effects of R&D expenditures are observed to be more pronounced in countries with low and medium levels of export performance, whereas they weaken at higher export levels. Overall, the results highlight the necessity of designing AI and R&D oriented policies within an integrated, differentiated, and country-specific framework that accounts for heterogeneity in export performance across OECD economies.

Anahtar Kelimeler:
OECD Ülkeleri, Araştırma ve Geliştirme, Yapay Zeka, Uluslararası Ticaret, İhracat

Jel Kodları:
C23, F14, O33

ÖZET

Bu çalışma, yapay zekâ (YZ) yatırımları ve araştırma geliştirme (Ar-Ge) harcamalarının ihracat performansı üzerindeki etkilerini 15 OECD ülkesi örneğinde incelemektedir. Analiz, 2013–2023 dönemine ait panel veri seti kullanılarak gerçekleştirilmiş ve Method of Moments Quantile Regression (MMQR) yöntemi uygulanmıştır. Bu yöntem, yapay zekâ ve Ar-Ge harcamalarının ihracat performansı üzerindeki etkilerinin yalnızca ortalama düzeyde değil, dağılımın farklı kantillerinde nasıl değiştiğini ortaya koymaya olanak tanımaktadır. Bulgular, yapay zekâ yatırımlarının ihracat performansı üzerindeki etkisinin doğrusal ve homojen olmadığını; ülkelerin ihracat düzeylerine bağlı olarak farklılaştığını göstermektedir. Özellikle yapay zekâ yatırımlarının kısa vadede ihracat üzerinde baskılayıcı bir etki yarattığı, buna karşılık ihracat performansındaki oynaklığı azalttığı ve istikrar sağlayıcı bir rol üstlendiği tespit edilmiştir. Ar-Ge harcamalarının etkisi ise daha çok düşük ve orta düzeyde ihracat performansına sahip ülkelerde anlamlı bulunmakta, yüksek ihracat düzeylerinde zayıflamaktadır. Elde edilen sonuçlar, yapay zekâ ve Ar-Ge politikalarının ülke ve performans düzeylerine duyarlı, bütünleşik ve farklılaştırılmış bir çerçevede tasarlanması gerektiğini ortaya koymaktadır.

Suggested Citation: Lahmeri, H. (2025). Artificial intelligence and export performance: Insights from OECD countries. *International Journal of Business and Economic Studies*, 7(4), 258-271, https://doi.org/10.54821/uiecd.1786964

1. INTRODUCTION

Competitive dynamics in global trade have changed significantly in recent years with the acceleration of digitalization and knowledge based production processes. Export performance of firms and countries is no longer determined solely by cost advantages or production capacity, but increasingly by technological capabilities, data processing capacity, and innovation generation ability. Within this transformation process, artificial intelligence (AI) and research and development (R&D) activities have emerged as fundamental strategic elements shaping export performance (Sohrabpour et al., 2021; Zhang & Deng, 2023; Lefebvre et al., 1998).

From a theoretical perspective, artificial intelligence affects export performance through information access and decision making quality. AI technologies reduce uncertainty and improve resource allocation by enhancing processes directly related to exporting, such as demand forecasting, market selection, pricing, and logistics planning (Sohrabpour et al., 2021). In addition, AI applications integrated with sensor technologies accelerate digital transformation in agricultural and food exports by improving product traceability and quality control (Neethirajan, 2023). In this context, artificial intelligence is positioned as a tool that increases operational efficiency in export activities. However, the impact of artificial intelligence on exports is not limited to efficiency gains. The development of corporate AI capacity has the potential to improve the quality level, technical complexity, and environmental characteristics of export products (Liu et al., 2025; Xu & Tian, 2025; Lin et al., 2024; Fang & Liu, 2025). Complementary factors such as smart city infrastructure and regional digital development levels emerge as institutional frameworks that strengthen the effect of artificial intelligence on exports (Ou et al., 2024). At the same time, AI investments may generate short term adjustment costs for firms and countries due to high fixed costs and organizational transformation requirements (Zhang & Deng, 2023).

R&D activities, by contrast, affect export performance primarily through innovation generation and technological capability accumulation. R&D investments create a basis for high value added exports by enhancing firms' ability to differentiate products and achieve technological superiority (Sandu & Ciocanel, 2014; Goldar, 2013; Bojnec, 2014). R&D based capabilities have long been recognized as key determinants of export performance, particularly at the firm level (Lefebvre et al., 1998). Nevertheless, the impact of R&D expenditures on exports often emerges indirectly, through innovation outputs and with a time lag (Leung & Sharma, 2021; Carboni & Medda, 2020).

The interaction between artificial intelligence and R&D provides a complementary framework for explaining export performance. While R&D activities build the knowledge infrastructure and learning capacity required for the effective implementation of AI technologies, artificial intelligence enhances the efficiency of R&D processes and accelerates the innovation cycle (Kumar et al., 2025; Rahman et al., 2024). This reciprocal interaction strengthens both competitiveness and sustainable growth capacity in export activities (Chen et al., 2025; Wang et al., 2023). Moreover, the effects of artificial intelligence and R&D investments on export performance are expected to differ depending on countries' export performance levels, institutional structures, and degrees of technological maturity. While R&D investments play a competitiveness enhancing role in countries with low and medium export performance, AI investments may generate higher short term adjustment costs in high export performing economies due to the transformation of existing production and export structures (Benfratello et al., 2022; Zaman & Tanewski, 2024; Chen & Dong, 2025).

The primary objective of this study is to examine the effects of artificial intelligence investments and R&D expenditures on export performance within a quantile-based and heterogeneous framework, taking into account structural differences across country groups. The existing literature predominantly analyzes the impact of technological developments on international trade using linear models based on average effects; however, this approach fails to adequately capture the asymmetric effects that emerge across countries and at different levels of export performance. This study aims to fill this gap by analyzing the relationship between artificial intelligence and exports across different points of the distribution. The empirical analysis is conducted using a panel dataset covering the period from 2013 to 2023 for 15 OECD countries (France, Greece, Spain, Germany, Italy, the United Kingdom, Sweden, Norway, Canada, Belgium, Luxembourg, Portugal, Türkiye, Poland, and the United States). In the study, export performance is treated as the dependent variable, while artificial intelligence investments and R&D expenditures are included as the main explanatory variables. In addition, to control for the effects of macroeconomic conditions, economic growth (GDP growth rate) and inflation are incorporated as control variables. Methodologically, the study adopts the Method of Moments Quantile Regression (MMQR) approach. Unlike traditional panel regressions that focus solely on average effects, the MMQR method allows for the examination of how the effects of explanatory variables on export performance vary across different quantiles of the distribution. Moreover, by decomposing the model into location and scale components, the method enables the joint analysis of both level effects and volatility effects within a unified framework. In this way, the study

evaluates not only how artificial intelligence and R&D investments influence the level of exports but also how they affect the stability of export performance.

Existing studies mostly reduce the effects of artificial intelligence and R&D activities on foreign trade to one directional and average outcomes, and fail to sufficiently examine how these investments operate across different levels of export performance. In particular, the fact that the cost-benefit structure of technological investments differs between countries with high export capacity and those with low and medium export levels has been largely overlooked in the literature. This limitation leaves the literature inadequate in explaining why technology based trade policies yield the expected results in some countries while producing only limited effects in others. Therefore, there is a clear need for studies that systematically compare the effects of artificial intelligence and R&D investments on exports across different points of the distribution. The findings expected to be obtained from this study are anticipated to make important contributions to the design of technology and foreign trade policies. Revealing how the effects of artificial intelligence and R&D investments on export performance differ across countries and across varying export levels will allow policymakers to plan technology driven transformation processes in a more realistic and gradual manner. In particular, distinguishing between the short and long term effects of technological investments will contribute to better management of adjustment costs encountered during transition periods and to more effective timing of support mechanisms. In this context, the study provides an analytical framework suggesting that technology policies should be evaluated not only in terms of growth objectives, but also with respect to export stability and predictability.

This study consists of seven sections. Following the introduction, the second section presents the literature. The third section includes the data, model, and variables. The fourth section reports the MMQR results. The fifth section provides the discussion. The sixth section presents policy recommendations. Finally, the seventh section includes future studies and limitations.

2. LITERATURE REVIEW

In recent years, the literature on the determinants of export performance has moved beyond traditional factors and increasingly focused on the role of artificial intelligence (AI) and research and development (R&D) expenditures. Artificial intelligence enables firms to manage their export processes more effectively, particularly through demand forecasting, market analysis, and decision support systems. Indeed, the use of AI-based models in export sales forecasting reduces uncertainty and provides more accurate predictions, thereby supporting export performance (Sohrabpour et al., 2021). Similarly, AI applications integrated with sensor technologies have been shown to accelerate digital transformation by improving quality, traceability, and efficiency in agricultural and livestock exports (Neethirajan, 2023).

Firm-level studies demonstrate that artificial intelligence affects export performance not only in quantitative terms but also in its qualitative dimensions. Empirical analyses based on Chinese firm-level data indicate that AI adoption increases export volumes and strengthens firms' competitiveness in global markets (Zhang & Deng, 2023). In addition, corporate AI development has been found to significantly enhance the quality of export products (Liu et al., 2025), with this effect being particularly pronounced in technology intensive sectors (Xu & Tian, 2025). It is also emphasized that AI reduces production errors and enhances learning capacity, thereby upgrading the technical complexity of exports (Lin et al., 2024).

The literature further reveals that the relationship between artificial intelligence and export performance is sensitive to regional and institutional contexts. Smart city infrastructure and regional digital development levels emerge as complementary factors that strengthen the effect of AI on export product quality (Ou et al., 2024). Moreover, AI applications generate sustainable export value added through channels such as natural resource management and environmental efficiency (Wang et al., 2023). In this context, artificial intelligence has been shown to support the sustainable growth of exporting firms (Chen et al., 2025) and to increase the green sophistication level of exports (Fang & Liu, 2025).

Studies focusing on multinational corporations indicate that the relationship between artificial intelligence and export performance is influenced by cultural and institutional factors. Cultural distance may weaken the translation of AI utilization into export performance (Chishty et al., 2025), while regional market development and cultural distance play a moderating role in this relationship (Chen & Dong, 2025). On the other hand, AI investments are closely associated with macroeconomic conditions, ICT exports, and patent capacity, which indirectly shape export performance (Rahman et al., 2024).

The relationship between R&D expenditures and export performance, by contrast, has long occupied a central position in the literature. Early studies emphasize that R&D and innovation support high technology exports (Sandu & Ciocanel, 2014). R&D investments have been shown to strengthen growth and export performance in small and medium sized enterprises, although this effect depends on the balance between firms' exploration and exploitation capabilities (Battaglia et al., 2018). Classical studies further demonstrate that R&D related capabilities are among the key determinants of export performance (Lefebvre et al., 1998).

More recent research suggests that the relationship between R&D intensity and export performance exhibits an indirect and heterogeneous structure. The effects of R&D intensity and R&D internationalization on firm performance largely operate through innovation performance (Leung & Sharma, 2021). It has also been found that the impact of corporate sustainability practices on export intensity is strengthened by R&D intensity (Aksoy et al., 2024). Moreover, R&D expenditures generate heterogeneous effects across the export intensity distribution, indicating that the relationship is nonlinear rather than uniform (Benfratello et al., 2022).

Evidence from European and emerging economies shows strong linkages between R&D, innovation, investment, and export performance (Carboni & Medda, 2020). Sectoral analyses reveal that R&D intensity significantly increases exports, particularly in pharmaceutical and high technology industries (Goldar, 2013; Bojnec, 2014). The development of the financial system has also been shown to influence comparative advantage and export performance through R&D intensity (Gur & Avşar, 2016). Innovation capacity has been found to enhance export performance, especially among high technology SMEs (D'Angelo, 2012).

Recent studies further indicate that the relationship between R&D investment and export performance varies depending on firm size, public support mechanisms, and organizational motivators (Zaman & Tanewski, 2024; Tinits et al., 2025). Digital transformation has been shown to improve performance, particularly in manufacturing export firms (Wang et al., 2024), while green practices and innovation ecosystems exert complementary effects on export performance (Khiewngamdee & Chanaim, 2025; Shu et al., 2024). In addition, the effects of domestic and foreign R&D on exports differ in magnitude and direction (Rauf & Bao, 2024), and exporting itself strengthens the relationship between R&D investment and new product development performance (Sousa et al., 2025).

Finally, export performance has been shown to be shaped through innovation, owner characteristics, and locational factors (Han et al., 2024). R&D and exports jointly support employment growth (Naidoo, 2024), and the interaction between R&D, advertising, and exports varies depending on firm-level capabilities (Kwon et al., 2025). Overall, the literature indicates that artificial intelligence and R&D expenditures function as complementary strategic assets that enhance export performance in both quantitative and qualitative terms.

3. METHODOLOGY

3.1. Model

Our study assesses the impact of artificial intelligence on international trade, with particular focus on examining the influence of artificial intelligence on exports. The analysis is based on econometric model using panel data for 15 OECD countries including France, Greece, Spain, Germany, Italy, the United Kingdom, Sweden, Norway, Canada, Belgium, Luxembourg, Portugal, Türkiye, Poland, and the United States. Over the period from 2013 to 2023. The following equation specifies the regression model:

$$I\_Expo_{i,t} = \beta_0 + \beta_1 AI\_inv_{i,t} + \beta_2 R\_D_{i,t} + \epsilon_{it} \quad (1)$$

In the model, the i denotes the country, while t represents the sample year ranging from 2013 to 2023. The dependent variable is I_Expo which measures the Exports of goods and services provided to the rest of the world. The dependent variables are AI (investment in Artificial Intelligence), and R&D (expenditures on research and development). Additionally, we include other control variables such as gross domestic product growth (GDP) and annual inflation (inf). which are potentially related to international trade, in order to analyze their effects on the Exports.

$$I\_Expo_{i,t} = \beta_0 + \beta_1 AI\_Inv_{i,t} + \beta_2 R\_D_{i,t} + \beta_3 GDP_{i,t} + \beta_4 Inf_{i,t} + \epsilon_{it} \quad (2)$$

3.2 Data

The data were collected from multiple sources. The exports of goods and services provided to the rest of the world (% of GDP) were obtained from the World Bank. Data on investments in AI and data start-ups were obtained from OECD, which measures investment in AI and data ecosystems and indicates which countries attract more investments. Finally, data on research and development expenditures (as a percent of GDP), gross domestic product growth (GDP), and annual inflation (Inf) data were obtained from the World Bank.

Table 1. Summary Statistics

	Variable	Mean	Median	Std. Dev.	Maximum	Minimum
Dependent variable	I_Expo	1.603	1.563	0.255	2.328	1.003
Independent variable	AI_inv	2.317	2.363	1.274	5.630	0.041
	R_D	3.027	3.000	0.814	4.600	1.000
Control variable	GDP	28.259	27.00	15.90	226.0	0.600
	Inf	5.471	3.730	7.553	74.30	0.264

3.3. Econometric Strategy

In this research, the empirical analysis is conducted using the Method of Moments Quantile Regression (MMQR) approach, introduced to the literature by Machado & Silva (2019). Contrary to the constrained structure of traditional estimators that focus solely on the conditional mean, MMQR allows the coefficients of independent variables to vary across the distribution of the dependent variable. This methodological flexibility enables the detection of distributional heterogeneity within the context of sustainability performance, revealing how the relationship between variables fluctuates across low, medium, and high-performance levels. Consequently, rather than imposing a uniform effect across all observations, MMQR analyzes the impacts of regressors on the dependent variable through a multidimensional perspective across the entire spectrum.

$$Q(\tau|X_{it}) = X'_{it}\,\beta(\tau) + \delta i + \varepsilon_{it}(\tau) \quad (3)$$

In this framework, $Q(\tau|X_{it})$ indicates the conditional quantile of the dependent variable at level (τ). The coefficient vector $\beta(\tau)$ reflects how the explanatory variables affect the dependent variable at different points of its conditional distribution. The MMQR methodology is implemented through a sequential two-stage framework. Initially, the location and scale parameters are obtained using a conventional panel data specification. Subsequently, these estimated components are modeled as functions of the explanatory variables to generate quantile specific coefficient estimates. This structured approach preserves the clarity and economic interpretation of the parameters, while simultaneously capturing potential asymmetries across the conditional distribution. In the empirical analysis, the estimation is performed for quantiles ranging from the 25th to the 90th percentiles, which allows for a nuanced assessment of differential impacts across countries exhibiting low, medium, and high outcome levels.

4. FINDINGS

In this section, empirical findings on the effects of artificial intelligence investments and R&D expenditures on export performance are presented.

Table 2. Cross Sectional Dependence Test

Variable	CD	CDw+
I_Expo	546.53***	3042.15***
AI_inv	354.24***	3521.25***
R_D	312.94***	4294.93***
GDP	252.03***	4931.28***
Inf	194.13***	5519.13***

Note: *** p<0.01

The Pesaran (2015) CD and Fan et al. (2015) CDw+ test results reported in Table 2 provide strong evidence of significant cross sectional dependence across all panel variables. While the CD test captures conventional dependence, the CDw+ statistic offers greater sensitivity in large panels, confirming the strength of cross sectional linkages. These results imply that SDG indicators, green bond activity, and economic growth exhibit synchronized

movements driven by common external factors. Consequently, relying on standard fixed effects or traditional panel estimators would be inappropriate, and econometric methods that explicitly accommodate cross sectional dependence are required.

Table 3. Slope Heterogeneity Test

Model	Stat	Value
Model 1	Delta	29.43***
	Adj.	25.12***
Model 2	Delta	33.94***
	Adj.	29.13***

Note: *** p<0.01

The results of the slope heterogeneity test reported in Table 3, based on Pesaran & Yamagata (2008), indicate that the coefficients differ significantly across countries in all models. The statistical significance of both the Delta and the adjusted Delta statistics reveals that the impact of the independent variables on the dependent variable is not uniform; rather, it varies depending on countries' economic, institutional, and environmental conditions. This finding demonstrates that the assumption of homogeneous slope coefficients commonly adopted in traditional panel models is not appropriate for the structure of the data, and it underscores the necessity of employing heterogeneous panel methods that explicitly account for cross country differences.

Table 4. Unit Root Test

Variable	At I(0)	At I(1)
I_Expo	-1.02	-4.32***
AI_inv	-1.29	-4.76***
R_D	-0.85	-3.54***
GDP	-0.79	-3.68***
Inf	-1.07	-4.39***

Note: *** p<0.01

The results of the Pesaran (2007) panel unit root test reported in Table 4 present a clear picture of the stationarity properties of the variables employed in the analysis. The findings indicate that I_Expo, AI_inv, R_D, GDP, and Inf are not stationary at their level values, implying that the series contain unit roots at I(0). In contrast, all variables become statistically significant and achieve stationarity once their first differences are taken. These results demonstrate that all variables are integrated of order one (I(1)). Accordingly, the series follow a common time trend and attain stationarity only after differencing. This structure highlights the necessity of employing econometric methods that explicitly account for I(1) processes and potential long run relationships among the variables in the subsequent analysis.

Table 5. Cointegration Analysis

		Gt	Ga	Pt	Pa
Model 1	Val	-8.69	-24.39	-31.28	-28.12
	Z-stat	-21.27	-26.55	-33.87	-28.95
Model 2	Val	-7.24	-27.64	-35.64	-30.08
	Z-stat	-24.22	-27.64	-37.53	-32.64

The Westerlund (2007) panel cointegration test results reported in Table 5 investigate the long run relationship between exports and artificial intelligence investments and R&D expenditures (Model 1), as well as this structure augmented with macroeconomic control variables (Model 2). Evaluating both the group statistics (Gt and Ga) and the panel statistics (Pt and Pa) enables an assessment of cointegration at the country level as well as for the panel as a whole. In both models, the fact that all test statistics take negative values and that the associated Z-statistics are highly significant provides strong evidence of a long term equilibrium relationship among the variables. This finding indicates that artificial intelligence investments and R&D activities are linked to export performance not only through short term fluctuations but also via persistent and structural dynamics. Moreover, the continuation of the cointegration relationship in Model 2 after the inclusion of control variables confirms the robustness and stability of the results. Overall, these findings suggest that investments in artificial intelligence and innovation oriented activities constitute key determinants shaping countries' export capacity in the long run and that technological transformation generates lasting effects on international trade dynamics.

Table 6. MMQR Model 1

	(1)	**(2)**	**(3)**	**(4)**
	0.25	0.50	0.75	0.90
Location				
AI_inv	-0.1576***	-0.1576***	-0.1576***	-0.1576***
	(-4.49)	(-4.49)	(-4.49)	(-4.49)
R_D	0.0548	0.0548	0.0548	0.0548
	(1.19)	(1.19)	(1.19)	(1.19)
Scale				
AI_inv	-0.0603**	-0.0603**	-0.0603**	-0.0603**
	(-2.25)	(-2.25)	(-2.25)	(-2.25)
R_D	-0.0123	-0.0123	-0.0123	-0.0123
	(-0.35)	(-0.35)	(-0.35)	(-0.35)
qtile				
AI_inv	-0.1238*	-0.1675***	-0.2101***	-0.2938***
	(-5.62)	(-4.78)	(-3.95)	(-2.98)
R_D	0.0616**	0.0528	0.0441	0.0271
	(2.08)	(1.04)	(0.59)	(0.22)
N	165	165	165	165
t istatistics in parentheses: * p<0.10, ** p<0.05, *** p<0.01				

The results of MMQR Model 1 presented in Table 6 indicate that the effects of artificial intelligence investments and R&D expenditures on export performance in OECD countries exhibit a heterogeneous structure both across different quantiles of the distribution and in terms of the location and scale components. According to the location component results, the impact of artificial intelligence investments on export performance is negative and statistically strong across all quantiles. This finding suggests that artificial intelligence investments may exert a suppressing effect on export performance in the short run. In contrast, although the coefficients of R&D expenditures in the location component are positive, they are not statistically significant, indicating that the effect of R&D on exports may materialize through more indirect and long term channels.

The scale component results reveal that artificial intelligence investments reduce the volatility of export performance and that this effect is statistically significant. This finding demonstrates that artificial intelligence investments play a stabilizing role in export performance and serve a function of reducing uncertainty. R&D expenditures, on the other hand, do not exhibit a statistically significant effect in the scale component. When the quantile specific coefficients are examined, it is observed that the negative effect of artificial intelligence investments on export performance becomes stronger as one moves toward the upper quantiles. This indicates that in OECD countries with high export performance, artificial intelligence investments create a more pronounced downward pressure due to transformation costs, restructuring processes, and short-term adjustment problems.

The quantile results related to R&D expenditures indicate that the effect is positive and statistically significant at lower quantiles, while it weakens and becomes insignificant at middle and upper quantiles. This finding suggests that R&D expenditures play a competitiveness-enhancing role particularly in countries with low and medium export performance, whereas their marginal impact diminishes in high performing countries. Overall, the results demonstrate that the relationship between artificial intelligence investments and export performance is not linear, exhibits quantile sensitivity, and implies that policy design should develop differentiated strategies according to countries' export performance levels.

Figure 1 clearly illustrates the quantile sensitive effects of artificial intelligence investments and R&D expenditures on export performance. In the left panel, the curve associated with artificial intelligence investments follows a distinctly downward trajectory from lower to higher quantiles; this indicates that as export performance increases, the effect of artificial intelligence investments becomes stronger and more negative. The widening of the confidence intervals at the upper quantiles suggests that this effect is characterized by greater uncertainty and heterogeneity, particularly at high levels of export performance. In the right panel, the results for R&D expenditures display a more horizontal and limited slope; while a relatively positive effect is observed at lower quantiles, this effect weakens and becomes more uncertain toward higher quantiles. Overall, Figure 1 confirms

that the impact of artificial intelligence investments on export performance is nonlinear and varies significantly across quantiles, whereas the effect of R&D expenditures appears to be more limited and dependent on countries' performance levels.

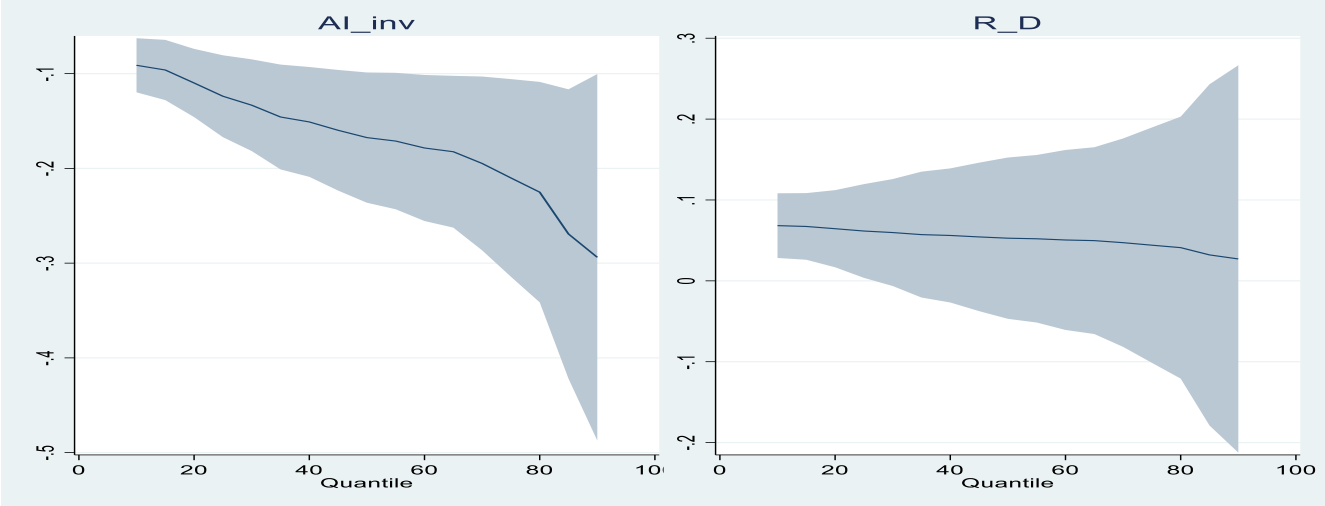

Figure 1. MMQR Model 1

Table 7. MMQR Model 2

	(1) 0.25	**(2)** 0.50	**(3)** 0.75	**(4)** 0.90
location				
AI_inv	-0.1555*	-0.1555*	-0.1555*	-0.1555*
	(-1.65)	(-1.65)	(-1.65)	(-1.65)
R_D	0.0481	0.0481	0.0481	0.0481
	(0.38)	(0.38)	(0.38)	(0.38)
GDP	-0.8596	-0.8596	-0.8596	-0.8596
	(-0.13)	(-0.13)	(-0.13)	(-0.13)
Inf	0.0041	0.0041	0.0041	0.0041
	(0.08)	(0.08)	(0.08)	(0.08)
scale				
AI_inv	-0.0597	-0.0597	-0.0597	-0.0597
	(-0.75)	(-0.75)	(-0.75)	(-0.75)
R_D	-0.0122	-0.0122	-0.0122	-0.0122
	(-0.11)	(-0.11)	(-0.11)	(-0.11)
GDP	-0.4803	-0.4803	-0.4803	-0.4803
	(-0.13)	(-0.13)	(-0.13)	(-0.13)
Inf	0.0030	0.0030	0.0030	0.0030
	(0.07)	(0.07)	(0.07)	(0.07)
qtile				
AI_inv	-0.1219***	-0.1636*	-0.2113*	-0.2885
	(-2.68)	(-1.76)	(-1.41)	(-1.17)
R_D	0.0549	0.0464	0.0367	0.0210
	(0.81)	(0.33)	(0.16)	(0.06)
GDP	-0.5893	-0.9244	-1.3083	-1.9286
	(-0.17)	(-0.13)	(-0.12)	(-0.11)
Inf	0.0024	0.0045	0.0069	0.0108
	(0.09)	(0.08)	(0.07)	(0.07)
N	165	165	165	165
t istatistics in parentheses: * p<0.10, ** p<0.05, *** p<0.01				

Table 7 presents the results of MMQR Model 2, which are obtained by re-estimating the model with the inclusion of economic growth (GDP) and inflation (Inf) as additional control variables. According to the location component, the effect of artificial intelligence investments on export performance remains negative across all quantiles and is statistically significant at the 10% level. This finding indicates that, even after controlling for macroeconomic factors, AI investments continue to exert a short term suppressing effect on export performance, suggesting that this relationship is robust to model specification. In contrast, the coefficients of R&D expenditures, economic growth, and inflation in the location component are not statistically significant, implying that the effects of these macroeconomic variables on export performance may operate through more indirect channels or materialize over a longer horizon.

An examination of the scale component reveals that, unlike in Model 1, the volatility reducing effect of AI investments on export performance loses its statistical significance in Model 2. Similarly, R&D expenditures, GDP, and inflation do not exhibit significant effects in the scale component. This result suggests that once macroeconomic controls are introduced, fluctuations in export performance are more strongly driven by broader economic conditions and structural factors rather than firm-level technological investments alone.

The quantile specific coefficients show that the negative impact of AI investments on export performance is statistically significant in the lower and middle quantiles but weakens and becomes insignificant toward the upper quantiles. This pattern indicates that AI investments have a more pronounced effect in OECD countries with low to medium export performance, while their impact diminishes in high performing countries due to greater adaptive capacity, economies of scale, and institutional maturity. R&D expenditures, economic growth, and inflation do not display statistically significant effects across the quantiles. Overall, the results of Model 2 confirm that the relationship between AI investments and export performance is nonlinear and quantile-dependent, while the inclusion of macroeconomic control variables does not fundamentally alter this relationship.

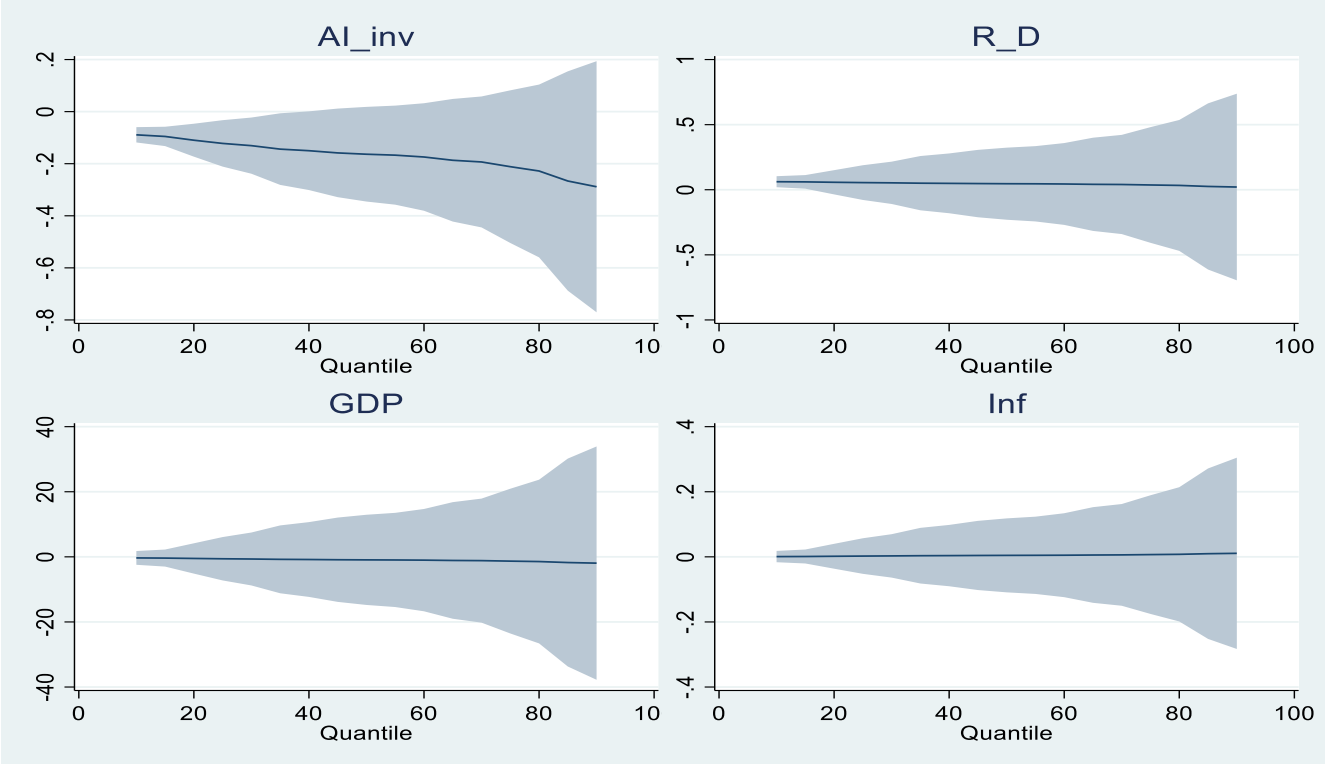

Figure 2. MMQR Model 2

Figure 2 visually presents the quantile sensitive effects of artificial intelligence investments (AI_inv), R&D expenditures (R_D), economic growth (GDP), and inflation (Inf) on export performance within the framework of MMQR Model 2. In the upper left panel, the curve representing artificial intelligence investments exhibits an increasingly pronounced negative trend as quantiles rise; this indicates that the suppressing effect of AI investments becomes stronger as export performance improves. The widening of the confidence intervals at the upper quantiles suggests that this relationship becomes more heterogeneous and uncertain at higher levels of export performance. In the panel corresponding to R&D expenditures, the coefficients remain relatively flat across quantiles while the confidence bands widen, implying that the effect of R&D on export performance is limited and statistically weak. In the lower panels, the estimated curves for GDP and inflation remain close to zero across

quantiles and lack a clear trend, indicating that these macroeconomic control variables do not exert a strong or direct quantile dependent effect on export performance. Overall, Figure 2 clearly demonstrates that the impact of artificial intelligence investments on export performance is nonlinear and varies significantly across quantiles, whereas the effects of R&D, economic growth, and inflation remain comparatively limited.

5. CONCLUSION AND DISCUSSION

The findings obtained in this study show that the relationship between artificial intelligence investments, R&D expenditures, and export performance is neither unidirectional nor linear, but instead is shaped by short term costs, adjustment processes, and country level heterogeneity. In particular, the negative effect of artificial intelligence investments on export performance partially diverges from the dominant narrative in the literature, which frequently emphasizes productivity gains and enhanced competitiveness. Many studies explain the export enhancing role of artificial intelligence through long term productivity improvements and increases in product quality (Zhang & Deng, 2023; Liu et al., 2025; Xu & Tian, 2025). In contrast, the findings of this study reveal that artificial intelligence investments may suppress export performance in the short run, thereby drawing attention to the transition costs and transformation burden that have received relatively limited emphasis in the existing literature. This result is consistent with the arguments implicitly suggested by Sohrabpour et al. (2021) and Neethirajan (2023), who highlight that artificial intelligence investments require organizational restructuring and learning processes.

The results also show a strong alignment with the literature regarding the volatility reducing effect of artificial intelligence on export performance. Existing studies emphasize that artificial intelligence reduces uncertainty through improvements in demand forecasting, risk management, and supply chain coordination (Wang et al., 2023; Chen et al., 2025), which supports the stabilizing effect observed in this study. Therefore, despite exerting a negative effect on export levels in the short term, artificial intelligence appears to make export performance more predictable and stable. This finding indicates that the effects of artificial intelligence on exports should be evaluated not only in terms of levels but also in terms of risk and uncertainty dimensions.

The quantile-based results are largely consistent with the growing literature emphasizing heterogeneous effects. The finding that artificial intelligence investments exert a stronger negative effect in countries with high export performance suggests that transformation costs may be higher in technologically advanced and highly export integrated economies. This result aligns with the view that technological transformation is more costly and time-consuming in countries characterized by complex production networks and advanced value chains (Ou et al., 2024; Chen & Dong, 2025). In contrast, the absence of the positive average effects reported in some studies (Kumar et al., 2025) indicates that the impact of artificial intelligence varies across country groups and export performance levels.

The findings related to R&D expenditures show a high degree of consistency with the existing literature. The positive and statistically significant impact of R&D at low and medium levels of export performance supports studies arguing that R&D investments enhance competitiveness, particularly in technologically lagging countries (Lefebvre et al., 1998; Sandu & Ciocanel, 2014; Goldar, 2013). Conversely, the weakening of the R&D effect in countries with high export performance is consistent with the diminishing marginal returns argument for economies operating close to the technological frontier (Benfratello et al., 2022; Zaman & Tanewski, 2024). This result demonstrates that R&D is not a universally export enhancing tool under all conditions and that its effectiveness depends on a country's position in the export performance distribution.

Moreover, the absence of a statistically significant effect of R&D expenditures on export volatility is consistent with the literature suggesting that R&D primarily influences long term structural competitiveness rather than short term fluctuations in export performance (Carboni & Medda, 2020; Tinits et al., 2025). This finding implies that the effects of R&D investments on exports tend to be indirect, lagged, and mediated through innovation related channels.

6. POLICY RECOMMENDATIONS

The findings of this study show that the effects of artificial intelligence (AI) investments and R&D expenditures on export performance are neither linear nor homogeneous; rather, they vary depending on countries' export levels and structural characteristics. Therefore, policy recommendations should be designed within a framework that

places artificial intelligence at the center and integrates it with R&D activities. Treating AI and R&D as independent policy domains may limit the potential gains in export performance.

First, the fact that AI investments exert a suppressing effect on export performance in the short run suggests that such investments are associated with high initial costs, restructuring processes, and institutional adaptation requirements. In this context, public policies should focus on reducing the costs and uncertainties firms face during the transition to artificial intelligence. Designing direct incentives for AI investments together with tax incentives for R&D expenditures, grant programs, and public-private partnership-based research centers will enable firms to adopt these technologies more effectively. The findings also reveal that AI investments reduce volatility in export performance and play a stabilizing role. This indicates that artificial intelligence provides firms with significant advantages in areas such as demand forecasting, production planning, logistics management, and supply chain optimization. However, making these advantages permanent depends on the development of original and sector specific AI solutions supported by R&D activities. Therefore, it is critical for policymakers to prioritize AI-based R&D projects, particularly in export oriented sectors, and to strengthen university-industry collaborations.

Quantile-based results indicate that the effects of AI investments can be more pronounced and costly in countries with high export performance. In these countries, policy focus should not be limited to investment incentives alone; it should also include strengthening advanced data infrastructure, developing highly qualified R&D human capital, and clarifying the regulatory framework for AI applications. These elements will facilitate the transformation of AI investments into long term productivity and competitiveness gains. For countries with low and medium levels of export performance, AI and R&D supported policies can be considered a strategic tool to enhance export capacity. In these countries, strengthening basic R&D infrastructure, facilitating access of SMEs to AI technologies, and developing knowledge sharing mechanisms should be prioritized. Overall, differentiated policy frameworks that are AI oriented yet integrated with R&D and that take country and sector specific characteristics into account will play a key role in achieving sustainable and stable export performance.

7. LIMITATIONS AND FUTURE RESEARCH

While the findings of this study provide important insights, they should be interpreted within the framework of certain limitations. First, the analysis covers a limited group of OECD countries and the period from 2013 to 2023. This restricts the direct generalizability of the results to developing countries or economies with different institutional structures. In addition, the variable used to represent artificial intelligence investments may not fully capture all dimensions of artificial intelligence, such as sectoral intensity of use, firm-level adoption speed, or the effects of skilled labor. Similarly, R&D expenditures provide only limited information regarding the quality and effectiveness of innovation activities.

Another limitation of the study is the use of macro level data. Country level analyses may overlook firm-level heterogeneity and sector specific differences. Moreover, several important factors that may influence international trade such as exchange rate volatility, trade policies, integration into global value chains, and geopolitical risks are not explicitly included in the model. The omission of these elements may limit the ability to fully capture the effects of artificial intelligence and R&D investments on export performance.

Future research can be extended in several directions to overcome these limitations. First, the analysis can be expanded to include developing countries and regional blocs, thereby strengthening the comparative dimension of the findings. In addition, the use of firm-level or sector level microdata would allow for a more detailed examination of how artificial intelligence and R&D investments affect export performance. Furthermore, to better capture the interaction between artificial intelligence and R&D, future studies may employ models with interaction terms or adopt dynamic and nonlinear methodologies. Finally, future research may focus on the long term effects of artificial intelligence investments by examining the transmission channels through productivity, employment structures, and competitiveness. At the same time, comprehensive models that incorporate digital infrastructure quality, human capital, and institutional regulations would provide more robust and policy relevant insights for decision makers.

AUTHORS' DECLARATION:

This paper complies with Research and Publication Ethics, has no conflict of interest to declare, and has received no financial support.

AUTHORS' CONTRIBUTIONS:

The entire research is written by the author.

REFERENCES

Aksoy, M., Yilmaz, M. K., Golgeci, I., Tatoglu, E., Canci, M., & Hızarcı, A. E. (2024). Untangling the influence of corporate sustainability on export intensity: The moderating role of R&D intensity. *Journal of International Marketing*, *32*(4), 38-57. https://doi.org/10.1177/1069031X231214233

Battaglia, D., Neirotti, P., & Paolucci, E. (2018). The role of R&D investments and export on SMEs' growth: A domain ambidexterity perspective. *Management Decision*, *56*(9), 1883-1903. https://doi.org/10.1108/MD-02-2017-0136

Benfratello, L., Bottasso, A., & Piccardo, C. (2022). 'R&D and export performance: Exploring heterogeneity along the export intensity distribution'. *Journal of Industrial and Business Economics*, *49*(2), 189-232. https://doi.org/10.1007/s40812-022-00209-1

Bojnec, Š. (2014). Research and development spending and export performance by the technological intensity of the products. *Ekonomický Časopis*, *62*(10), 1065-1080. Available at: https://www.sav.sk/journals/uploads/0620145410%2014%20Bojnec%20+%20RS.pdf

Carboni, O. A., & Medda, G. (2020). Linkages between R&D, innovation, investment and export performance: Evidence from European manufacturing firms. *Technology Analysis & Strategic Management*, *32*(12), 1379-1392. https://doi.org/10.1080/09537325.2020.1769841

Chen, X., Wu, Y., & Long, Y. (2025). Does artificial intelligence promote sustainable growth of exporting firms?. *Sustainability*, *17*(16), 7273. https://doi.org/10.3390/su17167273

Chen, Y. A., & Dong, N. (2025). AI capabilities and export performance: The moderating role of province market development and cultural distance. *International Journal of Emerging Markets*, *20*(12), 4907-4925. https://doi.org/10.1108/IJOEM-12-2023-2014

Chishty, S. K., Sayari, S., Mohamed, A. H., Mallick, M. F., Khan, N., & Inkesar, A. (2025). The utilisation of artificial intelligence in the export performance of MNCs: The role of cultural distance. *Administrative Sciences*, *15*(5), 160. https://doi.org/10.3390/admsci15050160

D'Angelo, A. (2012). Innovation and export performance: A study of Italian high-tech SMEs. *Journal of Management & Governance*, *16*(3), 393-423. https://doi.org/10.1007/s10997-010-9157-y

Fan, J., Liao, Y., & Yao, J. (2015). Power enhancement in high-dimensional cross-sectional tests. *Econometrica*, *83*(4), 1497-1541. https://doi.org/10.3982/ECTA12749

Fang, Y., & Liu, W. (2025). Artificial intelligence and export green sophistication. *The Journal of International Trade & Economic Development*, *34*(7), 1737-1760. https://doi.org/10.1080/09638199.2025.2545761

Goldar, B. (2013). R&D intensity and exports: A study of Indian pharmaceutical firms. *Innovation and Development*, *3*(2), 151-167. https://doi.org/10.1080/2157930X.2013.828878

Gur, N., & Avşar, V. (2016). Financial system, R&D intensity and comparative advantage. *The Journal of International Trade & Economic Development*, *25*(2), 213-239. https://doi.org/10.1080/09638199.2015.1045928

Han, L., Wojan, T. R., Tian, Z., & Goetz, S. J. (2024). How export performance is mediated by innovation, owner characteristics, and location. *Economics Letters*, *237*, 111657. https://doi.org/10.1016/j.econlet.2024.111657

Khiewngamdee, C., & Chanaim, S. (2025). The role of institutional and innovation ecosystem in moderating the impact of green practices on export performance: Evidence from European countries. *Sustainability*, *17*(20), 9146. https://doi.org/10.3390/su17209146

Kumar, S., Kumar, V., Chatterjee, S., Mariani, M., & De Massis, A. (2025). The role of artificial intelligence capabilities in enhancing export performance: A study of ambidexterity and dynamic capabilities. *International Marketing Review, 42*(4), 698-714. https://doi.org/10.1108/IMR-10-2024-0426

Kwon, H. B., Lee, J., & Brennan, I. (2025). Complex interplay of R&D, advertising and exports in USA manufacturing firms: Differential effects of capabilities. *Benchmarking: An International Journal*, *32*(2), 459-491. https://doi.org/10.1108/BIJ-03-2023-0183

Lefebvre, E., Lefebvre, L. A., & Bourgault, M. (1998). R&D-related capabilities as determinants of export performance. *Small Business Economics*, *10*(4), 365-377. https://doi.org/10.1023/A:1007960431147

Leung, T. Y., & Sharma, P. (2021). Differences in the impact of R&D intensity and R&D internationalization on firm performance–Mediating role of innovation performance. *Journal of Business Research*, *131*, 81-91. https://doi.org/10.1016/j.jbusres.2021.03.060

Lin, C., Xiao, S., & Tang, P. (2024). Does artificial intelligence improve export technical complexity upgrade of manufacturing enterprises? Evidence from China. *Sage Open*, *14*(3), 21582440241267126. https://doi.org/10.1177/21582440241267126

Liu, J., Qin, C., & Chu, X. (2025). Development of corporate artificial intelligence and the quality of export products. *Finance Research Letters*, *78*, 107217. https://doi.org/10.1016/j.frl.2025.107217

Machado, J. A., & Silva, J. S. (2019). Quantiles via moments. *Journal of Econometrics*, *213*(1), 145-173. https://doi.org/10.1016/j.jeconom.2019.04.009

Naidoo, K. (2024). R&D, exports and employment growth: Firm-level evidence using administrative data from South Africa. *The Journal of International Trade & Economic Development*, *33*(5), 818-844. https://doi.org/10.1080/09638199.2023.2222423

Neethirajan, S. (2023). Artificial intelligence and sensor technologies in dairy livestock export: Charting a digital transformation. *Sensors*, *23*(16), 7045. https://doi.org/10.3390/s23167045

Ou, J., Zheng, Z., Ou, X., & Zhang, N. (2024). Smart city construction, artificial intelligence development, and the quality of export products: A study based on micro-level data of Chinese enterprises. *Sustainability*, *16*(19), 8640. https://doi.org/10.3390/su16198640

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265-312. https://doi.org/10.1002/jae.951

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, *142*(1), 50-93. https://doi.org/10.1016/j.jeconom.2007.05.010

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews*, *34*(6-10), 1089-1117. https://doi.org/10.1080/07474938.2014.956623

Rahman, M. S., Golder, U., & Ghosh, P. (2024). Corporate investment in artificial intelligence: The role of GDP, ICT exports, and patents. *Journal of Economics and Management*, *46*, 613-636. https://doi.org/10.22367/jem.2024.46.21

Rauf, A., & Bao, Y. (2024). Assessing the effect of domestic and foreign R&D on export: Empirical evidence from China. *International Journal of Emerging Markets*, *19*(11), 3828-3847. https://doi.org/10.1108/IJOEM-02-2022-0282

Sandu, S., & Ciocanel, B. (2014). Impact of R&D and innovation on high-tech export. *Procedia Economics and Finance*, *15*, 80-90. https://doi.org/10.1016/S2212-5671(14)00450-X

Shu, C., Zhao, J., Yao, Q., & Zhou, K. Z. (2024). Green innovation and export performance in emerging market firms: A legitimacy-based view. *Management and Organization Review*, *20*(1), 85-110. https://doi.org/10.1017/mor.2023.40

Sohrabpour, V., Oghazi, P., Toorajipour, R., & Nazarpour, A. (2021). Export sales forecasting using artificial intelligence. *Technological Forecasting and Social Change*, *163*, 120480. https://doi.org/10.1016/j.techfore.2020.120480

Sousa, C. M., Tsinopoulos, C., Yan, J., & Benito, G. R. (2025). Finding the sweet spot: Effects of exporting on the relationship between R&D investment and NPD performance. *International Marketing Review*, *42*(1), 35-63. https://doi.org/10.1108/IMR-02-2024-0039

Tinits, P., Yi, J., Fey, C. F., & Meng, S. (2025). Government R&D support's effects on export performance via innovation: An analysis of organizational motivators as moderators. *International Business Review*, *34*(1), 102345. https://doi.org/10.1016/j.ibusrev.2024.102345

Wang, F., Wong, W. K., Ortiz, G. G. R., Al Shraah, A., Mabrouk, F., Li, J., & Li, Z. (2023). Economic analysis of sustainable exports value addition through natural resource management and artificial intelligence. *Resources Policy*, *82*, 103541. https://doi.org/10.1016/j.resourpol.2023.103541

Wang, Y., Wang, T., & Wang, Q. (2024). The impact of digital transformation on enterprise performance: An empirical analysis based on China's manufacturing export enterprises. *Plos one*, *19*(3), e0299723. https://doi.org/10.1371/journal.pone.0299723

Westerlund, J. (2008). Panel cointegration tests of the Fisher effect. *Journal of Applied Econometrics*, *23*(2), 193-233. https://doi.org/10.1002/jae.967

Xu, X., & Tian, C. (2025). Does artificial intelligence improve the quality of export products? Evidence from China. *Applied Economics Letters*, *32*(1), 9-13. https://doi.org/10.1080/13504851.2023.2244224

Zaman, M., & Tanewski, G. (2024). R&D investment, innovation, and export performance: An analysis of SME and large firms. *Journal of Small Business Management*, *62*(6), 3053-3086. https://doi.org/10.1080/00472778.2023.2291363

Zhang, Z., & Deng, F. (2023). How can artificial intelligence boost firms' exports? Evidence from China. *Plos one*, *18*(8), e0283230. https://doi.org/10.1371/journal.pone.0283230