Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-025-04770-7 OPEN

Foreign direct investment and foreign reserves linkage: a global study based on wavelet coherence and granger causality

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In the contemporary global economy, foreign direct investment (FDI) and foreign reserves (FR) play a crucial role in economic stability, particularly amid geopolitical and financial uncertainties. This study examines the relationship between FR and FDI over a 23-year period (2002–2022), utilising panel data from 110 countries. By employing Wavelet Coherence analysis, the findings indicate that FR significantly influences FDI inflows across most regions, except in Europe, where the relationship is more complex. Additionally, the Granger causality test confirms a predominantly unidirectional linkage from FDI to FR in most countries, particularly in North America, Asia, and Oceania. These findings suggest that policies fostering economic stability, such as flexible tax regimes and strong governance, are essential for enhancing FDI attractiveness, particularly in regions where the FR-FDI relationship remains weak.

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Introduction

Foreign Direct Investment (FDI) refers to cross-border investments in which an investor from one economy establishes significant influence over an enterprise in another, typically evidenced by ownership of 10% or more of voting power. FDI plays a crucial role in international economic integration, technology transfer, trade, and economic development. Key indicators of FDI include inward and outward stocks, investment flows, income by partner country, industry breakdowns, and FDI restrictiveness (OECD, 2025). While ownership percentage is a commonly used metric, the defining characteristic of FDI is not merely equity control but the degree of managerial influence exerted by the investor. This influence distinguishes FDI from other investment categories, as it fosters long-term economic cooperation between the investing and host economies. FDI is not only a measure of development but also a catalyst for economic growth, particularly in emerging economies (Adebayo et al. 2020; Pebriyanti and Khoirudin, 2024). It facilitates the transfer of advanced technology, enhances human capital development, and increases government revenues through tax contributions generated by foreign firms (Cambazoğlu and Güneş, 2014; Phi et al., 2024).

Conversely, investors expand beyond their home country's borders when they cannot achieve the desired returns domestically or when they seek to diversify operations. Foreign investment decisions are influenced by several economic and institutional factors in the host country, such as labour productivity, exchange rates, tax policies, market size, infrastructure, growth potential, political stability, property rights, and currency volatility (Cambazoğlu and Güneş, 2014). Additionally, a country's Foreign Reserves (FR) act as a confidence signal for investors, reassuring them of economic stability and safeguarding returns on investment (Kaur and Sharma, 2013a).

Furthermore, the role of FDI in promoting green development has gained increasing attention as countries attempt to balance carbon emission reductions with high-quality international trade. The adoption of low-carbon city policies has influenced FDI patterns, leading to a decline in foreign-invested enterprises and reduced FDI efficiency (Wang et al., 2024). Aligning FDI with green development strategies has been shown to enhance green total factor productivity (GTFP), with stronger effects observed in innovation-driven regions (Wang et al.). Additionally, pilot free trade zone (FTZ) policies have successfully promoted regional innovation, though cities that were already involved in earlier open-city policies have not experienced further innovation gains (He et al., 2023).

Foreign Reserves (FR) are a key determinant of FDI inflows into a host country, with effects that can be positive, negative, unidirectional, or bidirectional (Maram and Kishore, 2012; Osigwe and Uzonwanne, 2015; Islam and Beloucif, 2023; Rasyid et al., 2023) Several studies have examined the FDI-FR relationship through different forms of reserves, including international reserves, foreign exchange reserves (FOREX), gold reserves, and government reserves. Some scholars argue that higher FR levels attract FDI, while others suggest that FDI contributes to FR accumulation, indicating a bidirectional relationship (Huang et al., 2011). Although the predominant view supports a positive correlation, some research identifies unidirectional or even negative influences between these variables. This study conducts a comprehensive literature review to analyse the global impact of FDI and FR at both regional and country-specific levels.

This study aims to provide a regional and cross-country analysis of the FDI-FR relationship. Prior research on this topic has been limited in scope, often focusing on a small number of countries without examining the relationship on a continental scale. Furthermore, many previous studies do not cover recent periods, making their findings less relevant to current economic trends. To address these gaps, this study leverages recent data from 110 countries over a 23-year period (2002–2022) to provide a more up-to-date and comprehensive perspective on the FDI-FR dynamic. The use of Wavelet Coherence Techniques (WCT) in data analysis adds a novel aspect to this study, allowing for a time-dependent analysis of causality and correlation.

Both FDI and FR are critical to a nation's economic stability and growth. Understanding their interdependencies can offer valuable insights into economic policy and investment strategies. This article explores the dynamic and causal linkage between FDI and FR across different economies. To achieve this objective, the study is guided by the following research question:

- How does FDI impact FR over time and across different regions?

This research question ensures a focused and structured analysis of the topic. Organising the study around this objective enhances clarity and coherence.

This study makes several key contributions to the empirical literature. Firstly, it explores the nature and causality between Foreign Reserves (FR) and Foreign Direct Investment (FDI) using Wavelet Coherence analysis, which allows for a more granular examination of short- and medium-term changes in their relationship—an approach largely absent in prior research. Secondly, it analyses over 110 countries across all inhabited continents over a 23-year period, offering a broader and more globally representative perspective. Although region-specific and country-level studies on this topic exist, a comprehensive global analysis has not yet been conducted. Thirdly, the study's ability to capture temporal variations within the specified period ensures that policy implications are better aligned with contemporary economic trends. Finally, conducting a cross-country comparative analysis adds depth to the literature, addressing existing gaps by offering both global and region-specific insights.

The remainder of the article consists of four main sections. The first provides a preliminary analysis; the second elaborates on the study's data and methodology; the third discusses the findings and data analysis; and the final section presents the overall conclusion.

Literature review and theoretical background

A comprehensive literature review was conducted by filtering through a large body of scholarly work on FDI and FR. From an initial pool of 67 articles, 25 were selected from reputable sources, including Springer Link, Emerald Insight, ScienceDirect, and Taylor and Francis Online. The selection criteria were based on the relevance of the studies to the FDI-FR relationship, with a particular focus on cross-country analyses in Asia, Africa, and Europe (Kyereboah-Coleman and Agyire-tettey, 2008; Ullah et al., 2012; Cambazoğlu and Güneş, 2014; Moraghen et al., 2021; Purba et al., 2024). Figure 1 illustrates the literature search flow process.

The relationship between Foreign Direct Investment (FDI) and Foreign Reserves (FR) has long attracted scholarly interest, yet several aspects remain ambiguous. Various studies have analysed this relationship, but their findings often differ, reflecting the complexity of FDI-FR dynamics across different regions. While many studies report a positive correlation between FR and FDI, others identify bidirectional causality or even a negative relationship influenced by macroeconomic conditions. The lack of consensus on the regional variations and the mechanisms driving these linkages remains a key research challenge.

The literature on FDI-FR dynamics in Africa presents mixed findings. Onyeiwu and Shrestha (2004), initially argued that an

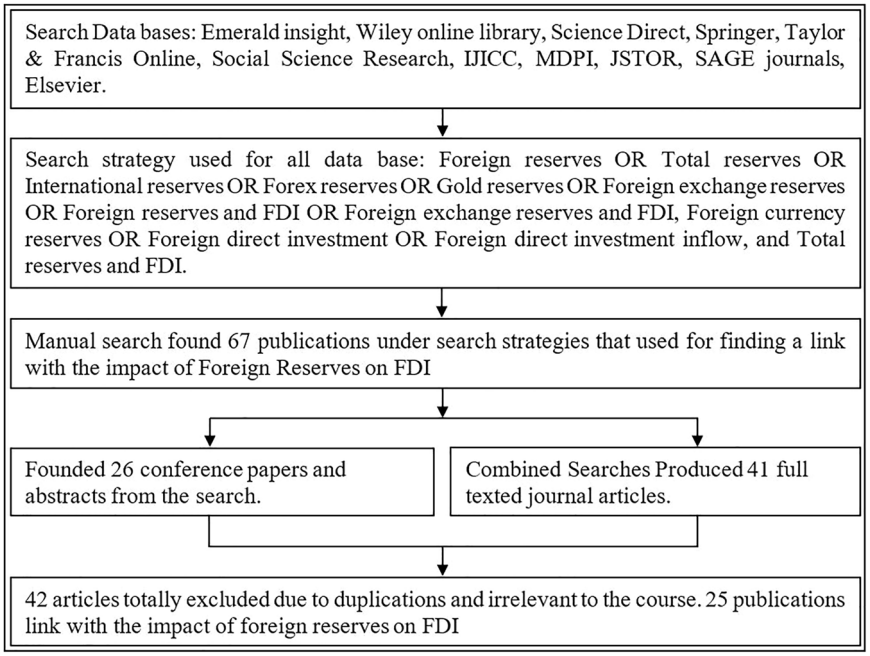

Fig. 1 Literature search flow diagram. Source: Authors' observations.

increase in FR could reduce FDI, suggesting that foreign investors prefer economies with high reserves as a stability signal. However, their study relied on outdated data, limiting its relevance to current trends. More recent research by Audu and Okumoko (2013) and Bourenane et al. (2022) identified a positive causal linkage, demonstrating that larger reserves can create a more attractive investment environment. However, these studies were country-specific, limiting the generalisability of their conclusions.

Asia has a larger body of literature on FDI-FR linkages, with most studies supporting a positive relationship. Awan et al. (2011) used an error correction model to analyse quarterly data from 1996–2008, finding a strong correlation between FDI inflows and FR. Similarly, Kaur and Sharma (2013b) employed co-integration analysis to confirm a positive FDI-FR relationship in India. However, these studies relied on older datasets, which may not fully reflect current economic realities. Additionally, while they highlight a general positive linkage, they fail to address national contexts, which are crucial for understanding the specific drivers of the FDI-FR relationship.

More recent studies reinforce this positive correlation. Rasyid et al. (2023) and Islam and Beloucif (2023) found further evidence of this interaction, though their studies lacked an in-depth analysis of country-specific variations that could reveal underlying causality mechanisms. The literature has also explored both bidirectional and unidirectional linkages between FDI and FR. For example, Huang et al. (2011) found that higher FR levels stimulate FDI inflows, suggesting that strong reserves enhance investor confidence. However, outdated data and a lack of country-specific analysis limit the applicability of these findings in the current economic climate.

Matsumoto (2022) explored the relationship between foreign reserve accumulation and FDI in developing economies, demonstrating that higher FR levels can depreciate the real exchange rate, making FDI more attractive. This dynamic also mitigates risks associated with external borrowing shocks, emphasising the importance of strategic FR accumulation to support foreign investment.

Khan and Anwar (2022) examined how natural disasters affect FR levels across different income groups. Their findings suggest that disaster-related economic losses typically reduce FR, but strong infrastructure, capital formation, renewable energy investments, and FDI inflows can help counteract these negative effects. They advocate for resilience-building strategies such as the Sendai Framework to mitigate economic vulnerabilities from external shocks.

In a separate study by Khan and Anwar (2022) investigated the role of central banks in managing FR to attract FDI, using Iraq as a case study. Their findings confirm a positive correlation between effective reserve management and FDI inflows, aligning with broader goals of economic stability and growth.

While much of the literature focuses on positive FDI-FR correlations, there is a growing recognition of how economic and policy contexts shape this relationship. Scholars have begun integrating environmental sustainability into FDI-FR discussions. For example, Khan and Anwar (2022) examined the Investment Development Path (IDP) theory, highlighting how FR levels influence investment flows in emerging markets. Zhou (2023) explored the relationship between economic growth, energy consumption, and CO_2 emissions, providing insights into how environmental policies interact with FDI and reserves. These studies underscore the need for a holistic approach that integrates economic, environmental, and financial factors in FDI-FR research.

The existing literature, while extensive, explores significant gaps in understanding the FDI-FR causality, particularly in terms of regional variations, country-specific dynamics, and the broader economic context. Previous studies have largely focused on outdated data or single-country case studies, which limit the generalisability and applicability of their findings. Moreover, the literature has not sufficiently examined how the FDI-FR linkage interacts with broader economic, environmental, and policy factors. This study aims to fill these gaps by integrating recent high-quality references to offer a more extreme understanding of the FDI-FR dynamics. By focusing on regional diversity and incorporating contemporary economic and environmental perspectives, this research will contribute to the theoretical and policy-oriented discourse surrounding FDI and FR, offering new insights into their complex interaction and implications for sustainable development.

Table 1 Data sources and definition of variables.

Variable	Definition	Measure	Source
FDI	Foreign direct investment	Data are in current United States Dollars (USD)	The World Bank (2024a)
FR	Foreign Reserves	Total reserves minus gold (Current US$)	The World Bank (2024c)

Source: Authors' compilation based on The World Bank (2024d).

FDI and FR are critical variables in a country's financial stability. FDI can positively impact a nation's FR by increasing foreign currency earnings and exports, which in turn can enhance FR levels. Conversely, high FR levels can attract FDI by indicating a stable investment environment and providing guarantees for foreign investments. According to the Balance of Payments theory, a country's balance of payments, including its current and financial accounts, significantly influences FDI and FR (Glantz and Kissell, 2014). Market imperfections, such as information asymmetry, can also lead to inefficient capital allocation between foreign and domestic investments (Dobbelaere and Kiyota, 2018).

However, high FR levels can also deter FDI if they lead to an overvalued currency, making investments less attractive due to lower returns. Moreover, excessive FR accumulation may result in currency appreciation, reducing export competitiveness and, subsequently, demand for FDI. Overreliance on FDI can undermine FR stability, especially in the event of sudden capital withdrawal.

The study follows international correspondence between FR and FDI analysing data from 110 countries over the period 2002 to 2022, as sourced from World Bank. The variables are selected based on past empirical studies, with FR reported in 'current US dollars,' reflecting the value of reserves adjusted to the prevailing exchange rate at the time of reporting (The World Bank, 2024b). By building on the existing literature, this study aims to provide a comprehensive analysis of the dynamic correlation and causality between FR and FDI.

Data and methodology

Data. The study employs panel-time series data for FR and FDI. Data from 2002 to 2022 were collected for analysis using World Bank data. Although the World Bank sources contain data from 1960, it was found that data for specific countries were incomplete. Therefore, data related to 110 of the 195 countries were used to analyse 21 years. The study covers 34 European countries, 28 Asian and Oceania countries, 21 African countries, and 17 and 10 North and South American countries, respectively. For ease of study, three countries in the Oceania region have been included in the Asia and Oceania region.

For analytical clarity, the global dataset is classified into developed and developing economies based on the United Nations (UN) classification (United Nations, 2022). The dataset includes 38 developed and 72 developing countries. A summary of the selected countries and regions is available in Appendix S1, while Appendix S2 provides the data file used in the study. Table 1 details the secondary data sources used in the research.

Methodology. The study employs Wavelet Coherence Analysis and Granger Causality techniques to investigate the dynamic correlation and causal relationship between FDI and FR across different regions and over time. These methodologies enable an in-depth exploration of short, medium, and long-term trends in the FDI-FR nexus.

Wavelet analysis. This study utilises Wavelet Coherence Analysis (WCT) to assess the relationship between FR and FDI across multiple time scales. WCT is a bivariate framework that evaluates co-movements and causality between variables in both time and frequency domains. Initially developed by Goupillaud et al. (1984), the Wavelet Coherence method was later elucidated by Vacha and Barunik (2012), Aloui and Hkiri (2014), R. C. Phillips and Gorse (2018), Kalmaz and Kirikkaleli (2019), and Adebayo et al. (2020). Over time, this technique has been used, inter alia, for medicine (Cui et al., 2012), finance (Asafo-Adjei et al., 2021; Nupehewa et al., 2022), economics (Galappaththi et al., 2023), and tourism (Wijesekara et al., 2022), etc.

Real-world data comprises subtle fluctuations that may be crucial for learning new things. Thus, while Fourier analysis is able to express some trends, it fails to express sudden changes. A wavelet is a rapidly decaying wave, such as an oscillation with zero mean, that exists for a limited duration and has different shapes and sizes (Acquaah et al., 2021). There are two main types of Wavelet transforms: Continuous and Discrete. These transformations differ based on the way the waves are scaled and drawn.

After a meticulous study, it was possible to identify some specific significances of WCT. Meanwhile, unlike other linear and non-linear method-based analyses, WCT analysis does not require pre-treatment of the data, and the data are rapidly filed for several time intervals. This aids in generating output as a visual representation without indicating mere numbers. Moreover, the data considered guide the analysis along short, medium, and long-term dimensions. Accordingly, the wave is visualised in a simple manner, but the overall plot includes complex and broader data. On the other hand, the function presents the complex and broader data in a simple visualised way. This function has zero mean and positions the data in time and frequency. Hence, the essential wavelet function (mother wavelet) is described as follows (Omane-Adjepong et al., 2019).

$$\varphi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\varphi\left[\frac{t-\tau}{s}\right] \quad (1)$$

$1/\sqrt{s}$ prescribes the normalisation determinant, which confirms the unity of the variance; t denotes the time parameter; s and τ determine the scale and position of the time parameter, respectively. In reality, many types of wavelets exist. We used a Wavelet Coherence-based technique to analyse the correlation and causality between FR and FDI.

The Morlet permits good segregation and isolation of periodic signals by providing a balanced between the localisation of time and frequency (Grinsted et al., 2004). It also appears to deliver a better interaction between perceiving oscillations and peaks or sanctions. The Morlet wavelet, invented by Gaussian, can be explained most easily as seen below:

$$\varphi(\eta) = \pi - \frac{1}{4}e^{iw_0\eta}e\frac{-\eta^2}{2} \quad (2)$$

Here, w_0 and η denote maximum frequency and time parameters, respectively. Rua and Nunes (2009) and Grinsted et al. (2004) proposed concluding w_0 to 6 as per the allotted reason that properly localises time frequency.

To better investigate the time-varying linkage between two-time series, the study utilised the bivariate concept called Wavelet Coherence. A most suitable explanation of Wavelet Coherence can be summarised by understanding the cross-wavelet transform, Wavelet power spectrum, and phase difference. The concept of cross-wavelet analysis presents a proper tool for comparing the frequency between two different time series and delivering suggestions about the simultaneity of the series at specific periods and across different time slots. The cross-wavelet transforms (XWT) of two different time series x_t and y_t can be depicted as $W^{xy} = W^x W^{y*}$

Here, the reconstructed wavelet transform (Wavelet comp) is as follows (Torrence and Compo, 1998),

$$W^{xy}(s,\tau) = \frac{1}{\tau} W^x(s,\tau) \cdot W^{y*}(s,\tau) \quad (3)$$

s and τ describe the frequency and time, respectively. Equation (3) depicts the cross-wavelet power, appraising the equality of different two series' wavelet power in the frequency and time series. Moreover, it indicates the different regions in the time-frequency space where the time series shows a high common power (warm areas) (Boako and Alagidede, 2017). The cross-wavelet power equation, which denotes the local variance between two different time series and different scales, is given below:

$$P^{xy}(s,\tau) = \left|W^{xy}(s,\tau)\right| \quad (4)$$

The phase of the wavelet transform indicates any lead relationship between two different time series, and it is given below:

$$\theta_{xy} = \tan^{-1}\frac{-I\{w_t^{xy}\}}{\Re\{w_t^{xy}\}}, \theta_x \in [-\pi,\pi] \quad (5)$$

Here, if the absolute value of θ_{xy} less than $\pi/2$, it indicates that the two-time series move in phase (positive relationship), while the total value is larger than $\pi/2$ denotes anti-phase (negative linkage). The direction of the phase indicates which variable (time series) leads to the relationship. The cone of influence (plot) depicts the phases as arrows (Graham and Nikkinen, 2011). The wavelet squared coherence coefficient was defined (Torrence and Webster, 1999). Thus, the following Equation (6) demonstrates the dynamic correlation and causality of FR on FDI (Adebayo et al., 2020).

$$R^2(k,f) = \frac{|S(f^{-1}pq(k,f)|^2}{S(f^{-1}|W_p(k,f)|^2)S(f^{-1}|W_q(k,f)|^2)} \quad (6)$$

In the equation, k denotes the time and place, while f demonstrates the frequency. $W_p(k,f)$ and $W_q(k,f)$ denote the continuous wavelet transition (CWT) of p(t) and q(t) respectively. $R^2(k,f)$ represent the value of squared Wavelet Coherence. The R2(k, f) reaches zero when there is no correlation between the two series. While $R^2(k,f)$ is closer to 1, it demonstrates a correlation between both series.

Accordingly, wavelet co-integration can be considered a proper tool to describe the correlation between FR and FDI over time. R Studio has been used in analysing the application of the Wavelet Coherence technique.

Granger causality. There are different approaches to testing causality in panel data series. This study used cross-country VAR Granger analysis (Galappaththi et al., 2023) to evaluate the causality between FDI and FR for each country included in the study. Initially, the study ran the augmented Dickey-Fuller test (ADF/dfuller) (Dickey and Fuller, 1979) and Phillips–Perron test (PP) (P. C. B. Phillips and Perron, 1988) to assess the stationarity $(H_0 : \delta = 0)$ and non-stationarity $(H_A : \delta \neq 0)$ of the two-time series (Hameed et al., 2022). Thus, the ADF equation is as follows:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \cdots \delta_{p-1}\Delta y_{t-P+}\varepsilon_t, \quad (7)$$

The ADF (dfuller) test results in a negative number; when the number is more negative, the hypothesis is rejected that there is a unit root with a high level of confidence. Here, α denotes the constant of the time series. β indicates the coefficient of the time series and ρ prescribes the lag order. Similarly, the PP test is derived from the dfuller test.

The study ran the Granger causality test to examine the causality between FDI and FR for each country. The study tested 110 countries using Granger causality for 2002–2022. For this objective, Eqs. (8) and (9) are developed as follows:

$$FDI_t = \sum_{m=1}^{r} \alpha_1 FDI_{t-m} + \sum_{m=0}^{r} \theta_m FR_{t-m} + u_t \quad (8)$$

$$FR_t = \sum_{m=1}^{r} \beta_m FR_{t-m} + \sum_{m=0}^{r} \vartheta_m FDI_{t-m} + e_t \quad (9)$$

Here, index t denotes the period($t = 1, \ldots, T$), r describes maximum lags, and m refers to the selected lag. The two equations test Granger causality for each country. θ_m and ϑ_m denote the vary of each country: rejecting the null hypothesis of no causality in each country separately demonstrates the existence of Granger causality between the variables considered in each country (Beyzatlar et al., 2014; Yetkiner and Beyzatlar, 2020).

Table 2 Interpretation of Wavelet Coherence.

Direction of arrows	Interpretation
Rightward arrows	In-phase (Positive relationship)
Leftward arrows	Anti-phase (Negative relationship)
Rightward and up arrows	The FDI lead (cause) the Foreign Reserves
Rightward and down arrows	The FR lead (cause) the FDI
Leftward and up arrows	The FDI lead (cause) the Foreign Reserves
Leftward and down arrows	The FR lead (cause) the FDI
Cold (blue)	No correlation
Warm (red)	Correlation
Low frequency	0.0–0.3
Medium frequency	0.3–0.7
High frequency	0.7–1.0

Source: Authors' compilation.

Empirical results and discussion

The Wavelet Coherence Analysis examines the dynamic relationship between FDI and FR over time, accounting for short-, medium-, and long-term interactions. The cone of influence delineates the observation period, with significant relationships indicated by black contour lines. Table 2 provides the interpretation of the Wavelet Coherence Analysis.

Wavelet Coherence analysis illustrates various relationships between FDI and FR. The rightward and leftward arrows represent positive and negative correlations, respectively. Upward and downward trends indicate whether FDI or FR is leading in the causal relationship. The blue (cold) area signifies no correlation, while the red (warm) area shows a correlation with varying intensities. The colour bar represents the correlation intensity across short, medium, and long frequencies. Figures 2–7 depict the causality and correlation between FDI and FR for the period 2002–2022.

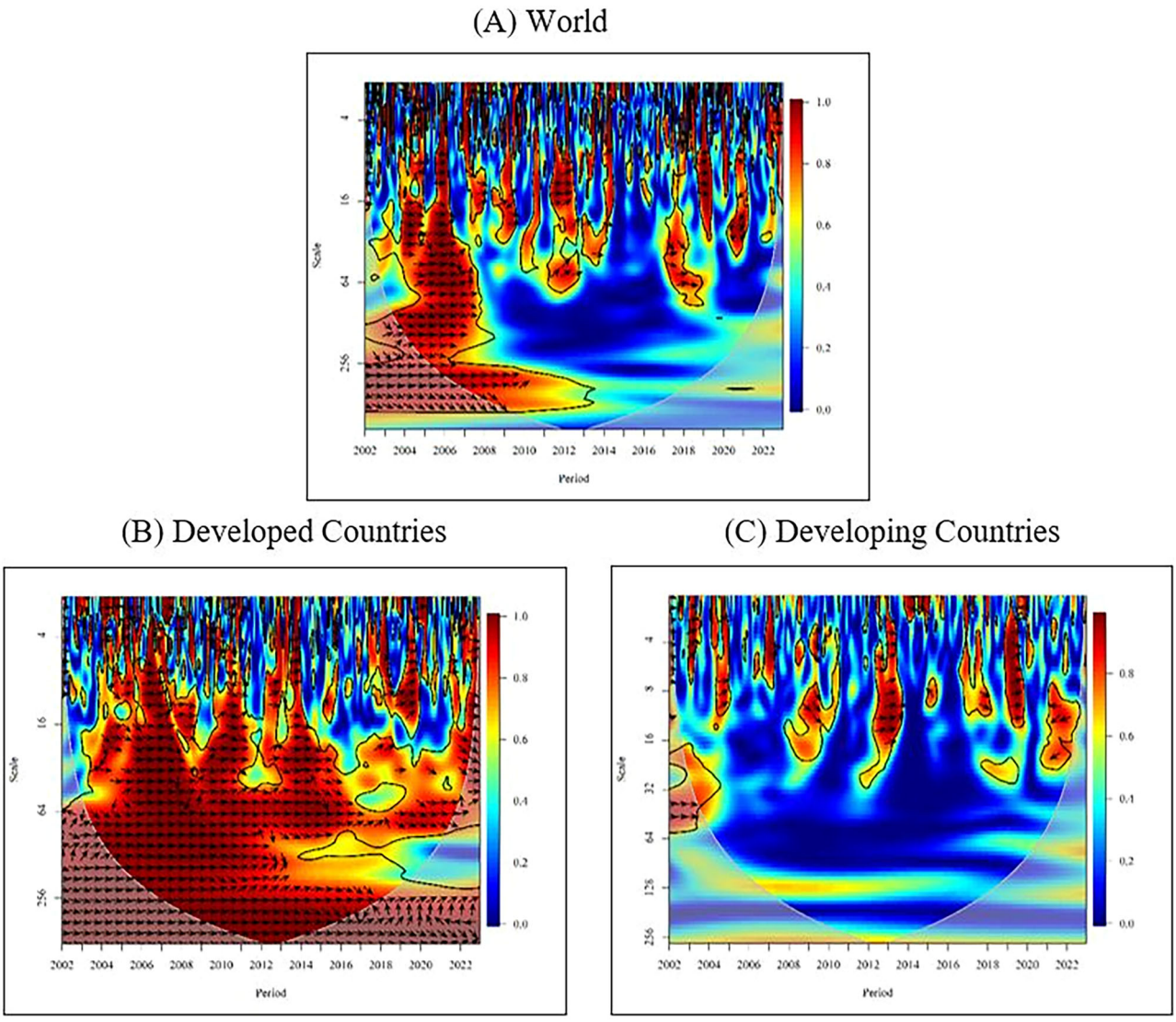

Fig. 2 Wavelet Coherence: FR vs FDI for Global. Source: Authors' illustration using R-Software.

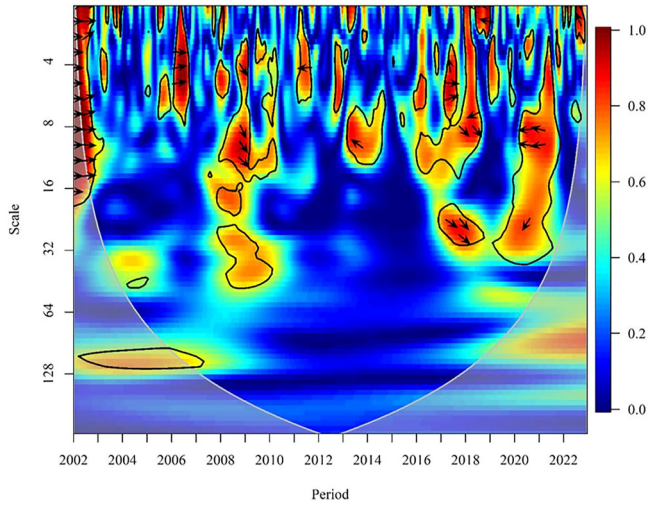

Fig. 3 Wavelet Coherence: FR vs FDI for Europe Continent. Source: Authors' illustration using R-Software.

Figure 2 presents the global relationship between FDI and FR from 2002 to 2022. Subfigure 2(A) indicates a generally positive correlation with rightward arrows, particularly in the short term at high frequencies. Notably, a leftward shift in 2018 suggests a temporary negative correlation. In the medium term, arrows show rightward and downward trends between 2004–2008 and 2017–2019, and rightward and upward trends during 2011–2012. In the long run, the arrows indicate a rightward and downward trend from 2003 to 2009, revealing a positive correlation from FR to FDI.

The findings align with Suripto et al. (2023), who observed a positive relationship between FER and FDI, influenced by exports, inflation, and exchange rates. In developed countries (Fig. 2B), the rightward and up arrows indicate that FDI leads to FR, whereas the rightward and down arrows show the opposite in the short term. A bidirectional relationship is evident in the short and medium terms. In the long term, a rightward and up trend is observed from 2003 to 2014, with a rightward and down trend thereafter. Huang et al. (2011), corroborate these findings, noting that market developments and government measures in China have fostered a growing bilateral relationship between FDI and FR.

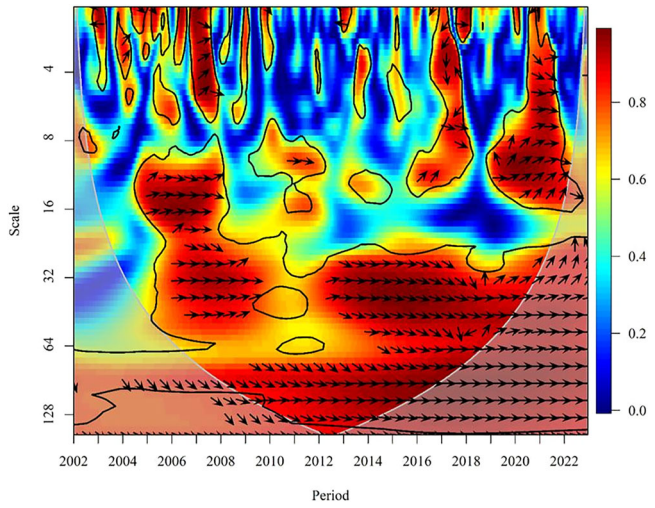

Fig. 4 Wavelet Coherence: FR vs FDI for Africa Continent. Source: Authors' illustration using R-Software.

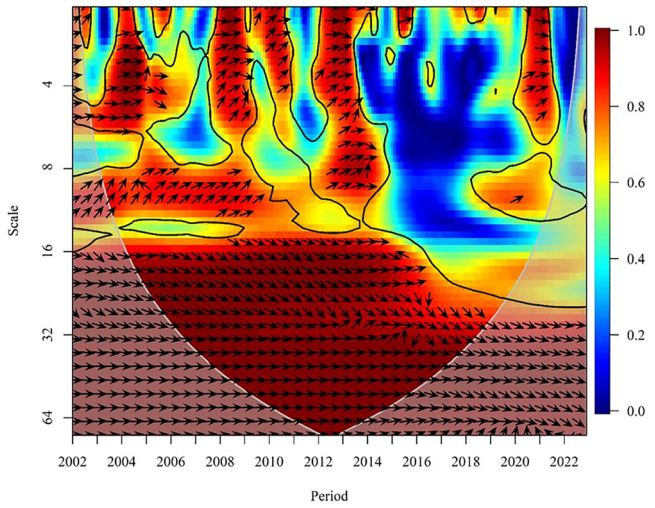

Fig. 6 Wavelet Coherence: FR vs FDI for South America Continent. Source: Authors' illustration using R-Software.

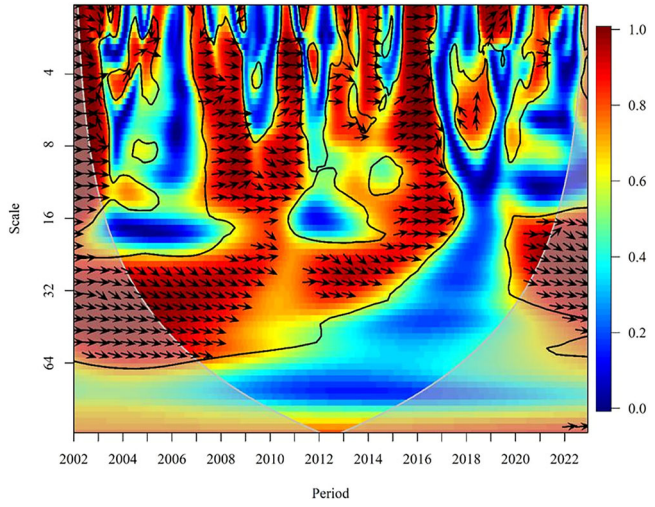

Fig. 5 Wavelet Coherence: FR vs FDI for North America Continent. Source: Authors' illustration using R-Software.

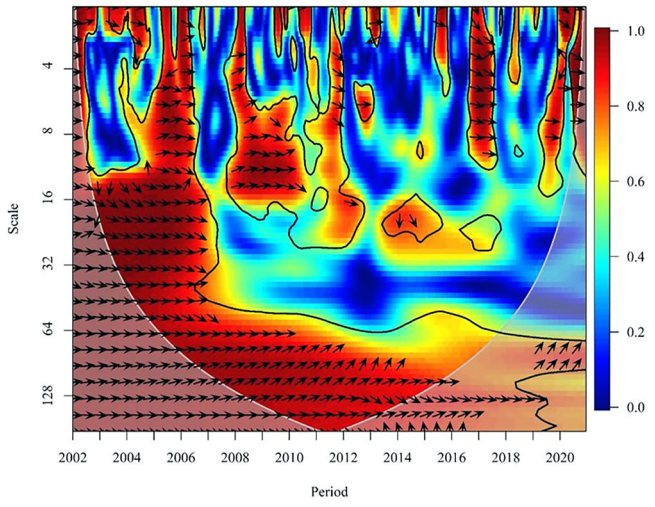

Fig. 7 Wavelet Coherence: FR vs FDI for Asia and Oceania Continents. Source: Authors' illustration using R-Software.

Figure 3 illustrates the European context, showing a generally positive correlation from 2002 to 2018, with an exception from 2011 to 2013. The arrows depict a negative impact from FDI to FR in 2020. A bidirectional relationship is observed in the short term, consistent with Huang et al. (2011). In the medium term, a rightward and downward trend suggests a positive impact from FR to FDI from 2017 to 2019, aligning with Khachoo (2013) and Nurunnabi (2021), who suggest that increased reserves attract more FDI. The European variability can be attributed to the European Monetary Union's impact on capital mobility (De Grauwe and Ji, 2018a; Grauwe and Ji, 2018).

In Fig. 4, Africa shows a rightward trend indicating a positive short-term correlation. Bidirectional causality is observed in the short term with high frequency, while in the medium term, the arrows depict a positive correlation between FDI and FR. In the long term, a rightward and down trend from 2008 to 2018 shows a positive correlation from FR to FDI. Elroukh (2024) supports these results, indicating that increased FR attracts more FDI. The study aligns with (Bourenane et al., 2022), showing a positive long-term correlation between FR and FDI .

Figure 5 demonstrates a generally positive correlation from 2002 to 2021, with a rightward and downward trend indicating FR leading to FDI. A positive short-term correlation is observed from 2018 to 2020, while medium and long-term trends show a rightward and downward correlation from FR to FDI. Maram and Kishore (2012) confirm that FR attracts more FDI, which is evident in the results.

In Fig. 6, the short-term correlation is positive, with FR leading to FDI. From 2002 to 2022, the arrows depict a rightward and uptrend between FR and FDI, with a positive long-term correlation from 2005 to 2019 Huang et al. (2011) suggest that China's large foreign reserves have attracted FDI from developed countries. This aligns with the positive long-term correlation observed in the South American context .

Figure 7 shows a rightward and downtrend between 2003 and 2014 in the short term, with a positive correlation where FR leads to FDI. The rightward and up arrows in 2017 and 2020 indicate that FDI leads to FR. In the medium term, a rightward and down trend suggests FR leads to FDI, while the long-term shows a bidirectional relationship. These findings are consistent with Huang et al. (2011) and Osigwe and Uzonwanne (2015) indicating a bidirectional causality between FR and FDI.

Furthermore, the plot illustrates a positive correlation where FR attracts FDI to the host countries. Rahman and Bristy (2015)

Table 3 Comparison of Wavelet test results: FR vs FDI for Global context.

Region	Short Term	Medium Term	Long Term
All countries	FDI ↔ FR (+)	FDI ↔ FR (+)	FDI ↔ FR (+)
Europe	Mixed Relationship	FR → FDI (+)	No-way
Africa	FDI ↔ FR (+)	FDI ↔ FR (+)	FR → FDI (+)
North America	FDI ↔ FR (+)	FDI ↔ FR (+)	FR → FDI (+)
South America	FDI ↔ FR (+)	FDI ↔ FR (+)	FDI ↔ FR (+)
Asia and Oceania	FDI ↔ FR (+)	FR → FDI (+)	FDI ↔ FR (+)

Source: Authors' compilations based on the test results generated.

Table 4 Interpretation of granger causality test.

Elements	Interpretation
FDI ↔ FR	Bidirectional causality between FDI and FR
FR → FDI	Unidirectional causality from FR to FDI
FDI ↔ FR	Unidirectional causality from FDI to FR
*	Reject H_0 at 10% (0.1) level of significance
**	Reject H_0 at 5% (0.05) level of significance
***	Reject H_0 at 1% (0.01) level of significance

Source: Authors' compilations.

provide evidence for a strong positive relationship between FR and FDI for the period 2002 to 2012 for SAARC countries. Similarly, Ali and Ismail (2024) have explored a positive and favourable linkage between FDI and FR. A summary of Wavelet coherence analyse is demonstrate for the well understanding of the results. Table 3 includes short, medium and long run behaviour of the causality between FDI and FR.

Country-level wavelet analysis results for Europe, Africa, North America, South America, and Asia and Oceania are provided in S7 Appendix. In Europe, countries such as Albania, Belarus, the Netherlands, Russia, and Turkey show a rightward and downward trend in the short term. Countries like Cyprus, Finland, France, Lithuania, North Macedonia, and the Slovak Republic exhibit a leftward and downward trend, indicating a positive unidirectional causality from FR to FDI. Conversely, Bulgaria, Poland, and Portugal show a positive causality from FDI to FR, while Czech Republic, Romania, and Switzerland depict a negative causality.

In Africa, Botswana, Djibouti, Egypt, Ethiopia, and Madagascar show a unidirectional causality from FR to FDI. Cabo Verde, Kenya, and Mauritius exhibit a causality from FDI to FR. Bidirectional causality is found in countries such as Egypt, Ghana, Malawi, Namibia, Seychelles, and Zambia.

For North America, countries like Bahamas, Belize, Canada, and Costa Rica demonstrate a unidirectional causality from FDI to FR. Dominica, Panama, and St. Vincent and Grenadines show a causality from FR to FDI.

In South America, countries such as Guyana, Peru, and Uruguay demonstrate a unidirectional causality from FR to FDI. Bolivia and Chile show a causality from FDI to FR. Argentina and Brazil exhibit a bidirectional relationship.

In Asia and Oceania, a unidirectional causality from FR to FDI is observed in countries such as Azerbaijan, Saudi Arabia, and Thailand. Malaysia shows a mixed relationship, while countries like Maldives, Philippines, and India exhibit a bidirectional causality.

Table 4 demonstrates the interpretation of the Granger causality test. FDI ↔ FR describes the bidirectional causality between

Table 5 Granger- Causality Test: FR vs FDI for European Countries.

Country	FR → FDI	FDI → FR	Causality Findings
Belarus	19.245*	8.573*	FDI ↔ FR
Bulgaria	17.321	2.987**	FDI → FR
Croatia	78.432*	54.982**	FDI ↔ FR
Cyprus	2.357**	98.731	FR → FDI
Czech Republic	45.678	13.549**	FDI → FR
Denmark	82.357**	42.108**	FDI ↔ FR
France	98.231	32.107**	FDI → FR
Greece	43.789***	0.53549*	FDI ↔ FR
Hungary	11.972	8.8243**	FDI → FR
Italy	12.531*	5.0508***	FDI ↔ FR
Latvia	3.3812*	9.7213*	FR → FDI
Malta	17.931***	3.7778*	FDI ↔ FR
Norway	3.974**	3.9135*	FDI ↔ FR
Poland	10.82**	1.5306*	FDI ↔ FR
Portugal	6.076	3.3175**	FDI → FR
Romania	1.4212*	4.7784	FR → FDI
Russia	5.3404***	3.3789	FR → FDI
Slovak republic	3.676**	20.026	FR → FDI
Spain	9.7213	6.4284***	FDI → FR
Switzerland	30.711***	4.5072**	FDI ↔ FR
Turkey	15.806***	0.08937	FR → FDI
UK	5.687**	6.7852	FR → FDI
Ukraine	3.7173*	14.105	FR → FDI

Source: Authors' compilations.

Table 6 Granger Causality Test: FR vs FDI for African Countries.

Country	FR → FDI	FDI → FR	Causality Findings
Botswana	55.156***	61.2348	FR → FDI
Cabo Verde (Cape Verde)	2.965	1.9374**	FDI → FR
Djibouti	23.689**	33.9347	FR → FDI
Egypt, Arab Rep.	9.3654*	23.9125	FR → FDI
Ethiopia	3.2549**	8.3695	FR → FDI
Ghana	29.364***	1.36954*	FDI ↔ FR
Kenya	22.36	33.3999*	FDI → FR
Madagascar	68.93**	21.6587	FR → FDI
Malawi	11.153	18.4597***	FDI → FR
Morocco	5.5334	64.985***	FDI → FR
Nigeria	26.1239	7.1234**	FDI → FR
Seychelles	2.9534	1.9574***	FDI → FR
Sierra Leone	39.128***	5.599*	FDI ↔ FR
Tunisia	2.369	3.661*	FDI ↔ FR
Zambia	8.369***	29.369***	FDI ↔ FR

Source: Authors' compilations.

FDI and FR. FR → FDI and FR → FDI denote the unidirectional causality from FR to FDI and FDI to FR, respectively. *, **, and *** depict the level of significance 10%, 5%, and 1% that reject null hypothesis (H_0) (Galappaththi et al., 2023). Tables 5–9 describe the causality between FDI and FR, while Table 10 indicates the panel Granger results across the regions.

The results were generated using the Granger Causality test conducted country-wise for each continent (Asia and Oceania, Europe, Africa, North America, and South America). Prior to performing the Granger Causality test, it was essential to ensure data stationarity, which was verified using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests with

Table 7 Granger Causality Test: FR vs FDI for North American Countries.

Country	FR → FDI	FDI → FR	Causality Findings
Bahamas	53.2236	14.3698***	FDI → FR
Belize	15.2154	9.332**	FDI → FR
Canada	3.3365	11.956**	FDI → FR
Costa Rica	6.2241	32.2398***	FDI → FR
Dominica	1.354***	7.248	FR → FDI
Grenada	7.4489	3.9584*	FDI → FR
Guatemala	1.2147	9.225***	FDI → FR
Jamaica	23.3325	9.2354*	FDI → FR
Mexico	9.1242	34.154***	FDI → FR
Nicaragua	14.2473***	0.365	FR → FDI
Panama	8.147***	11.2354	FR → FDI
St. Vincent and the Grenadines	6.1147**	4.3549	FR → FDI
Trinidad and Tobago	11.3654**	7.6954**	FDI ↔ FR

Source: Authors' compilations.

Table 8 Granger Causality Test: FR vs FDI for South American Countries.

Country	FR → FDI	FDI → FR	Causality Findings
Argentina	6.8243**	1.264***	FDI ↔ FR
Bolivia	1.95389	56.234***	FDI → FR
Brazil	11.6655	1.2143*	FDI → FR
Paraguay	18.508***	3.2569	FR → FDI
Uruguay	21.972***	5.3654	FR → FDI

Source: Authors' compilations.

Table 9 Granger Causality Test: FR vs FDI for Asia and Oceania Countries.

Country	FR → FDI	FDI → FR	Causality Findings
Armenia	4.3652	17.1501***	FDI → FR
Australia	11.9725	36.41**	FDI → FR
Azerbaijan	36.224	12.2547*	FDI → FR
Bangladesh	19.935***	7.01114**	FDI ↔ FR
China	6.247**	3.0014	FR → FDI
India	47.00247***	6.1247*	FDI ↔ FR
Indonesia	24.3365***	2.2348	FR → FDI
Israel	19.247	6.1953***	FDI → FR
Kazakhstan	2.48	2.2301**	FDI ↔ FR
Kyrgyz Republic	14.248***	32.2214	FR → FDI
Malaysia	6.0039	4.247***	FDI → FR
Maldives	8.2584	4.935***	FDI → FR
Mongolia	7.2247***	11.4147	FR → FDI
Nepal	9.2284***	2.852***	FDI ↔ FR
Oman	7.8743	3.369***	FDI → FR
Philippines	14.872***	2.365*	FDI ↔ FR
Saudi Arabia	1.3665	1.021***	FDI → FR
Singapore	2.984	6.001***	FDI → FR
Solomon Islands	2.2558***	6.0014	FR → FDI
Sri Lanka	11.395***	1.658	FR → FDI
Thailand	6.248	8.248**	FDI → FR
Vanuatu	3.3695	52.365***	FDI → FR

Source: Authors' compilations.

appropriate lag selection. Unit root test results and lag selection for all countries are detailed in S3 Appendix, while full Granger Causality results are provided in S4 Appendix.

Table 5 presents the Granger Causality results for European countries. Excluding Albania, Estonia, Finland, Germany, Iceland, Lithuania, Moldova, Netherlands, North Macedonia, Slovenia, and Sweden, all other countries exhibit Granger causality between FDI and FR among the 34 European countries analysed, nine display bidirectional causality between FDI and FR (Belarus, Croatia, Denmark, Greece, Italy, Malta, Norway, Poland, and Switzerland). Cyprus, Latvia, Romania, Russia, Turkey, the UK, Ukraine, and the Slovak Republic show unidirectional causality from FR to FDI while six countries demonstrate causality from FDI to FR.

Table 6 provides the Granger Causality test results for African countries. Among 21 countries analysed, only Sierra Leone, Tunisia, and Zambia exhibit bidirectional causality between the FDI and FR. Botswana, Djibouti, Egypt Arab Republic, Ethiopia, and Madagascar show unidirectional causality from FR to FDI, while Cabo Verde, Kenya, Malawi, Morocco, Nigeria, and Seychelles display causality from FDI to FR (Osigwe and Uzonwanne, 2015). The variation in results is attributed to the use of different lag orders, with lag three identifying bidirectional causality and lag two showing unidirectional causality from FR to FDI.

Table 7 summarises the Granger Causality test results for North American countries. The findings indicate that Bahamas, Belize, Canada, Costa Rica, Guatemala, Grenada, Jamaica, and Mexico exhibit one-way causality from FDI to FR. Dominica, Nicaragua, Panama, and St. Vincent and the Grenadines show one-way causality from FR to FDI. No causality between FDI and FR is observed in Antigua and Barbuda, Dominican Republic, St. Lucia, and the United States. Trinidad and Tobago are the only country with bidirectional causality.

Table 8 presents the Granger Causality test results for South American countries. Of the ten countries analysed, Brazil and Bolivia display one-way causality from FDI to FR, while Paraguay and Uruguay show unidirectional causality from FR to FDI. Argentina is the sole country with bidirectional causality among the South American nations.

Table 9 shows the Granger Causality test results for Asia and Oceania countries. Most countries (11) display a one-way causality from FDI to FR, while six countries (China, Indonesia, Kyrgyz Republic, Mongolia, Solomon Islands, and Sri Lanka) exhibit causality from FR to FDI. Bangladesh, India, Nepal, and the Philippines are characterised by bidirectional causality. The study aligns with previous research indicating unidirectional relationships from foreign exchange reserves to FDI (Osigwe and Uzonwanne, 2015; Huang et al., 2011).

However, this country-wise analysis provides evidence regarding the fact that even in the same region, behaviour and the nature of the relationship differ for the reasons which are geographical, cultural, and even institutional reasons across the countries and differences in the conditions of variables.

As a robustness check, a panel Granger causality test was conducted in the study. The results of the global context and impulsive response of FDI and FR are shown in Table 3, which is included in S 6Appendix.

Table 10 provides the Granger Causality test results for the global context. Overall, the analysis of 110 countries reveals a unidirectional causality from FR to FDI. In contrast, Africa shows bidirectional causality, consistent with findings from Huang et al. (2011) and Maram and Kishore (2012), which reported bidirectional and unidirectional relationships, respectively, between FR and FDI.

Table 10 Granger Causality Test: FR vs FDI for Global context.

Classification	FR → FDI	FDI → FR	Causality Findings
Global	15.611**	3.195**	FR → FDI
Africa	19.921***	15.678*	FDI ↔ FR
Asia and Oceania	9.981**	4.101	FR → FDI
North America	21.152 **	8.021	FR → FDI
South America	12.287**	4.791	FR → FDI

Source: Authors' compilations.

Conclusion, limitations and future research

Conclusion. This study examines the global linkage between FR and FDI, addressing gaps in existing research. By employing continent-wise analysis and panel data from 2002 to 2022, the study investigates the effects of cultural, institutional, and economic factors on this relationship. Key findings reveal necessary causality between FR and FDI, a global positive correlation, and varying short- and medium-term dynamics. The Granger Causality analysis highlights country-specific causal interrelationships, with FR predominantly influencing FDI, although some cases exhibit bidirectional causality.

At a global level, the analysis confirms a positive relationship between FDI and FR in both developed and developing nations. However, the European region displays a more complex correlation, influenced by the European Monetary Union (De Grauwe and Ji, 2018b). The implications for policymakers are significant. Understanding the complex interrelation between FDI and FR is essential for crafting effective strategies to leverage FR to attract investment. Policymakers in developing economies should focus on building up FR to signal financial stability, which can make these countries more attractive to foreign investors. At the same time, creating a stable investment climate is crucial, which can be achieved by maintaining fiscal discipline, fostering export growth, and implementing favourable tax policies. These efforts not only enhance FR but also make a country more appealing to foreign investors. For instance, nations with substantial foreign reserves, such as China, have successfully utilised their reserves to position themselves as leading global icon in foreign investment.

Beyond these broader recommendations, there are several more actionable, micro-level suggestions for governments and policymakers. First, countries should improve foreign reserve management by adopting strategies that build reserves in line with economic stability. This could involve policies to increase reserves, such as encouraging exports, managing external debt effectively, and promoting trade surpluses. Second, governments should focus on improving their domestic investment climate by simplifying business regulations, providing tax incentives for foreign investors, and upgrading infrastructure. Countries in regions with a strong link between FDI and FR, such as Asia or South America, can use these measures to strengthen their position in attracting foreign capital.

Additionally, developed countries should explore ways to encourage outward FDI, especially in case of global uncertainty. By helping capital flows to developing economies, these countries can support strengthen FR in host nations and aid in global economic recovery, generating mutually beneficial opportunities for both developed and developing nations.

This research contributes to the academic discourse by addressing critical questions about the FDI-FR relationship and offering valuable insights into how these factors interact across different regions. While the study provides broad recommendations, future research should explore these dynamics through case studies and granular data, addressing challenges faced by countries at different levels of economic development. The application of advanced analytical models and detailed datasets will further refine our understanding of this complex relationship, leading to more targeted national policy recommendations.

In conclusion, this study highlights the role of FR in attracting FDI and provides practical recommendations for policymakers. By strengthening financial systems, enhancing export incentives, fostering outward investment, and creating an investment-friendly environment, countries can develop the stability necessary to attract and sustain foreign investment. These efforts will support FR growth and promote long-term economic development. Future research should focus on region-specific policies to offer more actionable insights for governments worldwide.

Limitations and future research. This study analysed data from 110 countries over a 21-year period (2002–2022). The conceptual framework identifies FDI as the dependent variable and FR as the independent variable. However, this research did not consider other significant variables, such as economic growth, the degree of openness, market size, human capital, and government stability. Future researchers should assess the relationship between these variables, which were not considered in this study.

Additionally, for analytical clarity, countries were classified by region. However, the impact of current economic situations, such as inflation, financial crises, and terrorism may vary by country. Government regulations, macroeconomic and trade policies, and other prevailing conditions may also influence the relationship between exchange rates and FDI. By addressing these limitations, future studies can provide a more nuanced understanding of FDI-FR dynamics and their policy implications in different economic environments.

Data availability

Data generated during this analysis are provided as Supplementary Materials.

Received: 24 May 2024; Accepted: 13 March 2025;
Published online: 02 April 2025

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Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

No informed consent was needed for this article.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-025-04770-7.

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