# Out-of-Sample Analysis of International Reserves for Emerging Economies with a Dynamic Panel Model*

Kuk Mo Jung†
Hanyang University

Ju Hyun Pyun‡
Korea University Business School

April 2018

***Abstract***

Using data for 51 emerging countries during 1990-2011, we reinvestigate the validity of both traditional and recently proposed determinants of international reserves. The dynamic panel model controlling for endogeneity and country heterogeneity reveals that not only traditional determinants but also new financial variables—M2/GDP and foreign capital inflows through over-the-counter markets—have significant effects on reserves hoarding. More importantly, out-of-sample forecasts show that the dynamic model yields the best goodness-of-fit, and its predicted values successfully account for the recent patterns in reserve accumulations.

*JEL code*: C23, E44, E58, F21, F31
*Keywords*: foreign exchange reserves, dynamic panel estimation, out-of-sample analysis, emerging economies, over-the-counter markets

---

* We are deeply indebted to Paul Bergin, Athanasios Geromichalos and two anonymous referees for their constructive comments and suggestions. We also thank the participants at the UC Davis International/Macro Brownbag Seminar and Henan University for their constructive comments and suggestions. Jung acknowledges that this work was supported by the research fund of Hanyang University (HY-2018). All errors are our own.
† Division of International Studies, International Building 5th floor, Hanyang University, Seoul, 04763, Tel: +82-2-2220-2246, E-mail: kmjung@hanyang.ac.kr
‡ Corresponding Author: Korea University Business School, 145, Anam-Ro, Seongbuk-Gu, Seoul 136-701, Tel: +82-2-3290-2610, E-mail: jhpyun@korea.ac.kr

## 1 Introduction

This study investigates the determinants of reserves hoarding in a unified framework, using a sample of 51 emerging and developing economies from 1990 to 2011. The data clearly shows that many emerging and developing countries' international reserves grew in a highly persistent way yet, many current studies even employ static panel techniques without considering possible biases in the parameter estimates. A minor contribution of this study adopts various dynamic panel techniques that are able to account for the dynamics of reserves accumulation to correct possible misspecification errors in the conventional estimation strategies although this approach is not new but follows previous studies on the international reserves such as Bastourre et al. (2009), Steiner (2011) and Qian and Steiner (2014).

The results of this study reveal that reserve accumulation is significantly persistent, which implies that many of previously proposed reserve determinants have long term effects on reserves hoarding. We also show that the reserve determinants indeed affect reserve-hoarding behavior of emerging economies. For example, trade openness and the terms of trade turn out to have significant effects on the reserves (Lane and Burke 2001, Aizenman and Lee 2007). M2/GDP is shown to be positively associated with the reserves, which indicates that financial stability motives may drive reserve hoarding (Obstfeld et al., 2010). OTC capital inflows measured by foreign debt inflows to GDP exhibit a positive correlation with international reserves although we control for external debt "stock" to GDP as is in previous studies. Thus, we find support for Jung and Pyun's (2016) conclusion that the development of new financial products and the international capital market structure (e.g., OTC foreign capital inflows) may be another important factor of the recent, unprecedented increases in certain countries' foreign exchange reserves.

More importantly, this study offers practical insight on whether the current reserve level is excessive by providing out-of-sample forecasts based on the various model specifications. We find that the dynamic panel model performs best in terms of forecast accuracy: the dynamic panel approach reduces the gap between the actual and predicted levels of international reserves more than any other approach. Interestingly, the dynamic specification is even able to predict the reserves of countries previously regarded as outliers, whose actual level of reserves far exceeds the level predicted by theories such as China and Korea. Thus, our results indicate that major emerging economies' current levels of international reserves are *neither* excessive *nor* inexplicable (Cheung and Ito, 2009 and Obstfeld et al., 2010 arrive at similar conclusions). Additionally, our methodology may be of particular interest to policy makers in that it would allow them to more accurately predict changes in emerging economies' reserves.

The remaining part of this study is organized as follows: Section 2 provides literature review. Section 3 details the data set and model specifications. Section 4 presents the empirical results. Our concluding remarks appear in Section 5.

## 2 Literature review

Since the turn of the millennium, monetary authorities in developing countries have begun to accumulate international reserves on an unprecedented scale. Over the last decade, China's international reserves alone have grown more than tenfold. Other oil-producing, emerging economies in Asia and Latin America (most notably Russia) have experienced average growth rates of reserve accumulation more than 20% per year over the same period of time. Many scholars cite this phenomenal build-up of reserve stocks as the driving force behind many of the recent changes in the international monetary system.

Despite the importance of this phenomenon, the debate over its causes and how long it is likely to endure is far from settled. A plethora of studies have identified and tested various motives for holding international reserves. As Aizenman and Lee (2007) summarize, such motives can be broadly divided into two basic categories, namely precautionary and mercantilist motives. Precautionary motives reflect the desire to insure against external shock. Mercantilist motives, on the other hand, reflect the desire to promote exports or manipulate currency (See Dooley, Folkerts-Landau, and Garber (2007) for a more detailed literature review on the mercantilist view.) Cheung and Ito (2009) also provide good summaries of various empirical studies on the effects of precautionary motives on reserve accumulation. Indeed, the literature is divided on the subject of which motive has played a greater role in the accumulation of reserves. Note that some have even suggested that neither of the two motives is quantitatively consistent with the current level of reserves held by emerging economies, and call this build up a puzzle (Jeanne and Ranciere, 2011).

Furthermore, recent works propose additional determinants of reserves accumulation. For instance, Obstfeld et al. (2010) argue that many emerging countries rely on foreign exchange reserves as a tool for protecting domestic credit markets (i.e., the financial stability view). Their key idea, which can be traced back to Thornton (1802), is that the possibility of domestic capital outflows can place extraordinary demands on reserves. In other words, while previous studies (with precautionary views) primarily focused on external shock driven sudden stops, they focus on domestic financial liabilities (proxied by M2/GDP), and empirically show the latter's significant and positive correlation with stocks of international reserves. Pina (2015) offers alternative theory arguing reserve accumulation could naturally follow from central bank policies trying to smooth out inflation costs.

Jung and Pyun (2016) maintain that bilateral trading frictions in international capital markets might provide a fundamental reason behind a huge accumulation of reserves by emerging economies. Their argument goes as follows. First, they point to the fact that emerging economics are in constant need of foreign investments. Thus, they always try to attract inward foreign investments through international capital markets. But, the latter is inherently decentralized meaning that investment recipients, i.e., domestic firms, and foreign investors must trade in a bilateral fashion. To put it differently, FDI recipients must search for investors from abroad. Once they get

matched, they negotiate terms of trade, which eventually get implemented by both parties.

The point is bilateral trade suffers from limited commitment problems, which hinders both parties from reaching an agreement on terms of trade. This is where US government bonds or international reserve assets come in as a facilitator for decentralized trade in international capital markets. In other words, reserve assets held by developing countries effectively act as a medium of exchange or as a collateral for foreign capital inflows. Then, a fall in the degree of trading frictions in international capital markets through deregulations, technological advancement, and etc, widely observed over the last few decades worldwide, must enhance the reserve assets' value as a "trade facilitator" or liquidity value. This in turn should induce (emerging) economies in need of foreign investments to accumulate the reserve asset in equilibrium. Therefore, one can intuitively predict to observe a positive correlation between capital inflows through OTC markets (e.g., private equity funds, emerging market debts, financial foreign direct investment (FDI) through mergers and acquisitions (M&A), and wholesale funding for multinational banks) and international reserves held by emerging economies, which is what this study is primarily trying to test.

## 3 Empirical methodology

### 3.1 Data

Data is collected from World Development Indicators (WDI), the World Bank, International Financial Statistics (IFS), the IMF, and updated and extended versions of Lane and Milesi-Ferretti's (2007) dataset. Owing to data availability especially for Lane and Milesi-Ferretti's external wealth dataset, total observations from 51 emerging and developing countries (with substantial reserve holdings) for the years 1990 to 2011 are arranged in an unbalanced panel dataset. Our sample includes only emerging economies because Cheung and Ito (2009) show that international reserves and their determinants are significantly different between advanced and developing economies. Note that Cheung and Ito (2009) take a positive approach to examine the determinants of international reserves between developed and developing countries. In our expanded sample, we cover a more broad set of countries up to 70 countries (by excluding external debt variable). The sample countries are listed in Appendix Table 1.

The dependent variable is the ratio of official international reserves to GDP. Neither sovereign wealth funds nor official gold holdings are included in the reserve measure. We adopt explanatory variables, which are widely regarded as important determinants of international reserves (Aizenmann and Lee, 2007; Cheung and Ito, 2009; Obstfeld et al., 2010; Steiner 2011). Appendix Table 2 summarizes the construction and sources of the explanatory variables. We include trade openness. According to Lane and Burke (2001), the reserves are financing option of last resort in covering import demand so trade openness would be positively associated with the

reserves. Crisis, exchange volatility, financial openness and external debt variables may also capture precautionary motives. The terms of trade generate wealth shocks (especially for commodity trade), so the reserves are likely to be used to buffer those shocks. In addition, the terms of trade are included as mercantilist motive proxy because emerging market policy makers would increase reserves in response to currency appreciation driven by the terms of trade improvement (see Aizenman and Lee (2007) for more mercantilist variables such as the export growth rate and real exchange misalignment). Note that Aizenman and Lee (2007) show precautionary motives tend to dominate mercantilist ones, and most discussions in the literature focus on the former's effects on the reserves management.

Since OTC foreign capital inflow is a new variable in the literature, no other benchmark variables exist. Furthermore, to the best of our knowledge, no aggregate data on these flows is available for emerging economies. Note that a few online databases, such as Hedge Fund Research (HFR), the Trading Advisor Selection System (TASS), and the Center for International Securities and Derivatives Markets (CISDM), provide data for hedge fund inflows by country. Additionally, the Emerging Market Private Equity Association (EMPEA) provides one of the most comprehensive datasets on private equity funds invested in emerging markets. However, not all of this data is available to the public, let alone a dimension of panel is relatively narrow. For this reason, we must rely on indirect measures gathered from IFS. First, we exploit the stylized fact that most emerging market debts are traded in OTC markets (Duffie et al., 2005). As such, foreign debt liability flows have been chosen as our baseline proxy for OTC foreign capital inflows. Furthermore, as FDI inflows into emerging and developing countries have increasingly been in the form of M&A (especially in financial FDI activities, Goldberg, 2007), and since substantial portions of M&A activities are transacted outside of the centralized market clearing system (e.g., the stock exchange), we also choose to add FDI liabilities to the debt liabilities in order to calculate OTC foreign capital inflows. We readily admit that this methodology may produce measurement errors as the IFS does not offer segregated data on portfolio debt or FDI in terms of trading characteristics. Consequently, this limitation in the data forces us to conduct our study with the second best measure, but by controlling for country fixed effects, we may be able to partially reduce any measurement errors.

Appendix Table 3 displays the descriptive statistics for the sample. The mean of reserves to GDP is 0.15 but its variations are from 0.002 to 1.083. The mean and standard deviation for other variables are also reported (i.e., the mean of GDP per capita is 6,260 international dollar adjusted by PPP). In particular, we report the correlations of reserves to GDP and other determinants in the last column. M2/GDP shows the highest positive correlation with the reserves to GDP (0.644) among all the variables. GDP per capita, trade and financial openness and OTC flows also show a high positive correlation with the reserves, whereas crisis variables have a slightly negative correlation with the reserves.

To examine the determinants of reserves to GDP, we introduce a dynamic specification since international reserves turn out to exhibit a high degree of

autocorrelation in most countries. Because we deal with large panels (N=51; T=22) of heterogeneous countries, we also check a possibility of panel unit roots using the test proposed by Im et al. (2003) for continuous variables in our unbalanced panel. Then, we implement Pesaran (2004)'s cross sectional dependence test to check whether there is cross sectional dependence in the panel. The panel unit root test including a time trend indicates that for most variables including reserves to GDP, we reject the null hypothesis that all panels contain unit-roots. However, we do not reject the unit roots of M2/GDP and GDP per capita. We discuss this non-stationarity of two variables in the following.

Our baseline estimation methodology for dynamic panel is system GMM. In addition, to address possible heteroscedasticity and autocorrelation and the nonstationarity of above two variables, we include other estimation methods such as quasi-maximum likelihood (QML) estimation of dynamic panel models (Hayakawa and Pesaran, 2015) and first-difference maximum likelihood (FDML) in dynamic panel in case of panel unit roots (Han and Phillips, 2010).

### 3.2 Empirical Specification

The dynamic panel regression analysis is conducted using the following equation:

$$y_{i,t} = \lambda \cdot y_{i,t-1} + X'_{i,t}\beta + \eta_i + \phi_t + \varepsilon_{i,t} \qquad (1)$$

where the subscripts $i$ and $t$ represent specific countries and time periods, respectively. $y_{i,t}$ is the ratio of official international reserves to GDP. We add the lagged dependent variable, $y_{i,t-1}$, as one of the regressors. $X_{i,t}$ represents a vector of explanatory variables (as described in the previous section), and $\eta_i$ captures unobserved and time-invariant country-specific effects. This regression equation also includes a time dummy, $\phi_t$, to control for the common effect of specific years (such as those with a global financial crisis). $\varepsilon_{i,t}$ is the error term. The coefficient $\beta$ measures the impact of the regressors, $X_{i,t}$ on reserves at $t$. Pesaran's test of cross sectional independence for the error terms across panels does not reject the null hypothesis of cross sectional independence (-2.03, p-value = 1.958). Note that the test statistics reject cross-sectional independence without time dummies, but including year dummies seems to relieve cross-sectional dependence problem.

We first implement country fixed effects (henceforth FE) estimation to control for this heterogeneity because $\eta_i$ can be correlated with $\varepsilon_{i,t}$. Accordingly, the FE estimator, in general, is consistent; however, its estimates may be biased as well due to the lagged dependent variable, $y_{i,t-1}$. For instance, the first difference of equation (1) will eliminate the country-specific effects, $\eta_i$, and generate the following equation (2):

$$y_{i,t} - y_{i,t-1} = \lambda \cdot (y_{i,t-1} - y_{i,t-2}) + (X'_{i,t} - X'_{i,t-1})\beta + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \qquad (2)$$

Indeed, the first-differencing process creates a correlation between ($y_{i,t-1} - y_{i,t-2}$) and ($\varepsilon_{i,t} - \varepsilon_{i,t-1}$) and causes a "Nickell" bias in the estimation of $\lambda$ (Nickell, 1981).

Arellano and Bond (1991) assert that it is crucial to allow for dynamics (i.e., including a lagged dependent variable among the regressors) in the panel estimation, and suggest a correction method that uses instruments to control for endogeneity (i.e., the correlation between ($y_{i,t-1} - y_{i,t-2}$) and ($\varepsilon_{i,t} - \varepsilon_{i,t-1}$)). Arellano and Bond's (1991) methodology specifies that all dependent variable lags and the first-differences of the other regressors can be used as instruments, $Z'_{i,t} = [y_{i,t-2}, y_{i,t-3}, ..., y_{i,1}, \Delta X'_{i,t}]$ . Furthermore, in this estimation it is commonly assumed that all of the explanatory variables are strictly exogenous, that is, all of their leads and lags are uncorrelated with the error term, $\varepsilon_{i,t}$. In contrast, we assume that some variables such as trade openness, terms of trade and OTC capital flows are endogenous in all specifications. When the set of explanatory variables (X) are weakly exogenous, the following moment conditions hold $E[y_{i,t-k}(\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0$ for $k \geq 2$; $t = 3,\ldots,$ T, and $E[X_{i,t-k}(\varepsilon_{i,t} - \varepsilon_{i,t-1})]=0$ for $k \geq 2$; $t = 3,\ldots,$ T. This allows for the possibility of simultaneity between the dependent variable and these explanatory variables. We also allow different assumptions about pre-determined and endogenous variables (see Column (4) of Table 1). Then, based on the moment conditions, the difference-GMM method can be used to estimate the differenced Equation (2).

However, Alonso-Borrego and Arellano (1996) and Blundell and Bond (1998) point out that the difference-GMM estimator cannot account for cross-country variations and that the regressors' lagged levels might be weak instruments for the first-differences if the regressors are persistent (close to a random walk process) over time. Thus, the difference-GMM performs poorly because the past levels convey little information about future changes. To overcome this obstacle, Arellano and Bover (1995) propose the system-GMM estimator, which combines the differences regression (2) with the levels regression (1). Using Equation (1), level variables are instrumented with suitable lags of their own first differences based on that these differences are uncorrelated with the country fixed effects and error terms. The moment conditions of levels regression are $E[(y_{i,t-1} - y_{i,t-2})(\eta_{i,t} + \varepsilon_{i,t})]=0$ and $E[(X_{i,t-1} - X_{i,t-2})(\eta_{i,t} + \varepsilon_{i,t})]=0$.

As the reliability of the GMM estimator depends on whether the explanatory variables' lagged values are valid instruments, we conduct weak instrument test (Bazzi and Clemens, 2013) and over-identification restriction tests (i.e., Hansen (1982) tests) (where failure to reject the null hypothesis gives support for the valid instruments). Lastly, for the specification test, it is necessary to check whether the error term, $\varepsilon_{i,t}$, is serially correlated; if it is not, then the first order differenced error terms ($\varepsilon_{i,t} - \varepsilon_{i,t-1}$) are expected to have serial correlation. As a result, it is expected that the second-order differenced error terms ($\varepsilon_{i,t} - \varepsilon_{i,t-2}$) will have no serial autocorrelation. So, test results for first and second order autocorrelation in the differenced error terms are also reported.

## 4 Empirical Results

### 4.1 Main Results

We begin by estimating Equation (1) with an array of variables that affect the reserves to GDP ratio. Table 1 shows our benchmark results. Column (1) of Table 1 shows the results with country fixed effects. We introduce the lagged dependent variable as a regressor. As expected, the lagged reserves/GDP is significantly positive at the 1% level and its magnitude is fairly large (about 0.72). The estimated coefficients on financial openness is positive and significant at the 1% level, indicating that countries that have more open financial market tend to hold more reserves. This result supports Aizenmann and Lee's (2007) argument that reserves accumulation is fueled by precautionary motives. Note that since some variables such as trade openness and the terms of trade are related to not only precautionary motives but also mercantilist motives, it is challenging to distinguish empirical determinants of the reserves exactly according to two views. While Aizenmann and Lee (2007) limit variables of mercantilist motives to lagged export growth and deviations of national price levels from the trend based on income levels, they argue that financial and trade openness (import to GDP) are variables that represent precautionary motives for the reserves.

Since the fixed effects estimations may be biased due to the possible correlation between the lagged dependent variable and the error terms, difference-GMM estimators are presented in Column (2). However, these results are similar to those in Column (1), interestingly, the estimated coefficient on financial openness remains positive and significant. Notice that the difference-GMM results in Column (2) present another misspecification problem. The specification tests for first and second order auto-regression (AR) in the first differences of the error terms show that neither test is rejected at the 5% level. We can assume that the model is well specified if the null hypothesis of no first-order AR in the differences of the error terms is rejected and the second-order AR hypothesis is not. Further, F-statistics (1.7) of weak IV test shows that the instruments are weak.

The system-GMM estimator may be used to address such issues. The system-GMM results are reported in Columns (3) and the findings in both columns are consistent with each other. Unlike in the difference-GMM case, all tests including AR specification tests, weak IV tests, and the Hansen's over identification test confirm that our model is well specified and the instruments are valid. Note that if cross-country panel data have relatively long length of the sample time period, the number of instruments tend to be greater than the number of countries. Bowsher (2002) argues that instrument proliferation vitiates the Hansen test of over-identification, and the test may implausibly return a perfect p-value of 1. Thus, we restrict the maximum lag on instruments to four periods in order to reduce the number of instruments to below or close to the number of countries (see also Roodman (2006, 2009)).

The estimated coefficient on the lagged dependent variable is significantly positive at the 1% level. Its magnitude is 0.967. This magnitude of coefficient, close to 1, implies that the long-term effect of individual regressors on reserves hoarding is about 30 (1/(1-0.967)) times greater than the short-term effect. Many independent

variables are found to be statistically significant in this specification: peg, soft peg dummies and short term external debt/GDP are shown to have a negative effect on reserves to GDP, while trade openness, the terms of trade, M2/GDP and OTC inflows are shown to have positive effects. Peg and soft peg dummies lower the level of reserves. Although this is contrary to our expectations, it is accordance with the previous findings (Lane and Burke 2001, Steiner 2011). An explanation for this finding might be that the precautionary motive—prevalent under flexible exchange rate systems—is associated with a higher demand for the reserves than the intervention motive.

The terms of trade are expected to have a positive effect on reserve accumulation. This implies i) Emerging market policy makers would accumulate reserves to buffer the wealth shock driven by the terms of trade change or ii) The terms of trade improvement, associated with home currency appreciation, would induce central banks to actively purchase foreign reserve assets so that the currency appreciation forces are mitigated. The estimated coefficients on total external debt to GDP and short term debt to GDP are positive and significantly negative respectively, which is consistent with Steiner (2011). This supports the hypothesis that reserves are considered as a means to protect the economy from negative repercussions associated with a sudden stop of foreign capital. A high share of short-term debt in total external debt might be an indication of an evolving crisis (international creditors are reluctant to lend long-term) in previous literature. Therefore, the finding that short-term external debt is negatively associated with reserve level somewhat contradicts precautionary motives for the reserves.

The results also show that new variables, both M2/GDP and OTC capital inflows, are the greatest contributors to this trend; these findings support not only financial stability motive arguments put forth by Obstfeld et al. (2010) but also liquidity motive arguments proposed by Jung and Pyun (2016). In particular, positive coefficient on OTC capital inflows indicates that emerging and developing economies are motivated by a desire for liquidity in their accumulation of reserves. Furthermore, the goodness-of-fit, as measured by the correlation between the actual and the predicted reserves to GDP ratios, increases to 0.908. In sum, the main results in Column (3) of Table 2 suggest that the key driving forces behind the recent surge in foreign exchange reserves are precautionary motives and reserves' role as an effective form of aggregate liquidity.

In Column (4), we implement different identification for the system-GMM to check whether our baseline estimation in Column (3) is sensitive to the selection of instruments. We now include our endogenous variables—trade openness, the terms of trade, and OTC inflows as a weakly exogenous variable. The results in Column (3) echo our main findings. Especially, the coefficient on currency crises turns out to be significant. The positive influence of currency crises on reserves to GDP makes sense as emerging economies are vulnerable to external shocks and would voluntarily accumulate reserves in order reduce their exposure to risk (precautionary motives).

Total external debt and short-term debt data from WDI are not available for

major emerging market countries that hoard international reserves such as Korea, Singapore, Hong Kong, Russia, and Saudi Arabia. Thus, Column (5) excludes total external debt to GDP and short term debt to GDP variables to cover more broad set of countries (up to 70 countries). Again, the results in Column (5) are consistent with our main results in Column (3).

**[Insert Table 1]**

### 4.2 Robustness Check

In this section, we reinforce the robustness of our results by re-estimating our preferred system-GMM specification (Column (3) of Table 2) with different sub-samples and alternative measures for external debt, financial and trade openness. In Columns (1)–(3) of Table 2, we report the results of the specifications that include alternative measures of external debt to GDP (Lane and Milesi-Feretti, 2007), financial openness (the Chinn-Ito index) and trade openness (imports over GDP). In Column (4), we exclude the period of the global financial crisis from the sample, and in Column (5), we focus on the period after 1999 in order to test whether any specific time period may be influencing our results.

The coefficients on the lagged reserves to GDP are significant and positive in Table 2. Certainly, this result shows that many emerging and developing countries' international reserves grew in a highly persistent manner, which emphasizes the validity of dynamic panel framework. The results in Table 2 again provide empirical evidence that precautionary, financial stability and liquidity motives drive reserves accumulation as is in previous studies. Trade openness and the terms of trade have positive effects on reserves to GDP in column (2). M2/GDP shows positive signs in all columns but become insignificant in columns (1) and (3). Total external debt to GDP and short-term debt to GDP show positive and negative signs respectively but their coefficients become insignificant in some specifications. Interestingly, OTC capital inflows are significant and positive in all columns in Table 2.

Table 3 provides various estimation methods of dynamic panels to strengthen robustness of the results. First, we introduce the QML estimation of dynamic panel models proposed by Hayakawa and Pesaran (2015), which extends the transformed maximum likelihood approach for estimation of dynamic panel to the case where the errors are cross-sectionally heteroskedastic. Note that QML fails to retrieve the results for our baseline dynamic specification in (1) owing to the failure of convergence of maximum likelihood function, so we report valid results from a sub-sample for 1990~2006 before the global financial crisis for the expanded sample. In addition, columns (2)-(4) use first-difference maximum likelihood (FDML) in dynamic panel in case of panel unit roots (Han and Phillips, 2010). Column (2) shows the results for the expanded sample of 70 countries. Column (3) includes debt variables and column (4) contains sub-sample analysis for countries with a large amount of reserves hoarding, in particular, East Asia, Latin America and Middle East & Africa countries. Overall, the results are consistent with our main results in Table 1.

**[Insert Table 2]**

**[Insert Table 3]**

### 4.3 Out-of-sample analysis

This section focuses on model fit and quantitative significance associated with the out-of-sample prediction. We estimate the pooled OLS, fixed effect, and baseline system-GMM models with data from 1990 to 2001. The estimates are then used to forecast the reserves to GDP ratios through 2011.

Table 4 reports the root-mean-squared-errors (RMSE) of the three models' predicted values for different time horizons over the 2001–2011 period. This statistic is our principle means of comparing the prediction power of the three models,

$$RMSE = \left\{ \sum_{s=0}^{N_k-1} \frac{\left(F(t+s+k) - A(t+s+k)\right)^2}{N_k} \right\}^{1/2} \tag{3}$$

where the forecast begins at $t$=2001, and $k$=1, 3, 6, 10 denotes the forecast horizon. $N_k$ is the total number of forecasts in the projection period when the actual reserves to GDP ratio, $A(t)$, is known and $F(t)$ is the forecasted value of reserves to GDP. A lower RMSE indicates that the model had fewer prediction errors. At all horizons, the system-GMM model produces the most accurate predictions with the lowest RMSE, while pooled OLS has the greatest RMSE.

**[Insert Table 4]**

Figure 1 compares the three models' out-of-sample predictions for a selection of 10 important reserve holders. From the graph of the actual reserves to GDP ratios against the out-of-sample predictions, one can see that the dynamic panel model's specification outperforms the other two models. In fact, it not only predicts the magnitude of the ratios more effectively, it also predicts their movements better than the other two models. It should be noted that reserves accumulation in these countries over the last decade is in no way inexplicable. In fact, the actual reserves/GDP for many countries are quite close to the system-GMM specification's predictions. Interestingly, China, Korea, Hong-Kong, and Singapore, who in many studies have been identified as excessive reserves hoarders, (Jeanne and Ranciere, 2011; Obstfeld et al., 2010) are shown to be under-savers in 2011 according to this model's specification. Chinese and Russian reserves accumulation before the global financial crisis is still greater than what the model would predict, though. Yet, as Obstfeld et al. (2010) suggest, China's reserves holdings (the greatest in the world) may be affected by a variety of other factors. Note that China may require a great deal more international reserves to recapitalize domestic banks and, the large number of Chinese non-performing bank loans may require greater holdings as well.

**[Insert Figure 1]**

## 5 Conclusion

The phenomenal build-up of reserves in emerging economies (especially in China) has attracted a great deal of scrutiny and study. Consequently, the century old international macro theory of central bank determined reserves was revived. Among the topics addressed in the recent literature, the question of whether the determinants of international reserves change over time has drawn a great deal of attention. This is because it is widely believed that only the traditional determinants, such as the short-term debt to GDP ratios or trade openness, cannot explain the recent rapid accumulation of reserves. In response, many pundits and scholars have proposed a variety of new factors to explain this surge in demand. Obstfeld et al. (2010), for instance, argue that the central bank will be more concerned with an internal-external drain on credits, and will hold more reserves as financial depth and openness increase. Subsequent research by Jung and Pyun (2016) emphasize the role of the international reserves in facilitating foreign capital inflows, especially through OTC markets.

We empirically test both these new factors and the traditional determinants using dynamic panel model specifications. This approach allows us to dissect the dynamics of international reserves. We also conduct an out-of-sample analysis in order to shed new light on the current reserves adequacy debate. The results of our empirical investigation confirm the traditional determinants for the reserves that previous studies specified, including M2/GDP and OTC foreign capital inflows, significantly influence cross-country variations in the reserves. More importantly, the dynamic panel specification appears to most accurately predict reserve accumulation.

Our findings have important implications for the study of reserves accumulation. First, they indicate that more nuanced theories regarding precautionary motives are needed; for instance, a model of reserves demand may need to be developed in which the openness in financial markets does not directly determine reserves accumulation (though frictions in the financial market that react to currency crises would need to be included as they would fundamentally alter the demand for reserves). Note that there is growing literature that distinguishes different insurance motives of the precautionary approach including Obstfeld et al. (2010). Cheng (2015) shows the insurance effect of public assets (the reserves) to mitigate private risks (private foreign liabilities), for example, through the prism of balance sheet effects. Bianchi et al. (2014) explain the accumulation of international reserves as a hedge against roll-over risk because keeping reserves allows the government to have liquid assets available in states of the crisis.

Both academics and policy makers may draw important implications from our findings. First, the influence of OTC foreign capital inflows on changes in reserves demonstrates that using a frictionless Walrasian model for the theory of recent reserves accumulation would incur a certain loss of generality. Second, international capital market risks should also be taken into account in such a way that fundamental

market risk aversion would interact with crisis, more so than mere varying degrees of financial stability or openness. Lastly, our out-of-sample results imply that policy makers should carefully consider highly persistent reserves dynamics when engaging in debates over reserve adequacy or forecasting changes in reserves.

## References


**Aizenman, Joshua and Jaewoo Lee.** 2012. "International Reserves: Precautionary versus Mercantilist Views, Theory and Evidence." *Open Economies Review*, 18(2), 191-214.

**Alonso-Borrego, César, and Manuel Arellano.** 1996. "Symmetrically Normalised Instrumental-Variable Estimation Using Panel Data. *Journal of Business and Economic Statistics*, 17, 36–49.

**Arellano, Manuel, and Stephen Bond.** 1991. "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations." *Review of Economic Studies*, 58, 277–297.

**Arellano, Manuel, and Olympia Bover.** 1995. "Another Look at the Instrumental-Variable Estimation of Error-Components Models." *Journal of Econometrics*, 68, 29–51.

**Bastourre, Diego, Jorge Carrera, and Javier Ibarlucia.** 2009. "What is Driving Reserve Accumulation? A Dynamic Panel Data Approach." *Review of International Economics*, 17: 861–877.

**Bazzi, Samuel, and Michael A. Clemens.** 2013, "Blunt instruments: avoiding common pitfalls in identifying the causes of economic growth." *American Economic Journal: Macroeconomics* 5(2), 152–186.

**Bianchi, Javier, Juan Carlos Hatchondo, and Leonardo Martinez.** 2012. "International reserves and rollover risk." National Bureau of Economic Research, (No. w18628).

**Blundell, Richard, and Stephen Bond.** 1998. "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models." *Journal of Econometrics*, 87, 115–143.

**Bowsher, Clive G.** 2002. "On Testing Overidentifying Restrictions in Dynamic Panel Data Models." *Economic Letters*, 77, 211–220.

**Cheng, Gong.** 2015. "Balance sheet effects, foreign reserves and public policies." *Journal of International Money and Finance*, *59*, 146-165.

**Cheung, Yin-Wong, and Hiro Ito.** 2009, "A Cross-Country Empirical Analysis of International Reserves." *International Economic Journal*, 23, 447-481.

**Chinn, Menzie D., and Hiro Ito.** 2008. "A New Measure of Financial Openness." *Journal of Comparative Policy Analysis,* 10(3), 309–322.

**Dooley, Michael, David Folkerts-Landau, and Peter Garber.** 2007. "Direct Investment, Rising Real Wand the Absorption of Excess Labor in the Periphery." In *G7 Current account imbalances: sustainability and adjustment* (pp. 103–132). University of Chicago Press.

**Duffie, Darrell, Nicolae Gârleanu, and Lasse Heje Pedersen.** 2005. "Over-the-

Counter Markets." *Econometrica*, 73(6), 1815–1847.

**Goldberg, Linda S.** 2007. "Financial Sector FDI and Host Countries: New and Old Lessons." *Economic Policy Review*, 13(1).

**Han, Chirok and Peter C.B. Phillips.** 2010. "GMM Estimation for Dynamic Panels with Fixed Effects and Strong at Unity." *Econometric Theory*, 26; 119-51.

**Hayakawa, Kazuhiko., and Pesaran, M. Hashem.** 2015. "Robust standard errors in transformed likelihood estimation of dynamic panel data models with cross-sectional heteroskedasticity." *Journal of Econometrics*, *188*(1), 111-134.

**Im, K. S., Hashem. Pesaran, and Y. Shin.** 2003. "Testing for unit roots in heterogeneous panels." *Journal of Econometrics* 115: 53-74.

**Jeanne, Olivier, and Romain Rancière.** 2011. "The Optimal Level of International Reserves for Emerging Market Countries: a New Formula and Some Applications." *Economic Journal*, 121(555), 905–930

**Jung, Kuk Mo and Ju H. Pyun.** 2016. "International reserves for emerging economies: A liquidity approach." *Journal of International Money and Finance*, *68*, 230-257.

**Kripfganz, S.** 2016. "Quasi-maximum likelihood estimation of linear dynamic short-T panel-data models." *Stata Journal* 16: 1013-1038.

**Lane, Philip R., and Dominic Burke.** 2001. "The empirics of foreign reserves." *Open Economies Review* 12, 423–434

**Lane, Philip R., and Gian Maria Milesi-Ferretti.** 2007. "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004." *Journal of International Economics*, 73(2), 223–250

**Laeven, Luc, and Fabian Valencia.** 2012. "Systemic Banking Crises Database: An Update." IMF Working Papers 12/163, International Monetary Fund.

**Nickell, Stephen.** 1981. "Biases in Dynamic Models with Fixed Effects." *Econometrica*, 49, 1417–1426.

**Obstfeld, Maurice, Jay C. Shambaugh, and Alan M. Taylor.** 2010. "Financial Stability, the Trilemma, and International Reserves." *American Economic Journal: Macroeconomics*, 2, 57–94.

**Pesaran, M. Hashem.** 2004. "General diagnostic tests for cross section dependence in panels." University of Cambridge, Faculty of Economics, Cambridge Working Papers in Economics No. 0435.

**Pina, Goncalo.** 2015. **"**The Recent Growth of International Reserves in Developing Economies: A Monetary Perspective." *Journal of International Money and Finance,* 58, 172-190.

**Qian, Xingwang, and Andreas Steiner.** 2014. "International Reserves and the Composition of Foreign Equity Investment." *Review of International Economics*, 22(2), 379–409.

**Roodman, David.** 2006. "How to Do Xtabond2: An Introduction to "Difference" and "System" GMM in Stata." Center for Global Development Working Paper No. 103.

**Roodman, David.** 2009. A Note on the Theme of Too Many Instruments. *Oxford Bulletin of Economic and Statistics*, 71, 135–158.

**Steiner, Andreas.** 2011. "Do Dynamics and Heterogeneity in Panel Data Models Matter?" *Empirical Economics* 40, 1:165-176.

**Thornton, Henry.** [1802] 1939. "An Enquiry into the Nature and Effects of the Paper Credit of Great Britain." Edited with an introduction by F. A. von Hayek. London, George Allen and Unwin.

## Table 1. Dynamic Panel Model for Reserves/GDP

| Dependent variable: Reserves to GDP | | | | | |
|---|---|---|---|---|---|
| | Fixed Effects model | Difference-GMM | System-GMM | System-GMM (Alternative identification) | System-GMM (Expanded sample) |
| | (1) | (2) | (3) | (4) | (5) |
| Lagged Reserves/GDP | 0.7194*** | 0.3946** | 0.9667*** | 0.9091*** | 0.9888*** |
| | (0.0431) | (0.1779) | (0.0387) | (0.0414) | (0.0403) |
| Population (billions) | 0.1288 | 0.0360 | 0.0175** | 0.0016 | 0.0079 |
| | (0.1183) | (0.4913) | (0.0069) | (0.0054) | (0.0122) |
| GDP Per Capita (thousands) | -0.0012 | -0.0032 | -0.0012 | -0.0011*** | -0.0004 |
| | (0.0015) | (0.0031) | (0.0007) | (0.0004) | (0.0003) |
| Trade/GDP | 0.0181 | 0.0656 | 0.0581*** | 0.0017 | 0.0161 |
| | (0.0153) | (0.0609) | (0.0224) | (0.0037) | (0.0176) |
| Terms of Trade | -0.0000 | -0.0007 | 0.0003** | 0.0001** | 0.0002 |
| | (0.0001) | (0.0006) | (0.0001) | (0.0001) | (0.0001) |
| Exchange Rate Volatility | -0.0482 | -0.0249 | -0.0882 | -0.0311 | -0.0262 |
| | (0.0398) | (0.0240) | (0.0692) | (0.0536) | (0.0672) |
| Peg | 0.0008 | 0.0056 | -0.0131** | -0.0071** | -0.0048 |
| | (0.0047) | (0.0046) | (0.0056) | (0.0035) | (0.0043) |
| Soft Peg | -0.0048 | -0.0006 | -0.0080** | -0.0047* | -0.0026 |
| | (0.0053) | (0.0034) | (0.0033) | (0.0028) | (0.0039) |
| *De facto* Financial Openness | 0.0246*** | 0.0550*** | -0.0042 | 0.0091 | -0.0009 |
| | (0.0087) | (0.0182) | (0.0115) | (0.0070) | (0.0014) |
| M2/GDP | 0.0080 | -0.0498 | 0.0240** | 0.0254** | 0.0121 |
| | (0.0284) | (0.0687) | (0.0122) | (0.0109) | (0.0149) |
| Total external debt/GDP | -0.0235* | -0.0177 | 0.0135 | 0.0019 | -- |
| | (0.0138) | (0.0272) | (0.0140) | (0.0100) | |
| Short term external debt/GDP | 0.0029 | -0.0009 | -0.0763** | -0.0160 | -- |
| | (0.0284) | (0.0312) | (0.0381) | (0.0150) | |
| OTC Capital Inflows/GDP | 0.0340 | 0.0886 | 0.1056** | 0.0986** | 0.0826** |
| | (0.0452) | (0.0606) | (0.0501) | (0.0446) | (0.0408) |
| Currency Crisis | 0.0115 | 0.0028 | 0.0159 | 0.0233* | 0.0090 |
| | (0.0101) | (0.0058) | (0.0104) | (0.0125) | (0.0117) |
| Banking Crisis | 0.0032 | -0.0031 | -0.0003 | 0.0001 | -0.0011 |
| | (0.0052) | (0.0039) | (0.0042) | (0.0049) | (0.0034) |
| Debt crisis | -0.0066 | 0.0007 | -0.0051 | -0.0044 | 0.0014 |
| | (0.0062) | (0.0071) | (0.0094) | (0.0085) | (0.0070) |
| AR(1) test (p-value) | | 0.06 | 0.000 | 0.000 | 0.000 |
| AR(2) test (p-value) | | 0.362 | 0.722 | 0.715 | 0.232 |
| Number of Instruments¶ | | 60 | 49 | 39 | 60 |
| Weak IV test (F-statistics) | | 1.7 | 9.6 | 18.1 | 17.9 |
| Hansen test over ID (p-value) | | 0.999 | 0.566 | 0.862 | 0.360 |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes |
| Observations | 953 | 900 | 953 | 953 | 1309 |
| Number of Countries | 51 | 51 | 51 | 51 | 70 |
| Corr $(y, \hat{y})$ ^2 | 0.941 | 0.568 | 0.908 | 0.925 | 0.947 |

Note: Two-step system GMM estimators are reported. Clustered robust standard errors in parentheses, * significant at 10%, ** significant at 5%, *** significant at 1%

¶ We restrict maximum instruments lags (lagged reserves to GDP ratio, trade openness, the terms of trade, OTC capital inflows) to four periods and use the "collapse" command to avoid an excess of instruments (Roodman, 2009).

## Table 2. Robustness Tests I with system GMM

| Dependent variable: Reserves to GDP | | | | | |
|---|---|---|---|---|---|
| | Alternative External Debt measure | Alternative Financial Openness (Chinn-Ito) | Alternative Trade Openness (IM/GDP) | Excluding the Global Financial Crisis | Sub-Sample 1999–2006 |
| | (1) | (2) | (3) | (4) | (5) |
| Lagged Reserves/GDP | 0.9876*** | 0.9609*** | 0.9733*** | 0.9407*** | 0.8681*** |
| | (0.0500) | (0.0304) | (0.0396) | (0.0802) | (0.1067) |
| Population (billions) | 0.0126 | 0.0165** | 0.0084 | 0.0186* | 0.0064 |
| | (0.0132) | (0.0074) | (0.0093) | (0.0112) | (0.0112) |
| GDP Per Capita (thousands) | -0.0004 | -0.0014* | -0.0010* | -0.0004 | -0.0009 |
| | (0.0003) | (0.0008) | (0.0006) | (0.0014) | (0.0009) |
| Trade/GDP | 0.0274 | 0.0533*** | 0.0212 | 0.0408 | 0.0084 |
| | (0.0211) | (0.0181) | (0.0397) | (0.0252) | (0.0230) |
| Terms of Trade | 0.0002 | 0.0003** | 0.0002* | 0.0002 | 0.0003 |
| | (0.0001) | (0.0001) | (0.0001) | (0.0002) | (0.0003) |
| Exchange Rate Volatility | -0.0397 | -0.0898 | -0.0653 | -0.0266 | 0.0244 |
| | (0.0844) | (0.0699) | (0.0704) | (0.0781) | (0.0925) |
| Peg | -0.0060 | -0.0131** | -0.0079* | -0.0073 | -0.0041 |
| | (0.0049) | (0.0056) | (0.0045) | (0.0055) | (0.0080) |
| Soft Peg | -0.0042 | -0.0075** | -0.0054* | -0.0034 | -0.0040 |
| | (0.0039) | (0.0031) | (0.0032) | (0.0037) | (0.0047) |
| *De facto* Financial Openness | -0.0033 | -0.0005 | 0.0044 | -0.0124 | -0.0017 |
| | (0.0061) | (0.0015) | (0.0080) | (0.0090) | (0.0081) |
| M2/GDP | 0.0116 | 0.0232** | 0.0125 | 0.0231* | 0.0406** |
| | (0.0136) | (0.0114) | (0.0084) | (0.0138) | (0.0185) |
| Total external debt/GDP | 0.0045 | 0.0085 | 0.0046 | 0.0218* | 0.0207 |
| | (0.0110) | (0.0057) | (0.0110) | (0.0120) | (0.0152) |
| Short term external debt/GDP | -- | -0.0686* | -0.0228 | -0.0390 | 0.0110 |
| | | (0.0352) | (0.0357) | (0.0369) | (0.0498) |
| OTC Capital Inflows/GDP | 0.0736* | 0.1124** | 0.1143* | 0.2213* | 0.1768* |
| | (0.0403) | (0.0480) | (0.0603) | (0.1259) | (0.0960) |
| Currency Crisis | 0.0121 | 0.0160 | 0.0168 | 0.0241* | 0.0114 |
| | (0.0145) | (0.0111) | (0.0111) | (0.0125) | (0.0145) |
| Banking Crisis | 0.0011 | -0.0000 | 0.0016 | -0.0063 | -0.0084 |
| | (0.0047) | (0.0045) | (0.0037) | (0.0047) | (0.0102) |
| Debt crisis | 0.0016 | -0.0060 | -0.0086 | 0.0036 | -0.0072 |
| | (0.0087) | (0.0092) | (0.0072) | (0.0101) | (0.0129) |
| AR(1) test in first diff. (p-value) | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| AR(2) test in first diff. (p-value) | 0.233 | 0.648 | 0.742 | 0.642 | 0.530 |
| Number of Instruments¶ | 52 | 49 | 49 | 41 | 32 |
| Weak IV test (F-statistics) | 8.7 | 4.8 | 10.7 | 6.1 | 0.8 |
| Hansen test of over ID (p-value) | 0.149 | 0.543 | 0.541 | 0.272 | 0.05 |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes |
| Observations | 1,282 | 939 | 953 | 707 | 391 |
| Number of Countries | 70 | 51 | 51 | 51 | 51 |
| Corr $(y, \hat{y})$^2 | 0.945 | 0.910 | 0.924 | 0.902 | 0.9 |

Note: Two-step system GMM estimators are reported. Clustered robust standard errors are in parentheses, * significant at 10%, ** significant at 5%, *** significant at 1%. ¶ We restrict the maximum instruments lag (lagged reserve to GDP ratio, trade openness, the terms of trade OTC capital inflows) to four periods and use the "collapse" command to avoid an excess of instruments (Roodman, 2009).

## Table 3. Robustness Tests II

| Dependent variable: Reserves to GDP | | | | |
|---|---|---|---|---|
| Estimation methods | QML: Hayakawa & Pesaran (2015) | FDML: Han and Philips (2010) | | |
| | Sub-sample 1990~2006 | Full sample | w/ external debt variables | Sub-sample (East Asia, Latin America, Middle East & Africa) |
| | (1) | (2) | (3) | (4) |
| Lagged Reserves/GDP | 0.8304*** | 1.1893*** | 1.0506*** | 1.1428*** |
| | (0.0803) | (0.1117) | (0.0891) | (0.1112) |
| Population (billions) | 0.3106* | 0.0541 | -0.3212 | -0.0088 |
| | (0.1644) | (0.3739) | (0.9109) | (0.7077) |
| GDP Per Capita (thousands) | -0.0020*** | -0.0055*** | -0.0088** | -0.0049 |
| | (0.0006) | (0.0013) | (0.0039) | (0.0052) |
| Trade/GDP | 0.0173* | 0.0294** | 0.0282** | 0.0507** |
| | (0.0103) | (0.0125) | (0.0143) | (0.0217) |
| Terms of Trade | 0.0003* | 0.0002* | 0.0001 | -0.0001 |
| | (0.0002) | (0.0001) | (0.0001) | (0.0002) |
| Exchange Rate Volatility | -0.0514 | -0.0118 | -0.0040 | -0.0125 |
| | (0.0499) | (0.0128) | (0.0121) | (0.0140) |
| Peg | -0.0040 | 0.0172*** | 0.0157*** | 0.0203*** |
| | (0.0058) | (0.0056) | (0.0053) | (0.0074) |
| Soft Peg | -0.0017 | 0.0070* | 0.0063* | 0.0119** |
| | (0.0034) | (0.0036) | (0.0037) | (0.0051) |
| *De facto* Financial Openness | 0.0029* | 0.0073*** | 0.0632*** | 0.0589*** |
| | (0.0016) | (0.0013) | (0.0082) | (0.0100) |
| M2/GDP | 0.0081 | 0.1145*** | 0.0340 | 0.1040*** |
| | (0.0257) | (0.0252) | (0.0289) | (0.0360) |
| Total external debt/GDP | -- | -- | -0.0560*** | -0.0600*** |
| | | | (0.0137) | (0.0164) |
| Short term external debt/GDP | -- | -- | 0.0059 | 0.0354 |
| | | | (0.0402) | (0.0536) |
| OTC Capital Inflows/GDP | 0.0960** | 0.0430* | 0.0261 | 0.0933* |
| | (0.0484) | (0.0245) | (0.0284) | (0.0524) |
| Currency Crisis | -- | 0.0027 | -0.0007 | 0.0025 |
| | | (0.0048) | (0.0046) | (0.0060) |
| Banking Crisis | -- | -0.0062 | -0.0025 | -0.0018 |
| | | (0.0045) | (0.0047) | (0.0059) |
| Debt crisis | -- | -0.0053 | -0.0012 | -0.0036 |
| | | (0.0066) | (0.0069) | (0.0079) |
| Year fixed effects | Yes | Yes | Yes | Yes |
| Observations | 909 | 1309 | 953 | 590 |
| Number of Countries | 66 | 70 | 51 | 30 |
| R-square | | 0.956 | 0.957 | 0.939 |

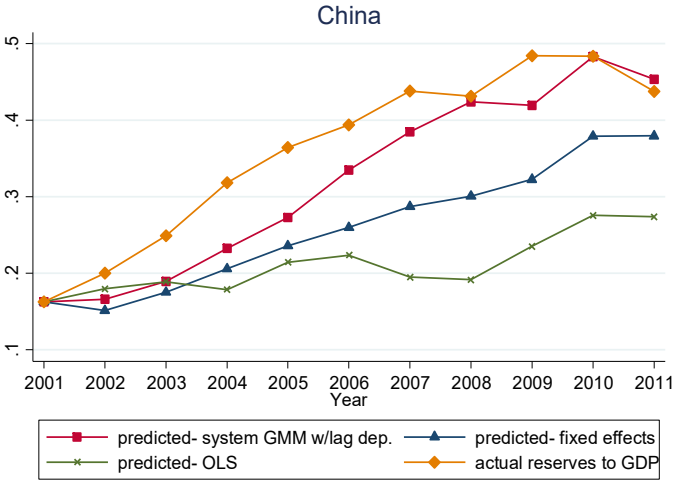
Note: Robust standard errors are in parentheses, * significant at 10%, ** significant at 5%, *** significant at 1%. Kripfganz's (2016) code is used for Hayakawa and Pesaran (2015).

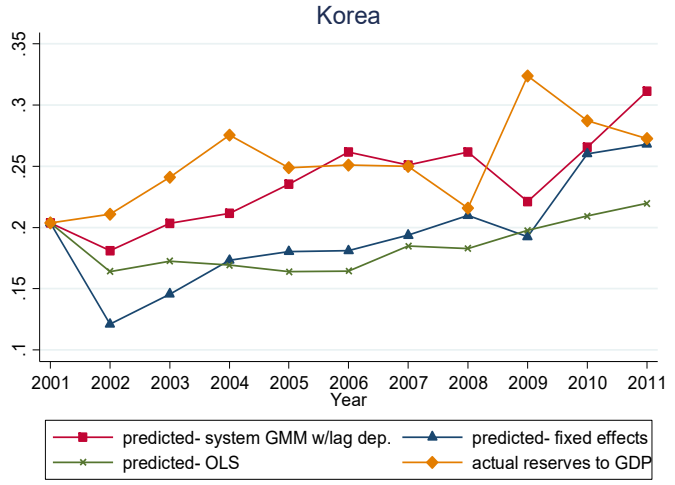
**Table 4. Out-of-Sample Analysis: Comparing Three Models**

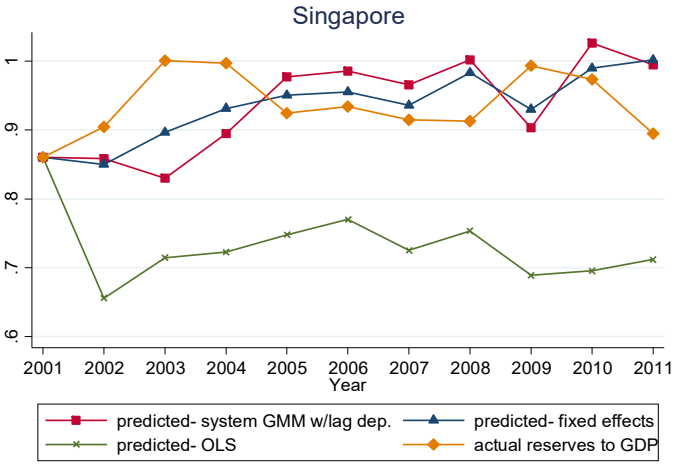
| | RMSE (Root-Mean-Squared-Error) | | | |
|---|---|---|---|---|
| | Horizon | | | |
| Model | 1 | 3 | 6 | 10 |
| OLS | 6.77 | 7.48 | 8.89 | 10.99 |
| Fixed Effects | 3.18 | 3.75 | 4.68 | 6.40 |
| Dynamic panel | 3.07 | 3.39 | 3.51 | 3.8 |

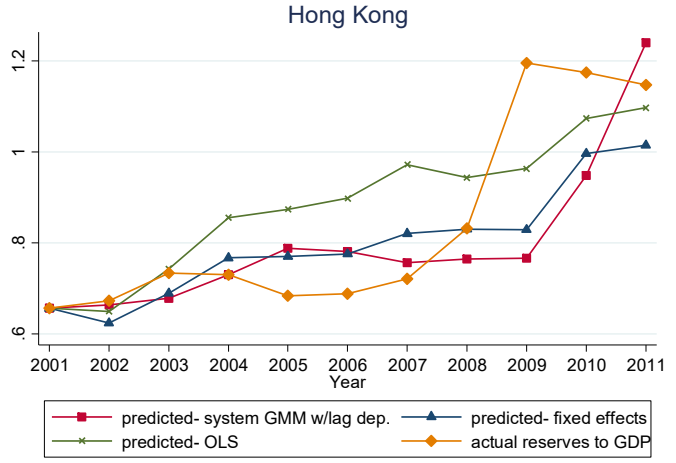
Note: RMSE are reported in terms of percentages. Forecasts are compared from 2002 to 2011

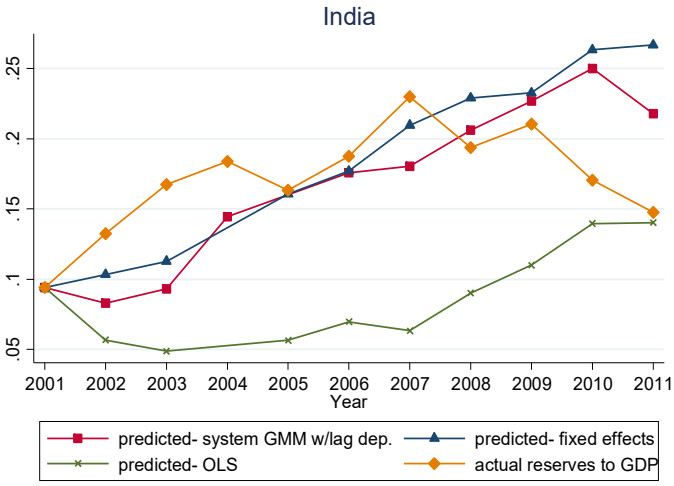
**Figure 1. Out-of-Sample Prediction Over Time: 10 Selected Countries**

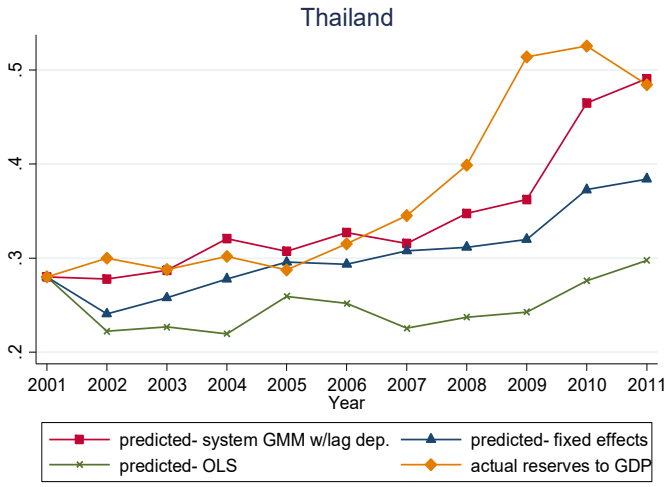


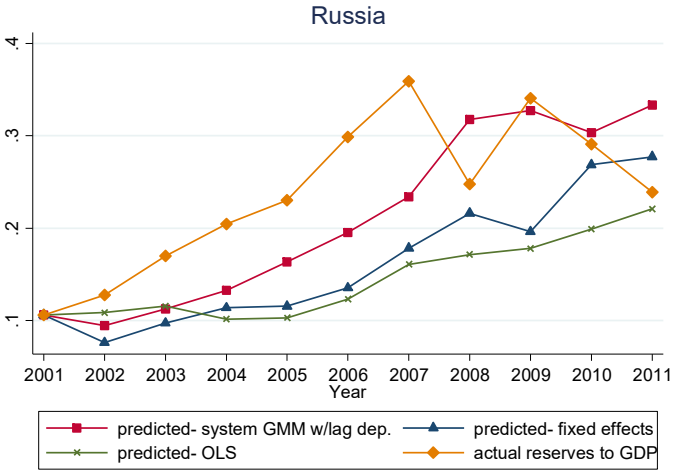



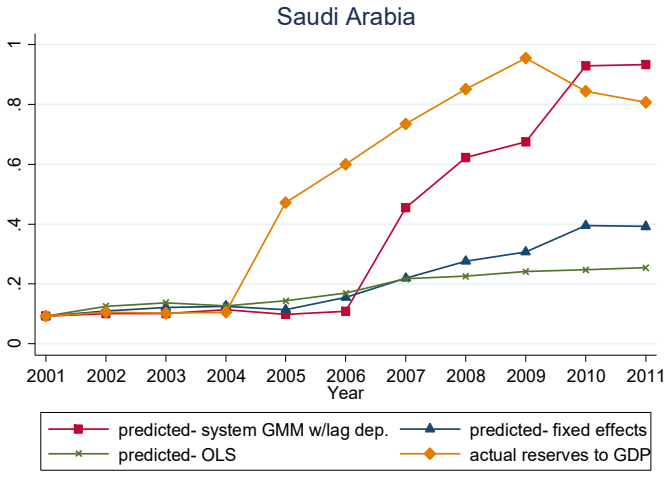

Singapore
1
.9
.8
.7
.6
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
predicted- system GMM w/lag dep.
predicted- fixed effects
predicted- OLS
actual reserves to GDP

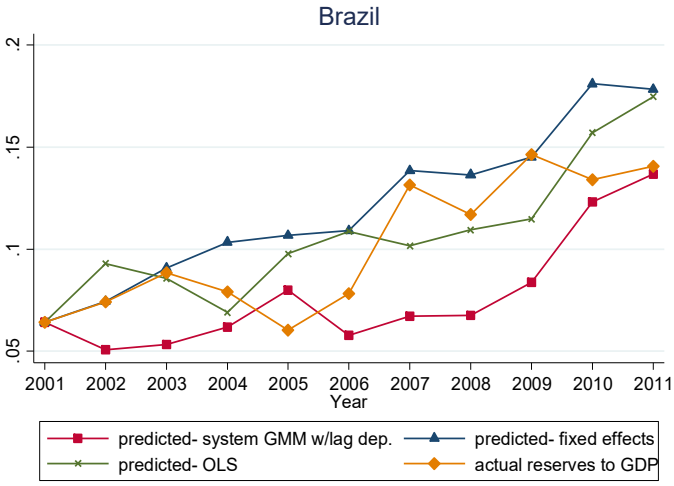

Hong Kong
1.2
1
.8
.6
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
predicted- system GMM w/lag dep.
predicted- fixed effects
predicted- OLS
actual reserves to GDP

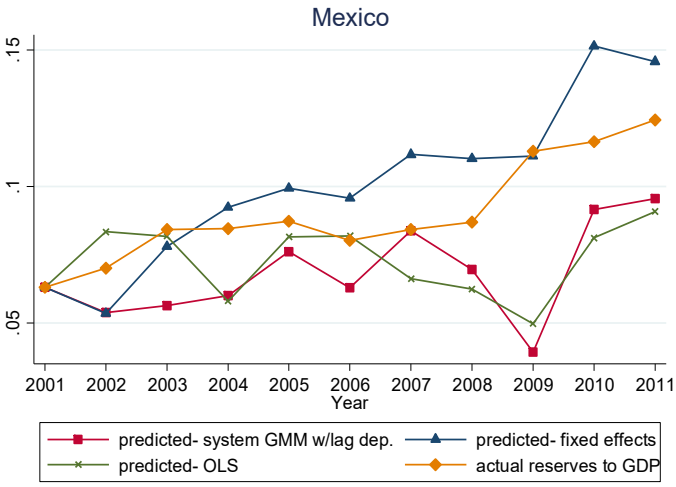

India
.05
.1
.15
.2
.25
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
predicted- system GMM w/lag dep.
predicted- fixed effects
predicted- OLS
actual reserves to GDP


Thailand
.2
.3
.4
.5
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
predicted- system GMM w/lag dep.
predicted- fixed effects
predicted- OLS
actual reserves to GDP


Russia
.1
.2
.3
.4
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
predicted- system GMM w/lag dep.
predicted- fixed effects
predicted- OLS
actual reserves to GDP


Saudi Arabia
0
.2
.4
.6
.8
1
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
predicted- system GMM w/lag dep.
predicted- fixed effects
predicted- OLS
actual reserves to GDP




Note: Total external debt and short-term debt data in WDI are not available for Korea, Singapore, Hong Kong, Russia, Saudi Arabia. Thus, total foreign debt liability variable from Lane and Milesi-Ferretti (2007) is included to derive out-of-sample forecasts for these countries.

**Appendix Table 1. List of 51 (70) Countries in the Sample**

*Asia (20)*

*East*
Cambodia
China, P.R.: Mainland
China: Hong Kong*
Indonesia
Korea, Rep.*
Lao People's Dem. Rep.
Malaysia
Philippines
Singapore*
Thailand
Vietnam

*South*
Bangladesh
India
Nepal
Pakistan
Sri Lanka

*Central*
Kazakhstan
Kyrgyz Republic
Mongolia
Tajikistan

*Middle East & Africa (13)*
Algeria
Bahrain*
Jordan
Egypt
Israel*
Kuwait*
Lebanon
Morocco
Oman*
Saudi Arabia*
South Africa
Tunisia
Turkey

*Latin America (16)*
Bolivia
Brazil
Chile
Colombia
Costa Rica
Dominican Republic
El Salvador
Guatemala
Honduras
Mexico
Nicaragua
Panama
Paraguay
Peru
Uruguay*
Venezuela, Rep. Bol.

*Caucasus & Eastern Europe (21)*

*Caucasus*
Azerbaijan
Armenia
Georgia
Russia*

*Eastern Europe*
Albania
Belarus
Bosnia and Herzegovina
Bulgaria
Czech Republic*
Croatia*
Estonia*
Hungary
Latvia*
Lithuania*
Macedonia
Moldova
Poland*
Romania
Slovak Republic*
Slovenia*
Ukraine

Note: * indicates countries that are included in the 70 expanded sample

**Appendix Table 2. Definitions and Sources for Regressors**

| Regressors | Definitions | Sources |
|---|---|---|
| Population | Population (billions) | World Development Indicator (WDI) |
| GDP Per Capita | GDP per capita (PPP converted, to current international dollars, thousands) | WDI |
| Trade/GDP | a ratio of total trade (export+import) to GDP | WDI |
| Terms of Trade | the terms of trade in goods and services | World Economic Outlook (WEO), IMF |
| Exchange Rate Volatility | annual standard deviation in monthly exchange rate changes | International Financial Statistics (IFS), IMF |
| Peg | a pegged exchange rate dummy (https://www2.gwu.edu/~iiep/about/faculty/jshambaugh/data.cfm) | Shambaugh (2004) and Obstfeld et al. (2010) |
| Soft peg | a soft-peg exchange rate dummy (https://www2.gwu.edu/~iiep/about/faculty/jshambaugh/data.cfm) | Shambaugh (2004) and Obstfeld et al. (2010) |
| Financial Openness | Lane and Milesi-Ferretti's *de facto* measure (http://www.philiplane.org/EWN.html) and Chinn-Ito's *de jure* measure (http://web.pdx.edu/~ito/Chinn-Ito_website.htm) | Lane and Milesi-Ferretti (2007) Chinn and Ito (2008) |
| M2/GDP | a ratio of M2 to GDP | WDI and the OECD economic outlook |
| External Debt to GDP | a ratio of total external debt to GDP or debt liabilities stock to GDP | WDI & Lane and Milesi-Ferretti (2007) |
| Short-term Debt to GDP | a ratio of short term external debt to GDP | WDI |
| Decentralized Capital Flows | (Debt liabilities + FDI liabilities)/GDP | IFS |
| Currency Crisis | a currency crisis dummy at t | Laeven and Valencia (2012) |
| Banking Crisis | a banking crisis dummy at t | Laeven and Valencia (2012) |
| Debt Crisis | a debt crisis dummy at t | Laeven and Valencia (2012) |

**Appendix Table 3. Summary Statistics**

| Variables | Obs. | Mean | Standard deviation | Min. | Max. | Corr. w/ Reserves/ GDP |
|---|---|---|---|---|---|---|
| Reserves/GDP | 970 | 0.153 | 0.125 | 0.002 | 1.083 | 1 |
| Population (billions) | 970 | 0.086 | 0.237 | 0.002 | 1.344 | 0.0202 |
| GDP Per Capita (thousands) | 970 | 6.260 | 4.067 | 0.691 | 22.413 | 0.3692 |
| Trade/GDP | 970 | 0.790 | 0.384 | 0.149 | 2.204 | 0.3468 |
| Terms of Trade | 970 | 103.393 | 22.988 | 46.600 | 259.514 | 0.1915 |
| Exchange Rate Volatility | 970 | 0.027 | 0.089 | 0 | 1.944 | -0.0895 |
| Peg | 970 | 0.265 | 0.442 | 0 | 1 | 0.241 |
| Soft peg | 970 | 0.354 | 0.478 | 0 | 1 | -0.0684 |
| Financial Openness (Lane-Milesi-Ferretti, 2007) | 970 | 1.261 | 1.024 | 0.225 | 21.695 | 0.3362 |
| M2/GDP | 970 | 0.473 | 0.335 | 0.065 | 2.284 | 0.644 |
| Total external debt to GDP | 970 | 0.543 | 0.743 | 0.030 | 20.837 | 0.0416 |
| Short term external debt to GDP | 970 | 0.079 | 0.170 | 0 | 4.695 | 0.1344 |
| Decentralized Capital Inflows/ GDP | 970 | 0.042 | 0.055 | -0.158 | 0.560 | 0.2114 |
| Currency Crisis | 970 | 0.031 | 0.173 | 0 | 1 | -0.0745 |
| Banking Crisis | 970 | 0.096 | 0.295 | 0 | 1 | -0.0471 |
| Debt crisis | 970 | 0.067 | 0.250 | 0 | 1 | -0.1443 |