The impact of exchange rate volatility on economic growth: a meta-analysis approach

Amirhosein Sheykhi, Reza Taleblou and Parisa Mohajeri
Department of Economics, Allameh Tabataba'i University, Tehran, Iran

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Abstract

Purpose – Empirical studies examining the impact of exchange rate volatility on economic growth present diverse and often conflicting findings. While some studies report a negative relationship, others find a positive or negligible impact, highlighting a gap in understanding the causes of these discrepancies. To date, no meta-analysis addressing this issue has been published in publicly available scientific sources.

Design/methodology/approach – This study aims to fill this gap by conducting a comprehensive meta-analysis of 158 empirical estimates from 36 studies.

Findings – After examining the heterogeneity of estimates and publication bias, the results of the meta-analysis reveal that exchange rate volatility has a significant negative impact (−0.2432) on economic growth. Further regression analysis identifies key sources of variation across studies, including differences in estimation methods, control variables and timeframes. The use of techniques such as ordinary least squares, generalized least squares, vector error correction model, random effects and GMM significantly amplifies the negative effect, while the inclusion of control variables like capital and inflation mitigates it. Conversely, variables such as exports and terms of trade intensify the negative relationship. Additionally, longer study periods exacerbate the adverse effects of exchange rate volatility on economic growth.

Originality/value – This study provides the first systematic synthesis of findings in this domain, offering valuable insights for future research and policymaking.

Keywords Exchange rate volatility, Economic growth, Meta-analysis, Publication bias, Bayesian averaging, Meta-regression

Paper type Research paper

1. Introduction

Economic growth and sustainable development are key priorities for all nations. Achieving sustainable economic growth necessitates the accurate identification of factors influencing it. Over recent decades, economic growth and its determinants have become central themes in economic research. Among these determinants, exchange rate volatility has garnered significant attention due to its complex and multifaceted impact. On one hand, exchange rate volatility poses challenges for economies by creating uncertainty and unpredictability. On the other hand, it can serve as a flexible mechanism for responding to external shocks, enabling economies to adjust rapidly to changing conditions. This positive perspective, first highlighted by Friedman, supported the argument for eliminating currency restrictions and abandoning the Bretton Woods system. Consequently, exchange rate volatility can act as either a disruptive force or a driver of economic growth, depending on the context (Hohensee and Lee, 2006).

Despite the extensive research on this subject, existing studies reveal significant variations and conflicting findings regarding the impact of exchange rate volatility on economic growth. This inconsistency necessitates a unified examination to identify the underlying causes. To address this gap, the present study conducts a comprehensive meta-analysis, synthesizing the findings of 36 empirical studies published up to April 30, 2024, sourced from Google Scholar. This study aims to answer two critical questions: Does exchange rate volatility significantly affect economic growth? And what is the direction of this impact?

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In addition to estimating the overall effect, the study investigates the factors contributing to variations in findings across studies. These variations may arise from differences in the economic structures of the countries analyzed, the choice of control variables, data characteristics, or methodological approaches. By addressing these issues, the article seeks to provide a holistic and nuanced understanding of the relationship between exchange rate volatility and economic growth.

The article is structured as follows: Section 2 reviews the relevant literature, offering insights into the factors influencing economic growth and the role of exchange rate volatility. Section 3 details the data collection process and explains the meta-analysis methodology employed in this study. Section 4 presents the results and discusses the research findings on the effects of exchange rate volatility on economic growth. Section 5 concludes the paper by summarizing the key findings and providing recommendations for future research and policy-making. By synthesizing existing research and identifying patterns in the data, this article contributes to bridging the gap in the literature and offers valuable insights into the broader implications of exchange rate volatility for economic growth.

2. Research literature review

Exchange rate volatility is a pivotal factor in analyzing economic efficiency and designing growth policies, attracting significant attention from researchers. This volatility profoundly influences macroeconomic indicators, particularly economic growth. In recent decades, understanding the structure and effects of exchange rate regimes has become an essential component of economic policymaking. The collapse of the Bretton Woods system in the early 1970s marked a global shift towards floating exchange rate regimes. Under this system, exchange rates are determined by market forces of supply and demand, offering flexibility to adapt to economic changes. However, this flexibility comes with concerns about the potential for severe exchange rate volatility and its adverse effects on economic growth. In fact, floating exchange rates may hinder growth by increasing investment risks and trade transaction costs.

Conversely, fixed exchange rate regimes provide greater stability, fostering investor confidence. This stability can encourage investment, enhance international trade, and ultimately support economic growth. The choice between fixed and floating exchange rate regimes depends on a country's economic structure, risk tolerance, and policy goals. Policymakers must weigh the trade-offs to balance short-term stability with long-term growth objectives. The effects of exchange rate volatility on economic growth are transmitted through three primary channels (Schnabl, 2009).

The first channel is *asymmetric shocks*. Floating exchange rate regimes are often considered effective tools for addressing asymmetric shocks. As Friedman (1953) argued, the flexibility of floating exchange rates allows economies to respond more quickly and proportionately to such shocks, which is particularly critical for open and vulnerable economies. In contrast, McKinnon (1963) emphasized the benefits of fixed exchange rate regimes for small open economies, where monetary and exchange rate policies are prone to volatility and uncertainty. Reduced exchange rate volatility under fixed regimes can help stabilize these economies, creating an environment conducive to economic growth (Mundell, 1973).

The second channel is *international trade*. From a microeconomic perspective, short-term exchange rate volatility introduces uncertainty, increasing hedging and transaction costs for businesses. Fixed exchange rates, by minimizing this volatility, enhance market transparency and simplify price comparisons, improving efficiency for producers and consumers. From a macroeconomic perspective, prolonged exchange rate volatility can erode the competitiveness of exports, particularly in economies heavily reliant on exports. This diminished competitiveness can constrain economic growth over the long term.

The third channel is *capital flows*. Exchange rate stability plays a critical role in shaping investor behavior. Unstable exchange rates can increase the risk premium for foreign

investments, deterring capital inflows. Conversely, stable exchange rates reduce investment risks, encouraging long-term capital formation, which is a crucial driver of economic growth. In the short term, fixed exchange rates can enhance capital allocation efficiency by facilitating international capital flows and reducing transaction costs (McKinnon, 1973). However, in the long term, exchange rate volatility poses significant risks for emerging economies. These risks are particularly evident in the balance sheets of banks and corporations that often carry foreign debt denominated in foreign currencies. Such exposure makes these entities vulnerable to exchange rate volatility, as highlighted by Eichengreen and Hausmann (1999).

The literature on the relationship between exchange rate volatility and economic growth reflects diverse perspectives. To further explore these variations, empirical studies on this topic can be grouped into three categories: the first category includes studies that reveal the negative impact of exchange rate volatility on economic growth. Numerous studies indicate that exchange rate volatility adversely affects economic growth. For example, Sabina *et al*. (2017) reported a significant negative impact of exchange rate volatility on Nigerian economic growth. Aghion *et al*. (2009) by analyzing data from 83 countries found that the negative effects of exchange rate volatility are more pronounced in countries with underdeveloped financial markets.

The second category includes research studies that have reported the positive impact of exchange rate volatility on economic growth For instance: Ali (2022) by investigating South Asian countries found that exchange rate volatility had a positive and significant impact on economic growth in the region, possibly due to increased competitiveness in global markets. The third group is dedicated to studies that have found no significant impact of exchange rate volatility on economic growth. For example: Bleaney and Greenaway (2001) by conducting research on sub-Saharan African countries concluded that exchange rate volatility did not significantly affect economic growth in the region.

In addition to individual case studies, meta-analyses have provided broader insights. A noteworthy study by Ridhwan *et al*. (2024) conducted a meta-analysis of 51 studies to examine the relationship between exchange rates and economic growth. Their findings revealed that, in developing countries, maintaining the exchange rate below its real value could effectively boost economic growth. While Ridhwan *et al*. focused on the broader implications of exchange rate policies, the present study takes a distinct approach. It emphasizes the specific effects of exchange rate volatility on economic growth, offering a more nuanced understanding of the mechanisms and contextual factors driving these outcomes.

The impact of exchange rate volatility on economic growth remains a complex and contested issue in economics. Divergent results in the literature stem from variations in methodologies, time periods, and the economic structures of the countries analyzed. Many studies argue that exchange rate volatility negatively affects economic growth by increasing market uncertainty and raising transaction costs of trade and investment. This perspective is particularly strong for economies heavily reliant on imports and exports, where volatility can disrupt economic stability and hinder growth. In contrast, other studies emphasize the complexity of the relationship, suggesting that the impact of exchange rate volatility cannot be definitively categorized as negative. These studies highlight the importance of factors such as financial market development, economic structure, and policy flexibility. These factors may moderate or amplify the effects of exchange rate volatility, making their impact highly context-dependent.

Given the divergence of findings and the variability in results, conducting a meta-analysis is essential. The present study employs meta-analyses techniques to integrate and analyze the findings of diverse studies. This approach aims to provide a more comprehensive and precise understanding of the overall impact of exchange rate volatility on economic growth. In addition, this meta-analysis identifies the factors most responsible for the observed differences in study results. By doing so, it offers valuable insights for policymakers to make informed decisions, tailored to the unique economic conditions of their countries. Furthermore, this research highlights gaps in the existing literature and suggests new directions for future

studies, contributing to the ongoing discourse on exchange rate dynamics and economic growth.

3. Methodology and data

Meta-analysis is a widely recognized and rigorous method for conducting systematic reviews, offering a statistical approach to integrating and synthesizing the findings of multiple studies. This approach is particularly effective when individual studies have small or inconsistent sample sizes, as it increases statistical power and stabilizes results (Hedges and Olkin, 1985). By combining diverse research outcomes, meta-analysis aims to arrive at a comprehensive conclusion (Stanley, 2001).

In this study, the meta-analysis was performed using R software, employing the Meta and metafor packages. Following the guidelines of Havranek *et al*. (2020), the meta-analysis process in this research comprised four main steps:

Step 1- Defining the Research Topic and Questions: The research topic and objectives were clearly outlined in the introduction, focusing on the impact of exchange rate volatility on economic growth.

Step 2- Search, Collection, and Coding of Studies: This step, the most time-intensive and critical phase of meta-analysis, accounted for approximately 90–95% of the overall effort (Hunter and Schmidt, 1990). It involved the following sub-steps: first, all articles were reviewed without time restrictions. These articles were sourced from the Google Scholar database using keywords such as "economic growth", "exchange rate", "exchange rate volatility", and "exchange rate fluctuations" and the search was concluded on April 30, 2024. Google Scholar was chosen as the preferred database due to its reputation as the most comprehensive resource for online published articles. To ensure the accuracy and relevance of the search, five seminal and highly regarded articles in the field were initially identified. The search was designed to confirm that these key studies were included in the results, and all of them appeared in the search outcomes. Moreover, to enhance the robustness of the search, it was repeated multiple times to ensure comprehensive coverage of the relevant literature. Second, among the first 400 studies retrieved in the search, those relevant to the research topic were added to the Excel spreadsheet. To ensure that no important studies were overlooked, the search was repeated in the ScienceDirect database, but no new studies were identified. Third, abstracts were reviewed to narrow the selection to studies meeting the following criteria:

- Regression models where the dependent variable was economic growth,
- Exchange rate volatility as the independent variable,
- Studies were excluded if they lacked complete information (e.g. missing t-statistics or standard errors) or focused solely on GDP instead of economic growth.

Finally, the final dataset consisted of 36 studies (for detailed information on the included studies, see Appendix) and 158 regressions after excluding studies that did not meet the criteria. To collect data from these 36 selected studies, a list of variables to be coded was first compiled. This list included key variables from the theoretical framework for examining the relationship between exchange rate volatility and economic growth, as well as variables that were frequently observed in the initial review of the studies and were expected to account for contextual differences across the studies. These variables included: general information about each study, data used in the study, dependent and independent variables, methods for measuring exchange rate volatility, regression and statistical results of each study, model estimation methods, and geographic information about the countries studied.

Subsequently, for coding the studies and collecting data, the full text of each study was carefully reviewed, and the relevant data were extracted. To minimize the possibility of errors,

the data collection process was carried out independently by two individuals, and their results were compared. Any discrepancies or errors in the data collection were identified and corrected. Furthermore, to ensure greater accuracy, the data were rechecked and verified through a repeat review of the studies. Descriptive statistics are reported in Table 1.

The forest plot (Figure 1) provides a visual representation of the variation and diversity in the results across studies. Upon examining the studies included in this meta-analysis, it was found that approximately 78% of the studies reported a negative effect of exchange rate volatility on economic growth. This indicates that the majority of the literature views exchange rate volatility as a detrimental factor for economic growth. However, about 22% of the studies observed a positive effect of exchange rate volatility on economic growth. This diversity in findings underscores the complexity of the relationship between exchange rate volatility and growth and highlights the importance of systematically synthesizing these results through a meta-analytic approach. The forest plot effectively captures these discrepancies, offering insights into the heterogeneity of the studies and emphasizing the need for a comprehensive and quantitative summary to resolve conflicting evidence.

A review of the studies reveals that much of the literature on exchange rate volatility and economic growth has concentrated on sub-Saharan Africa and the Middle East and North Africa (MENA) regions (see Figure 2). This concentration highlights the significant importance of exchange rate volatility in these regions, where economic growth is often affected by exchange rate volatility and external shocks.

Third Step- Statistical Analysis: The third stage of the meta-analysis involves the statistical evaluation of effect sizes extracted from the selected studies. One of the most significant challenges in comparing the results of different studies is the variation in sample size, measurement methods, control variables, models used to assess exchange rate volatility, and estimation techniques applied across studies. These differences make direct comparisons of estimates challenging and may compromise the accuracy and validity of the meta-analysis if not properly addressed. Therefore, standardizing effect sizes is essential to ensure meaningful comparison, aggregation, and comprehensive analysis of the results.

In this meta-analysis, the Partial Correlation Coefficient (PCC) is used as the standardized effect size. PCC allows for the uniform comparison of reported effects across studies, minimizing the influence of structural differences among them.

The formula to calculate PCC is derived from the t-statistic and the degrees of freedom (dof) of each study (Greene, 2008):

$$\mathrm{PCC_{ij}} = \frac{\mathrm{t_{ij}}}{\sqrt{t_{ij}^2 - dof_{ij}}} \tag{1}$$

Where $\mathrm{PCC_{ij}}$ represents the partial correlation coefficient of the estimate *i* from study *j* in which in the present study its coefficient represents the direction of the effect of exchange rate volatility on economic growth and its value represents the size of the effect of exchange rate volatility on economic growth. Also, $\mathrm{t_{ij}}$ is the t-statistic and dof_{ij} represents the degrees of freedom. The PCC value indicates both the direction and the magnitude of the effect of exchange rate volatility on economic growth. The range of the PCC is between −1 and 1, where a negative value indicates a negative effect and a positive value indicates a positive effect.

The standard error (SE) of the PCC is computed using the following formula:

$$SE_{\mathrm{PCC_{ij}}} = \frac{\mathrm{PCC_{ij}}}{t_{ij}} \tag{2}$$

The Pearson correlation coefficient (PCC) inherently accounts for differences in sample sizes because both the t-statistic and the degrees of freedom (dof) are directly influenced by the

Table 1. Statistical summary of meta-analysis variables

Variable	Description	Mean	SD	Min	Max
Year	Year of study publication	2011	5.66	2007	2023
Start	Starting year of sample period used for estimation	1988	9.19	1960	2002
End	End year of sample period used for estimation	2008	5.95	2000	2021
Data.Length	Duration of data period used for estimation	21.54	10.78	6.00	48.00
Data.Midpoint.1960s	= 1 if data starts from the 1960s	0.03	0.18	0.00	1.00
Data.Midpoint.1970s	= 1 if data starts from the 1970s	0.08	0.28	0.00	1.00
Data.Midpoint.1980s	= 1 if data starts from the 1980s	0.42	0.50	0.00	1.00
Data.Midpoint.1990s	= 1 if data starts from the 1990s	0.92	0.27	0.00	1.00
Data.Midpoint.2000s	= 1 if data starts from the 2000s	1.00	0.00	1.00	1.00
Data.Midpoint.2010s	= 1 if data starts from the 2010s	0.37	0.48	0.00	1.00
Data.Midpoint.2020s	= 1 if data starts from the 2020s	0.06	0.23	0.00	1.00
NER	= 1 if nominal exchange rate is used	0.55	0.50	0.00	1.00
RER	= 1 if real exchange rate is used	0.45	0.50	0.00	1.00
RGDP	= 1 if economic growth is the dependent variable	0.75	0.43	0.00	1.00
GDP	= 1 if GDP is the dependent variable	0.14	0.35	0.00	1.00
GDP.per.Capita	= 1 if GDP per capita is the dependent variable	0.11	0.31	0.00	1.00
SD	= 1 if standard deviation is used to measure exchange rate volatility	0.39	0.49	0.00	1.00
Garch	= 1 if GARCH models are used to measure exchange rate volatility	0.34	0.47	0.00	1.00
z.score	= 1 if Z-Score method is used to measure exchange rate volatility	0.24	0.43	0.00	1.00
Coefficient	Regression coefficient for exchange rate volatility	−1.02	3.55	−25.20	15.59
SE	Standard error of the regression coefficient	0.70	1.67	0.00	10.54
t	t-statistic	−3.61	4.60	−35.59	12.80
Sample.size	Sample size	12.82	10.55	1.00	69.00
STR	= 1 if Smooth Transition Regression (STR) is used	0.01	0.11	0.00	1.00
OLS	= 1 if Ordinary Least Squares (OLS) estimator is used	0.04	0.21	0.00	1.00
GLS	= 1 if Generalized Least Squares (GLS) estimator is used	0.28	0.45	0.00	1.00
EGLS	= 1 if Estimated Generalized Least Squares (EGLS) method is used	0.01	0.11	0.00	1.00
VECM	= 1 if Vector Error Correction Model (VECM) estimator is used	0.03	0.16	0.00	1.00
IV	= 1 if Instrumental Variables (IV) estimator is used	0.03	0.18	0.00	1.00
FE	= 1 if Fixed Effects (FE) estimator is used	0.08	0.28	0.00	1.00
RE	= 1 if Random Effects (RE) estimator is used	0.01	0.11	0.00	1.00
GMM	= 1 if Generalized Method of Moments (GMM) estimator is used	0.34	0.48	0.00	1.00
VAR	= 1 if Vector Autoregressive (VAR) estimator is used	0.03	0.16	0.00	1.00
ARDL	= 1 if Autoregressive Distributed Lag (ARDL) estimator is used	0.13	0.33	0.00	1.00
Capital	= 1 if capital is an explanatory variable	0.06	0.23	0.00	1.00
Lag_GDP	= 1 if lagged GDP is an explanatory variable	0.09	0.29	0.00	1.00

(*continued*)

Table 1. Continued

Variable	Description	Mean	SD	Min	Max
H.Capital	= 1 if human capital is an explanatory variable	0.03	0.18	0.00	1.00
Health	= 1 if health is an explanatory variable	0.01	0.08	0.00	1.00
Inflation	= 1 if inflation is an explanatory variable	0.43	0.50	0.00	1.00
Labor	= 1 if labor force is an explanatory variable	0.05	0.22	0.00	1.00
FDI	= 1 if foreign direct investment is an explanatory variable	0.07	0.26	0.00	1.00
Investment	= 1 if investment is an explanatory variable	0.15	0.35	0.00	1.00
Gsize	= 1 if government size is an explanatory variable	0.13	0.34	0.00	1.00
Trade.openness	= 1 if trade openness is an explanatory variable	0.20	0.40	0.00	1.00
Oil	= 1 if oil price is an explanatory variable	0.06	0.23	0.00	1.00
EXP	= 1 if exports are an explanatory variable	0.35	0.48	0.00	1.00
IM	= 1 if imports are an explanatory variable	0.01	0.11	0.00	1.00
TOT	= 1 if terms of trade are used	0.04	0.19	0.00	1.00
INT	= 1 if interest rate is an explanatory variable	0.24	0.43	0.00	1.00
Population	= 1 if population is an explanatory variable	0.04	0.21	0.00	1.00
FD	= 1 if financial development is an explanatory variable	0.10	0.30	0.00	1.00
Foreign.debt	= 1 if foreign debt is an explanatory variable	0.04	0.19	0.00	1.00
M	= 1 if liquidity is an explanatory variable	0.03	0.18	0.00	1.00
Regressors	Total number of explanatory variables included in the regression (excluding constant)	4.93	2.21	1.00	12.00
East.Asia . . . Pacific	= 1 if East Asia and Pacific countries are included in the sample	0.34	0.48	0.00	1.00
South.Asia	= 1 if South Asian countries are included in the sample	0.06	0.23	0.00	1.00
Asia	= 1 if Asian countries are included in the sample	0.13	0.33	0.00	1.00
Europe	= 1 if European countries are included in the sample	0.47	0.50	0.00	1.00
Latin.America . . . Caribbean	= 1 if Latin American and Caribbean countries are included in the sample	0.20	0.40	0.00	1.00
Middle.East . . . North.Africa	= 1 if Middle Eastern and North African countries are included in the sample	0.18	0.39	0.00	1.00
Sub.Saharan.Africa	= 1 if Sub-Saharan African countries are included in the sample	0.26	0.44	0.00	1.00
Rest.of.the.world	= 1 if other regions are included in the sample	0.06	0.23	0.00	1.00
Iran	= 1 if Iran is included in the sample	0.12	0.33	0.00	1.00
Panel	= 1 if the coefficient is extracted from panel data regression	0.73	0.45	0.00	1.00
Time.series	= 1 if the coefficient is extracted from time-series data regression	0.27	0.45	0.00	1.00
Citation	Number of citations for the study	75.82	63.74	0.00	254
log_Citation	Logarithmic transformation of citations	3.38	1.86	0.00	5.54
log_Sample.size	Logarithmic transformation of sample size	1.98	1.30	0.00	4.23
log_Data.Length	Logarithmic transformation of data length	2.93	0.54	1.79	3.87

sample size. This means that when computing PCC, variations in sample size are considered as part of the standardization process. However, even though PCC is standardized, it still maintains a connection to the true effect size. This relationship exists because the t-statistic is directly dependent on the true effect size, and in turn, the standardized effect size is derived

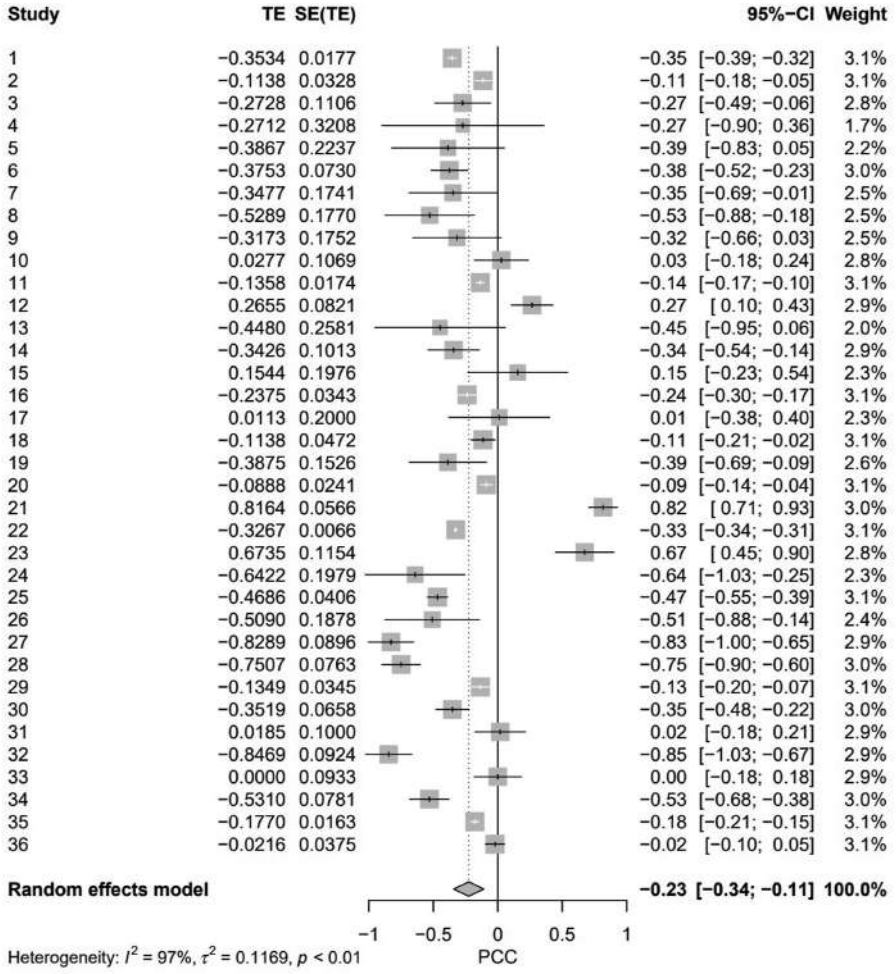

Figure 1. Forest plot: weighted average effect size (PCC) per study Source: Authors' own creation

from the t-statistic. Furthermore, since PCC is a unitless measure, it enables meaningful comparisons between different studies, without attention to differences in study designs. This makes it a useful and consistent metric for assessing the strength and direction of the relationship between two variables across various research contexts.

From this point forward, effect size refers to the standardized effect size calculated using PCC. With the necessary sensitivity to detect differences between studies and sufficient stability for reliable cross-study comparisons, PCC serves as a robust and scalable measure in meta-analysis.

Before proceeding with the meta-analysis, it is essential to assess the heterogeneity of the studies. Heterogeneity measures the variation in effect sizes between studies and informs the choice between a fixed-effects model or a random-effects model for the analysis. The fixed-effects model is appropriate when studies are assumed to estimate the same effect size (i.e., homogeneity among studies). The random-effects model is employed when there is heterogeneity between studies, meaning that the studies estimate different effect sizes. The random-effects model adjusts for variability in study results, acknowledging that each study

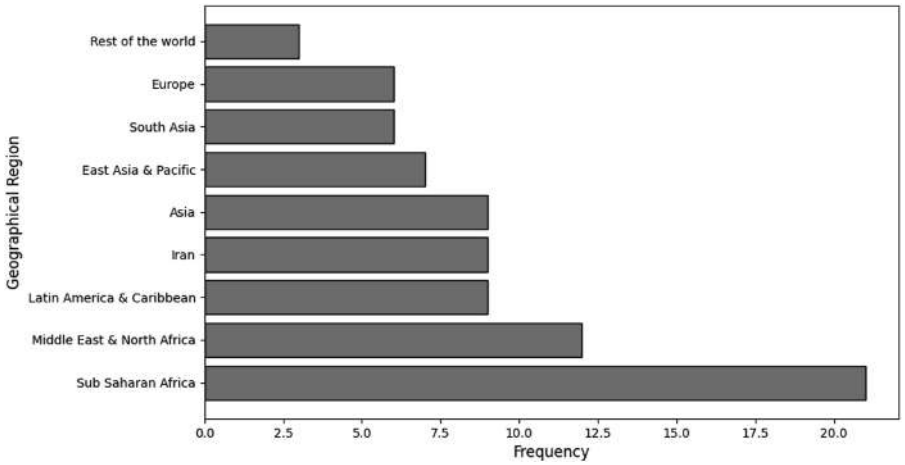

Figure 2. Distribution by geographical region Source: Authors' own creation

has its own unique effect size (Schwarzer *et al*., 2015). The *Q* test, proposed by Cochran (1954), is commonly used to assess heterogeneity in meta-analysis. The null hypothesis of the *Q* test posits that all studies share the same effect size. The *Q* statistic is calculated as follows:

$$Q = \sum_{k=1}^{K} \omega_k \left(\widehat{\theta}_k - \widehat{\theta}\right)^2 \tag{3}$$

Where *K* is the number of studies, ω_k is the weight of study *k*, $\widehat{\theta}_k$ is the effect size estimate for study, and $\widehat{\theta}$ is the overall effect size estimate. The value of *Q* indicates the degree of heterogeneity in the studies. A significant *Q* value suggests that heterogeneity exists.

Another measure of heterogeneity is the I^2 statistic, which quantifies the percentage of total variation in study results that is due to heterogeneity rather than sampling error. It is calculated as follows:

$$I^2 = \frac{Q - dof}{Q} \times 100 \tag{4}$$

Where *Q* is the *Q* statistic from the previous formula, and *dof* is degrees of freedom. The I^2 statistic ranges from 0% to 100%. Although Higgins *et al*. (2003) state that one set of I^2 values will not be appropriate for all situations, they suggest that values less than 25 percent be considered low heterogeneity, values between 25 and 50 percent as moderate heterogeneity, values between 50 and 75 percent as high heterogeneity, and values greater than 75 percent as very high heterogeneity.

One of the common methods used for analyzing data in meta-analysis is the random effects model. This model accounts for the fact that each study included in the meta-analysis may estimate a different effect size, and it considers both within-study variance and between-study variance. The random effects model can be represented as:

$$\widehat{\theta}_k = \theta + \mu_k + \sigma_{k\ k}\ .\ _k \sim N(0,1);\ \mu_k \sim N\left(0, \tau^2\right) \tag{5}$$

Where $\widehat{\theta}_k$ is the estimated effect size for study *k* and θ is the total effect size to be estimated, μ_k represents the study-specific random effect, $_k$ is the error term with a normal distribution, τ^2 is

the variance of the random effects, which captures between-study variability. If $\tau^2 = 0$, the random effects model is equivalent to the fixed effects model. The estimation of random effects and its variance is as follows (Schwarzer *et al*., 2015):

$$\widehat{\theta}_R = \frac{\sum_{k=1}^{K} \omega_k \widehat{\theta}_k}{\sum_{k=1}^{K} \omega_k} \tag{6}$$

$$\widehat{Var}\left(\widehat{\theta}_R\right) = \frac{1}{\sum_{k=1}^{K} \omega_k} \tag{7}$$

The overall effect size ($\widehat{\theta}_R$) in the random effects model is estimated by taking a weighted average of the individual study effect sizes. The weight of each study (ω_k) is calculated as follows:

$$\omega_k = \frac{1}{\left(\widehat{\sigma}_k^2 + \widehat{\tau}^2\right)} \tag{8}$$

There are also different methods for estimating heterogeneity between studies (τ^2), the use of each of which may have a significant impact on the weighting of studies. Restricted maximum likelihood and empirical Bayesian methods are commonly recommended for estimating τ^2 (Schwarzer *et al*., 2015).

A critical concern in meta-analysis is publication bias, which occurs when studies with smaller sample sizes are more likely to be published if they report stronger effects. This phenomenon arises because a stronger effect can counteract the reduction in statistical significance caused by a small sample size. Additionally, publication bias can occur when the decision to publish a study is influenced by the magnitude or direction of the reported effect. The presence of publication bias poses a significant challenge to meta-analysis, as it suggests that a subset of conducted studies remains unavailable, leading to an analysis based on incomplete data. Consequently, this bias can distort the results of the meta-analysis and lead to misleading conclusions.

In the present study, publication bias may stem from several factors, primarily related to how researchers report their findings and the editorial policies of academic journals. One of the most significant contributors is the tendency of researchers to report statistically significant findings and the preference of journals to publish studies with stronger results. This issue is particularly relevant in the context of examining the impact of exchange rate fluctuations on economic growth, as the prevailing hypothesis in the economic literature suggests a negative and significant relationship between exchange rate volatility and economic growth.

Under such conditions, researchers who obtain findings with low statistical significance or even positive effects may choose not to report or publish their studies. This reluctance may stem from the misalignment of their results with established theoretical expectations or concerns regarding the rejection of their manuscripts by academic journals. Similarly, journals may selectively avoid publishing studies that report an insignificant or even positive effect of exchange rate fluctuations on economic growth, prioritizing studies that align with conventional expectations. As a result, studies that report a weaker or non-significant effect of exchange rate volatility may be underrepresented, potentially biasing the meta-analysis results toward confirming the hypothesis that exchange rate fluctuations negatively affect economic growth.

Furthermore, the role of funding institutions may also influence the direction of reported results. For instance, studies funded by government-affiliated universities, international organizations, or financial policy institutions may exhibit a stronger tendency to present findings that align with the policy perspectives and interests of these institutions. One of the most common visual tools to detect publication bias is the funnel plot (Dwan *et al.*, 2008). This plot shows the effect sizes of studies on the *x*-axis and their standard errors (or sample sizes) on the *y*-axis. If there is no publication bias, the plot should resemble a symmetrical inverted funnel. Asymmetry in the plot may indicate the presence of publication bias. However, the funnel plot is a qualitative tool, and to accurately assess publication bias, quantitative tests are often necessary.

One widely used quantitative test for detecting publication bias is Egger's test, which involves simple linear regression. In this test, the effect size is regressed on its standard error. If a significant relationship is found between the effect size and the standard error, it suggests the presence of publication bias. A more advanced version of Egger's test is the Thompson and Sharp (1999) method, which improves upon Egger's test by accounting for heterogeneity among studies. This method uses a weighted linear regression to examine the relationship between the effect size and its standard error, providing more accurate results, especially when there is significant heterogeneity among the included studies.

To explore and explain the diversity in the effect sizes of studies, meta-regression is used as a powerful tool. Meta-regression helps to investigate the influence of study characteristics, such as the methodological approach, the exchange rate volatility, or the geographical region, on the overall effect size. The general form of a meta-regression equation is:

$$\widehat{\theta}_k = \theta + \beta_1 x_{1\,k} + \ldots + \beta_p x_{pk} + \mu_k + \sigma_{k\ k\ .\ \ k} \sim N(0.1);\ \mu_k \sim N\left(0.\tau^2\right) \tag{10}$$

Where $\widehat{\theta}_k$ represents the effect size of study *k*, and $k = 1, 2, \ldots, K$. The x_{pk} in this formula represent the control variables of the studies. After estimating the model, the coefficient of each control variable (β) provides insights into the influence of different study characteristics on the effect size (Schwarzer *et al.*, 2015). This allows researchers to determine which factors contribute most to the variation in the relationship between exchange rate volatility and economic growth.

In this study, due to the large number of variables under investigation, it is not practical to run regressions on all variables simultaneously. Instead, Bayesian Model Averaging (BMA) is employed to identify the most important variables to include in the analysis. BMA is a statistical method that calculates the Posterior Probability of Inclusion (PIP) for each candidate control variable. This measure reflects the likelihood that a given variable has a non-zero effect on the outcome variable. The PIP for each control variable is obtained by summing the posterior probabilities across all models that include that specific variable. This allows BMA to provide a probabilistic measure of the importance of each variable in predicting the outcome, effectively answering the question: "How likely is it that the control variable will influence the results?"

BMA operates by averaging over all possible models, which can be numerous depending on the number of variables under consideration. This characteristic of BMA makes it particularly valuable when dealing with a large set of potential variables, as it helps assess which variables are most important while considering a wide range of potential model configurations (Eicher *et al.*, 2011). Given its power and flexibility, BMA enables a more nuanced understanding of the relative importance of variables, thus streamlining the selection process.

Stage 4: Reporting and Interpreting the Findings: The final stage of the meta-analysis involves reporting and interpreting the findings. This stage is crucial for presenting the results of the meta-analysis in a clear and accessible manner. The results section will detail the findings from the previous stages, including the calculation of effect sizes, heterogeneity testing, and any other analyses conducted using methods such as BMA.

4. Results

As mentioned earlier, the collected effect sizes from the studies are not directly comparable. To standardize these results, we first need to calculate the PCC for each study's effect estimate. In the following, the calculated PCCs will be used as the effect size in the calculations. After calculating the PCCs, the heterogeneity in the studies will be examined. The results of the Cochran Q and I^2 tests to examine the heterogeneity between the 36 studies are given in Table 2.

As discussed, the Cochran's Q test indicated a large and significant value, suggesting that the studies included in the meta-analysis are heterogeneous and do not share a common effect size. This result rejects the homogeneity assumption and signals the need for a random effects model to account for the variations between studies. To further examine this heterogeneity, the I^2 test was also conducted, and with a value greater than 75%, it confirms the presence of very high heterogeneity among the studies (Higgins *et al*., 2003). Therefore, a random effects model is the most appropriate choice for estimating the total effect size.

The next step in meta-analysis is to calculate the total effect size, which determines the overall direction and magnitude of the effect of exchange rate volatility on economic growth across the studies. Based on the results from the random effects model, using the restricted maximum likelihood (REML), empirical Bayesian (EB), and maximum likelihood (ML) methods for estimating heterogeneity, the total effect size is found to be −0.2432 (see Table 3). This negative value suggests that, in general, exchange rate volatility has a negative impact on economic growth. According to Cohen's criteria for interpreting effect sizes, a small effect size is indicated, as the value of −0.2432 falls within the range typically considered slight in its strength (Cohen, 1988).

One of the key concerns in meta-analysis is publication bias, which can distort the results. Funnel plots are commonly used to visually inspect for bias. In an ideal situation without publication bias, the plot resembles a funnel, with symmetrical distribution of study estimates on both sides of the overall effect size. Figure 3 presents the funnel plot for this study.

Although the funnel plot gives a visual indication of potential bias, quantitative tests are used for a more reliable assessment of publication bias. To quantitatively assess publication bias, this study employs two commonly used tests including Egger and Thomson's test. The results of these two tests can be seen in Table 4.

Based on the results from both Egger's and Thompson's tests, there is insufficient evidence to confirm the presence of publication bias in the included studies. The P-values from both tests indicate that there is no significant bias, which means that the null hypothesis of data symmetry and the absence of publication bias is not rejected. This supports the validity of the

Table 2. Results of Cochran's Q and I^2 tests

Q-value	1012.90	$p < 0.0001$
I^2	96.5%	

Source(s): Authors' own creation, Research Findings

Table 3. Total effect size

Model	Observations	τ^2	Effect size	95% confidence interval	Z-value	P-value
RE-REML	158	0.0631	−0.2432	[−0.2856; −0.2009]	−11.26	<0.0001
RE-EB	158	0.0642	−0.2432	[−0.2859; −0.2005]	−11.17	<0.0001
RE-ML	158	0.0626	−0.2432	[−0.2854; −0.2010]	−11.30	<0.0001

Source(s): Authors' own creation, Research Findings

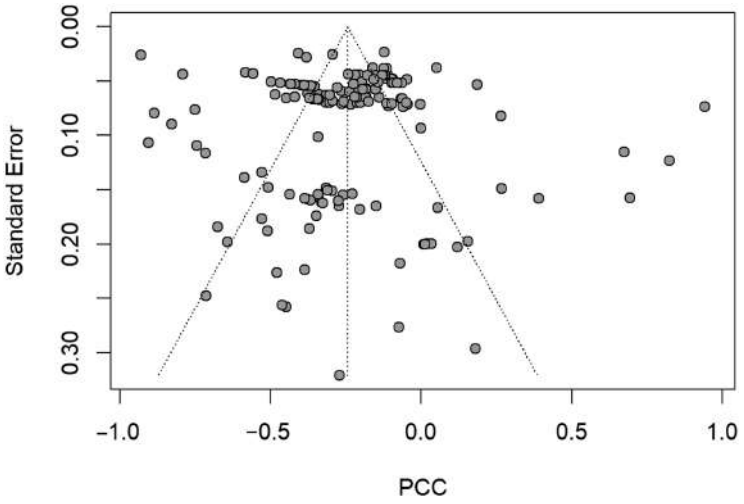

Figure 3. Funnel diagram Source: Authors' own creation

Table 4. The results of Egger and Thomson's test

Method	t	dof	*P*-value	Bias estimate	(SE)	Reference
Thompson	0.37	156	0.7122	0.1441	0.3897	Thompson and Sharp (1999)
Egger	1.43	156	0.1535	0.9466	0.6599	Egger *et al*. (1997)

Source(s): Authors' own creation, Research Findings

findings, suggesting that the meta-analysis results are not distorted by the selective publication of studies.

To further analyze the heterogeneity and explain the differences in the findings across studies, meta-regression is performed. However, before conducting the regression analysis, it is essential to identify the important variables that are likely to influence the results. For this purpose, Bayesian Model Averaging (BMA) is applied.

Bayesian Averaging provides a probabilistic framework that evaluates the likelihood of each variable appearing in the top models. The Posterior Inclusion Probability (PIP) is used as the metric to identify significant variables. Variables with a PIP greater than 10% are selected as the important variables to include in the meta-regression. Table 5 presents the results of the BMA analysis. The PIP values in the table indicate the likelihood of each candidate variable being included in the most influential models. Based on these values, the important variables will be chosen for inclusion in the meta-regression.

For a more intuitive understanding, the BMA results are displayed in Figure 4. This figure shows the presence of each variable in each iteration of the BMA model. The vertical axis represents the candidate variables and the horizontal axis shows the different models. A blue color indicates that the variable is included in the model and has a negative effect. In contrast, a red color indicates the variable is included in the model with a positive effect. Also, no color means that the variable is not included in the model for that iteration.

After identifying the important variables, regression analysis was performed using three estimators: restricted maximum likelihood (REML), empirical Bayesian (EB), and maximum likelihood (ML) to estimate heterogeneity. The results of this analysis are presented in Table 6.

Table 5. BMA results

Variable	PIP	Variable	PIP
Year	7.1	GMM	20.3
Start	99.2	Capital	100
End	96	Lag_GDP	6
log_Data.Length	89.1	H.Capital	7.1
Data.Midpoint.2010s	98.5	Inflation	100
Data.Midpoint.2020s	80.3	Labor	9.7
SD	49.9	FDI	5.5
Garch	38	Investment	4.8
z.score	13.6	EXP	98.9
OLS	84.3	TOT	99.9
GLS	12.7	M	5.8
VECM	52.4	Asia	23
IV	21.5	Europe	9.3
FE	6.5	Panel	14
RE	21.5	log_Citation	12.8

Source(s): Authors' own creation, Research Findings

The meta-regression analysis in this study sheds light on several key factors influencing the effect of exchange rate volatility on economic growth. The results from all three methods—restricted maximum likelihood (REML), empirical Bayesian (EB), and maximum likelihood (ML)—are consistent, showing no contradiction in their findings. This alignment indicates robustness in the results and enhances the credibility of the analysis. Findings from the Meta-Regression Analysis reveal that.

(1) *The negative Effect of Exchange Rate Volatility on Economic Growth*: The negative and significant intercept coefficient in the regression model reinforces the conclusion that exchange rate volatility generally has a negative effect on economic growth. This finding is consistent with the overall trend observed in the forest plot and highlights the detrimental impact of exchange rate volatility on economic stability and growth.

(2) *Methods for Estimating Exchange Rate Volatility:* The regression results show no significant effect from the method used to estimate exchange rate volatility. This suggests that researchers can confidently use different methods for estimating exchange rate volatility without it affecting the outcome of their studies.

(3) *Model Estimation Methods:* The choice of estimation method significantly impacts the results. Specifically: The OLS, GLS, VECM, RE, and GMM methods all have a negative and significant effect on the partial correlation coefficient, indicating that these methods tend to produce estimates that suggest a stronger negative impact of exchange rate volatility on economic growth. In contrast, the IV method, although positive in its effect on the results, was not found to be statistically significant.

(4) *The Influence of Choosing Control Variables on Results:* The use of different control variables explains a substantial part of the variation in the study results. Notably, the inclusion of Capital and Inflation as control variables tends to reduce the negative effect of exchange rate volatility on economic growth. Conversely, the inclusion of Exports and Terms of Trade intensifies the negative effect of exchange rate volatility on economic growth.

(5) *No Significant impact of Geographical Regions, Data Type, and References on Results:* This suggests that, while regional economic contexts are often emphasized in studies, these factors did not significantly alter the overall trend of exchange rate volatility negatively affecting economic growth.

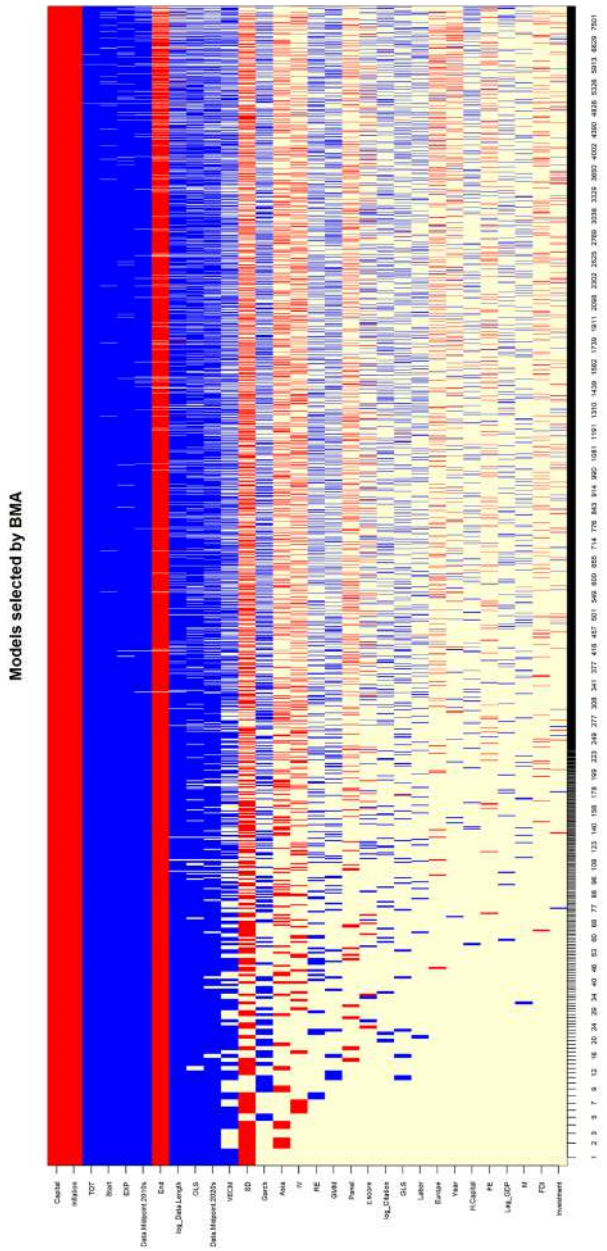

Figure 4. BMA results Source: Authors' own creation

Table 6. The results of meta-analysis

Estimator Variable	REML Coefficient	SE	EB Coefficient	SE	ML Coefficient	SE
intercept	−89.147 ***	21.994	−89.364 ***	22.379	−88.207 ***	20.558
Start	−0.037 ***	0.009	−0.037 ***	0.009	−0.036 ***	0.008
End	0.082 ***	0.017	0.082 ***	0.017	0.081 ***	0.016
log_Data.Length	−0.540 **	0.168	−0.543 **	0.171	−0.530 ***	0.159
Data.Midpoint.2010s	−0.639 ***	0.127	−0.641 ***	0.129	−0.632 ***	0.119
Data.Midpoint.2020s	−0.336 ***	0.100	−0.335 **	0.102	−0.339 ***	0.093
SD	−0.020	0.132	−0.021	0.134	−0.014	0.123
Garch	−0.140	0.122	−0.142	0.124	−0.130	0.114
z.score	−0.083	0.134	−0.084	0.136	−0.077	0.125
OLS	−0.421 ***	0.113	−0.421 ***	0.115	−0.422 ***	0.106
GLS	−0.125 .	0.074	−0.125 .	0.076	−0.127 .	0.070
VECM	−0.279 *	0.130	−0.278 *	0.132	−0.281 *	0.124
IV	0.106	0.115	0.107	0.118	0.101	0.107
RE	−0.323 *	0.136	−0.324 *	0.139	−0.320 *	0.125
GMM	−0.126 .	0.069	−0.126 .	0.070	−0.127 *	0.065
Capital	0.581 ***	0.088	0.579 ***	0.089	0.589 ***	0.083
Inflation	0.237 ***	0.039	0.237 ***	0.040	0.236 ***	0.036
EXP	−0.159 ***	0.048	−0.159 **	0.049	−0.158 ***	0.044
TOT	−0.517 ***	0.130	−0.518 ***	0.132	−0.511 ***	0.123
Asia	−0.006	0.075	−0.006	0.076	−0.004	0.070
Panel	0.072	0.083	0.071	0.085	0.074	0.079
log_Citation	−0.010	0.015	−0.010	0.015	−0.008	0.014
R^2	60.702%		59.446%		67.526%	

Note(s): $p < 0.0001$ ***, $p < 0.001$ **, $p < 0.01$ *, $p < 0.05$.
Source(s): Authors' own creation, Research findings

5. Conclusion

Economic growth is a critical issue of any nation's development, and a substantial amount of research has been dedicated to understanding the factors that influence it. Among these factors, exchange rate volatility has long been a subject of debate, with mixed findings regarding its impact on economic growth. While the majority of studies suggest a negative effect of exchange rate volatility on growth, some studies have yielded conflicting results, pointing to the complexity of this relationship. In response to these inconsistencies, this study employs meta-analysis method to provide a more thorough and unified understanding of the effect of exchange rate volatility on economic growth.

This meta-analysis involved 36 studies with 158 individual estimates. The analysis found no evidence of publication bias, which affirms the validity of the results and reinforces the robustness of the meta-analytic approach. The total effect size of the meta-analysis was estimated to be −0.2432. Therefore, in response to the research questions—Does exchange rate volatility significantly affect economic growth? And what is the direction of this impact?—the findings indicate that exchange rate volatility has a negative and statistically significant effect on economic growth. This result suggests that an increase in exchange rate volatility reduces economic growth. However significant heterogeneity observed across studies. The presence of high heterogeneity suggests that the relationship between exchange rate volatility and economic growth is not uniform, and several factors contribute to the variation in results.

To explain this heterogeneity, meta-regression was employed, to identify the most influential factors contributing to the observed differences. The regression analysis revealed that the time period of the study, the control variables used in the models and the methodologies for estimation are the primary sources of variation in the results. The

study's most important conclusion is that the effect of exchange rate volatility on economic growth is influenced by a range of variables, and the results of individual studies cannot be universally applied to all contexts. The findings underscore the importance of considering various factors when analyzing the effect of exchange rate volatility. These include:

(1) *Time dynamics*: The period during which the data was collected can significantly alter the findings. In some periods, the negative effect of exchange rate volatility on growth is more pronounced, while in other periods, this effect may be weaker or even negligible.

(2) *Country-specific economic characteristics*: The economic conditions and characteristics of the countries under study can influence the magnitude and direction of the effect.

(3) *Estimation methods*: The choice of estimation method can impact the results. Different methods of analysis (e.g. OLS, GMM, IV) can produce varying conclusions about the relationship.

(4) *Control variables*: The inclusion of different control variables in the models, such as inflation, capital, exports, and terms of trade, can either strengthen or diminish the perceived effect of exchange rate volatility on economic growth.

In light of these complexities, this study highlights the need for precision and caution in empirical research on this topic. It emphasizes the importance of considering the relevant contextual and methodological factors in order to draw more reliable conclusions about the impact of exchange rate volatility on economic growth. A comprehensive and detailed approach to analysis is necessary to better understand this dynamic relationship and avoid oversimplified generalizations.

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(The Appendix follows overleaf)

Appendix

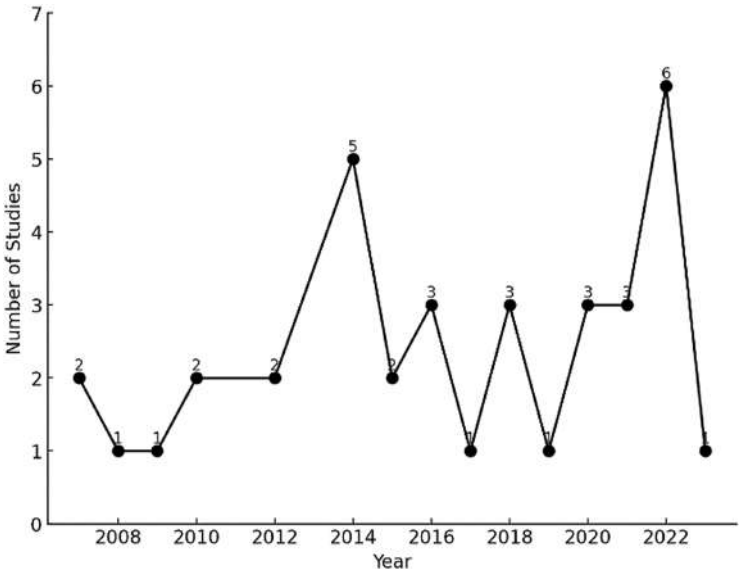

Figure A1. The number of studies published per year Source: Authors' own creation

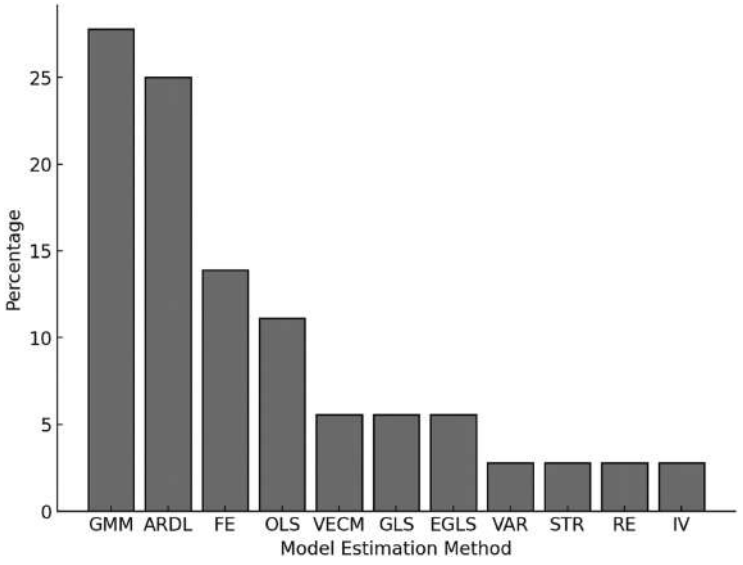

Figure A2. Model estimation methods Source: Authors' own creation

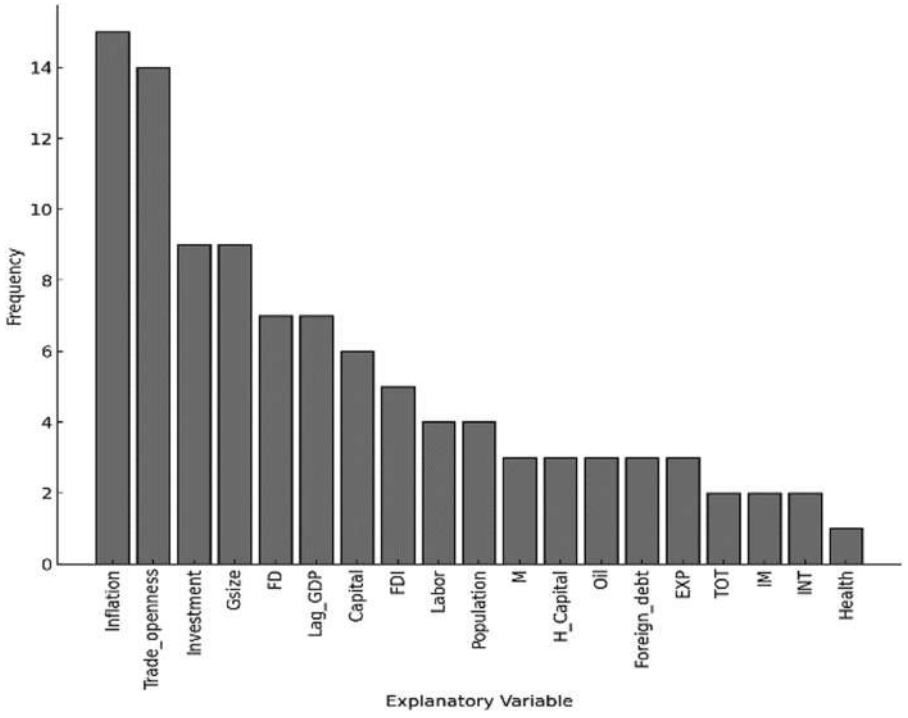

Figure A3. Frequency of control variables used in studies Source: Authors' own creation

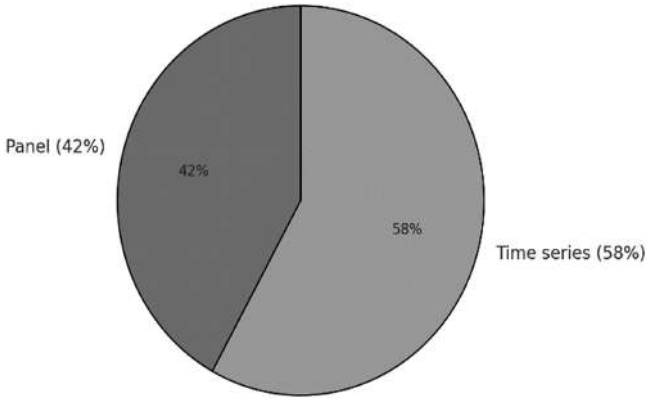

Figure A4. Data type of studies Source: Authors' own creation

Table A1. Studies included in the meta-analysis

	Authors	Year	Number of estimations
1	Achouak Barguellil *et al.*	2018	2
2	Amjad Ali	2022	1
3	Asln Mohamadzade *et al.*	2017	3
4	Bahram Sanginabadi, Hassan Heidari	2012	2
5	Blessing O. Agbo *et al.*	2022	1
6	Corina Georgeta Boar	2010	12
7	Danson Musyoki *et al.*	2012	1
8	DF Meyer, AS Hassan	2020	1
9	Dina Nabil Elshahawany *et al.*	2022	4
10	Erkan Ozata	2020	1
11	Eunice Adjei	2019	1
12	Fatbardha Morina *et al.*	2020	4
13	Fourie, Justin *et al.*	2016	2
14	Gatot Nazir Ahmad *et al.*	2021	1
15	Gunther Schnabl	2009	72
16	Hamidreza Halafi	2007	5
17	Hilal Yildiz *et al.*	2016	1
18	Hussaini Umaru *et al.*	2018	4
19	Joseph Yensu *et al.*	2022	3
20	Karim Ameziane, Bouchra Benyacoub	2022	4
21	Mahmud Khataei, Seyed Hadi Mousavinik	2009	3
22	Mbulaheni Albert Dagume	2022	1
23	Mehdi Basirat *et al.*	2015	1
24	Mehdi Basirat *et al.*	2014	1
25	Mostafa Mobini Dehkordi, Teymour Mohammadi	2014	2
26	Nina Mirani *et al.*	2015	3
27	Nsofor Ebele Sabina *et al.*	2017	1
28	Olusuyi E. Ajayi *et al.*	2016	1
29	Onyango Dickson Wandeda	2014	1
30	Pabai Fofanah	2022	3
31	Paul Alagidede, Muazu Ibrahim	2017	3
32	Sajjad Ebrahimi	2011	4
33	Sarvedin Fathi *et al.*	2023	2
34	Tayyba Aslam	2021	1
35	Thorsten Janus, Daniel Riera-Crichton	2015	5
36	Zahoor Javed, Muhammad Farooq	2009	1

Note(s): This table lists all 36 studies included in the meta-analysis, along with the number of estimations extracted from each study

Corresponding author
Amirhosein Sheykhi can be contacted at: sheikhi.mir@gmail.com