Accumulation of foreign currency reserves and risk-taking

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Abstract

We assess whether the accumulation of foreign currency reserves in the Asia-Pacific region may have unintended consequences in the form of increased private sector risk-taking. To do so we carry out a country-specific daily data event study analysis of the relationship between official announcements of reserves stocks and various proxy measures of risk-taking. Overall, our results suggest that reserves accumulation does not assert a significant influence on risk-taking.

Keywords: Foreign exchange reserves; risk-taking; implied volatility; credit default swaps

JEL classifications: F31, G15

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1. Introduction

The massive accumulation of foreign currency reserves across economies in the Asia-Pacific region is well-known, and the cost of holding (possibly excessive) reserves has been much discussed.[2] We attempt to add to the discussion by assessing whether reserves accumulation in the region is systematically associated with changes in private sector risk-taking in the accumulating economies.[3] This is an important research question since evidence of a largely ignored indirect cost of reserves accumulation via a risk-taking channel would have implications for central bank policies.

For example, if foreign exchange reserves stocks are accumulated for the purpose of providing insurance in the event of financial stress, but the accumulation of those stocks has the unintended consequence of encouraging greater risk-taking, then the direct benefits of such policies should be juxtaposed against the indirect adverse effects. The desirability of such policies may then need to be re-evaluated. At the same time, evidence to suggest that the indirect costs of reserves accumulation in the form of increased risk-taking are negligible would also aid central bank decision-making by providing support for the conventional wisdom regarding what the costs of reserves accumulation are, as documented elsewhere.[4]

Ideally, to assess the relationship between reserves accumulation and risk-taking would require comparing pairs of equivalent scenarios whose primary difference is that reserves are being accumulated in one scenario but not in the other. In practice, however, such scenarios are difficult to identify since economies differ across many dimensions. Instead, we focus on the near-term response to the accumulation of reserves within a given economy, and assess whether the announcement has a significant effect on proxies for risk-taking.

Our risk-taking proxies are intended to reflect the willingness of firms to take on risk. Quantitative measures (such as the total amount of new foreign currency denominated debt) would provide one such measure, if it was available on a timely basis. Instead, we assume that any change in the willingness of agents to take on risk will be reflected in prices. This offers the added advantage that quantity variables are likely to respond only with a lag, given the administrative steps required to take out a new loan for example, whereas price responses can be near-instantaneous.

An existing literature treats reserves as a dependent variable, with the demand for reserves decreasing in the opportunity costs of holding reserves and increasing in volatility of international payments (Frenkel and Jovanovic, 1981). One way to view this paper is that we reverse the relationship and look at the effect of reserves as an independent variable. In this respect, our paper is in line with Yeyati (2008), who look at the effect of reserves holdings on interest rates, and Jeanne and Rancière (2011) who focus on the trade-off between the self-insurance benefits associated with a lower crisis propensity with higher international reserves and the costs of carrying those reserves. But whereas this literature tends to use lags to deal with endogeneity, we use an event study around the time of announcements of reserves levels instead.

We carry out a country-specific daily data event study analysis of whether official announcements of reserves stocks influence risk-taking. As our baseline risk-taking proxy measure we consider the implied volatility of currency options. Our sample encompasses the following ten economies: Australia,

[2] See, for example, Filardo and Yetman (2012) and Park and Estrada (2009).

[3] We use the term "risk-taking" to mean the willingness to take on currency risk. We do not attempt to distinguish between whether a change in risk-taking is because of changed expectations about the direction of the exchange rate, the expected volatility of the exchange rate or the associated risk premium.

[4] See ECB (2006) for an excellent overview of the more traditional costs associated with large foreign currency reserves holdings.

China, Hong Kong SAR, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore and Thailand. The sample period for our study is determined by data availability by economy with 11 March 1999 as the earliest start date (Singapore) and 9 January 2017 as the latest end date (Australia, Indonesia and Singapore).

We then extend our analysis by considering alternative risk-taking proxies as well as reserves measured relative to market expectations (where possible). We also consider whether higher reserves lead to decreased risk-taking instead. Finally, we conduct a number of robustness checks, including focusing separately on the post-crisis period, measuring the announcement effect as the size of reserves relative to a forecast derived from a simple projection model, and allowing for asymmetric effects of reserves depending on the direction of the exchange rate, the sign of the reserves change or the size of the reserves change.

Our baseline results suggest that reserves accumulation does not exert a significant influence on risk-taking. Only when we extend our analysis to consider the effects of reserves accumulation based on an estimated measure of the surprise component of reserves stock news do we find relatively more, yet still largely sporadic, indications of a significant link between reserves announcements and risk-taking. Overall, while excessive reserves accumulation might be costly for reasons already acknowledged in the literature, our findings suggest that any additional indirect costs via a risk-taking channel are likely to be small.

The rest of the paper is organized as follows. Section 2 outlines the macroeconomic context of our study and summarizes previous studies of particular relevance. Section 3 details the empirical methodology and describes the data. Section 4 presents the results. Sections 5 and 6 discuss extensions and robustness checks, respectively. Section 7 concludes.

2. Context and previous results

2.1 Macroeconomic context

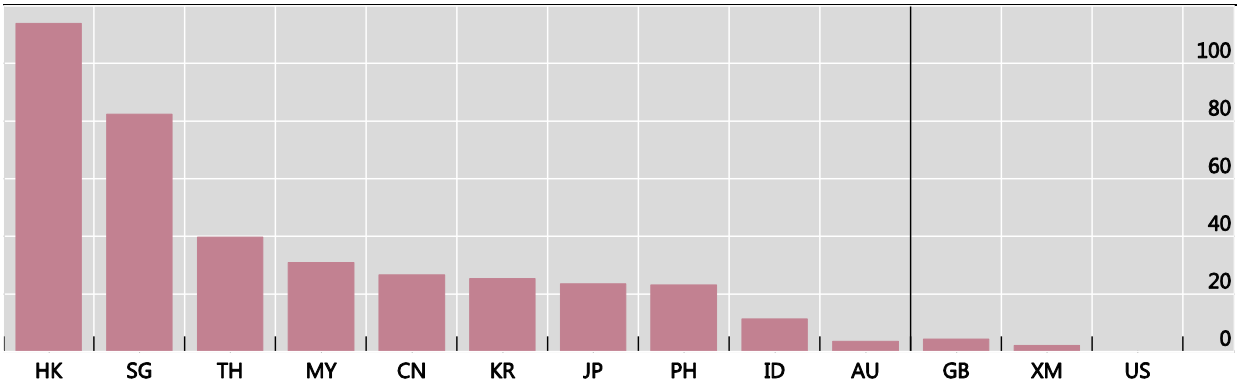
Underlying our study of the possible effects of a build-up of foreign exchange reserves on risk-taking is the massive stocks of reserves across economies in the Asia-Pacific region. Graph 1 displays total foreign exchange reserves as a share of GDP for 10 major Asia-Pacific economies that we study and, for comparison, three major economies from outside the region, as of the end of 2016. What is clear from the graph is that reserves in the region are large, in both absolute and relative terms. They exceed 20% of GDP for eight regional economies, and are more than 80% of GDP for Singapore and Hong Kong.

Another remarkable feature of the Asian reserves data is the importance of foreign exchange reserves' growth in accounting for changes in the overall size of central bank balance sheets. For many regional economies, foreign exchange reserves growth is responsible for virtually all of the increase in balance sheet size in the region over the past decade, but very little of it for those same economies from other regions displayed above (Graph 2).

The question we address is whether this accumulation of reserves might have had unintended consequences on private sector risk-taking. High levels of reserves may be perceived to reduce the cost of currency mismatches, for example if market participants view reserves as providing a form of insurance, since the central bank can use them to stabilize exchange rates in the event of sharp depreciation pressures. This could increase the willingness by market participants to take on unhedged foreign currency liabilities on their balance sheets.

Foreign exchange reserves

2016 Q4, as a percentage of nominal annualized GDP — Graph 1

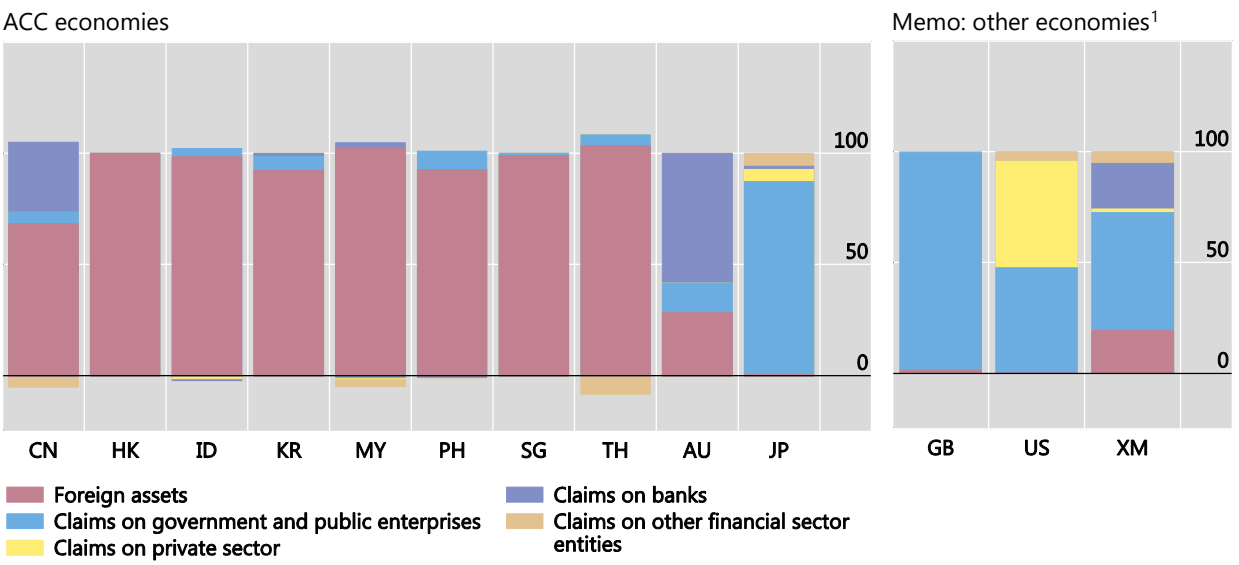


AU= Australia; CN = China; GB = United Kingdom; HK = Hong Kong SAR; ID = Indonesia; JP = Japan; KR = Korea; MY = Malaysia; PH = Philippines; SG = Singapore; TH = Thailand; US = United States; XM = euro area.

Sources: CEIC; Datastream; IMF *International Financial Statistics*; national data.

Change in the composition of central bank assets in ACC economies, 2006–16

As a percentage of change in total assets — Graph 2



AU = Australia; CN = China; GB = United Kingdom; HK = Hong Kong SAR; ID = Indonesia; JP = Japan; KR = Korea; MY = Malaysia; PH = Philippines; SG = Singapore; TH = Thailand; US = United States; XM = euro area.

[1] For United Kingdom, *net* claims on central government instead of claims on government and public enterprises.

Source: IMF *International Financial Statistics*.

A circumstance where reserves may seem particularly likely to encourage such risk-taking is where the central bank has used reserves to act as a provider-of-foreign-currency-liquidity-of-last-resort in the past, and may therefore be expected to do so again in future. For example, many central banks either used their own reserves or the proceeds of swaps with the US Federal Reserve or other central

banks during 2007-2009 crisis to ameliorate dislocations in FX markets (Jara et al, 2009; Baba and Shim, 2014).[5,6]

2.2 Existing evidence

Our paper builds on an existing literature modelling and documenting possible links between reserves accumulation and risk-taking. For example, Chutasripanich and Yetman (2015) use simulations of a simple model to illustrate how intervention intended to limit exchange rate volatility can increase the level of speculative activity of risk-averse speculators, and may hence be counterproductive. Caballero and Krishnamurthy (2000) show that reserves accumulation, and associated sterilisation operations, can have important (and perhaps counter-productive) effects on capital flows and risks. Caballero and Krishnamurthy (2004) argue that foreign exchange intervention policies limit the development of domestic financial markets and so contribute to the underinsurance of foreign currency risks. Burnside et al (2004) illustrate how implicit guarantees to banks' foreign creditors (which reserves can be used to provide) can be a root cause of self-fulfilling twin banking-currency crises. The existence of the guarantees encourage banks to take unhedged foreign currency exposures, and to then renege on these in the event of an exchange rate devaluation.

In terms of empirical evidence, a number of papers provide evidence that there is a relationship between reserves accumulation and various indicators of risk-taking. Cook and Yetman (2012) report that higher foreign exchange reserves appear to provide banks with insurance against exchange rate shocks, in that their equity prices become less sensitive to exchange rate movements. Sengupta (2010) finds that reserves accumulation appears to lead to greater currency risk-taking (in terms of a higher level of dollar denominated debt) in the corporate sector in Latin America based on data for 1500 firms in six Latin American economies. In contrast, Berkman and Cavallo (2009) report mixed evidence of the direction of causality: while economies with high levels of liability dollarization tend to have more active exchange rate stabilisation operations, floating exchange rates do not result in de-dollarization in their sample. Meanwhile Ismailescu and Phillips (2015) find that high levels of foreign exchange reserves are associated with less trading of sovereign CDS in a sample of 41 countries, which could reflect less efforts being taken to insure against currency risks. Relatedly, Amstad and Packer (2015) report a positive relationship between the stock of foreign exchange reserves in Asian economies and credit ratings on foreign currency debt, which may be expected to translate into a lower cost of taking on foreign currency exposures for many borrowers.

The increase in risk-taking could, in principle, lie in the countries who are the recipients of the reserves flows rather than in the source, especially if reserves accumulation influences asset prices. Along this line, Gerlach-Kristen et al (2016) report that, during the 2003-2004 period, official Japanese purchases of foreign exchange appear to have lowered long-term interest rates in the US and, to a lesser extent, in other major advanced economies (including Japan) as well. However, in this paper we focus on the relationship between reserves and risk-taking within the currency where the reserves accumulation is taking place.

One channel via which reserves accumulation could have an effect is via the balance of payments. For example, Bayoumi et al (2015) find that reserves accumulation results in large effects on current account balances. Alberola et al (2016) focus on periods of market stress and find that holdings of international reserves facilitate disinvestment by residents overseas. These papers are complementary

[5] Baba and Shim (2010, 2014) find that, in the case of Korea, auctioning off the proceeds of swaps with the US Federal Reserve was more effective than the use of own reserves in alleviating currency market dislocations, and postulate that this may be because the former did not result in a reduction in the level of reserves, and hence did not reduce market confidence.

[6] Ideally one might like to proxy for the reason behind the reserves accumulation in considering the effects on risk-taking more generally, although that it beyond the scope of the current exercise.

to ours: to the extent that these actions affect risk-taking, we would expect to also see some effect on the proxies that we analyse here.

3. Empirical Methodology

3.1 The event study methodology

To address whether the accumulation of foreign currency reserves is systematically associated with changes in financial market risk appetite, we employ the event study methodology. We choose this empirical approach as it enables us to perform a very general test of a very specific hypothesis without reliance on specification and estimation of time-series models of the risk appetite proxies that we consider. This is a particularly appealing aspect in our context of studying movements at relatively high (daily) frequency in variables that are highly volatile and likely to be influenced by numerous factors, including forward-looking variables that are not observable at a daily frequency.

Event studies are an effective way to address concerns about endogeneity, for three related reasons. First, we are looking at the effects around the time of the announcement of reserves, rather than when any associated intervention in foreign exchange markets takes place, so any direct effects of central bank actions on our proxies of risk-taking are likely to have occurred outside of the windows that we focus on. Second, if there was some common factor that was fuelling a change in our risk-taking measure and the change in reserves, this is unlikely to occur just at the time of the announcement. Third, for most of our tests we compare the behaviour of a variable in a pre-event window with a post-event window, which reduces the effect of any conflating factors that affect both windows.

The starting point for an event study is to define the events of interest and to identify the time-periods – the event windows – during which the response variable of interest is examined. The events in our context are the recurring announcements of the stock of foreign currency reserves held by the respective economies considered in our study. The event windows capture the movement of the response variable of interest before and after the event, during the pre-event and post-event windows, respectively. For our baseline event study analysis we set the event window length to two days and include the day of the event itself in the first day of the post-event window. We subsequently vary the length of the event windows from one to three days. We also vary whether the event day is included in the post-event window or excluded (such that the event day becomes a separate event day window separating the associated pre- and post-event windows).

3.2 Events

The key explanatory variable in our study is official reserves of foreign exchange. We collate all available public releases of foreign exchange reserves for our sample period in terms of billions of US dollars, where necessary converting them from domestic currency using market exchange rates. For each release, we collect the time and date of the announcement, the size of reserves, the previous reserves announcement and, for China, the expected level of reserves based on survey evidence.

For our event study, what is important is not the level of reserves that is published, but rather the information content (ie relative to some measure of the expected announcement). We consider three different measures of this announcement effect. Our base specification considers the change in reserves relative to the previous announcement. For China we also consider the level of reserves less the expected level of reserves based on survey evidence. Finally, as a robustness check, we consider the size of reserves less the predicted size based on a simple projection model.

Note that the announcement of reserves includes both the effects of intervention and valuation. We make no attempt to separate the effect of each of these, although the three different measures of the announcement effect that we consider may tend to (implicitly) place a higher weight on one or other of the components.

We focus on 10 major economies in the Asia-Pacific region, with the selection of both time-period and economy coverage determined by data availability. Table 1 below contains a summary of the official reserves announcements data used in our study. As the table shows there is a wide variety in the level and variability of reserves and the frequency of announcements over our sample. China and Japan both have average reserves exceeding one trillion US dollars whereas, at the other extreme, those of Australia, Indonesia and the Philippines average around 50 billion USD. While reserves announcements are made once every month on average for the majority of economies in our sample, they're once every two months for China, fortnightly for Indonesia and Malaysia, and weekly for Thailand.

Table 1. Reserves announcement data.

	First observation	Last observation	Number of announcements	Average days between announcements	Average reserves (USD bn)	Standard deviation of reserves
Australia	08.08.2006	09.01.2017	126	30.5	46.7	9.0
China	16.10.2003	07.01.2017	66	66.4	2202.6	1259.4
Hong Kong SAR	10.06.2003	06.01.2017	163	30.6	230.4	90.1
Indonesia	05.01.1999	09.01.2017	456	14.5	46.4	28.9
Japan	07.02.2003	07.12.2016	167	30.4	1042.6	215.1
Korea	02.01.2002	04.01.2017	169	30.4	270.8	73.8
Malaysia	09.04.2001	06.01.2017	377	15.3	90.5	34.9
Philippines	07.12.2005	06.01.2017	134	30.4	59.0	23.8
Singapore	11.03.1999	09.01.2017	197	32.1	172.5	71.2
Thailand	03.03.2000	06.01.2017	873	7.1	105.9	59.3

Note: for China, there are survey measures of expected reserves for 36 of the announcements.
Source: Bloomberg.

Our economies differ in other important respects as well. Silva Jr (2016) estimates the costs of holding reserves for different economies, and finds wide variation for the economies in our sample, between 0% of GDP for Japan, Hong Kong and Singapore to 0.8% or more for Indonesia, China and the Philippines. High costs could reduce the desirability of policymakers to hold reserves.

In looking for any link between reserves announcements and risk-taking, we focus on the economies in our sample one-at-a-time. If the effects were to vary in a systematic way between economies with different characteristics, we would expect this to be reflected in heterogeneous results across economies. But, as we will see, however, there is little evidence of a relationship between reserves announcements and our proxies for risk-taking for any of the economies in our sample.

3.3 Response variables

We consider a number of different response variables, each of which serves as a proxy for risk-taking. As discussed earlier, one important channel through which foreign exchange reserves may influence risk-taking is by reducing the perceived risks associated with exchange rate exposures. In that case, we would expect the cost of insuring against exchange rate changes to vary systematically with changes in the known level of foreign exchange reserves. We thus use the cost of insuring against exchange rate changes vis-à-vis the US dollar as a measure of risk-taking. We consider four measures of this: the implied volatility of each of calls and puts, at one month and 12 month horizons. Our implied volatility measures are based on 25-delta options. These are out-of-the-money, to the extent

that a given change in the exchange rate results in approximately 25% of that change in the value of the options.[7]

We examine the implied volatility of calls and puts separately since, depending on the mechanism at work, one could expect to see a different link between either and risk-taking. Calls may be used to insure against exchange rate appreciation, and puts to insure against exchange rate depreciation. The implied volatility is a measure of the cost of taking out such insurance. On the one hand, if an increase in the level of reserves is perceived to reduce the risk of a large exchange rate depreciation more than appreciation, since the central bank can use those reserves to counter depreciation pressures, we might expect to find a stronger link between reserves and the implied volatility of puts than calls. On the other hand, if an increase in the level of reserves is thought to reflect active intervention to prevent exchange rate appreciation, and this pattern of intervention is expected to persist into the future, then this may act as a bound on expected appreciation risks and so lower the cost of insuring against appreciations more than depreciations. In that case, the link between reserves and the implied volatility of calls will be stronger than that of puts.

In addition to examining the effect of reserves on implied volatility, we also assess the effects on other variables that may capture risk-taking for which the effect might be less direct. Since reserves may be used to stabilise exchange rates, they may also lower the perceived risk of foreign currency denominated debt. We therefore examine the effects of reserves on an index of sovereign CDS spreads for US dollar denominated debt for each economy. Finally, we investigate the link between reserves and equity prices, based on the main stock market index for each economy, as a very broad measure that might capture changes in risk-taking.

Data for each of the response variables is collected at daily frequency. Table 2 contains summary statistics for each of the measures, and sources are listed in Table A1 in the appendix.

3.4 Synchronisation

In order to perform an event study, we need to ensure that the timing of the event variable and response variables are correctly aligned. We have time stamps for foreign exchange reserves announcements and these vary, both from economy to economy and, within most economies, over the sample. When we construct pre-event and post-event windows, we sometimes need to adjust the dates of other variables by one day in order to ensure that the windows are correctly aligned. For example, the implied volatility variables are quoted as of 5pm New York time (5am Hong Kong time when daylight savings' time applies in the US; 6am Hong Kong time otherwise). For most observations, reserves announcements are made later in the day than this. In this case, no change is necessary. But where reserves announcements are made prior to 5pm New York time, the proxies for risk-taking need to be lagged by one day to ensure that the "before event" window does not contain the event, and the "post event" window is also correctly aligned.[8]

[7] The implied volatility of currency options have previously been used to consider the effects of central bank foreign exchange intervention. For example, Bonser-Neil and Tanner (1996) show that central bank intervention is generally associated with a positive change in ex ante exchange rate volatility, where ex ante exchange rate volatility is estimated from implied volatilities of currency options, while Disyatat and Galati (2007) find some evidence that central bank intervention systematically influences risk reversals derived from implied volatility of currency options.

[8] For example, Korean reserves are typically announced at 5am HK time, which is before 5pm New York time when daylight savings' time does not apply and hence must be adjusted. Note also that the period during which daylight savings' time applies in New York varies during our sample: from the first Sunday in April until the last Sunday in October before 2007, and from the second Sunday in March until the first Sunday in November thereafter.

Table 2. Proxies for risk-taking.

	Implied volatility				CDS spread	Equity index
	1 month call	1 month put	12 month call	12 month put		
Australia						
mean	11.50	12.86	11.54	13.90	4355	33.4
std deviation	4.42	5.22	3.01	4.12	997	29.3
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	01.01.1999	30.04.2003
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
China						
mean	2.76	2.55	5.60	4.68	2286	69.4
std deviation	1.77	1.35	3.37	2.09	921	42.0
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	01.01.1999	02.01.2001
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
Hong Kong SAR						
mean	0.76	1.01	1.17	2.09	17891	43.6
std deviation	0.44	0.55	1.49	1.42	5026	26.7
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	01.01.1999	29.08.2003
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
Indonesia						
mean	12.01	9.81	16.09	11.53	2310	233.0
std deviation	7.39	4.55	7.33	3.63	1718	127.3
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	01.01.1999	13.12.2001
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
Japan						
mean	10.12	11.22	10.11	11.97	13123	39.0
std deviation	2.84	3.96	2.08	2.96	3469	32.6
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	01.01.1999	04.01.2001
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
Korea						
mean	11.71	10.03	13.00	9.93	352	82.7
std deviation	9.62	7.46	7.08	3.95	294	66.6
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	06.11.2000	28.03.2001
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
Malaysia						
mean	8.76	7.73	10.26	8.09	1176	96.5
std deviation	3.64	3.06	3.65	2.29	413	55.7
first obs	21.03.2006	21.03.2006	21.03.2006	21.03.2006	01.01.1999	23.04.2001
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
Philippines						
mean	8.00	6.99	10.26	8.09	3442	245.3
std deviation	3.34	2.38	4.05	2.45	2134	155.4
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	01.01.1999	22.03.2001
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017
Singapore						
mean	6.27	5.83	7.35	6.30	2517	28.0
std deviation	2.39	1.97	2.62	1.71	657	26.4
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	31.08.1999	18.07.2003
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	26.03.2012
Thailand						
mean	7.29	6.74	8.40	7.31	820	99.1
std deviation	2.97	2.76	2.38	1.70	405	52.3
first obs	02.10.2003	02.10.2003	02.10.2003	02.10.2003	01.01.1999	28.02.2001
last obs	08.07.2016	08.07.2016	11.07.2016	11.07.2016	30.09.2016	09.01.2017

Note: For some series there are gaps in the sample

For the other proxies of risk-taking, there are also complications. For equity indices, we use the closing price at the end of each trading day, the time of which varies across economies (which, in the case of Australia, varies by one hour due to daylight savings' time there which applies from the first Sunday in October to the first Sunday in April). With CDS spreads, these are based on weighted average prices over a 24 hour period ending at 0230 GMT (11:30am Tokyo time), so there is no precise demarcation line between pre- and post-event windows for this variable. We consider this variable to have a time stamp of 11:30am Tokyo time. In this case, focusing on the results based on longer window lengths may be advisable.

3.5 Tests of the effects of reserves on risk-taking

To evaluate the hypothesis that the accumulation of foreign currency reserves leads to an increase in risk-taking within the context of our event study set-up, we employ four variations of the non-parametric sign test of the median.[9]

Test 1: direction criterion

The first test assesses if the response variable (the proxy for risk-taking) moves in the direction consistent with the reserves announcement during the post-event window. That is, does the announcement of an increase (decrease) in reserves (relative to either the previous announcement, projected reserves or expected reserves) correlate with an increase (decrease) in risk-taking? We refer to this as the "direction" criterion test. The null hypothesis is that reserves have no influence on risk-taking. Thus the probability of observing an event consistent with the direction criterion is the same as observing an event that is not consistent with the direction criterion. That is, under the null hypothesis the probability of either outcome is 0.5.

If x denotes the number of events consistent with the direction criterion and n the total number of events (that is, the number of reserves announcements) in our sample, the corresponding probability density function (PDF) is given by:

$$P(x) = \frac{n!}{x!(n-x)!} p^x (1-p)^{(n-x)},$$

where p is the probability of success under the null hypothesis (in this case, 0.5). The p-value for the test is the sum of PDFs with at least x events consistent with the "direction" criterion:

$$\text{p-value} = \sum_{y=x}^{n} P(x).$$

To implement this test we count the number of events consistent with the direction criterion and calculate the associated p-value. We do so economy-by-economy and across each of the risk-taking proxy response variables separately.[10]

[9] Our methodological approach is broadly consistent with the foreign exchange intervention event studies of Fatum (2000) and Fatum and Hutchison (2003).

[10] When classifying and counting events as either consistent or not with any given test criteria we only include events where the response variable is non-zero in the post-event and, where applicable, in the pre-event window.

Test 2: reversal criterion

The second test also assesses if the response variable during the post-event window moves in a direction consistent with an increase in risk-taking, but in this case is applied only across the sub-set of events where the response variable was moving in the opposite direction during the pre-event window. That is, if risk-taking was increasing (decreasing) during the pre-event window and then the reserves announcement indicates that reserves are lower (higher) than expected, does risk-taking decrease during the post-event window? We refer to this as the "reversal" criterion test.[11]

The null hypothesis is, once again, that reserves have no influence on risk-taking. For a given response variable, the probability parameter of the PDF (p) is calculated as the share of non-events where the direction of the change in the response variable is strictly different (ie changes from increasing to decreasing or vice versa) across pre- and post-non-event windows.[12] The PDF and p-value are then calculated in an analogous way to Test 1.

Test 3: smoothing criterion

The third test assesses if the change in the response variable in the post-event window relative to the pre-event window moves in the direction consistent with the reserves announcement if the behaviour in the pre-event window was inconsistent with reserves announcement. That is, if the measure of risk-taking in the pre-event window increased, and then the reserves announcement was positive, did risk-taking increase by less or decline in the post-event window (a success) or increase by more (a failure)? Conversely, if the measure of risk-taking in the pre-event window decreased, and then the reserves announcement was negative, did risk-taking decrease by less or increase in the post-event window (a success) or decrease by more (a failure)? This test is applied only to the same sub-set of events that are considered for Test 2. We refer to this test as the "smoothing" criterion test.

The null hypothesis remains that reserves have no influence on risk-taking. For a given response variable, the probability parameter of the PDF (p) is calculated as the share of non-events where either an increase in the pre-non-event window is followed by a decrease or smaller increase in the post-non-event window or a decrease in pre-non-event window is followed by an increase or a smaller decrease in the post-non-event window. Again, the calculation of the PDF and p-value is analogous to Test 1.

Test 4: information criterion

The fourth test is a simple assessment of whether reserves announcements contain any information value at all to predict changes in the risk-taking proxy variables considered. If the events have information value, then the magnitude of the change in a given response variable should be larger in the post-event window than in the pre-event window. In other words, this test considers if an announcement of any kind (indicating an increase, decrease or no change at all in reserves) is systematically associated with a post-event increase in the absolute value of the movement of the response variable compared to the absolute value of its pre-event movement. We refer to this as the "information" criterion test.

Events are consistent with the information criterion of if the absolute size of the change in risk-taking is larger in the post-event window than in the pre-event window:

[11] An event associated with a no-change for a given response variable during the post-event window is classified and counted as an event not consistent with the "reversal" criterion.

[12] Test 2 involves both pre- and post-event windows which affects the number of non-events. Because periods with overlaps are not considered, the number of non-events available becomes limited in cases of frequent reporting of reserves holdings.

$$|\text{post}| - |\text{pre}| > 0\,,$$

and inconsistent with the information criterion if the reverse is true:

$$|\text{post}| - |\text{pre}| < 0\,.$$

The null hypothesis is that reserves have no influence on risk-taking and the probability parameter of the PDF (p) is 0.5. Thus the PDF and p-value for Test 4 are as described for Test 1.[13]

4. Results

We first carry out the event study analysis of the implied volatility response variables using 2-day event windows (with the event day itself included as the first day in the post-event window) and reserves accumulation events defined as the difference between the current and immediately preceding announcement of reserves holdings. This is our baseline set-up. The results of our baseline analysis are reported in Table 3.

Table 3 consists of 12 sub-tables, one for each economy. The first row of each sub-table displays the results of Test 1 separately across each of the four implied volatility series considered, the second row of each sub-table displays the results of Test 2 across each of the four implied volatility series, and so on. As the first sub-table of results shows, for the case of Australia we find one instance of a rejection of the null hypothesis that reserves accumulation does not lead to an increase in risk-taking, namely when considering the "direction" criterion (Test 1) in conjunction with the 1-year implied volatility of currency put options series. In this one instance we reject the null hypothesis at the 95% level of significance. In none of the remaining 15 test results pertaining to Australia do we find any indication that an increase in reserves accumulation is systematically associated with an increase in risk-taking.

Turning to the next four sub-tables, for China, Hong Kong, Indonesia and Japan we accept the null hypothesis in all instances (16 tests for each economy). Korea, however, is associated with three instances of rejection of the null hypothesis, and thus 13 instances of failure to reject.

Of the final four economies, we cannot reject the null hypothesis in any cases for Malaysia, the Philippines and Singapore, and in only one case for Thailand.

Clearly, the baseline results do not provide strong support for the suggestion that accumulation of reserves leads to increased risk-taking. However, with 16 tests conducted for each economy, even a single instance of a significant test result for any given economy is in excess of a Type-1 error at the 5% level. Therefore, while we can, according to the baseline results, with some confidence conclude that reserves accumulation does not appear to increase risk-taking for most of the economies in our sample, we are more hesitant in drawing the same conclusion for Australia and Thailand (one significant result each) and Korea (three significant results). However, grouping all the results in Table 3 together, the five rejections from 160 tests corresponds to a 3% rejection rate, smaller than the 5% that we would expect due to Type-I errors in the event that there was no relationship between reserves accumulation and risk-taking.[14]

[13] Unlike tests 1 through 3, only the timing of the announcement is used to implement Test 4, and the sign of the announcement is not utilised.

[14] The 5% cut-off of significant results that would be expected in the event of no relationship due to Type-I errors should be interpreted as indicative, given that the tests are not completely independent.

Table 3. Baseline results: implied volatility, 2-day windows

		Implied vol 1 month call		Implied vol 1 month put		Implied vol 12 month call		Implied vol 12 month put		Implied vol 1 month call		Implied vol 1 month put		Implied vol 12 month call		Implied vol 12 month put	
		Events	Non	Events	Non	Events	Non	Events	Non	Events	Non	Events	Non	Events	Non	Events	Non
Test		**Australia**								**China**							
1	Yes	67		69		67		67		24		26		28		26	
	No	51		48		50		50		35		33		30		32	
	p-val	0.08		0.03 **		0.07		0.07		0.94		0.85		0.65		0.82	
2	Yes	33	1462	32	1374	30	1292	26	1259	14	1467	16	1469	16	1432	13	1459
	No	21	1255	21	1566	21	1425	26	1458	14	1541	14	1539	16	1576	20	1549
	p-val	0.17		0.19		0.07		0.35		0.52		0.38		0.46		0.89	
3	Yes	43	2084	42	2073	43	1979	37	1969	22	2222	24	2237	26	2196	22	2203
	No	11	614	11	623	8	651	15	672	6	693	6	671	6	678	11	666
	p-val	0.41		0.42		0.09		0.77		0.49		0.44		0.34		0.94	
4	Yes	58		56		55		60		26		28		25		31	
	No	62		64		64		60		33		31		33		26	
	p-val	0.68		0.79		0.82		0.54		0.85		0.70		0.88		0.30	
Test		**Hong Kong**								**Indonesia**							
1	Yes	73		73		68		76		78		82		79		81	
	No	62		62		68		60		75		71		73		71	
	p-val	0.20		0.20		0.53		0.10		0.44		0.21		0.34		0.23	
2	Yes	37	1199	37	1202	31	1160	33	1169	27	986	33	1058	31	1012	38	1062
	No	30	1358	34	1355	43	1397	38	1388	29	1227	28	1155	32	1202	34	1152
	p-val	0.11		0.23		0.76		0.49		0.34		0.20		0.33		0.24	
3	Yes	56	1808	52	1801	59	1784	56	1795	43	1538	48	1589	45	1559	59	1567
	No	11	449	19	464	15	470	15	463	13	522	13	467	18	488	13	480
	p-val	0.30		0.92		0.52		0.62		0.43		0.47		0.85		0.17	
4	Yes	76		72		67		75		80		79		82		72	
	No	67		72		80		71		65		66		63		72	
	p-val	0.25		0.53		0.88		0.40		0.12		0.16		0.07		0.53	
Test		**Japan**								**Korea**							
1	Yes	78		79		72		71		76		73		75		75	
	No	70		68		78		78		68		72		69		72	
	p-val	0.28		0.21		0.72		0.74		0.28		0.50		0.34		0.43	
2	Yes	29	1367	32	1332	25	1228	25	1194	27	1177	33	1216	37	1116	42	1142
	No	35	1187	37	1222	35	1326	40	1360	41	1380	43	1341	29	1442	32	1416
	p-val	0.93		0.99		0.87		0.93		0.88		0.80		0.03 **		0.02 **	
3	Yes	46	1940	41	1928	45	1866	41	1856	46	1860	50	1884	51	1809	58	1830
	No	18	594	18	600	15	614	24	624	22	629	26	610	15	635	16	612
	p-val	0.85		0.91		0.59		0.99		0.93		0.98		0.33		0.30	
4	Yes	81		75		73		80		77		82		76		86	
	No	70		77		75		71		72		67		67		59	
	p-val	0.21		0.60		0.60		0.26		0.37		0.13		0.25		0.02 **	

Notes: Day of event included in post-event window. Columns labelled "Non" display the number of non-events used in tests 2 and 3. Only non-overlapping events / non-events are included. Results for Thailand are based on 1-day windows due to the small number of non-overlapping 2-day events. **/*** denote rejection of null hypothesis of no increase in risk-taking at 95/99% levels of significance.

Table 3. Baseline results: implied volatility, 2-day windows (continued)

		Implied vol 1 month call		Implied vol 1 month put		Implied vol 12 month call		Implied vol 12 month put		Implied vol 1 month call		Implied vol 1 month put		Implied vol 12 month call		Implied vol 12 month put	
		Events	Non	Events	Non	Events	Non	Events	Non	Events	Non	Events	Non	Events	Non	Events	Non
Test		**Malaysia**								**Philippines**							
1	Yes	97		105		99		98		53		52		51		51	
	No	113		105		111		113		63		64		62		61	
	p-val	0.88		0.53		0.82		0.87		0.85		0.89		0.87		0.85	
2	Yes	44	643	50	649	38	631	44	650	23	1012	21	1036	20	970	22	1014
	No	54	805	51	799	63	818	58	799	32	1492	31	1468	35	1534	32	1490
	p-val	0.50		0.20		0.90		0.67		0.47		0.61		0.69		0.54	
3	Yes	69	1020	73	1024	64	1024	69	1033	35	1614	33	1617	38	1606	36	1642
	No	29	349	28	345	37	332	33	323	20	501	19	497	17	457	18	417
	p-val	0.85		0.76		1.00		0.98		0.99		0.99		0.95		0.99	
4	Yes	122		127		124		127		69		64		64		67	
	No	115		110		115		112		54		59		57		54	
	p-val	0.35		0.15		0.30		0.18		0.10		0.36		0.29		0.14	
Test		**Singapore**								**Thailand**							
1	Yes	78		76		75		72		313		309		315		314	
	No	62		64		68		68		298		302		286		284	
	p-val	0.10		0.18		0.31		0.40		0.29		0.40		0.13		0.12	
2	Yes	27	1226	30	1229	32	1174	27	1152	152	689	150	681	162	694	160	723
	No	34	1343	33	1340	40	1395	40	1417	151	641	150	649	116	637	120	608
	p-val	0.75		0.56		0.63		0.81		0.74		0.68		0.02 **		0.19	
3	Yes	46	1865	51	1881	53	1843	46	1862	227	1003	221	987	231	973	228	999
	No	15	607	12	591	19	568	21	540	76	223	79	242	47	229	52	200
	p-val	0.57		0.23		0.76		0.97		1.00		1.00		0.20		0.82	
4	Yes	78		78		77		79		306		311		284		288	
	No	70		71		69		66		307		304		325		322	
	p-val	0.28		0.31		0.28		0.16		0.53		0.40		0.96		0.92	

Notes: Day of event included in post-event window. Columns labelled "Non" display the number of non-events used in tests 2 and 3. Only non-overlapping events / non-events are included. Results for Thailand are based on 1-day windows due to the small number of non-overlapping 2-day events. **/*** denote rejection of null hypothesis of no increase in risk-taking at 95/99% levels of significance.

Our next step is to redo the analysis across different window lengths and vary whether or not we include the event day itself in the post-event window. Specifically, we consider three different window lengths – one, two and three day – and for each window length we carry out the event study analysis with the event day included in the post-event window (as in the baseline analysis) as well as with the event day not included (such that the event day separates the post-event window from the pre-event window). Doing so yields six sets of results (three different window lengths and two different post-event window definitions), of which one set is the baseline results described in detail in Table 3. To streamline presentation of the results, we present all six sets of results in the form of a "meta-analysis". This presentation provides separately for each economy the total count of significant test results (at 95% or higher) across the six event study variations, separately across each of the 16 combinations of tests (each of the four tests, 1 through 4, applied to each of the four implied volatility series considered: 1-month call, 1-month put, 1-year call and 1-year put).

Table 4. Implied volatility meta-analysis results

	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put
Test	**Australia**				**China**			
1	0	2	0	0	0	0	0	0
2	0	0	0	0	0	0	1	0
3	0	0	2	0	0	0	0	0
4	0	0	0	1	0	0	0	1
Test	**Hong Kong**				**Indonesia**			
1	0	0	0	1	0	0	0	0
2	0	1	2	2	0	1	1	0
3	0	0	0	0	0	0	1	0
4	0	0	0	0	1	1	2	2
Test	**Japan**				**Korea**			
1	0	0	0	0	1	0	0	0
2	0	0	0	0	0	0	2	1
3	0	0	0	0	0	0	0	0
4	0	0	0	2	0	0	0	1
Test	**Malaysia**				**Philippines**			
1	0	0	0	0	0	0	0	0
2	0	0	1	1	1	1	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1
Test	**Singapore**				**Thailand**			
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	1	1
3	0	0	0	0	0	0	0	0
4	1	0	0	0	1	0	0	0

Notes: Each cell counts, across the six window definition variations (1, 2 and 3 day windows, with the event day either included or excluded from the post-event window) the number of significant rejections at the 95% level of the hypothesis that an increase in reserves is not associated with an increase in risk-taking. For Thailand, only the two cases of 1-day windows are considered due to the small number of non-overlapping 2-day non-events.

The results of the "meta-analysis" are reported in Table 4. Similar to Table 3, Table 4 consists of 12 sub-tables, one for each economy. The first row of each sub-table displays the total number of significant results from the six event study variations pertaining to Test 1 separately across each of the four implied volatility series considered, and so on. The maximum number possible for each cell is six (two in the case of Thailand[15]), which occurs if a given test pertaining to a given implied volatility series is significant across all three window lengths considered (ie one, two and three day) and regardless of whether or not the post-event window includes the event itself. Accordingly, the minimum number possible is zero, which occurs if a given test pertaining to a given implied volatility series is insignificant across all six combinations of window lengths and post-event window definition.

As Table 4 shows, the total number of significant rejections of the null hypothesis that reserves accumulation does not increase risk-taking is, in ascending order of significant rejections, one for Singapore, two for China, Japan and Malaysia, three for the Philippines, four for Thailand, five for

[15] In the case of Thailand only 1-day windows are considered due to the small number of non-overlapping 2-day (and 3-day) non-events as a result of the high frequency of reserves announcements. Thus, for Thailand, the maximum number possible in each cell is two instead of six.

Australia and Korea, six for Hong Kong and nine for Indonesia. With a total of 96 tests performed for each economy (except for 32 in case of Thailand) the "meta-analysis" results clearly suggest that, with the possible exceptions of Hong Kong, Indonesia and Thailand, there is little evidence of an association between reserves and risk-taking since the number of significant results is no higher than that associated with the number of Type-I errors at a 5% level of significance.[16]

Grouping all the results together, the evidence for any link between reserves accumulation and increased risk-taking is limited. Table 4 summarises the results of 896 tests in all, 39 of which are significant at the 5% level. This represents 4.4% of the total number of tests, very close to the expected 5% level due to Type-I errors if there was no relationship between the variables at all. Similarly, while the meta-analysis results relay a similar overall message to the baseline analysis (where the baseline results constitute 1/6th of the meta-analysis results) of little link between reserves announcements and proxies for risk-taking, the set of economies for which the evidence of a link between reserves and risk-taking is strongest (Australia, Korea and Thailand in the base specification; Hong Kong, Indonesia and Thailand in the meta-analysis) has only one economy in common: Thailand. This weakens the evidence of any link between the series for any given economy.

If we further divide up the significant results in the meta-analysis by series (5, 7, 13 and 14 for 1-month calls, 1 month puts, 12 month calls and 12 month puts respectively) or tests (4, 18, 3 and 14 for tests 1, 2, 3 and 4 respectively), again no clear patterns emerge. If we separate results between those where the event day is included in the post event window from those where the event day lies between the two windows, the overall rejection rate is a little higher for the latter (5.4%) than the former (3.3%). There is marginally more evidence of a link at the 12-month horizon than the 1-month horizon, although little difference between calls and puts at both horizons, and slightly more evidence in favour of the reversal criterion and the information criterion than the direction criterion or the smoothing criterion, but results remain weak in all cases.

5. Extensions

In this section we extend the analysis in three ways. We first consider two alternative response variables as possible risk appetite proxies, namely economy-specific credit default swap spreads (CDS) for US dollar denominated sovereign debt series and economy-specific equity indices. While neither of these alternative series seems as straightforward as the implied volatility series used for extracting our main results in terms of how their movements are translated into changes in risk appetite, both the CDS spread and equity prices may provide some insights to either corroborate or question our implied volatility-based results.[17]

We also consider reserves announcements relative to expected reserves based on survey evidence as a measure of the announcement effect for the case of China (the one economy in our sample for which survey expectations are available), and reverse our tests to see if there is any evidence of the opposite effect: that increased reserves decrease (rather than increase) risk-taking.

[16] The 5% level of significance cut-off is 5 (rounded from 4.8) significant rejections for 96 tests and 2 (rounded from 1.6) for 32 tests.

[17] We employ the alternative response variables the exact same way we did the implied volatility series but for brevity we only report the results in the form of "meta-analysis" tables.

5.1 CDS spreads

Our CDS spread series represent the cost of insuring against default of US dollar denominated sovereign debt for each of the economies in our sample. A decrease (increase) in CDS amounts to a decrease (increase) in the cost of insuring against sovereign default. Thus, an argument similar to that put forward in the context of the implied volatility series can be applied. A likely manifestation of an increase in risk appetite is a reduction in demand for insurance, in this case insurance against sovereign default. If demand for insurance against sovereign default decreases, the price of such insurance should, ceteris paribus, also decrease. Consequently, a decrease in CDS as reserves increase would be consistent with reserves accumulation leading to an increase in risk appetite.

Table 5. CDS meta-analysis results

Test	**Australia**	**China**
1	0	1
2	5	1
3	0	1
4	0	0
Test	**Hong Kong**	**Indonesia**
1	0	0
2	3	0
3	0	1
4	0	0
Test	**Japan**	**Korea**
1	2	5
2	2	2
3	1	0
4	0	1
Test	**Malaysia**	**Philippines**
1	0	0
2	0	1
3	0	0
4	1	0
Test	**Singapore**	**Thailand**
1	0	0
2	2	0
3	0	0
4	0	1

Notes: Each cell counts, across the six window definition variations (1, 2 and 3 day windows, with the event day either included or excluded from the post-event window) the number of significant rejections at the 95% level of the hypothesis that an increase in reserves is not associated with an increase in risk-taking. For Thailand, only the two cases of 1-day windows are considered due to the small number of non-overlapping 2-day non-events.

Table 5 reports the results for the CDS meta-analysis. Australia, Japan, and Korea are associated with the most rejections of the null hypothesis that reserves accumulation does not increase risk-taking, at five or more, while Indonesia, Malaysia, the Philippines, Singapore and Thailand are associated with the least rejections of the null hypothesis, at two or less. With only 24 tests in total per economy (eight

for Thailand), the 5% Type-I error significance level translates into two rejections per non-Thailand economy (rounded from 1.2) and one for Thailand (rounded from 0.4). As a result, although we do not find strong evidence to reject the null hypothesis that reserves accumulation has no effect on risk-taking, since the sum of significant rejections across all ten economies amounts to a total of 30 rejections out of a total of 224 tests (9x24 plus 1x8), we also cannot interpret these test results as conclusive evidence that reserves accumulation does not increase risk-taking for any of the economies considered either.

Table 6. Equities meta-analysis results

Test	**Australia**	**China**
1	1	0
2	0	3
3	0	0
4	0	0
Test	**Hong Kong**	**Indonesia**
1	0	2
2	0	4
3	0	0
4	0	1
Test	**Japan**	**Korea**
1	1	0
2	1	1
3	0	0
4	0	0
Test	**Malaysia**	**Philippines**
1	0	0
2	0	0
3	0	0
4	0	1
Test	**Singapore**	**Thailand**
1	0	0
2	0	1
3	0	1
4	0	0

Notes: Each cell counts, across the six window definition variations (1, 2 and 3 day windows, with the event day either included or excluded from the post-event window) the number of significant rejections at the 95% level of the hypothesis that an increase in reserves is not associated with an increase in risk-taking. For Thailand, only the two cases of 1-day windows are considered due to the small number of non-overlapping 2-day non-events.

5.2 Equity indices

Equity prices provide a very broad measure of risk-taking in the sense that increased risk appetite is likely to increase demand for equities in general. Therefore, an admittedly indirect assessment of our reserves accumulation and risk appetite hypothesis is to consider if reserves accumulation is associated with an increase in equity indices.[18]

The meta-analysis results pertaining to the event study analysis with equity indices as response variables are displayed in Table 6. Similar to the meta-analysis of the CDS spreads, 24 tests are carried out for each economy (eight for Thailand). The number of rejections for China, Indonesia, Japan and Thailand exceed the 5% level for a Type-I error. For all other economies the number of rejections is either one or zero. These results are generally stronger than our implied volatility-based main results.

5.3 Reserves relative to expectations

Our next extension focuses on China. China is unique in our sample in the sense that we have been able to obtain survey expectations of the Chinese reserves to coincide with 36 of the announcements. This allows us to carry out the event study analysis and associated tests on reserves announcement surprises. This is potentially important as 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.[19] Table 7 reports the meta-analysis results of re-doing the event study on the four implied volatility series (first four columns) as well as on the two alternative response variables, the CDS spread and the equity index series (columns five and six, respectively). The first four columns report four significant rejections of the null hypothesis that reserves accumulation does not increase risk-taking. With a total of 96 tests performed across the four implied volatility series, four significant rejections is consistent with (and below the cut-off for) a Type-I error at the 5% level. Thus, even when we are able to disentangle the surprise component of the reserves announcement event, at least for China, our main results remain and, in the case of China, confirm that it is not the case that reserves accumulation is associated with an increase in risk-taking.

Table 7. China meta-analysis results based on estimated reserves from survey

Test	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	CDS	Equity
1	0	0	0	0	1	0
2	0	0	1	0	5	2
3	0	0	0	0	4	0
4	0	0	0	0	0	0

Notes: Each cell counts, across the six window definition variations (1, 2 and 3 day windows, with the event day either included or excluded from the post-event window) the number of significant rejections at the 95% level of the hypothesis that an increase in reserves is not associated with an increase in risk-taking.

Turning to the results pertaining to the alternative response variables, these are less conclusive than the implied volatility-based findings. When considering the CDS series we find ten significant rejections of the null hypothesis out of 24 tests performed, well above the 5% level of a Type-I error cut-off. The equity index results show two rejections out of 24 tests performed. Overall, the results stemming from analysing the China reserves announcement surprises are qualitatively similar to the

[18] For all proxies for risk-taking except for equities, a reduction in the variable indicates increased risk-taking. For easy of comparison across results, we therefore multiply the equity indices by -1 in our estimation exercises.

[19] See Fatum and Scholnick (2008).

results based on China reserves announcements that include the expected component of the announcement. This is important as it gives us comfort that not being able to extract the expected component from the reserves announcement for any of the other economies in our sample is not likely to be driving our failure to identify a relationship between reserves announcements and risk-taking.

5.4 Reserves accumulation and decreases in risk-taking

Our last extension is to consider if reserves accumulation decreases risk-taking. In other words, we are now considering the "opposite" research question of what has so far been the focus of our study. Technically, testing the opposite hypothesis is straightforward to implement since the event study set-up that is required is exactly the same as before, as are the events themselves as well as the associated pre- and post-event windows. Further, to consider the "opposite" research question we take advantage of the symmetry of our four tests and simply redo the analysis with the opposite alternative hypothesis, ie the null hypothesis becomes that an increase in reserves does not decrease risk-taking and, accordingly, the alternative hypothesis becomes that an increase in reserves decreases taking risks.

This extension serves two purposes. The first purpose is to address the research question of whether an increase in reserves decreases risk-taking. This is a relevant research question in and of itself, as reserves accumulation could be associated with a decrease rather than an increase in risk-taking if reserves accumulation reflected a more interventionist policy stance that reduced the potential rewards to risk-taking, for example.

The second purpose is to challenge the consistency of our results in the sense that economies for which we cannot dismiss the possibility that reserves accumulation is associated with an increase in risk-taking seem less likely to simultaneously be among economies where the results of the "opposite" hypothesis suggest that reserves accumulation might be associated with a decrease in risk-taking.

The meta-analysis results pertaining to the opposite hypotheses are shown in Table 8. We first focus on the tests using the implied volatility series (reported in the first four columns for each economy, respectively). With a total of 96 tests performed for each economy (32 for Thailand), the implied volatility-based results for Australia, China, Hong Kong, Indonesia, Korea and Singapore suggest that it is not the case that reserves accumulation is associated with a decrease in risk-taking since the number of significant rejections for these six economies is no higher than the 5% level of significance associated with a Type-I error. Notably, this group of economies includes Hong Kong and Indonesia, two of the three economies where our main results suggest that we cannot dismiss the possibility that reserves accumulation is associated with an increase in risk-taking. The number of rejections for the remaining countries (Japan, Malaysia, the Philippines and Thailand) exceeds what can reasonably be explained as Type-I errors, thereby suggesting that for these four countries we cannot rule out that accumulation of reserves is associated with decreased risk-taking. In all of these cases, this is consistent with the previous evidence of no clear link between reserves accumulation and increased risk-taking.

For the alternative variables, we also find evidence of a relationship between reserves and decreased risk-taking in terms of the CDS spread for Malaysia (with 9 out of a possible 24 significant results) and Thailand (two out of a possible eight), but results are consistent with Type-I errors for the CDS spread for other economies, and for equities across all economies.

Thailand, however, presents itself as the only case where the results of the "opposite" hypothesis testing are at odds with the results of the main analysis. For Thailand, our main results suggest that we cannot rule out that reserves accumulation increases risk-taking while our opposite hypothesis results suggest that we cannot rule out the opposite. Although not inconsistent per se, these particular findings might indicate that the event study methodology is not well-suited to handle the very frequent announcements of Thai reserves holdings, where this frequency means that we need to focus on short (1-day) windows to ensure sufficient non-overlapping events and non-events.

Table 8. Opposite results meta-analysis

	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	CDS	Equities	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	CDS	Equities
Test	**Australia**						**China**					
1	0	0	0	0	0	1	0	0	0	1	0	0
2	0	0	0	0	0	1	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	1	1	0	0
4	0	0	0	0	1	1	0	0	0	0	2	0
Test	**Hong Kong**						**Indonesia**					
1	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	1	0	0	1	0	0	0	1	2	0
4	0	0	1	0	0	1	0	0	0	0	1	0
Test	**Japan**						**Korea**					
1	0	0	1	1	0	0	0	0	0	0	0	0
2	1	2	1	0	0	0	0	0	0	0	0	0
3	2	2	0	2	0	0	1	2	0	0	0	0
4	0	0	0	0	0	1	0	0	1	0	0	0
Test	**Malaysia**						**Philippines**					
1	0	0	2	2	4	0	1	0	1	0	0	0
2	0	0	0	0	1	0	0	0	0	0	0	0
3	3	1	3	3	3	2	2	1	3	4	0	0
4	0	0	0	0	1	1	0	1	0	0	1	1
Test	**Singapore**						**Thailand**					
1	0	0	0	0	5	1	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	0	0	0
3	0	0	0	1	0	1	2	1	1	0	2	0
4	0	0	0	0	0	1	0	0	1	0	0	0

Notes: Each cell counts, across the six window definition variations (1, 2 and 3 day windows, with the event day either included or excluded from the post-event window) the number of significant rejections at the 95% level of the hypothesis that an increase in reserves is not associated with a decrease in risk-taking. For Thailand, only the two cases of 1-day windows are considered due to the small number of non-overlapping 2-day non-events.

6. Robustness

In order to test the robustness of our results, we consider a number of further checks. We analyse the post-International Financial Crisis (IFC) period separately and then repeat the event study analysis after extracting from the reserves announcements the expected announcement component obtained via auxiliary estimations. We also repeat the base analysis splitting the sample in three different ways: by the direction of the exchange rate change in the pre-event window, by whether the reserves announcement represents a positive or negative surprise, and by the size of the announcement compared with the median size across the sample for each economy. Finally, we take into account the magnitude of the reserves announcement's effects by estimating linear event-by-event regression models.[20]

[20] For brevity, tables of the results of only a portion of the robustness checks are included; other results are available from the authors.

6.1 Post-IFC sample

We redo our event study analysis on the sub-sample of reserves announcements that occur after the IFC. We do so because reserves accumulation during the IFC is typically not representative for reserves accumulation and different from the rest of our sample period as a whole.[21] Aizenman and Hutchison (2012) identify the IFC as a period when central bank behaviour vis-à-vis exchange rates changed, with policymakers reducing their reliance on foreign exchange intervention in the face of depreciation pressures, but allowed exchange rates to adjust instead. Thus the relationship between reserves announcements and risk-taking may be unrepresentative during this period.

Table 9. Post- international financial crisis meta-analysis results

	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	CDS	Equities	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	CDS	Equities
Test	**Australia**						**China**					
1	0	0	0	0	0	1	0	0	0	0	2	0
2	0	0	0	1	0	0	0	0	1	0	3	1
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	1	0	0	2	0	0
Test	**Hong Kong**						**Indonesia**					
1	0	0	0	0	0	0	0	0	0	1	0	2
2	0	0	2	1	0	1	0	0	2	0	0	5
3	0	0	0	0	0	0	0	0	1	0	0	0
4	0	0	0	0	0	0	2	3	3	2	0	3
Test	**Japan**						**Korea**					
1	0	0	0	0	2	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	1
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	1	0
Test	**Malaysia**						**Philippines**					
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	1	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1	0	0	0	1
Test	**Singapore**						**Thailand**					
1	0	0	0	0	0	0	0	0	0	0	1	0
2	0	0	0	0	0	2	0	0	0	0	0	1
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	1	0	0	0

Notes: These results are based on a sample period beginning 1 January 2010. Each cell counts, across the six window definition variations (1, 2 and 3 day windows, with the event day either included or excluded from the post-event window) the number of significant rejections at the 95% level of the hypothesis that an increase in reserves is not associated with an increase in risk-taking. For Thailand, only the two cases of 1-day windows are considered due to the small number of non-overlapping 2-day non-events.

We choose a starting date for the post-crisis period of 1 January, 2010. The results are reported in Table 9. As the table shows, with the exceptions of China and Indonesia, rejections of the null hypothesis that reserves accumulation increases risk-taking are scarcer than for the previously discussed full sample results. Overall, the post-IFC findings seem to suggest that, generally, if there is a systematic link between reserves accumulation and increased risk-taking, it might be time-dependent.

[21] Given the limited number of (typically) monthly reserves announcements available during the IFC, it is not meaningful to implement the event study separately over the IFC period.

Furthermore, we conjecture that such a link might be more likely to manifest itself during stress periods where there are more unusual or pronounced changes in reserves accumulation.

6.2 Reserves relative to projected levels

Second, we redo the event study after extracting from the reserves' announcements the expected announcement component obtained from auxiliary estimations. We do so to address the previously discussed concern that the assessed influence of reserves accumulation might be biased downwards if the reserves announcements that constitute the events under study contain an expected component. As already mentioned, only for China are survey expectations of reserves announcements available. Thus, to implement this robustness check, we proxy the expected component of reserves announcements for all economies, including China, using the residual from economy-specific projections of reserves announcements.

For the projection model, we take account of the fact that the length of time between announcement dates varies over the sample for some economies. If daily reserves were to follow:

$$x_t = \alpha + \beta x_{t-1} + \varepsilon_t ,$$

then, by iterating, reserves after j days are given by:

$$x_t = \frac{\alpha(1-\beta^j)}{1-\beta} + \beta^j x_{t-j} + \sum_{l=0}^{j-1} \beta^l \varepsilon_t .$$

We estimate α and β by non-linear least squares in rolling samples of previous reserves announcements (up to a maximum of 25 observations) and use an out-of-sample forecast as projected reserves for the following announcement. The difference between the actual and projected announcement is then a measure of the announcement effect.

Table 10 reports the results of analysing the estimated reserves announcement surprises. Clearly, there is some variation compared to our main results, where we did not attempt to separate the expected component from the reserves announcements. Now, combining all the different risk-taking proxies, the number of rejections of the null hypothesis exceed those that can reasonably be ascribed to Type-1 errors for six of the 10 economies in our sample: Australia, China, Hong Kong, Indonesia, the Philippines and Thailand. However, even then, taking all the tests together, the 84 statistically significant results at the 5% level represents 6.25% of the 1344 tests, barely above the number that could be ascribed to Type-I errors. So while the results of this robustness check less clearly support the idea that accumulation of reserves is not associated with risk-taking, they provide only weak evidence of a positive link between reserves announcements and risk-taking.

6.3 Sample splits

Third, we consider three different sample splits using the baseline specification (analogous to the results presented in Table 3 in terms of window length, and with reserves measured relative to the previous announcement) to examine whether there are differences in the results depending on the direction of the exchange rate, or either the sign or the size of the change in reserves.

Split 1: Exchange rate direction

The market response to a reserves announcement is likely to vary depending on how the central bank was expected to respond, and the central bank's response is likely to vary with the direction of the exchange rate. We therefore examine periods in which the exchange rate was appreciating against the US dollar in the pre-event window separately from those in which it was not (that is, it was either

unchanged or depreciating). Where announcement effects are compared with the behaviour when there is not an event (tests 2 and 3), the relevant non-event comparators are those with matching exchange rate behaviour.

Table 10. Projected reserves meta-analysis results

	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	CDS	Equities	Imp vol 1m call	Imp vol 1m put	Imp vol 12m call	Imp vol 12m put	CDS	Equities
Test	**Australia**						**China**					
1	2	0	1	1	1	0	0	0	1	1	0	1
2	0	0	0	1	6	0	0	0	2	0	1	2
3	0	0	0	0	1	0	0	0	0	0	0	0
4	0	0	0	1	0	0	0	0	0	1	0	0
Test	**Hong Kong**						**Indonesia**					
1	0	1	1	1	0	0	0	0	0	1	0	0
2	0	2	1	2	1	0	0	1	0	0	0	4
3	0	0	1	0	0	0	0	0	1	0	0	0
4	0	0	0	0	0	0	1	0	2	2	0	1
Test	**Japan**						**Korea**					
1	0	0	0	0	0	0	0	0	0	0	2	0
2	0	0	0	0	2	1	0	0	0	0	0	1
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	2	0	0	0	0	0	1	1	0
Test	**Malaysia**						**Philippines**					
1	0	0	0	0	0	0	0	0	0	0	1	0
2	0	0	1	1	0	0	1	1	0	1	1	0
3	0	0	0	0	0	0	0	1	0	0	1	0
4	0	0	0	0	1	0	0	0	0	2	0	1
Test	**Singapore**						**Thailand**					
1	1	1	0	1	0	0	0	0	0	0	0	0
2	0	1	0	0	3	0	1	1	1	1	0	1
3	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	0	0	0	1	0	0	0	1	0

Notes: Each cell counts, across the six window definition variations (1, 2 and 3 day windows, with the event day either included or excluded from the post-event window) the number of significant rejections at the 95% level of the hypothesis that an increase in reserves is not associated with an increase in risk-taking. For Thailand, only the two cases of 1-day windows are considered due to the small number of non-overlapping 2-day non-events.

We find little evidence that exchange rate direction affects the response to reserves announcements: of the 160 different tests for each sample split, the overall rejection rate for the null hypothesis is less than 1% for exchange rate appreciations and 5% otherwise.

Split 2: Sign of the reserves change

Next, we examine whether the results are different for decreases in reserves compared with other cases (ie when reserves either increase or remain unchanged). Here, because there are no known reserves changes for non-events, for tests 2 and 3 we compare each category of the events against all non-events.

Here, we find a higher rejection rate for reserves increases (8%) versus reserves decreases (1%), with three rejections each for the former for Hong Kong, Korea and Australia, and four for Thailand. However, Thailand's results are somewhat puzzling: positive reserves announcements are associated with increased risk-taking, but negative reserves announcements are even more strongly associated with increased risk-taking. In six cases we can reject the reverse null hypothesis that a decrease in

reserves is not associated with an increase in risk-taking at the 5% level. There is a similar contradictory effect at work with the results for Korea as well.

Split 3: Size of the reserves change

As a final sample split, we divide the sample in half based on the absolute size of the announcement, economy-by-economy. Here, the results again indicate only a limited effect for each sample: the rejection rate is 5% for large reserves changes, vs 1% for smaller changes.

Combining all the sample splits we examine, the results suggest that the effects of reserves announcements are limited, regardless of the direction of the exchange rate, the sign of the reserves change or the size of the reserves change.

6.4 Event regressions

Our fourth, and final, robustness check is to estimate standard event-by-event regression models in order to see if the magnitude of the reserves announcements help explain risk-taking, across all the specifications considered above. We estimate standard models separately for each of the risk-taking response variables considered with the magnitude of the reserves announcement entering linearly, one country at a time. Our estimated equation takes the form:

$$\Delta\text{post} - \Delta\text{pre} = \alpha + \beta\Delta\text{res} + \varepsilon,$$

where the left hand side is the difference in change in the risk measure in the post-event window vis-à-vis the pre-event window, and the key dependent variable on the right hand side is the change in reserves between subsequent announcements.

Table 11 displays the results with two day windows, where the event occurs in the first day of the post-event window.[22] In only one case (Malaysia, implied volatility of 12 month puts) is the coefficient significant at the 5% level. The positive sign on the coefficient indicates that a larger change in reserves is associated with a decrease in risk-taking, consistent with the "opposite" hypothesis discussed earlier.

Table 11. Event regressions: implied volatility, 2-day windows

	Imp vol 1m call		Imp vol 1m put		Imp vol 12m call		Imp vol 12m put		Imp vol 1m call		Imp vol 1m put		Imp vol 12m call		Imp vol 12m put	
	Australia								**China**							
β	-0.021	0.025	-0.028	0.027	-0.003	0.010	-0.006	0.012	-0.002	0.002	-0.002	0.002	-0.003	0.002	-0.002	0.002
p-val	0.40		0.31		0.76		0.61		0.40		0.43		0.13		0.34	
	Hong Kong								**Indonesia**							
β	0.003	0.004	0.005	0.004	0.001	0.007	0.002	0.007	0.107	0.094	0.015	0.056	0.089	0.095	0.023	0.062
p-val	0.39		0.22		0.93		0.79		0.25		0.79		0.35		0.71	
	Japan								**Korea**							
β	-0.004	0.004	-0.004	0.006	-0.001	0.002	0.001	0.002	-0.021	0.056	0.031	0.027	-0.058	0.059	-0.027	0.032
p-val	0.34		0.50		0.65		0.73		0.71		0.25		0.32		0.39	
	Malaysia								**Philippines**							
β	0.053	0.033	0.047	0.032	0.033	0.020	0.038	0.019	-0.007	0.037	-0.001	0.040	0.047	0.035	0.049	0.037
p-val	0.11		0.14		0.10		0.05 **		0.85		0.98		0.18		0.19	
	Singapore								**Thailand**							
β	-0.023	0.016	-0.024	0.013	-0.001	0.008	-0.001	0.007	0.001	0.035	0.001	0.033	-0.029	0.039	-0.018	0.034
p-val	0.16		0.06		0.91		0.92		0.98		0.99		0.47		0.59	

Notes: Day of event included in post-event window. ** denotes rejection of null hypothesis of β=0 at 95% levels of significance.

[22] For this exercise, we use 2-day windows for all economies, including Thailand, given that we are only looking at events and do not need to compare them with non-events.

We also repeat the analysis for all six window definitions, the alternative proxies of reserves expectations and six risk measures for all economies. Overall, in 3.3% of cases, the linear term is negative and statistically significant at the 5% level (consistent with higher reserves encouraging risk-taking) vs 3.2% of cases where it is positive and statistically significant. Each of these proportions is consistent with the level that one would expect due to Type-I errors under the null hypothesis of no relationship between the variables.

7. Conclusion

In this paper, we have carried out a country-specific daily data event study analysis of whether official announcements of reserves stocks influence risk-taking in the Asia-Pacific region. Our focal risk-taking proxy measure is the implied volatility of currency options. Our results generally suggest that reserves accumulation does not assert a significant influence on risk-taking and any such indirect costs via a risk-taking channel are negligible.

This is an important finding that implies that policy-makers are not missing an important (but perhaps overlooked) cost channel of reserves accumulation. Since our results suggest that the absence of effects of reserves accumulation on risk-taking is symmetric, our findings imply that a future decline in reserves are not likely to result in a large pull-back in risk-taking in the region either.

Although our findings are based on negative results, in the sense that our insights are based on lack of evidence to reject the absence of any relationship between reserves accumulation and risk-taking, they are based on numerous tests across multiple specifications and many robustness checks, as well as several different risk-taking measures. Our findings are surprisingly consistent: there is little evidence to suggest that an increase in reserves manifests itself in the form of an increase in risk-taking.

Nevertheless, our results are only as strong as our assumptions. We readily acknowledge two limitations of our study and, thereby, at the same time, offer suggestions for future research. One limitation is that our risk-taking proxies may not adequately capture the type of risk-taking that might be associated with reserves accumulation. Specifically, our risk-taking proxies are aggregate measures that may not sufficiently reveal changes in risk-taking at the micro or industry level. For example, if increased reserves saw a redistribution in risk-taking away from non-financial to financial firms, our risk-taking measures may not capture this, yet it would have important policy implications. Therefore, an interesting extension of this study would be to consider if reserves accumulation is associated with changes in risk-taking using disaggregated risk-taking measures or proxies. Another limitation is that perhaps the daily frequency of our data may be too low a frequency to capture risk-taking effects associated with announcements of reserves changes. If markets react to reserves stock announcements the same way as they react to some other traditional macro news, it might be that any risk-taking reactions are non-discernible unless higher frequency real-time financial market data is employed. Subject to data availability, therefore, another interesting extension would be to assess the influence of reserves announcements on risk-taking in the context of an intraday study.

References

Aizenman, J and M Hutchison (2012): "Exchange market pressure and absorption by international reserves: emerging markets and fear of reserve loss during the 2008-2009 crisis," *Journal of International Money and Finance* 31(5), 1076-1091.

Alberola, E, A Erce and J Serena (2016): "International reserves and gross capital flows dynamics," *Journal of International Money and Finance* 60, 151-171.

Amstad, M and F Packer (2015): "Sovereign ratings of advanced and emerging economies after the crisis," *BIS Quarterly Review*, December, 77-91.

Baba, N and I Shim (2010): "Policy responses to dislocations in the FX swap market: the experience of Korea," *BIS Quarterly Review*, June, 29-39.

Baba, N and I Shim (2014): "Dislocations in the won-dollar swap markets during the crisis of 2007-2009," *International Journal of Finance and Economics* 19(4), 279-302.

Bayoumi, T, J Gagnon and C Saborowski (2015): "Official financial flows, capital mobility, and global imbalances," *Journal of International Money and Finance* 52, 146-174.

Berkman, A and E Cavallo (2009): "Exchange rate policy and liability dollarization: what do the data reveal about causality?" *IMF Working Paper* 07/33.

Bonser-Neil, C and G Tanner (1996): "Central bank intervention and the volatility of foreign exchange rates: evidence from the options market," *Journal of International Money and Finance* 15(6), 853-878.

Burnside, C, M Eichenbaum and S Rebelo (2004): "Government guarantees and self-fulfilling speculative attacks," *Journal of Economic Theory* 119(1), 31-63.

Caballero, R and A Krishnamurthy (2000): "International liquidity management: sterilization policy in illiquid financial markets," *NBER Working Paper* no 7740.

Caballero, R and A Krishnamurthy (2004): "Smoothing sudden stops," *Journal of Economic Theory* 119(1), 104-127.

Chutasripanich, N and J Yetman (2015): "Foreign exchange intervention: strategies and effectiveness," *BIS Working Papers* no 499.

Cook, D and J Yetman (2012): "Expanding central bank balance sheets in emerging Asia: a compendium of risks and some evidence." In: Are Central Bank Balance Sheets in Asia Too Large? *BIS Papers* no 66, 30-75.

Disyatat, P and G Galati (2007): "The effectiveness of foreign exchange intervention in emerging market countries: evidence from the Czech koruna," *Journal of International Money and Finance* 26(3), 383-402.

ECB (2006): "The accumulation of foreign reserves", *Occasional Paper Series* no 43.

Fatum, R (2000): "On the effectiveness of sterilized foreign exchange intervention," *European Central Bank Working Paper* no 10.

Fatum, R, and M Hutchison (2003): "Is sterilized foreign exchange intervention effective after all? An event study approach," *Economic Journal* 113(487), 390-411.

Fatum, R, and B Scholnick (2008): "Monetary policy news and exchange rate responses: do only surprises matter?" *Journal of Banking and Finance* 32(6), 1076-1086.

Filardo, A and J Yetman (2012): "The expansion of central bank balance sheets in emerging Asia: what are the risks?" *BIS Quarterly Review*, June, 47-63.

Frenkel, J and B Jovanovic (1981): "Optimal international reserves: a stochastic framework," *Economic Journal* 91(362), 507-514.

Gerlach-Kristen, P, R McCauley and K Ueda (2016): "Currency intervention and the global portfolio balance effect: Japanese lessons," *Journal of the Japanese and International Economies* 39, 1-16.

Ismailescu, I and B Phillips (2015): "Credit default swaps and the market for sovereign debt," *Journal of Banking and Finance* 52, 43-61.

Jara, A, R Moreno and C Tovar (2009): "The global crisis and Latin America: financial impact and policy responses," *BIS Quarterly Review*, June, 53-68.

Jeanne, O and R Rancière (2011): "The optimal level of international reserves for emerging market countries: a new formula and some applications," *Economic Journal* 121(555), 905-930.

Park, D and G Estrada (2009): "Are Developing Asia's foreign exchange reserves excessive? An empirical investigation", *ADB Economics Working Paper no 170*.

Sengupta, R (2010): "Does reserve accumulation lead to higher currency-risk taking in the corporate sector? Firm-level evidence for Latin America," *Santa Cruz Institute for International Economics Working Paper* no 11-08.

Silva Jr, A (2016): "The self-insurance role of international reserves and the 2008-2010 crisis," Journal of Insurance and Financial Management 1(3), 1-24.

Yeyati, (2008): "The cost of reserves," *Economics Letters* 100(1), 39-42.

Appendix

Table 1A. Data sources

Data series	Units	Sources	Time stamp	Notes
Foreign exchange reserves	USD bn	Bloomberg	Varies	Includes date and time stamps; supplemented and with information from central bank press releases where information incomplete; observations dropped if no date stamp known; converted from local currency at market exchange rates where necessary.
Implied volatility of currency call and put options, one month and 12 months	Implied volatility	Bloomberg	5pm New York time	Adjusted for daylight savings' time.
CDS (Credit Default Swap) spreads	Basis points	Markit	Average over 24 hour period ending at 02:30 GMT	5-year US dollar-denominated sovereign CDS spreads.
Equity prices	National index	Bloomberg	Market close	Adjusted for daylight savings' time for Australia.

Note: Equity indexes are as follows: Australia: S&P/ASX 200 INDEX; China: SHANGHAI SE COMPOSITE; Hong Kong: HANG SENG INDEX; Indonesia: JAKARTA COMPOSITE INDEX; Malaysia: FTSE Bursa Malaysia KLCI; Japan: NIKKEI 225; Korea: KOSPI INDEX; Philippines: PSEi - PHILIPPINE SE IDX; Singapore: Straits Times Index STI; Thailand: STOCK EXCH OF THAI INDEX.