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UNDERSTANDING THE RECENT SURGE IN THE ACCUMULATION OF INTERNATIONAL RESERVES

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ASTRACT/RESUMÉ

Understanding the recent surge in the accumulation of international reserves

This paper looks at the empirical determinates of foreign currency reserve holdings across a panel of around 130 countries between 1980 and 2008. The paper builds on the existing literature by adopting a panel error-correction model specification and by extending the sample to include the recent period that saw a continuing acceleration in the accumulation of reserves in many countries. The results of the analysis suggest that the levels of trade and domestic financial depth are robust determinates of the level of reserves in the long run, particularly over the past decade and a half. The estimations also find that changes in GDP, the exchange rate regime, exchange rate volatility, and financial openness can all have permanent one-off effects on the level of reserves. Furthermore, country fixed effects are found to be significant, suggesting that time-invariant country specific factors are important in explaining the variance in reserve holdings across countries. Nevertheless, several countries stick out in terms of holding reserves well in excess of that implied by these empirical results, above all in recent years. Among these countries, China and Japan are particularly notable, especially when the deviation from average behaviour is expressed in dollar terms.

JEL classification codes: E44, E58, F21, F31, F36, F41, N10, O24

Keywords: reserves; foreign currency; central bank; trade; money supply; sudden stop; current account; crisis

Comprendre la récente accélération de l'accumulation de réserves internationales

Ce document est consacré à l'étude des déterminants économétriques des réserves de change de 1980 à 2008 à partir d'un panel de quelque 130 pays. Il s'appuie sur les publications existantes en adoptant un modèle à correction d'erreurs sur données de panel et en élargissant l'échantillon de façon à couvrir la période récente qui a été marquée par une accélération continue de l'accumulation de réserves dans de nombreux pays. Les résultats de l'analyse tendent à montrer que le volume des échanges commerciaux et la profondeur du système financier national sont des déterminants robustes du volume des réserves sur le long terme, en particulier depuis une quinzaine d'années. Les estimations permettent aussi de constater que des changements en matière de PIB, de régime de change, d'instabilité des cours de change ou d'ouverture financière sont autant de facteurs ponctuels qui peuvent produire un effet permanent sur le volume des réserves. En outre, on observe des effets fixes significatifs spécifiques aux pays, ce qui suggère que des facteurs spécifiques à des pays et invariants dans le temps sont importants pour expliquer la variance des réserves de change entre différents pays. Néanmoins, plusieurs pays continuent à détenir des réserves très supérieures à ce qu'impliquent ces résultats économétriques, surtout ces dernières années. Parmi ces pays, on retiendra en particulier la Chine et le Japon, surtout lorsque l'on exprime en dollars l'écart que présentent ces pays avec le comportement moyen.

Classification JEL : E44, E58, F21, F31, F36, F41, N10, O24

Mots-clés : réserves ; changes ; banque centrale ; échanges commerciaux ; masse monétaire ; arrêt brutal ; balance courante ; crise

TABLE OF CONTENTS

Understanding the recent surge in the accumulation of international reserves

By Petar Vujanovic[1]

1. Introduction

The past decade has seen an unprecedented accumulation of international foreign reserve holdings, especially in developing countries, and most particularly among emerging Asian and oil exporting countries. Over the decade to 2009, world foreign reserve holdings rose from around 5½% of world GDP to close to 14% (Figure 1).[2] While there was a brief pause during the recent global recession, the accumulation of reserves has reaccelerated with renewed vigour as the recovery has taken hold. Indeed, by March 2011 the foreign exchange reserves of China alone totalled over USD 3 trillion or around half of its annual GDP and almost one third of total global foreign exchange reserves. In dollar terms the second largest holder of reserves in the world is Japan with over USD 1 trillion as of mid-2010 or around 20 percent of GDP. In terms of reserves-to-GDP ratios oil exporters and small Asian export-orientated economies lead the world.[3]

The acceleration in the accumulation of reserve holdings over the past decade has prompted a considerable academic literature examining what motivates countries to hold reserves and, in light of these motivations, a number of studies have tried to make some assessment as to what the optimal level of reserves might be. The hypotheses fall into two broad categories. The first is the idea that reserves have been amassing as a direct result of export-led growth strategies. This neo-mercantilist argument encompasses a deliberate strategy of managing competiveness whereby large foreign reserves holdings are a direct result of export promotion by means of holding down the value of the local currency.[4] Foreign currency reserves accumulate because to convert inflows into the domestic currency in the international foreign exchange market would have implications for the currency peg. The second hypothesis is that foreign reserves constitute both self-insurance and deterrent against balance of payments crises, including sudden-stops in access to external funding. Traditionally, the focus was on adequately covering imports, with the rule of thumb target, dating from the Bretton Woods era, being sufficient reserves to fund three months of imports, thereby avoiding import bottlenecks in the event of an adverse external shock. In the late 1990s, around the time of the Asian crisis, the focus shifted to short-term debt coverage and lead to the so-called Guidotti-Greenspan rule.[5] The rationale is that countries should have sufficient reserves in the

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1. Economics Department, email: petar.vujanovic@oecd.org. The author is grateful to Jörgen Elmeskov, Jean-Luc Schneider, Luiz de Mello, Isabell Koske and Linda Rousova for helpful comments on earlier drafts. The author retains full responsibility for all errors and omissions.

2. Despite a temporary abatement with global economic downturn and its dramatic impact on trade, reserve accumulation across the world has continued apace. IMF (2010) reports that by 2009 world reserve holdings reached 13% of GDP and the most recent evidence suggests that it shows no sign of slowing.

3. Countries with the highest reserves to GDP ratios in 1990 were Libya (158%), Hong Kong (121%), Saudi Arabia (109%), Algeria (%), and Singapore (103%).

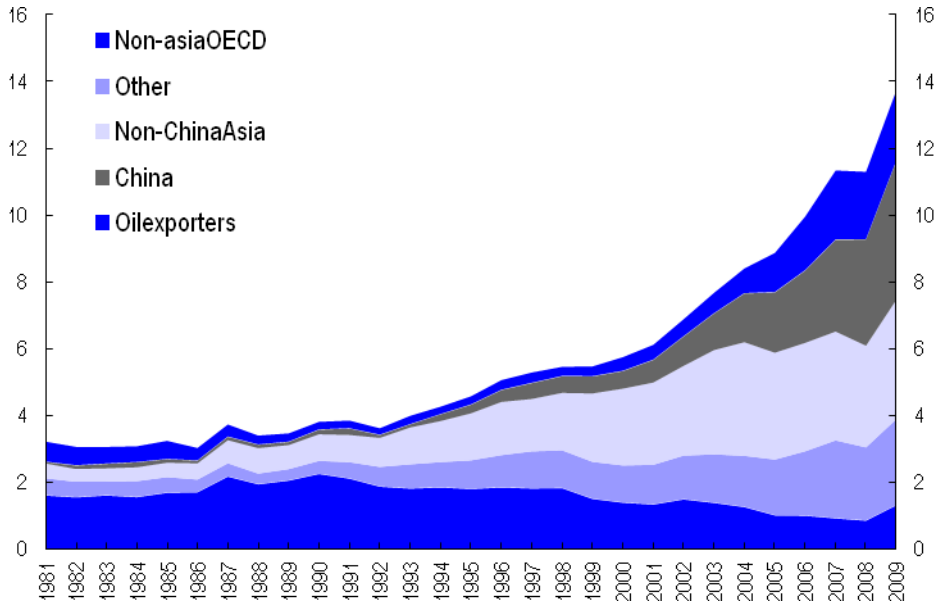
4. Korinek and Servén (2010) argue that this approach to export promotion (with its benefits of learning-by-doing) is preferable to the strategies adopted by Japan and the East Asian tigers during their formative years of development, not least in the current environment of WTO-enforced trading rules. Furthermore, exchange rate undervaluation obviates the need to allocate subsidies and pick winners, leaving that to the foreigner customer.

5. The Guidotti-Greenspan rule of thumb is that reserves should equal short-term external debt (one-year or less maturity), the rationale being that countries should have enough reserves to resist a massive withdrawal of short term foreign capital. This rule emerged in light of the experiences of a number of

event that refinancing or rolling-over short-term foreign debt becomes impossible. However, after the Argentine Crisis the scope of self-insurance broadened to include protecting local financial systems that are exposed to foreign market sentiment, capital flight by domestic agents and exchange rate movements. In each instance, this evolution of motivations is likely to have implied very large changes in the level of reserve holdings, as what was considered to be the optimal ratcheted upwards.

Figure 1. World foreign exchange reserves

Per cent of world GDP



Source: World Bank, World Development Indicators.

In addition to these reasons for holding reserves there can be factors particular to individual countries that could contribute to the continuing accumulation of reserves. For instance, in the case of China, there are a number of distinct institutional factors. Assisted by its fixed exchange rate, China has recorded a long period of large surpluses on its external balances, meaning net inflows of foreign currency. With Chinese residents and most Chinese companies only allowed to keep limited amounts of foreign currency, as well as being prohibited from holding foreign exchange overseas, and with the capital account controls preventing outflows, the excess ends up in the central bank via the retail banks (Pan and Zhu, 2008). Moreover, relatively higher returns in China and expectations of future yuan appreciations also motivate local residents and companies to convert into yuan.

This paper surveys the existing literature on the motivations for countries to hold reserves and then looks at the body of work that attempts to assess the adequacy of reserve holdings. The original contribution of the paper is to extend the empirical branch of the adequacy-of-reserves literature, both chronological and technically. Most of the existing empirical literature has only examined developments up to the mid-2000, but as we have seen, since then reserves holdings have accelerated further and consequently seem to invalidate many of the conclusions of the existing literature. On the technical front, this paper looks closely at the time-series properties of the cross-country panel data and consequently, in

Latin American countries (Pablo Guidotti was the Argentine deputy minister of finance) and the Asian crisis, and the finding that the ratio of reserves to external debt is a predictor of an external crisis (for example Galafell and del Bosque, 2002).

contrast to the static approach taken in the existing literature, adopts a more dynamic panel error-correction formulation. This allows one to assess long-run adequacy levels while at the same time accounting for the dynamics of accumulation and other short-run factors.

In the next section of the paper we look briefly at the closely related issue of sovereign wealth funds (SWF) and how these might fit into the framework of this analysis of reserves holdings. We also discuss the class of reserve accumulating countries whose external accounts are dominated by commodity exports. As we have seen, these countries have been among the largest accumulators of foreign exchange reserves in recent years, on the back of surge world commodity prices. Section 3 briefly discusses the currency denomination of reserves holdings and the so-called "dollar trap". Section 4 surveys the existing literature on the motivations for holding reserves while Section 5 reports the results of our empirical analysis. Finally, Section 6 tries to make an assessment of the levels of reserve holding in a number of countries on the basis of the empirical results.

2. Sovereign Wealth Funds and commodity exporters

In recent years, an increasing number of governments have been establishing SWFs.[6] SWFs are commonly established to manage assets coming from balance of payments surpluses (particularly from commodity exports), official foreign currency operations, the proceeds of privatisations, and fiscal surpluses, often with a view to intergenerational fairness. The principle mandate of these funds is to maximise long-term returns, and their assets tend to be invested in a broad array of instruments, both riskier (including in equities) and longer-term, than central bank-held foreign reserves.

SWFs are by definition closely held by governments, and as such, the foreign-currency denominated financial resources that they manage could perhaps be considered close substitutes for international reserves. To the extent that their assets are sufficiently liquid, these funds could be used for the same crisis-abatement purposes, and indeed, could serve the same crisis-prevention (deterrent) function as traditional international reserves. This is additionally true given that, in contrast to sovereign *pension* funds, SWFs do not have explicit liabilities and the sole shareholder is the government. For this reason, SWFs are typically less obliged to be transparent about the structure of their investment holdings, and indeed their investment strategies (Aizenman and Glick, 2008).

In the analysis in this paper we make the assumption that funds held in SWFs do not constitute foreign reserves for the purposes of meeting all the various motivations for holding foreign exchange reserves in central banks. To the extent that the results of our analysis reflect domestic arrangements whereby current account surpluses are mechanically converted into reserves held by the central bank, and which are then transferred to SWFs to manage, this assumption may be problematic. That said, to the extent that countries are readily moving central-bank held reserves into SWFs, this might suggest reserves levels in excess of those warranted by the self-insurance and other traditional motives.

Countries that export commodities, such as oil and gas, are among the largest holders of foreign exchange reserves. And indeed, as noted immediately above, they are among the principle practitioners of

6. Currently the largest SWFs belong to oil exporting countries including the United Arab Emirates (Abu Dhabi Investment Authority: $600 billion), Norway (Government Pension Fund - Global: $440 billion), Saudi Arabia (SAMA foreign Holdings: $415 billion) and Kuwait (Kuwait Investment Authority: $200 billion). However, an increasing number of other countries are establishing SWFs including China, Korea and Australia. Indeed, the four largest Chinese SWFs (SAFE Investment Company, China Investment Corporation, National Social Security Fund, China-Africa Development Fund) currently hold assets in excess of $830 billion (15% of GDP). Truman (2008) shows that over three-quarters of the value of funds held in SWFs around the world are held in foreign assets with the ratio for developing-country SWFs being significantly higher.

more active reserve management using SWFs. The commodities that these countries export will deplete with time and are, as such, a finite resource. Consequently, prudent economic management and intergenerational equity implies that countries that export these commodities should only consume the real return to the stock of proven commodity reserves. The motivation is therefore to maximize the real return rather than holding this wealth in a conservative central-bank portfolio of foreign exchange and highly liquid foreign government instruments. This is why oil exporters operate such large SWFs. The motivation for accumulating reserves in these countries is therefore entirely different to the more mainstream motivations posited above, including self insurance against capital account shocks. It is for this reason that oil exporters are excluded from this empirical analysis.

3. Currency denomination of reserves and the "dollar trap"

Large current account surpluses inevitably mean large inflows of foreign currency which cannot be invested locally without putting upwards pressure on the exchange rate. Coupled with the motivation to hold low-risk liquid reserves for self-insurance purposes, the ready supply of riskless government securities from developed countries are a natural candidate for accumulation. Even with the trend towards handing off the management of surpluses to SWFs, fixed exchange rate regimes still mean a preference for foreign-currency denominated liquid assets, rather than reinvesting more productively at home or in other third-party countries. Indeed, given the massive stock of reserves currently held in a number of countries, any precipitous adjustment is likely to result in adverse exchange rate movements and potentially large valuation losses (the so-called "dollar trap").

That having been said, there are very good reasons that the US dollar is the preferred currency in which to hold foreign reserves. Firstly, reserves need to be in a currency that holds its value in a crisis. Secondly, the market for US dollars is deep and liquid. Thirdly, to the extent that stocks of reserves serve as insurance against trade and debt shocks, given that trade and debt are predominately dominated in US dollars, so therefore should be reserves. Furthermore, if the purpose is to defend a peg to particular currency, then holding reserves in that counterpart currency would be preferable.

The largest single holder of US dollar reserves is likely to be China (Hu, 2010), although this is difficult to confirm as China remains one of the few major countries that does not publically disclose the portfolio composition of its foreign exchange reserves.[7] However, it is assumed that US dollar assets make up as much as 70% of the total Chinese foreign exchange reserves, which is higher than the world average of 64% in 2008 and the emerging and developing economies average of just below 60% in 2008 (IMF, 2009).[8] This preponderance of US dollar assets in China's portfolio is not out of line with the currency-composition of either trade or foreign debt. While direct exports to the US make up as little of 18% of total Chinese exports and imports around 8% of the total (China Customs and Ministry of Commerce, 2010), a very much higher proportion of trade is denominated in US dollars, including most of China's commodity imports, as well as most trade with countries like Korea and Taiwan. Pan and Zhu (2008) estimate that in 2005 over half of Chinese imports were conducted in US dollars, around one-third in yen and around one-fifth in euros. Similarly they estimate that around 70% of China external debt servicing is denominated in US dollars.

4. Existing literature on the motivations for holding reserves

There are two broad categories of studies looking at the issue of the motivation for holding foreign currency reserves and the adequacy thereof – there are those that attempt to quantify an optimal level of

7. According to US Treasury survey data China eclipsed Japan in 2009 as the largest holder of US government securities (Hu, 2010; US Department of Treasury, 2010).

8. Financial Times, 26 May 2010; http://www.ft.com/cms/s/0/7049ad6e-68ea-11df-910b-00144feab49a.html.

international reserves using behavioural models, and those that estimate demand for reserves across a large set of countries over time and then make inferences based on statistically determined drivers.

- Modelling optimal levels relies critically on the underlying assumptions made about the motivation for holding reserves, and then in turn the parameters values chosen when calibrating the model. This approach has most recently been taken by Jeanne (2007) and Jeanne and Rancière (2008). In general those that take the model approach find that actual reserves levels tend to far exceed the optimal levels calculated using realistically calibrated models.

- The second approach, of statistically estimating the determinates of demand for reserves, suffers from the usual data issues. For instance, many studies find prominent structural breaks, particularly around the time of major crises such as the 1997-98 Asian crisis. Recent papers taking this approach include Aizenman and Lee (2007), Obstfeld *et al.* (2008) and Cheung and Ito (2009). The bulk of studies taking this empirical approach conclude that there is only limited evidence of excess reserves in the large accumulating countries at the end of each studies sample period.

Recent notable work on the demand and adequacy of reserves include the following papers:

- **Aizenman and Marion (2002)** argue that between 1980 and 1996 the holdings of international reserves by 125 developing countries are well explained by a number of factors, including size of international transactions and the volatility thereof, and exchange rate regimes. However, the relationship breaks down after the 1997 Asian crisis when the model significantly under-predicts holdings. In order to account for this, the authors argue that the crisis increased demand for precautionary holdings as loss aversion increased in the aftermath of the crisis. The puzzle as to why other crisis-hit countries did not increase holdings is explained by offsetting high discount rates, political instability and corruption factors.

- **IMF (2003, Chapter 2)** examines the reasons countries hold international reserves using an empirical approach and concludes that the main determinates were: *i)* size of the economy; *ii)* current account vulnerability; *iii)* exchange rate flexibility; and *iv)* opportunity cost.

- **Aizenman and Lee (2005)** test whether precautionary or mercantilist motives explain reserve accumulation. Variables representing capital account regimes and crisis episodes are found to be significantly more important than trade shares.

- **Jeanne (2007)** develops a model of reserve accumulation that nests self-insurance against capital flow volatility and capital crises. The model finds it difficult to explain large reserve accumulations, particularly after around 2000 when those countries that did build up large reserve holdings were also those that were most protected from capital flows by capital account restrictions. The author also makes the observation that the crisis insurance motivation is somewhat contradicted by recent moves to invest reserves in less-liquid higher-yield assets.

- **Jeanne and Rancière (2008)**, using a similar framework to Jeanne (2007), focus on how reserves can help to smooth domestic absorption in the face of the risk of a sudden stop that is induced by a fall in domestic output. The implication of the model is the central role played by the sudden-stop risk faced by individual countries. In order to quantify this, the authors use a probit approach to estimate the probably of a sudden-stop. The variables used closely mirror those used in many demand-for-reserves estimations, which given the parallels between modelling the demand for self-insurance and the modelling probability of having recourse to that insurance, is not surprising. The conclusion is that, while successfully accounting for the

accumulation of reserves in many emerging countries since the 1980s, the large increases in recent years, particularly in Asia, are not well explained.

- **Obstfeld *et al.* (2008)** use a panel of 140 countries between 1980 and 2004 and conclude that much of the accumulation of reserves up to that period can be explained by a number of factors including domestic financial development, financial openness, access to debt markets, and exchange rate policy. Notably, the paper does not resort to dummies for the Asia and other financial crises. The paper puts most emphasis on financial deepening (M2/GDP) as the underlying cause of increases in demand for international reserves. The argument is that as the domestic banking system develops, countries (particularly those with pegged exchange rate regimes) demand higher international reserves in order to be in a better position to deal with threats to the banking system from both funding stops and capital flight. The paper argues that prior to the Asian crisis many countries (including Japan, China and other emerging Asian economies) were holding insufficient reserves, and that what transpired post-1997 was a catch up rather than a structural break in behaviour.

- **Cheung and Ito (2009)** also use a large panel over the period 1975 to 2005 and include traditional macro variables, financial variables and institutional variables in their analysis. This paper chooses three sub-periods (1975-1981, 1983-1993 and 1999-2005) and undertakes panel regression for developed and developing countries separately over these sample periods. The relationships are not found to be stable over time, but on the basis of a regression over a recent period sub-sample, the paper concludes that there is only limited evidence that East Asian countries, including China and Japan, have accumulated excess reserves.

5. The empirical analysis

The methodology

This paper adopts the empirical approach to understanding the accumulation of reserves. Importantly this analysis extends the sample period to 2008. The studies to date that have taken this approach only examine developments up to 2004/05. However, since then reserve accumulation has, if anything, accelerated in the big accumulator countries, while many of the posited underlying determinates have not. Indeed, post-2004, China and many other emerging economies continued to accumulate reserves at a rapid rate, with China's reserve holdings climbing from 31% of GDP to 45% of GDP over the four years to 2008.

Another innovation is to estimate the relationships in a two-stage panel error correction model (ECM) procedure. This contrasts with the pure static specifications that have tended to be used to this point. The critical role played by trade and M2 found in a number of papers in explaining the level of reserves suggests that there may be a long-run relationship between these three variables. If this is confirmed in that data, it suggests that a panel error-correction formulation might be a good way to model changes in the demand for reserves over time. Given that the stocks of reserves tend to be very large relative to trade and capital account flows, it is likely to take time for countries to move in response to any abrupt change in the perceived optimal level of reserves that may come about due to changes in the underlying determinants. However, that said, over the three years to 2008 the current account balance for both China and Japan was around 20 per cent of the value of the stock of reserves. This suggests a considerable capacity, at least in these countries, to substantially adjust reserves levels, even in the short term.

The data

Unless otherwise indicated, all data are taken from the World Bank's World Development Indicators (WDI) database. The dependent variable is the level of US dollar foreign currency reserves. Reserves held as gold and assets held by SWFs are excluded. All non-index variables are logged. The explanatory variables considered are listed below.

- Trade (imports plus exports) (TRADEUSD) to capture the import-cover motivation for holding reserves, as well as neo-mercantilist drivers.

- Money supply (M2) (M2USD) to account for the degree of domestic financial depth and the size of the banking system to be "insured".

- Real per capita GDP (GDPPCPPP) in purchasing power parity dollars to account for scale and affluence effects.

- Exchange rate volatility (the coefficient of variation of monthly data over the year of the US dollar exchange rate) (XRVOL) to account for the degree of self-insurance risk. This data is taken from the IMF's International Financial Statistics (IFS) database.

- Financial openness index (FINOPEN) by Chinn and Ito (2006, 2008) normalised between zero and one representing the degree of *de jure* capital controls. There is some evidence that a relaxation of *de facto* capital controls has taken place in many countries in recent years, particularly in Asia (Patnaik and Shah, 2010; Laurenceson and Tang, 2005). However, given that we are modelling policy intentions, a *de jure* measure may be more appropriate.

- Exchange rate regime (0 for free floating and 1 for fixed. Based on Shambaugh, 2004) (XRREG) to capture the motivation to hold reserves in order to defend a fixed exchange rate.

Several other variables, including population size and short-term foreign debt, were examined but were found to be insignificant. Cross-sectional dummies (to account for different country types) were not considered as all estimations of the long run included country fixed effects. Time dummies (to account for crisis years, for example) were not included as the general specifications all include time fixed effects.

Unit root and cointegration tests

The time series properties of the candidate long-run variables will be assessed using three stationarity tests. The first two tests consider the case of cross-sectional independence in the panel data (Im-Pesaran-Shin and Maddala-Wu) while the third test allows for cross sectional dependence (Pesaran CADF) – that is, common factors across countries in the panel. Cross-sectional dependence is likely to be important, particularly for our dependent variable RESUSD due commonality in the global business cycle, and due possibly to common factors and/or spatial spillovers such as periods during which reserve accumulation became a shared priority across countries but related to variables omitted from our regression, or simply do to fashion or ratcheting (see below). Because these three tests require strongly balanced panels, the panel used in the unit root tests has been truncated to include only those countries with a full complement of data for the entire sample period 1980 to 2008. In addition to testing the stationarity of reserves, M2 and trade we also examine the properties of the financial openness and exchange rate regime variables. Given the general trend over the past few decades toward capital account deregulation and greater exchange rate flexibility these variable may contain local unit roots and may be valid long-run explanators of the level of reserves over time and across countries.

The results of the panel unit root tests are summarised in Table 1. For the first four series being tested (reserves, trade, M2 and GDP per capita) there is strong evidence of unit roots, and in levels all four appear to be first order integrated with the null hypothesis of no unit root being strongly rejected for the first difference forms of the variables. In the case of financial openness and exchange rate regime the evidence is more mixed. Indeed for these two variables the Pesaran CADF fails to reject the null of a unit root even in first differences.

Table 1. Panel unit root tests[1]

	Level		First difference	
	Test statistic	Num. panels	Test statistic	Num. panels
Im-Pasaran-Shin test (H_0: unit root; W t-bar statistics)				
LRESUSD	-1.344 *	92	-12.038 ***	92
LTRADEUSD	2.690	77	-6.208 ***	77
LM2USD	2.484	64	-7.302 ***	64
LGDPPCPPP	0.858	93	-0.736 ***	93
FINOPEN	0.914	89	-9.534 ***	89
XRREG	-12.351 ***	132	-34.870 ***	132
Maddala-Wu (ADF) test (H_0: unit root; prob > Inverse chi squared)				
LRESUSD	0.0764 *	92	0.0000 ***	92
LTRADEUSD	0.9795	77	0.0000 ***	77
LM2USD	0.9723	64	0.0000 ***	64
LGDPPCPPP	0.6574	93	0.0000 ***	93
FINOPEN	0.9860	89	0.0000 ***	89
XRREG	0.4707	132	0.0000 ***	132
Pesaran CADF test (H_0: unit root; Z t-bar statistic)				
LRESUSD	0.835	92	-6.541 ***	92
LTRADEUSD	5.751	77	-5.203 ***	77
LM2USD	4.242	64	-3.753 ***	64
LGDPPCPPP	4.777	93	-4.724 ***	93
FINOPEN	3.009	89	-0.798	89
XRREG	20.671	132	15.317	132

1. Sample period is 1980 to 2008 and restricted to countries containing complete data over that sample period. All tests include constant and trend terms, and number of lags is truncated at two. Statistical significance at the 1, 5 and 10 percent levels are denoted by ***, ** and * respectively. Im-Pasaran-Shin tests for FINOPEN and XRREG include demeaning.

The results of panel cointegration tests for candidate long-run variables are reported in Tables 2 and 3. Two sets of cointegration tests are undertaken: first with all six candidate long-run variables included, and second, in which the financial openness and exchange rate regime variables are excluded on the basis of the weaker unit root test results reported above. GDP per capita is also excluded in the second set of tests in anticipation of the results of the long-run panel estimations reported below and for the sake of brevity. The first of the two tests used is the Pedroni (1997, 1999) procedure which allows heterogeneity in the slope coefficients, as well as fixed effects and trends in the data. The second cointegration test is by Kao (1999). One failing of both of these tests is that, unlike the Pesaran CADF unit root test used above, they

do not allow for the presence of common factors which are likely to be important. In the case of both sets of long-run variables, the tests suggest that there is good evidence of cointegrating relationships. However, in accordance with the relatively weak evidence of unit roots in the exchange rate regime and financial openness variables, the cointegration results appear to be more robust with the inclusion of just the reserves, trade and M2 variables.

Table 2. Panel cointegration tests – six long-run variables

LRESUSD, LM2USD, LTRADEUSD, LGDPPCPPP, FINOPEN, XRREG (Number of observations = 2772) [1]					
Pedroni Residual Cointegration Test (H_0: no cointegration)					
Within dimension			*Between dimension*		
Panel v-statistic	-5.0234		Group rho-Statistic	6.8821	
Panel rho-statistic	4.0051		Group PP-Statistic	-8.1194	***
Panel PP-statistic	-2.8762	***	Group ADF-Statistic	-3.5415	***
Panel ADF-statistic	-3.7890	***			
Kao Residual Cointegration Test (H_0: no cointegration)					
ADF t-statistics	1.4476	*			

1. Sample period is 1980 to 2008. All tests include constants and automatic lag selection. Using degrees of freedom corrected Dickey-Fuller residual variances. Statistical significance at the 1, 5 and 10 percent levels denoted by ***, ** and * respectively.

Table 3. Panel cointegration tests – three long-run variables

LRESUSD, LM2USD and LTRADEUSD (Number of observations = 2772) [1]					
Pedroni Residual Cointegration Test (H_0: no cointegration)					
Within dimension			*Between dimension*		
Panel v-statistic	0.5849		Group rho-Statistic	2.4699	
Panel rho-statistic	-2.1746	**	Group PP-Statistic	-7.1714	***
Panel PP-statistic	-6.2369	***	Group ADF-Statistic	-97.7951	***
Panel ADF-statistic	-5.6923	***			
Kao Residual Cointegration Test (H_0: no cointegration)					
ADF t-statistics	-12.2779	***			

1. Sample period is 1980 to 2008 and observations are restricted to be identical to that used in the 5-variable cointegration tests above. Degrees-of-freedom corrected Dickey-Fuller residual variances are used. All tests include constants and automatic lag selection. Statistical significance at the 1, 5 and 10 percent levels are denoted by ***, ** and * respectively.

The specification and estimation

In order to avoid steady state bias, the econometric estimation of the error correction model in this paper is done in two stages – first the long-run and then the short-run with the lagged long-run residual included. The rationale for this is that within the framework of an error correction model formulation, a first-difference estimation with a non-zero constant term (or non-zero cross-sectional fixed effects) constitutes steady-state bias – that is to say, the inclusion of a non-zero constant in the short-run implies growth in the dependent variable (reserves) even when its level is at the implied long-run equilibrium and all of the short-run drivers are zero. This would clearly be problematic. The solution is to estimate the long run (with country fixed effects) by itself as the first step, and in this way the country fixed effects can be attributed entirely to the long-run and be interpreted as time-invariant country-specific *level* effects. Time fixed effects are also estimated in the long-run regression. These, if significant, can be interpreted as an unexplained trend that is common across countries and could account for unexplained factors shared by all

countries, such as a steady increase in global awareness about the role of reserves can play as a self-insurance mechanism.

Table 4. Long run estimation results, full sample

Dependent variable: LRESUSD, country and time fixed effects, 1980-2008

	(1) Horserace	(2) Specific	(3) Simple
LM2USD	0.2000	0.1819	0.1815
	(0.126)	(0.100)*	(0.102)*
LTRADEUSD	0.7467	0.7801	0.8013
	(0.153)***	(0.130)***	(0.131)***
LGDPPCPPP	-0.0066		
	(0.189)		
XRREG	0.0841	0.1211	
	(0.065)	(0.065)*	
XRXOL	-1.4251***		
	(0.275)		
FINOPEN	0.2638*	0.3010	
	(0.139)	(0.146)**	
Constant	-1.2514	-1.7462	-2.0742
	(3.533)	(2.774)	(2.768)
Time effects significant	Yes	Yes	Yes
Sample size	2461	2461	2461
R^2 between	0.94	0.93	0.93
R^2 within	0.71	0.72	0.71

Note: A consistent data set it used across all regressions so that comparisons of results across specifications are not influenced by the unbalanced data across variables. Robust standard errors in parentheses. Significant at * 10%, ** 5% and *** 1% levels.

Table 4 presents the results of the first stage long-run regressions over the sample period 1980-2008 with both cross-sectional fixed effects and time fixed effects. In the first column all candidate long-run variables are included, and as suggested by the weak cointegration test results for this broad set of regressors, the estimation results are weak, with only trade and exchange rate volatility highly significant. However, as in other studies that take this approach (for example Obstfeld *et. al.*, 2008), the parameter estimate on exchange rate volatility takes a negative sign. So while high exchange rate volatility may imply higher risk and motivate higher reserve holding, the dominant causality seems to run in the opposite direction, with higher reserves affecting the ability of a country to manage the exchange rate. Because of this endogeneity we omit exchange rate volatility. The second column presents results of the long-run regression with the incorrectly signed parameters dropped – the trade variable remain highly significant and M2, the exchange rate regime and finance openness all become more significant and are correctly signed. The third column presents the long-run estimation results for just the two explanators for which the evidence of cointegration with reserves is strongest. It is notable that after the exclusion of all other variables the parameters estimates on M2 and trade remain largely unchanged. This is the form that will be used in the dynamic formulation below.

Table 5. Error correction model estimation results, full sample

Dependent variable: ΔLRESUSD, 1980-2008

	(1) Horserace	(2) Specific
Error correction term	-0.2612 (0.021) ***	-0.2426 (0.019) ***
ΔLM2USD	0.3632 (0.079) ***	0.3867 (0.068) ***
ΔLTRADEUSD	0.4939 (0.101) ***	0.5593 (0.098) ***
ΔLGDPPCPPP	0.0689 (0.103)	
ΔXRREG	0.1136 (0.027) ***	0.1104 (0.025) ***
ΔXRXOL	-0.3698 (0.215) *	
ΔXRXOL(-1)	0.2195 (0.130) *	0.3705 (0.089) ***
ΔFINOPEN	0.2294 (0.084) ***	0.2550 (0.095) ***
Sample size	2322	2461
R^2	0.26	0.25

Note: Robust standard errors in parentheses. Significance at 10%, 5% and 1% levels is donated by *, ** and *** respectively.

Table 5 reports that results of the second (short-run) stage of the two-step ECM regressions. In addition to first differences of long-run variables and any other stationary short-run explanators, a lagged residual from the first stage (long-run) regressions is included and represents the deviation of the level of reserves from that suggested by its long-run cointegrated determinates. As expected, the parameter estimates for this lagged long-run residual are negative in all regressions, suggesting that any gap between the previous period's level of reserves and the level of reserves implied by the long-run determinates does indeed trend to close in the current period. However, while the negative sign is pleasing, the magnitude of the estimated values of the error correction term in these regressions should be interpreted with caution, particularly in light of their seemingly high values. Given that in most countries the level of reserves is very large relative to the size of capital flows, it seems unlikely that around one quarter of any deviation from an implied equilibrium could be closed over the period of just one year. Part of the reason that the estimated values of the error correction terms are so large is related to the use of country fixed effects in the regressions. Using cross-sectional fixed effects removes the average deviation in the fit of the estimated equation for each country – a deviation that might have otherwise built up over time given that the left-hand side variable in the short-run equation is a growth rate. This means that in the empirical specification used here the sum of the growth-rate errors for each country regression is zero over the sample period and this has the effect of narrowing any persistent long-run gap. Consequently the gap between the implied long run and actual reserves would appears to close more quickly than is probably actually the case, and this could explain the large estimated value of the error correction parameters. A further discussion of the implications of using cross-sectional fixed effects is included below.

Column one of Table 5 presents the results for a general specification with the first difference of all variables included. All variables are significant except GDP per capita and the sign on the contemporaneous exchange rate volatility parameter is negatively signed. In regressions that tested the

significance of lags of all the short-run variables, but not reported here, it was found that a first lag of the exchange rate volatility parameter was both correctly signed and significant. And indeed in the second column we see that when GDP per capita and the contemporaneous exchange rate volatility are dropped, the estimated parameter on the lag of exchange rate volatility becomes highly significant. The significance of this lagged variable suggests causality from higher exchange rate volatility in the previously period to higher growth in reserves in the next period, perhaps as countries increase insurance in the face of the higher perceived risk.

Estimates over sub-periods

Table 6 presents the results of regressions of the long-run variables over two sub-periods: namely the period prior to the Asia crisis (1980-1996) and the period thereafter (1998-2008). There are two notable features that emerge from this set of regressions. Firstly, M2 is insignificant in the first sub-period but highly significant in the second, while the opposite is the case for financial openness. Secondly, for those variables that are significant across both sub-periods, namely trade and the exchange rate regime, there is a remarkable consistency in the values of the estimated parameters.

Table 6. Long run estimation results, sub-samples

Dependent variable: LRESUSD, country and time fixed effects

	(1) 1980-1996 Horserace	(2) 1980-1996 Specific	(3) 1998-2008 Horserace	(4) 1998-2008 Specific
LM2USD	-0.1446 (0.173)		0.3576 (0.113)***	0.3389 (0.103)***
LTRADEUSD	0.7913 (0.231)***	0.9480 (0.207)***	0.7860 (0.171)***	0.7985 (0.162)***
LGDPPCPPP	0.2585 (0.220)		-0.0584 (0.151)	
XRREG	0.1422** (0.066)	0.1715 (0.068)**	0.1620 (0.076)**	0.1800 (0.077)***
XRXOL	-0.2985 (0.235)		-1.008 (0.286)***	
FINOPEN	0.4807* (0.0.252)	0.5211 (0.241)**	-0.0106 (0.172)	
Constant	0.3671 (5.315)	-1.5545 (4.599)	-4.6604 (3.133)	-5.0850 (2.832)*
Time effects significant	Yes	Yes	Yes	Yes
Sample size	1395	1395	1173	1173
R^2 between	0.87	0.91	0.92	0.92
R^2 within	0.51	0.50	0.70	0.69

Note: A consistent data set it used across all regressions so that comparisons of results across specifications are not influenced by the unbalanced data across variables. Robust standard errors in parentheses. Significant at * 10%, ** 5% and *** 1% levels.

The fact that M2 become significant only in the second half of the sub-period is consistent with the evolution of reserve policy around the world. As previously discussed, it was not until around the turn of the century, in the aftermath of the Asia and Argentine crises, that awareness emerged of the risk of a crisis generated by capital flight from the domestic financial system, and the exchange rate exposures of domestic financial sectors.

6. Interpreting the empirical results

Another advantage of using a dynamic ECM formulation is that it allows us to compare the level of reserves in individual countries to their estimated long-run equilibrium (as implied by average behaviour) over time. Figures 2 and 3 present the average deviation from the implied long-run for a select group of countries for the last three years of the sample period (2006-08). The first figure presents the deviation in terms of reserve-to-GDP ratios. It is immediately evident that the group of countries that are found to have the largest positive deviations correspond very closely to those that have been the largest accumulators of reserves in recent years, namely China, Japan, Korea, and India.

While in the first of these charts we see a smooth continuum of deviations, ranging from China at around positive 14 percentage points of GDP to Singapore at negative 20 percentage points of GDP, when the deviations are represented in terms of nominal US dollars, as is done in Figure 3, only two countries are prominent, namely China and Japan. These results suggest that on average over the three years to 2008 these two countries each held around half a trillion US dollars of reserves in excess of that implied by average behaviour across countries in our sample. Furthermore, taking a three year average of the deviations disguises a divergence between even these two countries over that period, with Japan's deviation equalling roughly a constant 450 billion in each of the three years, while for China the deviation starts at around 300 billion in 2006 and reaches 900 billion in 2008, the final year of the sample (Figure 4, left panel). Furthermore, back-of-the-envelope calculations suggest that in the case of China, where the accumulation of reserves indeed accelerated after the end of 2008, the deviation from the long-run equilibrium eclipsed $1 trillion by 2009.

Figure 2. Reserve deviations from long-run average behaviour

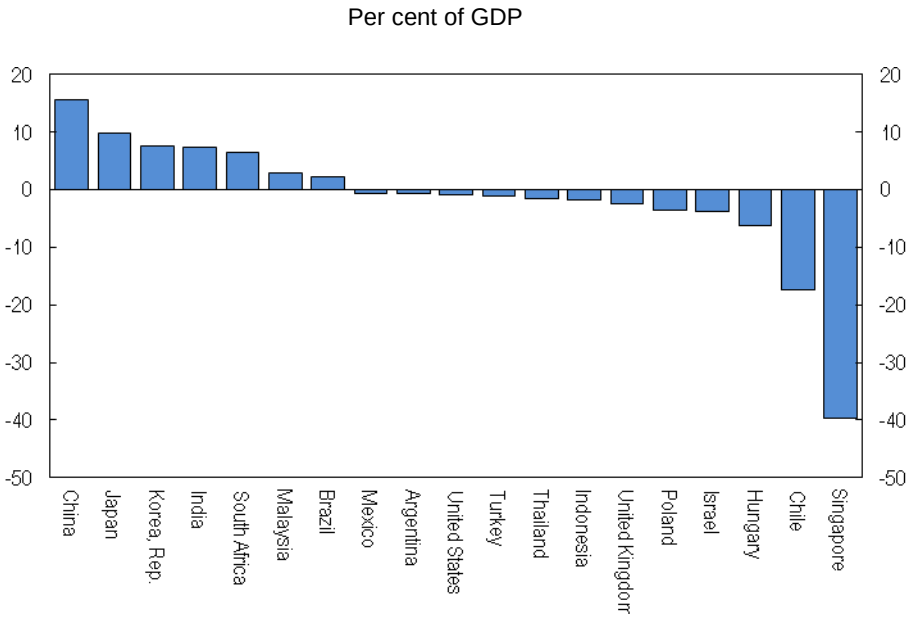
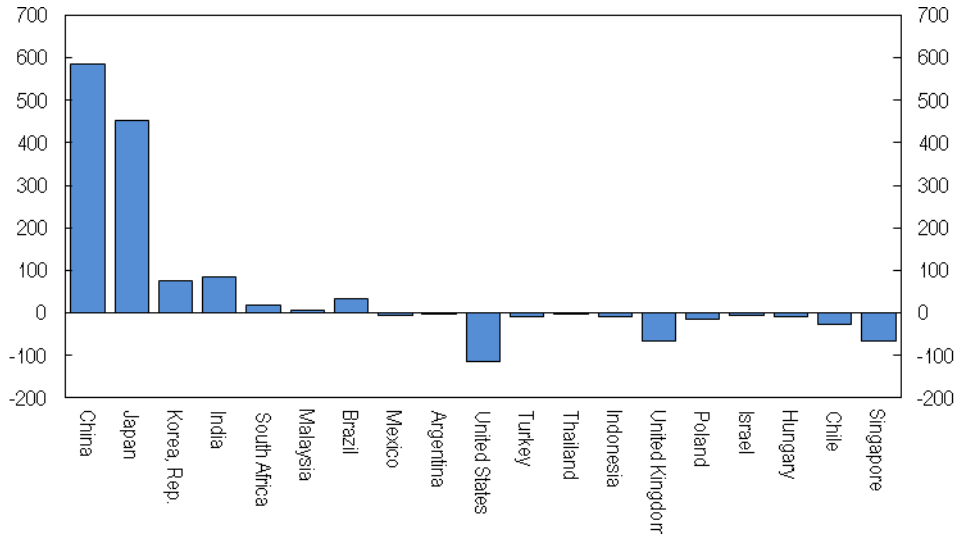


Figure 3. Reserve deviations from long-run average behaviour

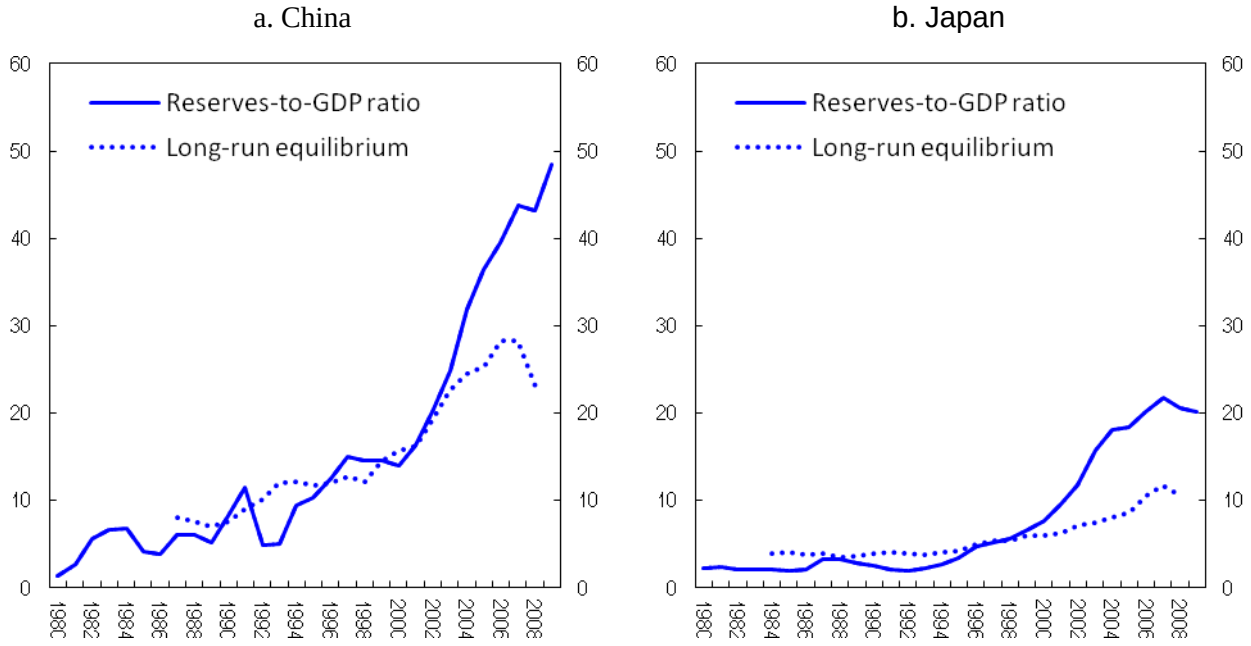
US$ billions



The fit of the long-run estimations for China and Japan is plotted in Figure 4. The corresponding charts showing the fits for a broader set of countries is including in Appendix 1.

Figure 4. Reserve-to-GDP ratio and implied long-run equilibrium

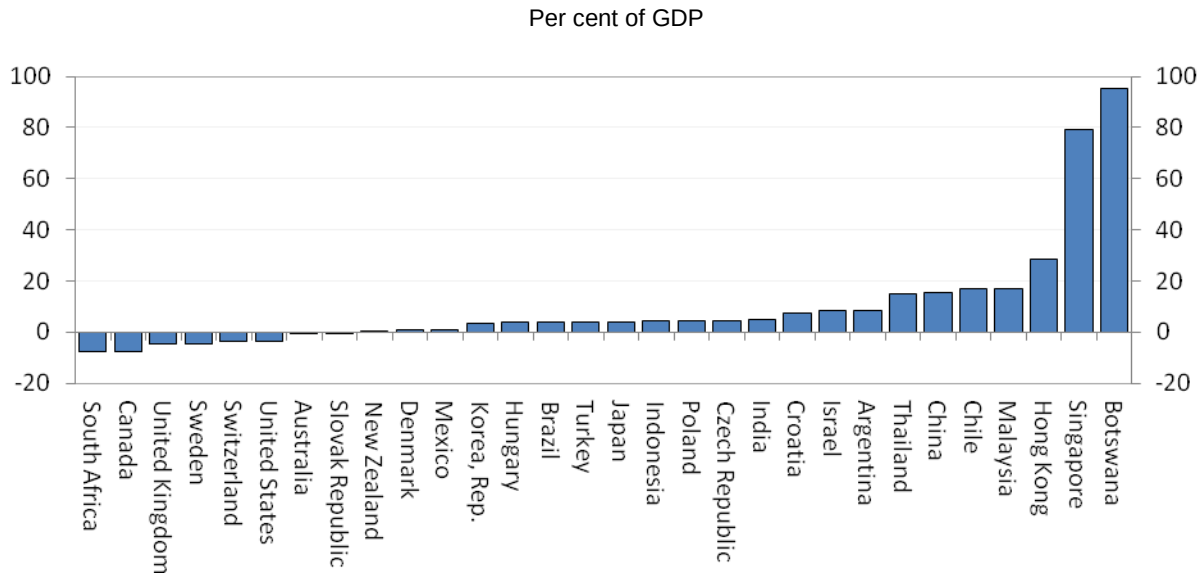
Per cent of GDP



As mentioned earlier, the long-run regressions include cross-sectional (country) fixed effects. These are in fact individual country intercepts that mean that the long-run residual for each country if forced to sum to zero over its sample period. While including country fixed effects is beneficial from an econometric standpoint, and can be used to account for time-invariant country-specific factors that are not accounted for

by the other explanators, it does introduce an interpretational issue. One of the intentions of this stream of research is to try to draw inferences from the empirical results about the adequacy of a country's level of reserve holdings at any point in time. The methodology adopted herein allows us to do this by making reference to the average behaviour of all the other countries in the panel. However, with the inclusion of country fixed effects, a direct comparison of the levels of reserve holdings across countries is washed out by these individual country intercepts and most of the deviation from the long-run equilibrium comes from the time dimension (this is illustrated more clearly by looking at the charts of the long-run fits in the Appendix). Figure 5 plots the estimated country fixed effect for a select group of countries as an (average) percentage of GDP. We see that for some countries the value of the country fixed effect is very large. For instance, in the case of Singapore the long-run fit excluding country fixed effects is close to eighty percent of GDP lower. This suggest that rather than having reserves 40 percent of GDP lower than that suggested by the long-run (with country fixed effects), the levels of reserve holdings could be interpreted as being 60 percent of GDP *too high* in 2008. While Singapore is an extreme case, the impact of the estimated country fixed effects are also significant for many other countries, including China for which the value averages around positive 17 percentage points. This implies that without these unspecified country factors included, the deviation of China's reserve holding from average behaviour is even larger than initially estimated.

Figure 5. Estimated cross-sectional fixed effects for selected countries



7. Conclusion

While one needs to be careful in making inferences about the optimal level of reserves based on the methodology used here, to the extent that the level of reserves do indeed exceed adequacy ratios in many countries, a greater proportion of these funds could be invested more diversely (and productively), therefore reducing the implicit opportunity cost of holding reserves (Rodrik, 2006). This might include transferring a greater proportion of reserves to SWFs which typically invest more aggressively than central banks. Indeed, recent moves in that direction only add credence to the conclusion that the current historically unprecedented levels of reserve holdings in some countries are excessive from the stand point of precaution or self-insurance. To the extent that the biggest holders of reserves have built large stocks in particular currencies and therefore constitute price-makers in the international markets for these currencies, the room to manoeuvre in managing the composition of their stock of reserves will be diminished, regardless of their national exchange rate regime.

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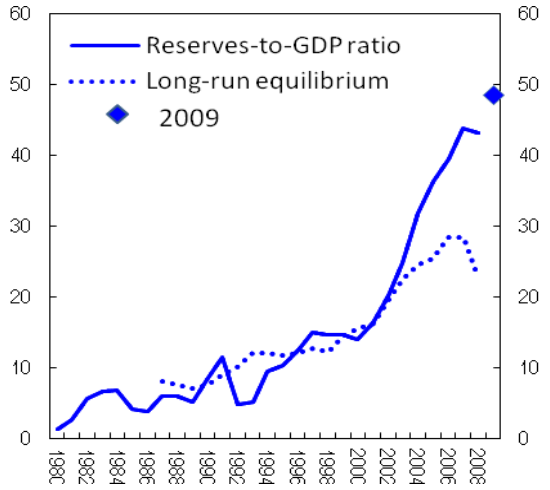
Appendix 1

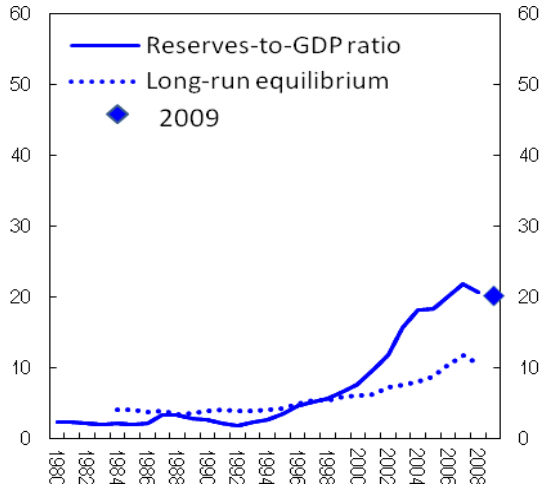
Figure A1.1 Reserve-to-GDP ratio and implied long-run equilibrium

Selected countries, per cent of GDP

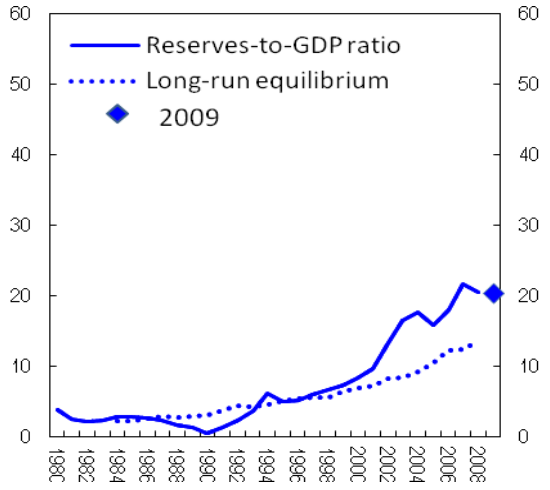
a. China



b. Japan



c. India



d. Indonesia

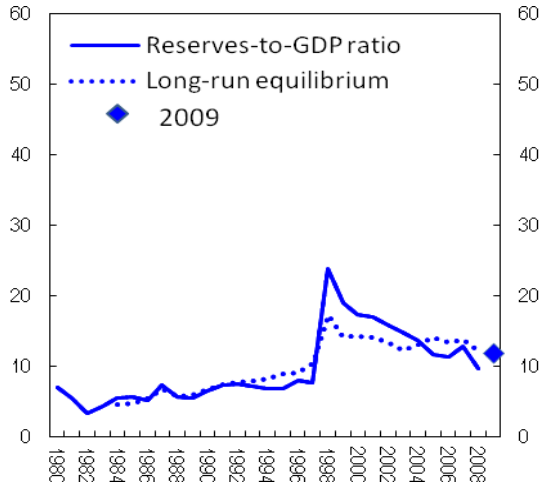
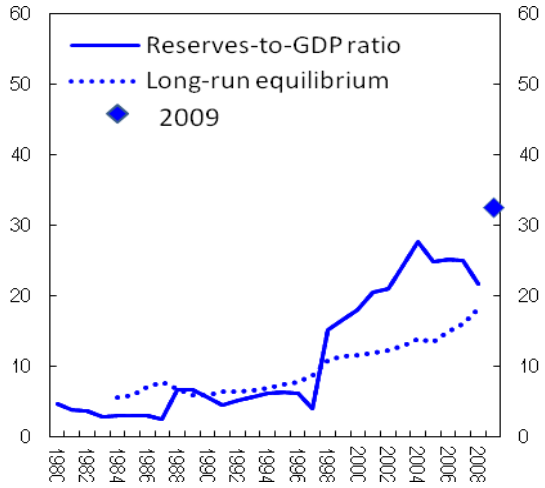
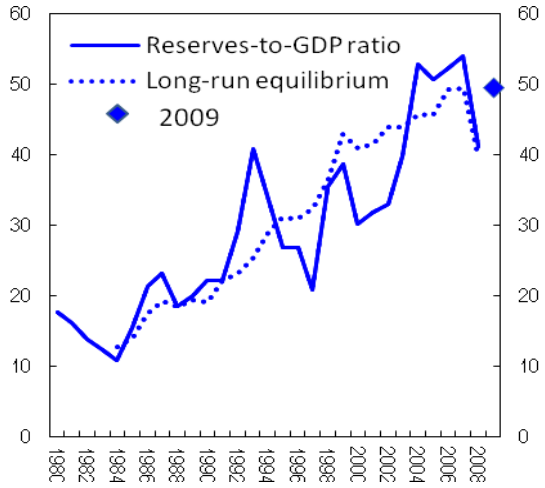


Figure A1.1. (continued)

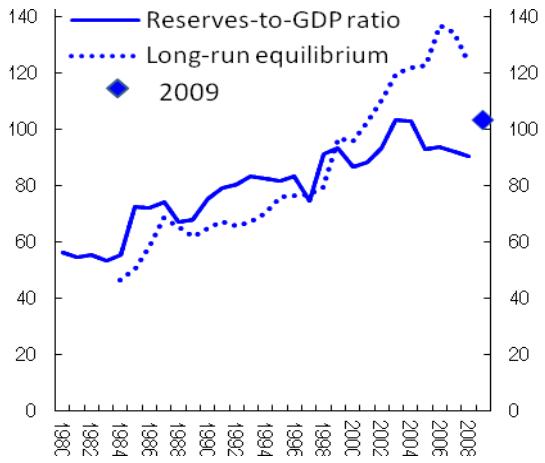
e. South Korea



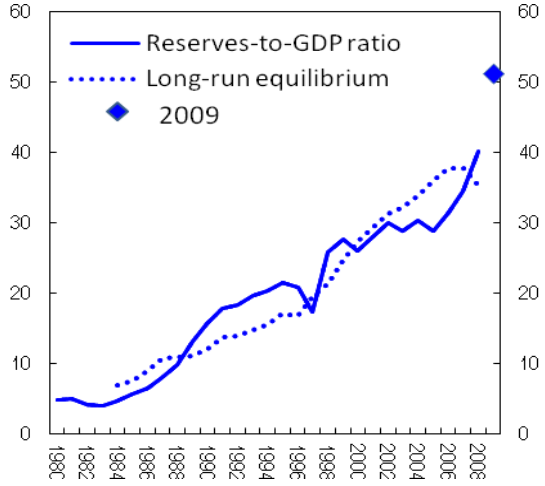
f. Malaysia



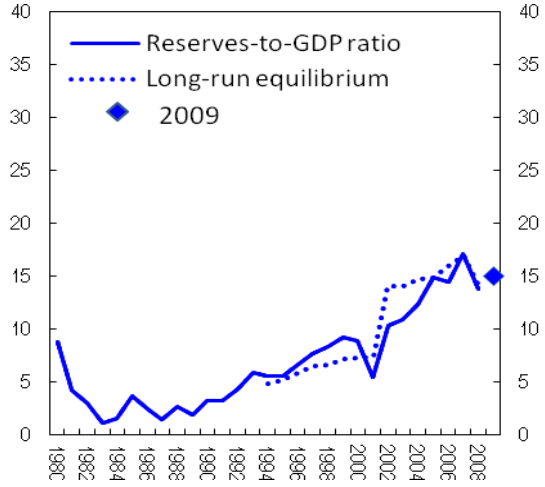
g. Singapore



h. Thailand



i. Argentina



j. Brazil

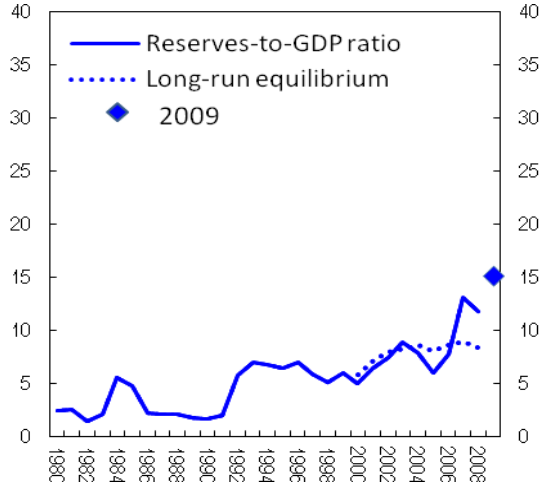
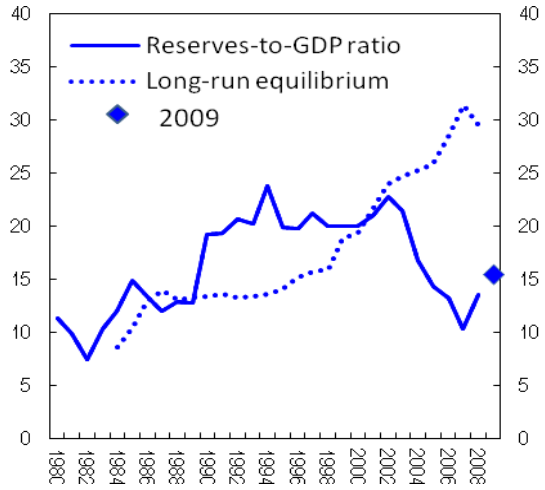
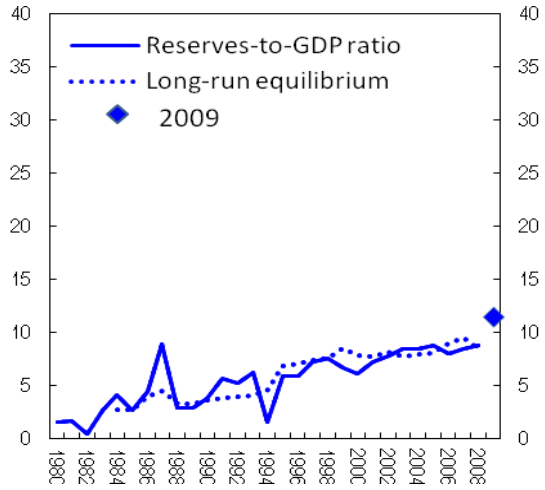


Figure A1.1. (continued)

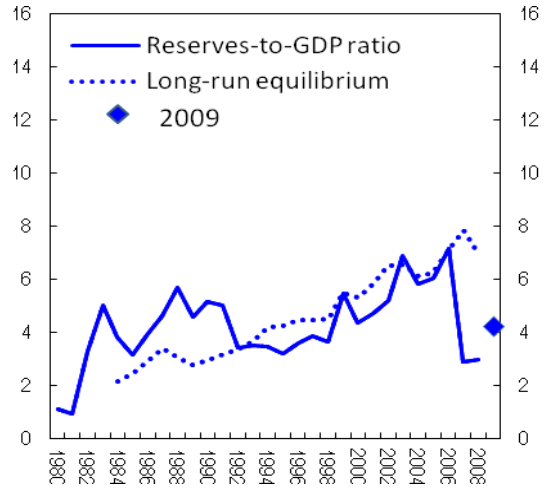
k. Chile



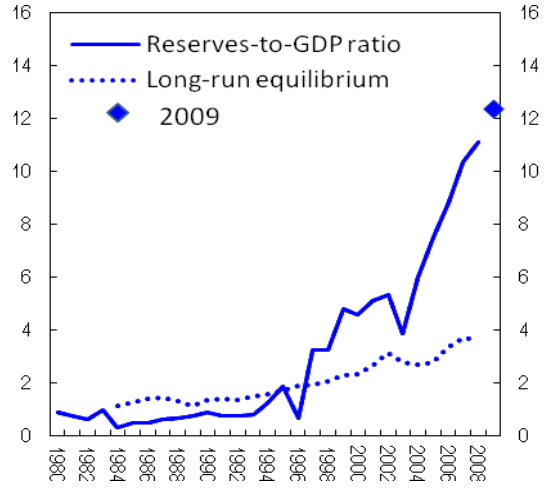
l. Mexico



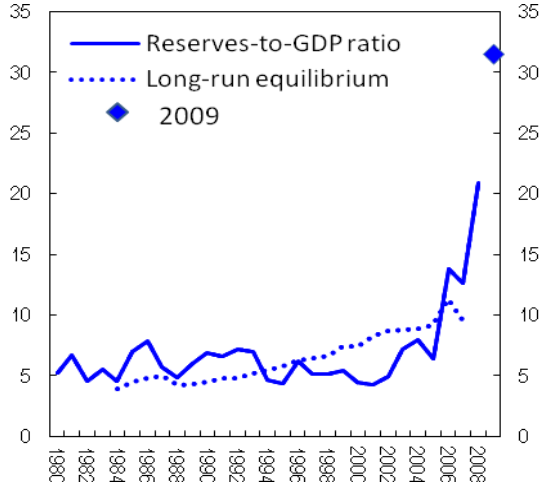
m. Australia



n. South Africa



o. Iceland



p. Israel

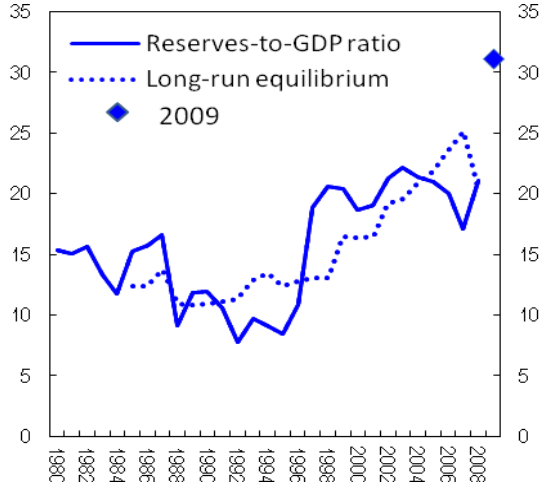
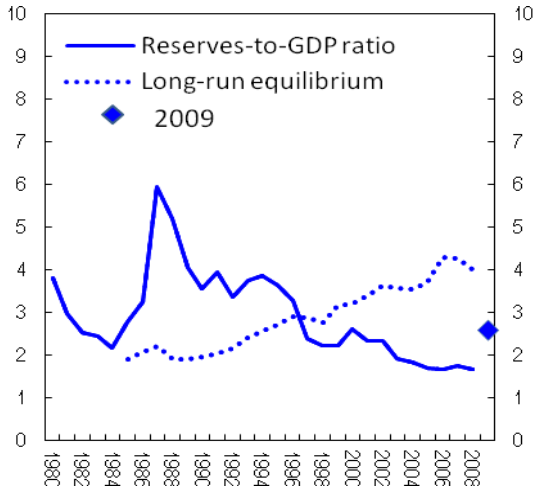
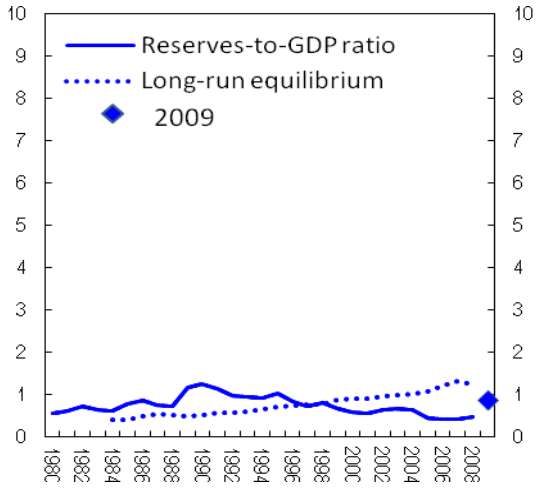


Figure A1.1. (continued)

q. United Kingdom



r. United States



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