NBER WORKING PAPER SERIES

INTERNATIONAL RESERVE MANAGEMENT, GLOBAL FINANCIAL SHOCKS, AND FIRMS' INVESTMENT IN EMERGING MARKET ECONOMIES

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Working Paper 29303
http://www.nber.org/papers/w29303

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2021

Joshua Aizenman is grateful for the support provided by the Dockson Chair in Economics and International Relations, USC. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research. Yin-Wong Cheung gratefully acknowledges the support provided by the Hung Hing Ying and Leung Hau Ling Charitable Foundation. And, part of the article was written when I was with City University of Hong Kong.

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NBER Working Paper No. 29303
September 2021
JEL No. F36,F42,F61,G31

ABSTRACT

We examine the effects of active international reserve management (IRM) conducted by central banks of emerging market economies (EMEs) on firm investment in the presence of global financial shocks. Using firm level data from 46 EMEs from 2000 to 2018, we document four findings. First, active IRM positively affects firm investment - the effect strengthens with the magnitude of adverse external financial shocks. Second, financially constrained firms, compared with unconstrained ones, are less responsive to active IRM. Third, our results suggest that the country credit spread is a plausible causal channel of the positive IRM effect on firm investment. Fourth, the policies of capital controls and exchange rate managements are complementary to the IRM – it is beneficial to form a macro policy mix including active IRM to safeguard firm investment against global financial shocks. Further, our results indicate the IRM effect on firm investment is both statistical and economical significance and is relevant to the aggregate economy.

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1 Introduction

The 2008 financial crisis originated in the US had emanated shock waves that wreaked havoc on economies and financial markets across the world. Emerging market economies (EMEs) were vulnerable and hit particularly hard.[1] In the presence of sudden spikes of global financial risk, EMEs can experience economic calamities, including sharp contraction, plunge in investment, credit supply crunch, widened credit spreads, *sudden stops*, capital flow reversals, and heightened speculation of a debt crisis.

The crisis experience, however, is not uniform across EMEs. An EME that holds a high level of international reserves and actively sells international reserves assets to stabilize its financial market during crisis periods tends to exhibit good economic recovery post-crisis. Central banks implement active international reserve management (IRM) strategy akin to 'leaning against the wind' policy – they accumulate international reserves during good times and sell them in challenging or crisis periods to provide a buffer against financial instability.[2] Under the counter-cyclical IRM policy, international reserves are hoarded in good times to self-insure against the probability of financial crises and sudden stops, and provide resources for intervening and stabilizing financial markets to alleviate the adverse crisis impact on the economy.

Global financial shocks could magnify uncertainty - cause a spike in the level of risk aversion among global investors, and result in a sharp contraction of global credit supply and capital flight from EMEs (Rey, 2015). The chain reactions can have detrimental effects on firm investment that spillover across sectors and economies.[3] Dominguez et al. (2012) and Aizenman and Jinjarak (2020), for example, find that central banks' active IRM policy is an effective stabilizer against external financial shocks and improves on average an EME's economic performance.[4] However, the macro-based evidence presented by these authors does not shed light on the active IRM policy effect at the firms' level.

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[1] For example, Carrière-Swallow and Céspedes (2013) find that, relative to developed countries, EMEs suffer more severe falls in investment and consumption following an exogenous uncertainty shock and take longer time to recover.

[2] EMEs have accumulated an astonishing level of international reserves since 1997 Asian financial crisis. The 2008 global financial crisis rekindled the accumulation trend. Reasons for excess hoarding of international reserves include the precautionary drive to self-insure against crisis, mercantilist motivation, and the Joneses effect, see, for example, Dooley et al., (2003), Aizenman and Lee (2007), Caballero and Panageas (2008), Cheung and Qian (2009), Jeanne and Rancière (2011), Gourinchas and Obstfeld (2012) and Qian and Steiner (2017).

[3] Bloom (2017), for example, suggests investment is the main channel that uncertainty shocks impact GDP growth.

[4] See, also, Jeanne (2016). Dominguez, Hashimoto, and Ito (2012) find that countries with a higher level of international reserves prior to the 2008 global financial crisis exhibit higher post-crisis GDP growth. Aizenman and

The current paper studies the empirical effect of active IRM on firm investment in EMEs in the presence of global financial market shocks. The quantitative assessment is conducted by applying a canonical Tobin-Q investment framework (Hayashi, 1982; Eberly et al., 2009) and using annual data of 21,447 publicly listed firms in 46 EMEs from 2000 to 2018. Because of the absence of official data, [5] we construct alternative measures of active IRM – two measures are based on the simulation approach of Dominguez, Hashinmoto, and Ito (2012) and three measures are derived from the detrended official international reserves data from IMF. These alternative measures are adopted to capture different IRM attributes related to valuation effects, interest rate compounding effects, and break effects.

The change in the VIX index (ΔVIX) are used as a proxy for global financial shocks.[6] A multiplicative regression setup (Brambor *et al*., 2006) is used to study the individual and interaction effects of IRM and ΔVIX on firm investment. We find that IRM has positive impacts on firm investment in EMEs, and the marginal impact depends on the type and the magnitude of global financial shocks.[7] In the presence of an adverse global financial shock, the marginal IRM effect increases with the magnitude of the adverse shock. If the global financial shock is favorable, the marginal IRM effect is inversely associated with the magnitude of the favorable shock. Further, the proxy for global financial shocks reduces firm investment even though IRM mitigates its impact.

Firm investment can be deterred by global financial shocks that heighten market uncertainty and push up financing costs (Christiano *et al*., 2014; Gilchrist *et al*., 2014; Arellano *et al*., 2019). Arguably, financially constrained firms are vulnerable to elevated financing costs. To assess the implications of a firm's financial conditions, our study considers three alternative ways to characterize financially constrained and unconstrained firms; namely, the capacity to access external financing (Rajan and Zingales, 1998), tangible assets coverage (Claessens and

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Jinjarak (2020) find that the active IRM policy can contribute up to about 3% of GDP during their sample period. An IRM policy may mitigate the impact of external adverse shocks and enhance economic performance via two channels; it a) lowers real exchange rate volatility induced by terms-of-trade shocks and b) provides self-insurance against sudden stops and fiscal shocks (Aizenman, 2008). In this paper, we focus on the latter – the self-insurance channel.

[5] Central banks of EMEs typically do not provide detailed information on their international reserves transactions (Dominguez et al., 2012).

[6] The VIX index, also known as the global financial fear factor, is commonly used to gauge the global financial market uncertainty and the degree of risk aversion (Forbes and Warnock, 2012, 2019; Rey, 2015; Di Giovanni et al., 2017).

[7] Results from alternative measures of IRM and global financial shocks are discussed in Section 5.

Laeven, 2003), and the shadow cost of external financing (Whited and Wu, 2006). Our results show that financial constraints can weaken a firm's response to the IRM policy and reduce the stabilizing IRM effect; the average positive effect of IRM on firm investment is about 40% smaller for financially constrained firms compared with unconstrained firms.[8]

Country spreads (or sovereign premiums) widen with unfavorable global financial shocks (Uribe and Yue, 2006; Akinic, 2013) and are a component of international borrowing costs faced by firms.[9] A high level of international reserves can alleviate the impact of global financial shocks on country spreads by acting as a buffer against speculative attacks triggered by these shocks (Ben-Bassat and Gottlieb, 1992; Bianchi et al., 2018, Cheung and Qian, 2009). Thus, we stipulate the active IRM policy affects firm investment via the country spread channel. Using the causal mediation analysis method (Krull and MacKinnon, 2001; Imai et al., 2010) with the country spread as the intermediate variable, IRM as the treatment, and firm investment as the outcome variable, we find statistical evidence that the IRM effect on investment is mediated through country spreads. The mediation effect differs across financially constrained and unconstrained firms – the former group has a level of 36% IRM effects channeled through country spreads, the latter group 22%, and the average across firms 28%.

Capital controls and exchange rate management are two policies deployed by EMEs to rein in the adverse effect of global financial shocks (Han and Wei, 2018; Obstfeld et al., 2019).[10] Our results show that countries with capital controls, compared with those without, display a more substantial IRM effect on firm investment. On the other hand, a flexible exchange arrangement reduces the downside effect of adverse external shocks. An IRM policy alone does not completely insulate an economy from external shocks; capital controls and flexible exchange management have a complementary role in alleviating the effect of adverse global financial shocks. These findings suggest a coordinated policy that integrates these macro-management measures to achieve efficient insulation of investment from global financial shocks.

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[8] The result is in line with Ottonello and Winberry (2019). They show in a New Keynesian model that low-risk firms (similar to non-financially-constrained firms in this paper) are responsive to monetary shocks because of their relatively flat marginal cost of financing investment.

[9] Two basic cost components of borrowing internationally are country (or sovereign) premium and firm specific risk premium. The Japan premium, for example, is a well discussed phenomenon in the 1990s.

[10] Bussière et al. (2015) and Acharya and Krishnamurthy (2018), for example, find capital controls complement international reserves in insuring against sudden stops.

Besides firm level impact, we assess the macroeconomic link between IRM and aggregate investment using a structural vector autoregression model that includes global financial shocks and country spreads. The country-level data also reveal the positive effect of active IRM on aggregate investment; specifically, EMEs on average increase their aggregate investment per GDP by 0.3 percent in two years in response to a one-standard deviation increase in active IRM. The country-level data also affirm the country spread causal channel effect revealed by firm level data – an adverse (favorable) global financial shock widens (narrows) country spreads, and deters (promotes) investment.

Our study makes several contributions. First, we identify the roles of IRM, global financial shocks, and their interactions in determining investment at the firm level in EMEs.[11] We extend the usual analysis of effects of international reserves on the macroeconomy[12] to firm level behavior. Second, we provide evidence of differential active IRM policy effects on financially constrained and unconstrained firms. Third, we hypothesize and verify that credit spreads are a channel through which an active IRM policy can alleviate adverse effects of global financial shocks on firm investment. In addition, our results suggest that active IRM is complementary to two other macro management policies: capital controls and exchange rate management in terms of stabilizing firm investment in the face of global financial shocks.

The remainder of the paper is organized as follows. Section 2 outlines channels and ways that IRM and global financial shocks can interact and affect firm investment. Section 3 introduces the alternative measures of active IRM policies and global financial shocks. Section 4 presents the main empirical specification and results on the effects of IRM and ΔVIX on firm investment. The results pertaining to financially constrained and unconstrained firms and country spreads are also reported. Section 5 provides additional analyses based on alternative measures of IRM and global financial shocks, and different sample configurations to assess the sensitivity of our results. Section 6 discusses the roles of capital controls and exchange rate management in determining the link between IRM and firm investment, and Section 7 assesses the macroeconomic relevance of our findings. Some concluding remarks are offered in Section 8.

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[11] Existing studies usually consider domestic or firm level investment uncertainty (Abel and Eberly, 1994; Bernanke, 1983; Bertola and Caballero, 1994; Caballero and Pindyck, 1996), macroeconomic and policy uncertainty (Aizenman and Marion, 1993; Beaudry et al., 2001; Bloom, 2009; Gulen and Ion, 2016; Kim and Kung, 2017), political uncertainty (Julio and Yook, 2012; Jens, 2017), and monetary policy uncertainty (Ottonello and Winberry, 2018; Husted et al., 2019).

[12] See, for example, Dominguez et al. (2012), Qian and Steiner (2014; 2017) and Aizenman and Jinjarak (2020).

2 Related literature surveys

In this section, we survey literature related to uncertainty, investment, and the precautionary role of international reserve. Based on the surveyed literature findings, we outline a plausible theoretical mechanism through which IRM and financial shocks interact to affect investment.

2.1 The related theories on uncertainty and investment

Investment literature has two main theories related to how uncertainty and financial risk shocks impact investment. One is the "wait and see" theory suggesting that, due to the irreversibility of investment, firms tend to hold off the investment and wait until the uncertainty is cleared before investing. This behavior creates an option value for "wait and see" strategy[13] and the value of option increases with uncertainty through the possibility of bad outcomes.

The other theory is based on the financial friction that limits firms' borrowing capacity. Uncertainty shocks drive up firms' credit spread (i.e., the premium in firm's debt interest rate over the risk-free interest rate) and increases the likelihood of default on their debt[14], thus leading firms to reduce capital expenditure. The financial friction theory has gained increasing attention since the havoc of the 2008 global financial crisis in the global financial market, which caused a plummet in global investment and other economic activities[15]. Several influential papers provide theoretical mechanisms by which financial uncertainty shocks can impact real economy activities through the channel of financial friction. For instance, Gilchrist *et al*. (2014) model financial friction as a conduit through which uncertainty shocks affect investment, and find that jumps in uncertainty reduce the collateral value of firms' capital assets, thus decreasing the firms' debt capacity and leading to widening credit spreads, which induces firms to simultaneously slash capital expenditures.

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[13] See Bernanke (1983), Bloom, Bond, and Van Reenen (2007) and McDonald and Siegel (1986), among others.
[14] A vast literature shows sovereign spread and cross-border capital flows in EMEs are typically driven by global factors; for example, Uribe and Yue (2006), Forbes and Warnock (2012), Rey (2015), and Aguiar et al. (2016).
[15] The literature indicates that financial shocks play an increasingly important role in affecting economic activities. Jermann and Quadrini (2012) find that financial shocks that affect firms' ability to borrow is more important for macroeconomic fluctuations than productivity shocks. Akinci (2013) suggested that global financial risk shocks explain about 20% of the movements both in the country spread and in the aggregate activity in emerging economies. In their comprehensive empirical work, Obstfeld et al. (2019) point out that global financial shocks negatively affect both financial conditions in EMEs (e.g., credit growth, house price, stock returns, change in loan-to deposit (LTD) ratio, and net capital flows) and real economy GDP growth.

Through the interest rate channel, Christiano *et al*. (2014) construct financial friction in their model by allowing a firm to receive debt, the interest rate on which includes a premium to cover the costs of default when the firm suffers a “bad” enough shock. These shocks, labeled as risk, are idiosyncratic and random. In a DSGE model setting, credit spreads fluctuate with the changes in risk. When risk is high, credit spreads are high and the firm’s borrowing ability is low; as a result, investment falls.

From the perspective of the possibility of debt default, Arellano *et al*. (2019) implement financial friction in their model by assuming financial markets are incomplete and firms can only borrow state-uncontingent debt, on which the firm may default. Idiosyncratic shocks occur after the hiring of labor inputs, but before the realization of the revenues generated by labor inputs. An increase in uncertainty arising from the volatility of idiosyncratic productivity shocks causes the revenues from any given amount of labor to be more volatile, the probability of a default more likely, and higher borrowing costs. In equilibrium, their model suggests that an increase in volatility leads firms to pull back on their hiring of inputs.

The financial friction theories are particularly applicable for EME firms that rely on borrowing external capitals to invest and output, but usually are bound by financial constraints and limited borrowing capacity. Caballero *et al*. (2019) find that adverse external financial shocks create a spillover effect to drive up EME corporate bond spreads, worsen financial friction, and restrain firms’ borrowing capacity, thus imposing a downside impact on output, consumption, and investment.

2.2 Theories on the precautionary role of international reserves and country spreads

EMEs usually deploy multiple macro-management tools to address the spillover from external uncertainty shocks (Ostry et al. 2012; Acharya and Krishnamurthy, 2018), one of which is the accumulation of international reserves that provide both self-insure and buffer stock against the external shocks, thus ensuing the stability of financial and economic activities. To support this line of argument, it is necessary to link together the models that study theoretical mechanism of international reserves’ stabilizing EMEs financial conditions and the models explaining how worsening financial frictions reduces investment. While the latter has been discussed above, the former comprises the models that focus on how international reserves reduce country/sovereign spreads by reducing the likelihood of *sudden stops* (either exogenous or endogenously generated in the model) or lowering risk of sovereign default, thus leading to lower sovereign borrowing costs and improving welfare. For instance, Jeanne and Ranciere (2011) model international reserves as a state contingent security that pays off in an exogenous sudden stop in a welfare-maximization model. Similarly, Caballero and Panageas (2008) propose a model with self-insure government financial instrument that is contingent to income-growth shock. They demonstrate significant output gain from the financial instrument that self-insure again both the occurrence of sudden stops and the changes in the probability of sudden stops. Endogenizing sudden stops in an open economy version of Diamond and Dybvig (1983) model, Aizenman and Lee (2007) show that reserves can serve as self-insurance to avoid costly liquidation of long-term projects susceptible to sudden stops. The welfare gain from the optimal IRM is found to be significant. It reduces the output cost of sudden stop shocks from first-order to second-order magnitude.

In addition to sudden stops, international reserves play a role in lowering sovereign default/rollover risk. Bianchi *et al*. (2016) model along this perspective, suggesting that an indebted government is better off to accumulate reserves when it borrows in long-term debt that is susceptible to default risks. The mechanism is that a negative shock tends to increase sovereign spreads, making it costly for the government to rollover its debt. Holding reserves in the state of bad shock can hold off the impact of shock by reducing the government's borrowing cost, hence mitigating the drop of consumption.

Related to IRM and global financial shocks, Jeanne (2016) outlines a welfare-based model of capital flow with banking friction. There is a possibility that banks have to fire-sale their assets and reserves are used to buy fire-sale assets. Thus, the fire-sale price, which can be considered as a country spread [or interest rate in Jeanne (2016)], is determined by the accumulated reserves and the probability of fire-sale. The model suggests that an EME government can mitigate financial friction by engaging in active IRM to gain social welfare benefits.

Summarizing the surveyed theories in Sections 2.1 and 2.2, we postulate that external uncertainty shocks widen the country spreads of EMEs, whereas IRM narrows their country spreads. An equilibrium credit spread, which balances the opposite impacts of uncertainty shocks and IRM, in turn, determines the level of investment, other things being equal.

3 Measurements for IRM and global financial shocks

3.1 Measurements for IRM

An active IRM strategy that accumulates international reserves in tranquil times while selling reserves assets during crisis periods is easy to describe but difficult to measure. Several issues complicate the measurement for IRM. First, central banks do not disclose the time and amount of their purchases and sales of international reserves; second, changes in reserves assets calculated from official international reserves data may mis-measure active IRM, as the changes in reserves may stem from the interest income of reserve assets and the valuation effect (two passive management components of IRM); third, central banks usually do not report reserve assets investment income and the valuation effect; Further, it is difficult to estimate these passive management components of IRM as central banks typically do not disclose reserve assets investment portfolio and the currency composition of international reserves. Finally, some countries with large international reserve holdings tend to “under-report” reserves to deflect criticism of mercantilist motives and excessive reserves.

Against this backdrop, we use two methods, a simulation and a detrend method, to estimate the measurement data for active IRM. The simulation method follows Dominguez et al. (2012) (DHI hereafter) to calculate IRM by adjusting the simulated passive management portion from the total change in international reserves. This simulated IRM, which is in US dollar term, is then scaled by GDP (in the current US dollar) to create the first IRM measurement[16], labeled as IRM-DHI-1. In addition, we extend the DHI approach by adjusting the valuation effect that are estimated from the currency composition of international reserves to create the second IRM measurement. We subsequently label it as IRM-DHI-2 after scaled by GDP.

The detrend method purges passive management components of IRM by using a linear regression to detrend the international reserves data; the remainder is considered as the active management components of IRM. The rational is that international reserves data contain a secular trend, which is partly due to two passive management components of IRM – the compounded interest income and the valuation effect on reserve assets. Detrending data may remove these passive management components from international reserves data. We detrend three types of trends, namely, a simple linear time trend, a time trend with a structure break at the

[16] Dividing GDP to the dollar term IRM is to make different IRM measurements be comparable across EMEs with different economy size.

2008 global financial crisis (Aizenemnt *et al*., 2014; Bussiere *et al*., 2015), and a time trend after the reserve data been adjusted for the valuation effect. These detrended reserves data are then scaled by GDP to create measurements for active IRM. We label them IRM-1, IRM-2, and IRM-3, respectively. The detail constructions of IRM measurements using both simulation and detrend methods are presented in Appendix A, in which we also use figures (See Figures A1 – A4) to analyze the similarities across these measurements and their comparability to those of Dominguez et al. (2012). Overall, these measurements of IRM reveal the general pattern of active IRM – central banks accumulate reserves at good times, while using them during crises periods (See Figure A5).

Between two groups of IRM measurements, we expect that the IRM measurements simulated from DHI approach to be more reliable than the detrended IRM measurements as DHI primarily uses the actual data to obtain the IRM data, whereas the estimated IRM measurements are regression estimated data. However, the DHI simulations are based on data from different data sources that might entail data compatibility issues. In addition, many EMEs do not subscribe to the IMF SDDS template, thus they do not have the data that we need to simulate for IRM. Furthermore, some subscribers to SDDS only started to report IR data in the 2010s. For example, China began to report its reserves data in 2015. These data availability issues could reduce about 1/4 of our sample size. On the other hand, the data used for regression estimated IRM measurements, although associated with possible estimation errors, is reported for most EMEs from 2000 to 2018 by the IMF IFS database. For these reasons, we will use the regression estimated IRM measurements to run main regression analyses, and use the DHI simulated IRM to check for robustness.

3.2 Measurements for global financial shocks

To empirically investigate how global financial shocks impact firm investment across EMEs, it is essential to have a measurement of global financial shocks that is exogenous to both firm and country specific conditions. Shocks that stem from center countries (e.g., the US) and have a global scale impact may meet the exogeneity condition.

We first use ΔVIX, the percentage change of the VIX index. The VIX index is commonly used to measure global scale financial uncertainties and risk averse (Forbes and Warnock, 2012, 2019; Rey, 2015; Di Giovanni et al., 2017). The VIX is the index for the implied volatility of the S&P 500 stock option, thus originated in the US. But it creates global impacts; for example, Miranda-Agrippino and Rey (2020) identify a global factor that explains 20% of international risky assets prices comoves with the VIX index.

Using ΔVIX as opposed to the VIX index itself as a measurement for global financial shocks is motivated by literature findings that it is the shock/innovation to uncertainty that impacts economic activities including investment, regardless of uncertainty level (Gilchrist *et al*., 2014)[17]. Some literature papers also use a simple time dummy variable to capture the notable financial shocks, such as the 2008 global financial crisis (Bloom, 2009). We argue that, relative to the time dummy measurement, using ΔVIX to measure global financial shocks is advantageous because the changes in the VIX index not only indicate the timing of global financial shocks, but also quantify the relative magnitude of those shocks and can suggest whether an external shock is favorable or adverse shock (i.e., we identify a shock to be adverse if $\Delta VIX > 0$ when the global financial uncertainty increases).

Second, we use the changes in the intra-annual volatility compiled according to Merton (1980) from the daily data of S&P 500 index (Appendix C provides details of data construction). Contrasting to the VIX index that measures the implied volatility of S&P 500 stock option, the intra-annual volatility provides a representative measure for the perceived volatility.

Third, using both the VIX and intro-annual volatility limit our study to the standard practice that the US equity market is the center of global finance. To broader the “global” sense, we compile a “risk-on/risk off” (RORO) index that captures the variation of risk aversion of various asset markets across the US and Europe to measure shocks in global financial market. Following Chari et al. (2020), we build the RORO index by extracting the first principal component of the daily data across several asset markets (e.g. treasury market, corporate bond market, equity market, and funding liquidity both in the US and in the Euro Area). To build a multifaceted index that reflects various risky asset markets, we include data of 1) credit risk: changes in the ICE BofA BBB Corporate Index, Option-Adjusted Spread for the United States and for the Euro Area, and Moody’s BAA corporate bond yield relative to 10-year Treasuries; 2) equity returns and implied volatility in the US and Europe: the additive inverse of daily total

[17] Other papers include, for example, Caballero et al. (2019) use ΔVIX to measure global credit market shock that affects the association between EME economic activities and their corporate bond spread. Similarly, Bloom’s (2009) suggests that large changes in uncertainty, have an important impact on investment and hiring behavior. Arellano et al. (2018) shows that “hiring inputs is risky because financial frictions limit firms’ ability to insure against shocks. An increase in volatility induces firms to reduce their inputs to reduce such risk.”

returns on the S&P 500 and STOXX50, together with the VIX and the VSTOXX index; 3) funding liquidity: changes in the TED spread and the bid-ask spread on 3-month Treasuries.

Fourth, we apply the percentage changes of the Federal fund rate as an alternative measurement for global financial shocks to EMEs. The US monetary policy is well documented to impose substantial spillover effect on the global financial market (Gilchrist *et al*., 2019; Obstfeld *et al*., 2020). When the Federal Reserve Bank tightens its policy, risky asset prices surge, accompanied by strong deleveraging of global banks and a surge of risk averse in global asset markets, ensuing the contraction of the global credit supply and a strong retrenchment of international credit flows from emerging markets (Miranda-Agrippino and Rey, 2020). The spillover effect of U.S. monetary shocks could transmit through the global banking system (Cetorelli and Goldberg, 2011; De Hass and Van Horen, 2012; Kalemli-Ozcan et al., 2013; Morais et al., 2019) and the international debt market (Caballero et al., 2019; di Giovanni et al., 2019).

Finally, we use the US monetary policy uncertainty index (MPU) and the US economics policy uncertainty index (EPU) of Baker *et al*. (2016) to measure global uncertainty shocks. Both are news-based indexes capturing the degree of policy uncertainty that the public perceives about the Federal Reserve's monetary policy and the US government's economic policy stance and their possible consequences. As a high MPU and EPU imply high uncertainty shocks emanated from the center country to EMEs, we expect both MPU and EPU to impose a spillover effect on firm investment in EMEs.

4 Empirical methodologies

4.1 The base model for firm investment

In this section, we examine the firm level evidence on the effects of IRM on investment in EMEs in the presence of global financial shocks. We specify a multiplicative regression model based on the canonical investment-Q framework (Hayashi, 1982; Eberly et al, 2009) as follows:

$$Invest_{i,t} = \alpha + \mu_j + \theta_t + \beta_1 IRM_{c,t-1} + \beta_2 \Delta VIX_t + \beta_3 IRM_{c,t-1} \times \Delta VIX_t + \gamma X_{c,t} + \delta Z_{i,t} + \varepsilon_{i,t} \quad (1)$$

The dependent variable $Invest_{i,t}$ is measured as $\frac{Captial\ expenditure_{i,t}}{Total\ Assets_{i,t-1}}$, the ratio of firms' capital expenditure on plants, properties, and equipments to total assets at the beginning of the year (Julio and Yook, 2012; Panousi and Papanikolaou, 2012; Gulen and Ion, 2016; Husted et al, 2019); undersubscriptions *c*, i, and *t* index country, firm, and year, respectively. Fixed effects that include country, industry sector (SIC-3 digit), and firm effect are included in μ_j and the year effect is in θ_t.

$IRM_{c,t-1}$ is the active reserve management variable. We first use IRM-1 as the IRM measurement for regression analyses (The results obtained from other IRM measurements are checked for consistence in Section 5). To mitigate for possible endogeneity, we lagged IRM-1 for one year to convert it into a predetermined variable. Further, we generate a IRM variable purged of common factors that affect both IRM and investment simultaneously. These common factors include relative income levels, net capital inflows, and competitive depreciation to maintain exports advantage, all of which tend to lead central banks to accumulate more reserves and firms to invest more. To purge the common factor effect, we run a regression of IRM on the ratio of national income per capita to the US national income per capita, the net international investment position, and the ratio of PPP convertor ratio to exchange rate (a measure of the relative price level), as well as the country and year effect. The residual of the regression is obtained as the IRM purged of common factors effect.

As we discussed previously, ΔVIX_t measures shocks to global financial market. A positive ΔVIX indicates an adverse global financial shock; the higher value of ΔVIX, the worse the shock. To quantify the total effect of IRM on firm investment conditional on the presence of external shocks, we include an interaction term, $IRM_{c,t-1} \times \Delta VIX_t$, thus specifying a multiplicative regression of equation (1) (Brambor et al., 2006). The total effect of IRM on investment estimated from equation (1) is given by $\partial Invest/\partial IRM = \beta_1 + \beta_3 * \Delta VIX_t$, which implies that the marginal effect of IRM depends on financial shocks, ΔVIX_t. The corresponding standard errors are calculated by $\hat{\sigma} = \sqrt{var(\hat{\beta}_1) + \Delta VIX_t{}^2 var(\hat{\beta}_3) + 2\Delta VIX_t cov(\hat{\beta}_1, \hat{\beta}_3)}$. Similarly, the effect of ΔVIX_t is given by $\partial Invest/\partial \Delta VIX_t = \beta_2 + \beta_3 * IRM_{c,t-1}$, indicating that the marginal effect of financial shocks on investment is conditional on active IRM.

Following the literature, we control for two domestic macroeconomic factors that affect firm investment (Julio and Yook, 2012; Gulen and Ion, 2016; Husted et al, 2019) in $X_{c,t}$, namely, the real GDP growth rate ($RGDPG$), which captures domestic investment opportunity, and investment risk profile ($Risk\ profile$) that measures the institutional risk of domestic investment. Using of $Risk\ profile$ captures the institutional risk and avoid the potential collinearity with ΔVIX_t. Although our study focuses on shocks in the global financial market, country specific domestic financial shocks can affect firm investment as well. An appropriate investment regression therefore needs to include both global and domestic financial shocks. However, including both financial shocks simultaneously gives rise to collinearity issue, as global shocks spillover into the domestic financial risks and they comove[18]. To address this issue, we use a domestic institutional risk factor, proxied by the "investment profile" index from the ICRG to measure domestic investment risk environment. Our investment profile index contains three risk components, namely contract viability, profits repatriation, and payment delays, which capture the institutional aspect of domestic investment risk and are less likely to be associated with short-term financial risk shocks.

Four commonly identified firm specific factors that determine firm investment behaviors are included in $Z_{i,t}$: 1) Tobin's Q, 2) cash flow from operation (*CF*), 3) firm size (*Size*), as represented by firm's total assets, and 4) sales growth rate (*Sales growth*); Tobin's Q measures the market to book value ratio of firm assets; *CF* measures the cash flows generated from business operation on firm's assets and reflects the marginal product of capital (Gilchrist et al, 2014); and *Sales growth* measures business growth. Literature found that firms invest more, when Tobin's Q (the shadow price of installed capital) is higher (Tobin, 1969; Able and Eberly, 1994), the firm size is larger, and there are more cash flows from operation and higher sales growth of the business (Julio and Yook, 2012; Gilcrist et al, 2014; Gulen and Ion, 2016; Ottonello and Winberry, 2018).

We estimate equations (1) on cross-firm annual data using the pooled OLS regression controlling for country, industry sector, firm and year effects. We calculate the robust standard errors clustered at the firm level. Firm level data are obtained from annual accounting statements

[18] For example, Akinci (2013) shows that global financial shocks explain 20% of country sovereign spreads. Gourio et al. (2013) found there is an international risk cycle in which country specific financial risks highly correlated across countries; they comove.

of 21,447 publicly listed companies in 46 EME from 2000 – 2018 in the Thomson Reuters Worldscope database[19]. Following the convention (Julio and Yook, 2012; Ottonello and Winberry, 2018; Husted et al., 2019), we exclude financial, insurance, real estate, public administration, and non-classifiable industry sectors in SIC code system and countries that have less than 15 listed companies from the dataset. We winsorize the investment variable at the 1st and 99th percentiles in order to minimize the impact of data errors and outliers. Then we match firm level data to global and country level data for our regression analyses.

The estimation results for the base model are reported in Table 1. We first show in column (1), without explicitly accounting for the possibility that the effect of IRM is conditional on global financial shocks, that active IRM is positively associated with investment and that global financial shocks (ΔVIX_t) are negatively associated with investment. Both findings are consistent with those reported in the literature discussed in Section 2. Among other factors, we find that higher real GDP growth and lower institutional risk promote firm investment in EMEs. Firms that have high Tobin's Q, more cash flows generated from operations, larger size, and higher sales growth rate are found to invest more. All these results are in accordance with literature findings. The regression explains 10.8% of firm investment variation[20].

Column (2) reports the results for the effect of IRM conditional on global financial shocks. Both β_1 and β_3 are estimated positively and significantly. The marginal effect of IRM therefore is evaluated at 0.02+0.034*ΔVIX_t, suggesting that IRM is positively associated with firm investment and the total effect depends on global financial shocks – in the presence of a one-standard-deviation adverse financial shock ($\Delta VIX_t = 0.28$), one percent increase in IRM is associated with about 3% higher firm capital expenditure to total assets ratio. To better assess the economic significance of IRM effects, we take the median size firm in the median GDP country (The Philippines [21]) in our data sample to calculate the aggregate effect of IRM on a country's

[19] Thomson Reuters' Worldscope database provides firm level accounting data of publicly listed companies from more than 70 developed and emerging markets, and accounts for more than 96% of the market value of publicly traded companies across the globe. However, the data availability varies substantially across countries, particularly for emerging markets and developing countries. Due to the limited availability of quarterly data (for some countries and firms, there are more missing data points in the quarterly data than in the annual data), we used annual data in this paper. Appendix C displays the variable definitions and data sources; Appendix D shows summary statistics.

[20] The R-squared we obtained is comparable to those of related literature papers; for example, Julio and Yook (2012) model estimates an R-squared of 7%, Gulen and Ion (2016) reported 3% and Ottonello and Winberry (2018) estimated 12%.

[21] The median GDP country is the Philippines whose average GDP in 2000 – 2018 is about 199 billion USD and the median size of Philippines firms is about 6 billion. There are totally 222 Philippines firms in our data sample.

firm investment. We find that one billion US dollar active IR accumulation is associated with about 0.92 million of more firm investment in the presence of one standard deviation VIX shock[22]. For a total of 222 Philippines firms in our data sample, the aggregate effect of one billion IRM in the Philippines is associated with about 200 million more investment made by these publicly listed firms in the Philippines[23].

To better interpret how the effect of IRM conditional on global financial shocks, we plot the linear relation between the marginal effect of IRM and ΔVIX_t in the upper panel of Figure 1. The solid line along with two dash-lines (95% confidence intervals) represents the linear relation, showing that the IRM effect becomes stronger as the magnitude of global shock increases. In the adverse shock zone ($\Delta VIX_t > 0$), where firms receive an adverse shock, active IRM has a positive effect on firm investment, regardless of the magnitude of realized global financial shocks. However, as the realized adverse shock grows worse, IRM's marginal effect on firm investment becomes larger. Figure (1) shows that, as the VIX index increases one percent, IRM is associated with 0.034 more firm investment compared to the situation lacking global financial shocks.

On the other hand, in the favorable shock zone (where $\Delta VIX_t < 0$ at the upper panel of Figure 1), the positive effect of IRM diminishes as the favorable shock increases in magnitude (i.e. ΔVIX_t becomes more negative). In fact, the effect of IRM may become insignificant if there are sufficient improvements in the risk aversion of global financial market. This occurred in 2009 when the global financial market stabilized from the turmoil of the 2008 financial crisis.

In addition to the direct analyses concerning the effect of IRM on firm investment, the multiplicative regression results suggest how IRM affects investment by reducing the downside effect of global financial shocks on investment. We estimate in column (2) that the marginal

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[22] We calculation the dollar value of 1 billion IRM effect on firm investment according to the following math formula: capital expenditure/total assets of the median firm = $(0.02 + 0.034 * \text{standard deviation of } \Delta VIX) * (1 \text{ billion} / \text{GDP of the median country})$, where total assets of the median firm = 6 billion, the standard deviation of ΔVIX is 0.28, and median country GDP is 199 billion USD. We can solve capital expenditure in the US dollar term for the effect of 1 billion US dollar IRM on individual firm investment. Additionally, as the distributions of country GDP and firm size within a country are not normally distributed, the median size firm and country are different from the average size firm and country. In our data sample, the average GDP country is Poland, which had an average annual GDP of 406 billion US dollar and listed 620 public companies with average size of about 1.36 billion US dollar in 2000 - 2018. Using the data of the average firm in Poland, our results suggest that 1 billion of IRM in Poland is associated with 61 million investments in Polish publicly listed companies.

[23] The effect is likely to be understate as we do not account for firms other than publicly listed companies in the Philippines.

effect of ΔVIX_t on investment is $-0.091 + 0.034 * IRM_{c,t-1}$, a term indicating that the marginal effect of ΔVIX_t depends on the level of IRM. That is, one percent more IRM last period reduces the effect of adverse shock by 0.034. Evaluating this effect of IRM on investment in US dollar values, we show that 1 billion dollars more IRM in the last period in the median GDP country tends to mitigate the downside impact of adverse global shock on firm investment about 1.04 million US dollar in a median size firm. This result is economically significant and suggests that IRM provides a buffer stock service to reduce the negative effect of global financial shocks[24].

To facilitate interpretation, we plot the marginal effect of ΔVIX_t at different levels of IRM in the lower panel of Figure 1. This plot shows that ΔVIX_t negatively impacts firm investment irrespective of the level of active IRM, implying that the adverse spillover from global financial shocks is not completely insulated, if EMEs rely on active IRM alone. Policy makers perhaps need to invoke other macro-tools to achieve their goals of maintaining the stability of financial and real economy in EMEs (Ostry et al., 2012). However, despite no complete insulation, the negative effect of ΔVIX_t is mitigated as the level of IRM increases, reflecting the buffer stock role of international reserves.

We also report the results using the IRM measurement purged of effects from the relative level of national income, net capital inflows, and the mercantilist motive to depreciate currency value in column (3). The results are similar to those in column (2) except that the IRM related variables display larger coefficients. Our results are consistent after controlling for the possible endogeneity issue arisen from the common factors that affect IRM and investment simultaneously. In fact, purging of common factors effect makes the estimated effect of IRM more prominent.

4.2 **Firm heterogeneity in financial frictions**

Firms, especially the corporate sector in emerging economies, borrow externally to finance their investment, a trend that has increased considerably since the early 2000s (Caballero *et al*., 2019). However, EME firms' accessibility to global capital market is severely hampered by financial shocks and crises that interrupt global credit supply and the ensuing sudden stops. Caballero *et al*. (2019) find that external borrowing costs, reflected in credit spreads, respond

[24] Although the buffer stock effect is estimated to be economically significant, it is possible that we under-estimate it because we do not explicitly account for the devastating crises avoided by countries that hold sufficient international reserves.

strongly to global financial risk shocks emanating from world capital markets, resulting in lower economic activities in EMEs. Issues related to how adverse external shocks heighten firm financial friction can reduce investment has been discussed in several recent papers (e.g. Christiano *et al*., 2014; Gilchrist *et al*., 2014; Arellano *et al*., 2019). Firms that are heterogenous in financial constraints are found to invest differently under uncertainty shocks.

In this section, we investigate how the investments of firms with heterogenous financial constraints respond to active IRM differently at the presence of global financial shocks. To do so, we augment equation (1) with a firm level financial constraint variable, $FinCnstr_{i,t}$, and its interaction term with IRM, ΔVIX, and $IRM_{c,t-1} * \Delta VIX_t$ as follows:

$$\begin{aligned} Invest_{i,t} = \alpha + \mu_j + \theta_t + \beta_1 IRM_{c,t-1} + \beta_2 \Delta VIX_t + \beta_3 IRM_{c,t-1} * \Delta VIX_t + \theta_1 FinCnstr_{i,t} \\ + \theta_2 FinCnstr_{i,t} \times IRM_{c,t-1} + \theta_3 FinCnstr_{i,t} \times \Delta VIX_t \\ + \theta_4 FinCnstr_{i,t} \times IRM_{c,t-1} \times \Delta VIX_t + \gamma X_{c,t} + \delta Z_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (2)$$

To facility the interpretation of three-way interaction term results, we follow the heterogeneity-based difference-in-difference methodology (Khwaja and Mian, 2008; Chodorow-Reich, 2014; Jimenez et al., 2014), to generate dichotomous dummy variables that categorizes whether a firm is financial constrained or financially unconstrained. Dummy variables are created based on the following three firm level financial constraint measurements, each of which will be included in $FinCnstr_{i,t}$ in equation (2) for regressions:

The first of these financial constraint measures is firms' capacity to access external finance, calculated as (Capital expenditure – CF)/Capital expenditure (Rajan and Zingales, 1998: RZ). Although we use the same formula as RZ to calculate firm external finance dependence, we depart from the usual interpretation of RZ's measurement, that is, a high external finance dependence indicates that firms are more financially constrained. We argue that higher RZ measurement in Emerging Markets may indicate firms' superior borrowing capability, reflecting firms' better access to external finance sources (possibly superior management, better reputation, etc.). Amidst periods of adverse global financial shocks, high borrowing capacity firms access to more external fund sources than lower capacity firms; or it is possible that high capacity firms win over external funding sources that previously funded lower capacity firms, thus exacerbating the dire situation of those lower capacity firms, leading to further drop in latter's investment activities. Based on this argument we generate a dummy variable, *Ext fin* = 1 to indicate a firm is financially constrained if a firm's RZ ratio is less than the country-industry sector (SIC 3-digit) average level of RZ ratio; Otherwise, *Ext fin* is assigned a value of 0 to indicate that the firm is a financially unconstrained firm.

The second measurement is the ratio of tangible assets to long-term liabilities (Claessens and Laeven, 2003; Rajan and Zingales, 1998). Tangible assets can be used as collateral to reduce the default risk of long-term debt; thus, a high tangible asset to long-term debt ratio suggests lower default risk and borrowing costs. When credit is scare during global financial shocks, firms with high tangible asset to long-term debt ratios are expected to be less impacted in terms of their ability to borrow externally and finance their investment than those low-ratio firms. Accordingly, we generate a dummy variable, *Tangi*, and assign a value 1 if the ratio of tangible assets to long-term liabilities is less than the country-industry sector (SIC 3-digit) average ratio. Otherwise, we set *Tangi* = 0 to indicate financially unconstrained firms.

The third one is the shadow cost of external financing. We use the Whited and Wu (2006) financial constraint index that is estimated based on a structural model:

$$WW\_cost_{it} = -0.091 * CF_{it} - 0.062 * \text{DIVPOS}_{it} + 0.021 * TLTD_{it} - 0.044 * LNTA_{it} + 0.102 * ISG_{it} - 0.035 * SG_{it}$$

where CF_{it} is cash flow to total assets ratio; $DIVPOS_{it}$ is a dummy variable indicating whether the firm pays cash dividend; $TLTD_{it}$ is the ratio of long-term debt to total assets; $LNTA_{it}$ measures the size of the firm; ISG_{it} is the sales of SIC three-digit industry sales growth; and SG_{it} represents total sales growth. A high shadow cost of external financing reduces firms' adjustment ability of investment when the global financial condition worsens. We generate a dummy variable, *WW* = 1 to indicate a firm is financial constrained if *WW_cost* is higher than the country-industry sector (SIC 3-digit) average level of *WW_cost*; otherwise, the firm is labeled as financially unconstrained firm and we let *WW* = 0.

Table 2 reports the results of equation (2). Column (1) shows how financially constrained firms (measured by *Ext fin*) invest differently than financially unconstrained firms in response to active IRM in the presence of global financial shocks. Although all firms positively respond to IRM, the investments of financially constrained firms are less responsive to IRM than those of unconstrained firms. According to our estimates, the total effect of IRM of financially unconstrained firms is 0.038 + 0.073*ΔVIX, whereas for financially constrained firms, it is 0.009

+ 0.011*ΔVIX. Applying these results to the median size firm at the median GDP country for a comparison in the US dollar term, our results suggest that the financially constrained median size firm invests 0.37 million in response to 1 billion US dollar increase in IRM when there is a one standard deviation global financial shock, while the median size unconstrained firm responses to IRM by investing as much as 1.8 million US dollar. This contrasting effects of IRM on the two types of firms is also showed on the upper panel of Figure 2, where the solid line and dash-line (their 95% confidence intervals are in dot-line) plot the total marginal effect of IRM at different magnitudes of global financial shock for financially constrained and unconstrained firms, respectively. As shown, financially unconstrained firms are more responsive to IRM irrespective of the magnitude of external shock. On average, financially unconstrained firms are 4.5 times more responsive than financially constrained firms. In addition, the responses of unconstrained firms' investment to IRM intensify sharply as the magnitude of adverse shocks increases. By contrast, the effect of IRM on investment in financially constrained firms appear to be relatively small and it becomes insignificant when there is large external shock, favorable or adverse. These results are consistent to Ottonello and Winberry (2019) who find that low default risk firms are more responsive to monetary policy stimulus shocks because the marginal cost curve of low-risk firms is relatively flat.

Similar results are found regarding how different types of firms respond to global financial shocks differently. As shown in the lower panel of Figure 2, global financial shocks reduce firm investment in both types of firms regardless of the level of IRM. However, this detrimental effect of global financial shocks is markedly alleviated in financially unconstrained firms, but not in firms that are financially constrained as the level of IRM increases. This contrasting result implies that financially unconstrained firms are more responsive to IRM than financially constrained in terms of IRM's role in reducing downside effect of global financial shocks.

Similar results are estimated in columns (2) and (3) when we use *Tangi* and *WW* to define financially constrained firms. In addition, although *Ext fin*, *Tangi* and *WW* measure financial constraint from different perspectives, they perhaps share a common dimension that aligns with firms' overall level of financial constraints. To capture this common dimension, we use principal component analysis (PCA) to extract the first principal component of three firm financial constraint measurements and label it *Fin constr*. We use *Fin constr* to create a dummy variable that measures financially constrained and unconstrained firms, then add it to equation (2) for regression. The results of this regression reported in column (4) of Table 2 are comparable to those in columns (1) – (3), except that both effects of IRM are smaller for both financially constrained and unconstrained firms.

In sum, active IRM extends a positive effect on firm investment in EMEs, the degree of which, however, differs across firms that are heterogenous in financial constraints. Financial unconstrained firms are substantially more responsive to the positive impact of IRM relative to financially constrained firms. These findings suggest the importance to consider firm heterogeneity in examining how macro-management policies, such as active IRM, affect financial and real economic activities. Macro management policies may be not very effective if firms are financially constrained; thus, to ensure the policy effectiveness, EME policy makers may need to consider the distribution of firms based on their financial constraints and apply corresponding policies.

4.3 **A causal effect mechanism**

We documented empirical evidences that active IRM is positively associated with firm investment. A further question is: what is the causal mechanism through which active IRM increases firm investment in EMEs? In this section, we test a plausible causal channel.

The results in Section 4.2 imply that firm financial constraints and the related cost of finance significantly influence the association between active IRM and firm investment. This is in line with the literature overviewed in Section 2. Active IRM lowers country spread (a key component of firms' finance cost), which, in turn, induces firm investment. Therefore, we conjecture that country spread serves as a causal channel through which IRM transmits its effect to firm investment. Our conjecture is consistent with Uribe and Yue (2006) and Akinci (2013). These authors show that the effect of international financial conditions on EME economic activities is driven by their effect on sovereign spread/country spread. Similarly, Caballero et al. (2019) find that the changes in corporate bond spreads serve as a powerful propagating mechanism for the effect of changes in global investors' risk appetite in emerging markets.

To test this plausible causal effect, we apply the causal mediation analysis approach (Krull and MacKinnon, 2001; Imai et al., 2010). Mediation analysis quantitatively evaluates the causal mechanism through which an intervention (central banks' active IRM strategy) affects an outcome (firm investment) and is able to separate the total intervention effect into an indirect effect that operates through observed mediators (country spread) and a direct effect that directly affect the outcome without going through the mediators. This analytic approach has been used in economics to produce an early macro-econometric model used by the US (Klein and Goldberger, 1955), to develop economic forecasts and policy (Theil, 1958), and, more recently, to study the effect of trade integration between China and Eastern Europe on voting in Germany (Dippel *et al.*, 2015) as well as to examine how the 1990s trade liberalization in Brazil affected crime through its impact on labor market condition (Dix-Carneiro *et al.*, 2018).

We use the J.P. Morgan Emerging Market Bond Spread Index (EMBI+) that reflects the difference between the yields of EME government bonds and those of the U.S. Treasury securities to measure country spreads. Since our data have two levels, the country level and firm level data, we use Krull and MacKinnon's (2001) multilevel mediation regression that allows firm data to cluster at the country level and accounts for within-country homogeneity in the error terms of the regression.

The multilevel mediation regressions are specified as follows:

$$Country\ spread_{c,t} = \alpha + \mu_c + \theta_t + \beta_1 IRM_{c,t-1} + \beta_2 \Delta VIX_t + \beta_3 IRM_{c,t-1} * \Delta VIX_t + \gamma_1 X_{c,t} + \varepsilon_{c,t} \quad (3)$$

$$Investment_{i,t} = \alpha + \mu_j + \theta_t + \beta_4 IRM_{c,t-1} + \beta_5 \Delta VIX_t + \beta_6 IRM_{c,t-1} * \Delta VIX_t + \tau\ \widehat{Country\ spread}_{c,t} + \gamma_2 X_{c,t} + \delta Z_{i,t} + \varepsilon_{i,t} \quad (4)$$

Equation (3) is the country level regression examining the marginal effect of IRM on country spreads. As we discussed in Section 2, global financial uncertainty shocks drive up EME credit spreads[25] and active IRM lowers them. We include IRM, ΔVIX, and their interaction term as the determinants to country spreads, along with two macro factors, *RGDPG* and *Risk profile*, and the country and year effects as the determinants of country spreads.

Equation (4) augments equation (1) with the mediator variable, $\widehat{Country\ spread}_{c,t}$. Due to endogeneity concern, we do not directly include $Country\ spread_{c,t}$ variable to be the

[25] Other papers examining the effect of global financial condition on EME credit spreads include Arora and Ceisola (2001), Gonzalez-Rozada and Levy-Yyati (2008), Ciarlone et al. (2009), Akinic (2013), de Giovanni et al. (2017), and Gilchrist et al. (2019).

mediator variable as suggested by the standard specification of causal mediation regression. Rather, we obtain the error terms of equation (3) that are orthogonal to $IRM_{c,t}$, ΔVIX_t, and $IRM_{c,t} * \Delta VIX_t$, label it as $\widehat{Country\ spread}_{c,t}$ and add it to equation (4). $X_{c,t}$ controls for country level variables, *RGDPG* and *Risk profile*; $Z_{i,t}$ controls for firm level factors, *Tobin Q*, *CF*, *Size*, and *Sales growth*. We also include the country, industry sector, firm and year effects.

In this causal mediation regression model, the average causal mediation effect (ACME) that mediated through country spreads is captured by $\beta_1 * \tau$, and the total effect of IRM is $\beta_1 * \tau + \beta_4$. Therefore, the percentage of total effect of IRM on firm investment explained by ACME is $\beta_1 * \tau / (\beta_1 * \tau + \beta_4)$. The standard errors of ACME are computed according to the Delta method (Oehlert, 1992).

We report the causal mediation regression results in Table 3, where column (1) shows the mediation analysis results for full samples. Columns (2) to (4) report results for financially unconstrained firms and columns (5) – (7) report results for firms that are financially constrained. In column (1), we estimate the ACME to be 0.009 and significant at 1%, indicating significant causal effect of IRM on firm investment through country spreads – for a median size firm, one billion US dollar more IRM causes about 0.28 million more investment through the channel of country spreads. The total effect of IRM on firm investment is estimated to be 0.032 (significant at 1%); therefore, our model suggests that about 28% of total effect of IRM on firm investment in EMEs is mediated through the country spread.

Consistent with the results in Section 4.2, we find financially unconstrained firms are more responsive to active IRM relative to those of financially constrained firms. The total effect of IRM estimated in columns (2) – (4) are on average higher and statistically more significant than those in columns (5) – (7). Although there is higher total effect of IRM in financially unconstrained firms, the percentage of total effect of IRM that is mediated through the country spread in these firm is lower than that in financially constrained firms – on average 22% of the total effect is mediated effect in unconstrained firms comparing to 36% in financially constrained firms. This perhaps attributes to the more responsive characteristics of country spread in financially risky country to global financial shocks. For example, Gilchrist et al., (2019) find that a tighten in conventional US monetary policy leads to a significant widening of credit spreads on sovereign bonds issued by countries with speculative-grade credit rating. The differed causal mediation effect between financially constrained and unconstrained firms reinforces the important of financial friction that policy makers in EMEs need to consider in order to implement macro-policies, such as active IRM, effectively.

The estimates for independent variables in equation (4) are consistent with those in Section 4.1. As expected, high country spread is negative and significantly associated with firm investment. Interestingly, compared to Table 1, adding country spread modifies the interaction term, $IRM_{c,t} * \Delta VIX_t$, to be mostly negative but insignificant in most cases (two cases are significant at 10%). This may empirically confirm that active IRM and global financial shocks interact and trade off their opposite effects to determine credit spreads. The result that the country spread variable deprives the significance of $IRM_{c,t} * \Delta VIX_t$ also justifies why we do not include a country spread variable in equation (1) in the first place – because country spread and $IRM_{c,t} * \Delta VIX_t$ are correlated and could cause multicollinearity issue. Importantly, including $IRM_{c,t} * \Delta VIX_t$ as opposed to country spreads reveals richer findings as we discussed in Section 4.1 and 4.2.

5 Additional analyses

Here we undertake additional empirical analyses to test the sensitivity of our results to the following variations: 1) alternative measurements for active IRM, 2) alternative measurement for global financial shocks, and 3) different data samples.

5.1 Alternative IRM measurements

We discussed different measurements for IRM and compared their advantage and disadvantages in Section 3.1 and in Appendix A. In this subsection, we use other IRM measurements than the IRM-1 to check the sensitivity of our results. Columns (1) – (4) in Table 4 report the results using IRM-2, IRM-3, IRM-DHI-1, and IRM-DHI-2, respectively. In general, these results are similar to those in column (2) of Table 1 with few differences. The values of some coefficients are slightly different and the significance of interaction terms turn from 1% to 5%. The largest difference is that ΔVIX_t is estimated to be insignificant, yet still negative, in column (4). Additionally, as all five previous IRM measurements are scaled by GDP, one may be concerned that the variation could be due to the changes of GDP as opposed to IRM. To address this issue, we use the IRM/IR ratio, measured as the ratio of the active changes in reserves based on DHI approach to total international reserves excluding gold, to run regression in column (5). The results remain consistent with other columns. Overall, these results do not materially change from those in column (2) of Table 1, suggesting that our results are robust to different measurements for IRM.

5.2 Alternative measurements for global financial shocks

In this subsection, we use four alternative measurements[26] for shocks in the global financial market to check the sensitivity of our results. We first use the intra-annual volatility that are compiled according to Merton (1980) from daily data of S&P 500 index. Contrasting to the VIX index that measures the implied volatility of S&P 500 stock option, the intra-annual volatility provides a representative measure for the perceived volatility. We expect the shocks to the perceived volatility and those to the implied volatility produce comparable impact on firm investment from emerging economies.

Second, we use RORO index as an alternative measurement for ΔVIX. Comparing to the VIX index measure, RORO index is more of "global" sense in that it includes risk information from different financial assets classes and across both the US and Europe financial markets. Third, we apply the percentage changes of the Fed's fund rate as alternative measurements for global financial shocks. The US monetary policy is well documented to impose spillover effect on emerging market (Miranda-Agrippino and Rey, 2020). We expect the US monetary policy shocks generate spillover effect over firm investment in EMEs. Finally, the news-based US monetary and economic policy uncertainty index of Baker et al. (2016) are used to directly measure the policy shocks from the center country to the global financial market.

We report the results using alternative measurements of global financial shocks (ΔAlt_shocks) in Table 5. Columns "S&P500", "RORO", "Feds rate", "US MPU", and "US EPU" show the results for intra-annual volatility, RORO, percentage changes in the US Federal fund rate, the US MPU index, and the US EPU index as ΔAlt_shocks, respectively. These results are comparable to those in Table 1, although the estimated coefficient for ΔAlt_shocks, and $IRM \times \Delta Alt\_shocks$ are smaller than ΔVIX, and $IRM \times \Delta VIX$, particularly when we using the US MPU and EPU to measure the shocks. $IRM \times \Delta Alt\_shocks$ turn to insignificant in the US Federal fund rate regression.

[26] The definitions and data compilations of these alternative measurements for external shock are discussed in Section 3.2.

5.3 Extraordinary shocks: The 2008 global financial crisis and the Federal Reserve's "taper tantrum"

A few influential papers related to uncertainty shocks use time dummy variables to capture extraordinary financial events to measure financial shocks (e.g. Bloom 2009). Both the 2008 global financial crisis and the Federal Reserve's "taper tantrum" triggered substantial global financial uncertainty. The 2008 global financial crisis highlights an extreme global financial risk shock (i.e., the VIX index spiked as high as 80%), which wreaked havoc on the global financial system and dried up the global credit supply in emerging markets. Similarly, the Federal Reserve's "taper tantrum" in 2013, which signaled to start tapering its QE program, was marked by a sharp reversal of capital flows to emerging markets, a sharp decrease in credit supply together with rising credit spreads, and significantly disruptions in EME financial markets (Avdjiev *et al*, 2020; Chari *et al*, 2020).

According to Gulen and Ion (2016), two thirds of corporate investment during 2008 financial crisis was attributed to surging uncertainty. To evaluate the impact of 2008 financial crisis and the 2013 Fed's taper tantrum on firm investment, we create an index variable, *Crisis&Tapper* (= 1 if year == 2007, 2008, 2009, 2013 and 2014; otherwise, 0) to indicate 2008 the financial crisis and the Fed's tapering[27]. We use this time dummy variable as an alternative measurement for global financial shocks and repeat regressions (1) to examine the effect of IRM on firm investment in the presence of extraordinary financial shock events.

The results are reported in Column (5) of Table 5. As we replace a continuous variable (ΔVIX) with a dummy variable (*Crisis&tapper*), the regression changes from a multiplicative regression to a difference-in-difference regression. The interpretation of economic meaning therefore is slightly different from that in Table 1. Column (5) shows that, during the 2008 financial crisis and the Fed's taper tantrum, EME firms dropped their investment by about 2.2 percent. Firms responded to a one percent increase of IRM in non-crisis-and-taper periods with 3 percent additional investment. However, during crisis and taper periods, the positive effect of IRM on investment was reduced by more than by 50% (i.e., -0.016/0.030) relative to that in normal periods. The reason is that EMEs sold international reserves to defend themselves against

[27] The NBER dated the 2008 global financial crisis from December 2017 to June 2019. We define the Fed's taper tantrum to be from June 2013, when Chairman Bernanke announced a "tapering" of the Fed's QE policies contingent upon continued positive economic data to October 2014 when the Fed halted its bond purchase program.

financial instability during the 2008 financial crisis and taper periods (Figure A5), more than half of IRM effect is traded off by the adverse effect of crisis and tapering.

5.4 Possible sample selection bias

In this section, we check the possible sample selection bias issues. First, we include all firm samples from any available emerging economies in the Worldscope database (i.e. including small countries that list fewer than 15 companies; this adds about 12% observations). Second, we run regressions with 50 largest firms (largest average total assets in sample periods) of each country to reduce the dominance of countries that has large number of public listed firms.

Third, one may be concerned about the impact of firms that do not survive in sample periods. As non-survival firms are likely to be financially constrained, including these firm may down-bias our estimation results. Thus, we run regression on non-survival firm samples to check the possibility of survivorship bias. We identify a firm as a non-survivor if it was marked as "inactive" at any sample year in the Worldscope database. However, this is a coarse identifier with caveats. Worldscope database marks a firm "Inactive" if the firm stopped produce annual accounting reports for unspecified reason and we are not able to distinguish whether a firm is bankrupt, de-listed or is merged by another firm. Using this identifier, we identify 4304 such non-survivor firms and run a regression on them to test the robustness of our previous results.

Fourth, it is possible that firms invest in their domestic market and foreign market simultaneously. The behaviors of domestic investment in response to IRM and global financial shocks presumably are different from that of foreign investment. For this reason, we test how sensitive of our results to domestic investment samples only. Our firm investment data studied in previous sections are total investments of a firm that do not differentiate the domestic investment from the foreign investment. However, the Worldscope database allows us to identify whether a firm has foreign subsidiaries by checking whether the firm reports consolidated accounting statement. We assume a firm invests domestically only if it does not report consolidated annual accounting reports. After checking for such reports, we find about 10% of our firm samples are domestic investors.

Finally, we run regression on the samples of firms from commodity exporting countries. Such countries may enjoy the buffer stock role of international reserves induced by term of trade shocks (Aizenman and Riera-Crichton, 2008). International reserve, in return, provides insulation to shocks of commodity term of trade (CTOT) in commodity countries (Aizenman et al., 2012).

To investigate whether investment of commodity country firms responds to active IRM differently and how *CTOT* shocks may change the way active IRM affects firm investment, we add a *CTOT* shock variable, measured as the changes of commodity term of trade, Δ*CTOT*, in the regression and ran it using firm samples from 16 commodity exporting countries (See Appendix B for commodity country samples).

The results of these regressions are reported in Table 6. Overall, regressions using different firm samples yield results comparable to Table 1. Column (1) reports full sample results. The results are similar, yet the coefficients of *IRM* and Δ*VIX* are slightly larger than those in Table 1, indicating that both active IRM and global financial shocks affect firm investment in small EMEs in the similar way to major EMEs, but are slightly more impactful. In column (2) which reports results for top 50 largest firms in each country, the effect of IRM seems to be smaller (i.e. the estimated coefficient of IRM is 0.014 at 5% significance, compared to 0.02 in Table 1), suggesting that large firms are less responsive to IRM as they might have other means to hedge financial instability.

Non-survivor firms do not significantly respond to active IRM as the IRM variable is estimated to be negative but statistically insignificant [column (3)]. Perhaps due to firm's specific dire situation, these firms have to reduce investment even when the financial system is stable and the economic outlook is good. Regarding firms that only invest domestically, we find that these firms are highly responsive to active IRM (the marginal of IRM in column (4) is 0.063 + 0.4 * ΔVIX, compared to 0.02 + 0.034 * ΔVIX in Table 1).

Finally, we find in column (5) that commodity country firms seem to be less responsive to active IRM than other firms as we estimate the coefficient of IRM to be insignificant. On the other hand, global financial shock is more impactful in commodity countries (ΔVIX estimates a coefficient of -0.118, higher than that in Table 1). Further investigation reveals the sluggish response of commodity exporter country's firms to IRM, but their higher response to global financial shocks may be due to the presence of CTOT shocks. CTOT shocks in commodity countries are closely associated with shocks in global financial market (Reinhart *et al*., 2016). Adding ΔCTOT, although not estimated significantly, diminishes the buffer stock role of IRM. In fact, if we drop ΔCTOT from the regression [column (6)], IRM turns to be significant and IRM × ΔVIX becomes more significant.

6 Coordination with capital controls and exchange rate arrangements

The Mundell-Fleming trilemma theory suggests that a country can insulate external shocks and achieve monetary independence if the country adopts either flexible exchange rate or controls cross-border capital mobility, suggesting the importance of coordination among macroeconomic policies to achieve macroeconomic stability. Emerging markets traditionally use macro-management policies, such as capital controls and exchange rate flexibility, to insulate global financial shocks.

The insulation of capital controls against global financial shocks is evident (Han and Wei, 2018). Ostry et al. (2012) find emerging markets with restrictions on financial openness survived better from the 2008 global financial crisis. In fact, many EMEs re-engaged the capital controls (Eichengreen and Rose, 2014) after the 2008 financial crisis and the IMF suggests to considering capital controls a viable policy tool to better stabilize financial system in emerging markets.

Regarding exchange rate regime, the literature suggests that it influences the sensitivity of developing countries to policy shocks from center countries (Aizenman et al, 2016). Flexible exchange rate was identified as a shock absorber as early as Friedman (1953). Emerging economies with flexible exchange rate regimes help mitigate the susceptibility to real and financial vulnerability and the occurrence of global financial instability (Gosh, et al. 2015; Obstfeld et al. 2019).

In addition to directly insulating shocks, capital controls and flexible exchange rate regime are complementary to international reserves in insulating EMEs from global shocks (Bussière *et al*., 2015; Acharya and Krishnamurthy, 2018). It is therefore interesting to examine how the effect of IRM on firm investment in EMEs may differ among countries that manage capital controls or adopt flexible exchange rate regime from those do not have capital controls or with pegged exchange rate regime.

To do so, we augment equation (1) with capital controls and exchange rate regimes as follows:

$$
\begin{aligned}
Invest_{i,t} = {} & \alpha + \mu_j + \theta_t + \beta_1 IRM_{c,t-1} + \beta_2 \Delta VIX_t + \beta_3 IRM_{c,t-1} \times \Delta VIX_t + \varphi_1 MacroMNGM_{c,t} \\
& + \varphi_2 MacroMNGM_{c,t} \times IRM_{c,t-1} + \varphi_3 MacroMNGM_{c,t} \times \Delta VIX_t \\
& + \varphi_4 MacroMNGM_{c,t} \times IRM_{c,t-1} \times \Delta VIX_t + \gamma X_{c,t} + \delta Z_{i,t} \\
& + \varepsilon_{i,t} \qquad (5)
\end{aligned}
$$

where $MacroMNGM_{c,t}$ include variables that measure whether a country has capital controls or adopt flexible exchange rate regime, or both. Other independent variables are same as in equation (1). As in Section 4.2, to facilitate interpreting the results of three-way interaction terms, we use dummy variables that categorize countries with capital controls or implementing flexible exchange rate regimes.

To generate a dummy variable for capital controls (*KC*) countries, we rely on the Chinn-Ito index. We let *KC* = 1 to indicate a country manages capital controls, if the country has Chinn-Ito index value < 0.065 (the mean of the Chinn-Ito index in our data sample); for those countries have Chinn-Ito index > 0.065, we assign *KC* = 0, suggesting they do not control capital mobility. Similarly, we generate a category dummy variable, *Xchg*, to categorize flexible exchange rate regimes versus peg exchange rate regimes. *Xchg* is measured based on the coarse classification index of exchange rate regime in Ilzetzki et al (2019). We set *Xchg* = 1 if the index > 3 to indicate countries that adopt flexible exchange rate regimes; *Xchg* = 0 to mark countries that endorse pegged exchange rate regimes.

We report the results in Table 7. Columns (1) and (2) provide results dealing with capital controls and flexible exchange rate regimes, and column (3) shows the results with countries that apply both capital controls and flexible exchange rates. In column (1), the effect of IRM is estimated as 0.005 + 0.023 * ΔVIX, but is insignificant, implying that firm investment in EMEs without capital controls do not respond to active IRM. Although no significant effect of IRM is found, IRM seems to reduce the downside effect of global financial shocks (ΔVIX is negative and the interaction term gets a coefficient 0.023, at 10% significance). On the other hand, countries that impose capital controls are found investing more and the effect of IRM is significantly stronger relative to those in no capital control countries. The marginal effect of IRM in capital-controlled counties is 0.051 + 0.061* ΔVIX; at the average level of ΔVIX, one percent increase in IRM is associated with about 5 percent higher firm investment. These results are in accordance with the complementary role of capital controls on international reserves identified in the literature. The detrimental effect of global financial shocks on investment is smaller in countries with capital controls comparing to those with no capital control – confirming the shock insulation role of capital control. However, we find no statistical evidence that the role of IRM in reducing the downside impact of global financial shocks is different between countries with or without capital controls (i.e. $KC \times IRM \times \Delta VIX$ is not statistically significant).

Regarding exchange rate arrangements, we find in column (2) that IRM has positive effect on firm investment in countries with pegged exchange rate system (the coefficient to *IRM* and $IRM \times \Delta VIX$ are both positive and significant). There is more firm investment in countries with flexible exchange regimes. However, we find no evidence that firm investment in flexible exchange regime countries responds differently to IRM from those in pegged exchange regimes (both $Xchg \times IRM$ *and* $Xchg \times IRM \times \Delta VIX$ are not significant). Similar to Obstfeld *et al*. (2020), we find evidence that flexible exchange rate insult adverse effect of global financial shocks on firm investment as $Xchg \times \Delta VIX$ is estimated to be significantly positive.

For countries that combine policies of capital controls and flexible exchange rate [column (3)], we find that IRM inserts a stronger positive effect on firm investment than countries either only have only capital controls, or flexible exchange regimes, or neither (the sum of coefficients to $KC\&Xchg \times IRM$ and $KC\&Xchg \times IRM \times \Delta VIX$ is 3.02, significant at 1%). These results may imply that a well-coordinated macro-management policy mix are more effective in insulating adverse global financial shocks. This echoes the call for coordinated policies to fend off downside global shocks discussed in Section 4.1.

Finally, we examine whether our results in columns (1) – (3) would change if we control for firm level financial constraints. To do so, we add the following terms to equation (5): $\theta_1 Fin\ constr_{i,t} + \theta_2 Fin\ constr_{i,t} \times IRM_{c,t} + \theta_3 Fin\ constr_{i,t} \times \Delta VIX_t + \theta_4 Fin\ constr_{i,t} \times IRM_{c,t} \times \Delta VIX_t$, where $Fin\ constr_{i,t}$ is the first principal component extracted from *Ext fin, Tangi* and *WW*. Results are reported in columns (4) – (6). All firm financial constraint variables are estimated to be significantly negative as in Table 2. Importantly, controlling for firm's financial constraints does not change our results in a meaningful way, except that the R-squares marginally increase from 0.108 to 0.116.

7 Macroeconomic significance

To gauge the macroeconomic significance of our findings in firm level data, we use a structural VAR model to study the causal relation among IRM, external shocks, country spreads, and investment in country-level aggregate data. We obtained an annual data set that includes 55 emerging economies[28] from 2000 – 2018. The aggregate investment is proxied by gross fixed capital formation[29] in percentage of GDP. Following Sims (1980) who suggests that VAR models provide a coherent and credible approach to macro-data description, macroeconomic structural inference, and macro-policy analysis, we use a structural VAR model to examine how and the degree to which a country's aggregate investment responds to active IRM, external shocks, and country spreads. The reduced form of the VAR model is specified as follows:

$$Y_{c,t} = \left\{\Delta VIX_t, IRM_{c,t}, Country\ spread_{c,t}, Aggregate\ investment_{c,t}\right\}$$

where, as in Section 4, ΔVIX_t measures global financial shocks; $IRM_{c,t}$ is represented by IRM-1; $Country\ spread_{c,t}$ is measured by EMBI+ spread.

Following Bloom (2009) as well as Carrière-Swallow and Céspedes (2013), we ordered ΔVIX to be the first component in the VAR model, assuming that global financial shocks are exogenous to local variables of emerging economies; then place IRM after ΔVIX, because global shocks may trigger EME central banks' IRM behavior to self-insure against the shocks. Following the theoretical mechanism outlined in Section 2 that IRM and global financial shocks impose the opposite effect on country spreads, thereby affect investment, we order $Country\ spread$ after IRM and position $Aggregate\ investment$ in the last place. A significant response of $Country\ spread$ to ΔVIX and IRM and the response of $Aggregate\ investment$ to $Country\ spread$, ΔVIX and IRM can validate the effect of IRM on

[28] Due to better availability of country level data, we include 9 more countries than previous sections using firm level data. Excluding these 9 additional countries yields similar results.

[29] According to the World Bank, gross fixed capital formation, formally called gross domestic fixed investment, includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. According to the 1993 SNA, net acquisitions of valuables are also considered capital formation.

investment along with its effect that mediates through country spreads to affect investment in the macroeconomic scope.

The contemporaneous and two lags of each variable are included in the model. We use the panel data VAR to obtain impulse response function (IRF) and confidence intervals that use Monte-Carlo simulation repeating for 200 times. Figure 3 reports the orthogonalized IRF with 95% confident interval to one standard deviation shocks. Panel A shows the responses of IRM, country spreads, and aggregate investment to one-standard deviation of ΔVIX_t. In line with the precautionary theory of IRM, EMEs immediately sell about 0.3% reserves/GDP to defend against an adverse global financial shock and follow up by accumulating to replenish reserve stockpiles (see Figure "IRM" in Panel A). The country spread responds to the VIX spike by widening about 1.5 percent of interest rate spread (Figure "Credit spread" in Panel A). By contrast, the aggregate investment does not respond to the VIX shock immediately, rather it takes the aggregate investment two year to respond to a one-S.D. spike of global financial shock by reducing investment about 0.4% of GDP. This sluggish significant responses of the aggregate investment to global financial shocks are consistent with the finding of Bertola and Caballero (1994) that the aggregate investment behavior is characterized as sluggish and continues adjustment[30].

In Panel B, we show that, in response to a one-S.D. increase in active IRM, EMEs boost their aggregate investment by 0.3% in two years, suggesting significant macroeconomic evidence for the positive effect of IRM on investment. In responding to a positive shock in active IRM, country spreads are found to narrow about 0.9% immediately. This result, combined those in Figure "Country spread" of Panel A that an adverse VIX shock widens country spreads, implies that adverse global shocks and active IRM impose opposite effects on country spreads and that IRM offsets the adverse effect of global financial shocks in determining the level of country spreads, other things being equal.

In fact, country spreads are found to go on to affect aggregate investment. Figure "aggregate investment" of Panel C shows that EMEs reduce about 0.2% aggregate investment in response to a one-S.D. widening shock in their country spreads (Panel C). These results are consistent with those reflecting the mediator role of country spread in the effects of IRM on firm investment (in Section 4.3).

[30] Similar findings are found in Uribe and Yue (2006), Bloom (2009), and Carrière-Swallow and Céspedes (2013).

Overall, this section confirms the positive effect of active IRM on investment at macroeconomic level and validates the macroeconomic significance of our findings. These results are consistent with the findings in Dominguez et al. (2012) and Aizenman and Jinjarak (2020).

8 Concluding remarks

Accumulating international reserves in good times to safeguard the economy against adverse global financial shocks is one of the recognized macro policy tools pursued by EMEs to manage their economies (Ostry et al., 2012; Acharya and Krishnamurthy, 2018). Aizenman and Jinjarak (2020), Aizenman and Lee (2007), Caballero and Panageas (2008), Dominguez, Hashimoto, and Ito (2012), Jeanne (2016), and Jeanne and Ranciere (2011), for example, theorize and illustrate the stabilizing effects of active IRM on the macro-economy. The current study extends the discussion of IRM by examining its implications for investment at the firm level; thus, it offers a glimpse of the micro-level mechanism with which the IRM alleviates the negative impact of global financial shocks.

Adopting a Tobin-Q type investment setup, we control for the canonical domestic and firm-specific factors and report the empirical roles of IRM, global financial shocks, and their interactions in determining investment at the firm level in EMEs. The IRM effect varies across firms with different financial conditions – financially constrained firms, compared with non-constrained ones, exhibit a smaller positive IRM effect on investment. The firm-level effect can be the underlying cause of the IRM effect on macro variables reported in the literature.

In accordance with the notion that an active IRM policy alleviates the impact of adverse global financial shock effects on country credit spreads, our empirical results show that country spreads are a significant channel through which IRM exerts positive effects on firm investment. The country spread mediation effect is stronger for financially constrained firms than for non-constrained ones.

Further, active IRM is shown to be complementary to two other macro management policies, namely capital controls and exchange rate management, in terms of stabilizing firm investment in the face of global financial shocks. That is, these macro policy tools play complementary roles in alleviating adverse global financial shock effects on firm investment in

EMEs. These results suggest the benefits of combining these tools in insulating firm investment from global financial shocks.

While the current exercise has established the firm-level effect of IRM, IRM may have other effects beyond the scope of the paper. For instance, in addition to serving as a buffer during a crisis, a high level of hoarding international reserves can reduce the probability of speculative attacks. Another issue is that the IRM effects can be asymmetric; a high level of international reserves is probably more relevant during crisis than normal periods, and a low level can limit the ability to conduct active IRM during a crisis. As with any policy tool, overdoing hoarding international reserves in good times may backfire, leading to possible moral hazard concerns,[31] and growing opportunity costs associated with accumulating low yielding international reserves instead of hoarding a balanced international portfolio in a well-run Sovereign Wealth Fund. These issues are left for future research.

[31] This may the case when international reserves are used to sustain ‘zombie’ state banks and state enterprises.

Appendices:

Appendix A: data construction for active IRM

1. The DHI simulation method

Reserve assets held in central banks include foreign exchange currencies and other non-currency assets, including SDR allocations, the reserve position in IMF, and other reserve assets [32]. Thus, the change in international reserves (ΔIR) is the sum of changes in foreign currency reserve ($ForexR$) and non-foreign currency assets ($nonCR$), i.e. $\Delta IR = \Delta ForexR + \Delta nonCR$. Foreign currency reserves can be further divided into two categories of financial assets: securities (*SEC*) and currency deposits (*DEPO*). Thus, the change of *IR* can be expressed as follows:

$$\Delta IR = r_i^s * \sum_{i=1}^{n} SEC + r_i^d * \sum_{i=1}^{n} DEPO + \Delta SEC + \Delta DEPO + \Delta nonCR \qquad (A1)$$

where r_i^s and r_i^d are the interest rates on currency i denominated securities and currency deposits that reserve assets invested, respectively. There are n different currency denominated reserves investment. Thus, $r_i^s * \sum_{i=1}^{n} SEC + r_i^d * \sum_{i=1}^{n} DEPO$ accounts for the total interest income from reserve assets investment; $\Delta SEC + \Delta DEPO$ is the value change in both securities and currency deposits, which can be further decomposed into the purchases and sales of reserve assets and the valuation changes. Thus,

$$\Delta IR = \left(r_i^s * \sum_{i=1}^{n} SEC + r_i^d * \sum_{i=1}^{n} DEPO \right) + (\Delta^{ps} SEC + \Delta^{ps} DEPO) + (\Delta^{val} SEC + \Delta^{val} DEPO) + \Delta nonCR \qquad (A2)$$

where $\Delta^{ps} SEC + \Delta^{ps} DEPO$ measures active IRM on purchases and sales of IR assets; $\Delta^{val} SEC + \Delta^{val} DEPO$ is the valuation effect due to exchange rate changes. Let $Interest\ income = \left(r_i^s * \sum_{i=1}^{n} SEC + r_i^d * \sum_{i=1}^{n} DEPO \right)$, $IRM = (\Delta^{ps} SEC + \Delta^{ps} DEPO)$, and $Valuation\ effect = (\Delta^{val} SEC + \Delta^{val} DEPO)$, we could then calculate IRM as the follows:

$$Active\ IRM = \Delta IR - Interest\ income - valuation\ effect - \Delta nonCR \qquad (A3)$$

As ΔIR and $\Delta nonCR$ have available data from IMF IFS, in order to measure active IRM, we need to estimate $Interest\ income$ and $Valuation\ effect$.

To pin down $Interest\ income$, we utilize IMF's Special Data Dissemination Standard (SDDS) Reserve Template data. Although SDDS does not provide data on the types of securities and types of deposits (by currency denomination) that we need to calculate $Interest\ income$, it does offer data on the share of these reserves held in securities (*SEC*) and the share in currency deposits (*DEPO*). As no country specific information about the currency composition of these reserve assets is available, we use the aggregate currency composition of international reserve assets in "emerging and developing economy" to proxy. For simplicity, we use four major

[32] International reserves literature typically refers international reserves as the total international reserves excluding gold. To be consistent, we exclude gold when simulating IRM data in a departure from Dominguez et al. (2012) who include gold as part of international reserves.

reserve currency shares, namely the US dollar, Euro, UK pound, and Yen, which account for more than 90% of total reserves in EMEs. These aggregate data on reserve currency shares are available from the Currency Composition of Official Foreign Exchange Reserves (COFER) database. Together with the interest rates of SEC and DEPO that are proxied by returns to treasury securities (10-year bond yields issued by US, German, UK, and Japanese government) and deposits (3-month LIBOR rate on USD, Euro, Pound, and Yen), we can calculate $Interest\ income$.

Regarding $valuation\ effect$, we apply two approaches to simulate. The first one follows Dominguez et al. (2102) to use the IMF Balance of Payment Statistics (BOP) data to backout the valuation changes in international reserves. The Reserve and Related Items category in the BOP records the market valued purchases and sale of reserve assets, which can be expressed as the follows:

$$Res_{BOP} = \left(r_i^s * \sum_{i=1}^{n} SEC + r_i^d * \sum_{i=1}^{n} DEPO \right) + (\Delta^{ps} SEC + \Delta^{ps} DEPO) + \Delta nonCR \quad (A4)$$

Subtracting Res_{BOP} from ΔIR of equation (A2), we backout the valuation effect that labeled as *valuation_BOP*, as the follows:

$$valuation\_BOP = \Delta IR - Res_{BOP} = \Delta^{val} SEC + \Delta^{val} DEPO \quad (A5)$$

The other approach directly estimates the total valuation change of foreign exchange currency reserves (*ForexR*) based on the information of currency composition in international reserves and exchange rate changes among four major reserves currencies. As before, we use COFER data of aggregate currency composition share in reserve holdings to proxy each country's reserve currency composition, along with *ForexR* data from SDDS and the annual data of exchange rate changes from IMF IFS, we can estimate the valuation effect, labeled as *valuation_EXR*, as:

$$valuation\_EXR = \sum_{j=1}^{3} ForexR * CurrencyShare_j * \Delta exr_j \quad (A6)$$

where $CurrencyShare_j$ $(j = 1, 2, 3)$ are the currency share of Euro, Pounds, and Yen in international reserves. Δexr_j are the average annual exchange rate change of Euro, Pounds, and Yen to the US dollar.

Subsequently, we use equation (A3) to simulate two measures for active IRM by using valuation effects of (A5) and (A6), respectively. The simulated IRM, in US dollar term, is then scaled by GDP (also in the US dollar) to be comparable across EMEs with different size and to be compatible with other measurements of IRM that we will discuss later. We label these two measurement IRM-DHI-1 and IRM-DHI-2, respectively. Figure A1 plots IRM-DHI-1 and IRM-DHI-2 of four emerging market countries, namely Bulgaria, Russia, Singapore, and South Korea[33], and the data of average IRM in EMEs from 2000 - 2018. Although EMEs actively accumulated more reserves before 2008, less so after the 2008 global financial crisis, individual emerging market presents heterogenous pattern in their active IRM behaviors. For example,

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[33] For comparison purpose, we follow Dominguez et al. (2012) to use Bulgaria, Russia, Singapore, and South Korea as representative EMEs to demonstrate the data simulation.

Bulgaria and Korea kept their IRM consistent before and after 2008, except the shape drop during the 2008 global financial crisis. Russia and Singapore, on the other hand, actively accumulated reserves before 2008, but slowed down the rate of accumulation after 2008. Adjusting the valuation effect lead a temporary deviation of these two measurements from each other, it does not, however, alter the overall pattern. Overall, these data patterns are comparable to the IRM data presented in Dominguez et al. (2012).

2. The detrend method

In our second approach, we use a linear regression to detrend the international reserve data and estimate active IRM. Official international reserves data are stock data that appear to trend upwards over time. As shown in Figure A2, the level of reserve holdings in EMEs has been increasing persistently since 2000. In addition to the persistent active accumulation of international reserves, the passive management of international reserves may contribute to its trending pattern. As we discussed earlier, the passive management components include interest incomes and the valuation effect. Interest incomes create the compounding effect that raises the value of reserve assets over time, i.e. the value of total reserve assets is compounded over time based on the interest rates that the investment of reserve assets yields. Similarly, the valuation effect would increase the value of reserves assets over time if the US dollar depreciates against other reserve currencies. This is because the official international reserves data are denominated in US dollar and appreciation of other reserve currencies increases the dollar value of reserves. In fact, the consistent depreciation of US dollar from 2000 – 2008 contributes to the upward trend in international reserve data. Thus, detrending the international reserve stock data may effectively purge the passive management components from the official reserves data, and the remainder is likely to be the active IRM. We then use these detrended reserves data divided by GDP (in current US dollar) to measure active IRM, and we label it as IRM-1.

Although trending, there seems to have been a structure break point in the pattern of reserve accumulation process in EMEs around 2008. The top panel of Figure A2 shows the secular increasing in reserves holding in EMEs before 2008 and a mitigated trend after the 2008 financial crisis. According to Aizenman et al. (2014), there was a pattern change in reserve holding behavior after the 2008 global financial crisis, because some newly identified factors[34] mitigate the reserve accumulation process in EMEs in the aftermath of the global financial crisis. To account for the structural break on reserve holding behavior in EMEs before and after the 2008 global financial crisis, we re-estimate the active IRM by imposing a break-point in the time trend at 2008. We create the estimated active IRM to GDP ratio as another measurement of IRM and label this as IRM-2.

Finally, as shown in the short-dash line in the bottom panel of Figure A2, the US dollar value index has a clear depreciation trend before 2008 and an appreciation trend after 2008. Removing these patterns in the valuation effect helps better detrend the reserve data. Thus, after purging the down-and-up pattern of valuation effect from the international reserve stock data, we re-estimate a IRM, subsequently divided by GDP to generate another IRM measurement to obtain the third detrended measurement of active IRM.. We label it as IRM-3.

[34] 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) find the slowing-down reserves accumulation may be related to the fact that most countries decelerated their accumulation of short-term debt after the global financial crisis.

Figure A3 shows the similarity of these detrended data measurements for IRM. IRM-1 and IRM-2 are virtually identical in all four EME countries. IRM-3 slightly deviates from the first two, but, they are highly correlated.

Thus far, we have obtained two groups of measurements for active IRM – the simulated and the regression estimated IRM. As they use different data sources and data compilation methods, we expect some differences and each may possess advantages and disadvantages in terms of applying to regression analyses. To compare the differences, we plot IRM-DHI-1 and IRM-1 for Bulgaria, Russia, Singapore, and Korea, along with the average measurement for EMEs in Figure A4. As shown in the fifth figure in Figure A4, for the average in EMEs, IRM-DHI-1 and IRM-1 comove with each other (the correlation is 0.83). Consistent with the finding of Dominguez et al. (2012), both measurements show active accumulation of international reserves in EMEs pre-crisis, a sale of reserves during the crisis, and a slowing-down in active accumulation of reserves aftermath the crisis. IRM-DHI-1 and IRM-1 for individual countries display heterogeneity. From the perspective of individual country, they match well in Russia and Korea, but not in Bulgaria and Singapore. However, all of them present the similar pattern of IRM before, during, and after the global financial crisis and as shown in the "average in EME" figure.

To demonstrate how well our measurements reflected the strategy of active IRM in EMEs against external shocks, in Figure 5 we plot IRM-1 and IRM-DHI-1 along with the percentage change in the VIX index (ΔVIX) – a large ΔVIX indicates a surge in global financial risk, thus a large shock in the global financial market. Both IRM measurements are negatively correlated with ΔVIX, implying that EME central banks moved to sell international reserves to intervene financial market when global financial risk surged and accumulated IR assets when global financial market stabilized. Moreover, a larger ΔVIX is matched by a larger opposite change in IRM measurements, which perhaps implies that, facing larger shocks in the global financial market, central banks responded by selling more reserve assets to intervene financial market.

Appendix B: country samples

Emerging markets:
Argentina, Bangladesh, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Czech Republic, Egypt, Hong Kong, Hungary, India, Indonesia, Israel, Jordan, Kazakhstan, Kenya, Korea, Kuwait, Latvia, Lithuania, Malaysia, Mexico, Morocco, Nigeria, Oman, Pakistan, Peru, Philippines, Poland, Qatar, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Sri Lanka, Thailand, Tunisia, Turkey, Ukraine, United Arab Emirates, Venezuela, Vietnam

Commodity exporter countries:
Chile, Colombia, Egypt, Indonesia, Kazakhstan, Kenya, Kuwait, Nigeria, Oman, Peru, Qatar, Russia, Saudi Arabia, South Africa, United Arab Emirates, Venezuela

Appendix C: variable descriptions

Variable	Description
Firm characteristics:	
Investment	The measure for investment using the ratio of capital expenditures on plant, property, and equipment divided by the book value of total assets at the beginning of year, i.e. $\frac{Capital\ expenditure_{i,t}}{Total\ Assets_{i,t-1}}$.
Tobin Q	Tobin's q, measured as the market value of equity plus the book value of assets minus book value of equity plus deferred taxes, then divided by book value of assets - The ratio of market to book values of firm assets.
CF	Cash flows calculated as earnings before interest and tax plus depreciation and amortization divided by the book value of total asset, a proxy for marginal product of capital (Gilchrist et al, 2014).
Size	The logarithm of the book value of total assets.
Sales growth	Sale changes from last year divided by the book value of total assets at the beginning of year, $\frac{Sales_{i,t} - Sales_{i,t-1}}{Total\ Assets_{i,t-1}}$.
Ext fin	The category variable for firm's capacity of external finance access. The capacity of external finance access is calculated as (Capital expenditure – CF)/Capital expenditure. (Rajan and Zingales, 1998).
Tangi	The long-term debt covered by tangible assets ratio, measured as the ratio of long-term debt to net plant, property and equipment in book-value (Claessens and Laeven, 2003; Rajan and Zingales, 1998).
WW	The financial constraint index of Whited and Wu (2006), measuring the shadow cost of external financing.
Macroeconomic factors:	
ΔVIX	The percentage change of VIX, calculated as $\log(VIX_t/VIX_{t-1})$. The VIX is Chicago Board Options Exchange S&P 500 implied volatility index, retrieved from FRED, Federal Reserve Bank of St. Louis.
IRM	Active international reserve management, using the detrend data of international reserves excluding gold to GDP ratio.

	International reserves and GDP data are retrieved from WDI, the World Bank (see section 3.1.2 for detail data construction).
IRM-DHI	Active international reserve management, measured by the ratio of changes in reserves using Dominguez et al. (2012) method to GDP (see section 3.1.1 for detail data construction).
IRM/IR ratio	Alternative measurement for international reserve management, evaluated by the ratio of IRM using Dominguez et al. (2012) method divided total international reserves excluding gold.
Country spread	The spread between EME US dollar denominated sovereign bond yield over one-year US treasury bill yield, measured by the J.P. Morgan Emerging Markets Bond Spread Index (EMBI+), in percentage points.
Aggregate investment	Gross fixed capital formation (% of GDP), retrieved from WDI, the World Bank.
RGDPG	The percentage rate of real GDP growth, retrieved from WDI, the World Bank.
Risk profile	The index of domestic investment risk profile from ICRG. In logarithm value.
ToT	Commodity term of trade index, year 2012 = 100. Source: IMF, Commodity term of trade.
Xchg	Indicator for countries with flexible exchange rate arrangements. Xchg = 3 if the coarse classification codes of de facto exchange rate arrangement classification of Ilzetzki, Reinhart and Rogoff (2019) is greater than 2.
KC	Indicator for countries with capital controls. KC = 1 if Chinn-Ito capital controls index, Chinn and Ito (2006) is less than 1.
Alternative measurements for global financial risk:	
S&P500	An alternative measurement for global financial shock, measured as the intra-annual volatility of S&P500 index, computed from S&P500 daily data according to Merton (1980). To construct these data, we first compute the daily contribution to annual volatility by taking the squared first difference to the daily changes in S&P500 index after dividing by the square root of the number of trading days:

	$$\sigma_t = \left(100\frac{\Delta x_t}{\sqrt{\Delta\varphi_t}}\right)^2$$ Where the denominator $\sqrt{\Delta\varphi_t}$ is to adjust the effect of calendar time elapsing between observations on the x process. Due to that no data are available on non-trading day, e.g. weekends and holidays, $\sqrt{\Delta\varphi_t} \in (1,5)$. For example, if data were generated on every calendar day, $\Delta\varphi_t = 1, \forall t$. The annual volatility of S&P500 index is defined as $\Phi_{t'}[x_t] = \sqrt{\sum_{t=1}^{T}\sigma_t}$ where the time index t' is at the annual frequency.
RORO	The first principal component of daily data across several asset classes, including 1) credit risk: changes in the ICE BofA BBB Corporate Index Option-Adjusted Spread for the United States and for the Euro Area, and Moody's BAA corporate bond yield relative to 10-year Treasuries; 2) equity return and implied volatility in the US and Europe: the additive inverse of daily total returns on the S&P 500 and STOXX50, and the VIX and the VSTOXX index; 3) funding liquidity: changes in the TED spread and the bid-ask spread on 3- month Treasuries. The data compiling approach follows Chari et al. (2020).
Feds rate	The changes in the Feds effective fund rate, retrieved from FRED, St. Louis Fed.
MPU	The US monetary policy uncertainty index (Baker et al., 2010), a news-based uncertainty index drawn from 10 major national and regional U.S. newspapers, retrieved from www.policyuncertainty.com.
EPU	The US economic policy uncertainty index of Baker et al., (2010), retrieved from www.policyuncertainty.com.

Appendix D: summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Investment	211,371	.07777	.11807	0	1.0681
ΔVIX	197,386	-0.0100	0.2782	-0.3611	0.6266
IRM-1	208,875	0.0012	0.0758	-0.6233	0.4254
IRM-2	208,226	0.0058	0.0822	-0.5549	0.3946
IRM-3	207,151	0.0028	0.0846	-0.5442	0.3225
IRM-DHI-1	147,526	0.0120	0.0425	-0.1888	0.3246
IRM-DHI-2	149,324	0.0127	0.0455	-0.1577	0.3510
IRM/IR ratio	155,952	.02855	.11951	-1.8938	0.5803
GDP growth	210,207	0.0529	0.0312	-0.1481	0.2617
Risk profile	210,771	8.7847	1.7387	2.5	12
Country spread	120,912	.95588	3.4493	-5.0568	55.7375
Tobin's Q	211,371	0.2151	0.2548	1.00E-06	2.4250
CF	209,605	0.0704	0.2711	-37.6254	69.4896
Size	211,371	22.0740	2.9833	5.3927	33.4614
Sales growth	200,985	.0962417	.6330927	-84.9367	111.9956
External finance access	205,978	-0.0001	0.1653	-38.318	54.0414
Tangible assets to LT liabilities ratio	185,299	0.0102	0.3364	-120.235	28.7530
WW index	173,117	-0.0135	0.3768	-129.135	0.1152
S&P500 intr-annual volatility	211,371	15.3533	7.1617	6.2618	37.006
RORO	211,371	0.1638	1.3097	-3.6986	1.9119
Fed rate	211,371	1.1863	1.5226	0.07	5.24
MPU	211,371	128.2747	28.17322	70.08334	176.4167
EPU	211,371	96.51186	28.19538	56.06212	134.2509

Notes: this table shows summary statistics of main variables. Country level and time series data are matched with the firm level data that winsorize the investment variable at the 1st and 99th percentiles.

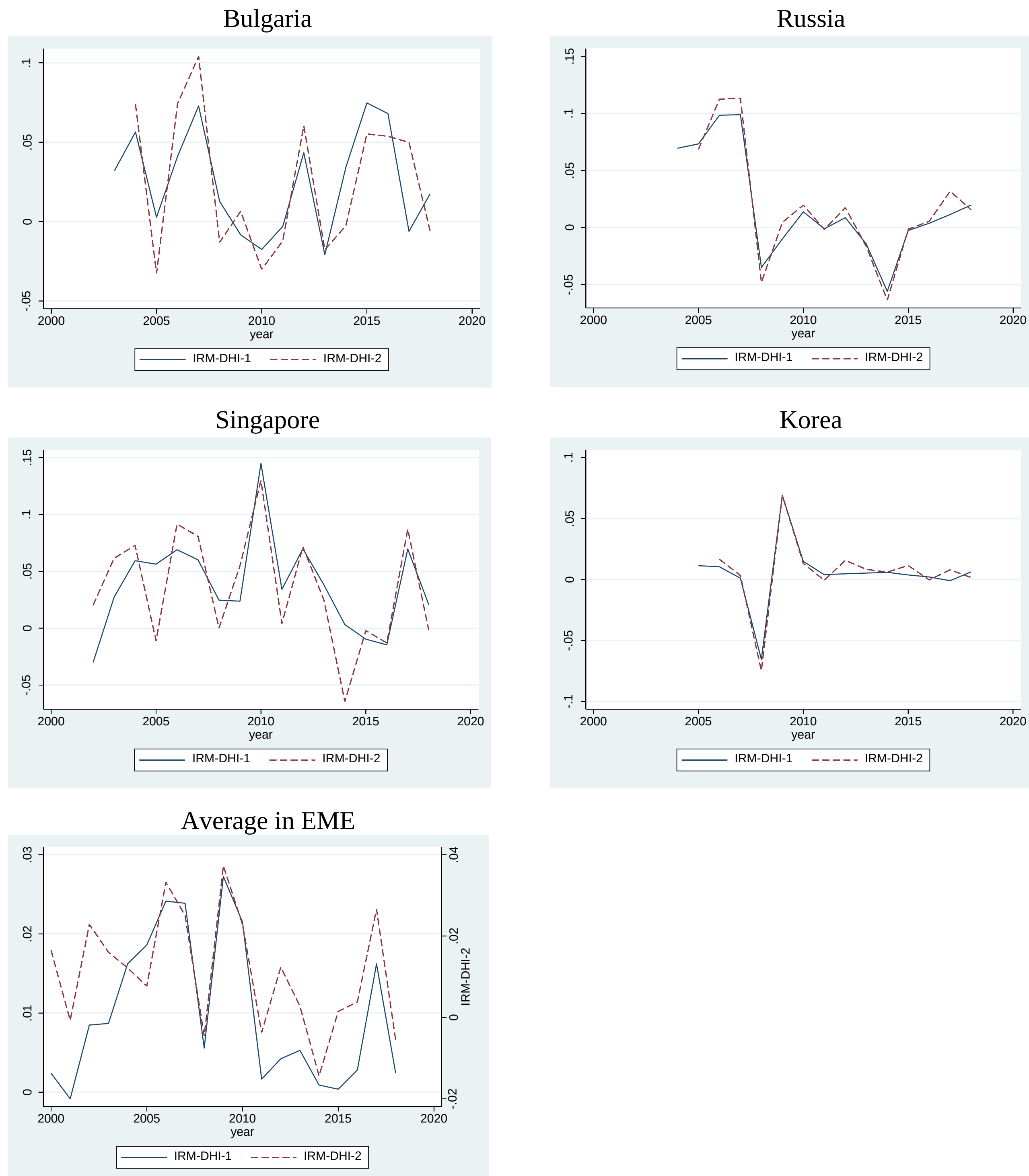
Appendix E: Variable correlations

	IRM-1	IRM-2	IRM-3	IRM_DHI_1	IRM_DHI_2	ΔVIX	SP500 voli	RORO	Fed rate	Tbill rate	Wu-xia
IRM-2	0.9913										
IRM-3	0.9756	0.9626									
IRM_DHI_1	0.474	0.4605	0.4951								
IRM_DHI_2	0.5374	0.5433	0.4674	0.2574							
ΔVIX	-0.1356	-0.1577	-0.0958	0.1301	0.2371						
SP500 voli	0.1519	0.0753	0.1964	0.1988	0.1201	0.6357					
RORO	-0.3383	-0.2893	-0.3269	-0.193	0.2473	-0.0738	-0.4207				
Fed rate	0.1599	0.1509	0.122	0.2707	-0.2635	0.3731	-0.0012	-0.1978			
Tbill rate	0.1106	0.1121	0.0731	0.2623	-0.2537	0.3788	-0.0302	-0.1821	0.9875		
Wu-xia	0.0657	0.0691	0.013	0.1941	-0.2511	0.3468	0.0351	-0.2321	0.9253	0.9499	
RGDPG	-0.2425	-0.2353	-0.2718	0.091	-0.0952	-0.0085	-0.2081	-0.0403	0.2557	0.2599	0.2462
Risk profile	0.3677	0.3308	0.3966	0.3229	-0.2287	0.0538	0.2607	-0.2308	0.1978	0.1713	0.1056
Tobin Q	-0.1265	-0.1196	-0.1506	-0.1242	0.0407	-0.0398	-0.1086	0.0473	0.0072	0.0104	0.0366
CF	0.0143	0.012	0.0165	0.0059	0.0016	0.006	0.0188	-0.0149	0.0077	0.0062	0.0064
Size	-0.1034	-0.094	-0.1	-0.0854	0.0755	0.0163	-0.0422	0.0993	-0.0623	-0.0551	-0.0426
KC	0.2017	0.1877	0.1624	-0.0793	-0.1674	-0.4132	-0.1816	-0.0799	-0.1143	-0.1607	-0.1417
Xchg	-0.2027	-0.2114	-0.2138	-0.3356	0.2564	0.1255	0.0226	0.0983	-0.0177	-0.0254	-0.0158
Ext fin	0.022	0.0209	0.0195	0.0073	-0.0068	-0.0028	0.0077	-0.0075	-0.0054	-0.0064	-0.0038
Tangi	-0.0259	-0.0261	-0.0242	0.0001	-0.0095	-0.0002	-0.0104	-0.0043	0.0151	0.0175	0.0181
WW	0.0325	0.0261	0.0353	0.0125	-0.0153	-0.0017	0.0434	-0.0502	0.0188	0.017	0.0148
Country spread	-0.0246	-0.0353	0.0129	-0.0965	0.1306	0.0503	0.2336	-0.0715	-0.1854	-0.187	-0.1565

	RGDPG	Risk profile	Tobin Q	CF	Size	KC	Xchg	Ext fin	Tangi	WW
Risk profile	-0.1302									
Tobin Q	0.1018	-0.173								
CF	-0.0207	-0.0136	0.0544							
Size	0.0303	-0.0676	0.0403	0.0321						
KC	0.0831	-0.2237	0.0532	0.0019	-0.1162					
Xchg	0.106	-0.1251	0.0858	0.0163	0.2558	0.1026				
Ext fin	-0.0168	-0.0064	0.0008	0.0115	-0.0318	0.0249	-0.0098			
Tangi	0.0122	-0.0033	-0.0144	0.0123	-0.1524	0.0216	-0.0163	0.0865		
WW	-0.0236	0.05	-0.0362	-0.0527	-0.1763	0.0178	-0.0219	0.0019	0.0472	
Country spread	-0.4569	-0.3122	-0.0485	0.0466	0.0353	0.0696	-0.029	0.0146	0.0113	0.0083

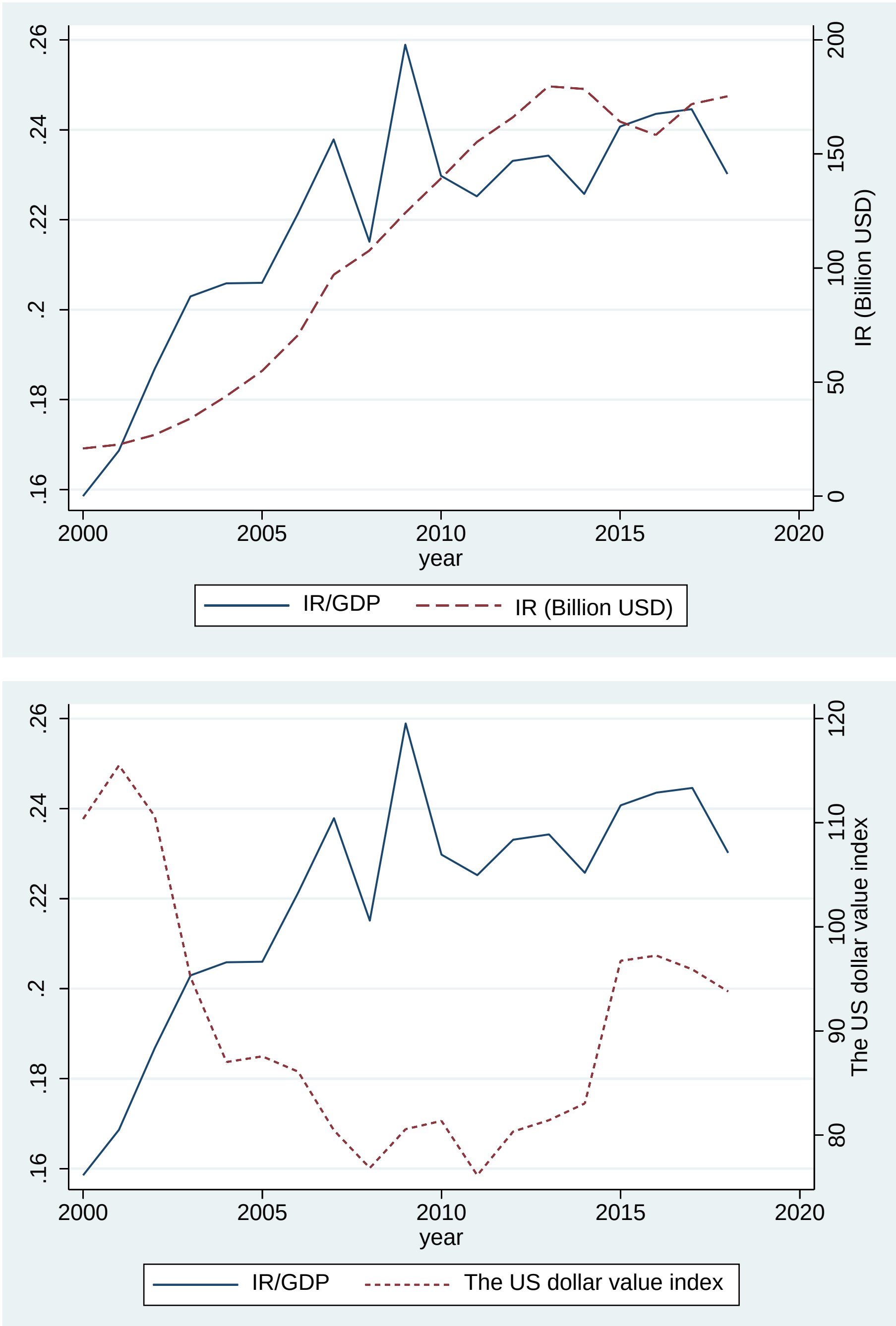
Notes: this table shows the correlation between main variables. Country level and time series data are matched with the firm level data that winsorize the investment variable at the 1st and 99th percentiles.

Figure A1: The simulated active IRM data using DHI method



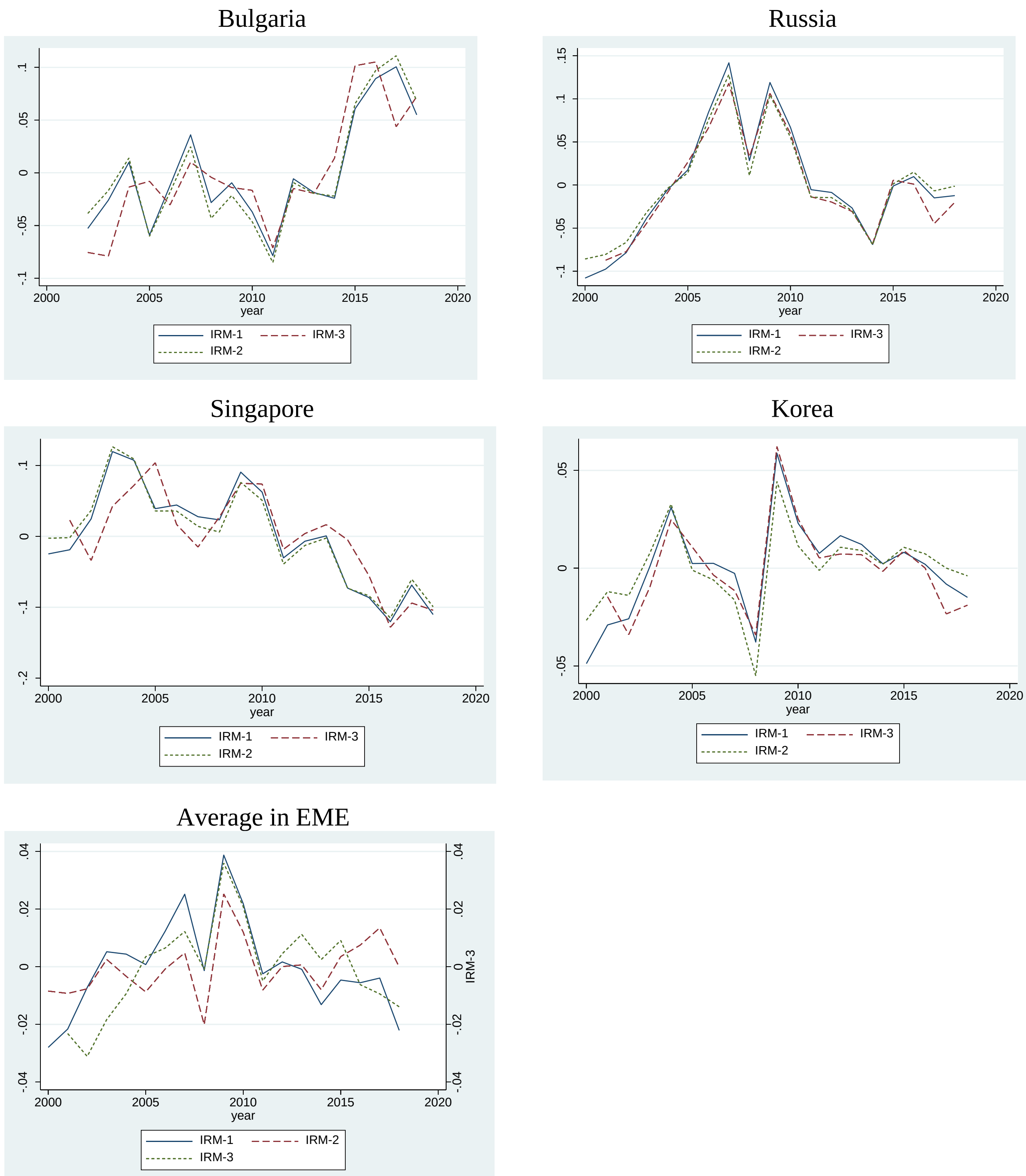
Notes: This figure plots the DHI method simulated IRM data of four EMEs (Bulgaria, Russia, Singapore, and South Korea). The solid line shows the simulated IRM data (IRM-DHI-1) that adjust the valuation effect using equation (5); the dashed line shows the simulated IRM using valuation effect of equation (6) (IRM-DHI-2).

Figure A2: The average level of international reserve holdings in EMEs



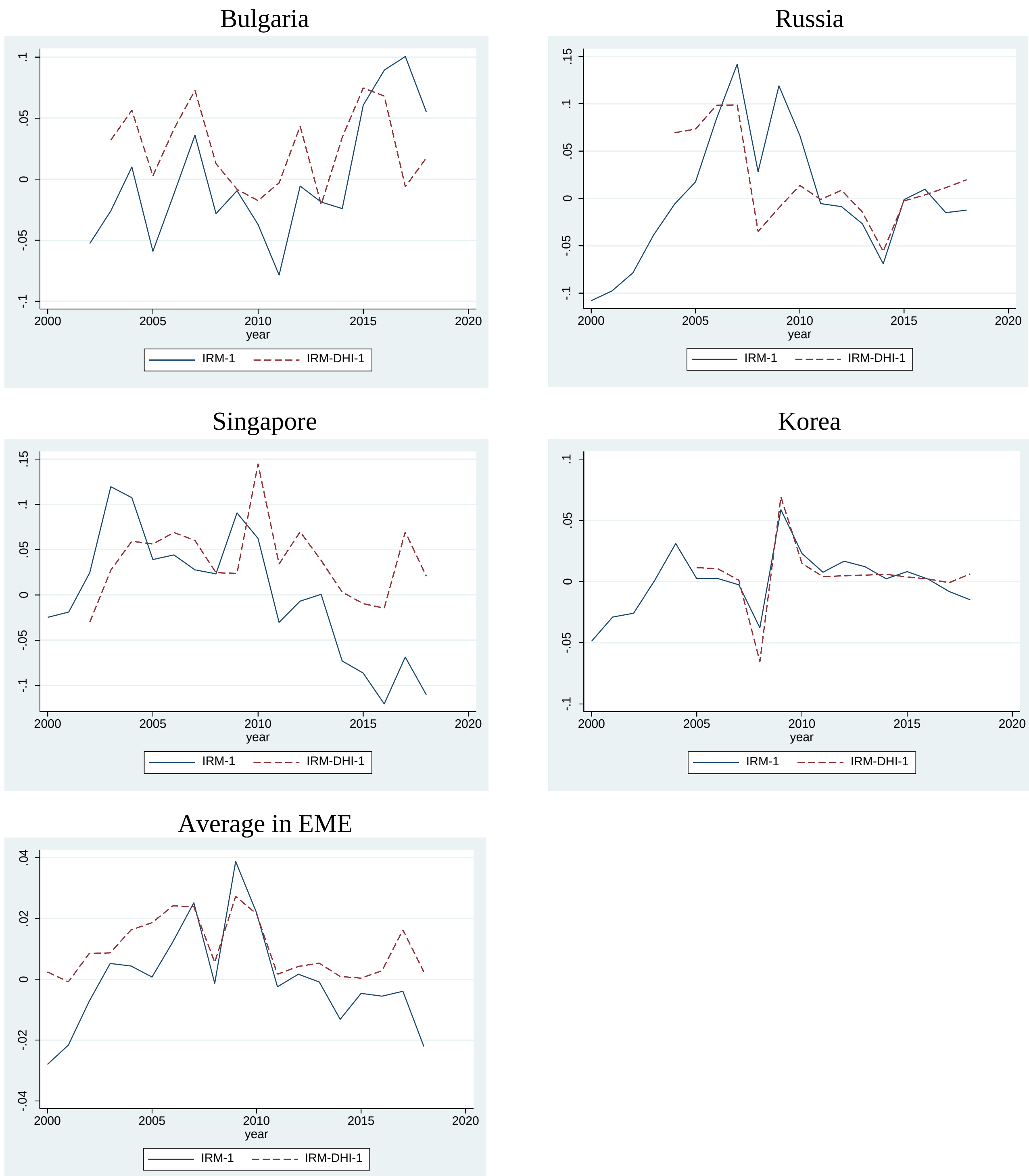
Notes: This figure shows the differed pattern in international reserves (IR) holding behavior in EMEs before and after the 2008 global financial crisis. The solid line plots the average of IR/GDP ratio (left scale); the long-dash line in the top panel plots the average IR holdings in EMEs (in Billion USD, right scale) and the short-dash line in the bottom panel shows the US dollar value index.

Figure A3: the estimated IRM using the detrend method



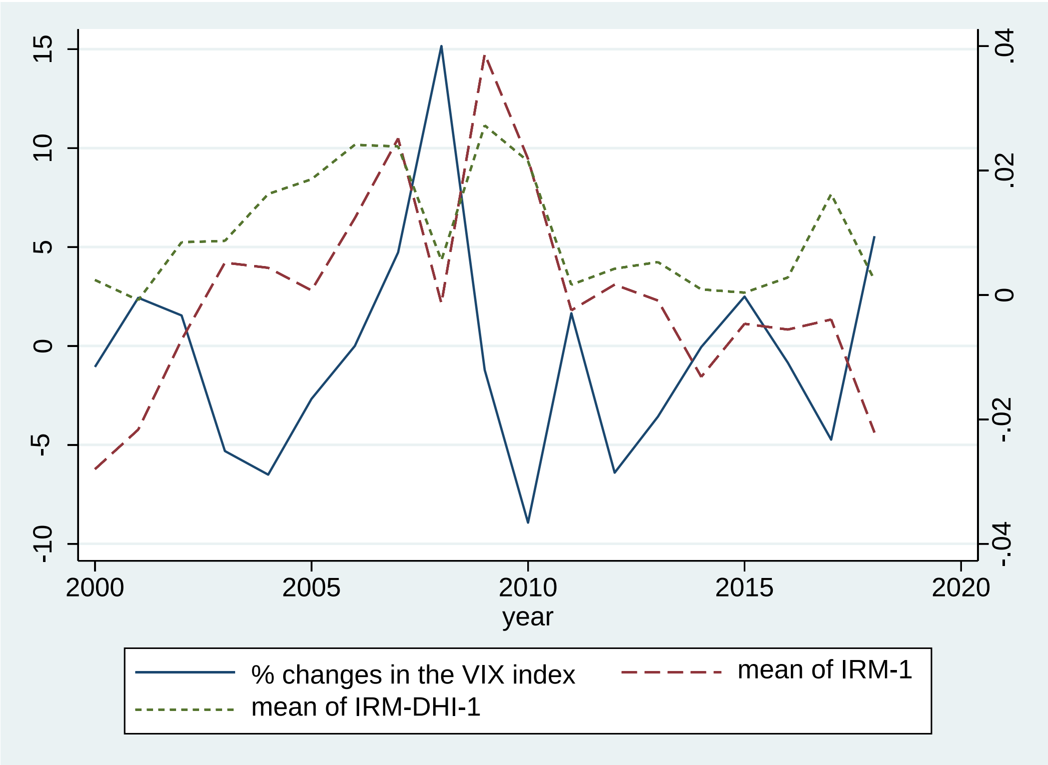
Notes: This figure plots estimated IRM of four EMEs (Bulgaria, Russia, Singapore, and South Korea). The solid line shows the linearly detrend IR/GDP ratio (IRM-1); the dot line shows the detrended IR/GDP with a time trend with a structure break at year 2008 (IRM-2); the dashed line shows the detrended IR/GDP after adjusting for the valuation effect (IRM-3)

Figure A4:The comparison of IRM-1 and IRM-DHI-1



Notes: This figure plots the simulated and estimated data for IRM in four EMEs (Bulgaria, Russia, Singapore, and South Korea) and the average IRM in 46 EMEs samples. The solid line plots IRM-1 and the dot line shows IRM-DHI-1.

Figure A5: Active IRM and global financial shocks



Notes: the solid line plots the percentage changes in the VIX index (left scale). The long-dash line is the mean of IRM-1 in 46 EMEs. The long-dash line is the mean of IRM-DHI-1 in 46 EMEs.

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Table 1: the effect of IRM on firm investment in the presence of global financial shocks

	(1)	(2)	(3)
IRM	0.021***	0.020***	0.040***
	(0.004)	(0.004)	(0.007)
ΔVIX	-0.092***	-0.091***	-0.095***
	(0.005)	(0.005)	(0.007)
IRM × ΔVIX		0.034***	0.102***
		(0.011)	(0.019)
RGDPG	0.073***	0.072***	0.080***
	(0.015)	(0.015)	(0.017)
Risk profile	0.011***	0.011***	0.002
	(0.003)	(0.003)	(0.004)
Tobin Q	0.034***	0.034***	0.034***
	(0.002)	(0.002)	(0.002)
CF	0.018**	0.018**	0.016*
	(0.009)	(0.009)	(0.008)
Size	0.007***	0.007***	0.008***
	(0.000)	(0.000)	(0.000)
Sales growth	0.022***	0.022***	0.021***
	(0.006)	(0.006)	(0.007)
#Obs	196779	196779	167094
R^2	0.108	0.108	0.110

Note: this table reports regression results for equation (7). IRM, lagged one year, is measured by IRM-1, the linearly detrended reserves/GDP ratio. Columns (3) use IRM that purges the IR accumulated due to the increase in relative national income, net capital inflows, and the mercantilist motive to depreciate currency value. All regressions control for the country effect, 3-digid SIC industry sector effect, firm and year effect. Firm level clustered robust errors that allow for intra-firm correlation are in parentheses. ***, **, * denote for 1%, 5% and 10% significance.

Table 2: The effect of IRM and global financial shocks on investment in firms heterogenous in financial constraints

	(1)	(2)	(3)	(4)
IRM	0.038***	0.039***	0.036***	0.024***
	(0.007)	(0.008)	(0.007)	(0.004)
ΔVIX	-0.088***	-0.087***	-0.088***	-0.095***
	(0.005)	(0.005)	(0.005)	(0.005)
IRM × ΔVIX	0.073***	0.125***	0.072***	0.046***
	(0.020)	(0.023)	(0.020)	(0.012)
Ext fin	-0.007***			
	(0.001)			
Ext fin × IRM	-0.029***			
	(0.008)			
Ext fin × ΔVIX	-0.005**			
	(0.002)			
Ext fin × IRM × ΔVIX	-0.062***			
	(0.023)			
Tangi		-0.013***		
		(0.001)		
Tangi × IRM		-0.027***		
		(0.009)		
Tangi × ΔVIX		-0.010***		
		(0.002)		
Tangi × IRM × ΔVIX		-0.124***		
		(0.026)		
WW			-0.020***	
			(0.002)	
WW × IRM			-0.022***	
			(0.008)	
WW × ΔVIX			-0.013***	
			(0.002)	
WW × IRM × ΔVIX			-0.064***	
			(0.023)	
Fin constr				-0.010***
				(0.000)
Fin constr × IRM				-0.017***
				(0.004)
Fin constr × ΔVIX				-0.006***
				(0.001)
Fin constr × IRM × ΔVIX				-0.059***
				(0.012)
#Obs	196779	196779	196779	196779
R^2	0.109	0.111	0.114	0.116

Note: this table reports results that considering firm heterogeneity in financial constraints. Column (1) is based on the firm level capacity on external finance for investment (*Ext fin*); column (2) uses a firm's long-term debt to its properties, plants, and equipment (tangible assets) coverage ratio as the measurement for firm's financial constraints (*Tangi*); column (3) uses firm level Whited and Wu (2006) index, the shadow cost of external financing (*WW*), to measure firm's financial constraints. *Ext fin*, *Tangi*, and *WW* are in the form of dummy variable, for which 1 is assigned when a firm-year observation is greater than the mean level financial constraint in the country-industry sector that the firm belongs to; otherwise, 0 is assigned. Column (4) extracts the first component of principal component analysis (PCA) on *Ext fin*, *Tangi*, and *WWI* and uses it measure firm's financial constraints. Results of *RGDPG, Risk profile, Tobin Q, CF, Size,* and *Sales growth* are not reported to save space. All regressions control for the country effect, 3-digid SIC industry sector effect, firm and year effect. Firm level clustered robust errors that allow for intra-firm correlation are in parentheses. ***, **, * denote for 1%, 5% and 10% significance.

Table 3: The effect of IRM on firm investment mediated through country spreads

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Country spread	-0.0004***	-0.0003***	-0.0004***	-0.0005***	-0.0006***	-0.0005***	-0.0004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
IRM	0.023***	0.028***	0.020**	0.029***	0.014	0.026	0.014
	(0.008)	(0.010)	(0.008)	(0.010)	(0.012)	(0.018)	(0.012)
ΔVIX	-0.143***	-0.139***	-0.128***	-0.119***	-0.148***	-0.154***	-0.188***
	(0.009)	(0.013)	(0.010)	(0.011)	(0.013)	(0.022)	(0.019)
IRM × ΔVIX	-0.040*	0.002	-0.025	-0.020	-0.058*	-0.040	-0.034
	(0.021)	(0.026)	(0.022)	(0.029)	(0.032)	(0.049)	(0.030)
#Obs	98571	52676	72114	51295	45895	26457	47276
R^2	0.109	0.119	0.107	0.109	0.132	0.145	0.122
ACME	0.009***	0.006***	0.008***	0.009***	0.011***	0.009**	0.008***
	(0.002)	(0.002)	(0.002)	(0.000)	(0.003)	(0.004)	(0.003)
Total effect	0.032***	0.034**	0.029***	0.040***	0.026**	0.032*	0.020*
	(0.008)	(0.010)	(0.008)	(0.010)	(0.013)	(0.019)	(0.012)

Note: this table reports the mediation effect regression results of equation (10). The "Country spread" variable is the estimated country spreads that are orthogonal to *IRM*, *ΔVIX*, *IRM* × *ΔVIX*, *RGDPG*, *Risk Profile*, and the country and year effect. Column (1) report the results estimated from the full samples. Columns (2) – (4) report the results for the samples of financially unconstrained firms that aremeasured in *Ext fin*, *Tangi*, and *WW*, respectively. Columns (5) – (7) reports results for the samples of financially constrained firms. All regressions control for thefirm and year effect. Results of *RGDPG*, *Risk profile*, *Tobin Q*, *CF*, *Size* and *Sales growth* are not reported. Firm level clustered robust errors that allow for intra-firm correlation are in parentheses. The standard errors of ACME and Total effect is calculated with the Delta method. ***, **, * denote for 1%, 5% and 10% significance.

Table 4: The effect of IRM on firm investment using alternative IRM measurements

	(1)	(2)	(3)	(4)	(5)
IRM	0.017***	0.020***	0.030***	0.042***	0.014***
	(0.004)	(0.004)	(0.009)	(0.007)	(0.003)
ΔVIX	-0.140***	-0.096***	-0.156***	-0.025	-0.156***
	(0.006)	(0.005)	(0.012)	(0.033)	(0.012)
IRM × ΔVIX	0.023**	0.022**	0.068**	0.060**	0.054***
	(0.010)	(0.010)	(0.030)	(0.026)	(0.009)
#Obs	192533	187063	137539	139208	136569
R^2	0.108	0.109	0.104	0.104	0.104

Note: this table reports regression results for equation (1) using alterative IRM measurements, lagged one period. Column (1) uses IRM-2 that detrends a nonlinear time trend with a breakpoint at 2008 from reserves/GDP data; column (2) uses IRM-3, a linearly detrended reserves/GDP, where reserves are adjusted for the valuation effect; Column (3) and (4) uses IRM-DHI-1 and IRM-DHI-2, simulated using Dominguez et al. (2012) approach. Column (5) uses IRM/IR ratio that measures the ratio of IRM-DHI-1to total international reserves excluding gold. Results of *RGDPG*, *Risk profile*, *Tobin Q*, *CF*, *Size*, and *Sales growth* are not reported. All regressions control for the country effect, 3-digid SIC industry sector effect, firm, and year effect. Firm level clustered robust errors that allow for intra-firm correlation are in parentheses. ***, **, * denote for 1%, 5% and 10% significance.

Table 5: The effect of IRM on firm investment using alternative measurements for global financial shocks

	S&P500	RORO	Feds rate	US MPU	US EPU	Crisis&Tapper
IRM	0.020***	0.018***	0.020***	-0.073***	-0.043***	0.030***
	(0.004)	(0.004)	(0.004)	(0.016)	(0.013)	(0.005)
ΔAlt_shocks	-0.061***	-0.047***	-0.111***	-0.001***	-0.003***	-0.022***
	(0.003)	(0.004)	(0.006)	(0.000)	(0.000)	(0.002)
IRM × ΔAlt_shocks	0.014**	0.007***	0.005	0.001***	0.001***	-0.016*
	(0.006)	(0.002)	(0.004)	(0.000)	(0.000)	(0.009)
#Obs	196779	196779	196779	196779	196779	206792
R^2	0.108	0.100	0.108	0.108	0.108	0.081

Note: this table reports results of regressions using alternative measurements for global financial shocks. Column "S&P500" uses the change of Merton (1980) intra-annual volatility of S&P500 index; column "RORO" reports results using risk on/risk off measurement of Chari et al. (2020) to measure global financial shocks; column "Feds rate" uses the change of the Feds fund rate; column "US MPU" uses Baker, Bloom and Davis (2016) index of US monetary policy uncertainty; column "US EPU" uses Baker, Bloom and Davis (2016) index of US economic policy uncertainty; column "Crisis&Tapper" uses a time dummy variable that captures the timing of the 2008 global financial crisis and the Federal reserves's tapper tantrum to measure global uncertainty shocks. Results of *RGDPG, Risk profile, Tobin Q, CF, Size,* and *Sales growth* are not reported. All regressions control the country effect, 3-digid SIC industry sector effect, firm and year effect. Firm level clustered robust errors that allow for intra-firm correlation are in parentheses. ***, **, * denote for 1%, 5% and 10% significance.

Table 6: The effect of IRM on firm investment estimated from various firm and country samples

	(1)	(2)	(3)	(4)	(5)	(6)
IRM	0.029***	0.014**	-0.023	0.063**	0.005	0.074***
	(0.004)	(0.006)	(0.018)	(0.025)	(0.019)	(0.024)
ΔVIX	-0.124***	-0.081***	-0.123***	-0.169***	-0.118***	-0.150***
	(0.006)	(0.006)	(0.019)	(0.019)	(0.016)	(0.018)
IRM × ΔVIX	0.030**	0.046***	0.002	0.400***	0.097*	0.215***
	(0.012)	(0.017)	(0.065)	(0.076)	(0.057)	(0.071)
ΔCTOT					0.005	
					(0.019)	
#Obs	220918	99086	24033	22144	22395	19895
R^2	0.080	0.123	0.136	0.090	0.141	0.091

Note: the table reports result of equation (1) with various firm and country samples. Column (1) uses full sample without censoring countries that listed less than 15 companies. Column (2) uses data of top 50 largest firms (in the book value of a firm's total assets) of a country. Column (3) shows the results of firms that are inactive before 2018. Column (4) reports the results for firms that only invest domestically. Columns (5) and (6) reports results for firm samples in commodity exporter countries. Results of *RGDPG, Risk profile, Tobin Q, CF, Size,* and *Sales growth* are not reported. All regressions control the country effect, 3-digid SIC industry sector effect, firm and year effect. Firm level clustered robust errors that allow for intra-firm correlation are in parentheses. ***, **, * denote for 1%, 5% and 10% significance.

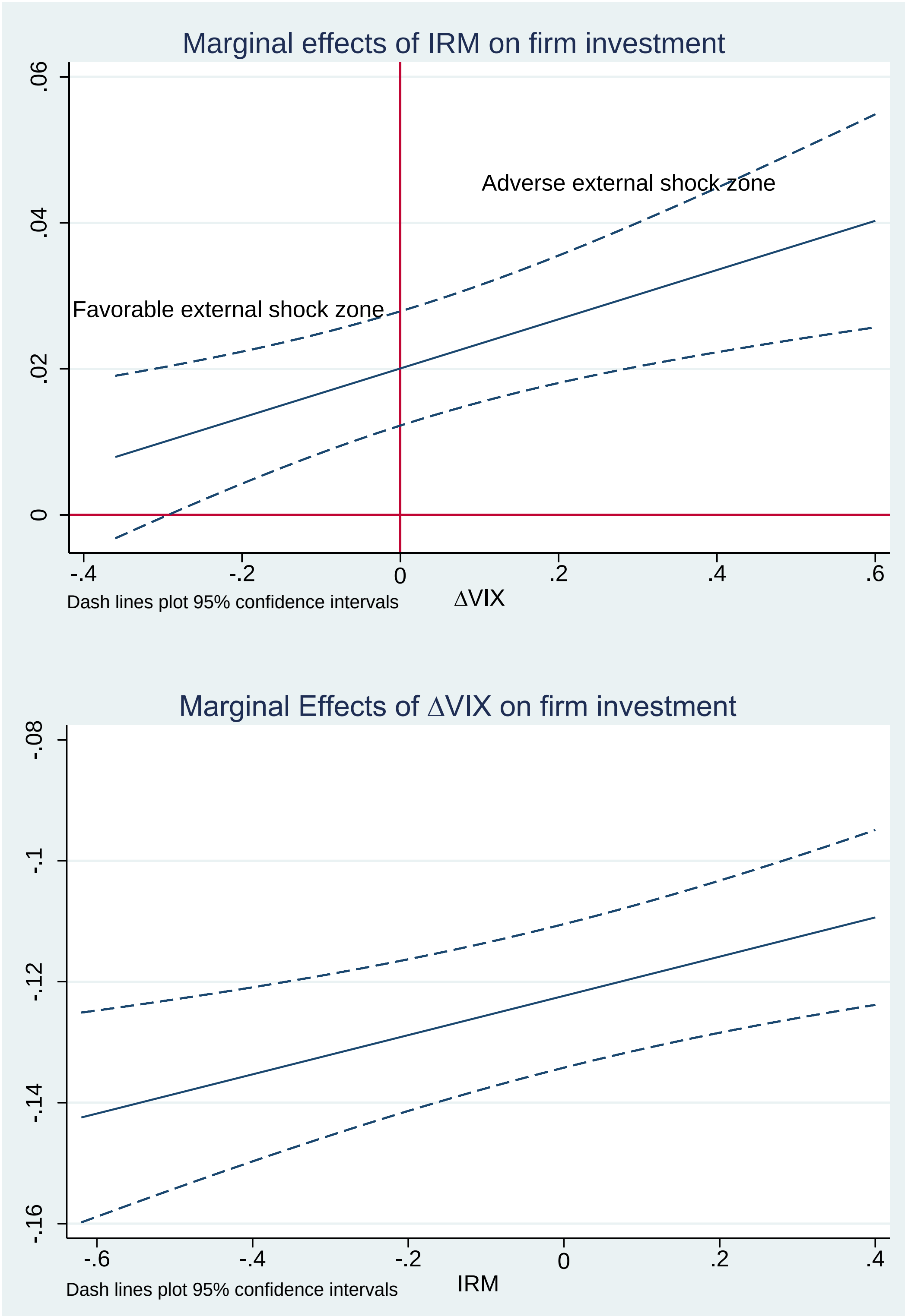
Table 7: the effect of IRM, capital controls, and exchange rate arrangement on firm investment

	(1)	(2)	(3)	(4)	(5)	(6)
IRM	0.005	0.019***	0.019***	0.006	0.020***	0.021***
	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)
ΔVIX	-0.088***	-0.163***	-0.090***	-0.085***	-0.162***	-0.088***
	(0.006)	(0.021)	(0.005)	(0.005)	(0.021)	(0.005)
IRM × ΔVIX	0.023*	0.031**	0.033***	0.031**	0.035**	0.039***
	(0.012)	(0.014)	(0.011)	(0.013)	(0.015)	(0.011)
KC	0.004***			0.004***		
	(0.001)			(0.001)		
KC × IRM	0.046***			0.046***		
	(0.009)			(0.009)		
KC × ΔVIX	0.008***			0.008***		
	(0.002)			(0.002)		
KC × IRM × ΔVIX	0.038			0.028		
	(0.030)			(0.030)		
Xchg		0.019***			0.019***	
		(0.007)			(0.007)	
Xchg × IRM		0.084			0.085	
		(0.103)			(0.102)	
Xchg × ΔVIX		0.035***			0.036***	
		(0.012)			(0.012)	
Xchg × IRM × ΔVIX		-0.184			-0.178	
		(0.251)			(0.248)	
KC&Xchg			0.027***			0.027***
			(0.009)			(0.009)
KC&Xchg × IRM			0.158			0.156
			(0.152)			(0.149)
KC&Xchg × ΔVIX			0.198***			0.194***
			(0.042)			(0.041)
KC&Xchg × IRM × ΔVIX			2.864***			2.729***
			(0.670)			(0.662)

Fin constr				-0.010***	-0.010***	-0.010***
				(0.000)	(0.000)	(0.000)
Fin constr × IRM				-0.017***	-0.019***	-0.019***
				(0.004)	(0.004)	(0.004)
Fin constr × ΔVIX				-0.006***	-0.006***	-0.006***
				(0.001)	(0.001)	(0.001)
Fin constr × IRM × ΔVIX				-0.067***	-0.065***	-0.065***
				(0.012)	(0.012)	(0.012)
#Obs	196779	196779	196779	196779	196779	196779
R^2	0.108	0.108	0.108	0.117	0.116	0.116

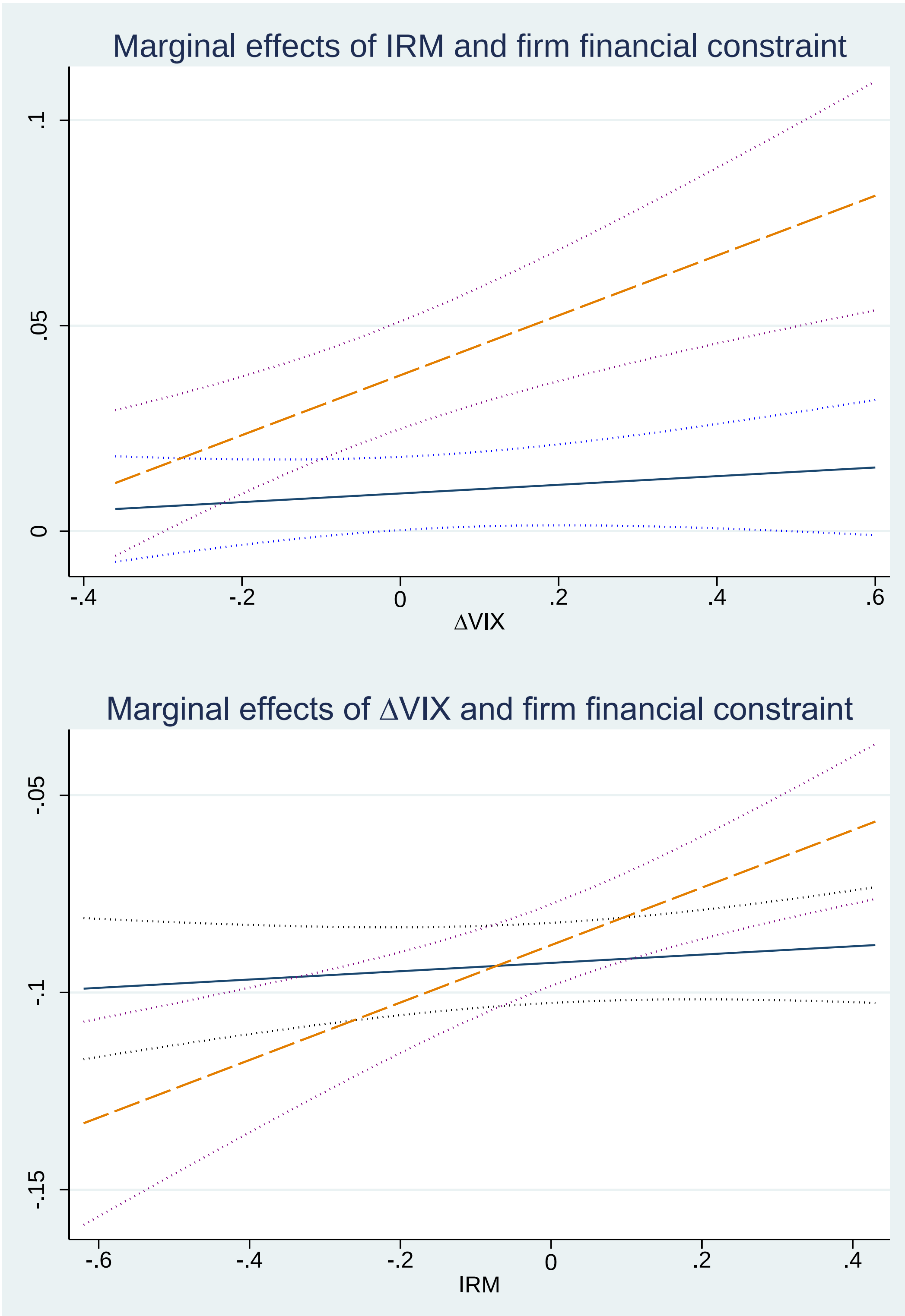
Note: this table reports results of regressions controlling for capital controls and exchange rage arrangements. KC is a dummy variable measuring capital control [*KC* = 1 if Chinn-Ito index < 0.065 (the mean of Chinn-Ito index of our data sample); =0, otherwise]; *Xchg*, a dummy variable, indicates exchange rate regime [Peg v.s. flexible regime; *Xchg* = 1 if the coarse index of Ilzetzki et al. (2019) >3; 0, otherwise) ; KC&Xchg measures countries that have both capital controls and flexible exchange rate. Columns (4) – (6) controls for firm level financial constraints. Results of *RGDPG, Risk profile, Tobin Q, CF, Size*, and *Sales growth* are not reported to save space. All regressions control for the country effect, 3-digid SIC industry sector effect, firm and year effect. Firm level clustered robust errors that allow for intra-firm correlation are in parentheses. ***, **, * denote for 1%, 5% and 10% significance.

Figure 1: The marginal effect of IRM and ΔVIX on firm investment in the multiplicative model



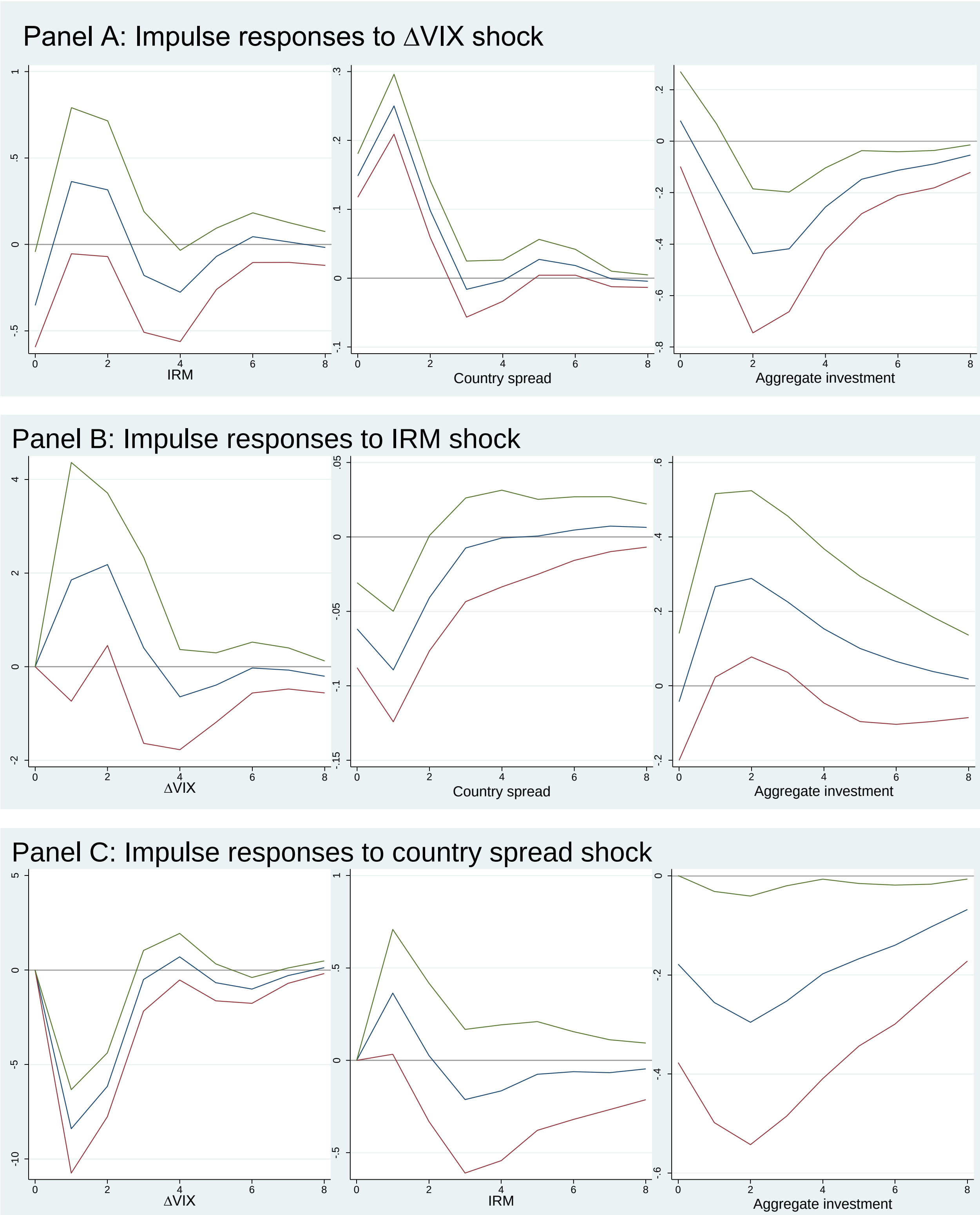
Notes: the upper figure shows the marginal effects of IRM on investment (y scale) at various level of ΔVIX (x scale). The lower figure depicts the marginal effects of ΔVIX on investment at different levels of active IRM.

Figure 2: The differed marginal effects of IRM and ΔVIX - financially constrained firms v.s. unconstrained firms



Notes: solid lines plot marginal effects in financially constrained firms and dash lines plot marginal effects in financially unconstrained firms. Dot lines are 95% confidence intervals.

Figure 3: The IRF of ΔVIX, IRM, country spreads, and aggregate investment



Notes: this figure reports impulse response to one standard deviation of Cholesky shock with 95% confidence intervals.