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Does Trade Freedom Affect Exchange Rate Movement? A perspective of High-Technology Trade

Abstract: Changes in the degree of trade freedom influence economic development and foreign investment, which in turn, affect currency values and exchange rate movements. Therefore, this study examined the direct and indirect impacts of trade freedom on exchange rate movement in emerging, developing, and developed economies. Empirical tests conducted using panel data from 75 countries revealed that trade freedom has a nonlinear U-shaped relationship with exchange rate movement, which is positively moderated by high-technology trade and foreign direct investment. Additionally, the results of heterogeneity analysis showed that trade freedom has a linear positive impact on the exchange rate movement of developed economies but a U-shaped impact on emerging and developing economies, with a stronger impact on emerging economies. The findings of this study provide valuable insights for governments to strike a balance between promoting trade freedom and maintaining currency exchange rate stability.

Keywords: Trade freedom; exchange rates; trade development; system GMM;

JEL: F4; F19

1 Introduction

The importance of the exchange rate lies in its direct impact on cross-border investment, capital flows, financial markets, and fiscal and monetary policies (Rafi and Ramachandran, 2018; Lu et al., 2022). Exchange rate research is, therefore, a valuable reference for firms, investors, and policymakers in understanding and adapting to exchange rate fluctuations and maximizing opportunities (Yildirim and Saraç, 2022).

Although most existing studies have examined the exchange rate issue from macro and micro perspectives, it is necessary to recognize that currently, many countries are actively participating in different agreements to promote the development of their economies. Among these, the following three agreements carry significant global impact at present: the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), the Belt and Road Initiative (BRI), and the Regional Comprehensive Economic Partnership (RCEP). The CPTPP and RCEP are regional trade agreements that aim to promote free trade, while the BRI emphasizes unimpeded international trade

as one of its key focus areas. Presumably, the degree of international trade freedom affects the level of international trade development (Keho, 2017; Ganguly and Acharyya, 2022), which can also cause exchange rate fluctuations in a country (Kang and Dagli, 2018).

Therefore, this study argues that the degree of trade freedom is an important factor influencing exchange rate movement. However, the impact of trade freedom on exchange rate movement is complex and contingent on several factors. First, from a trade development perspective, trade freedom can indirectly affect exchange rates through its impact on international trade. When countries implement trade freedom policies that reduce trade barriers and promote free trade and open markets, they increase the scale of international trade. Specifically, the trade of high-technology involves knowledge-intensive products and services, typically characterized by higher value-added and innovativeness. Thus, when a country increases its high-technology trade, it demonstrates superior competitiveness and productivity, which stimulates domestic currency appreciation and triggers exchange rate movements.

Second, from an investor's perspective, trade freedom can indirectly affect the exchange rate through its impact on foreign direct investment (FDI). Trade freedom encourages the expansion of international trade and economic development, which may attract more FDI inflows. Increased FDI alters capital flows and supply and demand in the foreign exchange market, thereby shifting the exchange rate. For example, more FDI may increase the demand for the national currency, leading to an appreciation of the exchange rate; conversely, a decrease in FDI may reduce the demand for the national currency, leading to a depreciation of the exchange rate. Thus, trade freedom indirectly affects exchange rate trends and movements through its impact on FDI.

Based on these arguments, this study endeavors to provide a comprehensive understanding of the relationship between trade freedom and exchange rate movement through the mechanisms of high-technology trade and FDI. In addition, to identify and compare differences in this impact between different types of countries, this study aims to perform heterogeneity analysis based on countries' economic size, i.e., developed, emerging, and developing economies. By achieving these objectives, this paper offers deeper insights into the direct, indirect, and heterogenous impacts of trade freedom on exchange rates, providing not only academic value but also a basis for policy formulation and national development towards increased trade freedom and exchange rate stability.

The overall structure of this article is as follows. The first section is the introduction, which has briefly described the purpose and significance of the study. The second section reviews the relevant literature, including previous studies and theoretical frameworks. The third section describes the data sources and methods used in the study, followed by the fourth section which reports and discusses, in depth, the results of the empirical analyses. Finally, the fifth section summarizes the findings of the study and provides relevant policy recommendations.

2 Literature Review and Hypotheses

2.1 Literature Review

The first part of the literature review focuses on the factors affecting the exchange rate, with particular emphasis on trade freedom. The second part presents the formulation of the hypotheses.

Extensive research has been conducted on exchange rates. Frenkel (1976) proposed a monetary exchange rate theory that links exchange rates to money supply and other monetary variables. Dornbusch (1976) expanded the theory of exchange rate by accounting for the full capital mobility and slow commodity market adjustment relative to capital markets. Subsequent in-depth studies of exchange rate-related theories by Taylor (1995), Sager and Taylor (2006) have provided detailed and up-to-date descriptions of the microstructure of the foreign exchange market and the behavior of participant groups. Evans and Lyons (2002), Evans and Lyons (2005), Gradojevic (2007), and Gençay and Gradojevic (2013) further established that microstructure models are highly sensitive to the choice of period and forecast horizon when used for forecasting.

With regards to empirical studies, there exists a large body of literature confirming the effects of various factors on exchange rate movement. For example, Giorgio et al. (2018), who studied the response of government spending to exchange rate shocks in a two-country model with productive government purchases and non-Ricardian households, found that the real exchange rate decreases as domestic public spending increases. More recently, Liu and Shaliastovich (2022) identified a significant relationship between government policies and exchange rate movement. It has also been proven that the exchange rate maintains a close relationship with macroeconomic and financial variables, such as the level of economic development (Chin et al., 2007b, Jamil et al., 2023), inflation rate (Purnomo, 2017), supply of money (Chin et al., 2007a, Chin et al., 2009b), government

debt (Lin, 1994), interest rates (Chin, et al. 2009a, Saraç and Karagöz, 2016), remittances (Singer, 2010; Kim, 2019; Saydaliyev et al., 2020), changes in industrial structure (Rashid and Basit, 2022), monetary policy (Kyin et al., 2013), financial openness (Rodriguez, 2017), and trade balance (Ozcelebi et al., 2021).

In addition, Anwer et al. (2022) explored the dynamic linkages among the currencies of the South Asian Association for Regional Cooperation (SAARC) countries and the Association of Southeast Asian Nations (ASEAN) countries using the continuous wavelet transform methodology. Their findings indicate that regional proximity does not necessarily translate into exchange rate correlation. Moreover, since exchange rate stability is a manifestation of financial stability, factors related to financial crises may also affect exchange rates. Marchionne et al. (2022a) found that the probability of a financial crisis rises as regulation is tightened from low to medium and falls as regulation is tightened from medium to high, conforming to an inverted U-shaped curve. Marchionne et al. (2022b) then supported their prior findings by revealing that countries with moderately stringent financial regulations face more financial instability than those with lax or stringent regulations.

Scholars have also analyzed the impact of trade on exchange rates from different perspectives of trade development. For instance, Chen (2022) used panel data of 45 major countries in the world to demonstrate that trade opening and real exchange rate fluctuations are negatively correlated. In addition, Manzor (1995) posited that terms of trade constitute an important factor driving exchange rate movement, while Kotil (2019) found that both exports and imports affect exchange rates.

Despite the evidence above, there is a noticeable lack of research on the nonlinear impact of trade on exchange rate movement, as scholars have predominantly focused on the opposite direction, i.e., the effect of exchange rate on trade. For example, Helmut (2003) explored the nonlinear impact of exchange rate uncertainty on trade, whereas Iyke and Ho (2018) found that real exchange rate changes have a significant nonlinear impact on South Africa's trade balance, supporting the findings of Arize et al. (2017). Most recently, Bosupeng et al. (2024) revealed the asymmetric effects of exchange rate fluctuations on the impact of trade balance appreciation and depreciation in developed and developing countries. In contrast, the perspective of trade freedom as a determinant of exchange rate movement has been understudied. To address this gap in the literature, this study examines the

relationship between trade freedom and exchange rate movement.

2.2 Hypothesis development

Freedom to trade has a significant impact on national economies (Cebula, 2010; Dempere and Pauceanu, 2022); in turn, national economic development affects changes in currency exchange rate (Tyers, 2008). Therefore, this study posits a relationship between trade freedom and exchange rate movement, as follows:

Hypothesis 1:

H₀: Trade freedom does not affect exchange rate movement.

H₁: Trade freedom affects exchange rate movement.

Significance Level: $\alpha = 0.1$

Increased trade freedom reduces tariffs and trade barriers, facilitates the free flow of international trade, expands market size, and promotes trade development (Kohi, 2014). As high-technology trade grows, in particular, the demand for domestic currency increases to a certain extent (Berggren and Jordahl, 2005). Therefore, it is hypothesized that:

Hypothesis 2:

H₀: High- technology trade does not play a moderating role in the effect of trade freedom on exchange rate movement.

H₁: High- technology trade plays a moderating role in the effect of trade freedom on exchange rate movement.

Significance Level: $\alpha = 0.1$

Trade freedom has also been found to promote FDI (Ghazalian and Frederick, 2019). As FDI inflows increase, investors demand more of the host country's currency, which increases the currency's value. This leads to a relatively stable or rising exchange rate (Hegerty, 2009). Accordingly, the following hypothesis is proposed:

Hypothesis 3:

H₀: FDI does not play a moderating role in the effect of trade freedom on exchange rate

movement.

H₁: FDI plays a moderating role in the effect of trade freedom on exchange rate movement.

Significance Level: $\alpha = 0.1$

From the perspective of international economics, initial trade freedom can lead to an appreciation of the national currency. However, when such freedom becomes excessive, it may reduce export competitiveness and eventually lead to a decline in the exchange rate. On the other hand, an initial increase in trade freedom may lead to a depreciation of the national currency as foreign investment and capital inflows increase money supply. As the economy grows and foreign investment increases, the national currency then appreciates as investors become more bullish towards the national economy and are willing to hold more of the national currency. The assumptions for these potential effects are set out below:

Hypothesis 4:

H₀: Trade freedom does not have a nonlinear effect on exchange rate movement.

H₁: Trade freedom has a nonlinear effect on exchange rate movement.

Significance Level: $\alpha = 0.1$

3 Research Methodology and Data

3.1 Dependent variable

Exchange rates (Rates): Exchange rate is the dependent variable of this research. In this study, the real effective exchange rate index (2010 = 100) was chosen to measure exchange rate movement, where the higher the real effective exchange rate index, the higher the exchange rate. The data for the real effective exchange rate index was obtained from the World Bank Development database.

3.2 Independent variables

Trade Freedom (Freedom): Trade freedom is the core explanatory variable of this study. To adequately measure the level of trade freedom, this study referred to Hussain and Haque (2016) and Brkić et al. (2020) in choosing the Trade Freedom Index of the Index of Economic Freedom. This index is jointly published by the Wall Street Journal and the Heritage Foundation, where a higher

index value reflects a greater level of trade freedom. The data was obtained from the Wall Street Journal and the Heritage Foundation.

3.3 Control Variables

Per Capita Gross Domestic Product (Pgdp): Economic development level is one of the most important factors affecting the value of national currencies (Tyers et al., 2008). A high level of economic development often reflects a better investment climate and economic stability, which contributes to the value of the national currency. Therefore, in this paper, the GDP per capita of each country was chosen to measure national economic development, and its correlation with exchange rate movement was expected to be positive.

Government Integrity (Integrity): Government behavior is the most direct reflection of a country's development status. Notably, government integrity can play a key role in the national development process, as it can increase investors' confidence in the country's economy and currency (Wang, 2020). This may attract more foreign investment and capital inflows, which contribute to national currency appreciation. To accurately measure the level of government integrity, this paper chose the Government Integrity Index from the Index of Economic Freedom, which was expected to have a positive correlation with exchange rate movement.

Remittance (Remit): Capital flows, in which remittances constitute a main component, are important factors in exchange rate movement. The receipt of large remittances implies the need for more domestic currency, which may lead to its appreciation (Nketiah et al., 2019). Therefore, this study chose the ratio of total annual remittances received to GDP to measure remittances, with an expected positive correlation with exchange rate movement.

Interest rates (Interest): The interest rate is an indicator of the cost of borrowing or the return on funds, and is usually set by central banks or financial institutions (Sanchez, 2008). Higher interest rates imply a higher cost of borrowing or a higher return on holding the financial asset of a currency, which attracts more investors to the country's currency and bonds; subsequently, the demand for the national currency increases, contributing to its appreciation (Bjørnland and Hungnes, 2006). Conversely, lower interest rates render the national currency less attractive and lead to its depreciation. Therefore, the average annual interest rate of the sample countries was selected as an indicator of their interest rate level, where the expected correlation sign with exchange rate

movement was positive.

Government Debt (Debt): Debt is the total amount of bonds or borrowings issued by national or regional governments to raise funds. An increase in the level of government debt may raise market concerns about the stability and sustainability of the country's economy, which would reduce investor confidence in the country's currency and depreciate the national currency value (Lin, 1994; Bleaney and Ozkan, 2011). Therefore, the level of government debt was measured as a share of GDP in this study, which was expected to have a negative correlation sign with exchange rate movement.

Inflation (Inflation): Higher rates of inflation may hurt the exchange rate. A decrease in purchasing power makes the national currency unattractive in the international market, reducing investors' and foreign buyers' demand for the national currency, thus triggering its depreciation (Ha et al., 2020). Therefore, the level of inflation was measured using the GDP deflator (annual percentage), which was expected to have a negative correlation with exchange rate movement.

Trade Balance (Balance): Trade balance is a state in which the total exchange of goods and services between a country's exports and imports is equal over a given period. There is an interaction between the trade balance and exchange rate movements; a trade surplus means that more foreign buyers demand the country's currency as they purchase the country's goods and services, thus pushing the currency to appreciate (Narayan, 2006). In this paper, trade balance was measured as the total trade balance of goods and services, with higher trade surpluses expected to have a positive impact on exchange rate movement.

Equity market (Equity): A country's stock market index is derived by tracking the overall performance of a representative basket of stocks in its stock market. The performance of the stock market can reflect economic conditions and investor confidence, thereby affecting the relative value of a country's currency (Mishra, 2004). When stock markets perform well, investors are more willing to invest in that country's assets, causing demand to rise and thereby driving the country's currency to appreciate. Conversely, a weak stock market depreciates the country's currency (Md-Yusuf and Rahman, 2012). Following the research of Fidora et al. (2007) and Dua and Tuteja (2016), this paper used the S&P Global Stock Index to measure the performance of a country's stock market index, where its correlation with exchange rate movement was expected to be positive.

3.4 Data description

This study used panel data for 75 countries from 2015 to 2021 to achieve its objectives. To better grasp the impact of trade freedom on the exchange rate of different countries' currencies, the selection of countries for this research included only nations that each possess their own independent currency and have adopted a floating exchange rate system. The variables' data was obtained from the World Bank Development database, the International Monetary Fund database, the Index of Economic Freedom (jointly published by the Wall Street Journal and the Heritage Foundation), the Trading Economics database, and the national statistical yearbooks of each country. The descriptive statistics for the variables are presented in Table 1. In addition, tests for multicollinearity were conducted, showing that all variance inflation factor values were below 5.0 (as in Appendix A1). This result alleviated concerns about bias in the estimates due to multicollinearity.

Table 1 Descriptive statistics of full sample

Category	Variable Name	Observations	Measurement	Mean	Standard Deviation	Min	Max	Expected Sign
Dependent variable	Rates	525	Index	97.81500	13.85974	53.7907	144.1530	
Independent variable	Freedom	525	Index	77.29	10.29308	45.2	95	
	Pgdp	525	US\$	22695.27	24901.17	216.8274	133711.8	+
Control variables	Integrity	525	Index	52.7845	22.6759	6.5	99.5	+
	Remit	525	Percentage	3.17145	4.62018	0.021	29.4390	+
	Interest	525	Percentage	4.90603	6.42064	-12.6627	41.7138	+
	Debt	525	Ratio	48.3591	26.9252	2.8895	170.3622	-
	Inflation	525	Percentage	3.44541	4.44095	9.1739	38.88167	-
	Balance	525	US\$	6.298E+09	8.888E+10	-8.4158E+11	4.61494E+11	+
	Equity	525	Index	4.00195	20.87531	-47.93718	135.7286	+

3.5 Empirical methodology

Due to the possible endogeneity between trade freedom and exchange rate, this study used a series of system Generalized Method of Moments (GMM) models for analysis. All the variables in this paper were upscaled into positive values before being logarithmized. A panel data model was constructed as shown in Equation (1), which excludes the control variables, and Equation (2), which includes the control variables. To test Hypothesis 4, a squared term for Freedom was added to the estimated models in Equations (1) and (2). If a nonlinear relationship exists, α_1 and α_2 should exhibit a statistically significant difference. If it is not statistically significant, Hypothesis 4 would

be rejected. After excluding the nonlinear effect, the squared term of Freedom was removed from the model and a new model, as shown in Equation (3), was built for re-estimation.

$$\text{Ln}(\text{Rates}_{i,t}) = \alpha_0 + \alpha_1 \text{Ln}(\text{Rates}_{i,t-1}) + \alpha_2 \text{Ln}(\text{Freedom}_{i,t}) + \alpha_3 (\text{Ln}(\text{Freedom}_{i,t}))^2 + \varepsilon_{i,t} \quad (1)$$

$$\text{Ln}(\text{Rates}_{i,t}) = \alpha_0 + \alpha_1 \text{Ln}(\text{Rates}_{i,t-1}) + \alpha_2 \text{Ln}(\text{Freedom}_{i,t}) + \alpha_3 (\text{Ln}(\text{Freedom}_{i,t}))^2 + \beta Z_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$\text{Ln}(\text{Rates})_{i,t} = \alpha_0 + \alpha_1 \text{Ln}(\text{Rates}_{i,t-1}) + \alpha_2 \text{Ln}(\text{Freedom}_{i,t}) + \beta Z_{it} + \varepsilon_{it} \quad (3)$$

In equation (2), z denotes all control variables that affected the change in the exchange rate. ε_{it} was the error term. α_1 , α_2 , α_3 and β were the coefficients to be estimated.

Several robustness checks were conducted to ensure the reliability of the benchmark estimates. First, considering that COVID-19 has had a huge impact on the world's economy, a dummy variable was introduced. Business shutdowns and economic downturns reduced currency demand while increasing the appeal of safe-haven assets among investors; as such, the impact of COVID-19 on exchange rate was expected to be negative. A dummy variable D_1 was thus added into Equation (2), in which D_1 takes the value '1' for the years 2020 and 2021, and '0' otherwise.

Second, the validity of the baseline test results was re-estimated using variable substitution. Specifically, the real effective exchange rate index was replaced with the official exchange rate and Equation (2) was re-estimated. Third, referring to Ding et al. (2022), the fixed effects model can control for individual fixed effects and reduce the effect of endogeneity. By comparing the model's results with system GMM estimates, the reliability of the latter can be better determined. Equation (4) presents the fixed effects model, where μ_i and ν_t are the fixed effects for country and year, respectively.

$$\text{Ln}(\text{Rates}_{it}) = \alpha_0 + \alpha_1 \text{Ln}(\text{Freedom}_{it}) + \alpha_2 \text{Ln}(\text{Freedom}_{it})^2 + \beta Z_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (4)$$

In Equations (4), μ_i and ν_t are the fixed effect for country and year respectively.

Finally, due to potential unobserved limitations in the study design, the benchmark regression results on the impact of trade freedom on exchange rate may be a mere placebo. Therefore, following Cong et al. (2023), a placebo test was conducted by removing all data from the sample, randomly reallocating the data, and re-estimating the baseline test using the modified dataset. If the

relationship between trade freedom and exchange rate in the original model was not a placebo effect, the results of the placebo test should not show the same degree of results.

4. Empirical Findings and Discussion

4.1 Baseline regression results

The preliminary estimation of Equations (1) and (2) was carried out using a system GMM model, the results of which are presented in Columns I and II of Table 2. The Sagan test and AR tests were conducted to ensure the validity of the GMM estimations. The Sagan test result was not significant at the 10% level in Columns I and II, indicating that the instrumental variables were valid and there was no over-identification. Moreover, AR(1) was significant at the 5% level while AR(2) was not significant at the 10% level. Therefore, the error terms were not autocorrelated and the GMM model was appropriate.

The GMM analysis shows that the coefficient of Ln(Freedom) was negative in all models, while the coefficient of its squared term was positive. Moreover, both coefficients were statistically significant at the 1% level. These results suggest that trade freedom significantly affects exchange rate movement, and this effect takes a U-shape. Hence, support was provided for Hypothesis 1. To further investigate this effect, a U-test was conducted, which confirmed the U-shaped relationship between trade freedom and exchange rate movement; therefore, Hypothesis 4 was supported as well. The U-shaped relationship between trade freedom and exchange rate can be explained as follows. Initially, increased trade freedom depreciates the national currency because an open trade policy attracts more foreign investment and capital inflows, leading to a higher supply of domestic currency for foreign investors to perform transactions and investments. This increased supply of money triggers a relative depreciation of the national currency, as more national currency becomes available in the market. Indeed, an excess of supply over demand typically causes a decline in the exchange rate.

Regarding the control variables in the benchmark model (Column II), the coefficients of six variables, namely Ln(Pgdp), Ln(Integrity), Ln(Remit), Ln(Interest), Ln(Balance) and Ln(Equity), were positive and statistically significant. This shows that, firstly, when a country's economic growth is strong, external investors are more likely to invest in that country, leading to increased

demand for the country's currency and subsequent exchange rate appreciation (Tyers et al., 2008). Secondly, the improvement of government integrity may boost investors' trust in the country, prompting them to purchase the country's currency and thereby promoting exchange rate appreciation (Wang, 2020). Thirdly, higher remittance inflows indicate that more external funds are flowing into the country, increasing foreign exchange supply and thus, appreciating the domestic currency (Nketiah et al., 2019). Fourth, higher interest rates may attract international investors as they can earn higher returns. Investors purchase the country's currency to obtain higher interest rates, thereby promoting the appreciation of the country's currency (Bjørnland and Hungnes, 2006). Fifth, when a country's exports exceed its imports, the resulting trade surplus creates demand for its currency. A trade surplus may prompt foreign countries to purchase domestic currency to pay for exported goods, promoting the appreciation of the domestic currency (Kharroubi, 2011). Finally, strong stock market performance may attract foreign investors, whose equity purchases involve purchases of the domestic currency; this promotes exchange rate appreciation (Dunne et al., 2010).

On the other hand, the coefficients of two control variables, Ln(Debt) and Ln(Inflation), were negative and statistically significant. Therefore, government debt depreciates the exchange rate of national currency, which is in agreement with Hsing's (2016) finding. This implies that an increase in government debt may trigger market concerns about the stability of the country's economy, which reduces investor confidence and leads to the depreciation of the national currency (Alzahrani, 2018). Furthermore, the negative effect of inflation on the exchange rate, supporting the finding of Achسانی et al. (2010), may be because inflation weakens the purchasing power of the currency, which in turn affects investor confidence.

4.2 Robustness checks results

To test the robustness of the baseline regression results, four tests were conducted, the results of which are shown in Columns III to V of Table 2. Column III shows the effect of the COVID-19 dummy variable (D_1) on exchange rate movement. The signs of trade freedom and its squared term were found to be consistent with those from the benchmark test, proving that the latter's results are robust. In addition, the effect of the COVID-19 dummy variable on exchange rate movement was negative but not significant. The exchange rate is affected by a variety of factors, such as economic data, monetary policy, and geopolitics. Although COVID-19 is an important

phenomenon, it may be less statistically dominant than other factors, making its effect insignificant.

In Column IV, the official exchange rate was used instead of the exchange rate index as the dependent variable in the baseline model. The results indicate that all estimated coefficients carried same signs as the baseline regression, and the Sagan and AR tests proved that these results were robust. Next, the results of the fixed effects model in Column V were similar to those of the baseline GMM regression, confirming the reliability and accuracy of the latter. Lastly, the results of the placebo test in Column VI show that the trade freedom coefficients were statistically insignificant and differed significantly from the baseline estimates, suggesting that the results of the baseline model were not placebo effects

4.3 Endogenous resolution

The results of the baseline regression may suffer from endogeneity, as exchange rate movement also has an inverse effect on trade freedom. In this study, the first-order lag term of the trade freedom variable was used as an instrumental variable to address the potential endogeneity problem. D'Agostino et al. (2023) found that economic freedom hinders the underground economy, which can be resolved by using first-order lag terms to address endogeneity in consideration of the advantages and disadvantages of the system GMM approach. Moreover, the change in the first-order lag term of trade freedom was not directly related to exchange rate movement, which is also in line with the exclusivity assumption of the instrumental variable. Therefore, this instrumental variable met the relevant requirements and was tested using the two-stage least squares method. The results of this analysis, shown in Column VII of Table 2, demonstrate that both trade freedom and its square term significantly affect exchange rate movement, verifying that the benchmark results are robust.

Table 2 Baseline regression and robustness check results

	Baseline regression			Robustness checks			Endogenous resolution
	SYS-GMM		COVID-19	Replacement variable	Fixed effect	Placebo effect	Two-stage least squares
	I	II	III	IV	V	VI	VII
<i>Ln(Freedom)</i>	-0.5267*** (-4.4327)	-0.5014*** (-4.2078)	-0.4837*** (-5.6974)	-0.6152*** (-6.3798)	-0.8217*** (-6.8435)	0.0049 (1.1214)	-0.0723*** (-5.4329)
<i>Ln(Freedom)²</i>	0.0628*** (3.6782)	0.0513*** (3.2541)	0.0429*** (4.6513)	0.0695*** (5.3257)	0.0799*** (4.7518)	0.0008 (0.2253)	0.0037*** (4.3261)
<i>Ln(Pgdp)</i>		0.1332*** (5.0427)	0.1373** (2.1807)	0.0489** (2.2921)	0.1057*** (5.2641)	0.0948** (4.9272)	0.1227*** (5.7019)
<i>Ln(Integrity)</i>		0.0069** (2.3836)	0.0421*** (3.9275)	0.1021*** (4.3284)	0.0781** (5.05271)	0.0762*** (6.0113)	0.0632*** (4.1483)
<i>Remit</i>		0.0009*** (6.4712)	0.0071*** (5.6181)	0.0172*** (4.0152)	0.0468*** (4.5712)	0.0521*** (4.9705)	0.0051* (1.6947)
<i>Ln(Interest)</i>		0.0307*** (4.5142)	0.0297** (2.5360)	0.0095** (2.5158)	0.0812*** (5.6828)	0.0794*** (5.7950)	0.0348*** (4.0396)
<i>Ln(Debt)</i>		-0.0073** (-2.5136)	-0.0136*** (-4.8137)	-0.0412*** (-5.0314)	-0.0273*** (-4.6815)	-0.0257*** (-5.1071)	-0.0334*** (-4.5176)
<i>Ln(Inflation)</i>		-0.1072*** (-4.5767)	-0.1031*** (-5.7182)	-0.1256*** (-4.7581)	-0.1137*** (-5.3996)	-0.1041*** (-5.5107)	-0.0563*** (-4.4672)
<i>Ln(Balance)</i>		0.3347*** (7.4167)	0.1948*** (6.8273)	0.2002*** (7.3290)	0.1923*** (6.8140)	0.1795*** (5.9074)	0.0548*** (6.2107)
<i>Ln(Equity)</i>		0.2174*** (6.2823)	0.1734*** (5.9726)	0.2034*** (6.8157)	0.1826*** (5.9743)	0.1749*** (6.1312)	0.0294*** (2.9714)
Constant	2.6475*** (6.5842)	3.7424*** (7.9627)	2.1732*** (5.2841)	1.2743*** (4.8702)	3.2715*** (8.6172)	3.2142*** (7.2103)	1.0637*** (5.2163)
<i>Ln(Rates_{t,t-1})</i>	0.7325*** (29.6018)	0.6922*** (8.6018)	0.6375*** (7.3254)	0.5304*** (6.7893)			
D ₁			-0.0040 (-1.1687)				
Sargan test	0.732	0.743	0.711	0.632			
AR(1)	0.031	0.028	0.034	0.038			

AR(2)	0.794	0.767	0.637	0.685	
DWH					39.71(p=0.000)
U Test					
Extreme point	4.47				
	Lower	Upper			
Interval	3.76	5.97			
Slope	0.58	-0.83			
t-value	1.75	-3.12			
P > t	0.00	0.00			
t-value	1.75				
P	0.00				

Notes: t-statistics are in parentheses, ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Test: H1: U shape vs. H0: Monotone or Inverse U-shape.

4.4 Further analysis

4.4.1 Mechanism analysis

Building on existing research, this study empirically examined how increased trade freedom affects the exchange rate through two main channels: high-technology trade and FDI. Currently, there is no relevant data on total high-technology trade in any database; hence, this paper referred to the study of Idris et al. (2021) to calculate total high-technology trade (exports and imports) according to the Standard International Trade Classification (SITC - Rev. 4) codes of relevant high-technology trade products in the United Nations Commodity Trade Statistics Database. The ratio of FDI inflows to GDP was taken as a measure of FDI, the data for which were obtained from the World Bank Development database and the statistical yearbooks of the sample countries.

First, a system GMM estimation was conducted without the trade freedom variable to determine the effects of high-technology trade and FDI on exchange rate movement. Second, to test whether trade freedom affects the exchange rate through high-technology trade, the interaction term between trade freedom and high-technology trade ($\text{Ln}(\text{Freedom}) * \text{Ln}(\text{Trade})$) was added to Equation (2), forming Equation (5). Similarly, $\text{Ln}(\text{Freedom}) * (\text{FDI})$ was included in Equation (2) to obtain Equation (6). All variables in Equations (5) and (6) remained the same as in the baseline regression.

$$\text{Ln}(\text{Rates})_{i,t} = \alpha_0 + \alpha_1 \text{Ln}(\text{Rates}_{i,t-1}) + \alpha_2 \text{Ln}(\text{Freedom}_{i,t}) + \alpha_3 (\text{Ln}(\text{Freedom}_{i,t}))^2 + \alpha_4 (\text{Ln}(\text{Freedom}_{i,t}) * \text{Ln}(\text{Trade}_{i,t})) + \beta Z_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$\text{Ln}(\text{Rates})_{i,t} = \alpha_0 + \alpha_1 \text{Ln}(\text{Rates}_{i,t-1}) + \alpha_2 \text{Ln}(\text{Freedom}_{i,t}) + \alpha_3 (\text{Ln}(\text{Freedom}_{i,t}))^2 + \alpha_4 (\text{Ln}(\text{Freedom}_{i,t}) * (\text{FDI}_{i,t})) + \beta Z_{i,t} + \varepsilon_{i,t} \quad (6)$$

Table 3 presents the estimated mechanisms of the relationship between trade freedom and exchange rate. Columns I and II show the estimation results of the moderating role of high-technology trade in the relationship between trade freedom and exchange rate. In Column II, the interaction term $\text{Ln}(\text{Freedom}) * \text{Ln}(\text{Trade})$ obtained a positive coefficient at the 1% significance level, supporting Hypothesis 2. This suggests that trade freedom promotes the appreciation of the exchange rate by expanding high-technology trade, as more foreign currencies are needed to purchase domestic goods, which increases the demand for domestic currency and drives up the exchange rate.

Columns III and IV present the estimates of the mediating role of FDI in the impact of trade

freedom on exchange rate movement. Notably, in the fourth column, the interaction term $\text{Ln}(\text{Freedom}) * (\text{FDI})$ obtained a significant positive coefficient at the 1% significance level, supporting Hypothesis 3 that trade freedom contributes to exchange rate appreciation by attracting FDI. Trade freedom expands economic activities in the country by drawing in FDI and increasing investor confidence in the country's economy, which leads to more foreign investors exchanging their national currencies for the currency of the host country. The purchasing behavior of foreign investors then increases the demand for the host country's national currency, driving up the exchange rate.

Table 3 Mechanism tests

	High Technology Trade		FDI Changes	
	I	II	III	IV
$\text{Ln}(\text{Freedom})$		-0.5150*** (-3.1327)		0.3186** (2.8723)
$\text{Ln}(\text{Freedom})^2$		0.0317*** (3.3401)		0.0421*** (3.9212)
$\text{Ln}(\text{Pgdp})$	0.1142*** (4.6017)	0.1355** (2.1085)	0.0545** (2.2534)	0.1127*** (4.1968)
$\text{Ln}(\text{Integrity})$	0.2140*** (3.1251)	0.0521** (1.9983)	0.1012*** (2.6765)	0.0821* (1.6788)
Remit	0.0068* (1.9395)	0.0062* (1.7453)	0.0071** (1.1205)	0.0186** (2.5723)
$\text{Ln}(\text{Interest})$	0.0531*** (4.7418)	0.0685*** (5.0256)	0.0578*** (4.6214)	0.0549*** (4.8412)
$\text{Ln}(\text{Debt})$	-0.0379*** (-5.5713)	-0.0478*** (-4.6250)	-0.0559*** (-5.4720)	-0.0531*** (-4.0681)
$\text{Ln}(\text{Inflation})$	-0.2140*** (-4.6821)	-0.1500*** (-4.3786)	-0.0242*** (-5.1290)	-0.0361*** (-5.0528)
$\text{Ln}(\text{Balance})$	0.2430*** (5.7024)	0.1771*** (3.8366)	0.1242*** (4.8864)	0.1121*** (3.9557)
$\text{Ln}(\text{Equity})$	0.0017 (0.4483)	0.0076** (2.5139)	0.0179*** (4.8775)	0.0146*** (5.6942)
$\text{Ln}(\text{Trade})$	0.0267*** (3.3271)	0.0347*** (2.9392)		
$\text{Ln}(\text{Freedom}) * \text{Ln}(\text{Trade})$		0.0411*** (3.6581)		
FDI			0.0574*** (5.2105)	0.0632*** (4.0692)
$\text{Ln}(\text{Freedom}) * \text{FDI}$				0.0762*** (5.3201)
Constant	0.6384*** (4.7282)	2.1752*** (5.9551)	1.4988*** (4.7662)	2.0314*** (6.8581)
$\text{Ln}(\text{Rates})_{i,t-1}$	0.6120***	0.5174***	0.6128***	0.6273***

	(7.4682)	(9.7768)	(8.5244)	(10.6843)
Sargan test	0.634	0.748	0.651	0.705
AR(1)	0.032	0.030	0.026	0.028
AR(2)	0.797	0.775	0.686	0.694

Notes: t-statistics are in parentheses, ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.4.2 Heterogeneity analysis-Economic Scale

Key differences exist in the trade level and exchange rate of various countries (Mendoza, 1995). As such, analyzing the country-wise heterogeneity of these variables' relationship helps shed light on the unique challenges faced by different countries, which can be useful in formulating appropriate policies for economic development. Therefore, to comprehensively examine the heterogeneous effect of trade freedom on exchange rate movement, this study divided the sample countries into three sub-samples—developed economies, emerging market economies, and developing economies—based on the countries' economic development level as classified in the World Bank and IMF reports (see Appendix A2 for the list of countries). Since the full sample of 75 countries was analyzed for heterogeneity, the number of countries in each sub-sample was less than 50 and could not be estimated using system GMM. Therefore, this study used the fixed effects model in Equation (4) to estimate the heterogenous effect of trade freedom on exchange rate in developed, emerging, and developing economies, the results of which are presented in Table 4.

Columns I and II of Table 4 show the results of the impact of trade freedom on exchange rate movement in developed economies. Trade freedom in developed economies contributes linearly and significantly to exchange rate appreciation, most likely due to the relatively mature and competitive economic systems of these countries that attract large amounts of foreign investment (Yu and Wang, 2023). Trade freedom makes it easier for domestic products to enter international markets, while also rendering foreign products more accessible to domestic markets. This two-way international trade increases international financial inflows and stimulates demand for the domestic currency, leading to an appreciation of the currency value and exchange rate.

Columns III and IV report the results of the effect of trade freedom on exchange rate movement in emerging and developing economies. The effect was found to be more pronounced in emerging market economies and relatively smaller in developing economies, likely because emerging market economies are at a higher stage of economic growth and experience more active foreign trade and investment activities. Trade freedom leads to greater international trade and foreign exchange flows, which fluctuates the supply of and demand for national currencies and consequently, impacts exchange rates more heavily. Emerging market economies may also be more vulnerable to international capital flows and market volatility, producing stronger exchange rate movement. On

the other hand, developing countries, with their slower economic development and relatively lower external trade, may have less influence in international markets. While trade freedom may have some impact on the exchange rates of these countries, it may be constrained by other economic factors such as external debt, government intervention, and policy stability.

Subsequently, U-tests were conducted for emerging and developing economies, and the results are shown in Table 4. The impact of trade freedom on the exchange rate was revealed to be U-shaped in both emerging and developing economies. The inflection point for emerging economies was 4.4¹; since the trade freedom of emerging economies (e.g., Bulgaria, Chile, Croatia, Czechia, Hungary, Malaysia, Mexico, Poland, Romania, Ukraine, Georgia, etc.) had already exceeded 81.45 as of 2021, trade freedom is theorized to further contribute to the exchange rate appreciation of these countries' currencies. For developing economies, the inflection point was 4.56²; however, as of 2021, none of the developing economies had trade freedom levels higher than 95.58. Therefore, trade freedom will further depress the currency exchange rate of developing economies.

Table 4
Heterogeneity analysis--Economic Scale

	Developed Economies		Emerging Market Economies	Developing Economies
	I	II	III	IV
<i>Ln(Freedom)</i>	-0.1149 (-1.1021)	0.8524*** (5.3921)	-1.9852*** (-6.3281)	-1.2071*** (-5.5433)
<i>Ln(Freedom)²</i>	0.0585 (1.0084)		0.0689*** (4.1053)	0.0463*** (4.6852)
<i>Ln(Pgdp)</i>	0.1021*** (4.9611)	0.1658*** (5.5152)	0.2859*** (4.6934)	0.1621*** (4.9174)
<i>Ln(Integrity)</i>	0.0603 (0.8591)	0.3512*** (4.3019)	0.1052*** (2.6511)	0.1162** (1.8813)
<i>Remit</i>	0.0584* (1.7453)	0.0033*** (5.8462)	0.0850*** (4.3014)	0.0088 (0.7501)
<i>Interest</i>	0.0027* (1.4138)	0.0045 (0.7342)	0.0031* (1.9060)	0.0021*** (4.5341)
<i>Ln(Debt)</i>	-0.0601** (-2.3625)	-0.0526*** (-5.1028)	-0.0384*** (-2.6812)	-0.0365 (-0.1387)
<i>Ln(Inflation)</i>	- 0.0511*** (-3.0845)	-0.0854*** (-3.5453)	-0.1261*** (-5.3324)	-0.1217*** (-4.5535)
<i>Ln(Balance)</i>	0.0719*** (5.8242)	0.0827*** (6.0554)	0.1695*** (4.2018)	0.2320*** (5.3812)

¹ The anti-log of 4.4 is 81.45

² The anti-log of 4.56 is 95.58

<i>Ln(Equity)</i>	0.0712*** (3.9281)	0.0725*** (4.2142)	0.1905*** (4.5284)	0.1035*** (3.6861)
Constant	2.0969*** (5.4861)	-0.0291 (-0.0258)	3.5322*** (5.8689)	1.5278*** (6.8799)
R-squared	0.660	0.611	0.803	0.724
U-test				
Extreme point			4.40	4.56
			Lower	Upper
Interval			3.76	5.82
Slope			-0.03	0.02
t-value			-5.42	2.25
P > t			0.00	0.00
t-value			2.25	2.12
P			0.00	0.00

Notes: t-statistics are in parentheses, ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Test: H1: U-shape vs. H0: Monotone or Inverse U-shape.

5. Conclusion

This study has assessed the relationship between trade freedom and exchange rate movement in 75 countries from 2015 to 2021. Using various techniques, namely system GMM, resolution of endogeneity, variable substitution, and placebo testing, the empirical results robustly validate the nonlinear U-shaped effect of trade freedom on exchange rate movement. Taking into account other factors that may affect exchange rate movement, the analysis of control variables revealed that a country's economic growth, government integrity, remittances, and interest rates contribute to exchange rate appreciation, while a country's money stock and government debt lead to exchange rate depreciation. In addition, the study's examination of intermediary mechanisms found that trade freedom influences exchange rate movement by enhancing high-technology trade and FDI. Finally, the heterogeneity of the impact of trade freedom on exchange rates across different economic levels was analyzed, indicating that trade freedom has a linear positive effect on the exchange rate movement of developed economies, but a nonlinear U-shaped effect on the exchange rate movement of emerging market economies and developing economies. Notably, a stronger effect of trade freedom on the exchange rate was observed in emerging market economies.

The findings of this study complement previous research in various ways. First, the extant literature on the relationship between international trade and exchange rate mainly focuses on the impact of trade volume (e.g., Bahmani-Oskooee and Harvey, 2022; Annelies et al., 2022), neglecting trade freedom as a factor driving exchange rate movement. The current findings thus enrich the literature by enhancing the understanding of the linear and nonlinear influence of this important trade policy on exchange rate movement. In addition, this study establishes high-

technology trade and FDI as facilitating mechanisms in the process by which trade freedom affects exchange rate movement. Trade freedom promotes technological innovation and competitiveness, encouraging a country to invest more in high-technology industries. The resulting increase in high-technology product exports improves the structure of trade, bringing more foreign exchange earnings to the country and supporting the appreciation of the national currency. Additionally, attracting FDI inflows, especially in the high-technology sector, contributes to technology transfer and the upgrading of the overall economy, which in turn, reinforces the national currency. Finally, becoming a major player in high-technology trade enhances a country's international reputation and confidence, contributing to the appreciation of the national currency in the international market.

6. Policy Implications

The findings of this study provide valuable insights for governments to ensure exchange rate stability while promoting trade freedom. First, given the U-shaped effect of trade freedom on the exchange rate, the government can raise interest rates and purchase local currency to stabilize the exchange rate when trade freedom inhibits it. Later, when trade freedom promotes exchange rate appreciation, the government can lower interest rates to make the local currency less attractive while selling it in the foreign exchange market to dampen exchange rate appreciation. In addition, the government can intervene in the exchange rate by encouraging or restricting imports and exports through trade policy adjustments that affect the foreign trade balance.

Second, the development of international trade in an environment of trade freedom promotes exchange rate volatility. To stabilize the exchange rate and mitigate volatility, governments can strengthen regulation and policy coordination to ensure the healthy development of international trade while avoiding overdependence on specific trading partners. They can also actively promote trade diversification, develop new export markets and products, and reduce reliance on a single trade source, thereby minimizing the risks associated with exchange rate fluctuations. At the same time, foreign trade enterprises should be encouraged to engage in risk management and exchange rate hedging to reduce the sensitivity of trade transactions to exchange rate fluctuations. Using a combination of these measures, governments can better stabilize their exchange rate and ensure the sustainable development of international trade under a free trade environment.

Given that FDI in a free trade environment promotes currency exchange rate volatility, governments can curb excessive foreign capital inflows by setting up foreign capital access restrictions or implementing capital flow controls to avoid excessive appreciation of the domestic currency. They can also build up foreign exchange reserves, which can be used to intervene in the foreign exchange market and stabilize the exchange rate. With these measures, the government can better cope with the impact of FDI on the exchange rate under trade freedom and maintain the exchange rate at a reasonable level.

Finally, for developed economies, governments can implement monetary policies to reduce appreciation pressures, such as by lowering interest rates to make currencies less attractive. Apart from that, export diversification and technological upgrading should be encouraged to improve export competitiveness and mitigate the adverse effects of exchange rate appreciation on exports. As for emerging and developing economies, comprehensive measures should be taken to manage the U-shaped relationship between free trade development and exchange rate movement. Initially, governments can curb exchange rate appreciation through monetary policy, foreign exchange reserve management, and export diversification strategies to mitigate the risk of trade dependence on a single market. As the economy matures and becomes more competitive, the government can then encourage technological innovation to increase productivity and economic diversification to alleviate appreciation pressures. Lastly, international collaboration is crucial to reduce global financial instability and maintain exchange rate stability in support of sustainable development.

7. Research limitations and Future

Despite the researchers' best efforts to conduct this empirical study, it still has limitations that provide directions for future research. First, due to data availability limitations, the researchers were able to collect data only for 75 countries between 2015 and 2021 in investigating the impact of trade freedom on exchange rate movement. If more up-to-date data becomes available in the future, other researchers could expand the scope of this study to examine a more inclusive sample of countries across a broader time period. In addition, in exploring the nonlinear effect of trade freedom on exchange rate movement, this paper only employed system GMM, squared terms, and U-tests. Future research should attempt to analyze this nonlinear effect using other methods, such as the

panel unit root test and nonlinear autoregressive distributed lag (NARDL) technique. Finally, this study empirically tested only two moderating channels of the relationship between trade freedom and exchange rate movement. Since there may be other unexplored channels at play, future research has the potential to further investigate and reveal the various mechanisms through which trade freedom affects exchange rate movement.

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Appendix

A1 Multicollinearity test

Variable Name	VIF	1/VIF
<i>Integrity</i>	3.64	0.274725
<i>Pgdp</i>	3.21	0.311526
<i>Freedom</i>	2.64	0.378787
<i>Inflation</i>	2.37	0.421941
<i>Remit</i>	2.02	0.495049
<i>Debt</i>	1.76	0.568182
<i>Balance</i>	1.48	0.675676
<i>Equity</i>	1.13	0.884956
<i>Interest</i>	1.05	0.952381
Mean VIF	2.14	

A2 City List

Developed economies:	Australia, Austria, Belgium, Canada, Denmark,Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States;
Emerging Market Economies	Armenia, Brazil, Bulgaria, Cameroon, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Croatia, Czechia, Cyprus, Dominican Republic, Fiji, Gabon, Georgia, Ghana, Hungary, Latvia, Malaysia, Mexico, Moldova, Morocco, Nicaragua, Nigeria, North Macedonia, Pakistan, Paraguay, Philippines, Poland, Romania, Russian Federation, Samoa, Sierra Leone, Slovakia, Solomon Islands, South Africa, Tunisia, Trinidad and Tobago, Ukraine, Uruguay, Zambia;
Developing economies:	Algeria, Burundi, Central African Republic, Equatorial Guinea, Lesotho, Malta, Togo, Uganda;
