Cyclicality of International Reserves, Exchange Rate Flexibility, and Output Volatility

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(*Preliminary, do not circulate!*)

Abstract: This paper examines the cyclicality of international reserves (IR) and estimates their macro-stabilizing effects. Whether acting as a traditional buffer stock or a modern macroprudential policy tool, IR play a crucial role in countering external forces and mitigating the volatility they induce. Accordingly, managing IR in a counter-cyclical manner, such as accumulating them in good times and decumulating in bad times, is advisable. However, our analysis of data from 177 countries reveals that such counter-cyclical IR practices are more often exceptions than rules. Moreover, we find that the volatility-mitigating effects of these reserves depend significantly on the exchange rate flexibility. Specifically, they exert significant offsetting effects on output volatility in countries with flexible exchange rate arrangements.

Keywords: *International reserves; cyclicality; exchange rate regime; macroprudential policy; output volatility.*

JEL Classifications: F34, F31

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1 Introduction

According to the International Monetary Fund (2009), international reserves (IR) are "external assets that are readily available to and controlled by monetary authorities for meeting balance of payments financing needs, for intervention in exchange markets to affect the currency exchange rate, and for other related purposes (such as maintaining confidence in the currency and the economy and serving as a basis for foreign borrowing)." While the specific purposes for which monetary authorities accumulate or decumulate IR may vary, they all aim to counter external forces that could otherwise generate macroeconomic volatility.

It is often argued that managing IR in a counter-cyclical manner, termed counter-cyclical international reserves (CCIR), is beneficial. Central banks can "lean against the wind" by accumulating IR during economic booms and decumulating them during downturns. This approach helps stabilize the real exchange rate volatility induced by trade shocks and facilitates smoother current account adjustments (Aizenman, Edwards, and Riera-Crichton, 2012; Aizenman and Riera-Crichton, 2008). Furthermore, CCIR can mitigate the effects of the "boom and bust" cycles in capital flows driven by global financial markets, acting as a substitute for counter-cyclical capital controls and promoting stable economic growth (Jeanne, 2016; Jeanne, Subramanian, and Williamson 2012; Ostry, Ghosh, Shamon, and Qureshi, 2011).

In this paper, we examine the behavior of IR across 177 countries in relation to their business cycles. Our sample includes both emerging markets and developing countries (EMDC) as well as advanced countries, spanning five decades from 1972 to 2021. Our objectives are twofold: first, to assess the prevalence of CCIR management among central banks worldwide, and second, to investigate the macroeconomic welfare implications of CCIR. Specifically, we aim to test whether CCIR significantly mitigate output volatility, as suggested in the literature.

To anticipate our findings, we observe that only 30% (53 countries) of the world's economies manage their IR in a counter-cyclical manner. Contrary to conventional views, approximately 13% (23 countries) exhibit pro-cyclical management of IR, while 60% (107 countries) show no significant association between IR and business cycles. Interestingly, this *a*-cyclical or "business cycle free" IR management has become predominant, particularly following the 2008 global

financial crisis. EMDC are more likely to adopt counter-cyclical IR policies compared to advanced countries.

CCIR alleviate exchange rate pressures by purchasing foreign currency assets during periods of economic prosperity (thus limiting local currency appreciation) and selling them during downturns (thereby preventing local currency depreciation). Despite the expectation that such official foreign exchange transactions would align with rigid exchange rate regimes, our findings suggest the contrary.

Our results indicate that CCIR management complements the buffering role of flexible exchange rates in coping with external shocks. While flexible exchange rate arrangements effectively absorb the impact of external shocks, they often lead to volatile exchange rate movements and their attendant consequences. By "leaning against the wind," CCIR help mitigate exchange rate volatility, thereby contributing to macroeconomic stability. Indeed, our analysis suggests that CCIR significantly mitigate output volatility specifically in countries with flexible exchange rate arrangements. The finding provides one explanation for the lack of a clear tradeoff between reduced exchange rate volatility and macroeconomic stability highlighted by Flood and Rose (1995).

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature. Section 3 outlines our data and defines the measure of IR cyclicality used in our analysis. In Section 4, we explore the cyclical behavior of IR across 177 countries worldwide and investigate the macroeconomic determinants of counter-cyclicality. Section 5 estimates the effects of CCIR on macroeconomic stability, emphasizing the implications of exchange rate flexibility. Section 6 extends the analysis by incorporating the effects of conventional stabilization policy, while Section 7 offers concluding remarks.

2 Literature review

IR have long been a focal point of academic and policy research, particularly regarding their optimal levels and policy implications. Early studies by Heller (1966), Hamada and Ueda (1977), Frenkel and Jovanovic (1981), and Ben-Bassat and Gottlieb (1992) primarily viewed IR as a buffer stock to manage fluctuations in external transactions. This line of inquiry has seen a resurgence

with recent contributions by Alfaro and Kanczuk (2009) and Jeanne and Rancière (2011), who revisit the optimal IR holding.

In the late 1990s, the notable accumulation of IR by EMDC, particularly those in Asia, sparked debates over its motives and implications within the context of global economic imbalances. Notably, Rodrik (2006) highlighted concerns over the IR holdings of EMDC reaching 30% of GDP and 8 months of imports, estimating that potential income losses due to yield spreads to be approximately 1% of GDP. Alfaro and Kanczuk (2009) argue that such high levels of IR hoarding cannot be justified as an optimal strategy.

One prominent explanation for the hoarding of IR is the precautionary motive among EMDC, particularly of the post-Asian financial crisis, as discussed by Aizenman and Marion (2003), Aizenman, Lee, and Rhee (2007), and Cheung and Qian (2009). This perspective views IR as a form of self-insurance against volatile capital flows. Alternatively, some argue that IR accumulation, particularly by China, reflects mercantilist motives aimed at maintaining large current account surpluses and managing currency appreciation pressures (Dooley, Folkerts-Landau, and Garber, 2003).[1]

Recent literature has shed new light on IR as a macro-prudential policy tool. Jeanne (2016) suggests that CCIR can serve as an alternative to counter-cyclical capital controls advocated by Ostry *et al.* (2011), IMF (2012), and Rey (2015). [2] In an era of financial globalization, EMDC often face challenges in managing volatile international capital flows. For instance, during economic overheating, conventional stabilization policies such as raising interest rates to cool the economy can inadvertently attract more capital inflows, exacerbating overheating. Conversely, during economic downturns, lowering interest rates to stimulate the economy can lead to capital outflows, worsening the downturn. In response, central banks can use IR to counteract these cycles by adjusting their accumulation or decumulation of foreign currency assets, thereby mitigating macroeconomic volatility induced by global financial cycles.[3]

[1] To evaluate the competing explanations, Aizenman and Lee (2007) analyzed data for 49 countries to find stronger support for the precautionary motives over the mercantilist motives. They argue that a large demand for IR arose as self-insurance to avoid costly liquidation of long-term projects when susceptible to sudden stops.
[2] See also Farhi and Werning (2014), Jeanne *et al.* (2012), and Korinek (2011).
[3] In Jeanne (2016), CCIR management is combined with a tax on capital inflows to achieve efficiency.

Moreover, central banks can utilize reserve requirements as a secondary monetary policy tool, as discussed by Cordella, Federico, Vegh, and Vuletin (2014). This approach allows them to balance currency defense with economic stimulus during challenging economic periods by adjusting both IR holdings and reserve requirements. More specifically, the typical policy mix for EMDC in bad economic times is to sell IR and raise short-term interest rates to defend the domestic currency. The dampening effects of rising interest rates can be offset, at least partially, by lowering reserve requirements that spurs the economy.

In summary, the evolving literature on IR as a macro-prudential policy tool highlights the complexities faced by countries navigating financial globalization. These challenges include managing volatile capital flows and vulnerable exchange rates across various phases of the business cycle.

3 Data and the IR cyclicality measure

3.1 Data

The data utilized in this study primarily originate from the World Bank's World Development Indicators and the IMF's International Financial Statistics. Additionally, we incorporate data on exchange rate regime classifications (Ilzetzki, Reinhart, and Rogoff, 2019), capital account openness indices (Chinn and Ito, 2006), and institutional quality from the *International Country Risk Guide* compiled by the Political Risk Services Group. The sample encompasses 177 countries, encompassing both EMDC and advanced economies (153 EMDC and 24 advanced economies).[4] The study period spans from 1972 to 2022, covering the post-Bretton Woods era. Due to data constraints, shorter sample periods may apply to some countries. All data are presented in annual frequency.

Our measure of IR is defined as total reserves excluding gold. Aggregate output is measured by real GDP. Detailed definitions of all variables used in the study are provided in Appendix A for reference.

3.2 The Measure of the IR Cyclicality

[4] Our analyses require sample countries to have enough number of observations for filtering IR and GDP, and the exchange rate regime classification information of Iltzeki *et al.* (2019). The requirements leave 163 countries as our sample. See Appendix A for further details.

To capture the cyclicality of IR, we utilized the Hodrick-Prescott filter (HPF) to extract the cyclical components of both IR and real GDP. Subsequently, for each country *i*, we calculated the correlation coefficient:

$$cyc_i = \frac{\sum_t r_{i,t} y_{i,t} - T\bar{r}_i\bar{y}_i}{(T-1)s_i^r s_i^y} \quad (1)$$

for which $r_{i,t}$ and $y_{i,t}$ represent the cyclical components of IR and real GDP, respectively, obtained through the HPF. $\bar{r}_i$ and $\bar{y}_i$ denote the mean, and s_i^r and s_i^y represent the standard deviation of $r_{i,t}$ and $y_{i,t}$, respectively. *T* denotes the number of observations (in the time dimension). Hereafter, we refer to (1) as the *cyclicality coefficient*.

Throughout this paper, we classify IR as counter-cyclical if the cyclicality coefficient cyc_i is significantly positive, indicating that IR tend to rise above (fall below) trend when real GDP deviates upward (downward) from trend.[5] This definition aligns with a counter-cyclical (prudential) policy stance, where additional assets are accumulated (decumulated) during favorable (unfavorable) economic conditions.[6] Conversely, IR are considered pro-cyclical if $cyc_i < 0$, indicating that IR tend to rise above trend when GDP falls below trend. IR are labeled as *a*-cyclical if there is no significant association with cyclical fluctuations in GDP.

The adoption of a cyclicality-based IR measure offers several advantages. Unlike traditional measures such as the ratio of IR to GDP, which do not differentiate between GDP trend growth and deviations from trend, the cyclicality-based approach provides insights crucial for decision-making regarding asset accumulation/decumulation and monetary and exchange rate policy.[7] Additionally, changes in IR reflect not only active central bank management (e.g., purchases or sales of foreign currency assets) but also interest income on existing securities and deposits.[8] Therefore, even in the absence of active management, IR can exhibit trend growth, while

[5] We adopted the 10% level of significance. This definition of IR cyclicality is used also by, for instance, Cordella *et al*. (2014).

[6] If the amount of IR increases as result of unsterilized intervention in the foreign exchange market, it may be viewed pro-cyclical as a monetary policy tool due to increasing domestic monetary base. However, our definition pertains to the correspondence between IR and business cycle. Therefore, we describe the case as counter-cyclical IR.

[7] It is implausible to assume that monetary policy responds constantly to changes in national income regardless of business cycle. Deviations from trend, generally considered unexpected components or a surprise, likely lead to responses of agents.

[8] See Dominguez, Hashimoto, and Ito (2012) for discussion on how to simulate active IR, and Aizenman *et al.* (2024) for detrending approach to estimate active IR.

deviations from trend typically indicate deliberate central bank actions. This perspective enhances understanding of the nature of IR management.

4 The IR cyclicality around the world

4.1 Overview of the IR cyclicality

Figure 1 illustrates the correlations between the cyclical components of IR and real GDP. The cyclicality coefficient estimates vary widely among countries, ranging from -0.78 (Panama) to 0.85 (Lebanon). Among the 177 countries studied, 103 exhibit positive cyclicality coefficients, while 74 show negative ones. Using a 10% level of statistical significance, 53 countries are identified as having CCIR, 23 as pro-cyclical, and 101 as *a*-cyclical, indicating that CCIR management applies to less than one-third of all countries.

Previous literature suggests that EMDC and advanced countries have different motivations for holding IR.[9] Therefore, we divided the sample accordingly. Figure 2 displays distinct behaviors in IR cyclicality between EMDC and advanced countries. The shaded area in the figure highlights statistically significant IR cyclicality at the 10% level. Among EMDC, there are three times more countries with counter-cyclical IR than pro-cyclical ones. In contrast, among advanced countries, the distribution is more balanced: six countries exhibit pro-cyclical IR, six show counter-cyclical IR, and 13 have *a*-cyclical IR.

The 2008 global financial crisis may have altered how CBs manage IR (Aizenman et al., 2015). To see if this is the case, we present the cyclical correlation estimates for 1972-2007 and 2008-2021 sub-samples in Figure 3. There is an indication of a shift in the distribution of the cyclical correlations between the two time periods. Specifically, in the pre-2008 crisis sample, the counter-cyclical IR tallies 70 countries, exceeding by far the pro-cyclical IR of 13. In contrast, for the post-crisis sample, the number of significant pro- and counter-cyclical countries are 20 and 25, respectively. More than 2/3 countries disregard business cycle after the 2008 crisis and simply adopt a-cyclical IR management.

The IR are a vital policy tool for countries to intervene in the foreign exchange markets. Therefore, we report the cyclicality coefficients organized by exchange rate arrangements. Using

[9] See Goldberg, Kennedy, and Miu (2011), Bussière, Cheng, Chinn, and Lisack (2015), and Aizenman *et al.* (2024).

the classification index of Ilzetzki *et al.* (2019), we grouped the countries by the extent of flexibility of their exchange rates. More specifically, we define the rigid, intermediate, and flexible regimes by the average indicator values of less than 4, between 5 and 8, and more than 8, respectively, of the fine classifications of Ilzetzki *et al.* (2019). They largely correspond to pegged, crawling peg and crawling band, and float classifications.

Figure 4 presents the cyclicality coefficients for these sub-samples. Notably, countries with flexible exchange rate arrangements show a higher prevalence of CCIR. An exception is the United States, where IR appear to be pro-cyclical. This unique behavior can be attributed to the US dollar's status as the world reserve currency, distinguishing it from other countries.

4.2 Exploring the determinants of the CCIR

The results so far indicate that CCIR are not universally adopted and are more prevalent among countries with flexible exchange rate arrangements. In this subsection, we formally investigate the determinants of CCIR adoption. What distinguishes countries practicing CCIR from those that do not? Are there common characteristics among countries managing their reserves counter-cyclically? To answer these questions, we examine whether CCIR adoption is significantly associated with the following factors: *exchange rate arrangements, monetary independence, capital openness, months of imports covered by reserves, institutional quality, real GDP per capita, short-term external debt, total external debt, debt service to export income ratio, financial development, M2 (broad money supply), trade openness, and terms of trade*. Definitions of these variables are provided in Appendix A.

We estimate cross-country logit regressions to identify factors that are associated the likelihood of adopting the CCIR:

$$CCIR_i = \alpha + X_i\Phi + \epsilon_i \qquad (2)$$

where $CCIR_i$ is a binary indicator which is set equal to unity if the cyclicality coefficient cyc_i is significantly negative; zero otherwise[10]. X_i is a vector of explanatory variables that measured by their mean value over the sample periods, and Φ is the coefficient vector.

[10] An OLS regression using continuous IR cyclical coefficients as the dependent variable is shown in Table B2 in Appendix B.

Initially, we included all explanatory variables in X_i and progressively removed insignificant ones. We found that exchange rate flexibility and months of imports covered by reserves were the most significant determinants, as shown in Table 1 (full estimates reported as Table B1 in Appendix B).

In the first column of Table 1, the coefficient for exchange rate arrangements is highly significant and positive, indicating that countries with more flexible exchange rates are more likely to adopt CCIR. This finding aligns with the observations in Figure 3. According to the estimated odds ratio (i.e., e^0.239 = 1.27), a country with one standard deviation (3.7) higher flexibility in its exchange rate arrangement index is associated with a 99.9% (=0.27*3.7) higher likelihood of adopting CCIR. This result might seem counter-intuitive since rigid exchange rate regimes often involve purchasing domestic currency during economic downturns to stabilize exchange rates. However, in flexible regimes, swift exchange rate adjustments absorb external shocks but lead to volatile currency movements and macroeconomic implications. CCIR can complement flexible regimes by mitigating exchange rate volatility and promoting macroeconomic stability. This conjecture will be tested further in Section 5.2, where we analyze the stabilizing effects of CCIR on output volatility.

Columns two and three of Table 1 present estimates for EMDC and advanced countries separately. EMDC estimates mirror those of the overall sample, reflecting their predominance in the sample. For advanced countries, none of the variables considered are significantly associated with CCIR adoption, possibly due to the smaller sample size (n=23).

Given arguments that the 2008 global financial crisis altered reserve management practices (Aizenman *et al.*, 2015), we analyzed pre- and post-crisis periods in the last two columns of Table 1. Exchange rate flexibility remains significantly associated with CCIR adoption in both periods. Notably, the positive association between months of imports covered by reserves and CCIR is significant only in the pre-crisis period, suggesting a shift in the motivation for reserve accumulation over time, as observed by Ghosh, Ostry, and Tsangarides (2017).

5. Does the CCIR help stabilize the economy?

Given the diversity in how countries manage their IR cyclically and the implication of "leaning against the wind" CCIR on real exchange rate stability and "boom and bust" capital flows, we now

examine whether adopting a counter-cyclical approach has significant welfare implications, particularly in terms of macroeconomic stability. Moreover, the findings of positive association between IR cyclicality and exchange rate arrangements in the preceding section led us to conject that CCIR can complement flexible regimes by mitigating exchange rate volatility and promoting macroeconomic stability. Indeed, numerous previous studies examine the implications of exchange rate flexibility for macroeconomic fluctuations (Tower and Courtney, 1974; Dornbusch, 1981; Melvin, 1985; Flood and Rose, 1995; Collard and Dellas, 2002)[11] and the literature underscores, although not in a clear consensus, the importance of considering the influence of exchange rate flexibility on macroeconomic stability. Thus, we explore how CCIR may influence macro stability and how it interacts with exchange rate flexibility in affecting macroeconomic fluctuations.

5.1. Does CCIR help macroeconomic stability?

We first examine whether CCIR helps macroeconomic stability. We use output volatility, defined the squared of cyclical component of real GDP (in logarithm value), to proxy macroeconomic stability (Frankel et al., 2013; Lane, 2003). High output volatility indicates stable macroeconomics. Specifically, we investigate whether CCIR management helps mitigate output volatility by estimating:

$$ln(y_i^2) = \alpha + \beta_1\, CCIR_i + \beta_2\, Flexible_i + X_i\Psi + \epsilon_i \qquad (3)$$

where $ln\,(y_i^2)$ represents our measure of output volatility. $CCIR_i$ is a binary indicator for countries adopting counter-cyclical IR policy as in Section 4.2.

For the degree of exchange rate flexibility ($Flexible_i$), we employ the *de facto* exchange rate arrangement index from Ilzetzki *et al.* (2019). Our primary measure sets $Flexible_i$ to 1 for countries with mean values of Ilzetzki's index in the fine classifications exceeding 8. For other countries, the variable is set equal to zero. This threshold effectively captures economies with free-floating exchange rates.

[11] The issue has also been analyzed in more specific contexts. Heipertz, Mihov, and Sanatacreu (2022) examines the implications of exchange rate flexibility in the context of target choices of monetary policy rule. Csonto and Gudmundsson (2020) discusses the implications of exchange rate arrangements for emerging markets in terms of effects on foreign currency debt.

As an alternative measure, we use Ilzetzki's fine index in raw values. This alternative measure allows varying degrees of exchange rate flexibility in estimating its effects on the output volatility. However, it imposes an assumption that the marginal effect of increasing/decreasing flexibility is constant between any two contiguous regime categories. The results for the second measure are reported in Table B4 in Appendix B.

X_i is a vector that includes 6 control variables that might be relevant to macroeconomics stability. They are month of imports covered by IR that represents the level of IR holding (Krugman, 1979; Mendoza and Quadrini, 2024; Obstfeld et al., 2010), monetary independence (Berger and Kißmer, 2013; Stein, 2012), capital account openness (Eichengreen and Mussa, 1998; Prasad et al., 2003), trade openness (Giovanni and Levchenko, 2009; Razin et al., 2003), financial development (Acemoglu and Zilibotti, 1997; Aghion et al., 1999; 2004), and institutional quality (Acemoglu et al., 2013; Duncan, 2014). Definitions of these variables are in Appendix A.

Tabel 2 reports regression results for Equation (3). Column [1] – [3] use OLS regressions for full country samples, EMDE, and Advanced countries, respectively. The estimations for CCIR are significantly negative across three regressions, suggesting that countries adopting CCIR policy have low output volatility. More specifically, across all 107 data-available sample countries, adopting CCIR policy countries are associated with about 3.1 percent lower output volatility relative to non-CCIR countries. This association is stronger in advanced countries than that in EMDE (-5.1 in Column [3] v.s. -2.9 in Column [2]). These results are in line with literature findings that "leaning against the wind" IR accumulation reduces real exchange rate volatility and smooths volatile capital flows, leading to stable macroeconomics (Aizenman et al., 2012; Jeanne, 2016).

High degree of exchange rate flexibility is found to positively associated with high output volatility. Indeed, a traditional argument against flexible exchange rate typically point to its erratic movement along the expectation of future economic fundamentals and move in a way often aggravate the macroeconomic stability problem (Dornbusch, 1982). We do not find many control variables have significant association with output volatility, except that trade openness is associated with low output volatility in full sample regression, capital account openness is associated with lower output volatility among EMDE[12], and there is a positive association

[12] Literature has no conclusive empirical evidence about the effect of capital account liberalization on output

between monetary independence and output volatility in advanced countries (Berger and Kißmer, 2013).

Although we find the significantly negative association between the CCIR and the output volatility, it could be a result of endogeneity arising from omission of variables or reversed causality. To address the issues, we estimated Equation (3) also by using instrumental variables (IV) regressions.[13] We use the fraction of the population of European descent in 1990 (Acemoglu, Johnson, and Robinson, 2001) and the legal origin of British and French dummy variables (La Porta et al., 1997) to instrument CCIR. "Leaning against the wind" CCIR policy requires democracy and executive constraints against government power to refrain spending but save in good times and use the savings in bad times. Acemoglu *et al.* (2001) argue that a high fraction of European descent population in colonies indicates better development of European settlement and a higher likelihood for the settlers to replicate European democracy and institutions that have constraints in executives. Moreover, implementing CCIR policy may need financial market facilitation. As La Porta et al. (1997) suggest that countries with British legal origin have higher development of their financial market than those of French origins, we add dummy variables for British and Franch legal origin as additional IVs for CCIR[14].

We proceed to use estimate IV regression using 2SLS approach. Columns [4] of Table 2 displays IV estimates for the full country sample, showing a negative and significant effect of CCIR on output volatility. That is, countries adopting CCIR policy significantly reduce their output volatility. The result is robust in EMDC but not in advance country samples perhaps due to reduced sample size (only 19 observations). The finding confirms the OLS results in Table 1, but it also suggests that the logistic regression may underestimate the true effect CCIR to reduce output volatility. Nonetheless, the coefficient estimates for the CCIR variable are noticeably larger than those in Table 1 (i.e. -23.78 vs. -3.11). This implies that, without addressing endogeneity issues, the OLS regression may underestimate the effect of CCIR on output volatility.

stability, see for example Eichengreen (2001) and Prasad et al. (2003).

[13] See Imbens and Angrist (1994), Angrist et al. (1996), and Angrist and Krueger (2001) for the use of the IV approach to identify and estimate the causal effect.

[14] The proposed instruments show good prediction to CCIR as shown in the results of first stage regression in Table B3 in Appendix B

5.2. How does CCIR interact exchange rate flexibility to enhance macro stability

In this section, we test the conjecture in Section 4.2 that CCIR can complement flexible regimes by mitigating exchange rate volatility and promoting macroeconomic stability. More specifically, we investigate whether CCIR management helps mitigate output volatility by estimating:

$$\ln(y_i^2) = \alpha + \beta_1 CCIR_i + \beta_2 Flexible_i + \beta_3 CCIR_i \times Flexible_i + X_i\Psi + \epsilon_i \qquad (4)$$

Equation (4) is an augmented specification from Equation (3). We incorporate $CCIR_i \times Flexible_i$ to explore interactive effects between CCIR and exchange rate flexibility. The interaction term allows us to capture how the effect of CCIR on output volatility varies depending on the flexibility of the exchange rate regime. Specifically: the baseline scenario is when $CCIR_i = 0$ and $Flexible_i$ =0, which represents countries with a rigid exchange rate regime and no implementation of CCIR. For baseline countries, their output volatility only depends on the constant, the effects of control variables, and the disturbance. The coefficient of CCIR, β_1, captures the marginal effect of adopting CCIR while maintaining a rigid exchange rate arrangement relative to the baseline. The coefficient of *Flexible*, β_2, represents the marginal effect of transitioning to a flexible exchange rate arrangement without implementing CCIR. The coefficient of the interaction term, β_3, reflects the additional marginal effect when both CCIR and a flexible exchange rate arrangement are adopted. And $\beta_1 + \beta_3$ and $\beta_1 + \beta_3$ capture the overall marginal effect of CCIR and flexible exchange rate arrangement, respectively, on output volatility in countries that implementing both CCIR and flexible exchange rate regime.

Thus, equation (4) enables us to analyze how the impact of CCIR on output volatility depends on the flexibility of the exchange rate regime, and vice versa. This approach provides insights into the combined effects of these policy choices on macroeconomic stability.

Table 3 presents the results from estimating equation (4). In column [1] for the full sample, β_1 , the coefficient for $CCIR_i$ is positive but statistically insignificant, indicating countries that adopt CCIR alone, without flexible exchange regime been implemented, does not have significant effect on output volatility, relative to those baseline countries that have rigid exchange rate regime and no CCIR. Conversely, β_2, the coefficient for $Flexible_i$, is significantly positive, indicating that adopting flexible exchange rate arrangements increases output volatility compared to rigid exchange rate arrangements.

The interaction term $CCIR_i \times Flexible_i$, β_3 is significantly negative at -5.99. This suggests that the volatility-mitigating effect of CCIR is significant in flexible exchange rate regime than those are in rigid regime. In fact, our results suggest that the overall marginal effect of CCIR for countries with flexible exchange rate regimes and simultaneously implementing CCIR is -5.6 (i.e. $\beta_1 + \beta_3 = 0.39 - 5.99$) and statistically significant at the 1% level. [15]

Therefore, we find that, while CCIR alone do not independently reduce output volatility, their implementation alongside flexible exchange rate arrangements effectively offsets the volatility-increasing effects of flexible exchange rates. This finding underscores the complementary role of CCIR in enhancing macroeconomic stability, particularly in economies with flexible exchange rate regimes.

The β_2 estimate of 5.59 suggests that countries adopting a free float exchange rate regime without implementing CCIR experience approximately 5.99% higher output variability compared to those with rigid exchange rate regimes, holding other factors constant. While flexible exchange rate regimes absorb external shocks and adjust exchange rates accordingly (Frankel, 2012), the resulting volatility in exchange rates can contribute to greater output variability. For countries that complement flexible exchange rate regimes with CCIR, the effect on output volatility is significantly reduced and effectively neutralized ($\beta_1 + \beta_3$ = -0.39, p-value 0.87). In examining the macroeconomic fundamentals of fixed and floating exchange rate regimes, Flood and Rose (1995) finds that the volatility of output does not differ significantly even though the volatility of exchange rate does. Our results provide one explanation for why there is no clear tradeoff between reduced exchange rate volatility and macroeconomic stability as Flood and Rose (1995) finds. In the subsequent columns [2] and [3] of Table 3, we present estimates for EMDC and advanced countries separately. The findings for EMDCs align closely with those of the full sample, indicating that CCIR significantly complements flexible exchange rate regimes in reducing output variability.

Conversely, the results for advanced countries, albeit based on a smaller sample size, exhibit notable differences. Here, counter-cyclical IR policies independently reduce output variability

[15] The standard error of $\beta_1 + \beta_3 * CCIR_i$ is computed using the Delta method (Oehlert, 1992), $\hat{\sigma} = \left[var(\hat{\beta}_1) + CCIR_i{}^2 var(\hat{\beta}_3) + 2CCIR_i cov(\hat{\beta}_1, \hat{\beta}_3)\right]^{\frac{1}{2}}$.

significantly. However, when combined with flexible exchange rate arrangements, the volatility-mitigating effect of CCIR diminishes (β_3=6.26). The overall effect of counter-cyclical IR policies on reducing output variability becomes slightly insignificant (i.e. $\beta_1 + \beta_3 = -2.22$, p-value is 0.29).

In sum, our empirical analysis underscores that the impact of CCIR on macroeconomic variability hinges significantly on the exchange rate regime adopted by the country. Implementing CCIR alongside flexible exchange rate arrangements effectively mitigates output volatility.

5.3. The shock of the 2008 global financial crisis

Both the pattern and motives of IR accumulation has changed since the 2008 financial crisis. The unprecedent pace of IR accumulation that reach the level of IR to more than 30 percent of world GDP before the 2008 crisis was decelerated and "flat out" in many countries in the post-crisis. Aizenman et al (2015) attribute this change to the emerge of new factors under different financial condition pre- and post-crisis. These factors include the saving rate, the accessibility to swap lines, implementations of macro-prudential policies, sovereign wealth fund, and the attitude towards outward FDI. Bussiere et al. (2015) argue the slowing-down reserves accumulation may be related to deceleration of short-term debt borrowing after the global financial crisis.

The changes in IR accumulation pattern seem to reflect in the IR policy regarding business cycle as well pre-crisis *vis-a-vis* post-crisis. As we described in Section 4, 45 countries changed from CCIR policy in pre-crisis periods to a-cyclical IR post-crisis and the determinants of CCIR policy adoption, as shown in Table 1, also changed as after the 2008 crisis. In this section, we examine if CCIR has changed the role in reducing output volatility since the 2008 crisis?

We re-estimated Equation (3) and (4) using data sample of pre- and post-crisis in Table 4. The results show that the reduction effect of CCIR on output volatility is noticeable different before and after the 2008 crisis. CCIR is found to mitigate output volatility pre-crisis, but we have no statistically significant evidence for post-crisis periods, although the sign of estimated coefficient of CCIR is negative. Compared to Table 2, the estimated CCIR effect on output volatility pre-crisis is smaller than that using entire sample periods (2.02 v.s. 3.11) and the flexible exchange rate regime is not found significant unless we control the interaction term between CCIR and flexible exchange rate regime. These results are robust both in OLS and IV regressions.

The complimentary effect of CCIR with flexible exchange rate regime in reducing output volatility is also found different pre- and post-crisis – the interaction term is significant for pre-crisis sample, but not significant post-crisis, indicating that, perhaps due to changes in other financial conditions after the 2008 financial crisis, the role of CCIR working through flexible exchange rate arrangement to mitigate output volatility is diminished. This perhaps is one of the reasons that many countries shift out CCIR policy while staying in flexible exchange regime after the 2008 financial crisis.

6. Panel data analyses for counter cyclical IR behavior

Sections 4 and 5 analyze CCIR behavior using cross-country data by capturing the cross-country variation. Remarkably differed CCIR behaviors before and after the 2008 crisis may suggest that it is important to scrutinize CCIR policy evolution along the time dimension. In this section, we use cross-country time series panel data and an alternative definition of IR cyclicality tailored for panel data structure (i.e. country × year observations) to examine CCIR determinants and how CCIR affects output volatility over time?

Literature typically use the statistical correlation between a cyclical economic factor and the business cycle to measure economic cyclicality, including monetary policy or fiscal policy cyclicality. This type of cyclicality measurement provides cross-sectional variation so that it is convenient for cross-country regression analyses. However, panel data analyses require variables that feature both cross-country and cross-time variations.

To tackle this issue, literature presents three different ways to study cyclicality in panel data. The first one uses panel data regression to directly link the cyclical economic factor to the business cycle (typically represented by the cyclical component of HP filtered real GDP data) and the sign of estimated coefficient associated with cyclical real GDP is interpreted as the indicator of counter- or pro-cyclicality (Lane 2003; Frankel et al., 2013). This approach is useful to estimate the intensity to a cyclicality, but it does not reveal the probability of a country adopting, for example, counter-cyclical IR policy for a given year.

The second way is utilizing rolling correlation coefficient to account for the cyclicality over time. This approach is intuitive but it entails serial correlation issue arising from overlapping years in their rolling window data. Cordella and Gupta (2015) use five-year rolling correlation

coefficient to investigate the determinants of currency pro-cyclicality. However, they reserve the caution due to the serial correlation issue. Frankel et al. (2013) use 20-year rolling window data, but only for the case study for Austrilia, Venezuela, and Chile to illustrate the evolution of their fiscal policy cyclicality over time. They do not directly regress on 20-year rolling data.

In a recent paper, de Haan and Gootjes (2023) used a different metric to measure cyclicality in country-year observation for panel data analyses. They consider a country's fiscal policy is pro-cyclical for a given year if the change of budget balance and the output gap have opposite signs, and the absolute change in the budget balance exceeds 0.2% of GDP. The approach is intuitive, but the 0.2% of GDP cut-off standard is rather arbitrary[16].

We propose a new approach which borrows "windows" idea from Cordella and Gupta (2015) and Frankel et al (2013). However, rather than using moving widow that contains overlapped years across windows, we divide 50 sample years into 10 individual "year windows", each of which has about 5 non-overlapping years. We also make sure that the 2008 financial crisis is a split point for different windows to control the impact of the crisis. Doing so, we compiled a cross-country cross-window (177 x 10) unbalanced panel data set.

We first run fixed effect panel data logistic regressions controlling the window (year) effect examine what determine the likelihood of CCIR policy. The regression is specified as the follows:

$$CCIR_{it} = \alpha + c_i + w_t + \beta X_{it} + \varepsilon_t \qquad (5)$$

Where the dependent variable is $CCIR_{it}$ indicating country i's implementation of counter-cyclical IR in time window t. $CCIR_{it}$ is a dummy variable that gives CCIR = 1 in a country-window observation if the cyclical components of real GDP and IR correlated at 10% level during the 5-year window; 0, otherwise. In addition to the fixed effect (c_i), we add the year effect (w_t) to control the global financial shocks that impact the output volatility across all countries simultaneously (Miranda-Agrippino and Rey, 2020). 13 relevant variables are included in X_{it} as independent variables. Each of these variables is measured by the mean of their yearly data in each window.

[16] We experimented de Haan and Gootjes' (2023) approach. As we do not have prior information what constitutes the appropriate standard level of GDP for IR cyclicality, we trialed 2%, 1%, 0.5%, 0.2% and 0.1% of GDP as the cut-offs. The results vary depending on which cut-off been used.

Table 5 shows the results for the full sample, EMDC, advanced countries, pre-crisis, and post-crisis samples. Due to missing observations in many independent variables, we again follow a strategy to gradually drop most insignificant variable until the remaining variables are significant at least in one of 5 regressions in Table 5. This allows us to increase the number of observations substantially from 460 to 1032 (The regression results with all variables are reported in Appendix Table B6).

The panel data regressions confirm our finding in cross-country regression analysis that flexible exchange rate and months of imports covered by reserves are positively associated with the likelihood of CCIR policy adoption. Specifically, one degree of more flexible in a country's exchange rate arrangement is associated with 8.1% (odd ratio = 1.081) more likely to adopt CCIR relative to non-CCIR policy. In addition, we find trade openness is positive associated with CCIR in all countries. Monetary independence is found to positively associated with CCIR in EMDC. However, we do not find any significant determinant for CCIR in advanced countries. Moreover, the determinants for CCIR adoption is different pre- and post-crisis. We find positive association between exchange rate arrangement, months of imports covered by reserve and the likelihood of CCIR in pre-crisis periods; but not in post-crisis era.

We then examine the output volatility reduction effect of CCIR in fixed effect panel data OLS regression as the follows:

$$\ln(y_{i,t}^2) = \alpha + c_i + w_t + \beta_1\, CCIR_{i,t} + \beta_2\, Flexible_{i,t} + \beta_3\, CCIR_{i,t} \times Flexible_{i,t} + X_{i,t}\Psi + \epsilon_{i,t} \qquad (6)$$

It is a replication of Equation (4) in panel data setting. The dependent variable and all independent variables have the same definition as those in Equation (4) except they are calculated from 5-year windows for a panel data setting. Underscription *i* and *t* are noted to index country *i* and time widow *t*, respectively. c_i and w_t are the country fixed effect and time widow effect.

We report results for Equation (6) in Table 6. We start with a regression in Column [1] without controlling the interaction term between CCIR and flexible exchange regime. The estimated result indicates that, within a country, its output volatility is about 82% lower at the time periods when it implements CCIR relative to the periods when it moves away from CCIR. This effect is significantly estimated at 1% level. The flexible exchange rate regime is not estimated significantly.

Among other relevant factors, only financial development had a positive and significant estimation – suggest that high development of domestic financial market is associated with high output volatility. This result is consistent in EMDC and both in pre- and post-crisis regressions, but it is insignificant in advanced countries.

In cooperating in the possible complimentary effect of CCIR with flexible exchange regime, we estimate how CCIR affect output volatility in full sample, EMDE, advance countries, pr-crisis, and post-crisis samples in Column [2] – [6], respectively. Consistent with the results in Table 3, we identify a significant complimentary effect of CCIR with flexible exchange regime to reduce output volatility. We find that, within a country, CCIR does not significantly reduce output volatility without the country's practice of flexible exchange regime (coefficient = -0.31, p value = 0.41). When the country had a flexible exchange rate regime in place, CCIR reduce 128% of output volatility (-1.28, p value =0.027) comparing to when it had a rigid exchange rate regime. This complimentary effect is stronger in advance countries and before the 2008 crisis.

We do not estimate a significant complimentary effect of CCIR in EMDC samples (Column [3]) – the coefficient for $CCIR_{i,t} \times Flexible_{i,t}$ is not significant, however, the overall marginal effect during flexible exchange regime is significantly negative (i.e. $\beta_1 + \beta_3$ = -0.38-0.81 = 1.19, delta method p value = 0.02). The results suggest that CCIR reduces output volatility when a country implements both CCIR and flexible exchange regime. But the output volatility reduction effect of CCIR conducting through flexible exchange rate regime is not statistically significant.

The CCIR complimentary effect presents in advance country regression (Column [4]) and it is more prominent relative to that is full sample regression (the coefficient for $CCIR_{i,t} \times Flexible_{i,t}$ is -3.28 in Column [4] versus -1.28 in Column [2]). With the prominent complimentary effect, the overall marginal effect of output volatility in an advance country is significantly negative ($\beta_1 + \beta_3$ = -2.92, p value =0.01) during the time when it adopts flexible exchange rate.

Across pre- and post-crisis (Column [5] and [6]), the complimentary effects of CCIR are different. It has significant complimentary effect with flexible exchange rate regime within a country during pre-crisis periods (Column [5]); in post-crisis era, however, it is insignificant (Column [6]). Despite presenting no significant compliment effect post-crisis, CCIR significantly reduces the output volatility during the time post-crisis when a country adopts both CCIR and flexible exchange rate (Column [6]; $\beta_1 + \beta_3$ = -2.02, p value =0.01).

Contrasting to Table 3 results, we do not find that flexible exchange regime is associated with high output volatility within a country, as $Flexible_{i,t}$ variable is insignificantly estimated across all regressions in Table 6. In addition, the complimentary effect in advance countries turns up to enhance the output volatility reduction effect of CCIR in the within effect of panel data regression of Column [6] in Table [6], whereas in Table 3 where we considering cross-country variation, CCIR's interaction with flexible exchange rate, interestingly, slows down the reduction effect on CCIR on output volatility.

Overall, using fixed effect panel data regressions, we yield intuitive and consistent results as those estimated in cross-country regressions. Our main finding that CCIR adoption complement flexible exchange rate regime to reduce output volatility and enhance macroeconomic stability, is robust across different regression specifications and country and time period samples.

7. Conclusions

As important public assets and policy tools, IR have been extensively studied in scholarly research and policy discussions. Recent literature particularly emphasizes their potential as macroprudential policy tools in an era of globalized financial capital, especially for EMDC. These countries face challenges such as volatile international capital flows, vulnerable exchange rates, and macroeconomic instability simultaneously, necessitating difficult policy decisions.

Conventional macroeconomic stabilization policies, effective in advanced economies, may not suit EMDC well. For instance, during periods of overheating or economic downturn, conventional interest rate policies can worsen situations by exacerbating international capital flows. Potentially, CCIR can play a crucial role as substitutes for counter-cyclical capital controls.

In this study, we empirically examine the prevalence of CCIR and their effectiveness in mitigating volatility. Our findings indicate that CCIR are more of an exception than a rule. Moreover, we observe that their volatility-reducing effects are contingent upon exchange rate flexibility. The significant dampening effects on output volatility due to CCIRs are specific to countries with flexible exchange rate arrangements. This specificity explains, at least in part, why CCIRs are not widely adopted globally.

According to the IMF (2022), only approximately 20% of countries worldwide operate under free-floating exchange rate systems. Given that CCIRs demonstrate effective volatility mitigation

primarily in countries with flexible exchange rates, their adoption remains naturally limited across countries.

This paper, to our best knowledge, is the first empirical paper that explicitly examines the "leaning against the wind" style counter-cyclical international reserve management policy. We study how prevalence the CCIR policy is across the world, what determine an adoption of CCIR, why adopt CCIR and how it works to enhance macroeconomic stability. While we attempt to provide a comprehensive exploration of CCIR policy behavior, there are vast areas remained unexplored and soliciting future researches to better understand CCIR and other cyclical IR behaviors. For instance, in addition to CCIR, many countries practice pro-cyclical IR. What are the motivations to adopt a pro-cyclical IR policy and its implication? Also, we identified the differed CCIR policy adoption pattern and the role of CCIR before and after the 2008 global financial crisis. What caused such regime shifts is an important question requiring future research.

Appendix A: Variable definitions and summary statistics

CCIR: a dichotomous index to measure a country's counter-cyclical behavior of international reserves (IR). In cross section regressions, we define CCIR = 1 if the correlation between the cyclical components of IR and real GDP from 1972 to 2022 is positive and significant at 10% p-value level. If it's insignificant, we assign Counter IR a zero. The cyclical components of IR and real GDP are obtained using PH filter. In panel data regressions, we divide the 50-year sample period into 10 sub-sample periods and define CCIR = 1 in a country-subperiod observation if the cyclical components of real GDP and IR correlated at 10% level during the subperiod.
PCIR: a dichotomous index of a country's pro-cyclical behavior of IR. The definition process is identical to CCIR, except that we assign PCIR 1 if the calculated cyclical correlation is negative and significant 10% level.
ACIR: an indicator for a country adopts neither Counter-cyclical nor Pro-cyclical IR.
Exchange rate arrangement: the de facto measure for exchange rate regime from Ilzetzki, Reinhart and Rogoff (2019)'s fine index that classified exchange rate flexibility into 15 categories. High index indicates more de facto exchange rate flexibility.
Monetary independence: the monetary independence index of Aizenman, Chinn and Ito (2010).
Capital account openness: the Chinn-Ito capital account openness index.
Institutional quality: the average of the indices of bureaucracy quality, corruption, investment profile, and law and order from ICRG country risk database.
Real GDP per capita: the logarithm of real GDP per capita, PPP (constant 2017 international $).
Financial development: the domestic credit to private sectors to GDP ratio, %.
M2/GDP: the broad money (M2) to GDP ratio, %.
IR months of imports: Total reserves in months of imports.
Short-term external debt: the short-term external debt to GDP ratio, %.
Long-term external debt: the long-term external debt to GDP ratio, %.
External debt: the total external debt to GDP ratio, %
Debt service to exports income: Total debt service (% of exports of goods, services and primary income)
Trade openness: the total trade to GDP ratio, %.
Term of trade: the term of trade index; Y2000 = 100.
Euro1900: The fraction of the population of European decent (Acemoglu et al, 2001).
Legal Origin: The French legal origin of company and commercial law from Acemoglu et al. (2001) and La Porta et al (1997).
Debt GDP ratio in 1900: The total debt to GDP ratio from Reinhart and Rogoff (2011).
Output variability: the variability of real GDP, measured by the squared of HP filtered cyclical component of real GDP, in logarithm value (Frankel et al., 2013).

Summary statistics

Variable	Obs	Mean	Std. dev.	Min	Max
CCIR	177	0.31	0.47	0	1
PCIR	177	0.13	0.34	0	1
ACIR	177	0.56	0.5	0	1
Exchange rate arrangement	161	6.44	3.7	1	13.05
IR month of imports	151	3.93	2.6	0.03	15.89
Financial development	161	46.59	37.79	3.21	188.22
Short-term external debt	107	5.8	5	0.02	25.1
External debt	107	49.3	24.47	9.06	168.39
Monetary independence	154	0.43	0.11	0.13	0.66
Institutional quality	120	0.58	0.17	0.21	0.92
Capital account openness	160	0.44	0.29	0.01	1
Trade openness	157	83.3	49.98	21.77	342.53
Term of trade	162	112.27	23.33	66.72	194.77
M2/GDP	142	54.86	48.58	0.04	446.41
Debt service to export income ratio	107	15.91	8.58	2.12	45.66
GDP per capita	163	8.15	1.42	5.26	11.08
Output volatility	163	11.08	7.19	-4.07	31.78

Appendix B: Additional results

Table B1: The estimates of equation (2) controlling for all explanatory variables

	[1] All	[2] EMDC	[3] Pre-crisis	[4] Post-crisis
Exch rate arrangement	0.278**	0.384**	0.196*	0.062
	(0.111)	(0.150)	(0.117)	(0.108)
IR month of imports	0.028	-0.070	0.276*	-0.19
	(0.099)	(0.122)	(0.153)	(0.154)
Monetary independence	-0.680	-5.394	-1.500	-3.718
	(3.585)	(5.678)	(4.611)	(3.347)
Institutional Quality	-1.235	2.749	-0.012	0.086
	(3.254)	(5.057)	(0.122)	(0.155)
Real GDP per capita	0.052	0.229	0.012	-0.086
	(0.343)	(0.479)	(0.389)	(0.447)
M2/GDP	-0.010	0.005	-0.027	0.021
	(0.011)	(0.018)	(0.017)	(0.015)
Financial development	0.004	-0.017	0.037	-0.012
	(0.013)	(0.022)	(0.026)	(0.024)
Capital openness	-0.147	0.814	-2.376	-0.021
	(0.963)	(1.284)	(1.465)	(1.036)
Trade openness	0.003	0.019	0.020**	-0.008
	(0.007)	(0.014)	(0.010)	(0.010)
Term of trade	-0.008	-0.019	0.006	0.012
	(0.010)	(0.013)	(0.014)	(0.009)
Debt service to export income ratio		-0.005		
		(0.043)		
ST debt/GDP		0.035		
		(0.089)		
Total debt/GDP		-0.003		
		(0.015)		
Psudo R^2	0.094	0.169	0.174	0.133
Obs.	89	65	72	72

Notes: This table reports cross-section logistic regression results with CCIR as the dependent variable. Advanced economy sample estimates are not available due to insufficient sample size. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

Table B2: The OLS estimate for IR cyclicality determinants controlling for all explanatory variables

	[1] All	[2] EMDC	[3] Pre-crisis	[4] Post-crisis
Exch rate arrangement	0.038***	0.033***	0.026**	0.023**
	(0.011)	(0.011)	(0.011)	(0.011)
IR month of imports	-0.004	-0.010	0.037**	0.033**
	(0.015)	(0.016)	(0.016)	(0.016)
Monetary independence	0.516	-0.198	0.354	0.088
	(0.414)	(0.775)	(0.503)	(0.477)
Institutional Quality	-0.091	0.134	-0.002	-0.002
	(0.459)	(0.510)	(0.015)	(0.014)
Real GDP per capita	0.05	0.085*	0.016	0.019
	(0.039)	(0.048)	(0.051)	(0.049)
M2/GDP	0.000	0.001	-0.001	-0.001
	(0.001)	(0.002)	(0.001)	(0.001)
Financial development	-0.002	-0.003	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Capital openness	-0.085	0.079	-0.313	-0.329*
	(0.119)	(0.117)	(0.189)	(0.183)
Trade openness	0.000	0.001	0.002***	0.002***
	(0.001)	(0.002)	(0.001)	(0.001)
Term of trade	0.000	-0.002	0.001	0.001
	(0.001)	(0.001)	(0.002)	(0.002)
Debt service to export income		-0.004		
		(0.006)		
ST debt/GDP		0.011		
		(0.010)		
Total debt/GDP		0.000		
		(0.002)		
Psudo R^2	0.140	0.073	0.130	0.093
Obs.	89	65	72	72

Notes: This table shows OLS regressions results with the IR cyclical coefficient as the dependent variable. Advanced economy sample estimates are not available due to insufficient sample size. ***, **, and * indicate 1%, 5%, and 10% significance level.

Table B3: The first stage regression results in IV regressions of Table 2

	[1] All	[2] EMDC	[3] Advanced
Euro1900	0.004**	0.005**	0.001
	(0.002)	(0.002)	(0.008)
British legal origin	0.190	0.269	0.206
	(0.155)	(0.210)	(0.476)
British legal origin	0.116	0.206	-0.145
	(0.138)	(0.185)	(0.464)
Exch rate arrangement	0.305***	0.280**	0.181
	(0.109)	(0.122)	(0.438)
IR month of imports	0.010	0.003	-0.056
	(0.020)	(0.022)	(0.103)
Monetary independence	0.181	-0.007	0.251
	(0.631)	(0.753)	(1.719)
Capital account openness	-0.125	-0.058	-1.520
	(0.216)	(0.238)	(1.356)
Trade openness	0.001	0.000	0.004
	(0.001)	(0.002)	(0.006)
Financial development	0.000	-0.001	0.011
	(0.002)	(0.002)	(0.006)
Institutional quality	-0.868	-0.22	-0.182
	-0.665	-0.834	-3.505
R2	0.072	0.035	0.039
Obs.	99	80	19

Notes: The first stage of IV regression in Table 2 are reported. The dependent variable is CCIR. Columns [1] – [3] report results of OLS and Column [4] – [6] report IV regression results. Euro1900 (fraction of the population of European decent in 1900) (Acemoglu et al, 2001) and the legal origin of British and French dummy variables (La Porta et al., 1997) are used to instrument CCIR. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

Table B4: The complementary effect of exchange rate arrangement and counter-cyclical IR on macro-stability

	[1] All	[2] EMDC	[3] Advanced	[4] Pre-crisis	[5] Post-crisis
CCIR	1.312	2.191	-12.297***	5.526	0.018
	(3.384)	(3.885)	(2.795)	(4.800)	(3.044)
Exch rate arrangement	0.634**	0.690*	0.397	0.293	0.083
	(0.301)	(0.365)	(0.374)	(0.178)	(0.272)
CCIR×Exch rate arrangement	-0.506	-0.604*	0.882*	-0.596*	-0.125
	(0.370)	(0.349)	(0.405)	(0.359)	(0.374)
IR month of imports	0.168	0.173	0.012	0.202	0.076
	(0.200)	(0.242)	(0.565)	(0.135)	(0.236)
Monetary independence	5.870	0.322	15.195	3.509	9.925
	(8.074)	(9.230)	(10.305)	(3.904)	(7.476)
Capital account openness	-3.783	-4.681	11.512	-3.017*	-3.887
	(2.659)	(3.051)	(8.048)	(1.655)	(3.344)
Trade openness	-0.021	-0.020	-0.031	-0.026***	-0.034**
	(0.013)	(0.020)	(0.022)	(0.010)	(0.014)
Financial development	0.006	0.009	0.019	0.016	0.007
	(0.024)	(0.033)	(0.044)	(0.016)	(0.023)
Institutional Quality	-0.810	0.372	-24.268	0.127	0.248
	(6.504)	(8.505)	(20.201)	(0.179)	(0.188)
R2	0.172	0.092	0.631	0.189	0.079
Obs.	107	86	21	88	88

Notes: This table reports cross-country OLS regression results. The dependent variable is output variability. Columns [1] and [2] and [3] are for full samples, developing and emerging countries, and advanced countries samples, respectively. The estimates in columns [5] and [6] are for pre- and post-2008 financial crisis samples, respectively. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

Table B5: The complementary effect of exchange rate arrangement and counter-cyclical IR on macro-stability

	[1] All	[2] EMDC	[3] Advanced	[4] Pre-crisis	[5] Post-crisis
IR cyclicality	-0.308	0.799	-10.054	3.599	-2.992
	(3.594)	(4.613)	(7.324)	(2.756)	(3.289)
Exch rate arrangement	0.521*	0.573*	0.520	0.292*	-0.138
	(0.270)	(0.311)	(0.611)	(0.170)	(0.235)
IR cyclicality×Exch rate arrangement	-0.570	-0.766*	1.016	-0.703**	0.440
	(0.487)	(0.422)	(1.192)	(0.341)	(0.425)
IR month of imports	0.165	0.152	0.229	0.144	0.053
	(0.210)	(0.252)	(0.737)	(0.140)	(0.222)
Monetary independence	6.937	1.633	11.519	2.959	10.764
	(7.927)	(9.312)	(12.043)	(3.881)	(7.635)
Capital account openness	-3.742	-4.580	17.014**	-3.036*	-3.240
	(2.753)	(3.208)	(7.175)	(1.554)	(3.169)
Trade openness	-0.021	-0.020	-0.025	-0.026**	-0.035***
	(0.013)	(0.020)	(0.022)	(0.011)	(0.013)
Financial development	0.004	0.006	-0.025	0.014	0.007
	(0.024)	(0.034)	(0.052)	(0.017)	(0.023)
Institutional Quality	-0.068	1.493	-32.297	0.141	0.221
	(6.885)	(9.100)	(19.873)	(0.182)	(0.191)
R2	0.154	0.078	0.504	0.207	0.076
Obs.	107	86	21	88	88

Notes: This table reports cross-country OLS regression results. The dependent variable is output variability. "IR cyclicality" is measured by the correlation coefficient of the cyclical components of IR and real GDP. Columns [1] and [2] and [3] are for full samples, developing and emerging countries, and advanced countries samples, respectively. The estimates in columns [5] and [6] are for pre- and post-2008 financial crisis samples, respectively. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

Table B6: Fixed effect panel date regression – the choice of counter-cyclical IR over years

	[1] All	[2] EMDC	[3] Advanced	[4] Pre-crisis	[5] Post-crisis
Exch rate arrangement	0.020	-0.011	-0.083	0.016	0.034
	(0.054)	(0.059)	(0.412)	(0.082)	(0.099)
IR month of imports	0.024	0.032	0.189	0.066	0.005
	(0.030)	(0.030)	(0.203)	(0.055)	(0.047)
Monetary independence	1.746	2.334	-1.102	5.344**	-1.75
	(1.478)	(1.831)	(14.687)	(2.340)	(1.928)
Institutional Quality	0.013	0.018	-1.615	0.093	-0.107
	(0.072)	(0.078)	(1.458)	(0.106)	(0.122)
Real GDP per capita	-0.015	-0.024	-4.686*	-0.121	0.196
	(0.238)	(0.246)	(2.710)	(0.389)	(0.321)
M2/GDP	0.000	-0.005	0.002	0.013	-0.005
	(0.005)	(0.007)	(0.025)	(0.011)	(0.008)
Financial development	0.011	0.010	-0.021	0.004	0.015
	(0.007)	(0.009)	(0.045)	(0.013)	(0.011)
Capital openness	-0.504	-0.817	22.116	-0.756	-0.198
	(0.812)	(0.943)	(16.260)	(1.202)	(1.093)
Trade openness	0.000	0.002	0.025	-0.004	0.005
	(0.002)	(0.003)	(0.024)	(0.005)	(0.006)
Term of trade	-0.002	-0.003	0.058	-0.01	-0.004
	(0.006)	(0.006)	(0.045)	(0.012)	(0.007)
Log Likelihood	-111.51	-94.27	-9.96	-58.99	-48.21
Obs.	460	368	31	234	226

Notes: This table report fixed effect logistic regressions results with CCIR as the dependent variable. Year effects are included to control for the effect global factors. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

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Table 1: The choice of counter-cyclical IR

	[1] All	[2] EMDC	[3] Advanced	[4] Pre-crisis	[5] Post-crisis
Exchange rate arrangement	0.239***	0.246***	0.295	0.090*	0.132*
	(0.063)	(0.066)	(0.217)	(0.047)	(0.070)
IR months of imports	0.008	0.012	-0.067	0.199***	-0.071
	(0.076)	(0.083)	(0.163)	(0.076)	(0.098)
Pseudo R2	0.113	0.116	0.139	0.065	0.041
Obs.	149	126	23	147	145

Notes: This table reports cross-country Logit regression results. The dependent variable is the dichotomous variable for the counter-cyclical IR (CCIR) behavior. The entries of the first three columns are the estimates for all countries, emerging and developing countries, and advanced countries. The entries of the last two columns are the estimates for pre- and post-2008 financial crisis periods. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level. As a preliminary step, we estimated equation (2) in the main text with all explanatory variables. We then sequentially dropped insignificant explanatory variables to preserve sufficient degrees of freedom. The estimates with all explanatory variables are attached in Appendix B1. Appendix B2 shows the results using IR cyclical coefficients as the dependent variable.

Table 2: The effect of counter-cyclical IR on macroeconomic stability

	[1] OLS All	[2] OLS EMDE	[3] OLS Advanced	[4] IV All	[5] IV EMDE	[6] IV Advanced
CCIR	-3.112**	-2.942*	-5.096*	-23.782**	-24.296**	-19.946
	(1.366)	(1.595)	(2.404)	(10.727)	(11.481)	(28.710)
Flexible	3.409**	3.254*	4.591*	10.042**	9.711**	9.355
	(1.508)	(1.681)	(2.288)	(4.230)	(4.492)	(10.319)
IR month of imports	0.218	0.217	-0.286	0.214	0.122	-1.517
	(0.200)	(0.237)	(0.452)	(0.454)	(0.560)	(2.668)
Monetary independence	8.181	3.054	18.392**	8.867	4.902	22.503
	(6.607)	(8.058)	(6.625)	(14.684)	(18.831)	(28.484)
Capital account openness	-3.954	-4.996*	10.578	-6.176	-4.428	-6.964
	(2.567)	(2.908)	(7.346)	(5.238)	(5.867)	(43.465)
Trade openness	-0.020*	-0.018	-0.024	-0.002	-0.026	-0.010
	(0.012)	(0.019)	(0.020)	(0.028)	(0.038)	(0.110)
Financial development	0.009	0.007	0.044	0.023	0.008	0.212
	(0.023)	(0.031)	(0.036)	(0.046)	(0.062)	(0.346)
Institutional Quality	-1.168	0.037	-28.804	-8.931	8.288	-25.268
	(6.443)	(8.657)	(19.033)	(14.055)	(19.610)	(38.573)
Over-identification test				1.48	1.07	0.92
Weak instrument test				1.92	2.38	1.33
R2	0.194	0.109	0.627	0.178	0.167	
Obs.	107	86	21	99	80	19

Notes: The OLS and IV estimate results are reported. The dependent variable is output variability. Columns [1] – [3] report results of OLS and Column [4] – [6] report IV regression results. Euro1900 (fraction of the population of European decent in 1900) (Acemoglu et al, 2001) and the legal origin of British and French dummy variables (La Porta et al., 1997) are used to instrument CCIR. The over-identification test is the Wald statistic; the null hypothesis is that the instruments are exogenous (i.e., uncorrelated with the error term). The weak-identification test is the first-stage F test of excluded instruments; the null hypothesis is that the model is weakly identified. First stage IV regression results are reported in Appendix B3. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

Table 3: The complimentary effects of counter-cyclical IR and flexible exchange rate on the output volatility

	[1] All	[2] EMDC	[3] Advanced
CCIR	0.399	1.185	-8.483***
	(2.121)	(2.278)	(1.203)
Flexible	5.597***	6.031***	3.094
	(1.715)	(2.036)	(2.481)
CCIR × Flexible	-5.991**	-7.128**	6.259**
	(2.810)	(3.227)	(2.265)
IR month of imports	0.151	0.159	-0.015
	(0.212)	(0.258)	(0.510)
Monetary independence	7.613	3.821	17.483**
	(6.395)	(7.654)	(6.933)
Capital account openness	-3.837	-4.372	11.820
	(2.559)	(2.938)	(6.804)
Trade openness	-0.023*	-0.024	-0.028
	(0.012)	(0.018)	(0.022)
Financial development	0.015	0.019	0.022
	(0.025)	(0.033)	(0.043)
Institutional quality	-2.212	-0.638	-30.122
	(6.630)	(8.435)	(19.745)
R2	0.228	0.158	0.666
Obs.	107	86	21

Notes: This table reports cross-country OLS regression results. The dependent variable is output variability. *Flexible* is a dichotomous variable for flexible exchange regime (=1) if the respective Ilzetzki et al (2019) index is greater than 8; rigid exchange regime (=0), otherwise. Columns [1] and [2] are for full samples, and Columns [3] and [4] for developing and emerging countries, and advanced countries samples, respectively. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level. Results using continuous measures for exchange rate regime and IR cyclicality coefficient are presented in Appendix B4 and B5.

Table 4: The effect of cyclical IR on macro stability pre- and post-2008 global financial crisis

	[1] Pre-crisis	[2] Post-crisis	[3] Pre-crisis (IV)	[4] Post-crisis (IV)	[5] Pre-crisis	[6] Post-crisis
CCIR	-2.025*	-1.074	-10.997**	-4.093	3.866	-0.647
	(1.155)	(1.190)	(5.079)	(4.842)	(2.462)	(1.457)
Flexible	0.968	0.861	2.185	1.365	2.501*	1.238
	(1.176)	(1.216)	(1.855)	(1.525)	(1.382)	(1.636)
CCIR × Flexible					-6.327**	-0.807
					(3.041)	(2.294)
IR month of imports	0.106	0.076	0.384	0.359	0.299**	0.061
	(0.214)	(0.221)	(0.344)	(0.388)	(0.130)	(0.233)
Monetary independence	8.795	8.299	2.755	5.769	1.187	8.536
	(6.377)	(6.535)	(11.836)	(10.216)	(3.465)	(6.647)
Capital account openness	-4.053	-3.866	-10.741**	-7.919**	-0.329	-3.789
	(3.291)	(3.243)	(4.203)	(3.682)	(1.703)	(3.210)
Trade openness	-0.031**	-0.033**	-0.015	-0.020	-0.038***	-0.033**
	(0.014)	(0.013)	(0.020)	(0.014)	(0.012)	(0.014)
Financial development	0.007	0.009	0.042	0.028	0.024*	0.009
	(0.023)	(0.022)	(0.037)	(0.024)	(0.013)	(0.022)
Institutional quality	0.228	0.216	0.590	0.255	0.168	0.217
	(0.175)	(0.182)	(0.379)	(0.234)	(0.190)	(0.183)
R2	0.122	0.095	0.132	0.152	0.173	0.084
Obs.	88	88	82	82	88	88

Notes: This table reports cross-section OLS regression results. The dependent variable is output variability. *Flexible* is a dichotomous variable for flexible exchange regime (=1) if the respective Ilzetzki et al (2019) index is greater than 8; rigid exchange regime (=0), otherwise. Columns [1] and [5] report pre-crisis OLS results. Columns [2] and [6] report post-crisis OLS results. Colums [3] and [4] report IV regression results. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level. Results using continuous measures for exchange rate regime and IR cyclicality are reported in Columns [4] and [5] in Appendix B4 and B5.

Table 5: Countries' choice of counter-cyclical IR over years – the within effect panel data analyses

	[1] All	[2] EMDC	[3] Advanced	[4] Pre-crisis	[5] Post-crisis
Exch rate arrangement	0.078**	0.097**	-0.009	0.108*	0.070
	(0.038)	(0.046)	(0.152)	(0.058)	(0.080)
IR month of imports	0.050*	0.068*	0.032	0.070*	0.04
	(0.028)	(0.035)	(0.065)	(0.040)	(0.036)
Monetary independence	1.432	2.705*	1.607	2.355	0.994
	(1.121)	(1.570)	(3.313)	(1.757)	(1.394)
Trade openness	0.005*	0.006**	0.000	0.006	0.005
	(0.003)	(0.003)	(0.006)	(0.005)	(0.003)
Log Likelihood	-242.96	-183.77	-51.9	-167.57	-69.39
Obs.	1032	850	160	658	374

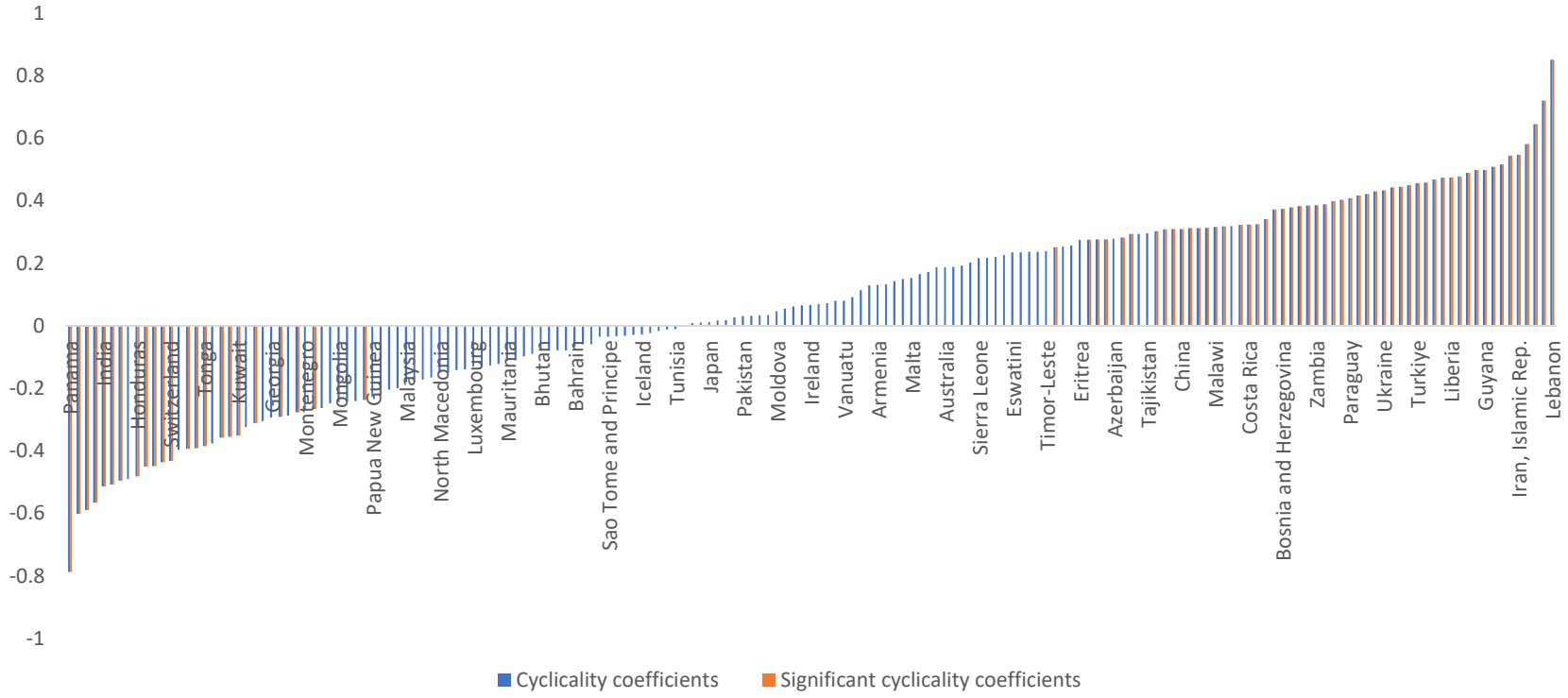
Notes: This table report fixed effect panel data logistic regressions results. CCIR is the dependent variable. Insignificant variables are dropped to increase sample size from 460 to 1032. Results with all independent variables included are in Appendix B6. Year effects are included to control for the effect global factors. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

Table 6: The macro stabilization effects of counter-cyclical IR over year – the within effect panel data analyses

	[1] All	[2] All	[3] EMDC	[4] Advanced	[5] Pre-crisis	[6] Post-crisis
CCIR	-0.821***	-0.310	-0.385	0.359	0.157	-0.542
	(0.297)	(0.375)	(0.392)	(1.000)	(0.607)	(0.625)
Flexible	-0.302	-0.117	-0.043	-0.766	-0.312	-0.081
	(0.344)	(0.352)	(0.363)	(1.204)	(0.611)	(0.721)
CCIR × Flexible		-1.284**	-0.813	-3.283**	-2.058**	-1.483
		(0.577)	(0.527)	(1.344)	(0.906)	(0.944)
IR month of imports	0.025	0.021	-0.003	0.548***	0.046	-0.109
	(0.041)	(0.041)	(0.042)	(0.153)	(0.077)	(0.087)
Monetary independence	-0.725	-0.798	0.459	-7.856***	0.774	-1.299
	(0.867)	(0.864)	(0.945)	(2.686)	(1.760)	(1.135)
Capital account openness	-0.548	-0.570	-0.658	0.452	1.113	0.434
	(0.642)	(0.639)	(0.653)	(3.019)	(1.010)	(2.186)
Trade openness	-0.009	-0.009	-0.006	0.001	-0.006	-0.014
	(0.007)	(0.007)	(0.007)	(0.025)	(0.012)	(0.016)
Financial development	0.015***	0.015**	0.019**	0.013	0.022*	0.018*
	(0.006)	(0.006)	(0.008)	(0.011)	(0.013)	(0.011)
Institutional quality	0.082	0.081	0.086	0.058	-0.014	0.073
	(0.067)	(0.066)	(0.070)	(0.218)	(0.099)	(0.168)
With-in R2	0.115	0.125	0.133	0.520	0.084	0.200
Obs.	576	576	473	103	291	285

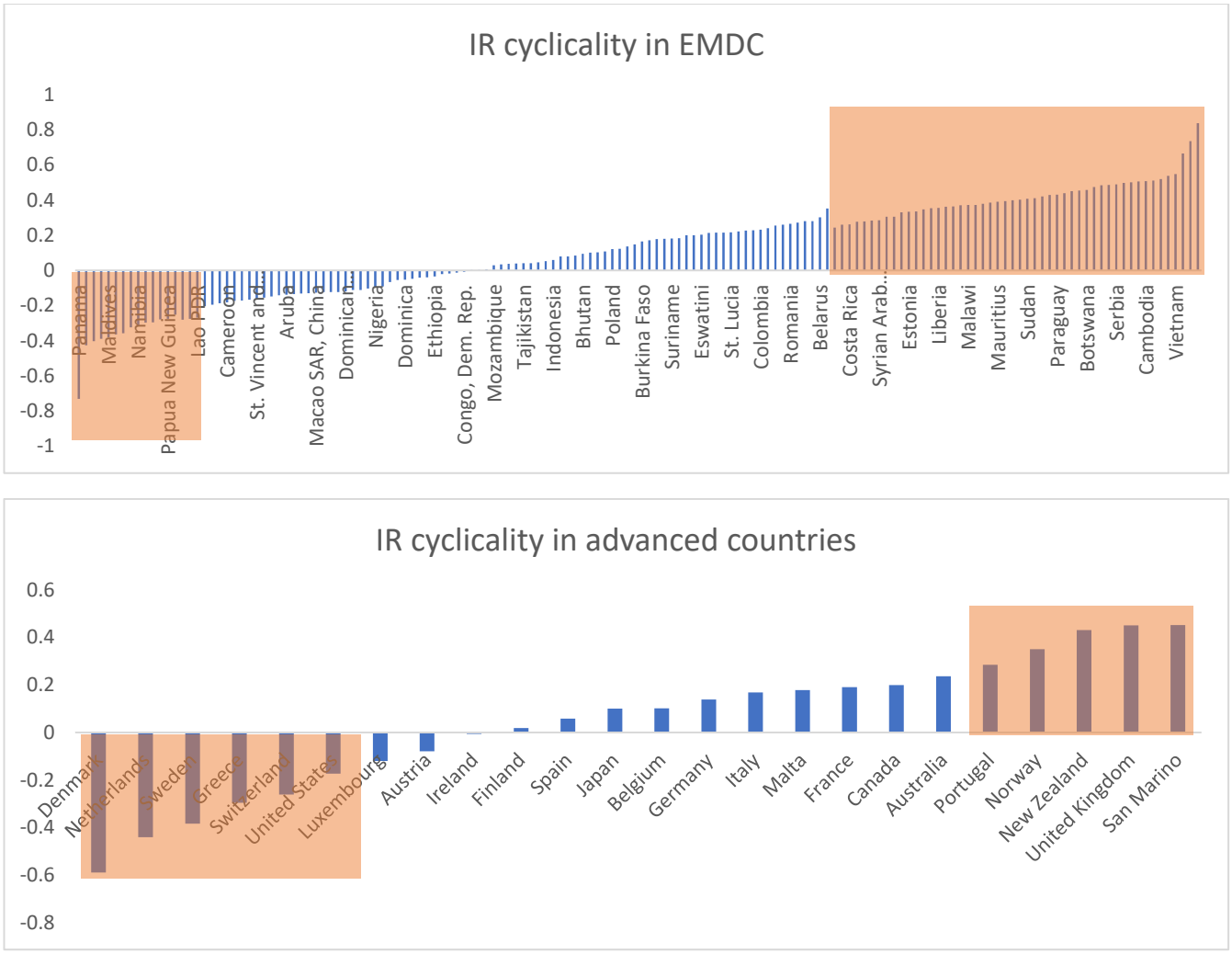
Notes: This table reports fixed effect panel data regression results. The dependent variable is output variability. Year effects are included to control for the effect global factors. Columns [1] and [2] report full sample results. Columns [2] and [3] are for developing and emerging countries and advanced countries samples. Robust errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level.

Figure 1. The Cyclicality of the International Reserves by Country



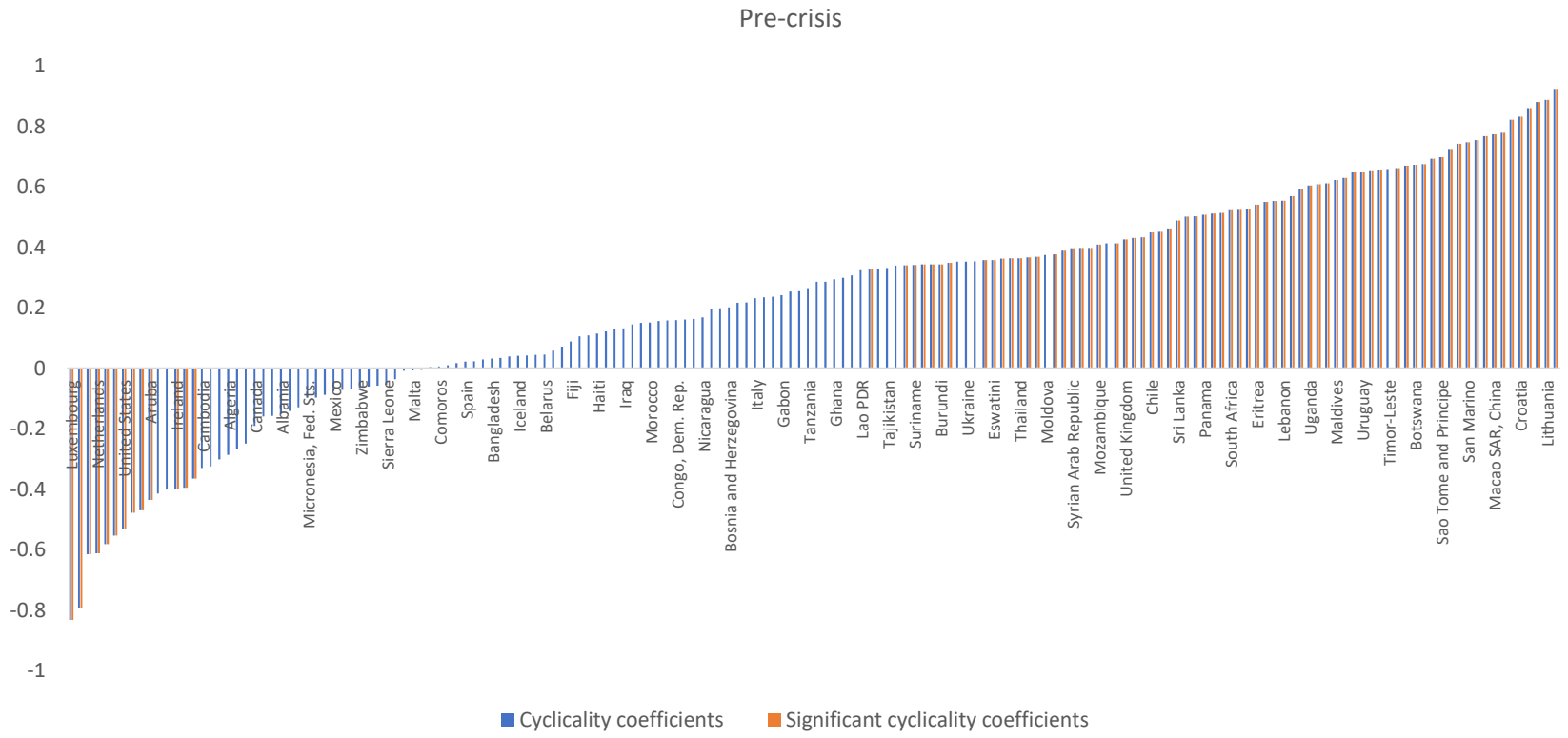
Notes: The cyclicality coefficient estimates of Eq. (1) in the main text are reported. A positive (negative) value indicates counter-cyclical (pro-cyclical) IR. Blue bars are the point estimates of the correlations. Orange bars show only statistically significant correlations at the 10 % level.

Figure 2: The Cyclicality of International Reserves for Emerging and Developing Countries and Advanced Countries



Notes: The cyclicality coefficient estimates of Eq. (1) in the main text are reported. A positive (negative) value indicates counter-cyclical (pro-cyclical) IR. The shaded areas indicate statistically significant cyclicality coefficients at the 10 % level.

Figure 3. Pre- and Post-World Financial Crisis



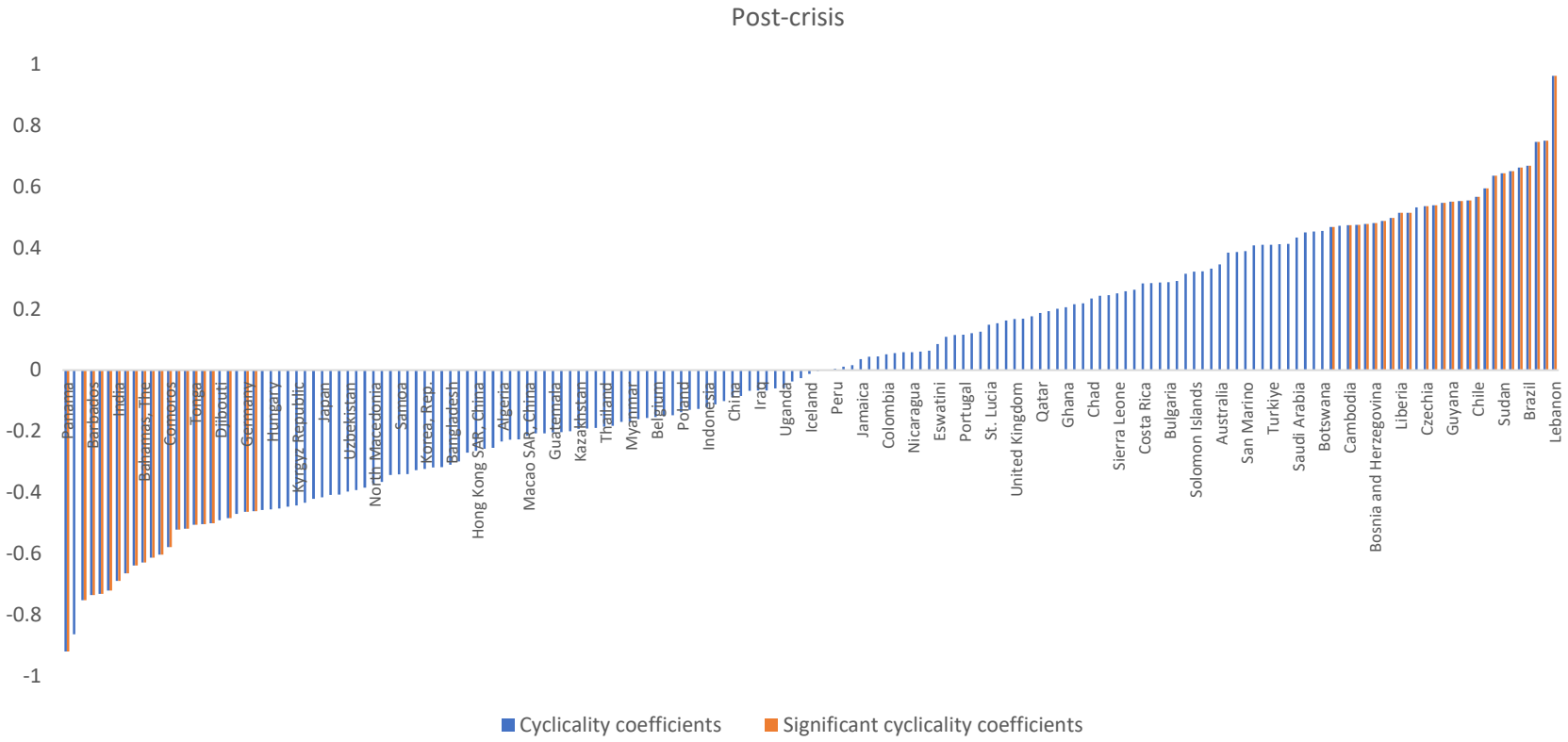
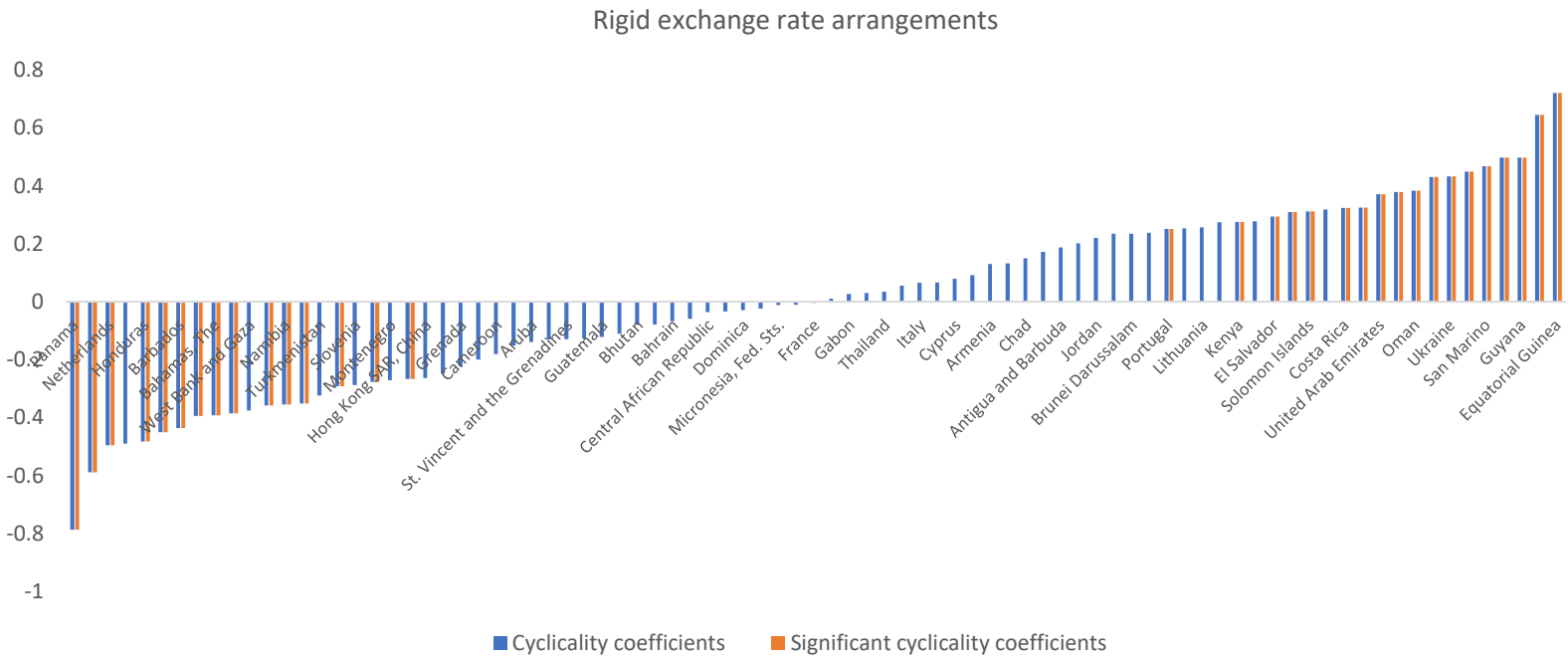
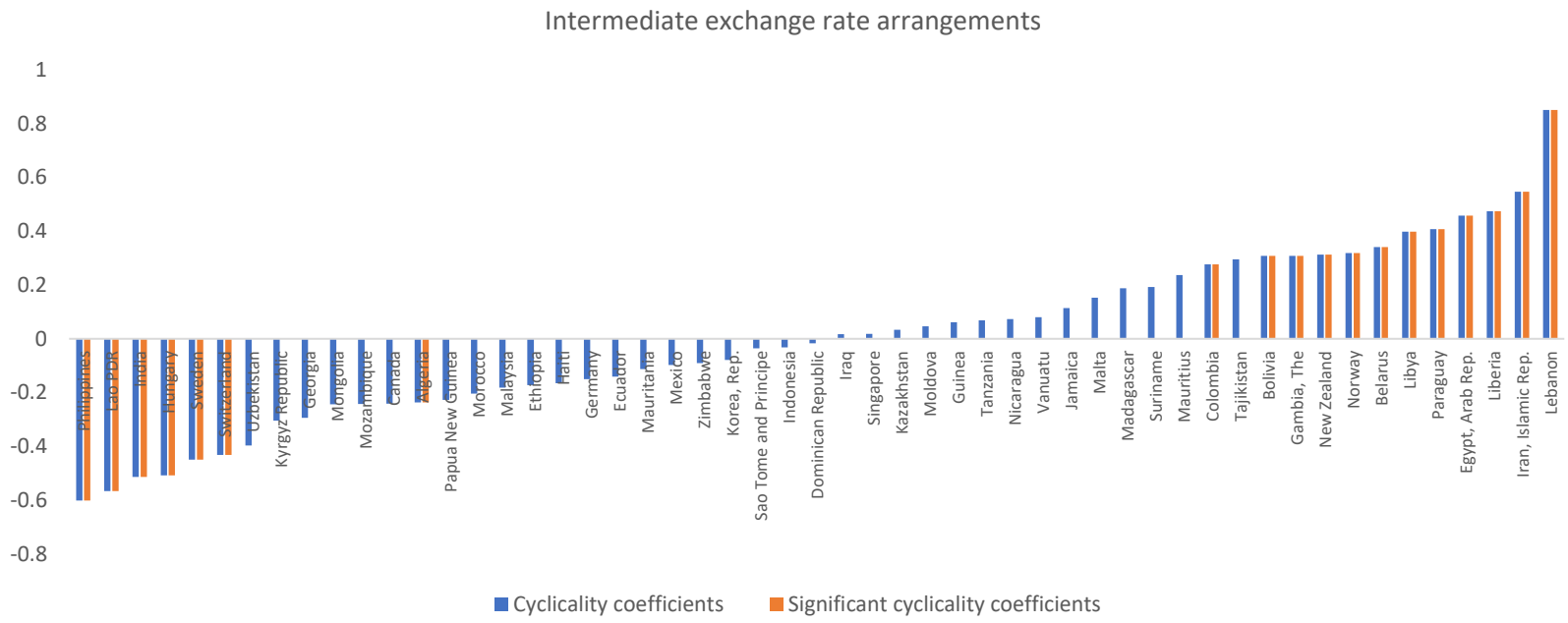
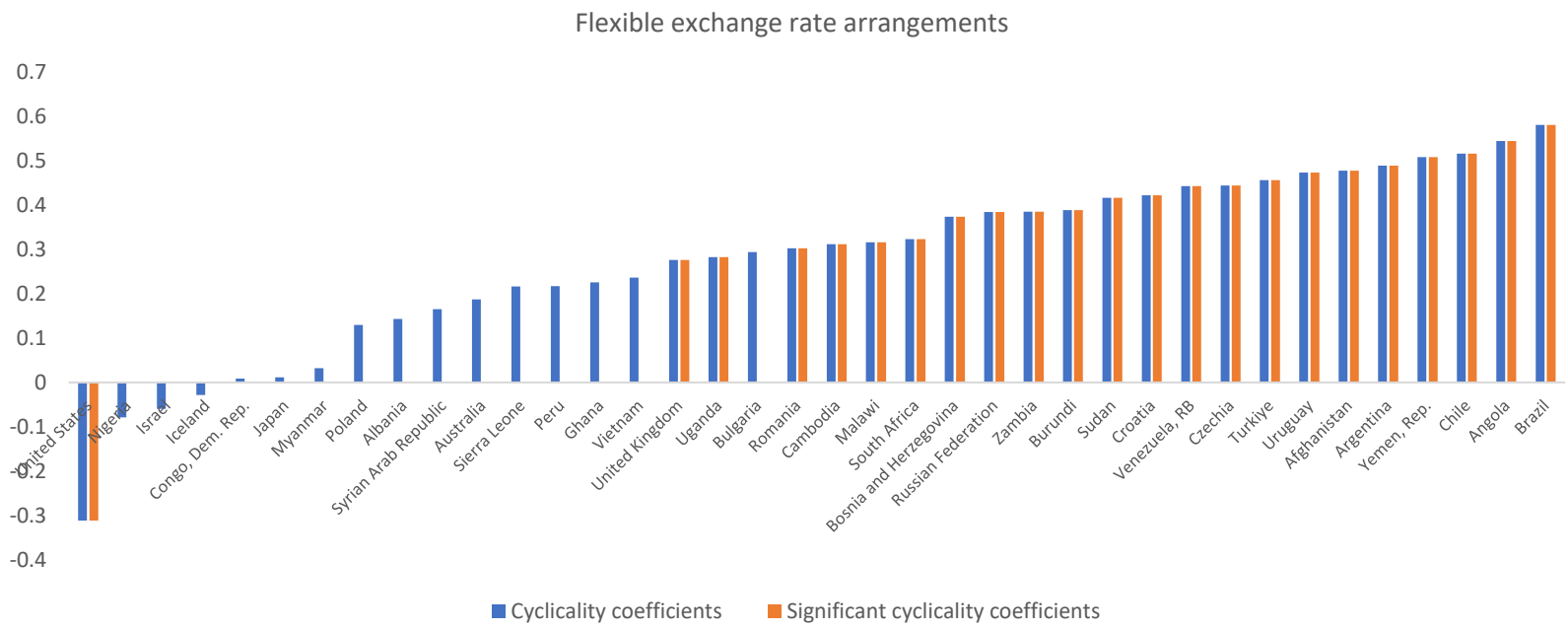

Post-crisis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Panama
Barbados
India
Bahamas, The
Comoros
Tonga
Djibouti
Germany
Hungary
Kyrgyz Republic
Japan
Uzbekistan
North Macedonia
Samoa
Korea, Rep.
Bangladesh
Hong Kong SAR, China
Algeria
Macao SAR, China
Guatemala
Kazakhstan
Thailand
Myanmar
Belgium
Poland
Indonesia
China
Iraq
Uganda
Iceland
Peru
Jamaica
Colombia
Nicaragua
Eswatini
Portugal
St. Lucia
United Kingdom
Qatar
Ghana
Chad
Sierra Leone
Costa Rica
Bulgaria
Solomon Islands
Australia
San Marino
Turkiye
Saudi Arabia
Botswana
Cambodia
Bosnia and Herzegovina
Liberia
Czechia
Guyana
Chile
Sudan
Brazil
Lebanon
Cyclicality coefficients
Significant cyclicality coefficients

Figure 4. The Cyclicality of International Reserves by Exchange Rate Arrangement




Intermediate exchange rate arrangements
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Philippines
Lao PDR
India
Hungary
Sweden
Switzerland
Uzbekistan
Kyrgyz Republic
Georgia
Mongolia
Mozambique
Canada
Algeria
Papua New Guinea
Morocco
Malaysia
Ethiopia
Haiti
Germany
Ecuador
Mauritania
Mexico
Zimbabwe
Korea, Rep.
Sao Tome and Principe
Indonesia
Dominican Republic
Iraq
Singapore
Kazakhstan
Moldova
Guinea
Tanzania
Nicaragua
Vanuatu
Jamaica
Malta
Madagascar
Suriname
Mauritius
Colombia
Tajikistan
Bolivia
Gambia, The
New Zealand
Norway
Belarus
Libya
Paraguay
Egypt, Arab Rep.
Liberia
Iran, Islamic Rep.
Lebanon
Cyclicality coefficients
Significant cyclicality coefficients


Flexible exchange rate arrangements
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
United States
Nigeria
Israel
Iceland
Congo, Dem. Rep.
Japan
Myanmar
Poland
Albania
Syrian Arab Republic
Australia
Sierra Leone
Peru
Ghana
Vietnam
United Kingdom
Uganda
Bulgaria
Romania
Cambodia
Malawi
South Africa
Bosnia and Herzegovina
Russian Federation
Zambia
Burundi
Sudan
Croatia
Venezuela, RB
Czechia
Turkiye
Uruguay
Afghanistan
Argentina
Yemen, Rep.
Chile
Angola
Brazil
Cyclicality coefficients
Significant cyclicality coefficients