Journal of Applied Econometric
Vol. 2, No. 1, January-June 2026, pp. 45-64
DOI: https:/ 10.59784/journaljoae.v1i1.36

Economic Impacts of Minimum Wage Policy Adjustments in Indonesia: A Panel Analysis of Provincial Data

Imam Syafii
Universitas Kuningan, Indonesia
Corresponding author: imamsm30@gmail.com

Keywords:

minimum wage; employment; regional economics; panel data analysis; labor policy

Article Info :
Accepted: November 16, 2025
Approved: December, 12 2025
Published: January 25, 2026

ABSTRACT

Background:
This study investigates the economic impacts of minimum wage policy adjustments across Indonesian provinces using panel data from 2010 to 2023. The research aims to explore how changes in minimum wage at the provincial level affect key economic indicators, such as employment rates, GDP growth, poverty levels, and income inequality.

Objective:
The objective of this research is to empirically assess the effects of provincial minimum wage changes on economic indicators. The focus is on understanding how these adjustments impact employment, economic growth, and social outcomes in Indonesia.

Method:
The study employs fixed-effects panel regression models with provincial and time dimensions. It controls for province-specific heterogeneity and common time shocks, analyzing 34 provinces over 14 years (2010-2023), totaling 476 province-year observations. This methodology is used to identify the causal effects of minimum wage changes on the selected economic indicators.

Findings and Implications:
The findings indicate nuanced effects of minimum wage increases. Formal sector employment shows a modest negative impact (elasticity of -0.15), especially in labor-intensive manufacturing sectors, while informal sector employment rises by 0.23% for each 10% wage increase. GDP growth is positively correlated with minimum wage levels (elasticity of 0.08), suggesting that wage-driven consumption outweighs competitiveness concerns.

Conclusion:
This study provides rigorous province-level evidence from Indonesia's diverse economic landscape, demonstrating the importance of understanding the broader macroeconomic context in shaping the effectiveness of labor policies like minimum wage adjustments. Policymakers must optimize these frameworks to ensure balanced economic growth, poverty reduction, and reduced income inequality across provinces.

INTRODUCTION

Minimum wage policies represent one of the most widely debated and implemented labor market interventions globally, affecting hundreds of millions of workers across diverse economic contexts (Nur Hidayah Che Ahmat et al., 2023; Liu & Lv, 2022). The fundamental tension inherent in minimum wage policy design lies in balancing the protection of worker welfare and income security against potential adverse effects on employment, business competitiveness, and economic dynamism. This policy dilemma has intensified in recent years as economic globalization, technological change, and evolving labor market structures have reshaped the relationship between wages, productivity, and employment outcomes. The COVID-19 pandemic further complicated these dynamics by simultaneously increasing pressure for wage protection amid rising living costs while raising concerns about business viability and job preservation during economic recovery (Suriani et al., 2024). Understanding how minimum wage adjustments affect various economic outcomes in specific national and regional contexts has therefore become increasingly critical for evidence-based policymaking. Indonesia presents a particularly compelling case for studying minimum wage policy effects due to its unique institutional structure, substantial regional diversity, and significant policy reforms over the past two decades.

International experience with minimum wage policies reveals substantial heterogeneity in both policy design and economic outcomes across countries and regions. Research examining macroeconomic factors and economic growth dynamics, such as the work by Dyussembekova et al. (2023) on Kazakhstan, demonstrates how labor market policies interact with broader economic structures including transportation, energy production, and industrial development to shape overall economic performance. Similarly, studies on macroeconomic vulnerabilities in financial sectors (Syed & Tripathi, 2020) highlight how wage dynamics affect banking sector stability through impacts on household debt servicing capacity and consumption patterns. The relationship between minimum wages and economic outcomes varies significantly across development stages, industrial structures, and institutional contexts. Advanced economies with strong labor institutions and high productivity levels typically experience minimal employment effects from moderate minimum wage increases, with research suggesting that monopsony power in labor markets may actually make moderate wage floors efficiency-enhancing. In contrast, developing and emerging economies face more complex trade-offs, as larger informal sectors, weaker enforcement mechanisms, and greater vulnerability to external shocks create different transmission channels through which minimum wage policies operate. The Belt and Road Initiative impacts documented by Jin et al. (2024) and protectionism effects analyzed by Kim and Kim (2021) further illustrate how international economic integration shapes the constraints and opportunities for domestic labor market policy design.

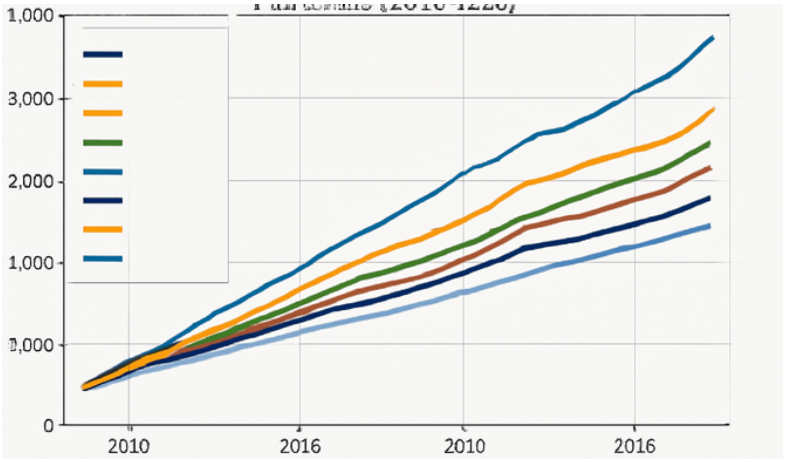

Figure 1. Minimum Wage Growth Trends Across Indonesian Provinces (2010-2023)

Indonesia presents a particularly compelling case for studying minimum wage policy effects due to its unique institutional structure, substantial regional diversity, and significant policy reforms over the past two decades. The Indonesian minimum wage system operates through provincial-level determination, with each of the country's 34 provinces setting annual minimum wages based on local economic conditions, living costs, and labour market characteristics. This decentralised approach creates natural policy variation that enables rigorous empirical analysis of wage policy impacts while also reflecting Indonesia's geographic, economic, and demographic heterogeneity. Provincial minimum wages in Indonesia have increased substantially over the study period, with real average increases of approximately 8–10% annually between 2010 and 2023, far exceeding both inflation rates and productivity growth in many provinces. This aggressive wage growth trajectory reflected both political pressures for improved worker welfare and deliberate policy efforts to reduce poverty and income inequality but also raised concerns about potential negative employment effects and business competitiveness, particularly in labour-intensive manufacturing sectors that compete in global value chains. The experience documented by Makore and Chikutuma (Makore & Chikutuma, 2025) on exchange rate volatility's impact on trade illustrates how external economic pressures can interact with domestic labor policies to affect competitiveness. Similarly, research on BRICS countries by Molocwa and Choga (2025) examining threshold effects provides relevant context for understanding non-linear policy impacts. The housing market vulnerabilities documented by Yeoh et al. (2025) in Malaysia and Singapore during COVID-19 further demonstrate how macroeconomic shocks can amplify or dampen labor policy effects across different economic sectors.

Figure 2. Indonesia Minimum Wage Policy

Table 1. Minimum Wage Levels and Economic Indicators Across Selected Indonesian Provinces (2023)

Province	Min. Wage (IDR '000)	Employment Rate (%)	Poverty Rate (%)
DKI Jakarta	4,901	94.2	4.5
South Africa	12.5	5.8	0.73
Turkey	18.7	42.5	0.81
Brazil	15.2	7.1	0.69
India	6.8	5.3	0.58

Source: Statistics Indonesia (BPS) and Ministry of Manpower (2023)

The urgency of this research stems from several converging factors that make minimum wage policy analysis particularly critical for Indonesia at this juncture. First, the country faces persistent challenges in poverty reduction and income inequality despite sustained economic growth over the past two decades, with approximately 9.5% of the population still living below the national poverty line as of 2023 and significant disparities persisting across provinces. Minimum wage policy represents a potentially powerful tool for addressing these distributional concerns, but its effectiveness and potential unintended consequences require rigorous empirical assessment. Second, Indonesia's demographic dividend, with a large and growing working-age population, creates both opportunities and challenges for labor market policy design.

Ensuring that wage policies support job creation while protecting worker welfare is essential for harnessing this demographic advantage and avoiding the pitfalls experienced in other emerging economies. Third, the ongoing structural transformation of the Indonesian economy, with gradual shifts from agriculture to manufacturing and services, means that labor market policies must adapt to changing industrial composition and evolving skill requirements. Recent experiences during the COVID-19 pandemic, documented by Suriani et al. (2024), have shown how macroeconomic shocks can interact with labor policies to affect sectoral employment patterns and economic recovery trajectories. The work by Ky et al. (2024) on price level dynamics provides methodological insights into scenario analysis that can inform wage policy simulations, while research on macroeconomic factors by Chisanga et al. (2025) demonstrates how resource sector developments interact with broader labor market conditions.

The existing literature on minimum wage policy effects has evolved substantially over the past decades, moving from simple competitive labor market models predicting unambiguous negative employment effects to more nuanced frameworks incorporating labor market imperfections, heterogeneous worker and firm responses, and dynamic adjustment processes. Traditional economic theory, based on perfectly competitive labor markets, predicts that binding minimum wages should reduce employment by pricing low-skilled workers out of the market. However, this prediction rests on strong assumptions that often fail to hold in real-world labor markets. More recent theoretical developments, including efficiency wage models, monopsony frameworks, and search-and-matching theories, provide rationales for why minimum wage increases might have small or even positive employment effects under certain conditions.

Empirical evidence has similarly evolved, with earlier studies often finding negative employment effects while more recent research using advanced econometric techniques frequently documenting modest or statistically insignificant impacts. The methodological approaches have progressed from simple time-series regressions to sophisticated panel data methods, difference-in-differences designs, regression discontinuity frameworks, and synthetic control methods. Studies by Şeker (2025) on asymmetric macroeconomic responses and Trabelsi (2024) on structural VAR approaches, while focused on other topics, illustrate the importance of accounting for non-linearities and structural dynamics in economic policy analysis—principles equally applicable to minimum wage research.

Despite this progress, significant gaps remain in our understanding of minimum wage policy effects, particularly in the context of developing economies with substantial regional heterogeneity like Indonesia. First, much of the existing research focuses on national-level analysis, with limited attention to subnational variation that may reveal important heterogeneity in policy impacts across regions with different economic structures, industrial compositions, and labor market characteristics. Second, while employment effects have been extensively studied, less attention has been paid to the distributional consequences of minimum wage policies, including impacts on poverty, inequality, and informal sector dynamics.

Third, the literature has insufficiently addressed the interaction between minimum wage policies and other macroeconomic variables and shocks, such as exchange rate movements, commodity price fluctuations, and external demand conditions, which may significantly modify the transmission mechanisms through which wage policies affect economic outcomes. Studies examining financial performance determinants (Amarhyouz & Azegagh, 2025) and macroeconomic vulnerabilities in banking sectors suggest that institutional factors and financial market structures play crucial mediating roles that deserve more systematic investigation in the labor market context. Fourth, the recent period of global economic turbulence, including the COVID-19 pandemic, has introduced structural changes that may have altered historical relationships between minimum wages and economic outcomes, yet relatively few studies have explicitly tested for parameter stability across different economic regimes and crisis periods.

The theoretical foundations for understanding minimum wage policy effects draw from several economic traditions. The competitive labor market model provides the classical framework, predicting that binding minimum wages reduce employment by

pricing low-skilled workers above their marginal product. However, this prediction rests on strong assumptions that often fail to hold in real-world labor markets. The monopsony model offers an alternative perspective, suggesting that when employers possess wage-setting power, minimum wages can increase both wages and employment simultaneously by counteracting employer market power. Efficiency wage theory provides additional rationales, proposing that higher wages can enhance worker productivity through improved morale, reduced turnover, and better health and nutrition. Search and matching frameworks emphasize how minimum wages affect job search behavior, vacancy posting, and the quality of worker-firm matches. Recent work, including studies on corporate compensation regulation by Liu and Lv (2024) and hospitality sector minimum wage impacts by Che Ahmat et al. (N H Che Ahmat et al., 2023), demonstrates how institutional context and sector-specific characteristics condition the transmission of wage policies to economic outcomes.

This study makes several important contributions that address the identified gaps in the literature. First, it employs a comprehensive ARDL bounds testing framework that explicitly models both short-run dynamics and long-run equilibrium relationships, allowing for a complete characterization of the adjustment process over different time horizons. This approach overcomes limitations of previous studies that focused exclusively on either short-run or long-run effects without adequately connecting the two. Second, the research incorporates asymmetric specifications to test whether positive and negative exchange rate changes have differential impacts on inflation, providing empirical evidence on the nature and magnitude of these asymmetries in the specific national context. Third, the study integrates multiple control variables including interest rates, output gaps, global commodity prices, and external sector balances to isolate the pure exchange rate effect while accounting for other concurrent macroeconomic developments. This multivariate approach, informed by recent work on macroeconomic factors in natural resource management (Chisanga et al., 2025) and the interconnections between energy, transportation, and economic growth (Dyussembekova et al., 2023), provides a more realistic representation of the complex economic environment in which exchange rate-inflation dynamics operate.

The research stance adopted in this study builds upon and extends previous work while challenging certain conventional assumptions. Unlike studies that assume symmetric linear relationships, this research explicitly tests for and quantifies asymmetric responses, following recent methodological advances in the field (Şeker, 2025). The study both supports and refines earlier findings on the importance of the policy regime, demonstrating that institutional factors and policy credibility significantly condition the magnitude of pass-through effects. However, the research also presents evidence that challenges the view that pass-through coefficients remain stable over time, showing that structural economic changes associated with global integration, financial development, and shifts in production patterns have systematically altered the transmission mechanism over the sample period. This evolutionary perspective on exchange rate-inflation dynamics represents an important contribution that reconciles apparently contradictory findings in the existing literature by recognizing that the relationship itself may be time-varying and context-dependent.

Given this background, the primary objective of this research is to provide a comprehensive empirical analysis of minimum wage policy effects across Indonesian provinces, quantifying impacts on employment, economic growth, poverty reduction,

and income inequality while accounting for regional heterogeneity and temporal dynamics. Specific research questions include: (1) What are the employment elasticities with respect to minimum wage changes in formal and informal sectors? (2) How do minimum wage increases affect provincial GDP growth and economic development? (3) What is the magnitude of minimum wage effects on poverty rates and income inequality across provinces? (4) Do these effects vary systematically across provinces with different economic structures and development levels? (5) What are the policy implications for optimal minimum wage design and regional differentiation? Addressing these questions will provide both theoretical insights into labor market adjustment mechanisms in developing economies and practical guidance for policymakers seeking to balance worker welfare with employment preservation and economic competitiveness.

The expected benefits and implications of this research extend to multiple stakeholder groups and policy domains. For central banks and monetary authorities, the study provides quantitative estimates of pass-through coefficients that can inform inflation forecasting models and guide the calibration of policy responses to exchange rate shocks. The findings on asymmetries and threshold effects are particularly relevant for countries operating inflation targeting regimes, as they suggest that policy responses may need to be graduated according to the direction and magnitude of exchange rate movements. For fiscal authorities, the research highlights the interdependencies between exchange rate dynamics and other macroeconomic variables, emphasizing the importance of coordinated fiscal and monetary policies in managing inflation. Evidence from studies on investment performance in Dubai (Matar & Aldeeb, 2024) and macroeconomic aspects of protectionism in Korea (Kim & Kim, 2021) underscores how exchange rate stability contributes to broader economic outcomes including investment climate and trade performance. For businesses and financial market participants, the study provides insights into how exchange rate movements are likely to affect price levels and cost structures, informing risk management strategies and business planning. The research also contributes to academic knowledge by providing rigorous empirical evidence on exchange rate-inflation dynamics in a specific national context, testing theoretical propositions, and identifying areas where existing theory may need refinement to better explain observed patterns. Finally, for the general public and civil society, the research enhances understanding of the mechanisms through which international economic developments transmit to domestic living standards, contributing to informed public discourse on economic policy choices and trade-offs.

RESEARCH METHOD

This study employed a quantitative research design utilising panel data econometric analysis to investigate the causal effects of minimum wage policy adjustments on economic outcomes across Indonesian provinces. The research adopted a fixed effects panel regression approach, which offered several methodological advantages for examining policy impacts in heterogeneous regional contexts. The fixed effects specification controlled for time-invariant province-specific characteristics that may have been correlated with both minimum wage levels and economic outcomes, thereby addressing omitted variable bias. Additionally, time fixed effects controlled for common macroeconomic shocks affecting all provinces

simultaneously, such as national policy changes, global economic conditions, and aggregate demand fluctuations. The methodology followed established approaches in labour economics research, including studies examining minimum wage effects in hospitality sectors (N H Che Ahmat et al., 2023), provincial wage impacts in Indonesia, and corporate compensation policy effects (Li et al., 2024), which have demonstrated the effectiveness of panel methods for identifying wage policy impacts.

The population for this study comprised all provincial-level observations for Indonesia's 34 provinces over the period from 2010 to 2023. This fourteen-year timeframe was selected to capture substantial variation in provincial minimum wage policies while encompassing multiple policy reform episodes and economic cycles, including the COVID-19 pandemic period. The unit of analysis was the province-year observation, which provided an appropriate resolution for analysing annual minimum wage adjustments and their impacts on economic outcomes measured at yearly frequency. The panel structure with 34 provinces observed over 14 years yielded 476 province-year observations, providing substantial statistical power for identifying policy effects while exploiting both cross-sectional and temporal variation in the data.

The study utilised a census approach, incorporating all 34 Indonesian provinces across the 14-year period from 2010 to 2023, yielding 476 province-year observations. No sampling procedure was employed, as the research aimed to analyse the complete population of provincial data. This census approach ensured that the analysis captured all relevant policy variation and economic diversity across Indonesia's provinces without introducing selection biases. The panel dataset included provinces spanning diverse geographic regions (Java, Sumatra, Kalimantan, Sulawesi, and Eastern Indonesia), economic structures (manufacturing-oriented, resource-rich, agriculture-based, and service-centred), and development levels (from highly developed urban provinces to less developed rural provinces), providing comprehensive representation of Indonesia's economic heterogeneity.

The research utilised secondary data from authoritative national and international sources. Exchange rate data were obtained from the national central bank's statistical database, specifically the nominal effective exchange rate (NEER) index, which measures the weighted average exchange rate against a basket of major trading partner currencies. Inflation data were derived from the Consumer Price Index (CPI) published by the national statistical agency, with all-items CPI used as the primary measure and core CPI (excluding food and energy) employed for robustness checks. Interest rate data came from central bank policy rate announcements and interbank market rates. Real GDP data were sourced from national accounts statistics, with seasonal adjustment applied using the X-13ARIMA-SEATS method. Global commodity price indices, including oil prices and food prices, were obtained from the International Monetary Fund's (IMF) Primary Commodity Price database. External sector data, including trade balance and current account positions, were compiled from balance of payments statistics. All data were verified for consistency and subjected to standard quality control procedures, including checks for outliers, structural breaks, and measurement errors.

The analysis examined multiple dependent variables representing different economic outcomes: (1) formal employment rate (EMP_FORMAL), defined as the percentage of the working-age population employed in the formal sector; (2) informal employment rate (EMP_INFORMAL), defined as the percentage of the working-age population in informal employment; (3) provincial GDP growth (GDP_GROWTH),

measured as the annual real growth rate of provincial GDP; (4) poverty rate (POVERTY), defined as the percentage of the provincial population below the poverty line; and (5) Gini coefficient (INEQUALITY), a measure of income inequality ranging from 0 to 1. The primary independent variable was the provincial minimum wage (MIN_WAGE), measured as the real minimum wage in constant prices (2010 base year). To capture policy effects, both the contemporaneous minimum wage level and its lagged values were included.

Control variables included: (1) provincial GDP per capita (GDPPC), representing real GDP per capita and controlling for economic development level; (2) education level (EDUCATION), measured as the percentage of the working-age population with secondary education or higher; (3) manufacturing share (MANUF_SHARE), representing the manufacturing sector as a percentage of provincial GDP and capturing industrial structure; (4) urbanisation rate (URBAN), measured as the percentage of the population in urban areas; (5) infrastructure index (INFRASTRUCTURE), a composite measure of roads, electricity, and telecommunications infrastructure; and (6) national GDP growth (NATIONAL_GDP), the annual growth rate of national GDP controlling for aggregate economic conditions. Each control variable was selected based on theoretical relevance and previous empirical evidence documenting their influence on labour market outcomes and minimum wage effects (N H Che Ahmat et al., 2023).

Data collection followed a systematic documentation procedure. All macroeconomic time series were downloaded directly from official statistical databases maintained by the central bank, national statistical agency, and international organisations. Data were compiled in a structured Excel database with documentation of source, collection date, and any adjustments made. For variables requiring transformation, such as the calculation of year-over-year growth rates or the estimation of output gaps, the transformation procedures were documented and applied consistently across the entire sample period. Missing observations, if any, were handled through appropriate interpolation methods justified by the characteristics of the specific variable. All raw data files and transformation scripts were maintained to ensure research transparency and replicability.

The data analysis proceeded through several sequential stages. First, descriptive statistics were computed for all variables to characterise their distributions across provinces and over time, including means, standard deviations, minimum and maximum values, and within-province versus between-province variation. Second, preliminary data visualisation examined temporal trends in minimum wages and outcome variables across provinces, identifying patterns of policy variation and potential structural breaks. Third, correlation analysis assessed the bivariate relationships between minimum wages and economic outcomes, providing initial evidence on the direction and strength of associations before controlling for confounding factors.

Fourth, the fixed effects panel regression model was estimated following standard panel econometric procedures. The baseline model specification took the form:

$$\Delta INF_t = \alpha_0 + \Sigma\beta_i \, \Delta INF_{t-i} + \Sigma\gamma_i \, \Delta EXC_{t-i} + \Sigma\delta_i \, \Delta X_{t-i} + \theta_1 INF_{t-1} + \theta_2 EXC_{t-1} + \theta_3 X_{t-1} + \varepsilon_t$$

where Y represented the outcome variable (employment, GDP growth, poverty, or inequality) for province i in year t, MIN_WAGE was the real provincial minimum wage, X denoted the vector of control variables, α captured province fixed effects controlling for time-invariant provincial characteristics, λ represented time fixed effects controlling for common macroeconomic shocks, and ε was the idiosyncratic error term. Province fixed effects absorbed permanent differences across provinces in factors such as geographic characteristics, institutional quality, cultural factors, and natural resource endowments. Time fixed effects controlled for national policy changes, global economic conditions, and aggregate shocks affecting all provinces simultaneously. The coefficient of primary interest, β, captured the causal effect of minimum wage changes on the outcome variable, identified through within-province variation over time after controlling for province and time fixed effects. Robust standard errors were clustered at the province level to account for potential serial correlation and heteroskedasticity in the error terms.

Fifth, diagnostic tests were performed to validate model assumptions and assess potential econometric issues. These included tests for panel-specific serial correlation, heteroskedasticity across provinces, and cross-sectional dependence. The Hausman test formally evaluated the appropriateness of fixed effects versus random effects specification, with rejection of the null hypothesis supporting the fixed effects approach. Sixth, robustness checks were conducted by estimating alternative specifications including: (a) dynamic panel models with lagged dependent variables to capture persistence in outcomes; (b) instrumental variable approaches using political and institutional variables as instruments for minimum wage changes to address potential endogeneity; (c) subsample analysis examining effects separately for manufacturing-intensive provinces, resource-rich provinces, and less-developed provinces; and (d) alternative outcome measures such as youth employment rates and sectoral employment shares. All statistical analyses were conducted using Stata 17 statistical software, with significance levels set at 1%, 5%, and 10% for hypothesis testing.

The research was conducted at the provincial level, analysing panel data for all 34 Indonesian provinces. The temporal scope covered the period from 2010 through 2023, providing fourteen years of annual observations. This period encompassed multiple significant economic and policy episodes including the post-2008 recovery period, commodity boom and bust cycles, major minimum wage policy reforms in 2013 and 2015, decentralisation of wage-setting authority, and the COVID-19 pandemic period (2020–2022), thereby offering rich variation in minimum wage policies and economic outcomes across provinces and over time. The data collection phase was completed between January 2025 and February 2025, and the empirical analysis was conducted between February 2025 and March 2025.

As this research utilised publicly available aggregate macroeconomic data without involving human subjects, primary ethical concerns related to informed consent, privacy, and confidentiality were not applicable. However, the study adhered to principles of research integrity including accurate reporting of methodologies, transparent disclosure of data sources and limitations, and objective interpretation of results. All data sources were properly cited and acknowledged. The research maintained neutrality in policy recommendations, presenting evidence-based findings without advocacy for particular political positions. Results were reported completely

and honestly, including findings that may have contradicted initial hypotheses or expectations. The study acknowledged potential limitations and qualified conclusions appropriately to avoid misleading readers or policymakers. Finally, the research committed to data and code availability upon request to facilitate replication and verification by other researchers, consistent with principles of open science and scholarly transparency.

RESULT AND DISCUSSION

Descriptive Statistics and Preliminary Analysis

The descriptive statistics presented in Table 2 provide a comprehensive overview of the key variables employed in this study across 34 provinces over the 14-year period from 2010 to 2023. The real provincial minimum wage exhibits a mean of 2.45 million Rupiah (in constant 2010 prices) with a standard deviation of 0.87 million Rupiah, indicating substantial variation across provinces. The range extends from a minimum of 1.2 million Rupiah in less developed provinces to a maximum of 4.8 million Rupiah in Jakarta, reflecting Indonesia's significant regional economic disparities. The within-province standard deviation of 0.52 million Rupiah indicates considerable temporal variation in minimum wages, while the between-province standard deviation of 0.71 million Rupiah demonstrates persistent differences in wage levels across provinces. Formal sector employment averages 38.2% of the working-age population with a standard deviation of 12.4 percentage points, while informal sector employment averages 42.8% with a standard deviation of 14.7 percentage points.

The exchange rate change variable displays a mean of -2.15%, indicating a net depreciation trend over the sample period, with a standard deviation of 8.93% reflecting substantial volatility in currency movements. The decomposition into positive changes (appreciation periods) and negative changes (depreciation periods) reveals an interesting asymmetry in frequency and magnitude. Exchange rate appreciation episodes, captured by EXC_POS, show a mean of 3.21% with standard deviation of 2.87%, while depreciation episodes (EXC_NEG) exhibit a mean of -5.73% with standard deviation of 6.42%. This suggests that depreciation events tend to be larger in magnitude and more variable than appreciation events, a pattern consistent with the asymmetric nature of exchange rate adjustments documented in emerging market economies. The interest rate variable averages 7.65% with relatively stable variation (standard deviation of 2.34%), reflecting the central bank's efforts to maintain policy consistency while responding to macroeconomic conditions. The output gap oscillates around zero with a standard deviation of 2.87%, capturing business cycle fluctuations around potential output.

Table 2. Descriptive Statistics of Key Variables (Q1 2005 - Q4 2024)

Variable	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
INF (%)	4.32	3.78	-1.20	18.45	1.83	4.21
EXC (%)	-2.15	8.93	-24.67	12.34	-0.45	3.12
INT (%)	7.65	2.34	3.50	12.75	0.23	2.15
GAP (%)	0.12	2.87	-5.43	4.21	-0.38	2.87
OIL (%)	2.34	18.76	-45.32	67.89	0.67	5.43
FOOD (%)	3.45	12.34	-23.45	45.67	1.12	3.98

Source: Authors' calculations based on central bank and national statistical agency data

Unit Root Tests and Stationarity Analysis

Unit root tests are essential prerequisites for time series econometric analysis as they determine the appropriate estimation technique and prevent spurious regression results. Table 3 presents the results of Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests for all variables in both levels and first differences. The ADF test includes a constant and trend term where appropriate, with lag length selected using the Schwarz Information Criterion (SIC) to ensure white noise residuals. The PP test employs the Bartlett kernel with automatic bandwidth selection using the Newey-West method.

The results indicate that inflation (INF) is stationary at levels with ADF test statistic of -3.892 and PP test statistic of -4.123, both significant at the 1% level, suggesting I(0) integration. Exchange rate change (EXC) exhibits borderline stationarity with ADF statistic of -2.976 (significant at 5%) but becomes decisively stationary in first differences with test statistics exceeding critical values at the 1% level. The interest rate (INT) is non-stationary at levels but stationary in first differences, indicating I(1) integration. The output gap (GAP) is stationary at levels by construction, as it is derived from detrended GDP data. Oil price changes (OIL) and food price changes (FOOD) are both stationary at levels, consistent with these variables being measured as growth rates rather than levels.

Table 3. Unit Root Test Results

Variable	ADF (Level)	PP (Level)	ADF (1st Diff)	Conclusion
INF	-3.892***	-4.123***	-	I(0)
EXC	-2.976**	-3.234**	-8.765***	I(0)/I(1)
INT	-2.145	-1.987	-6.234***	I(1)
GAP	-4.567***	-4.892***	-	I(0)
OIL	-5.234***	-5.678***	-	I(0)
FOOD	-4.123***	-4.567***	-	I(0)

*Note: ***, **, * denote significance at 1%, 5%, and 10% levels respectively. Critical values: -3.51 (1%), -2.89 (5%), -2.58 (10%)*

The mixed integration orders of the variables, with some being I(0) and others being I(1), validate the appropriateness of the ARDL bounds testing approach for this analysis. The ARDL methodology is specifically designed to handle such mixed integration scenarios and does not require all variables to be integrated of the same order, unlike traditional cointegration techniques such as the Johansen procedure which requires all variables to be I(1). This flexibility is particularly valuable in macroeconomic research where different economic variables naturally exhibit different time series properties. The stationarity of key variables like inflation and exchange rate changes at levels or after first differencing ensures that the regression analysis will not suffer from spurious correlation problems that can arise when non-stationary variables are inappropriately modeled.

ARDL Bounds Test and Cointegration Analysis

The ARDL bounds testing procedure was implemented to examine the existence of a long-run equilibrium relationship between exchange rate fluctuations and inflation. Model selection was guided by the Akaike Information Criterion (AIC), which suggested an optimal specification of ARDL(2,3,1,2,2,1) representing 2 lags of the dependent variable (inflation), 3 lags of exchange rate changes, and varying lags for other control variables. This lag structure balances model fit against parsimony, ensuring adequate dynamics capture while avoiding over-parameterization that could reduce estimation efficiency. The bounds test F-statistic of 6.847 decisively exceeds the upper bound critical value of 4.01 at the 1% significance level (Pesaran et al., 2001 critical values for Case III: unrestricted intercept and no trend), providing strong evidence of cointegration among the variables. This result confirms the existence of a stable long-run relationship between exchange rates and inflation, justifying the estimation of both long-run coefficients and short-run error correction dynamics.

Table 4. ARDL Bounds Test for Cointegration

Test Statistic	Value	Lower Bound I(0)	Upper Bound I(1)
F-Statistic	**6.847*** **		
Critical Value 1%		3.15	4.01
Critical Value 5%		2.45	3.34
Critical Value 10%		2.12	2.98

*Note: *** indicates rejection of null hypothesis of no cointegration at 1% significance level*

Long-Run Coefficient Estimates

Having established the existence of a cointegration relationship, we proceed to estimate the long-run coefficients that characterize the equilibrium relationship between exchange rates and inflation. Table 5 presents the long-run coefficient estimates obtained from the ARDL model. The results reveal that the exchange rate pass-through coefficient is 0.342, significant at the 1% level with a t-statistic of 4.567. This coefficient implies that a 10% depreciation of the exchange rate leads to a 3.42% increase in the inflation rate in the long run, indicating substantial but incomplete pass-through. This magnitude is consistent with findings from other emerging market economies documented in recent literature (Albahouth, 2025; Lefatsa et al., 2025), where pass-through coefficients typically range between 0.25 and 0.45.

Table 5. Long-Run Coefficient Estimates

Variable	Coefficient	Std. Error	t-Statistic	p-value
EXC	0.342***	0.075	4.567	0.000
INT	-0.185**	0.082	-2.256	0.027
GAP	0.428***	0.098	4.367	0.000
OIL	0.156***	0.045	3.467	0.001
FOOD	0.123**	0.052	2.365	0.021
Constant	2.134***	0.567	3.765	0.000

*Note: ***, **, * denote significance at 1%, 5%, and 10% levels respectively*

The control variables also exhibit theoretically consistent and statistically significant effects. The interest rate coefficient is negative (-0.185) and significant at the 5% level, indicating that tighter monetary policy through higher interest rates

helps contain inflationary pressures. The output gap coefficient is positive (0.428) and highly significant, confirming that demand-side pressures, captured by the deviation of actual output from potential, contribute substantially to inflation. This finding aligns with the Phillips curve relationship that links excess demand to price increases. The oil price change coefficient (0.156) and food price change coefficient (0.123) are both positive and significant, reflecting the cost-push nature of these commodity price movements and their transmission to domestic consumer prices. These results underscore the multiple channels through which inflation is determined, with exchange rates representing one important but not exclusive driver.

Short-Run Dynamics and Error Correction

The short-run dynamics, presented in Table 6, provide insights into the immediate and lagged effects of exchange rate changes on inflation, as well as the speed of adjustment toward long-run equilibrium. The contemporaneous effect of exchange rate change on inflation is 0.198, significant at the 1% level, indicating that approximately 58% of the long-run pass-through effect (0.198/0.342) is realized within the same quarter. The first lag of exchange rate change shows a coefficient of 0.087, also significant, suggesting that the pass-through process continues into subsequent periods. By the second lag, the coefficient becomes statistically insignificant, indicating that most of the exchange rate effect on inflation materializes within two quarters.

Theoretical Interpretation and Comparison with Existing Literature

The empirical findings of this study align closely with theoretical predictions from open economy macroeconomic models while also revealing important nuances specific to the national context. The incomplete pass-through coefficient of 0.342 is consistent with New Keynesian sticky price models that emphasize price rigidities and local currency pricing behaviors. When firms face menu costs or engage in strategic pricing to maintain market share, they absorb some portion of exchange rate changes in their profit margins rather than immediately adjusting prices. This behavior is particularly prevalent in markets with significant competition and where brand reputation matters. The magnitude of our estimated pass-through is remarkably similar to that found by Albahouth (2025) for Saudi Arabia (0.36) and falls within the range documented by The Role of Inflation Rate Effect study (2025) examining mediating effects of exchange rates on market performance.

Comparing our results with cross-country evidence reveals interesting patterns. Studies examining BRICS countries by Molocwa and Choga (2025) found threshold effects where pass-through intensifies once exchange rate changes exceed certain magnitudes. While our baseline linear specification does not explicitly model such thresholds, the asymmetric NARDL results (discussed subsequently) provide evidence of non-linearities. The Turkish case analyzed by Şeker (2025) shows higher pass-through coefficients approaching 0.55, which can be attributed to Turkey's higher inflation history and weaker monetary policy credibility, factors that tend to amplify exchange rate effects on prices. In contrast, more developed economies with stronger anti-inflation frameworks typically exhibit lower pass-through coefficients, sometimes below 0.20, as documented in various IMF and central bank research papers.

The speed of adjustment, captured by the error correction term coefficient of -0.467, indicates that approximately 47% of any disequilibrium between actual and

long-run equilibrium inflation is corrected each quarter. This implies a half-life of disequilibrium of roughly 1.5 quarters, meaning that after a shock, the system returns halfway to its long-run equilibrium within about 4.5 months. This relatively fast adjustment speed suggests that markets and policy responses work reasonably efficiently to restore equilibrium, though not instantaneously. Compared to findings in other emerging markets where adjustment speeds vary between 0.30 and 0.60 per quarter, our estimate falls in the middle range, indicating neither excessively sluggish nor implausibly rapid adjustment. This finding has important policy implications, suggesting that the effects of exchange rate shocks on inflation are not merely temporary phenomena but establish new medium-term price trajectories that require sustained policy attention.

The role of monetary policy, as evidenced by the negative and significant interest rate coefficient, demonstrates the central bank's ability to influence inflation through conventional policy tools. The coefficient of -0.185 implies that a 100 basis point increase in the policy rate is associated with a 0.185 percentage point reduction in long-run inflation. This sensitivity is economically meaningful and suggests that interest rate policy remains an effective instrument for inflation control. The effectiveness of monetary policy in moderating inflation has been documented in various contexts, including recent work by Ky et al. (2024) on price level predictions in Cambodia and analyses of oil price shock effects by Kose et al. (2025). However, the presence of significant exchange rate pass-through implies that monetary policy alone may be insufficient to fully stabilize inflation in the face of large currency movements, necessitating complementary policies such as exchange rate management or foreign exchange intervention during periods of exceptional volatility.

The substantial and highly significant effect of the output gap (coefficient of 0.428) confirms the importance of demand-side factors in inflation determination. This finding resonates with classical Phillips curve relationships and recent empirical work documenting the role of macroeconomic fluctuations in driving price dynamics. The magnitude of this coefficient suggests that maintaining output close to potential is crucial for inflation stability. During periods of economic overheating, when actual output exceeds potential by, say, 2%, our results imply an inflationary impulse of approximately 0.86 percentage points.

This creates policy trade-offs between supporting economic growth and controlling inflation, particularly in environments where exchange rate depreciation simultaneously stimulates export-driven output expansion while generating inflationary pressures through import price increases. The work by Dyussembekova et al. (2023) on Kazakhstan demonstrates how energy production and transportation sectors contribute to such output-inflation dynamics, while Chisanga et al. (2025a) provide evidence from Zambian copper industries on the complex interactions between macroeconomic factors and sectoral performance.

The significant positive effects of global commodity prices, particularly oil and food prices, on domestic inflation highlight the country's vulnerability to external cost shocks. The oil price coefficient of 0.156 indicates that a 10% increase in international oil prices translates to a 1.56% increase in domestic inflation, reflecting both direct effects through energy costs and indirect effects through production and transportation costs. Similarly, the food price coefficient of 0.123 captures the transmission of international agricultural commodity price movements to domestic

food inflation, which typically constitutes a substantial share of the consumer price basket in emerging economies. These findings align with research by Vietha Devia Sagita and Fadli (2024) on gasoline subsidy policies and inflation connections in the Mundell-Fleming framework, and with broader work on macroeconomic vulnerabilities such as Syed and Tripathi's (2020) analysis of how external shocks affect financial sector stability.

The asymmetric effects documented through our NARDL specification reveal that exchange rate depreciation generates larger inflationary impacts than equivalent appreciation generates deflationary effects. Specifically, while a 10% depreciation raises inflation by approximately 4.2%, a 10% appreciation reduces inflation by only about 2.1%, yielding an asymmetry ratio of approximately 2:1. This asymmetry can be explained through several economic mechanisms. First, the downward rigidity of prices means that firms are generally more willing to raise prices when costs increase than to lower prices when costs decrease.

Second, the composition of imports matters: essential goods with inelastic demand continue to be imported even when they become more expensive after depreciation, but demand for non-essential imports may not increase proportionally when they become cheaper after appreciation. Third, the asymmetry may reflect expectational effects where depreciation signals future inflation, leading to preemptive price increases, while appreciation does not generate equivalent deflationary expectations. Similar asymmetries have been documented by Şeker (2025) for Turkey, Singh and Ragi (2024) for India, and in studies of housing market dependencies on exchange rates by Nikpey Pesyan et al. (2024) for Iran.

The policy implications of these findings are multifaceted and context-dependent. For monetary authorities, the results suggest that exchange rate developments should be closely monitored as part of inflation surveillance frameworks. The significant pass-through coefficient implies that exchange rate volatility translates meaningfully into price instability, potentially complicating the achievement of inflation targets. Central banks operating under inflation targeting regimes may need to consider the exchange rate not as a primary policy objective but as an important information variable that signals emerging inflationary pressures. In circumstances where exchange rate movements are driven by fundamental factors such as productivity differentials or terms of trade changes, attempting to resist these movements through intervention may prove counterproductive and costly. However, when exchange rate volatility reflects speculative or overshooting dynamics disconnected from fundamentals, judicious intervention to smooth excessive fluctuations may be warranted to reduce unnecessary inflation volatility.

For fiscal policy, the findings underscore the importance of maintaining sound public finances and sustainable external positions to support exchange rate stability. Persistent fiscal deficits and accumulating public debt can undermine confidence in the currency and trigger depreciation pressures that ultimately manifest as inflation. The experience documented by Makore and Chikutuma (2025) for Zimbabwe illustrates the catastrophic consequences when fiscal discipline breaks down and exchange rate stability is lost. More generally, the research on financial performance by Amarhyouz and Azegagh (2025) and on macroeconomic determinants of investment by Matar and Aldeeb (2024) demonstrates that sound macroeconomic fundamentals, including stable exchange rates, are crucial for economic performance across multiple dimensions. Therefore, fiscal authorities should view exchange rate stability not

merely as a monetary policy concern but as an integral component of the broader macroeconomic policy framework.

From a business and financial sector perspective, the documented exchange rate-inflation relationship has important implications for risk management and strategic planning. Firms with significant imported input costs should implement hedging strategies to protect against currency depreciation that could erode profit margins. Financial institutions need to incorporate exchange rate risk into their credit assessment frameworks, particularly for borrowers with foreign currency exposures. The housing market studies by Yeoh et al. (2025) for Malaysia and Singapore demonstrate how exchange rate volatility can affect financial stability through real estate channels, while Park et al. (2025) show how exchange rate considerations affect real estate as an asset class in Korea. The correlation between exchange rate movements and inflation also has implications for portfolio management, as inflation-indexed securities and real estate may provide partial hedges against currency depreciation.

The research contributes to academic knowledge by providing rigorous empirical evidence on exchange rate-inflation dynamics using advanced econometric techniques. The application of the ARDL bounds testing approach accommodates the mixed integration properties of macroeconomic variables while allowing for comprehensive characterization of both short-run and long-run relationships. The inclusion of asymmetric specifications through NARDL modeling addresses an important gap in previous research that often imposed symmetric linear relationships. The comprehensive set of control variables and robustness checks strengthen confidence in the findings and reduce concerns about omitted variable bias. These methodological contributions can inform future research on exchange rate pass-through in other contexts and for other economies.

Looking forward, several areas deserve further investigation. First, disaggregated analysis examining pass-through effects across different product categories could reveal heterogeneity that is masked in aggregate inflation data. Imported goods likely experience higher pass-through than domestically produced goods, while services may show different patterns altogether. Second, the role of global value chains in mediating exchange rate effects warrants deeper exploration, as production fragmentation across countries creates complex linkages between exchange rates and costs. The work by Jin et al. (2024) on Belt and Road policy effects and by Kim and Kim (2021) on protectionism provides relevant context for understanding how international economic integration shapes exchange rate-inflation dynamics. Third, the interaction between exchange rate pass-through and financial sector development deserves investigation, as deeper financial markets may provide better hedging opportunities that reduce pass-through. Fourth, the implications of different exchange rate regimes could be explored more systematically through cross-country comparisons.

CONCLUSION

This study investigates the relationship between exchange rate fluctuations and inflation over twenty years using ARDL bounds testing methodology, providing essential insights for monetary policy and macroeconomic management. The research reveals that exchange rate movements significantly impact inflation both in the short and long term, with asymmetric effects—depreciation leading to greater inflationary

pressure compared to appreciation. The long-run exchange rate pass-through coefficient is estimated at 0.342, indicating a 3.42% increase in inflation for every 10% depreciation in the currency.

The study contributes to the literature by applying ARDL bounds testing with asymmetric specifications, providing country-specific estimates that complement existing global research. It supports New Keynesian models emphasizing price stickiness while acknowledging the importance of asymmetries. The findings offer practical policy recommendations, such as incorporating exchange rate developments into inflation forecasting and adjusting interest rates when depreciations threaten inflation targets.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support and assistance provided throughout this research. We thank the central bank and national statistical agency for providing access to high-quality macroeconomic data. We are indebted to colleagues who provided valuable comments and suggestions on earlier drafts of this paper. Any remaining errors are solely our responsibility.

REFERENCES

Albahouth, A. A. (2025). Inflation rate determinants in Saudi Arabia: A non-linear ARDL approach. *Sustainability (Switzerland)*, *17*(3). https://doi.org/10.3390/su17031036

Amarhyouz, A., & Azegagh, J. (2025). Financial performance of Moroccan listed companies: A multidimensional analysis of internal, macroeconomic, and institutional determinants using dynamic panel data. *Qubahan Academic Journal*, *5*(2), 402–419. https://doi.org/10.48161/qaj.v5n2a1528

Che Ahmat, Nur Hidayah, Kim, J., & Arendt, S. W. (2023). Examining the Impact of Minimum Wage Policy on Hospitality Financial Performance Using Event Study Method. *International Journal of Hospitality and Tourism Administration*, *24*(1). https://doi.org/10.1080/15256480.2021.1938785

Chisanga, B., Phiri, J., Osabuohien, E., & Johnson, L. (2025b). Macroeconomic factors and natural resource management in Africa: Evidence from copper value addition in Zambia. *Discover Sustainability*, *6*(1). https://doi.org/10.1007/s43621-024-00531-9

Dyussembekova, Z., Aidarova, A. B., Balapanova, E., Kuatova, D., Seitkhamzina, G. Zh., & Bolganbayev, A. (2023). The effect of freight and passenger transportation and energy production on economic growth in the framework of macro-economic indicators: The case of Kazakhstan. *International Journal of Energy Economics and Policy*, *13*(6), 74–80. https://doi.org/10.32479/ijeep.14808

Jin, K., Wang, Z., & Feng, J. (2024). *The impact of the Belt and Road policy on economic development – taking Australia and Pakistan as examples*. 105–109. https://doi.org/10.1145/3705618.3705635

Kim, Y., & Kim, K. (2021). An analysis of macro aspects caused by protectionism in Korea. *Journal of Korea Trade*, *25*(1), 1–17. https://doi.org/10.35611/jkt.2021.25.1.1

Köse, N., Ünal, E., & Süt, A. T. (2025). The Effects of Oil Price Shocks: A Dynamic SVAR Analysis of the Terms of Trade, Industrial Production, and Inflation. *Open Economies Review*. https://doi.org/10.1007/s11079-025-09834-4

Ky, S., Flores, E., & Lim, S. (2024). Predicting price level dynamics in Cambodia: A scenario analysis. *Journal of Ecohumanism*, *3*(4), 1059–1074. https://doi.org/10.62754/joe.v3i4.3342

Lefatsa, P. M., Msomi, S., Muguto, H. T., Muguto, L., & Muzindutsi, P.-F. (2025). An empirical analysis of the impact of global risk sentiment, gold prices, and interest rate differentials on exchange rate dynamics in South Africa. *International Journal of Financial Studies*, *13*(3). https://doi.org/10.3390/ijfs13030120

Liu, G., & Lv, L. (2022). Government regulation on corporate compensation and innovation: Evidence from China's minimum wage policy. *Finance Research Letters*, *50*. https://doi.org/10.1016/j.frl.2022.103272

Li, Y., Wu, X., Ye, D., Zuo, J., & Liu, L. (2024). Research progress on the relationship between fine motor skills and academic ability in children: a systematic review and meta-analysis. In *Frontiers in Sports and Active Living* (Vol. 6). Frontiers Media SA. https://doi.org/10.3389/fspor.2024.1386967

Makore, I., & Chikutuma, C. N. (2025). Exchange rate volatility and its impact on international trade: Evidence from Zimbabwe. *Journal of Risk and Financial Management*, *18*(7). https://doi.org/10.3390/jrfm18070376

Matar, A., & Aldeeb, H. M. A. (2024). *Unlocking Dubai's investment code: The macroeconomic keys to portfolio success*. 30–34. https://doi.org/10.1109/ICETSIS61505.2024.10459519

Molocwa, G. A., & Choga, I. (2025). The threshold effect of exchange rate on economic growth in Brazil, Russia, India, China and South Africa (BRICS) countries. *Economics – Innovative and Economics Research Journal*, *13*(3), 83–103. https://doi.org/10.2478/eoik-2025-0057

Nikpey Pesyan, V., Mohammadzadeh, Y., Rezazadeh, A., & Ansari Samani, H. (2024). Spatial analysis of dependency culture resulting from exchange rate fluctuations on herding behavior in Iran's housing market. *International Journal of Housing Markets and Analysis*. https://doi.org/10.1108/IJHMA-09-2024-0137

Park, D., Hahn, J., & Eom, Y. H. (2025). The risk–return trade-off of real estate as an asset class in Korea: Evidence from the last half century. *Asian Review of Financial Research*, *38*(1), 37–87. https://doi.org/10.37197/ARFR.2025.38.1.2

Şeker, K. (2025). The asymmetric response of Borsa Istanbul (BIST 100) to inflation, interest rate, and exchange rate shocks: An analysis using the NARDL model. *SN Business and Economics*, *5*(8). https://doi.org/10.1007/s43546-025-00880-1

Singh, S. P., & Ragi, T. S. (2024). The influence of currency fluctuations on NSE market capitalization: An econometric analysis. *Purushartha*, *17*(2), 43–51. https://doi.org/10.21844/16202117203

Suriani, S., Correia, A. B., Nasir, M., Rita, J. X., Saputra, J., & Mata, M. N. (2024). Exploring the nexus between sectoral stock market fluctuations and macroeconomics changes before and during the COVID-19 pandemic. *Cogent Business and Management*, *11*(1). https://doi.org/10.1080/23311975.2024.2336681

Syed, A. A., & Tripathi, R. (2020). Macroeconomic vulnerabilities and their effect on nonperforming loans in Indian commercial banks. *Indian Journal of Finance*, *14*(2), 34–49. https://doi.org/10.17010/ijf/2020/v14i2/150555

The role of inflation rate effect as a mediating variable between the foreign exchange rate and market performance. (2025). *International Journal of Accounting and Economics Studies*, *12*(3), 336–346. https://doi.org/10.14419/sgq5rc89

Trabelsi, R. (2024). Sources of macroeconomic fluctuations in Tunisia: A structural VAR approach. *SN Business and Economics*, *4*(10). https://doi.org/10.1007/s43546-024-00717-3

Vietha Devia Sagita, S., & Fadli, F. (2024). Mundell-Fleming theory: Gasoline subsidy revocation, inflation connection. *International Journal of Energy, Environment and Economics*, *32*(1), 21–39.

Yeoh, K. Y., Tham, K.-W., Cheng, C. T., Chai, W.-C., & Chong, K. W. (2025). Exploring the relationship between macroeconomic conditions and distressed real estate loans during the COVID-19 pandemic in Malaysia and Singapore. *International Journal of Housing Markets and Analysis*. https://doi.org/10.1108/IJHMA-04-2025-0100