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SPECTRAL ANALYSIS OF CYCLES IN EXCHANGE RATES, PETROLEUM PRODUCTS PRICES AND INTERNATIONAL RESERVES ACCUMULATION OF ASIAN PACIFIC COUNTRIES

Abstract: This study delves into the empirical exploration of the impact of exchange rate volatility and dwindling petroleum products prices on foreign reserves of Asian pacific countries, specifically focusing on Australia, Bangladesh, New Zealand, South Korea, and Taiwan. We conducted the frequency domain analysis using daily data over the sample period of January 2, 2021 to November 12, 2024. This method was chosen for its robustness in analyzing the cyclical behavior of the variables in our study namely exchange rate instabilities, petroleum price variations, capital inflows and foreign reserves. Cycles were calculated as daily variations in the currency rates, petroleum prices, and capital inflows. The results show that distribution of foreign reserves for all countries indicates no significant deviations from the historical trend. The analysis also revealed that petroleum product prices and the volatility in exchange rates of countries in the Asian pacific region exhibit significant cyclical patterns with foreign reserves, particularly in the low-frequency bands, which align with long-term cycles. These cyclical patters are significant factors in the management of foreign exchange reserves. There is therefore the need macroeconomic management, and structural reforms, as being indispensable for enhancing economic resilience and stability against international economic uncertainties. Asian pacific countries should regionally develop frameworks to address the encounters posed by international exchange rate volatility. Joint initiatives to enhance sustainable financial stability across the region could mitigate the impact of external shocks on foreign reserves. This could involve enhancing regulatory frameworks to ensure financial stability and adapting to changing worldwide economic conditions. Policymakers should implement measures to monitor and manage volatile capital flows that can exacerbate exchange rate fluctuations and

favourably impact reserves. This may include the use of capital controls during periods of extreme volatility, as well as measures to attract stable, and long-term capital investment. The governments of the Asian pacific countries should also largely focus on maintaining economic stability through effective exchange rate management, enhancing financial system resilience, and continue the transition to sustainable energy.

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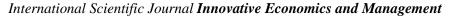*ემოაბინო მუჰამედი*
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ციკლების სპექტრული ანალიზი ვალუტის კურსებში, ნავთობპროდუქტების ფასები და საერთაშორისო რეზერვების აკუმულაცია წყნარი ოკეანის ქვეყნებში

აბსტრაქტი. *ნაშრომში ჩატარებულია გაცვლითი კურსის ცვალებადობისა და ნავთობპროდუქტების ფასების შემცირების ზემოქმედების ემპირიული კვლევა აზიის წყნარი ოკეანის ქვეყნების საგარეო რეზერვებზე, კონკრეტულად ფოკუსირებულია ავსტრალიაზე, ბანგლადეშზე, ახალ ზელანდიაზე, სამხრეთ კორეასა და ტაივანზე. ჩვენ ჩავატარეთ სიხშირის დომენის ანალიზი ყოველდღიური მონაცემების გამოყენებით 2021 წლის 2 იანვრიდან 2024 წლის*

12 ნოემბრის შერჩევის პერიოდის განმავლობაში. ეს მეთოდი შერჩეული იყო კვლევაში ცვლადების ციკლური ქცევის ანალიზისას, კერძოდ, გაცვლითი კურსის არასტაბილურობა, ნავთობის ფასის ვარიაციები, კაპიტალის შემოდინება და საგარეო რეზერვები. ციკლები გამოითვლებოდა როგორც ვალუტის კურსის, ნავთობის ფასების და კაპიტალის შემოდინების ყოველდღიური ცვალებადობა. შედეგები აჩვენებს, რომ უცხოური რეზერვების განაწილება ყველა ქვეყნისთვის არ მიუთითებს ისტორიული ტენდენციიდან მნიშვნელოვან გადახრებზე. ანალიზმა ასევე აჩვენა, რომ ნავთობპროდუქტების ფასები და აზიის წყნარი ოკეანის რეგიონის ქვეყნების გაცვლითი კურსების ცვალებადობა ავლენს მნიშვნელოვან ციკლურ სქემებს უცხოური რეზერვების მიმართ, განსაკუთრებით დაბალი სიხშირის დიაპაზონში, რომელიც შეესაბამება გრძელვადიან ციკლებს. ეს ციკლური ცვლილებები მნიშვნელოვანი ფაქტორებია სავალუტო რეზერვების მართვაში. აქედან გამომდინარე, საჭირო მაკროეკონომიკური მენეჯმენტი და სტრუქტურული რეფორმები, რაც აუცილებელია ეკონომიკური მდგრადობისა და სტაბილურობის გასაძლიერებლად საერთაშორისო ეკონომიკური გაურკვევლობის მიმართ. აზიის წყნარი ოკეანის ქვეყნებმა რეგიონალურად უნდა შეიმუშაონ ჩარჩოები საერთაშორისო გაცვლითი კურსის ცვალებადობის გამო წარმოქმნილი შეხვედრების მოსაგვარებლად. ერთობლივი ინიციატივები რეგიონის მასშტაბით მდგრადი ფინანსური სტაბილურობის გასაძლიერებლად შეიძლება შეამსუბუქოს საგარეო შოკების გავლენა საგარეო რეზერვებზე. ეს შეიძლება მოიცავდეს მარეგულირებელი ჩარჩოების გაღრმავებას ფინანსური სტაბილურობის უზრუნველსაყოფად და მსოფლიო ეკონომიკური პირობების ცვალებად ადაპტაციას. პოლიტიკის შემქმნელებმა უნდა განახორციელონ ზომები კაპიტალის არასტაბილური ნაკადების მონიტორინგისა და მართვის მიზნით, რამაც შეიძლება გააძლიეროს გაცვლითი კურსის რყევები და დადებითად იმოქმედოს რეზერვებზე. ეს შეიძლება მოიცავდეს კაპიტალის კონტროლის გამოყენებას ექსტრემალური ცვალებადობის პერიოდებში, ასევე ზომებს სტაბილური და გრძელვადიანი კაპიტალის ინვესტიციების მოსაზიდად. აზიის წყნარი ოკეანის ქვეყნების მთავრობებმა ასევე დიდი ყურადღება უნდა გაამახვილონ ეკონომიკური სტაბილურობის შენარჩუნებაზე გაცვლითი კურსის ეფექტური მართვის გზით, ფინანსური სისტემის მდგრადობის გაძლიერებაზე და განაგრძონ გადასვლა მდგრად ენერგიაზე.

საკვანძო სიტყვები: *დესტინაციის ბრენდინგი, ტურიზმის მარკეტინგი, საქართველო*
JEL classification: *A20, B10, C30*

INTRODUCTION AND LITERATURE REVIEW

Introduction

The relationship between exchange rate volatility, fluctuations in petroleum product prices, capital flows and foreign reserve holdings has been a subject of considerable academic scrutiny due to its significant implications for macroeconomic stability and policy formulation. This relationship is particularly pronounced in regions with varying economic structures and dependencies on external factors, such as Asian pacific countries covered by this study which include Australia, Bangladesh, New Zealand, South Korea, and Taiwan. The oil market, a critical

driver of global economic activity, exhibits its own set of volatilities that significantly impact European economies. For Asian Pacific countries, variation in petroleum prices and the variability associated with capital flows and the availability of international credit are critical factors influencing foreign reserve dynamics. Periods of global financial instability often led to capital outflows and increased pressure on foreign reserves, necessitating timely policy interventions to maintain economic stability (Buthelezi, 2024). As it were, Asian Pacific economies still face considerable economic implications from oil price shocks, particularly those with substantial industrial bases reliant on energy imports (Zhou & Sager, 2024.

Australia's foreign exchange reserves peaked in June 2024 at AUD94945.00 million, according to the Reserve Bank of Australia. Between 2008 and 2024, Bangladesh's foreign exchange reserves averaged USD24920.50 million. August 2021 had the largest reserve holding ever, with USD 48060.00 million in total reserves (World Bank, 2024). In March 2020, New Zealand's overall foreign exchange reserves reached their greatest point, totaling NZD39252.00 million. In July 1983, NZD1029.50 million was the lowest amount of foreign reserves (IMF, 2024). As of October 2021, South Korea had the greatest Foreign Exchange Reserves at USD 469207.70 million (Bank of Korea, 2024), whereas in June 2024, Sri Lanka's FX reserves were equivalent to 3.9 months' worth of imports. Taiwan's largest reserve holding was USD 5733.00 million. The research questions are as follows: What is the impact of daily exchange rate fluctuations and oil price fluctuations on the volume of exchange reserves in five Asian pacific countries covered by the study include Australia, Bangladesh, New Zealand, South Korea, and Taiwan? Hence, the study examine the impact of daily exchange rate fluctuations and petroleum products price variations on the volume of exchange reserves in the above mentioned countries.

The study offers significant benefits for policymakers, economists, investors, and academic researchers. This research significantly advances the understanding of how exchange rate volatility impacts foreign reserves, particularly in the context of oil-importing and producing Asian countries. By employing the frequency domain analysis, the study provides a nuanced view of the dynamic interactions between exchange rates, petroleum prices and foreign reserves. This multi-method approach enriches the existing literature by offering robust and comprehensive understanding into these relationships. The use of advanced econometric techniques in this study represents a methodological contribution to the field of economic research. The frequency domain analysis allows for a deeper exploration of the variability and dynamics of foreign reserves. This innovative approach demonstrates the value of employing diverse econometric tools to capture the complexity of economic phenomena, setting a precedent for future studies. The study is divided into five sections. The next section is devoted to review of studies, while section three is estimation techniques, data description and measurement. Section five is conclusion.

Reviews of relevant literature
Theories of equity flow

Theories of equity flow, also known as international capital flows, focus on the movement of capital across borders in the form of equity investments, such as stocks. One prominent theory in this area is the portfolio balance approach. This theory extends the concepts of portfolio theory to international finance, suggesting that investors hold diversified portfolios that include foreign assets to maximize returns and minimize risks. The PBA posits that international capital flows are

driven by investors seeking to balance their portfolios by diversifying into foreign equities. This diversification helps investors achieve a more optimal risk-return profile. The theory assumes that investors are rational and that they respond to differences in expected returns and risks associated with foreign and domestic assets (Malmendier, *et al.* 2020). One key aspect of this theory is the impact of exchange rates on equity flows, as changes in currency values can affect the returns on foreign investments. Asian pacific countries even with diversified economies may experience different dynamics in equity flows. The interconnectedness of global financial markets means that changes in exchange rates and oil prices can have ripple effects, influencing equity flows into and out of these regions.

Additionally, factors such as political risk, capital controls, and transaction costs can significantly impact international equity flows, making the actual flows deviate from those predicted by the theory. We can see its relevance in understanding how changes in exchange rates and oil prices influence international capital flows. For instance, in African countries heavily reliant on oil exports, fluctuations in oil prices can lead to changes in foreign investors' perceptions of risk and return, thereby affecting the flow of equity investments into these countries. Similarly, exchange rate volatility can alter the expected returns on foreign investments, influencing investors' decisions to allocate capital across borders. European countries, with more stable and diversified economies, may experience different dynamics in equity flows. The interconnectedness of global financial markets means that changes in exchange rates and oil prices can have ripple effects, influencing equity flows into and out of these regions.

Previous researches on exchange rate fluctuations and the volume of foreign reserve

Studies like those by Li *et al.* (2021) focused on predictive models without adequately accounting for how different policy interventions, such as monetary policy adjustments or strategic reserve management, can influence the outcomes. After aggregating several estimation methods, Adler & Mano (2021) estimated an ex-ante marginal costs that ranged from 2.0 to 5.5% yearly for growing economies and also estimated an ex-ante total costs that ranged between 0.2 to 0.7% of GDP per year in countries with less intervention to 0.3 to 1.2% of GDP annually in economies with substantial intervention. International oil price shocks and global economic fluctuations: Impact on foreign reserves accumulation in developing countries. Andriyani & Marwa (2020) examined the determinants of foreign exchange reserves in Indonesia, with a particular focus on the role of exchange rate fluctuations. Utilizing an empirical framework that incorporates variables such as foreign debt, exchange rates, and inflation, the study reveals that exchange rate volatility significantly impacts the accumulation of foreign reserves. The results indicate that maintaining a stable exchange rate is crucial for enhancing the country's reserve levels. This study shows the importance of strategic monetary policies in mitigating the adverse effects of exchange rate fluctuations on foreign reserves. You & Liu (2020) explore the predictive ability of monetary fundamentals in forecasting short-run exchange rate volatility using a GARCH-MIDAS model. The study combines high-frequency exchange rate data with low-frequency macroeconomic variables to predict daily exchange rate fluctuations. The findings suggest that incorporating monetary fundamentals improves the accuracy of exchange rate forecasts, which in turn helps in better managing foreign reserves. This research shows the importance of understanding the link between exchange rate volatility and reserve management. There is a gap in the empirical
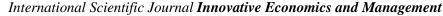
exploration of the role of policy responses in mitigating the impacts of exchange rate and oil price volatility on foreign reserves.

Kalu, Ugwu, & Ndubuaku (2019) explored the relationship between exchange rate fluctuations and foreign reserves in Nigeria. Their research employs econometric analysis to measure the responsiveness of foreign reserves to changes in exchange rates. The findings demonstrate a significant link between exchange rate movements and the volume of foreign reserves, suggesting that periods of high exchange rate volatility are associated with substantial changes in reserve levels. This empirical evidence shows the critical role of foreign reserves in stabilizing the national currency amidst exchange rate fluctuations. Yakub *et al.* (2019) investigated the effects of exchange rate volatility on trade flows and foreign reserves in Nigeria. By analyzing the trade balance data and foreign reserve levels, the study finds that exchange rate volatility adversely affects trade flows, leading to fluctuations in foreign reserves. The results indicate that stable exchange rates are essential for maintaining consistent trade flows and robust foreign reserve levels. This study provides valuable into how exchange rate policies can influence the economic stability of a country.

Qiang *et al.* (2019) examined the relationship between international crude oil price fluctuations and exchange rates in petroleum-importing countries. The study shows that fluctuations in oil prices significantly affect foreign exchange reserves by influencing the cost of oil imports. The findings suggest that higher oil prices lead to increased expenditure on oil imports, which depletes foreign reserves. Conversely, lower oil prices can help in the accumulation of reserves by reducing import bills. This empirical analysis shows the importance of maintaining adequate foreign reserves to buffer against oil price volatility and its impact on exchange rates. In the context of exchange rate volatility and oil price changes, the dynamics of foreign reserves become even more complex. For instance, oil price fluctuations can significantly impact the foreign reserves of oil-exporting countries. A sudden drop in oil prices can reduce export revenues, leading to a depletion of reserves, which, in turn, can limit the country's ability to defend its currency and manage economic stability (Ahmed *et al.,* 2023; Aizenman *et al.,* 2023; Arce *et al*. 2019). Conversely, oil-importing countries might experience an increase in reserves during periods of low oil prices due to reduced import bills, which can enhance their economic resilience. Aizenman *et al.* (2021) define foreign reserves as a form of insurance for countries, particularly emerging markets, to manage liquidity needs, stabilize the currency, and build investor confidence. This perspective shows the dual role of reserves in both short-term liquidity management and long-term economic stability.

Furthermore, the strategic management of foreign reserves involves not just accumulation but also effective utilization. Central banks must balance the need for liquidity with the goal of achieving higher returns on reserve assets. This involves careful investment in a mix of safe and liquid assets, such as U.S. Treasury bonds, and higher-yielding, but riskier, assets (Maurizio *et al.,* 2020; Caballero & Farhi, 2018). Largely, the extent to which a currency's value fluctuates over time can have significant implications for a country's economic stability and its management of foreign reserves. Foreign reserves, comprising foreign currencies, gold, and other reserve assets, are used by central banks to stabilize the national currency, facilitate international trade, and meet international financial obligations.

Previous researches on oil price fluctuations and the volume of foreign reserves

Umoru *et al.* (2024) found an extended relationship between foreign exchange markets and crude oil market returns, with currency changes having a negative effect on crude oil returns. The flow of the effect from the oil market to the currency market of countries which import oil is stronger than the spillover effect from the currency market to the oil market. Kocoglu et al. (2023) investigate how changes in oil prices affect exchange rates. They made reference to the Granger causality hypothesis that varies with time. The findings show that the oil price has varying effects on the exchange rate over a range of time periods. In order to account for potential asymmetries in the transmission of volatility shocks, Alam *et al.* (2019) used the realized semivariance technique and found that causal flows are more noticeable over longer time horizons and from currency markets to the crude oil market. We conclude this literature review with the work of Farooq & Zaghum (2019), who used econometric analysis to show that shocks to the price of petroleum have become more related to exchange rates since the financial crisis, with demand shocks having a leading influence.

Okere *et al.* (2023) identified slight, moderate, and substantial asymmetries in the oil prices -currency rates connection in African oil exporting nations within the framework of MANTARDL. This goes a long way to adversely impact reserve accumulation of the affected nations. According to the Chen & Yu (2022), for European countries that import significant amounts of oil, such as Germany and Italy, higher oil prices can lead to increased foreign exchange outflows, reducing the reserves available for other economic activities and policy interventions. In oil-importing countries, including many European nations, experience different dynamics. High petroleum sprices can increase production costs and inflationary pressures, negatively the volume of international reserves and hence, impacting economic growth. Conversely, declining oil prices can reduce import bills, improve trade balances, and provide a stimulus to the broader economy by lowering energy costs for consumers and businesses Szturo *et al.* (2021). This dichotomy shows the varying implications of oil price changes across different regions and economic structures.

David-Wayas *et al.* (2021) examine the macroeconomic impacts of oil price volatility in non-oil exporting countries in sub-Saharan Africa. Their study focuses on the indirect effects of oil price changes on foreign reserves through economic variables such as inflation, exchange rates, and investments. The study reveals that oil price volatility adversely affects economic stability, leading to significant fluctuations in foreign reserves. The findings suggest that non-oil exporting countries need to diversify their economic activities and enhance their reserve management strategies to mitigate the adverse effects of oil price shocks. The volatility of oil prices is another crucial consideration. Volatility refers to the degree of variation in oil prices over time, which can be caused by short-term market speculations, changes in production quotas by OPEC, technological advancements, and unexpected geopolitical events (Le *et al.*, 2024; Kuhe *et al.*, 2024; Smales, (2021). High volatility in oil prices creates uncertainty in the global markets, affecting investment decisions, trade policies, and economic planning. For example, the rapid fluctuations in oil prices during the Covid-19 pandemic created significant challenges for both oil-exporting and importing countries in terms of budgetary planning and economic forecasting.

Su *et al.* (2021) examined the relationship between oil price fluctuations and economic policy uncertainty in BRICS countries. The study finds that high oil price volatility increases

economic uncertainty, leading countries to use more foreign exchange reserves to stabilize their economies. The research shows the importance of maintaining substantial reserves to buffer against the economic instability caused by fluctuating oil prices, particularly in major emerging markets like BRICS countries. Xiao (2020) improved the Agarwal model's ability to divide Iraq's foreign currency market into six discrete subgroups by incorporating demand projections. From this, he concluded that Iraq's foreign exchange reserves as of 2004 had surpassed the whole exchange reserve scale. Iraq's needed foreign exchange reserves were adjusted to help preserve market and currency rate stability, which resulted in this excess reserve. Zulfigarov & Neuenkirch (2020) conducted an empirical analysis on the effects of oil price fluctuations on Azerbaijan's macroeconomic indicators, including foreign reserves. The study utilizes a linear VAR model to capture the dynamic interactions between oil prices and economic variables. The findings indicate that a decline in oil prices leads to a contraction in foreign reserves, as the Central Bank of Azerbaijan utilizes its reserves to stabilize the national currency. This shows the critical role of foreign reserves in mitigating the adverse impacts of oil price volatility on oil-exporting countries.

Oil price changes are also influenced by technological and policy developments. The advent of shale oil extraction in the United States, for example, has significantly altered the global oil supply landscape, leading to periods of oversupply and downward pressure on prices (Herrera & Rangaraju, 2020). Additionally, policy decisions such as sanctions on major oil-producing countries, environmental regulations, and strategic oil reserves management play critical roles in shaping oil price trends. Furthermore, the relationship between oil prices and exchange rates is a vital area of study. Changes in oil prices can lead to currency appreciation or depreciation, depending on a country's net oil export or import status. For oil-exporting countries, higher oil prices often lead to currency appreciation as foreign exchange inflows increase.

According to Farooq & Zaghum (2019), oil price changes are primarily driven by the balance between global oil supply and demand, with significant disruptions caused by geopolitical tensions, natural disasters, and policy changes by major oil-producing countries. This definition shows the fundamental economic principles that govern the pricing of oil in international markets. Wei *et al.* (2019) explored the relationship between oil price fluctuations, stock market performance, and macroeconomic fundamentals in China. The study shows how changes in oil prices can influence the economic stability of a country and subsequently its foreign reserves. During periods of high oil prices, China experienced increased inflation and reduced foreign reserves due to higher import costs. Conversely, low oil prices led to improved economic conditions and an increase in foreign reserves. This study shows the critical link between oil price management and foreign reserve stability in large, oil-importing economies.

Baumeister & Hamilton (2019b) described oil price changes as the result of complex interactions between production decisions by oil-exporting countries, technological advancements in oil extraction, and the macroeconomic environment, including the global economic growth rates and energy consumption patterns. This broader definition incorporates both the supply-side and demand-side factors that influence oil prices. Fluctuations in oil prices have profound implications for the accumulation and depletion of foreign reserves, influencing economic stability and policy responses in both oil-exporting and oil-importing countries. This relationship is particularly pertinent for a comparative analysis between African and European countries, where the economic

structures and dependencies on oil vary significantly. Oil price changes refer to the fluctuations in the market price of crude oil.

Gaps in the reviewed literature

Having provided a sizable review of empirical studies on the effects of exchange rate fluctuations and oil price changes on foreign reserves, it is worth mentioning that while the existing literature provides valuables. There is a gap in the theoretical exploration of non-linear and asymmetric responses of foreign reserves to exchange rate and oil price changes. Traditional theories often assume linear and symmetric relationships, as seen in many of the reviewed studies. However, real-world economic dynamics are often non-linear and asymmetric. For instance, the impact of an oil price increase may not be mirrored by an equivalent decrease in oil price, and similarly, the effects of currency depreciation might differ significantly from those of appreciation. Moreover, the existing theoretical frameworks often do not sufficiently account for the role of behavioral factors and market sentiment in influencing exchange rate movements and reserve management.

ECONOMETRIC MATERIALS AND METHODOLOGY

The data for this study was sourced from the IMF database. The analysis spans daily data collected from January 2, 2021 to November 12, 2024, providing a recent and relevant dataset that captures the economic fluctuations and trends in these regions. Hence, we calculated cycles as in terms of the daily fluctuations in the exchange rates, petroleum prices, and capital inflows. The countries selected for this study are key oil importers. Foreign reserve was calculated as the value of foreign currencies, and gold held by a country's central bank. Daily exchange rate volatility data is utilized to capture high-frequency changes and their immediate impacts on reserves. For this study, we utilized the bilateral exchange rates between the selected countries' currencies and the US dollar. Petroleum price variation measures the changes in the price level of all petroleum products. The capital inflows indicate value of foreign direct investment and official development assistance. Daily petroleum price variations are used to assess the interplay between energy demand and reserve dynamics.

The spectral frequency domain (SFD) and the cross-spectral density functions (CSDF) methods were applied in this study for measuring the impact of exchange rate volatility and unexpected oil price changes on foreign reserves. This method involves transforming the time series data into the frequency domain using Fourier transforms, which decompose the data into cyclical components. Spectral analysis is performed to estimate the power spectrum and cross-spectrum of the variables. This helps identify dominant cycles and the frequency at which variables interact most strongly. The frequency domain method helps in assessing into the periodicity of fiscal devaluation impacts and allows us to understand how these effects vary over different time horizons. Key metrics such as spectral density and coherence are analysed to interpret the results. The spectral density function $S(\partial)$ for each variable is defined as the Fourier transform of the autocovariance function $\gamma(\emptyset)$:

$$S(\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma(\emptyset)e^{-i\partial\emptyset} \qquad (1)$$

where: ω is the angular frequency, $\gamma(\emptyset)$ is the autocovariance function at lag $\emptyset$. For the variables in the study, the spectral density functions can be specified as follows:

$$Fxres\ (\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma Fxres(t)e^{-i\partial\emptyset} \quad (2)$$

$$\text{Exhvol}(\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma\text{Exhvol(t)}e^{-i\,\partial\emptyset} \quad (3)$$
$$\text{Petrevn}(\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma\text{Petrevn(t)}e^{-i\,\partial\emptyset} \quad (4)$$
$$\text{Cpinfl}(\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma\text{Cpinfl(t)}e^{-i\,\partial\emptyset} \quad (5)$$

To examine the relationships between variables in the frequency domain, the cross-spectral density functions can be specified as:

$$\text{Fxres. Exhvol}(\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma\text{Fxres. Exhvol(t)}e^{-i\,\partial\emptyset} \quad (6)$$
$$\text{Fxres. Petrevn}(\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma\text{Fxres. Petrevn (t)}e^{-i\,\partial\emptyset} \quad (7)$$
$$\text{Fxres. Cpinfl}(\partial) = 0.5\sum\emptyset = -\infty^{\infty}\gamma\text{Fxres. Cpinfl (t)}e^{-i\,\partial\emptyset} \quad (8)$$

The coherence function, which measures the degree of linear association between two variables at each frequency Ω, was given by:

$$\text{Fxres. Exhvol}_{(\Omega)} = |\text{ Fxres. Exhvol}_{(\Omega)}|^2 / [\text{Fxres}_{(\Omega)}\text{ Exhvol }_{(\Omega)}] \quad (9)$$
$$\text{Fxres. Petrevn}_{(\Omega)} = |\text{ Fxres. Petrevn}_{(\Omega)}|^2 / [\text{Fxres}_{(\Omega)}\text{ Petrevn}_{(\Omega)}] \quad (10)$$
$$\text{Fxres. Cpinfl}_{(\Omega)} = |\text{ Fxres. Cpinfl}_{(\Omega)}|^2 / [\text{Fxres}_{(\Omega)}\text{ Cpinfl}_{(\Omega)}] \quad (11)$$

These spectral density and cross-spectral density functions allow for a comprehensive analysis of the frequency components of the variables and their interactions, facilitating the identification of cyclical patterns and relationships over different frequencies.

RESULTS

Table 1 shows the all the Asian pacific countries examined when it comes to exchange rate spillover volatility. The standard deviation and the Jacque Bera statistics for the variation in exchange rate are large. This calls for caution on the part of investors in the world where huge volume of foreign exchange transaction in view of forex portfolio investment takes place. The result also shows that all the coefficients of kurtosis of the distribution of these countries is > 3 meaning that the distribution of exchange rate data is not normally distributed.

Table 1. Results of summary statistics for exchange rate volatility

Countries	Mean	Jacque Bera	Skewness	Std. Deviation	Kurtosis
Australia	1675.78	756.983	1.840	154.913	3.216
Bangladesh	346.200	167.462	2.678	225.701	5.958
New Zealand	153.749	432.849	2.492	258.333	4.469
South Korea	387.627	239.487	1.607	167.425	3.913
Taiwan	274.587	682.759	1.349	418.579	7.407

Source: Authors' Results (2024) with Eviews 13

Table 2 shows the summary statistics of petroleum product prices of the Asian Pacific countries. Apart from New Zealand, the Jacque Bera statistics and the kurtosis values indicate a non-normal distribution. Thus, only the kurtosis of New Zealand is normally distributed since the kurtosis value is less than 3. The however, the distribution is positively skewed. The average values

of petroleum prices are relatively large for all samples.

Table 2. Results of summary statistics for petroleum product prices

Countries	Mean	Jacque Bera	Skewness	Std. Deviation	Kurtosis
Australia	1306.573	1459.200	1.195	45.201	3.792
Bangladesh	1523.786	1958.389	0.719	13.635	3.958
New Zealand	1623.983	1489.800	1.916	57.045	2.941
South Korea	1824.190	1271.382	1.394	11.342	6.903
Taiwan	1926.146	1518.250	1.073	28.929	3.563

Source: Authors' Results (2024) with Eviews 13

Table 3 shows the statistics for summary statistics for capital inflows of the Asian Pacific countries covered by the study. Australia has the highest variation of inflows of 2544.591 followed by Bangladesh with 928.1709. South Korea recorded the highest capital inflows within the period of the study given a mean value of 23816.29, followed by Taiwan with a mean inflow of 19020.982 respectively. The lowest capital inflows were found in Bangladesh and Australia with mean values of 621.6513 and 704.2091respectively.

Table 3. Results of summary statistics for capital inflows

Countries	Mean	Jacque Bera	Skewness	Std. Deviation	Kurtosis
Australia	704.2091	27185.196	1.5047	2544.591	6.8163
Bangladesh	621.6513	1486.3000	1.2500	928.1709	9.6217
New Zealand	5566.063	23817.156	3.7840	371.4569	4.0379
South Korea	23816.29	25684.023	1.9250	198.9648	5.4709
Taiwan	19020.982	8014.3107	1.4980	251.6843	2.8510

Source: Authors' Results (2024) with Eviews 13

The descriptive statistics of foreign exchange reserves for all the Asian Pacific countries covered by the study are reported in Table 4 below. South Korea also recorded the highest foreign reserves within the period of the study given a mean value of 56713.784, followed by Taiwan with an average value of 29751.386. Bangladesh had the highest variation coefficient of 560.517. The distribution of foreign reserves falls outside the normal distribution.

Table 4. Results of summary statistics for foreign exchange reserves

Countries	Mean	Jacque Bera	Skewness	Std. Deviation	Kurtosis
Australia	13427.351	1831.287	1.3802	253.962	6.8909
Bangladesh	11941.382	4222.602	1.0256	560.517	3.2907
New Zealand	16756.782	6756.483	3.1840	157.153	3.9136
South Korea	56713.784	6756.125	1.0240	129.128	4.5926
Taiwan	29751.386	1498.200	1.0700	118.540	9.8173

Source: Authors' Results (2024) with Eviews 13

Table 5A shows unit test results for exchange rate volatility. At level the ADF-Fisher Chi-square statistic for the variation in exchange rate is 0.14102 with a probability of 0.5561, and the ADF-Choi Z-statistic is -1.34066 with a probability of 0.0900. Both probabilities are above the 0.05 significance level, indicating that the tests fail to reject the null hypothesis of a unit root at level for Australia. Similar results were obtained for Bangladesh, New Zealand, South Korea, and Taiwan whereby at level; the ADF-Fisher Chi-square and the ADF-Choi Z-statistics all had p-values greater than 0.05. Except for South Korea with a p-value of 0.0578 for the ADF- Choi Z-Statistic which marginally significant; at first difference, the ADF-Fisher chi-square statistics and the ADF-Choi Z-statistics all reported probability of 0.0000. All the probabilities are below the 0.05 significance level, indicating that we reject the null hypothesis of a unit root in the volatility of exchange rate for individual countries. This indeed is a confirmation of stationarity at the first difference. Hence, the variations in exchange rate is I (1).

As reported in Table 5B, the ADF-Fisher Chi-square statistics and the ADF-Choi Z-statistics of petroleum products prices are had probability values of 0.1287 and 0.9347 for Australia; 0.4261 and 0.2823 for Bangladesh; 0.3173and 0.0648 for New Zealand;0.3155   and 0.0578 for South Korea; and 0.3225 and 0.0597 for Taiwan respectively. These probabilities are indicative of a unit root at level for petroleum products prices. But at first difference, we obtained zero p-values that are below the 0.05 significance level, indicating that we reject the null hypothesis of a unit root for individual countries. The capital inflows stationarity test results reported in Table 5C appear to be stationary at the level for some countries (New Zealand, and South Korea) but not for others. The overall test suggests stationarity, indicating that capital inflows may not require differencing for these countries collectively. For the other countries, we obtained zero probabilities for the ADF-Fisher Chi-square statistics and the ADF-Choi Z-statistics. In effect, capital inflows is stationary at first difference I(1) in Australia, Bangladesh, and Taiwan respectively.

At level, the ADF-Fisher chi-square statistics and ADF-Choi Z-Stat for foreign exchange reserves data for the selected Asian countries are non-stationary at the level but become stationary after first differencing. This suggests that foreign reserves follow a unit root process without

differencing. At first difference, the calculated ADF-Fisher Chi-square statistics for Australia, Bangladesh, New Zealand, South Korea, and Taiwan are 76.0749, 28.650, 120.856, 140.0749, and 156.650 with zero p-values while the calculated ADF-Fisher Chi-Square statistics are -119.545, -190.126, -126.127, -112.795, and -160.487 respectively. The probabilities of 0.0000, for these calculated statistics are below the 0.05 significance level, indicating that we reject the null hypothesis of a unit root, for individual countries. The results indicate that foreign reserve holding is I(1). For robust econometric modeling, variables exhibiting unit roots should be transformed to their first differences to ensure stationarity, while the stationary variables can be used in their original form. This approach ensures accurate and reliable forecasting and measurement of the impacts of exchange rate volatility and oil price changes on foreign reserves in the selected Asian countries.

Table 5A. Unit root test results for exchange rate volatility

Asian Pacific Countries	ADF-Fisher Chi-Square (P-value)	ADF- Choi Z-Stat (P-value)	ADF-Choi Z-Stat (P-value)	ADF-Fisher Chi-Square (P-value)
Australia	0.14102 (0.5561)	-1.34066 (0.0900)	114.361 (0.0000)	26.901 (0.0000)
Bangladesh	0.18638 (0.4261)	-0.57605 (0.2823)	137.159 (0.0000)	149.658 (0.0000)
New Zealand	0.47526 (0.3173)	-1.51578 (0.0648)	20.9542 (0.0000)	206.461 (0.0000)
South Korea	0.48046 (0.3155)	-3.92690 (0.0578)	78.4841 (0.0000)	67.809 (0.0000)
Taiwan	0.46075 (0.3225)	-1.55693 (0.0597)	162.527 (0.0000)	391.057 (0.0000)

Source: Authors' Results (2024) with Eviews 13

Table 5B. Unit root test results for petroleum products prices

Asian Pacific Countries	ADF-Fisher Chi-Square (P-value)	ADF- Choi Z-Stat (P-value)	ADF-Choi Z-Stat (P-value)	ADF-Fisher Chi-Square (P-value)
Australia	0.2482 (0.1287)	0.6494 (0.9347)	100.593 (0.0000)	134.678 (0.0000)
Bangladesh	0.42109 (0.6632)	0.34478 (0.6349)	1.99791 (0.7361)	1.99073 (0.7375)
New Zealand	2.32446 (0.9899)	2.32253 (0.9899)	1.58360 (0.9537)	1.64833 (0.9490)
South Korea	0.23046 (0.3155)	-5.92690 (0.0000)	78.4841 (0.0000)	69.6809 (0.0000)
Taiwan	0.1209 (0.3225)	-1.55693 (0.0597)	11.5271 (0.0734)	14.4977 (0.0245)

Source: Authors' Results (2024) with Eviews 13

Table 5C. Unit root test results for capital inflows

Countries	ADF-Fisher Chi-Square (P-value)	ADF – Choi Z-Stat (P-value)	ADF – Choi Z-Stat (P-value)	ADF-Fisher Chi-Square (P-value)
Australia	0.2564 (0.3679)	-0.1673 (0.0259)	61.559 (0.0000)	70.456 (0.0000)
Bangladesh	0.1522 (0.8763)	-1.5868 (0.4525)	127.6879 (0.0000)	56.789 (0.0000)
New Zealand	6.5679 (0.0052)	9.2375 (0.0005)	-	-
South Korea	18.487 (0.0050)	-15.247 (0.0000)	-	-
Taiwan	1.460 (0.1375)	-1.593 (0.2675)	291.526 (0.0000)	154.173 (0.0000)

Source: Authors' Results (2024) with Eviews 13

Table 5D. Unit root test results for foreign exchange reserves

Countries	ADF-Fisher Chi-Square (P-value)	ADF – Choi Z-Stat (P-value)	ADF – Choi Z-Stat (P-value)	ADF-Fisher Chi-Square (P-value)
Australia	0.3257 (0.985)	2.2461 (0.0693)	76.0749 (0.0000)	-119.545 (0.0000)
Bangladesh	1.2789 (0.3456)	2.03784 (0.0670)	28.650 (0.0000)	-190.126 (0.0000)
New Zealand	0.3881 (0.2570)	0.5679 (0.6732)	120.856 (0.0000)	-126.127 (0.0000)
South Korea	2.37487 (0.0548)	1.03893 (0.8872)	140.0749 (0.0000)	-112.795 (0.0000)
Taiwan	0.2467 (0.4797)	1.94673 (0.8732)	156.650 (0.0000)	-160.487 (0.0000)

Source: Authors' Results (2024) with Eviews 13

The panel co-integration test results of Table 6 reject the null hypothesis of no co-integration as against the alternative hypothesis of co-integration amongst the variables.

Table 6. Panel co-integration test results

Measure	Statistic	Probability of significance
Group rho-Statistic	-197294	0.0000
Group PP-Statistic	-190.341	0.0000
Group ADF-Statistic	-234.589	0.0000

Source: Authors' Results (2024) with Eviews 13

Table 7 displays the findings of the Spectral Frequency of Domain (SFD) analysis for Australia. The foreign reserves of the country display an angular frequency of 0.073452, a

frequency of 0.066653 cycles per time unit, and a cycle frequency of 1364.7500 time units per cycle. This suggests that fluctuations in foreign reserves happen over an extended period of time. The periodogram value of Australia's foreign reserves is a very high 5.0289090 billion, indicating that although the cycle is long, the amplitude of the reserve swings is significant and hence important for the country's economic stability. Exchange rate variation reported an angular frequency of 0.085821 and cycle frequency of 0.092529, suggesting that exchange rate fluctuations follow higher long-term cycle than reserves.

The periodogram value for exchange rate variation is much higher at 9.0942500 compared to 5.0289090, indicating that while exchange rates do fluctuate, their impact on foreign reserves is highly considerable. This suggests that exchange rate volatility does play a major role in influencing Australia's reserves compared to the significant fluctuations in petroleum price variations. Petroleum price variations have a slightly lower angular frequency of 0.046730, resulting in a frequency of 0.024785 cycles per time unit and also a long cycle frequency of 1819.0000 time units per cycle. This indicates that petroleum price fluctuate more frequently than reserves not second to the fluctuations in the exchange rates. The periodogram value for petroleum price variations is 6.0560470, which is still relatively high, suggesting that while petroleum price variations do have an impact on reserves; it is modest compared to the influence of fluctuations in the exchange rates. Capital inflows share the same cyclical characteristics as exchange rate with an angular frequency of 0.083285 and a similar cycle frequency of 0.091349 per time units. The periodogram value for capital flows is 9.0174520, indicating that inflows of foreign capital has a noticeable impact on reserves like exchange rate volatility.

Table 7. Spectral frequency of domain results for Australia

Frequency Domain	Variables			
	Fxres	Exhvol	Petrevn	Cpinfl
Angular Frequency (Omega)	0.073452	0.085821	0.046730	0.083285
Frequency (Cycle/Time Unit)	0.066653	0.092529	0.024785	0.091349
Cycle Frequency (Time Unit/Cycle)	1364.7500	1991.7500	1819.0000	1073.7500
Periodogram	5.0289090	9.0942500	6.0560470	9.0174520

Source: Authors' Results (2024) with Eviews 13

The SFD results for Bangladesh, as presented in Table 8, show that foreign reserves in Bangladesh exhibit an angular frequency of 0.041952, and a frequency of 0.031253 cycles per time unit and a cycle frequency of 4563 time units per cycle. This suggests that changes in total reserves occur over a relatively long cycle. The periodogram value for foreign reserves is significant at approximately 1.51 billion, indicating that fluctuations in reserves are substantial, making them a critical factor in Bangladesh's economic stability. Exchange rate volatility had a angular frequency of 0.067214, together with a frequency of 0.060180 cycles per time unit and a cycle frequency of 3251 time units per cycle. This indicates that exchange rate fluctuations occur over a longer cycle compared to reserves and are less frequent. The periodogram value for volatility of exchange rate is extremely high at 2.038621, suggesting that exchange rate fluctuations have a significant impact on Bangladesh's foreign reserves. Petroleum price variations had an angular frequency and cycle

frequency of 0.046239, and 0.051257 respectively, suggesting that petroleum prices exhibit considerable cyclical pattern.

The periodogram value for petroleum price variations is 1.472934, reflecting Bangladesh's strong reliance on exports of petroleum product, where changes in petroleum products export levels are closely tied to the country's reserve dynamics. Accordingly, while the impact of petroleum price variations on reserves is notable; its significance does not exceed that of the fluctuations seen in exchange rate. Capital inflows exhibit a lower angular frequency of 0.002166, and a frequency of 0.015762 cycles per time unit than petroleum prices. Also, capital inflows had a shorter cycle frequency of 1562.4286 time units per cycle. This indicates that capital inflows changes occur more frequently compared to the other variables. The periodogram value for capital inflows is 0.017216, suggesting that while capital inflows do significantly influence reserves and its influence occurs over a shorter cycle.

Table 8. Spectral frequency of domain results for Bangladesh

Frequency Domain	Variables			
	Fxres	Exhvol	Petrevn	Cpinfl
Angular Frequency (Omega)	0.041952	0.067214	0.046239	0.002166
Frequency (Cycle/Time Unit)	0.031253	0.060180	0.051257	0.015762
Cycle Frequency (Time Unit/Cycle)	4562.7500	3251.0000	2300.7500	1562.4286
Periodogram	1.512709	2.038621	1.472934	0.017216

Source: Authors' Results (2024) with Eviews 13

The SFD results for the New Zealand as outlined in Table 9, the reserves for the South Korea exhibit an angular frequency of 0.017214, corresponding to a frequency of 0.031940 cycles per time unit and a cycle frequency of 334.67 time units per cycle. This point to the fluctuations in aggregate reserves occurs over a long cycle one year. The periodogram value for reserves is significant, at 8,305,736, indicating that despite the long cycle, the magnitude of fluctuations in total reserves is substantial. This suggests that changes in reserves have a critical impact on the New Zealand's economic stability. Exchange rate variation, petroleum price variations and capital inflows all had angular frequency and cycle frequency of 0.017214 and 0.03194; 0.011486 and 0.001348; and 0.013512 and 0.081285 indicating that these variables follow short cycles in the determination of foreign reserves holdings in the case of New Zealand. However, the periodogram values for these variables are notably lower, with exchange rate variation at 0.003792, petroleum price variations at 0.025753, and capital inflows at 0.004246. This suggests that while these variables cycle in tandem with reserves, their direct impact on the international foreign reserves accumulation is minimal.

Table 9. Spectral frequency of domain results for New Zealand

Frequency Domain	Variables			
	Fxres	Exhvol	Petrevn	Cpinfl
Angular Frequency (Omega)	0.017214	0.011486	0.013512	0.012679
Frequency (Cycle/Time Unit)	0.031940	0.001348	0.081285	0.015632

Cycle Frequency (Time Unit/Cycle)	334.6700	276.7800	299.0000	213.0000
Periodogram	0.018954	0.003792	0.025753	0.004246

Source: Author's Results (2024) with Reviews 13

The SFD estimates for South Korea are reported in Table10. It can be seen from the plots that foreign reserves in South Korea exhibit an angular frequency of 0.014952, corresponding to a frequency of 0.003653 cycles per time unit and a cycle frequency of nearly 13.75 time units per cycle. This suggests that fluctuations in foreign reserves occur over a relatively short cycle in South Korea. The periodogram value for foreign reserves is significantly high, at nearly 0.003 billion, indicating that with a short cycle, the fluctuations in reserves are inconsequential, making low fluctuations essential ingredients of South Korea's economic stability. Exchange rate volatility has 0.001603 angular frequency and0.001863 cycle frequencies, implying that exchange rate fluctuations follow the same short-term cycle as reserves. The periodogram value for exchange rate volatility is lower, at 1.003482, indicating that while fluctuates in exchange rates has less impact on the reserves. This suggests that exchange rate volatility, while present, does not have a devastating influence on South Korea's foreign reserves accumulation compared to other countries.

Petroleum price variations also share the same low cyclical characteristics as exchange rate variations, with the 0.016321 angular frequency and cycle frequency of 0.001953. The periodogram value for petroleum price variations is 0.010634, indicating a much lower impact on reserves. Capital inflows also have an angular frequency of 0.004769 and cycle frequency of 0.000730, with a periodogram value of 1.051704. The low periodogram values for exchange rate volatility, petroleum price variations and capital inflows and the relatively ;low cycle frequency of 14.27500, 9.32500, 19.27500, for the respective aforementioned variables all indicate that fluctuations in exchange rates, petroleum price variations and capital inflows have a relatively modest effect on the total reserves of the South Korea. This could suggest that the South Korea's economic policies and structural factors are effective in buffering the impact of exchange rate volatility, changes in petroleum price variations and capital inflows on its foreign reserves. The dominance of the periodogram value for reserves highlights the critical significance of managing reserves directly by the central bank of South Korea.

Table 10. Spectral frequency of domain results for South Korea

Frequency Domain	Variables			
	Fxres	Exhvol	Petrevn	Cpinfl
Angular Frequency (Omega)	0.014952	0.001603	0.016321	0.004769
Frequency (Cycle/Time Unit)	0.003653	0.001863	0.001953	0.000730
Cycle Frequency (Time Unit/Cycle)	13.75100	14.27500	19.32500	19.27500
Periodogram	0.003209	1.003482	0.010634	1.051704

Source: Authors' Results (2024) with Eviews 13

The SFD estimates for Taiwan, as presented in Table 11. According to Table 11, exchange rate variation has a lower angular frequency of 0.000152 and to a frequency of 0.003653 cycles per

time unit and a cycle frequency of 18.3 time units per cycle. This suggests that exchange rate fluctuations occur over a shorter cycle. The periodogram value for exchange rate volatility is 1.000705, indicating that while exchange rates have a measurable impact on reserves; their influence is far less significant in causing devastation in the accumulation of foreign reserves. Petroleum price variations has 0.013952 angular frequency and 0.003653 cycle frequency while capital inflows had 0.000752 and 0.004566 angular frequency and cycle frequency respectively. All these are indication that they follow a similar cyclical pattern.

The periodogram value for petroleum price variations is 0.003350, suggesting that fluctuations in petroleum price variations have a relatively modest impact on reserves. This reflects the role of petroleum price variations in Taiwan's economy, where changes crude oil prices are essential. Capital inflows has an angular frequency of 0.000752, conforming to a frequency of 0.004566 cycles per time unit and a cycle frequency of 10 time units per cycle. This indicates that changes in capital inflows occur over a cycle that is shorter than that of exchange rates and petroleum price variations but longer than that of reserves. The periodogram value for capital inflows is 5.115295, showing that capital inflows has a more significant short term cycle impact on reserves than exchange rates or petroleum price variations.

Table 11. Spectral frequency of domain results for Taiwan

Frequency Domain	Variables			
	Fxres	Exhvol	Petrevn	Cpinfl
Angular Frequency (Omega)	0.034428	0.000152	0.013952	0.000752
Frequency (Cycle/Time Unit)	0.005479	0.003653	0.003653	0.004566
Cycle Frequency (Time Unit/Cycle)	18.25000	73.18600	22.09500	10.0000
Periodogram	1.895865	1.000705	0.003350	5.115295

Source: Authors' Results (2024) with Eviews 13

Discussion

In Australia, fluctuations in foreign reserves occur over a long period of time. Although the cycle is long, the amplitude of the reserve swings is significant and hence important for the country's economic stability. This fluctuations or swings suggest that conservative monetary management policies, which have been in place with the purpose of stabilizing the exchange rate between the US dollar and the Australian Dollar over time, have not been successful. These set of findings support those of Ijokoh (2024), Lasisi & Fijabi's (2024), Aizenman *et al*. (2024), Adedeji & Adebayo (2023), Irefin & Yaaba (2023), Oyeniran & Alamu (2020), Adama *et al.* (2022), Lee & Yoon (2020), Kalu *et al.* (2019), and Abdul-Rahaman & Yao (2019).The findings of Ijokoh (2024) pointed to a long-term, one-way linkage between the naira's exchange rate and external reserves. According to Lasisi & Fijabi's (2024) research, external reserves had a positive and noteworthy impact on both Ghana's and Nigeria's economic growth. Ghana's external reserve and economic progress were positively correlated. According to Aizenman *et al*. (2024), nations with underdeveloped financial institutions could use international reserves as a buffer against the real exchange rate's negative effects from terms-of-trade shocks. Using the Bound ARDL approach, Adedeji & Adebayo (2023) demonstrated that exchange rates significantly and favourably affect

foreign reserves. The authors used the Bound ARDL approach and established that foreign reserves are positively and significantly impacted by exchange rates. Based on the Granger type of causality test, there is a one-way causal connection between foreign reserves and currency rates.

Irefin & Yaaba (2023) asserted that having sufficient reserves lowers exchange rate volatility. In keeping with the findings of Oyeniran & Alamu (2020), Nigeria's ideal foreign reserves level was neither significantly impacted by import or opportunity costs associated with maintaining reserves, nor was it responsive to exchange rate volatility or adjustment costs of holding reserves. In the case of Adama *et al.* (2022), Nigeria's output growth was significantly and favourably responsive to changes in external reserves by 0.22%. For five Eastern nations, Lee & Yoon (2020) validated the characteristics of the quantile- and tail-dependent connection between changes in international reserves and foreign currency rate movements. Specifically, the causal association between the exchange rate and Korean foreign exchange reserves was weaker during mild variations in the variables and heavier at rapid fluctuations.

Based on the results of the ARDL model, Kalu *et al.* (2019) determined that the real exchange rate and reserves have a positively significant association, while the nominal exchange rate has a positive but non-significant link with foreign reserves. Abdul-Rahaman & Yao's (2019) estimation research offers empirical support for the long-term test of limiting exchange rate depreciation on the central bank's positive reserve build-up. The exchange rates' short-term changes on reserves, however, invalidated this association. The results from the research also identified that exchange rate fluctuations follow higher long-term cycle than reserves. The periodogram value for exchange rate variation is much higher at 9.0942500 compared to 5.0289090, indicating that while exchange rates do fluctuate, their impact on foreign reserves is highly considerable. This suggests that exchange rate volatility does play a major role in influencing Australia's reserves compared to the significant fluctuations in petroleum price variations. These results are in conformity with those obtained by Khudhair & Ghadeer (2023), Zorgati (2023), and Karel & Quang (2023), Chatziantoniou *et al.* (2023), Szturo *et al*. (2021), and Akinsola *et al*. (2020). According to Khudhair & Ghadeer (2023), the rapid decline in the size of Iraq's exchange reserve was explained by the drop in petroleum prices on international oil markets. Thus, oil earnings, the primary source of funding for it, and the window for selling the currency, which serves as a conduit for its leaking, had an impact on Iraqi reserves. The Central Bank's direct foreign exchange sales were the cornerstone of Iraq's exchange rate policy.

The study results published by Zorgati (2023) confirmed that the intensity of risk spillover varies between petroleum prices and exchange rates and found a long-term reliance and asymmetry of bidirectional risk spillover between these two variables. Agreeing to Karel & Quang (2023), there were both direct and indirect asymmetric influences of petroleum shocks on the EUR/USD exchange rate. The indirect impact was heavier, and the EUR/USD responded less smoothly and swiftly to positive petroleum shocks than to negative ones.

Chatziantoniou *et al.* (2023) assessed the dynamics of contagion between various kinds of exchange rate and petroleum price shocks. The findings indicate that, in a significant number of nations prior to Covid-19, oil shock net effects accounted for the majority of net connectedness values. Countries that buy and export oil were equally affected by shocks. But there were significant changes throughout the Covid-19 era. By shifting revenue from petroleum imports to

oil exports, Szturo *et al*. (2021) found that the price of petrol affects the nation's wealth by influencing exchange rates, which in turn affect the terms of trade. By breaking down the petroleum price into both positive and negative changes, Akinsola *et al*. (2020) used the NARDL model to investigate the asymmetric impact of oil prices on economic growth. The authors revealed that while an increase in the price of oil has a major unfavourable influence on growth, a drop in the price has a positive and considerable impact.

According to the results, Bangladesh relies very strongly on exports of petroleum product, where changes in petroleum products export levels are closely tied to the country's reserve dynamics. Accordingly, while the impact of petroleum price variations on reserves is notable; its significance does not exceed that of the fluctuations seen in exchange rate. Capital inflows had a shorter cycle. This indicates that capital inflows changes occur more frequently compared to the other variables. Exchange rate variation, petroleum price variations and capital inflows all follow short cycles in the determination of foreign reserves holdings in the case of New Zealand. Also, the results indicate a substantial magnitude of fluctuations in total reserves is substantial. However, fluctuations in aggregate reserves occur over a long cycle one year in New Zealand. In Taiwan, exchange rate fluctuations occur over a shorter cycle in Taiwan. This reflects the role of petroleum price variations in Taiwan's economy, where changes crude oil prices are essential. The results indicate that fluctuations in exchange rates, petroleum price variations and capital inflows have a relatively modest effect on the total reserves of the South Korea. In sum, cycles measured in terms of daily changes in the price of petroleum and the exchange rate have enormous influence on the amount of exchange reserves in the Asian-Pacific nations that are the subject of the study.

CONCLUSIONS

This study embarked on an empirical investigation of the impact of exchange rate volatility and petroleum price variations in midst of dwindling crude oil prices on foreign reserves of Asian pacific countries, specifically focusing on Australia, Bangladesh, New Zealand, South Korea, and Taiwan. The frequency domain analysis was conducted. The frequency domain analysis was chosen for their robustness in capturing the complexities and nuances of the relationships between exchange rate fluctuations, petroleum products price changes, capital inflows and foreign reserves. The frequency domain analysis reveals significant differences in the cyclical relationships between the variables in Asian Pacific countries. The analysis indicates that the relationship between petroleum prices, exchange rates, capital inflows and foreign reserves is more pronounced in the low-frequency bands, corresponding to long-term cycles. This suggests that Asian Pacific countries are better able to manage long-term economic cycles, maintaining stability over extended periods despite external shocks. This result agrees with those reported by Montagnoli & Napolitano (2021). The distribution of outcomes shows the possibilities of variation within expected bounds and do significantly deviate from historical reserve patterns.

The investigation of exchange rate volatility and petroleum products price fluctuations on foreign reserves in Asian Pacific oil importing countries yields profound policy implications that are critical to the Asian Pacific region. These implications stretch across macroeconomic management and structural reforms that are essential for enhancing economic resilience and stability in the face of global economic uncertainties. The findings suggest that effective exchange rate management is crucial in maintaining foreign reserve stability as a basis of macroeconomic

stability. The evidence suggests that Asian pacific countries such as South Korea and Taiwan have demonstrated that economies with diversified revenue streams, particularly those less reliant on petroleum, are better equipped to absorb external shocks without significant depletion of foreign reserves. The results highlight the critical role of robust capital flight policy frameworks in managing external economic shocks. The Asian pacific countries could benefit from continued regional frameworks to address the encounters posed by international currency rate volatility. Joint initiatives to enhance sustainable economic and financial stability across the region could help mitigate the impact of external shocks on foreign reserves. This could involve enhancing regulatory frameworks to ensure financial stability to changing global petroleum products price changes and economic conditions. Policymakers should implement measures to monitor and manage volatile capital flows that aggravate exchange rate fluctuations and favourably impact reserves. This may include the use of capital controls during periods of extreme volatility, as well as measures to attract stable, and long-term capital investment. The governments of the Asian pacific countries should also fundamentally engage in the maintenance of economic stability through effective exchange rate management, enhancing financial system resilience, and continue the transition to sustainable energy.

One significant limitation of this study is the relatively short time frame (2021-2023) used for the analysis. While this period captures recent trends, it may not fully encompass longer-term economic cycles or the full impact of structural economic changes. Future research should consider extending the analysis to cover a more extended period, allowing for the analysis of longer-term trends. Additionally, the study primarily focuses on reserves, exchange rates, changes in the prices of petroleum products, and capital inflows. Other macroeconomic variables such as interest rates, government spending, and trade and current account balances could also play significant roles in influencing foreign reserves. Future research should expand the scope of analysis to include these variables, and provide a more comprehensive understanding of the factors affecting foreign reserves. Finally, there is a need for more longitudinal studies that track the same populations over time to understand the long-term effects of exchange rate and petroleum price volatility on foreign reserves. Such longitudinal studies explain the dynamic interaction of the links amongst economic variables and help policymakers to develop long-term strategies for managing foreign reserves.

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