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Reserves and risk: Evidence from China

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ABSTRACT

We consider if Chinese accumulation of reserves is associated with private sector risk taking. Using sovereign credit default swap spreads and stock index prices as indicators of risk taking we provide evidence to suggest that as reserve holdings increase, so does the willingness to take on more risk.

1. Introduction

We attempt to contribute to the empirical literature on reserves by considering if Chinese reserve accumulation after the global financial crisis (GFC) is associated with private sector risk taking. Using sovereign credit default swap spreads (CDS) and stock index prices as indicators of risk taking we provide evidence to suggest that as reserve holdings increase, so does the willingness to take on more risk.

We take our cue from Fatum and Yetman (2020) and their country-specific daily data event study analysis of whether official announcements of reserves influence risk taking. Using a sample of 10 Asia-Pacific economies, emerging as well as advanced, they generally find no systematic link between reserves and risk. However, when considering the case of China, they are unable to consistently accept the hypothesis that changes in reserves do not influence risk taking. This is interesting and calls for further analysis to possibly establish a causal effect between Chinese reserve accumulation and changes in risk. Moreover, China is particularly interesting in the context of reserve accumulation for two reasons. First, China holds more reserves than any other country, thereby making China particularly at risk for adverse and unintended consequences of reserve accumulation.[2] Second, to our knowledge, China is the only emerging economy for which survey data on market expec-

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[2] At the end of 2015, China overtook Japan as the country holding the largest amount of reserves in the world. While it is beyond the scope of our analysis to assess whether the reserve levels of China are excessive, we note that when Obstfeld et al. (2010) compare actual levels of reserves to predictions from models of optimal reserves augmented to account for changes in financial openness and financial development, they only find systematic and substantial deviations between actual and predicted reserves for the case of China (and only after 2002 when the pace of reserve accumulation in China increased markedly). Similarly, reserve levels in China deviate dramatically from what rule of thumb guidelines would suggest, e.g. since the GFC reserves have consistently been in excess of at least six times the value of three months of imports, and reserves have consistently been in excess of more than double the value of external short term debt. However, Bianchi, Hatchondo, and Martinez (2018), in their study of reserve accumulation and roll-over risk, find that simulated optimal reserve levels can reach 40% of GDP, corresponding to roughly double the current Chinese reserves to GDP ratio, indicating that as per this metric, Chinese reserve holdings are not necessarily excessive.

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tations of reserve announcements exists. Specifically, survey expectations of Chinese reserve announcements are available from 2008 and onwards. This is important as it enables us to identify the surprise component of reserve announcements and, in turn, effectively address reverse causality endogeneity bias when estimating the effects of reserve accumulation on risk taking.[3]

The evolution of the Chinese exchange rate regime is described in detail elsewhere, e.g. Clark (2017), but two important regime changes need mentioning. First, on 21 July 2005, the PBC announced a move from a fixed USD peg to a regime where the RMB is managed relative to a reference rate based on a basket of currencies. While the basket currencies were not announced the new regime included a disclosed ±0.3% daily trading band of the RMB against a USD central parity.[4] The trading band was widened to ±0.5% on 21 May 2007 and suspended during the global financial crisis. Subsequently, the trading band widened to ±1.0% on 14 April 2012, and to ±2.0% on 15 March 2014. Second, on 11 August 2015 the PBC depreciated the RMB relative to the USD by 1.9% and announced a change in the RMB/USD central parity quoting mechanism such that domestic banks would submit quotes based on the closing rate of the previous day alongside demand and supply conditions and exchange rate movements of major currencies.

To carry out our analysis of the influence of Chinese reserve accumulation and risk we employ as indicators of risk taking two model-free and market based measures: Sovereign CDS spreads and stock index prices.[5] The CDS spreads represent the cost of insuring against default on US dollar denominated Chinese sovereign debt. A likely manifestation of an increase in the willingness to take on more risk is a reduction in demand for default insurance which, ceteris paribus, would lead to a decrease in the price of obtaining insurance. Therefore, a decrease in CDS spreads as reserves increase would be consistent with reserve accumulation leading to an increase in risk taking. Similarly, an increase in risk taking is likely to increase the demand for, and thus willingness to pay more for, inherently risky assets. Thus, an increase in stock prices as reserves increase would also be consistent with reserve accumulation leading to an increase in risk taking. Since CDS spreads provide a risk measure specifically pertaining to extreme events, i.e. default or restructuring of sovereign debt, whereas stock prices provide a broad measure of risk reflecting changes in market sentiment that are not necessarily related to extreme events, the two risk indicators, while complementary, capture different types of risk.

We first carry out monthly frequency time-series estimations to assess the influence of GDP-normalized reserves separately on the two risk taking indicators, CDS and stock market index prices. Our full sample spans the July 2001 to October 2019 time-period. We pay particular attention to the post-GFC sub-sample. We initially estimate our time-series models using OLS and, subsequently, we consider non-linearities by estimating threshold models with endogenously defined thresholds according to reserve levels as well as according to global market uncertainty. Next, we carry out daily data event study regressions of the effects of reserve announcement surprises on our two risk taking indicators. Third, we extend our analysis to incorporate tick-level prices from three Chinese stock indices to perform an intraday analysis of whether reserve announcement surprises influence risk taking as indicated by stock prices over 1-, 2-, and 5-minute windows. This extension addresses endogeneity stemming from possible omitted variable concerns pertaining to the lower frequency estimations. Finally, to complement and provide context to our China-focused investigation we also carry out monthly frequency time-series estimations of the influence of reserve accumulation on risk taking for five other Asian emerging economies (Indonesia, South Korea, Malaysia, Philippines, and Thailand).

Overall, our results suggest that as Chinese reserve holdings increase, CDS prices decrease while stock prices increase. This is consistent with the suggestion that an increase in reserve holdings is associated with an increase in risk taking. When we consider the effects of reserve accumulation separately across before and after GFC sub-samples, we show that our full sample results are driven by post-GFC effects. Our threshold estimations further confirm that reserves matter more for risk taking after the GFC. Daily data as well as intraday estimations provide additional evidence that reserve accumulation is systematically and significantly associated with increased risk taking after the GFC.

Although a very different study with respect to methodology, data, and sample period, our findings are broadly consistent with those of Tong and Wei (2021) in which they use pre-GFC firm-level data on corporate leverage spanning 6610 non-financial companies across 23 emerging economies to show that higher levels of reserves is systematically and significantly related to higher corporate leverage.[6] Furthermore, our CDS-based results can be seen as in line with Ismailescu and Phillips (2015) and their finding that high levels of reserves are associated with less trading of sovereign CDS in the sense that less CDS trading could reflect that less efforts are being taken to insure against risk. Our findings are also consistent with Fatum and Yetman (2020) in the sense that while their stock price and CDS spread risk indicator based results do not reject that Chinese reserve accumulation matters for risk taking, our results go further and provide evidence of a significant link between reserves and risk, specifically that as reserve holdings increase, CDS prices decrease and stock prices increase.

[3] It is well-known that failure to disentangle the expected component of an announcement may lead to an underestimation of the impact of the announcement. See, for example, Fatum and Scholnick (2008).

[4] Das (2019) notes that the fluctuation of the RMB vis-a-vis the USD remained muted until August 2006 and that the Chinese exchange rate regime therefore can be considered a de-facto fixed peg well beyond the July 2005 announcement.

[5] Augustin, Subrahmayam, Tang and Wang (2014) show that market participants primarily use CDS instruments for risk taking purposes, and Illing and Aaron (2005) note that a high degree of risk appetite may lead to rising stock prices. Since there is no universally accepted way to measure risk appetite, and different theoretical and empirical approaches to measuring risk appetite tend to provide markedly different outcomes, as discussed in Illing and Aaron (2005), it is preferable to use model-free and market based measures of risk taking.

[6] Similarly, Sengupta (2010) uses firm-level data spanning 1500 firms across six Latin American emerging economies to show that higher levels of reserves are associated with higher levels of USD denominated corporate debt.

The rest of the paper is organized as follows. Section 2 provides some background on reserve accumulation. Section 3 describes the data. Sections 4 and 5 present and discuss the empirical framework and the results, respectively. Section 6 discusses extensions and robustness checks. Section 7 concludes.

2. Reserve accumulation

The build-up of international reserves across several emerging economies, including and most noticeably in the case of China, took off after the Asian financial crisis (AFC) and has further accelerated since the GFC. Generally, a rationale underlying accumulation of reserves is the precautionary savings motive, i.e. the desire to hold liquid insurance, in the form of foreign currency, against adverse financial market shocks and sudden capital outflows.[7] Other key drivers are export-driven growth in conjunction with varying degrees of managed exchange rate systems pushing up the level of reserves if foreign exchange intervention operations aimed at mitigating pressure for the domestic currency to appreciate are undertaken, as well as less developed domestic financial systems where, for example, capital controls interfere with private investments.[8]

While the precautionary savings motive may explain part of the observed accumulation of reserves, several Asian emerging economies hold reserves in excess of levels typically dictated by models of optimal reserve holdings as well as by rule of thumb guidelines.[9] This may seem surprising, considering that holding reserves is costly.[10] However, the willingness to incur the cost of holding high levels of reserves can be rationalized by the expectation that holding substantial reserves may reduce the severity of a financial crisis, expedite subsequent recovery, and make a financial crisis itself less likely.[11,12]

Traditionally, the cost of holding reserves is measured as the spread between the return on reserves held versus the opportunity cost of reserves held, i.e. the foregone return on investment in physical or human capital or, simply, the cost of external borrowing.[13] However, the cost of holding reserves goes beyond opportunity costs from foregone returns, or incurred borrowing costs, and includes indirect costs such as sterilization costs, interest rate costs and difficulties in implementing monetary policy.[14]

Importantly, and the focus of our study, reserve accumulation may also be associated with an additional and perhaps particularly concerning counterproductive cost from moral-hazard induced private sector risk taking. If reserves correlate with the ability of the government to provide insurance in times of financial stress, private sector agents may be willing to take on more risk knowing that as reserve holdings increase, so does the ability of providing insurance and private sector bailouts. In doing so, private sector risk taking can increase the probability of overinvestment and asset bubbles which, in turn, can make a financial crisis more likely. In other words, while emerging economies accumulate reserves to provide insurance in the event of a financial crisis, this may have the unintended counterproductive effect of increasing the likelihood of a financial crisis. If this is the case, rather than the insurance premium paying for itself, as suggested by Rodrik (2006), the insurance premium includes an increase in the probability of a financial crisis and thus that the insurance will be put to use.

3. Data

Our data on Chinese reserves consists of date- and time-stamped PBC announcements and spans the July 2001 to October 2019 time-period. The reserve announcements occur at a monthly frequency. Following rapid growth rates from the onset of our sample period Chinese reserve holdings peaked at almost USD 4000 billion in June 2014. Subsequently, reserve holdings gradually declined before stabilizing at around USD 3000 billion. Fig. 1 shows the evolution of Chinese reserves and Table 1 provides descriptive statistics.[15]

[7] See Jeanne and Sandri (2020) for a recent contribution on optimal reserves and precautionary savings.

[8] See ECB (2006) for a useful overview of traditional drivers of reserve accumulation. Cheung and Qian (2009) suggest keeping up with the Joneses as an alternative driver of reserve accumulation.

[9] For example, Jeanne (2007) uses a model of optimal reserve levels with an insurance motive to show that the build-up of reserves in Asian emerging economies after the AFC can only be explained if the expected output cost associated with a sudden stop capital account crisis is unrealistically large. Similarly, Jeanne and Rancière (2011) show that the build-up of reserves in Asian emerging economies can only be explained within the confines of their model when expected output cost of a sudden stop crisis is combined with a high degree of risk aversion. As for rule of thumb guidelines for reserve accumulation, these typically pertain to reserves relative to imports or reserves relative to external short-term debt ratios. While the former suggests that the level of reserves should amount to the value of three months of imports, and the latter, known as the Guidotti-Greenspan rule, suggests that the level of reserves should cover (at least) the external short-term debt of a country, reserve levels in Asian emerging economies are often in excess also of these rule of thumb guidelines.

[10] See Aizenman and Jinjarak (2020) for a recent study of optimal management of reserves aimed at mitigating the cost of holding reserves. People's Bank of China (PBC) (2019) addresses reserves management practices aimed at reducing the cost of holding reserves in the context of China.

[11] See, for example, Feldstein (1999).

[12] Interestingly, there is no consensus on whether a high level of reserves helped facilitate faster post-GFC recovery. For example, Blanchard et al. (2009) do not report that more reserves lowered output declines whereas Dominguez et al. (2012) find that higher levels of reserves prior to the GFC are associated with higher post-GFC output growth.

[13] See Baker and Walentin (2001) and Rodrik (2006). Rodrik (2006) refers to the opportunity cost of holding reserves as the social cost of self-insurance. Yeyati (2008) suggests that the social cost of self-insurance via reserves is overstated if reserves reduce default risk.

[14] See ECB (2006) for a detailed discussion of indirect costs associated with holding reserves and Yun (2020) for an interesting study of a crowding-out effect in the form of reduced commercial bank credit expansion as a result of reserve accumulation.

[15] For the purpose of our empirical analysis we follow Fatum and Yetman (2020) and others in normalizing reserves by domestic GDP.

Our data on survey expectations of Chinese reserve announcements is obtained from Money Market Services (MMS) and Bloomberg News Service. Quarterly survey data is available from January 2008 and monthly after September 2015. Following Andersen et al. (2003) and others we construct for each reserve announcement the standardized announcement surprise as the unexpected component of the announcement divided by the sample standard deviation.[16] Fig. 2 shows the reserve announcement surprises.[17]

Our stock market risk taking indicator is the Morgan Stanley Capital International (MSCI) China index and our sovereign CDS risk taking indicator, obtained from Markit Inc., is the cost (spread) of insuring against default of sovereign Chinese USD-denominated debt on a five-year term. The two risk indicator series are depicted at the top of Fig. 3 and descriptive statistics provided in Table 1.

We employ as control variables the CNY/USD exchange rate and the MSCI US stock index. The control variables are displayed at the bottom of Fig. 3 and descriptive statistics provided in Table 1. Additionally, as an indicator of global market uncertainty we make use of the VIX series.[18,19]

For the purpose of our intraday assessment of whether reserve accumulation influences risk taking we employ tick-level traded prices for three major Chinese stock market indices, the CSI 300 Index, the Shanghai SE Composite Index, and the Shenzhen SE Composite Index. The tick-level data series are provided by Tick Data Inc.

To provide a comparison point for our results on China, we extend our analysis to consider other Asian emerging market economies. Specifically, we consider reserve accumulation and risk taking in Indonesia, Malaysia, Philippines, South Korea, and Thailand.[20] Our data on normalized reserves for these countries also span the July 2001 to October 2019 time-period except for Indonesia where the reserve series start April 2004. Risk indicator series for the five comparison countries are also constructed from country-specific MSCI stock price indices and country-specific five-year sovereign CDS spreads obtained from Markit Inc.[21]

4. Econometric methodology

To assess whether reserve accumulation influences risk taking we first estimate (separately) the following monthly frequency baseline models:

$$\Delta S_t = \beta_0 + \beta_1 \Delta RES_t + \beta_2 \Delta CNYUSD_t + \beta_3 \Delta USS_t + e_t \tag{1}$$

$$\Delta CDS_t = \beta_0 + \beta_1 \Delta RES_t + \beta_2 \Delta CNYUSD_t + \beta_3 \Delta USS_t + e_t \tag{2}$$

where ΔS_t and ΔCDS_t denote, respectively, the change in the Chinese stock market index and the CDS spread, i.e. these are our two risk indicators, ΔRES_t is the change in percent of normalized Chinese reserve holdings, i.e. this is our focal explanatory variable, $\Delta CNYUSD_t$ and ΔUSS_t are, respectively, the change in the CNY/USD exchange rate and the US stock market index, i.e. these are our control variables, and e_t is the zero-mean error term. We include control variables to reduce omitted variable endogeneity bias in our estimates and choose as our controls US stock prices and the CNY/USD exchange rate for both models.[22] The models are estimated using ordinary least squares (OLS) with White (1980) heteroskedasticity-robust standard errors.

To allow for the possibility that reserve accumulation influences risk taking differently depending on whether reserve levels are relatively high or relatively low, we extend our analysis to incorporate the non-temporal testing model originally developed by Hansen (2000) and estimate the following

$$\Delta S_t = \begin{cases} \beta_0^L + \beta_1^L \Delta RES_t + \beta_2^L \Delta CNYUSD_t + \beta_3^L \Delta USS_t + e_t \, if RES_t < q \\ \beta_0^H + \beta_1^H \Delta RES_t + \beta_2^H \Delta CNYUSD_t + \beta_3^H \Delta USS_t + e_t \, if RES_t \geq q \end{cases} \tag{3}$$

[16] Let A_t denote the value of a given reserve announcement on day t. Let E_t refer to the median value of the preceding survey expectations, and let $\widehat{\sigma}$ denote the sample standard deviation of all reserve announcement surprise components across the entire sample period. The standardized reserve announcement surprise on day t is then defined as $\frac{A_t - E_t}{\widehat{\sigma}}$.

[17] Note that Fig. 2 depicts pre-scaled (i.e. $A_t - E_t$) surprises. Note also that announcements are typically made outside of market hours (67 out of 76) and that the expectation errors are smaller after 2014, the latter suggesting that Chinese reserve announcements are increasingly predictable.

[18] The Chicago Board Options Exchange (CBOE) Volatility Index (VIX) is an oft-used indicator of global risk. The VIX is a forward-looking, model-free measure of the near-term (30-day) implied volatility of S&P 500 index options.

[19] Risk indicators as well as VIX and control variables are obtained as daily data series. For the purpose of our monthly frequency estimations (baseline and threshold), monthly series data points are generated from the daily data as the difference between previous end of month and current end of month observations.

[20] The reserve accumulation of these five economies is also considered in Jeanne (2007).

[21] Descriptive statistics on intraday data and comparison country series are available upon request.

[22] See, for example, Phylaktis and Ravazzolo (2005) and Longstaff, Pan, Pedersen, and Singleton (2011), respectively, for studies showing the relevance of exchange rates and US stock prices when modeling non-US stock prices and sovereign CDS spreads, respectively. Moreover, since reserve accumulation is in part a reflection of pursuing an active exchange rate management policy, including the exchange rate in our estimations ensures that the effects of reserve accumulation are not exaggerated from the reserve variable inadvertently serving as an exchange rate proxy variable.

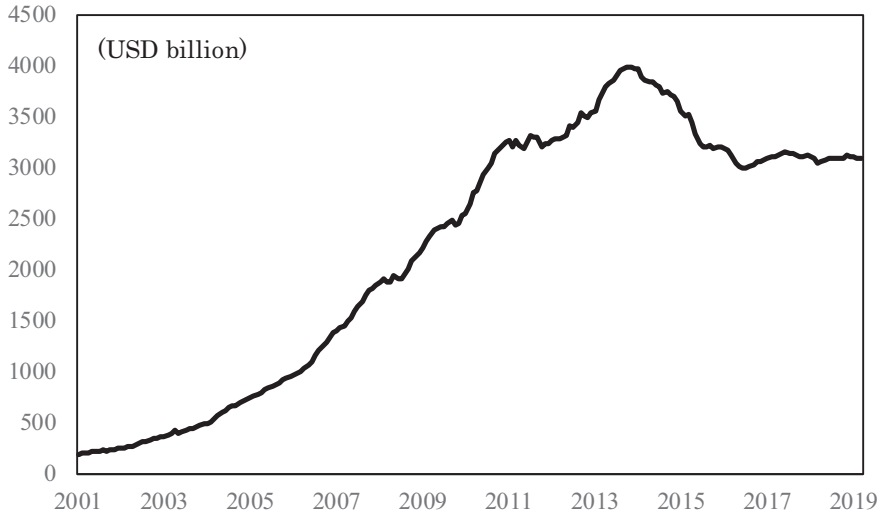

Fig. 1. Reserves: China. Source: Bloomberg.

Table 1
Descriptive statistics: July 2001 to October 2019.

	Start of Period	End of Period	Mean	Max	Min	Standard Deviation
Reserves: China (USD billion)	195.8	3092.4	2210.5	3993.2	195.8	1253.8
Stock Price Index: China (HKD)	1.9	75.0	53.1	103.9	13.7	22.2
CDS Spread (bps)	67.6	40.8	68.3	245.8	9.8	39.8
CNY/USD Exchange Rate	8.28	7.15	7.10	8.28	6.05	0.79
Stock Price Index: US (USD)	989.9	2891.2	1506.3	2891.2	700.7	569.7

Source: Bloomberg and Markit.

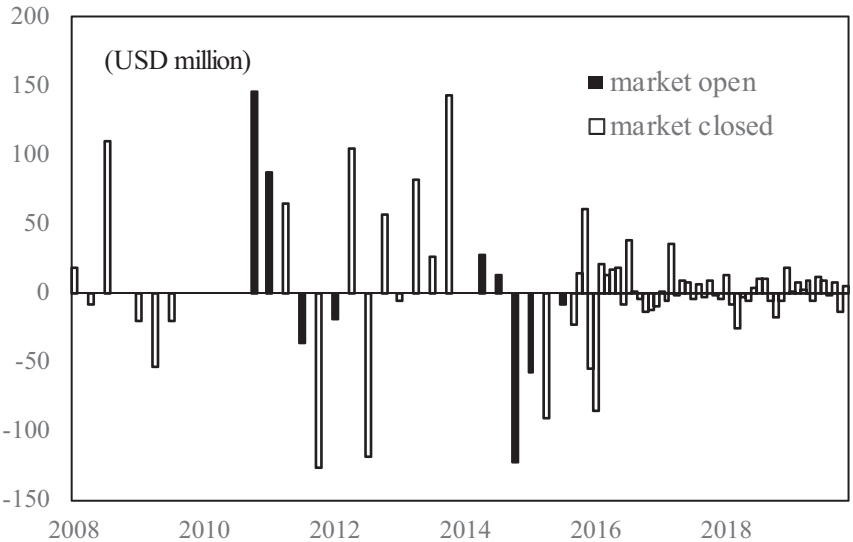

Fig. 2. Reserve Announcement Surprises: China. Source: Own calculations based on data from Bloomberg.

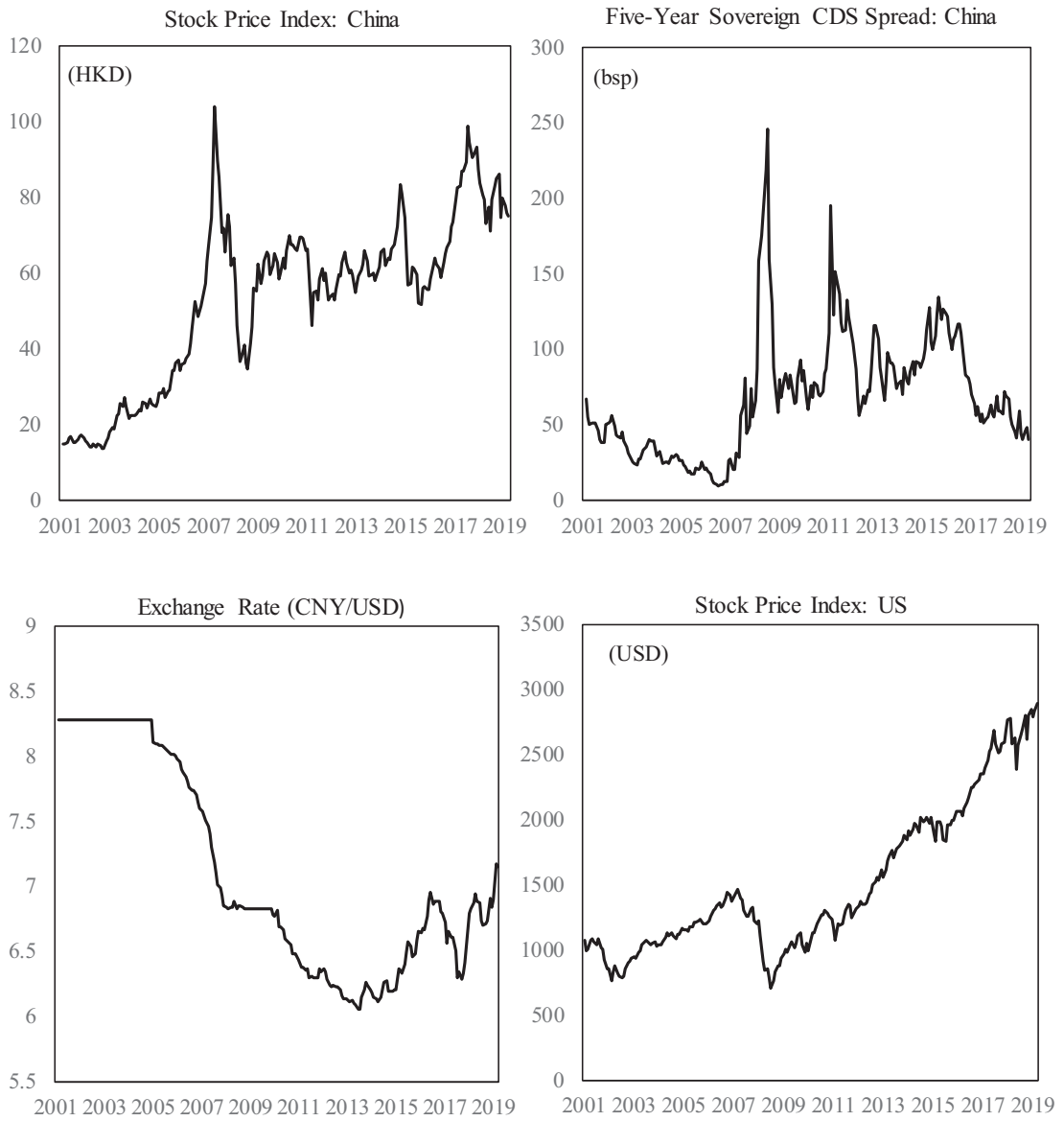

Fig. 3. Risk Indicators and Control Variables. Source: Bloomberg and Markit.

$$\Delta CDS_t = \begin{cases} \beta_0^L + \beta_1^L \Delta RES_t + \beta_2^L \Delta CNYUSD_t + \beta_3^L \Delta USS_t + e_t \, if RES_t < q \\ \beta_0^H + \beta_1^H \Delta RES_t + \beta_2^H \Delta CNYUSD_t + \beta_3^H \Delta USS_t + e_t \, if RES_t \geq q \end{cases} \tag{4}$$

where q is the reserve level threshold value to be estimated by the maximand of the likelihood ratio statistics over all permissible values. [23]Superscripts L and H denote low and high reserve levels, respectively. The non-temporal test of Hansen (2000) is similar to a standard temporal parameter change test for a single unknown breakpoint (e.g. Andrews 1993). However, instead of analyzing a temporally-ordered data set, the Hansen (2000) procedure dictates that we sort our data in a non-temporal fashion according to, in our context, levels of reserve holdings. Doing so allows us to endogenously identify in a non-temporal modeling framework the reserve level, if any, around which the influence of reserve accumulation on risk taking changes.[24]

[23] The permissible threshold values exclude the first and last 1% of the ordered sample.

[24] We also employ a non-temporal version of the Bai and Perron (1998) sequential test to consider a null hypothesis of one threshold against an alternative of two thresholds.

We subsequently extend the threshold analysis by also considering if the influence of reserve accumulation on risk taking depends on the level of global market uncertainty. To do so we re-estimate the models described in Eqs. (3) and (4) with sorting according to market uncertainty as measured by VIX levels.[25]

Next, we estimate daily frequency event study versions of the models described in Eqs. (1) and (2) with the surprise component of the reserve announcement, denoted $RESSURP_t$, in place of ΔRES_t, and all other variables describing the corresponding daily change on the day of the announcement. We include in these estimations only announcement day observations. Importantly, since the PBC does not announce reserve holdings for a given month until the beginning of the following month (typically on day 7 of the following month), and survey expectations pertaining to the announcement of a given month are formed and released prior to the day of the announcement, the announcement surprises are pre-determined relative to the risk taking measures. Therefore, the daily frequency estimations are effectively addressing reverse causality endogeneity bias in the reserve variable coefficient estimates.[26]

Lastly, we incorporate the intraday tick-level stock price data into our analysis. We do so by estimating 1-minute, 2-minute, and 5-minute intraday event study versions of Eq. (1) for each of the three Chinese stock market indices considered (the CSI 300 Index, the Shanghai SE Composite Index, and the Shenzhen SE Composite Index). As in our daily frequency event study estimations we use the surprise component of reserve announcements in place of ΔRES_t.[27]As noted earlier, most Chinese reserve announcements occur outside of market hours, leaving us with only 9 announcements for which intraday windows can be constructed as described.[28] Nevertheless, by assessing the influence of announcement surprises pertaining to pre-determined reserve levels across window lengths sufficiently short that we can reasonably assume that no other relevant news or events occur, we are effectively addressing both omitted variable and reverse causality endogeneity concerns.

5. Results

Table 2 shows the results of our full sample baseline regressions. The top panel pertains to estimations of the model described in Eq. (1), where the Chinese stock price index is the risk indicator, and the bottom panel pertains to estimations of the model described in Eq. (2), where the Chinese sovereign CDS is the risk indicator. To provide a nuanced picture of the influence of reserve accumulation on the risk indicators, we estimate all models without control variables included, with only the exchange rate control variable included, and with both exchange rate and US stock price control variables included. As the top panel results show, the reserve variable coefficient estimate with respect to the stock price risk indicator is consistently positive and significant. The addition of the exchange rate control variable does little to change the magnitude and significance of the reserve variable coefficient estimate, and while controlling for US stock prices noticeably does, the reserve variable remains positive and significant at conventional levels, thereby implying that an increase in Chinese reserve holdings is systematically associated with an increase in domestic stock prices and thus consistent with more willingness to assume risk. Similarly, the bottom panel results show that the reserve variable coefficient estimate with respect to the CDS spread indicator is consistently negative and significant at the 5% level or higher in all three estimations. This conforms to the suggestion that as reserve levels increase, investors become less inclined to obtain insurance against sovereign default or restructuring in reflection of more willingness to assume risk.

Tables 3 and 4 report the results of re-estimating Eqs. (1) and (2) separately across three sub-samples spanning, respectively, the pre-GFC period (August 2001 to July 2007), the GFC period (August 2007 to December 2008), and the post-GFC period (January 2009 to October 2019).[29] The results pertaining to both risk indicators are remarkably consistent. Both sets of estimations strongly indicate that reserve accumulation prior to the GFC did not systematically influence neither Chinese stock prices (first panel of Table 3) nor CDS spreads (first panel of Table 4). Similarly, even though some significant effects of reserve accumulation are reported across the reserves only and the reserves and exchange rates only specifications, once we control for US stock prices we again find no effects of reserves (second panel of Tables 3 and 4). However, when we consider the post-GFC sample, our full sample results for both risk indicators are repeated (third panel of Tables 3 and 4). Clearly, the sub-sample results suggest that the influence of reserves on risk is stronger after the GFC. This is an interesting finding that, since reserve levels at any point before and during the GFC are markedly lower than at any point after the GFC, might suggest that discernable risk taking effects of reserve accumulation do not manifest until reserve holdings have reached a given level.

To further consider whether this is the case we turn to threshold estimations. Tables 5A and 5B display the results of estimating Eq. (3), i.e. the threshold model where Chinese stock prices serve as the risk indicator, with reserve levels and VIX levels, respectively, as the sorting variables. All threshold estimations are carried out separately across the full sample and across the post-GFC sample. Comparing significance of the reserve variable coefficient estimates across the full and

[25] See Fatum and Yamamoto (2016) for an application of the non-temporal threshold procedure along with additional details.

[26] We subsequently employ a heteroskedasticity-based identification procedure to address the potential issue of unaccounted for variables that influence both reserves and risk taking measures in our daily data models and we perform a test for endogeneity. These extensions are discussed in Section 6.

[27] For each of the three stock price indices employed, the event window is set to start at the open price of the minute of the announcement and end at the closing price of the minute corresponding to the given window length. For example, if the announcement is made at 10:05, the windows start at the open price of 10:05 and the 1-, 2-, and 5-minute windows end at the closing prices of 10:05, 10:06, and 10:09, respectively.

[28] The PBC does not pre-announce release times of their statistics, and most are announced outside of market hours, typically late afternoon. There is no rationale provided by the PBC, or the Bloomberg data source, regarding why the PBC reserves announcement times are not pre-scheduled and vary, thus there is to our knowledge no special circumstances pertaining to the 9 announcements that were made during domestic market hours.

[29] GFC dates are set in accordance with Melvin and Taylor (2009).

Table 2
Baseline Estimations (Full Sample): Stock Price Index and CDS.

Dependent Variable (Risk Indicator): ΔS_t			
Dependent Variable: Stock From August 2001 to October 2019			
ΔRES	1.25***	1.09***	0.45*
	(3.72)	(3.28)	(1.82)
ΔCNYUSD		−1.87***	−1.33***
		(-3.50)	(-3.48)
ΔUSS			0.97***
			(8.93)
Constant	0.75	0.65	0.39
	(1.58)	(1.43)	(1.05)
R2	0.09	0.13	0.42
obs	218	218	218
Dependent Variable (Risk Indicator): ΔCDS_t Dependent Variable: CDS			
From August 2001 to October 2019			
ΔRES	−2.87***	−2.77***	−1.33**
	(-3.81)	(-3.61)	(-2.52)
ΔCNYUSD		1.17	−0.02
		(1.35)	(-0.03)
ΔUSS			−2.17***
			(-6.71)
Constant	0.53	0.59	1.16
	(0.52)	(0.59)	(1.45)
R2	0.10	0.11	0.42
obs	218	218	218

Notes: 1. *t* statistics in parentheses.
2. ***, **, and * denote significant at the 1%, 5%, and the 10% levels, respectively.

the post-GFC sample, Table 5A confirms that reserves are particularly influential after the GFC. Noticeably, the table also shows that for the post-GFC sample reserves matter regardless of whether prevailing reserve levels are high or low. By contrast, this is not the case when considering the full sample results where the effects of reserve accumulation when prevailing reserve holdings are relatively low are found to be smaller in magnitude and mostly insignificant compared to when prevailing reserve holdings are relatively high. Again, since reserve levels at any point in time after the GFC are higher than at any point in time before the crisis, this is consistent with the suggestion that perhaps it is not that reserves matter more for risk taking after the GFC per se, but, rather, that reserves matte more for risk taking when reserve holdings are already high, as is the case after the GFC.

Table 5B again confirms that reserves matter more after the GFC compared to across the full sample, but only as far as magnitude of coefficient estimates goes. Interestingly, the Table 5B results suggest that the influence of reserves on the stock price risk indicator is more pronounced when the overall level of uncertainty is high.

Tables 6A and 6B pertain to the threshold model described in Eq. (4), i.e. the threshold model where Chinese CDS spreads are used to indicate risk. Table 6A results are similar to Table 5A results just described, except once we include the US stock price control variable in our estimations we no longer maintain significance of the reserve variable regardless of whether we consider the full or the post-GFC sample and regardless of whether prevailing reserve levels are high or low. The results provided in Table 6B show a (marginally) significant effect of reserves on the CDS spread only for the post-GFC high uncertainty segment, even after controlling for both exchange rates and US stock prices, again suggesting that the influence of reserves on risk is more discernable after the GFC and when uncertainty is high.

Table 7 shows the results of the daily data event study analysis of the January 2008 to October 2019 period for which reserve announcement surprises can be constructed. The top panel pertains to the daily data event study estimation of the stock price risk indicator with reserve announcement surprises in place of ΔRES_t, i.e. the daily data event study version of Eq. (1). As the panel shows, the reserve variable coefficient estimates are consistently positive and highly significant, at the 1% level, regardless of whether or not we control for exchange rates and US stock prices. Even the magnitudes of the three reserve variable coefficient estimates are very similar. These are strong findings as they after addressing potential reverse causality endogeneity concerns further confirm that an increase in reserve holdings is systematically and significantly associated with an increase in the stock price risk indicator.

Table 3
Baseline Estimations (Sub-Samples): Stock Price Index.

Dependent Variable (Risk Indicator): ΔS_t			
Pre GFC Sample			
From August 2001 to July 2007			
ΔRES	−0.48	−0.40	−0.52
	(-0.97)	(-0.73)	(-1.30)
ΔCNYUSD		−4.95**	−3.66*
		(-2.46)	(-1.75)
ΔUSS			0.81***
			(4.74)
Constant	3.08***	2.33*	2.52
	(2.77)	(1.86)	(2.68)
R2	0.02	0.07	0.29
obs	71	71	71
GFC Sample			
From August 2007 to December 2008			
ΔRES	3.20	4.61***	−0.60
	(1.43)	(2.89)	(-0.27)
ΔCNYUSD		8.29*	5.12
		(1.81)	(1.38)
ΔUSS			1.88***
			(3.54)
Constant	−2.05	3.05	5.86
	(-0.62)	(0.81)	(1.63)
R2	0.11	0.22	0.56
obs	17	17	17
Post GFC Sample			
From January 2009 to October 2019			
ΔRES	2.59***	2.23***	1.05***
	(7.76)	(6.35)	(2.90)
ΔCNYUSD		−1.96***	−1.54
		(-4.77)	(-5.56)
ΔUSS			0.73***
			(6.51)
Constant	1.99***	1.87***	0.52
	(4.13)	(4.10)	(1.11)
R2	0.31	0.41	0.54
obs	129	129	129

Notes: Same as Table 2.

In complete tandem, the bottom panel results, pertaining to the daily data event study estimation of the CDS risk indicator and the daily data event study version of Eq. (2), similarly add to the evidence that an increase in reserve holdings is associated with a systematic and significant decrease in the CDS risk indicator, thereby again supporting the suggestion that reserve accumulation leads to an increase in risk taking.

Finally, our intraday results are reported in Table 8 and pertain to the intraday event study version of Eq. (1) without control variables. While all but one of 9 coefficient estimates are positive, consistent with the suggestion that an increase in reserves is associated with an increase in stock prices and thus increased willingness to assume risk, only one of these estimates is significant (the Shanghai SE Composite Index for the 1-minute window). As noted earlier, our intraday analysis effectively addresses both omitted variable and reverse causality endogeneity concerns but is restricted by the very low number of reserve announcements made during market hours. In that sense the consistency with respect to the sign of the reserve surprise coefficient estimates is quite remarkable, as is the significant effect of reserves with respect to one of the stock market indices for the 1-minute window.

Overall, our results provide very consistent evidence across monthly frequency estimations, and across daily and intraday event study estimations, that PBC reserve accumulation after the GFC is systematically associated with an increase in willingness to take on more stock market risk (as domestic stock prices on average rise in response to reserve accumulation) and more sovereign credit default risk (as prices and thus demand for sovereign default insurance on average decline in response to reserve accumulation), thereby supporting the suggestion that reserve accumulation comes at the additional cost of an increase in risk taking. Although a very different study with respect to methodology, data, and time-period focus, our findings are consistent with those of Tong and Wei (2021). By contrast, our findings are different from those of Fatum and Yetman (2020) and their lack of systematic evidence that reserve accumulation influences risk taking as per their focal risk measure of implied volatility of currency options. However, our findings are not at odds with their stock price and CDS spread risk indicator based results to the extent that for these two measures Fatum and Yetman (2020) do not reject that reserve accumulation matters for risk taking. Our CDS-based findings are broadly consistent with Ismailescu and Phillips

Table 4
Baseline Estimations (Sub-Samples): CDS.

Dependent Variable (Risk Indicator): ΔCDS_t			
Pre GFC Sample			
From August 2001 to July 2007			
ΔRES	−0.09	−0.09	−0.03
	(-0.39)	(-0.38)	(-0.12)
ΔCNYUSD		−0.03	−0.65
		(-0.02)	(-0.40)
ΔUSS			−0.39**
			(-2.01)
Constant	−0.22	−0.23	−0.32
	(-0.37)	(-0.36)	(-0.47)
R2	0.00	0.00	0.11
obs	71	71	71
GFC Sample			
From August 2007 to December 2008			
ΔRES	−9.06**	−10.39**	−1.39
	(-2.09)	(-2.35)	(-0.51)
ΔCNYUSD		−7.78	−2.30
		(-0.99)	(-0.39)
ΔUSS			−3.25***
			(-6.60)
Constant	8.57*	3.78	−1.07
	(1.76)	(0.56)	(-0.18)
R2	0.32	0.35	0.72
obs	17	17	17
Post GFC Sample			
From January 2009 to October 2019			
ΔRES	−6.52***	−6.30***	−2.34*
	(-4.77)	(-4.35)	(-1.94)
ΔCNYUSD		1.20	−0.21
		(1.33)	(-0.22)
ΔUSS			−2.46***
			(-4.90)
Constant	−4.48	−4.40	0.10
	(−2.98)	(−2.93)	(0.08)
R2	0.25	0.26	0.45
obs	129	129	129

Notes: Same as Table 2.

(2015) showing that high levels of reserves are associated with less trading of sovereign CDS, in the sense that less CDS trading could reflect less efforts being taken to insure against risk.

6. Robustness and extensions

In this section we re-estimate our daily data models using heteroskedasticity-based identification, test for endogeneity, consider the influence of reserves on risk for other Asian emerging economies, address if Chinese reserve accumulation increases domestic market uncertainty, and analyze separately the post-July 2005 floating CNY regime.

First, we consider the possibility that missing variables affect both our exogenous variable and our risk taking indicators, resulting in our exogenous variable becoming a noisy measure of the reserves surprise.[30] Rather than attempting to address the missing variables concern by controlling for any and all variables that could possibly influence both risk taking measures and reserves surprises, or relying on our intraday results that are subject to small sample limitations, we pursue an alternative approach which requires weaker assumptions, namely the heteroskedasticity-based identification procedure proposed by the seminal studies of Rigobon (2003a,b) and Rigobon and Sack (2003, 2004). Our context lends itself well to the application of this procedure because our sample period encompasses a well-defined policy shift that occurred when China to increase transparency in October 2015 started to disclose its reserve portfolio.[31] When we run the heteroskedasticity-based identification procedure with stock returns as the risk-taking indicator we obtain a reserves surprise point estimate of 0.38, thus somewhat smaller than the corresponding OLS estimate previously discussed, but still statistically significant at the 10% level. When using

[30] See Nakamura and Steinsson (2018) and Gürkaynak, Kısacıkoğlu and Wright (2020).

[31] As shown in Fig. 2, this policy shift appears to have resulted in a noticeable decrease in the variance of investor forecast errors for the total reserve amounts. At the same time this policy change and resulting forecast error variance decrease should not influence how other shocks might affect investor risk-taking.

Table 5A
Stock Price Index and Reserve Amount Thresholds.

Dependent Variable (R isk Indicator):ΔS_t						
Threshold variable:RES_{t-1}						
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔRES (High)	3.72***	3.42***	1.19	2.37***	2.52***	1.84**
	(6.08)	(5.60)	(1.27)	(4.38)	(4.26)	(2.29)
ΔCNYUSD (High)		2.88	1.58		2.15	2.09
		(1.13)	(0.87)		(1.39)	(1.37)
ΔUSS (High)			0.94***			0.37
			(2.92)			(1.17)
Constant (High)	−0.70	1.56	−1.15	−0.93	−0.53	−0.83
	(-0.68)	(1.59)	(-0.91)	(-1.10)	(-0.54)	(-0.78)
R2 (High)	0.46	0.32	0.58	0.48	0.50	0.54
obs (High)	40	62	36	24	24	24
ΔRES (Low)	0.76**	0.30	0.29	2.76***	2.27***	1.09***
	(2.24)	(0.94)	(1.11)	(7.21)	(5.87)	(2.63)
ΔCNYUSD (Low)		−2.67***	−1.74***		−2.20***	−1.68***
		(-6.64)	(-4.35)		(-5.62)	(-6.48)
ΔUSS (Low)			0.95***			0.76***
			(7.37)			(6.27)
Constant (Low)	1.30***	1.20***	0.91**	2.76***	2.66***	0.99*
	(2.59)	(2.72)	(2.22)	(4.96)	(5.14)	(1.79)
R2 (Low)	0.04	0.19	0.40	0.31	0.46	0.58
obs (Low)	177	155	181	104	104	104
SupF(1|0)	18.10***	23.53***	13.01	11.34*	18.14**	11.18
SupF(2|1)	6.40	7.48	13.60	4.35	10.61	4.90
Threshold	0.435	0.405	0.438	0.447	0.447	0.447

Notes: Same as Table 2.

Table 5B
CDS and reserve amount thresholds.

Dependent Variable (Risk Indicator):ΔS_t						
Threshold variable:VIX_{t-1}						
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔRES (High)	3.38***	1.95***	0.93***	2.62***	3.84***	2.40***
	(4.78)	(4.27)	(2.81)	(7.69)	(5.56)	(3.40)
ΔCNYUSD (High)		−0.39	0.33		−7.48**	−6.61***
		(-0.22)	(0.24)		(-2.51)	(-4.08)
ΔUSS (High)			0.96***			0.74***
			(6.80)			(3.34)
Constant (High)	−0.74	−0.25	−0.17	1.58***	2.28	0.37
	(-0.45)	(-0.32)	(-0.27)	(3.09)	(1.34)	(0.26)
R2 (High)	0.50	0.17	0.50	0.34	0.77	0.87
obs (High)	22	98	91	114	13	13
ΔRES (Low)	0.91***	0.22	0.00	3.04*	1.57***	0.54
	(2.69)	(0.52)	(0.01)	(1.79)	(4.47)	(1.49)
ΔCNYUSD (Low)		−2.84***	−2.05***		−2.09***	−1.63***
		(-6.62)	(-5.97)		(-4.93)	(-5.73)
ΔUSS (Low)			0.94***			0.73***
			(5.25)			(5.99)
Constant (Low)	0.90*	1.41***	0.88**	5.90***	1.37***	0.11
	(1.86)	(3.02)	(1.95)	(4.26)	(2.95)	(0.23)
R2 (Low)	0.05	0.24	0.37	0.24	0.34	0.48
obs (Low)	195	119	126	14	115	115
SupF(1|0)	11.29**	11.99	10.12	8.00	17.69**	16.69**
SupF(2|1)	4.07	11.12	6.55	5.96	17.48**	8.97
Threshold	29.15	17.47	18.07	11.99	14.19	26.05

Notes: Same as Table 2.

the CDS spread, the coefficient estimate is −0.94, i.e. closer to the corresponding OLS estimate, and significant even at the 1% level. Clearly, this extension provides further evidence of the causal effect of reserves on risk-taking.

Second, we implement the Hausman (1978) specification test to assess whether endogeneity is present in our baseline model described in Equation (2). A rejection indicates of the null hypothesis indicates the presence of endogeneity. When considering stock returns as our risk indicator, the test statistic is 1.97 with the asymptotic p-value 0.104, indicating that

Table 6A
Stock price index and market uncertainty thresholds.

Dependent Variable (Risk Indicator): ΔCDS_t						
Threshold variable: RES_{t-1}						
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔRES (High)	−8.55***	−9.01***	−1.83	−7.52**	−7.50**	−1.55
	(-4.42)	(-4.34)	(-1.24)	(-2.38)	(-2.34)	(-0.68)
ΔCNYUSD (High)		−5.27	−0.03		2.23	−2.74
		(-1.10)	(-0.02)		(0.52)	(-0.84)
ΔUSS (High)			−3.22***			−3.82***
			(-6.89)			(-3.61)
Constant (High)	1.66	0.01	1.66	5.54**	5.84*	2.67
	(0.61)	(0.00)	(0.93)	(2.04)	(1.76)	(1.00)
R2 (High)	0.31	0.32	0.58	0.39	0.43	0.55
obs (High)	62	62	81	25	26	46
ΔRES (Low)	−0.76**	−0.53	−0.37	−6.38***	−6.06***	−1.24
	(-2.24)	(-1.57)	(-1.20)	(-5.14)	(-4.40)	(-1.08)
ΔCNYUSD (Low)		2.43***	1.75**		1.93**	1.17
		(3.05)	(2.32)		(2.16)	(1.36)
ΔUSS (Low)			−0.76***			−1.40***
			(-3.91)			(-3.71)
Constant (Low)	−0.74	−0.87	−0.35	−7.15***	−7.20***	−0.60
	(-1.07)	(-1.29)	(-0.60)	(-4.02)	(-3.88)	(-0.41)
R2 (Low)	0.03	0.10	0.27	0.26	0.27	0.33
obs (Low)	155	155	136	103	102	82
SupF(1|0)	37.29***	38.54***	32.91**	19.40*	20.89*	9.76
SupF(2|1)	5.69	3.85	12.63	18.18**	21.43***	8.21
Threshold	0.405	0.405	0.393	0.447	0.400	0.399

Notes: Same as Table 2.

Table 6B
CDS and Market Uncertainty Thresholds.

Dependent Variable (Risk Indicator): ΔCDS_t						
Threshold variable: VIX_{t-1}						
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔRES (High)	−12.57***	−12.11***	−5.85	−13.31***	−14.81***	−5.62*
	(-5.34)	(-4.54)	(-1.52)	(-3.26)	(-3.62)	(-1.79)
ΔCNYUSD(High)		29.03	30.64		30.89*	25.29**
		(0.87)	(1.43)		(1.75)	(2.50)
ΔUSS (High)			−2.46**			−4.76***
			(-2.19)			(-3.10)
Constant (High)	7.19	8.28	5.52	−9.30	−3.21	9.08
	(1.14)	(1.33)	(0.89)	(-0.97)	(-0.31)	(1.25)
R2 (High)	0.48	0.50	0.64	0.48	0.57	0.75
obs (High)	22	22	22	13	13	13
ΔRES (Low)	−1.25***	−1.10***	−0.53	−3.50***	−2.98***	−0.63
	(-3.18)	(-2.86)	(-1.62)	(-4.54)	(-3.52)	(-0.73)
ΔCNYUSD (Low)		1.46*	0.47		1.91**	0.85
		(1.72)	(0.68)		(2.28)	(1.04)
ΔUSS (Low)			−1.55***			−1.68***
			(-7.45)			(-5.09)
Constant (Low)	−0.08	0.00	0.65	−2.49**	−2.31	0.57
	(-0.12)	(0.00)	(1.08)	(-2.35)	(-2.23)	(0.50)
R2 (Low)	0.04	0.06	0.33	0.15	0.18	0.37
obs (Low)	195	195	195	115	115	115
SupF(1|0)	116.73***	99.34***	30.29*	27.13*	30.86**	81.38***
SupF(2|1)	8.03	6.21	5.42	1.16	2.99	6.62
Threshold	29.15	29.15	29.15	26.05	26.05	26.05

Notes: Same as Table 2.

the evidence of endogeneity is non-existent or very weak. We obtain a test statistic of 0.03 with the asymptotic p-value 0.874 when the CDS spread is used as the risk indicator. Hence, there is very little statistical evidence to suggest the presence of endogeneity even in our daily data baseline model.

Third, to provide more context to our investigation we extend our monthly frequency time-series estimations described in Equations (1) and (2) to consider the influence of reserve accumulation on risk taking for Indonesia, South Korea, Malaysia,

Table 7
Daily data estimations: reserve announcement surprises.

Dependent Variable (Risk Indicator):ΔS_t			
RESSURP	0.50***	0.47***	0.45***
	(3.32)	(3.29)	(3.18)
ΔCNYUSD		−0.82	−0.65
		(-1.17)	(-1.07)
ΔUSS			0.41**
			(2.34)
Constant	0.07	0.09	0.06
	(0.49)	(0.61)	(0.45)
R2	0.13	0.15	0.22
obs	76	76	76
Dependent Variable (Risk Indicator):ΔCDS_t			
RESSURP	−0.98***	−0.96***	−0.96***
	(-3.57)	(-3.47)	(-3.34)
ΔCNYUSD		0.46	0.35
		(0.42)	(0.33)
ΔUSS			−0.26
			(-1.17)
Constant	−0.37	−0.38	−0.36
	(-1.08)	(-1.10)	(-1.07)
R2	0.10	0.10	0.10
obs	76	76	76

Notes: Same as Table 2.

Table 8
Intraday estimations: reserve announcement surprises.

(a) CSI 300 Index			
	1-minute	2-minute	5-minute
RESSURP	1.01	2.32	0.62
	(0.78)	(0.80)	(0.11)
Constant	−0.47	−1.99	−3.68
	(-0.29)	(-0.72)	(-0.55)
R2	0.04	0.06	0.00
obs	9	9	9
(b) Shanghai SE Composite Index			
	1-minute	2-minute	5-minute
RESSURP	2.04**	2.63	1.20
	(2.48)	(1.18)	(0.33)
Constant	−0.12	1.06	−0.94
	(-0.10)	(0.32)	(-0.17)
R2	0.21	0.05	0.00
obs	9	9	9
(c) Shenzhen SE Composite Index			
	1-minute	2-minute	5-minute
RESSURP	0.97	2.00	1.82
	(0.99)	(0.88)	(0.34)
Constant	0.19	−0.68	−2.03
	(0.14)	(-0.25)	(-0.31)
R2	0.05	0.05	0.01
obs	9	9	9

Notes: Same as Table 2.

Philippines, and Thailand. Tables 9 (domestic stock price as risk indicator) and 10 (local currency sovereign CDS as risk indicator) present the results. When we make use of the domestic stock price risk indicator, we find that the results for Indonesia are particularly similar to those of China, and when we employ the local currency sovereign CDS risk indicator the results for South Korea are particularly similar to those of China. Overall, these results suggest that while we do not find systematic evidence to support that reserve accumulation increases risk taking to the same extent as in the case of China, we nevertheless find indications that reserve accumulation has qualitatively similar risk consequences for other Asian emerging econo-

Table 9
Baseline Estimations for Comparison Countries: Stock Price Indices.

Dependent Variable (Risk Indicator): $\Delta LOCSTOCK_t$						
	Indonesia (Full Sample)			Indonesia (Post GFC)		
	From May 2004 to October 2019			From January 2009 to October 2019		
ΔLOCRES	0.88***	0.47***	0.40***	0.88***	0.51***	0.44***
	(4.79)	(4.11)	(4.01)	(6.55)	(3.82)	(3.63)
ΔLOCUSD		−1.22***	−0.94***		−1.19***	−0.95***
		(-7.40)	(-6.27)		(-6.53)	(-5.64)
ΔUSS			0.46***			0.39***
			(5.18)			(4.04)
Constant	1.38***	1.67***	1.34***	1.01**	1.31***	0.87***
	(3.45)	(4.97)	(4.23)	(2.47)	(3.65)	(2.57)
R2	0.21	0.45	0.51	0.23	0.45	0.51
obs	185	185	185	129	129	129
	South Korea (Full Sample)			South Korea (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	1.08***	0.64**	0.31	1.04***	0.34	0.16
	(3.87)	(2.22)	(1.45)	(3.26)	(1.60)	(0.81)
ΔLOCUSD		−0.55***	−0.07		−0.85***	−0.44***
		(-4.39)	(-0.53)		(-7.92)	(-3.71)
ΔUSS			0.86***			0.57***
			(8.79)			(5.64)
Constant	0.70*	0.77**	0.45	0.45	0.51	−0.01
	(1.84)	(2.11)	(1.49)	(1.24)	(1.58)	(-0.04)
R2	0.10	0.17	0.42	0.14	0.38	0.52
obs	218	218	218	129	129	129
	Malaysia (Full Sample)			Malaysia (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	0.41***	0.29**	0.22**	0.32**	0.14	0.09
	(2.95)	(2.12)	(1.97)	(2.40)	(1.24)	(0.87)
ΔLOCUSD		−0.58***	−0.33***		−0.52***	−0.35***
		(-6.14)	(-3.27)		(-5.65)	(-3.55)
ΔUSS			0.35***			0.24***
			(4.58)			(2.77)
Constant	0.42*	0.46*	0.29	0.52**	0.55**	0.26
	(1.69)	(1.95)	(1.29)	(2.02)	(2.32)	(1.13)
R2	0.08	0.16	0.28	0.06	0.21	0.29
obs	218	218	218	129	129	129
	Philippines (Full Sample)			Philippines (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	0.39*	0.15	0.14	0.75**	0.42	0.44
	(1.88)	(0.84)	(0.82)	(2.28)	(1.38)	(1.48)
ΔLOCUSD		−1.28***	−0.87***		−1.19***	−0.79***
		(-5.06)	(-3.58)		(-4.49)	(-2.74)
ΔUSS			0.47***			0.34***
			(4.48)			(3.40)
Constant	0.78**	0.82**	0.61*	1.06***	1.16***	0.77**
	(2.07)	(2.34)	(1.81)	(2.79)	(3.34)	(2.28)
R2	0.02	0.14	0.25	0.08	0.23	0.30
obs	218	218	218	129	129	129
	Thai (Full Sample)			Thai (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	0.74***	−0.08	−0.02	1.03***	0.29*	0.12
	(4.22)	(-0.37)	(-0.10)	(5.40)	(1.73)	(0.59)
ΔLOCUSD		−2.02***	−1.42***		−1.64***	−1.35***
		(-6.27)	(-5.76)		(-8.40)	(-5.68)
ΔUSS			0.67***			0.44***
			(6.19)			(4.15)
Constant	0.74*	0.59	0.38	0.92**	0.82**	0.40
	(1.83)	(1.63)	(1.19)	(2.41)	(2.49)	(1.28)
R2	0.07	0.25	0.43	0.19	0.40	0.50
obs	218	218	218	129	129	129

Notes: 1. *t* statistics in parentheses.
2. ***, **, and * denote significant at the 1%, 5%, and the 10% levels, respectively.
3. LOCSTOCK is the MSCI stock price index for a given comparison country. LOCRES is the amount of reserves (USD million) held by a given comparison country. LOCUSD is the exchange rate in local currency per USD for a given comparison country.

Table 10
Baseline Estimations for Comparison Countries: CDS Spreads.

Dependent Variable (Risk Indicator): $\Delta LOCCDS_t$						
	Indonesia (Full Sample)			Indonesia (Post GFC)		
	From May 2004 to October 2019			From January 2009 to October 2019		
ΔLOCRES	−5.39**	−2.34**	−1.76**	−4.54***	−2.01*	−1.36
	(-2.47)	(-2.40)	(-2.26)	(-3.91)	(-1.76)	(-1.44)
ΔLOCUSD		9.02***	6.38***		8.25***	6.01***
		(3.91)	(3.44)		(5.31)	(4.46)
ΔUSS			−4.32***			−3.65***
			(-5.33)			(-4.65)
Constant	−2.47	−4.54**	−1.53	−3.22	−5.31**	−1.19
	(-0.91)	(-2.19)	(-0.78)	(-1.20)	(-2.23)	(-0.58)
R2	0.17	0.46	0.59	0.16	0.43	0.58
obs	185	185	185	129	129	129
	South Korea (Full Sample)			South Korea (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	−4.74***	−2.60	−1.80**	−4.73***	−2.35***	−1.86***
	(-3.89)	(-2.20)	(-1.98)	(-4.47)	(-3.60)	(-3.07)
ΔLOCUSD		2.67***	1.48***		2.88***	1.79***
		(5.04)	(2.85)		(6.81)	(3.74)
ΔUSS			−2.08***			−1.51***
			(-4.68)			(-4.74)
Constant	2.11	1.75	2.53**	0.25	0.05	1.45
	(1.55)	(1.41)	(2.14)	(0.20)	(0.04)	(1.47)
R2	0.15	0.28	0.40	0.24	0.47	0.56
obs	218	218	218	129	129	129
	Malaysia (Full Sample)			Malaysia (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	−1.77**	−0.65	−0.10	−3.10***	−1.31	−0.76
	(-2.39)	(-1.00)	(-0.21)	(-2.76)	(-1.55)	(-1.08)
ΔLOCUSD		5.45***	3.71***		5.13***	3.29***
		(6.68)	(4.95)		(5.83)	(4.19)
ΔUSS			−2.47***			−2.71***
			(-7.25)			(-6.16)
Constant	−0.32	−0.70	0.46	−2.2	−2.50*	0.74
	(-0.25)	(-0.64)	(0.51)	(-1.23)	(-1.68)	(0.59)
R2	0.06	0.32	0.54	0.11	0.40	0.59
obs	218	218	218	129	129	129
	Philippines (Full Sample)			Philippines (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	−2.12**	−0.45	−0.38	−1.88*	0.42	0.26
	(-1.98)	(-0.45)	(-0.39)	(-1.93)	(0.56)	(0.33)
ΔLOCUSD		8.91***	5.63***		8.22***	4.58***
		(5.39)	(4.65)		(6.14)	(4.52)
ΔUSS			−3.79***			−3.09***
			(-5.15)			(-5.70)
Constant	−1.74	−2.07	−0.39	−2.55	−3.24**	0.26
	(-0.79)	(-1.04)	(-0.21)	(-1.33)	(-2.04)	(0.20)
R2	0.02	0.19	0.39	0.02	0.33	0.55
obs	218	218	218	129	129	129
	Thai (Full Sample)			Thai (Post GFC)		
	From August 2001 to October 2019			From January 2009 to October 2019		
ΔLOCRES	−1.92**	0.05	−0.17	−3.62***	−1.38	−0.29
	(-2.39)	(0.05)	(-0.27)	(-3.21)	(-1.21)	(-0.35)
ΔLOCUSD		4.87***	2.62***		4.98***	3.10
		(4.40)	(3.55)		(3.49)	(3.13)
ΔUSS			−2.50***			−2.78***
			(-7.44)			(-6.37)
Constant	−0.06	0.29	1.07	−1.36	−1.04	1.60
	(-0.05)	(0.25)	(1.06)	(-0.87)	(-0.70)	(1.22)
R2	0.05	0.17	0.44	0.15	0.26	0.51
obs	218	218	218	129	129	129

Notes: 1. *t* statistics in parentheses.
2. ***, **, and * denote significant at the 1%, 5%, and the 10% levels, respectively.
3. LOCCDS is the five-year sovereign CDS series for a given comparison country. LOCRES is the amount of reserves (USD million) held by a given comparison country. LOCUSD is the exchange rate in local currency per USD for a given comparison country.

mies and thus that unintended increases in risk taking as a result of holding large amounts of reserves is not unique to China (see Table 10).

Fourth, we address if Chinese reserve accumulation increases domestic stock market uncertainty by estimating equation (1) at the monthly and the daily frequency with the China ETF volatility index ("Chinese VIX") as the dependent variable.[32] Using monthly data our results suggest that an increase in reserve accumulation reduces market uncertainty when we include either no control variables or only the exchange rate variable. Once we control for US stock prices the influence of reserves is no longer significant. When we carry out daily data event study estimations of the effects of reserve announcement surprises we find no systematic influence of reserves on market uncertainty, regardless of whether or which control variables are included. Overall, these estimations do not point to a systematic link between reserves and domestic market uncertainty.

Fifth and final, we redo the monthly frequency analysis on a reduced sample that excludes the August 2001 to June 2005 period of fixed CNY/USD exchange rates. We do so to ensure that the absence of significant reserve variable coefficient estimates pre-GFC is not due to the fixed exchange rate regime that describes most of the pre-GFC period. As it turns out, our previously described results remain unchanged.[33]

7. Conclusion

We consider if the Chinese accumulation of reserves is associated with unintended consequences in the form of increased private sector risk taking over the 2001 to 2019 period. Using sovereign CDS spreads and stock index prices as indicators of private sector risk taking we first estimate monthly frequency models of the effects of reserve accumulation on our risk taking indicators. Our results suggest that as reserve holdings increase so does the willingness of the private sector to take on more risk. When we compare the effects of reserves on risk taking across sub-samples, our results show that the effects are noticeably more pronounced after the GFC while largely absent prior to and during the GFC. Our monthly frequency threshold models confirm that reserves matter more for risk taking after the GFC when reserve levels are consistently high.

We incorporate survey expectations of Chinese reserve announcements to identify the surprise component of reserve announcements and, in turn, estimate event study models at both daily and intraday frequencies to assess the effects of reserve surprises on the risk indicators. Doing so allows us to effectively address omitted variable as well as reverse causality endogeneity concerns and obtain more precise estimates of the effects of reserve accumulation. The reserve surprise estimations provide further, and even stronger, evidence that reserve accumulation is significantly and systematically associated with risk indicator changes consistent with the suggestion that as reserve holdings increase so does private sector risk taking.

Our results are important in that they point to what can be considered an unintended consequence of reserve accumulation that is not accounted for in standard studies of reserve accumulation and costs of holding reserves. Moreover, reserve accumulation driving up risk taking is an effect that may seem particularly counterproductive if a main objective of reserve accumulation is to provide insurance in the event of financial crises and then increased risk taking in and of itself makes such crises more likely.

Our evidence supporting the notion that reserve accumulation is associated with increased risk taking and is therefore potentially costly by making crises more likely does not in any way suggest that this unintended cost outweighs or offsets the benefits of holding large amounts of reserves. Indeed, our results do not call into question the validity of the precautionary savings motive for reserve accumulation or, for that matter, that reserves for other reasons and via other mechanisms may deter or reduce the probability of crises. Rather, our study suggests that more reserves are associated with private sector willingness to hold more risk which, in and of itself, may attenuate the benefits of accumulating reserves.

Data availability

The authors do not have permission to share data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[32] The China ETF volatility index (VXFXI) series starts in March 2011 and is available from the Chicago Board of Trade.
[33] Results pertaining to the VXFXI and the post-June 2005 estimations are available upon request.

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