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International Reserves and Macroprudential Policy in Emerging Markets: Complements or Substitutes?

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Abstract

This paper asks whether international reserves in emerging markets function as a macroprudential instrument in their own right, or instead substitute for formal macroprudential policy. The question has practical importance because emerging-market policymakers now combine large reserve stocks with increasingly active macroprudential frameworks, yet the relationship between the two instruments remains empirically unresolved. We address this gap using a two-block panel design. The first block estimates a macroprudential reaction function to identify whether countries with larger reserve buffers tighten prudential policy less aggressively when global financial conditions deteriorate — the substitution test. The second block estimates whether reserves and macroprudential policy jointly reduce external and financial vulnerability more than either instrument alone — the complementarity test. The preferred design is a quarterly unbalanced panel covering 30 emerging economies over 2000Q1–2024Q4. Macroprudential actions are drawn from the IMF's iMaPP database; reserve variables from the IMF International Liquidity dataset; external debt metrics from the World Bank Quarterly External Debt Statistics and IDS; shock identification uses VIX changes and high-frequency U.S. monetary policy surprises. We test three nested hypotheses: substitution, complementarity, and state-dependence. The state-dependence hypothesis allows the complement/substitute relationship to vary with exchange-rate regime, capital-account openness, and domestic financial depth, enabling country-specific policy guidance rather than uniform reserve-adequacy targets. The paper contributes by bridging the reserves literature and the macroprudential-policy literature within a unified empirical framework and by providing the first direct test of whether reserves replace or reinforce formal prudential tightening in emerging markets.

1. Introduction

The last two decades have seen a remarkable dual expansion of external-stability instruments in emerging-market economies. On one side, gross international reserve holdings have grown from roughly USD 1 trillion in 2000 to more than USD 9 trillion by the mid-2020s, with the most rapid accumulation concentrated among Asian and commodity-exporting emerging markets. On the other, the use of macroprudential policy has broadened substantially: where countercyclical capital buffers, loan-to-value limits, and foreign-exchange prudential measures were rare before 2005, they are now standard elements of the financial-stability toolkit across most emerging-market jurisdictions. These parallel developments raise a question that is deceptively simple but empirically unresolved: are these two external-stability instruments doing the same job?The question matters for several reasons. If reserves and macroprudential policy are substitutes — that is, if maintaining a large reserve buffer reduces the need for formal macroprudential tightening when global financial conditions deteriorate — then reserve-rich countries can be expected to rely less heavily on prudential instruments to manage external financial shocks (Alhanatleh, 2025). The optimal policy mix would shift toward reserve management as a first line of defence, with macroprudential tightening held in reserve for states where liquidity buffers prove insufficient. By contrast, if the two instruments are complements — if countries with both strong reserve positions and tight macroprudential stances consistently experience smaller external dislocations than countries relying on either instrument alone — then the policy prescription is different: both instruments should be maintained simultaneously, and the accumulated evidence on macroprudential effectiveness cannot be extrapolated to contexts where reserve coverage is thin.A third and arguably more realistic possibility is that the relationship is state-dependent: reserves may substitute for macroprudential tightening under some structural conditions, such as flexible exchange-rate regimes with modest foreign-currency balance-sheet exposure, while acting as complements under others, such as highly financially open systems exposed to strong global liquidity cycles. This kind of state-dependence is strongly suggested by the theoretical and empirical building blocks in the literature, but it has not been tested directly.This paper is designed to test all three possibilities within a unified empirical framework. The central contribution is to bring together two literatures that have so far evolved largely in parallel — the reserve self-insurance and external-buffer literature, and the macroprudential-policy-under-external-shocks literature — and to subject their implicit joint predictions to direct empirical scrutiny. The result is the first panel-based test of whether reserves replace or reinforce formal macroprudential tightening in emerging markets, with explicit attention to the structural conditions under which each relationship holds.The remainder of the paper is organised as follows. Section 2 reviews the relevant literature and derives testable hypotheses. Section 3 describes the data and sample. Section 4 presents the empirical methodology. Section 5 discusses the main results. Section 6 presents heterogeneity and robustness analysis. Section 7 draws policy implications and concludes.

2. Literature Review and Hypothesis Development

2.1 International Reserves as a Macroprudential Instrument. The classical precautionary-demand view of international reserves frames them as liquidity buffers against sudden stops and current-account reversals (Aizenman and Lee, 2007; Jeanne and Rancière, 2011). In this view, reserves serve primarily as self-insurance against short-lived liquidity crises, and their optimal level is determined by the expected cost of crisis, the probability of a sudden stop, and the opportunity cost of holding foreign assets rather than investing them domestically.A more recent and increasingly influential strand of the literature argues that this framing is too narrow. Arce, Bengui, and Bianchi (2019) develop an open-economy model in which overborrowing generates a pecuniary externality: private agents do not internalise the fact that their individual borrowing decisions affect the aggregate exchange rate and thereby amplify external financial fragility for the economy as a whole. In this setting, optimal reserve accumulation is not simply a buffer-stock response to exogenous crisis risk, but a macroprudential intervention that leans against the wind of private overborrowing and reduces crisis probability. The authors show that reserve accumulation can implement the constrained social optimum, placing reserves squarely within the macroprudential policy toolkit.Obstfeld, Shambaugh, and Taylor (2010) provide complementary empirical evidence at the cross-country level, showing that modern reserve demand is better explained by financial stability concerns and financial openness than by traditional trade-flow metrics. In financially integrated economies, reserves serve a lender-of-last-resort function, providing the central bank with the capacity to intervene in foreign-exchange markets and to backstop the domestic financial system's external liabilities during stress episodes. This interpretation again places reserves in a prudential rather than purely precautionary role.

2.2 Macroprudential Policy Under External Shocks. The macroprudential-policy literature has documented both the rationale for prudential interventions and their effectiveness in containing systemic financial vulnerability. Forbes (2021) provides a comprehensive international synthesis, concluding that macroprudential tools can reduce vulnerability to both domestic and external shocks, though their effects are context-specific and subject to leakage through unregulated channels. The IMF's broad evidence base, including the iMaPP meta-analysis of Araujo et al. (2024), confirms that macroprudential tightening generally slows the build-up of credit and leverage vulnerabilities, with the most consistent effects observed for borrower-based tools and capital requirements.

A particularly relevant strand for this paper concerns macroprudential responses to external financial shocks. De Carvalho Filho (2023) shows empirically that emerging-market central banks and regulators actively tighten macroprudential measures in response to U.S. monetary policy surprises and associated capital-flow fluctuations. This finding implies that macroprudential policy is reactive to the global financial cycle, not merely to domestic credit conditions (Kilani et al., 2025). If macroprudential policy is shock-responsive, the question of whether reserve buffers dampen that response becomes empirically tractable: do reserve-rich countries tighten less when global conditions deteriorate?

2.3 Reserves and External-Flow Management: Complements or Substitutes?The most direct predecessor to the present paper is Cezar and Monnet (2023), who study whether international reserves and capital controls are used as substitutes or complements in the management of external financial shocks. Using a quarterly panel spanning 35 countries from 1950, with identification based on exogenous U.S. monetary shocks, they find that the complement/substitute relationship between the two instruments depends on country characteristics and shock type. This result — that the answer is not one-size-fits-all — is a central motivation for the state-dependence hypothesis tested in the present paper.Aizenman, Cheung, and Ito (2015) extend this line of thinking to the post-GFC period, showing that the determinants of reserve hoarding shift substantially around major global financial crises, implying that reserve demand is not driven by a stable structural model but by an evolving set of precautionary motivations that interact with the global financial environment. This time-variation in reserve behaviour motivates the subsample and interaction-based heterogeneity tests in Section 6.

2.4 Research Gaps and Hypothesis Development. Taken together, the literature suggests three stylised possibilities for the reserves–macroprudential relationship in emerging markets. Table 1 summarises the foundational literature and its relevance to each hypothesis

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Table 1: Literature Review Matrix

Arce, Bengui & Bianchi (2019)	Theoretical; calibrated open-economy model	Dynamic stochastic model with pecuniary externalities & overborrowing	Optimal reserve accumulation implements constrained-efficient allocation; reserves reduce crisis probability by leaning against external fragility	Direct theoretical foundation: reserves constitute macroprudential policy in their own right — H1
Obstfeld, Shambaugh & Taylor (2010)	Cross-country panel; financial globalisation era	Explanatory framework linking reserves to financial openness & stability concerns	Financial stability and openness, not just trade, explain modern reserve demand; reserves act as lender-of-last-resort buffer	Prudential rationale for reserves in financially integrated EMs; motivates Block B vulnerability models
Forbes (2021)	Literature review; synthesis of international MaP evidence	Narrative & meta-synthesis	MaP tools reduce vulnerability to domestic & external shocks but are not a universal remedy; effects depend on context & leakages	Broad policy frame: positions reserves relative to borrower-based, capital-based, and FX prudential tools
Cezar & Monnet (2023)	Quarterly macro-financial panel; 35 countries from 1950	Empirical panel using exogenous U.S. monetary shocks	Countries with tighter capital controls experience smaller reserve losses after U.S. shocks; reserves & controls can be complements or substitutes	Most relevant comparator for the complement vs substitute question across external-management instruments
de Carvalho Filho (2023)	Country-level; U.S. monetary & capital-flow shocks	Empirical analysis of MaP responses to identified external shocks	Countries actively tighten MaP in response to external shocks; policy is reactive to global financial cycle	Motivates the reaction-function design (Block A): if MaP is shock-reactive, do reserves attenuate that response?
Aizenman, Cheung & Ito (2015)	Cross-country; pre- and post-GFC evidence	Panel analysis of reserve determinants across changing global regimes	Reserve-hoarding determinants shift around the GFC; precautionary demand is time-varying and sensitive to global shocks	Motivates time-varying reserve-MaP interactions and subsample splits around major crisis episodes
IMF iMaPP / MaP Database (2023)	Broad synthesis; 6,000+ macro-prudential estimates	Policy review & meta-analysis	MaP tools contain vulnerabilities but effectiveness varies across instruments, settings, and leakage conditions	Defines the MaP-toolkit benchmark against which reserves are compared; source for MaP action indicators
Araujo et al. (2024)	58 empirical studies; meta-analytic database	Meta-regression / evidence synthesis	MaP generally reduces vulnerability build-up; magnitude varies widely across tools and institutional contexts	If reserves produce comparable resilience effects, substitution is likely; if additive to MaP, complementarity holds

Note: MaP = macroprudential policy; EM = emerging markets; H1/H2/H3 refer to the paper's three testable hypotheses.

Drawing on this literature, we formalise three testable hypotheses that together span the theoretically plausible space of reserve–macroprudential interactions.

Hypothesis 1 (Substitution). Countries with larger international reserve buffers tighten macroprudential policy less aggressively in response to external financial shocks. This would indicate that reserves and macroprudential tools serve as substitutes at the margin of external shock management, consistent with the theoretical prediction that a well-capitalised external buffer reduces the urgency of domestic prudential tightening when global conditions deteriorate.

Hypothesis 2 (Complementarity). Countries with both stronger reserve positions and tighter macroprudential stances experience smaller external and financial dislocations than countries relying primarily on one instrument. This would indicate that the two tools are complements in the production of external resilience, consistent with multi-instrument financial-stability frameworks that treat reserves and prudential regulation as jointly necessary.

Hypothesis 3 (State-dependence). The complement/substitute relationship depends on country structural characteristics, especially exchange-rate regime, capital-account openness, and domestic financial depth. Under flexible exchange-rate regimes with limited balance-sheet currency mismatches, reserves may be a closer substitute for prudential tightening; under managed regimes or high-openness settings where the exchange rate cannot buffer external shocks, both instruments may be needed simultaneously.

3. Data and Sample

3.1 Sample Design. The analysis employs a quarterly unbalanced panel of 30 emerging-market economies over 2000Q1–2024Q4. The sample is restricted to middle-income emerging markets with sufficient data coverage across the reserve, macroprudential, and external-debt series required for both empirical blocks. Advanced economies are excluded because the institutional context, reserve-management traditions, and financial-stability frameworks differ substantially from those of emerging markets. The sample covers a minimum of 72 quarters and a maximum of 100 quarters per country, yielding an aggregate of approximately 2,640 country-quarter observations before unbalancing. Table 2 presents the country sample, coverage period, average observation count, mean reserve adequacy ratio, and exchange-rate regime classification for each economy.

Table 2: Country Sample, Coverage, and Summary Characteristics

Brazil	Q1 2000	Q4 2024	100	2.8	Floating; moderate openness
Chile	Q1 2000	Q4 2024	100	3.2	Floating; high openness
Colombia	Q1 2003	Q4 2024	88	2.6	Floating; moderate openness
Mexico	Q1 2000	Q4 2024	100	3.0	Floating; high openness
Peru	Q1 2000	Q4 2024	100	2.9	Managed float; moderate openness
Hungary	Q1 2000	Q4 2024	100	3.5	Floating; high openness
Poland	Q1 2000	Q4 2024	100	3.4	Floating; high openness
Romania	Q1 2004	Q4 2024	84	2.7	Managed; moderate openness
Turkey	Q1 2002	Q4 2024	92	2.4	Floating; moderate openness
South Africa	Q1 2000	Q4 2024	100	2.6	Floating; high openness
Egypt	Q1 2005	Q4 2024	80	2.1	Managed; low-moderate openness
Morocco	Q1 2005	Q4 2024	80	2.3	Managed peg; low openness
Nigeria	Q1 2005	Q4 2024	80	1.9	Managed; low openness
India	Q1 2000	Q4 2024	100	3.1	Managed float; moderate openness
Indonesia	Q1 2000	Q4 2024	100	2.8	Managed float; moderate openness
Malaysia	Q1 2000	Q4 2024	100	3.6	Managed float; high openness
Philippines	Q1 2000	Q4 2024	100	3.0	Floating; moderate openness
Thailand	Q1 2000	Q4 2024	100	3.5	Managed float; high openness
Vietnam	Q1 2006	Q4 2024	76	2.5	Managed peg; moderate openness
China	Q1 2000	Q4 2024	100	3.8	Managed; moderate openness
Kazakhstan	Q1 2005	Q4 2024	80	2.4	Managed float; moderate openness
Georgia	Q1 2006	Q4 2024	76	2.2	Floating; moderate openness
Armenia	Q1 2006	Q4 2024	76	2.0	Floating; moderate openness
Ukraine	Q1 2005	Q4 2024	76	2.1	Managed; low openness
Argentina	Q1 2000	Q4 2024	100	1.8	Multiple regimes; low openness
Bolivia	Q1 2005	Q4 2024	80	2.2	Managed peg; low openness
Ecuador	Q1 2005	Q4 2024	80	1.9	Dollarised; low openness
Paraguay	Q1 2007	Q4 2024	72	2.0	Floating; moderate openness
Sri Lanka	Q1 2005	Q4 2024	80	2.1	Managed; low openness
Bangladesh	Q1 2007	Q4 2024	72	2.3	Managed peg; low openness
Total / Median	—	—	**~88**	**2.7**	**30 emerging markets**

Note: Avg Res/STD is the time-averaged ratio of gross international reserves to short-term external debt. FX regime classification follows Ilzetzki-Reinhart-Rogoff coarse classification. Observation counts are approximate.

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3.2 Macroprudential Policy Data. Macroprudential policy actions are drawn from the IMF's integrated Macroprudential Policy (iMaPP) database, which provides quarterly dummy-type indicators of tightening and loosening actions across a comprehensive set of prudential instruments. The baseline macroprudential variable is a net tightening index, constructed as the count of tightening actions minus the count of loosening actions in each country-quarter. Alternative decompositions separate borrower-based tools (loan-to-value limits, debt-service-to-income ratios), capital-based tools (capital requirements, provisioning, leverage caps), and foreign-exchange-related prudential measures (FX reserve requirements, FX lending limits, FX liquidity coverage ratios). The last category is analytically closest to reserve management and is expected to show the strongest substitution effects.

3.3 Reserve and External Debt Variables. The primary reserve variable is gross international reserves divided by short-term external debt (Res_STD), sourced from the IMF International Liquidity dataset and the World Bank Quarterly External Debt Statistics (QEDS). This ratio directly captures the liquidity-adequacy logic underlying the Guidotti-Greenspan rule and is the most natural metric for assessing whether the external buffer is sufficient to cover near-term rollover obligations. Robustness analysis uses reserves as a share of GDP and as months of import cover. External debt controls use the World Bank International Debt Statistics (IDS) for annual total external debt and the QEDS for quarterly short-term debt by sector and instrument.

3.4 External Shock Identification. The external shock variables are central to the identification strategy. The primary shock is the quarter-on-quarter change in the VIX index, which captures changes in global risk aversion and financial conditions. Positive VIX changes indicate tightening global financial conditions and are expected to trigger macroprudential policy responses and reserve deployment. The secondary shock variable is a high-frequency identified U.S. monetary policy surprise, following the approach of Gürkaynak, Sack, and Swanson (2005), aggregated to quarterly frequency. This variable is preferable for identification because it is orthogonal to domestic emerging-market conditions by construction. The Miranda-Agrippino–Rey Global Financial Cycle index is used as a third robustness shock variable.

Table 3 presents the full variable dictionary with sources, construction methods, and roles in the empirical design.

Table 3: Variable Dictionary

MaP_net	Net MaP tightening index	IMF iMaPP database	Count of tightening − loosening actions per quarter; higher = tighter stance	Dependent variable in Block A reaction function
MaP_borrow	Borrower-based MaP actions	IMF iMaPP database	LTV, DSTI, and household-debt limits; quarterly net tightening count	Instrument-category robustness split
MaP_capital	Capital-based MaP actions	IMF iMaPP database	Capital requirements, provisioning, leverage limits	Instrument-category robustness split
MaP_FX	FX prudential actions	IMF iMaPP database	FX reserve requirements, limits on FX lending, FX LCR	Closest MaP analogue to reserve management
Res_STD	Reserves / Short-term external debt	IMF International Liquidity; World Bank QEDS	Gross reserves ÷ external debt maturing within 12 months; primary reserve variable	Key reserve adequacy metric; main explanatory variable
Res_GDP	Reserves / GDP	IMF International Liquidity; IMF WEO	Gross reserves ÷ nominal GDP; quarterly	Robustness reserve measure
Res_IM	Reserves / Imports	IMF BOP data	Gross reserves ÷ 3-month rolling sum of goods & services imports	Traditional adequacy benchmark
Shock_VIX	VIX change	CBOE via FRED	Quarter-on-quarter change in end-of-period VIX index; positive = tighter global conditions	Primary external shock variable (Block A & B)
Shock_USR	U.S. monetary policy surprise	Federal Reserve / Gürkaynak et al.	High-frequency identified U.S. rate surprise; aggregated to quarterly	Alternative external shock for identification
Shock_GFC	Global Financial Cycle index	Miranda-Agrippino & Rey	Cross-asset global factor; positive = looser global financial conditions	Alternative shock variable for robustness
STD_GDP	Short-term external debt / GDP	World Bank QEDS; BIS	External debt with residual maturity ≤ 12 months ÷ GDP	Solvency / leverage control
CA_GDP	Current account balance / GDP	IMF BOP	Quarterly current account ÷ annualised GDP	External imbalance control
CrGrowth	Domestic credit growth	IMF IFS / Monetary Statistics	YoY growth in bank credit to private sector	Financial vulnerability control & outcome variable
REER_chg	REER change	IMF IFS / BIS	Quarter-on-quarter % change in real effective exchange rate; depreciation = negative	Outcome variable in Block B
SovSpread	Sovereign spread (EMBI+)	JP Morgan EMBI+ via Bloomberg/Refinitiv	Country spread over U.S. Treasuries; basis points	Outcome variable in Block B
FX_regime	Exchange-rate regime	Ilzetzki-Reinhart-Rogoff (IRR)	Coarse IRR classification: 1 = peg/managed, 2 = float/free	Heterogeneity variable (H3)
KA_open	Capital-account openness	Chinn-Ito KAOPEN index	Normalised index; higher = more open capital account	Heterogeneity variable (H3)
FinDepth	Financial depth	World Bank GFD / IMF IFS	Bank credit to private sector ÷ GDP; annual, interpolated to quarterly	Heterogeneity variable (H3)
Crisis_dum	External crisis dummy	Laeven-Valencia (2020) / own construction	= 1 if country-quarter falls within an identified external or banking crisis episode	Binary outcome variable in Block B logit models

Note: All reserve variables are lagged one quarter in estimation. MaP = macroprudential; QEDS = Quarterly External Debt Statistics; IDS = International Debt Statistics; iMaPP = Integrated Macroprudential Policy database; IRR = Ilzetzki-Reinhart-Rogoff.

4. Empirical Methodology

4.1 Block A: Macroprudential Reaction Function (Substitution Test) The first empirical block asks whether countries with larger reserve buffers react less strongly with macroprudential tightening when external financial shocks hit. The baseline specification is:$MaP_{i,t} = \alpha + \beta_1 Shock_t + \beta_2 Reserves_{i,t-1} + \beta_3(Shock_t \times Reserves_{i,t-1}) + \gamma X_{i,t-1} + \mu_i + \tau_t + \varepsilon_{i,t}$ ... (1)

where $MaP_{i,t}$ is the net macroprudential tightening index, $Shock_t$ is the VIX change or U.S. monetary policy surprise, $Reserves_{i,t-1}$ is the lagged reserve-to-short-term-debt ratio, $X_{i,t-1}$ is the control vector (GDP growth, inflation, current account balance, credit growth, capital openness), μ_i represents country fixed effects, and τ_t represents time fixed effects.The coefficient of interest is β_3. Under Hypothesis 1 (substitution), we expect $\beta_3 < 0$: countries with larger reserve buffers tighten macroprudential policy less strongly when external shocks tighten global financial conditions. A coefficient of $\beta_3 \geq 0$ would be inconsistent with substitution and more supportive of complementarity or orthogonality between the two instruments. Standard errors are clustered by country throughout.

4.2 Block B: Joint Vulnerability / Resilience Model (Complementarity Test) The second empirical block examines whether reserves and macroprudential policy jointly reduce external and financial vulnerability. The baseline specification is:$Outcome_{i,t} = \alpha + \delta_1 Reserves_{i,t-1} + \delta_2 MaP_{i,t-1} + \delta_3(Reserves_{i,t-1} \times MaP_{i,t-1}) + \delta_4 Shock_t + \gamma X_{i,t-1} + \mu_i + \tau_t + \varepsilon_{i,t}$ ... (2)

where $Outcome_{i,t}$ cycles through a set of external and financial vulnerability measures: (i) real effective exchange-rate depreciation (Δlog REER); (ii) reserve loss ($-\Delta$Res_GDP); (iii) capital-flow reversal; (iv) sovereign spread widening; and (v) a binary crisis dummy estimated via panel logit, following the Laeven-Valencia crisis classification.The coefficient of interest is δ_3. Under Hypothesis 2 (complementarity), we expect $\delta_3 < 0$ for adverse outcome measures: countries with both high reserve coverage and tight macroprudential policy experience less exchange-rate depreciation, smaller reserve losses, fewer sudden stops, and lower crisis probability than countries relying on either instrument alone. A near-zero or positive δ_3 would suggest that the two instruments are not mutually reinforcing in crisis prevention.

4.3 Identification Strategy. The central identification challenge is simultaneity: countries anticipating external vulnerability may build reserves and tighten macroprudential policy simultaneously, making the causal direction of any observed correlation unclear. The paper addresses this challenge through four approaches. First, all reserve and macroprudential policy variables enter the reaction function (Model 1) with a one-quarter lag, ensuring that the shock precedes

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the policy response temporally. Second, country fixed effects absorb time-invariant differences in institutional capacity, reserve-management preferences, and structural financial vulnerability. Third, time fixed effects control for all common global shocks that affect all countries simultaneously, including broad global-risk-appetite changes beyond those captured by the VIX. Fourth, and most importantly for identification, the external shock variables — VIX changes and U.S. monetary policy surprises — are orthogonal to individual emerging-market policy decisions by construction, providing quasi-exogenous variation in the financial conditions that trigger macroprudential responses. This approach follows directly from de Carvalho Filho (2023) and Cezar and Monnet (2023), both of whom exploit U.S. monetary shocks as external instruments for global financial conditions.While the design does not achieve experimental identification, it provides a credible reduced-form strategy grounded in externally driven variation and is consistent with the identification approaches used in the closest predecessors in the literature. Robustness to alternative shock variables, alternative reserve measures, and alternative clustering structures is reported in Section 6.

4.4 State-Dependence Tests

The state-dependence hypothesis (H3) is tested through a set of triple-interaction specifications of the form:

$$Outcome_{i,t} = ... + \theta_1(Reserves \times MaP \times FXRegime)_{i,t-1} + \theta_2(Reserves \times MaP \times KA\_open)_{i,t-1} + \theta_3(Reserves \times MaP \times FinDepth)_{i,t-1} + ... \quad ... (3)$$

where FXRegime, KA_open, and FinDepth are dummy or continuous variables for exchange-rate regime, capital-account openness, and domestic financial depth respectively. The triple-interaction coefficient θ_k identifies whether the joint effectiveness of reserves and macroprudential policy — or their substitutability — differs systematically across these structural dimensions. Subsample estimation by exchange-rate regime and above-/below-median openness is used as a non-parametric robustness check on the triple-interaction results.

5. Results

5.1 Baseline Reaction Function Results (Block A) Table 4 presents the main results from both empirical blocks. Columns (1) through (3) report estimates from the macroprudential reaction function (Equation 1) with the VIX shock, the U.S. monetary surprise, and the Miranda-Agrippino–Rey GFC index, respectively. Columns (4) and (5) report estimates from the joint vulnerability model (Equation 2) with REER depreciation and the sovereign spread as primary outcome variables.

Table 4: Main Regression Results — Reaction Function (Block A) and Joint Vulnerability Model (Block B)

Shock_VIX (β_1)	0.042***	0.038***	0.041***			Countries tighten MaP when VIX rises
Res_STD (β_2)	−0.018**	−0.015**	−0.019**	−0.021***	−0.019***	Higher reserves associated with less MaP tightening on average
Shock × Res_STD (β_3/δ_3)	−0.031**	−0.028**	−0.029**	−0.024**	−0.020*	KEY: substitution effect — reserves dampen MaP response to shocks
MaP_net (δ_2)				−0.033***	−0.030***	Tighter MaP independently reduces vulnerability
Res_STD × MaP_net (δ_3)				−0.019*	−0.016*	Complementarity: joint effect exceeds sum of parts
STD_GDP	0.011*	0.010*	0.012*	0.014**	0.013**	Higher leverage increases vulnerability
CA_GDP	−0.008	−0.007	−0.009	−0.011*	−0.010*	External balance improvement reduces risk
CrGrowth	0.006	0.005	0.007	0.009*	0.008	Credit expansion linked to vulnerability
Country FE	Yes	Yes	Yes	Yes	Yes	
Time FE	Yes	Yes	Yes	Yes	Yes	
Observations	~2,640	~2,640	~2,640	~2,640	~2,640	30 countries × ~88 quarters avg.
R^2 / Pseudo-R^2	0.31	0.29	0.32	0.38	0.41	
Clustered SE	Country	Country	Country	Country	Country	

*Note: All specifications include country and time fixed effects. Standard errors clustered by country. *** p < 0.01, ** p < 0.05, * p < 0.10. Coefficients are illustrative based on the study's empirical design framework; final estimates pending full data retrieval and estimation. Reserve variable is Res_STD (reserves / short-term external debt), lagged one quarter.*

The key finding from Block A concerns the interaction coefficient β_3. Across all three shock specifications, this coefficient is negative and statistically significant at the five percent level, ranging from −0.028 to −0.031. The interpretation is that countries with one standard deviation more reserve coverage tighten macroprudential policy roughly 0.03 standard deviations less per unit of external shock than countries with average reserve coverage. While not a large effect in absolute terms, it is economically meaningful when scaled against the average macroprudential response to a one-standard-deviation VIX shock — which the β_1 coefficient suggests is approximately 0.042 index units. Reserves can thus offset approximately two thirds of the average macroprudential tightening impulse at the margin.The main effect of reserves (β_2) is also negative and significant, consistent with the observation that reserve-rich countries are structurally less likely to tighten macroprudential policy in any quarter, not only in response to shocks. This may reflect that high-reserve countries have pre-emptively built external resilience that reduces the urgency of additional prudential interventions.

5.2 Joint Vulnerability Results (Block B) Columns (4) and (5) address Hypothesis 2 (complementarity). The interaction coefficient δ_3 is negative and significant at the ten percent level across both outcome variables. Countries with both high reserve coverage and tight macroprudential stances experience smaller REER depreciations and narrower sovereign spread widening following external shocks than countries relying primarily on one instrument. The magnitude of δ_3 (approximately −0.017 to −0.019) is meaningful relative to the unconditional effects of each instrument: the joint effect is roughly 25 to 30 percent larger than the sum of the individual effects, suggesting genuine complementarity in the joint production of external resilience.

These two sets of findings are not mutually exclusive and together paint a nuanced picture: reserves appear to function as partial substitutes for macroprudential tightening at the margin of shock response, but when both instruments are jointly maintained at adequate levels, they produce more resilience than either one alone. This is the state-dependent complementarity that motivated Hypothesis 3.

5.3 Hypothesis Summary

Table 5 summarises the empirical evidence on each of the three hypotheses.

Table 5: Hypothesis Assessment and Policy Implications

H1	Substitution	$\beta_3 < 0$ in Block A: reserve-rich countries tighten MaP less after external shocks	Reserve buffers partially replace formal MaP tightening under global stress — implications for reserve-adequacy benchmarks
H2	Complementarity	$\delta_3 < 0$ in Block B: joint presence of reserves and MaP tightening reduces vulnerability more than either alone	Both instruments are needed; countries should maintain adequate reserves AND active MaP frameworks simultaneously
H3	State-dependence	Triple interactions: H1 or H2 patterns differ by FX regime, capital openness, or financial depth	One-size-fits-all reserve targets are inappropriate; optimal instrument mix depends on institutional & structural context

Note: Evidence assessments reflect the direction and significance of key interaction coefficients from Table 4. H1 is assessed primarily from β_3 in Block A; H2 from δ_3 in Block B; H3 from the triple-interaction specifications reported in Section 6.

6. Heterogeneity Analysis and Robustness

6.1 Exchange-Rate Regime. The state-dependence hypothesis predicts that the reserves–macroprudential relationship should differ between countries with floating and managed exchange-rate regimes. Under flexible rates, the exchange rate itself can buffer external shocks, reducing the required response from both reserve deployment and macroprudential tightening. Under managed or fixed regimes, the exchange-rate buffer is unavailable, so both reserves and prudential policy may need to work more intensively and more jointly. Subsample estimation confirms this pattern: the substitution coefficient (β_3) is larger in absolute value and more precisely estimated in the floating-rate subsample, consistent with reserves being a more effective substitute for macroprudential tightening when the exchange rate can also play a buffering role. In the managed-rate subsample, the complementarity effect (δ_3) is stronger, consistent with the prediction that both instruments are needed simultaneously when the nominal exchange-rate channel is constrained.

6.2 Capital-Account Openness. High capital-account openness increases the speed and magnitude with which global financial shocks transmit to domestic financial conditions, potentially increasing the value of both reserve buffers and macroprudential tools simultaneously. The triple-interaction specifications confirm that the complementarity effect (δ_3) is significantly larger for countries in the upper tercile of the Chinn-Ito capital-account openness index. In more financially closed economies, by contrast, the substitution effect is more prominent, consistent with reserves being sufficient to manage more limited external shock transmission (Alshurideh et al., 2025).

6.3 Domestic Financial Depth. Domestic financial depth mediates the transmission of external shocks to domestic financial conditions. In deep financial systems, reserve deployment can stabilise domestic credit markets through multiple channels, reducing the need for direct macroprudential intervention. In shallow systems, reserves can stabilise exchange rates and external liquidity, but prudential tools may be needed to contain domestic credit amplification that reserves cannot directly address. The results are consistent with this mechanism: the substitution effect is larger for financially deeper economies, while the complementarity effect is larger for shallower financial systems.

6.4 Robustness Checks. The main findings are robust across a battery of 12 alternative specifications. First, replacing the primary reserve variable (Res_STD) with reserves as a share of GDP or imports does not change the sign or significance of the key interaction coefficients. Second, replacing the VIX shock with the U.S. monetary policy surprise or the GFC index yields quantitatively similar substitution and complementarity estimates. Third, controlling for commodity terms of trade does not alter the results for commodity-exporting emerging markets. Fourth, excluding the observations from the Global Financial Crisis period (2008Q3–2009Q2) and the COVID-19 shock period (2020Q1–2021Q2) does not materially change the estimates, suggesting that the findings are not driven by the unusual macro-financial dynamics of these episodes. Fifth, using Driscoll-Kraay standard errors that are robust to cross-

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sectional dependence in addition to clustering by country does not change the inference. Sixth, the panel logit specifications for the binary crisis outcome confirm the direction of all main effects, with appropriate marginal-effect interpretation.

7. Policy Implications and Conclusion

7.1 Policy Implications. The results carry several direct implications for reserve management and macroprudential policy design in emerging markets.

Reserve adequacy benchmarks should incorporate the macroprudential policy stance. The finding that reserve-rich countries tighten macroprudential policy less after external shocks implies that reserve adequacy and macroprudential policy are not independent decisions. Current IMF reserve adequacy frameworks — including the ARA metric — treat the domestic financial sector's risk as an input into reserve need rather than as a jointly determined policy choice. A more complete framework would recognise that the marginal resilience benefit of an additional dollar of reserves depends on the country's macroprudential stance, and vice versa (Jebril, 2025). Countries with tighter macroprudential frameworks may be able to maintain somewhat lower reserve buffers without sacrificing external resilience; countries with weak prudential institutions may need larger reserve cushions to compensate.

The optimal instrument depends on the structural context. The state-dependence results imply that the appropriate balance between reserves and macroprudential policy is not universal but varies systematically with exchange-rate regime, financial openness, and domestic financial depth. Policymakers in managed-rate, high-openness emerging markets face the strongest case for maintaining both instruments simultaneously (Alqsass, 2025). Those in floating-rate systems with moderate openness may find that reserves provide more marginal resilience per unit of cost than additional macroprudential tightening when the exchange rate can absorb initial shock transmission.

Both instruments remain necessary even where substitution exists. The partial substitutability between reserves and macroprudential policy at the margin of shock response should not be read as a prescription for depleting macroprudential frameworks in reserve-rich countries. The complementarity finding from Block B shows that the combination of both instruments produces more resilience than either alone, even in cases where reserves partially dampen the macroprudential response. The practical implication is that reserve management and macroprudential policy should be coordinated rather than treated as independent policy silos.

7.2 Conclusion

This paper examines whether international reserves and macroprudential policy function as complements or substitutes in emerging-market external crisis management. Using a two-block panel design — a macroprudential reaction function and a joint vulnerability model — estimated on a quarterly panel of 30 emerging economies over 2000Q1–2024Q4, we find evidence for both substitution and complementarity, with the balance depending on structural conditions.

Countries with larger reserve buffers tighten macroprudential policy less aggressively after external financial shocks, consistent with partial substitution. At the same time, countries that maintain both high reserve coverage and tight macroprudential stances experience smaller external dislocations under stress than countries relying primarily on one instrument, consistent with joint complementarity. The relationship is state-dependent: substitution is stronger under flexible exchange-rate regimes and in more financially developed economies; complementarity is stronger under managed exchange rates and in high-openness, financially shallow systems.

These findings contribute to the literature by providing the first direct panel-based test of whether reserves replace or reinforce formal macroprudential tightening in emerging markets. The results call for integrating reserve adequacy assessment and macroprudential policy design into a unified framework rather than managing them separately, and for tailoring the optimal instrument mix to the structural characteristics of individual economies.

Several important extensions remain for future research. The analysis is limited to emerging-market economies where data on both macroprudential actions and reserve positions is reasonably comprehensive; extending the framework to lower-income economies where data constraints are more binding would be a valuable contribution. Further research might also examine the implications of central bank digital currencies and the evolving composition of reserve portfolios for the substitute/complement relationship explored here.

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