Why Countries Accumulate Foreign Reserves? A Dynamic Panel Approach

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Abstract

Foreign reserves accumulation is a widespread phenomenon in recent years, particularly among emerging economies. Using a panel of 139 countries for the period 1973-2003, we demonstrate the need of using both a dynamic specification of demand reserves and the GMM-System estimator. These improvements change results found by previous studies on reserves determinants. Opportunity cost, exchange rate regime and both trade and financial volatility are no longer statistically significant. Openness, regional imitation, persistence, a U-shaped relationship between reserves and development and the global financial deregulation are the factors driving reserve hoarding. Results suggest that financial openness and economic development are more important determinants than exchange rate flexibility in order to explain recent reserves accumulation.

Resumen

La acumulación de reservas internacionales es en los años recientes un fenómeno generalizado, especialmente entre las economías emergentes. Usando un panel de 139 países para el período 1973-2003, demostramos la necesidad de emplear una especificación dinámica de la demanda de reservas y el estimador System GMM. Estos avances cambian los resultados encontrados por estudios previos. El costo de oportunidad, el esquema cambiario y la volatilidad comercial y financiera pierden significatividad estadística. La apertura, la imitación regional, la persistencia, el nivel de desarrollo y la desregulación financiera global son los principales factores que determinan la demanda. Los resultados sugieren que la apertura financiera y el desarrollo económico son factores más importantes que la flexibilidad del arreglo cambiario para explicar la reciente acumulación de reservas.

JEL Codes: C23, F30, F33

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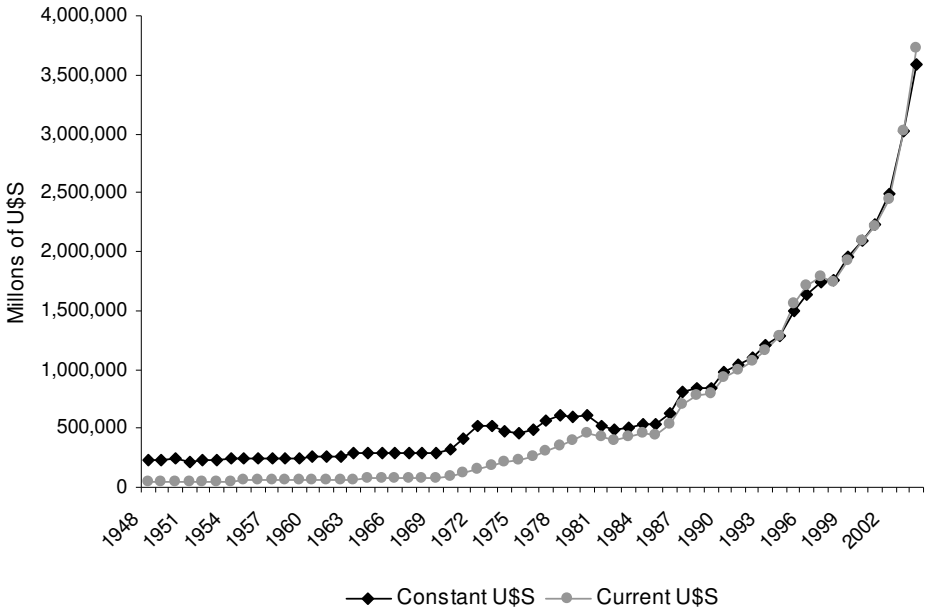
Why Countries Accumulate Foreign Reserves?

A Dynamic Panel Approach

Introduction

The strong increase in international reserves is one of the most surprising and controversial recent issues in international economics. The interest in the causes and implications of this is straightforward once the data is observed. In fact, over the last ten years, foreign reserves have increased 220% reaching a world record of 3.8 billon dollars in 2004 (see Figure 1).

Figure 1. Total international reserves: 1948-2004



Source: authors calculations based on International Financial Statistics (IMF)

However this behaviour is neither homogeneous across countries nor over time. Table 1 shows an evaluation of the dynamics of this process in the post Breton Wood period of flexible global exchange rates for a sample of 139 countries, two different periods (1973-1990 and 1990-2003) and three classifications (type of economy, income level and geographical regions). Even when total stock of reserves is highly influenced by mayor countries which are well known accumulators like Japan, Korea, China, Taiwan, India or Russia, accumulation is widely diffused across countries. With a few exceptions, emerging economies are the leaders in the accumulation process and South and East Asia are the regions from which most of these leaders come from. On the contrary, Europe and North America have dramatically decreased their share in total international reserves.

Table 1. International Reserves growth and volatility: 1973-2005

Country Group	Period			
	1973 - 1990		1990 - 2005	
	Average Annual Growth	Average Growth Volatility	Average Annual Growth	Average Growth Volatility
Markets				
OECD	3.09	3.60	5.27	1.17
Emerging	4.20	2.83	17.36	0.42
Others	3.94	3.24	9.84	0.54
Income Level				
Low	-0.30	10.00	21.57	0.75
Lower Middle	3.22	3.65	18.14	0.59
Upper Middle	4.07	3.89	10.27	1.09
High Non OECD	6.76	0.99	9.66	0.59
High OECD	3.19	3.50	6.10	1.02
Regions				
East Asia & Pacific	6.15	2.40	16.77	0.59
South Asia	-2.52	26.35	29.74	0.88
Europe and Central Asia	2.80	4.05	0.28	13.23
Latin America & Caribbean	1.20	6.74	10.71	1.35
North America	3.69	2.99	0.69	8.24
Middle East & North Africa	1.89	6.00	11.51	0.59
Sub-Saharan Africa	1.63	4.86	10.86	1.52

Source: authors' calculations based on International Financial Statistics (IMF).

Average annual volatility is measured as the standard deviation normalized by the mean (coefficient of variation).

The magnitude of the whole phenomenon implies new questions to be answered by international macroeconomics literature. Why do so many countries accumulate international reserves? Is there a common reason behind accumulation or are there multiple causes and motives? What are the roles of reserves in an era of capital liberalization and exchange rate flexibility? Are the theoretical models and the empirical estimations adequate to explain the rationality of accumulation?

In this broad research program, this paper deals with the issue of reserves determinants using an econometric approach. We employ a wide and extended panel data model in order to detect general determinants at the cost of losing some factors that could be important in particular countries or regions. It is shown that new estimation techniques that encounter endogenity problems in a dynamic setting of the reserves demand equation change the established results of previous empirical works.

The rest of the paper is organized as follows. Section 1 presents the theoretical considerations distinguishing three branches of literature related to the explanation of the underlying causes of reserves accumulation. Section 2 is about methodology. It describes the main drawbacks of previous empirical research on this field and the econometric methodology that solves those problems. The empirical variables selected, their sources and construction are then specified. In the fourth section the empirical results are presented and discussed. The conclusions follow.

1. Theoretical considerations

The literature of international reserves has changed over time.

Traditional views emphasized the main role of three variables: i) the benefit of building up reserves stocks which is calculated by the reciprocal of the marginal propensity to import;[1] ii) the opportunity cost of hoarding reserves which is the spread between interest rate earned by reserves and the alternative social use of these resources; and iii) the volatility of balance of payments, to take into consideration the degree of synchrony between external flows.

Pioneering work by Heller (1966) obtained an explicit formula for optimal reserves depending on the mentioned factors and assuming a probabilistic distribution of external deficits and surpluses in a cost-benefit framework. Subsequent papers by Clark (1970), Kelly (1970), Hamada and Ueda (1977) and Frenkel and Jovanovic (1981) modified some algebraic relationships and changed some assumptions, but did not alter the fundamental conclusions: optimal reserves increases with volatility and decreases with propensity to import and the opportunity cost. It is important to note that this literature focuses on the stochastic time series properties of reserves highlighting the dynamic nature of reserves stock adjustments.

Bretton Woods crisis was a major milestone in international finance and was particularly important to the ideas about international reserves.

Previous to the abandonment of BW agreement, there was an important debate concerning liquidity creation that eventually gave rise to Special Drawing Rights. The idea was to separate liquidity dependence from dollar injection originated in United States balance of payments deficits in order to avoid Triffin paradox. Once the Smithsonian Agreement of 1972 finally crumpled and thus the main international currencies started to float in 1973, it was believed that international reserves were to diminish. But contrary to this, accumulation began to grow faster under exchange rate flexibility. This puzzling outcome was first pointed out by Frenkel (1983).

In spite of some explanations offered by Frenkel himself and Grimes (1993), increasing reserves in a more flexible exchange rate environment continues to be surprising. But to properly treat this result it must be taken into consideration that the passage to flexible regimes was done in a period of capital account liberalization.[2] Precisely this is the core of more recent literature on foreign reserves that views these assets as a precautionary cushion against sudden stops and financial volatility. In fact, current research is motivated by the accelerating growth of international reserves initiated around 1990 which was again a phase of capital account deregulation mainly in emerging market countries (see Figure 1).

Currently the precautionary view of reserves could be tackled by dividing literature in three related fields. In the first place is the issue of reserves as an insurance against sudden stops and capital reversals. Aizenman and Marion (2004) for instance examined a two-period economy that experiences productivity shocks and can borrow abroad up to a limit due to the existence of some probability of default in the second period. The main idea is that reserves provide insurance as long as there is a difference between first period and second period marginal utility when there is default and there is no reserve cushion. In this way, international liquidity could helps the economy to smooth consumption intertemporally even in the default scenario. Jeanne and Ranciére (2005) have also worked in this field calibrating a model for optimal reserves in emerging countries. An important feature in their model is the different maturity of private (short) and public (long) financing. In the margin, reserves have to be financed with long-term debt since short positions are very difficult to roll over in a crisis scenario.

[1] The idea here is that reserves could avoid the need of make an external adjustment consisting in reducing national income to shrink imports.

[2] In fact both exchange rate flexibility and capital account regulations are highly related. For instance, it is recognized that Eurocurrency markets in the 1950s and subsequent deregulations were a challenge to fixed parities. At the same time, the abandonment of these parities created huge incentives to arbitrage and this unleashed pressure on the regulatory structure of capitals flows.

The second research area is about international reserves and currency crisis literature. In a second generation[3] type model international liquidity is a fundamental asset that could play a determinant role (in triggering or not a currency crisis) when fundamentals are in an "intermediate" zone. Recently Li and Rajan (2005) have formalized the idea that high reserves can help offset moderately weak fundamentals. However, if fundamentals are sufficiently weak, no level of reserves will be able to counterbalance this structural flaw in the economy.

The precautionary view of reserves also highlights a third channel associated with financial risk. There is a two-way relationship between these variables.

On the one hand, credit risk agencies monitor reserves, among other variables, in order to assign ratings to sovereign debt. Since such ratings influence investors sentiments there exists an important signalling effect of reserves. The "battle for reserves" view (Hawkings and Turner, 2000) highlights the impossibility of establishing a general adequacy criterion and this implies that reserves should be similar among countries of similar characteristics to avoid a negative judgement of financial markets.

On the other hand, it is possible to argue that in a more risky environment more reserves will be necessary. For instance, Ben-Bassat and Gottileb (1992) develop a model to stress the cost of past default on the demand for international reserves. A defaulting record would entail proportionally more reserves.

Finally, there is a branch in current international reserves literature that views accumulation as a by-product of real exchange rate targeting in Asia. This vision is mainly supported by Dooley and Garber in a couple of recent papers.[4]

Summing up, whilst strong reserve growth is a definite fact, the reasons that justify it are currently a matter of debate. Central banks of different countries could have different objectives in each case and these terms are not empirically distinguishable observing only the data.[5]

2. Econometric Methodology

The existing empirical works of international reserves determinants have three major drawbacks. In the first place, they ignore the underlying inertia in the stock of reserves and thus neglect an important issue which, in turns, generates estimations that are biased and inconsistent. In the second place, they do not control for endogenous regressors in the right side of the demand equation. Lastly, the time and cross section dimensions of the employed panel set are not too extended and thus the conclusions are not compelling to all countries. For this reasons, new estimations that take into account this drawbacks are needed. Our proposal is to employ a System GMM methodology proposed by Arellano and Bover (1995) and Blundell and Bond (1998) to deal with the first two problems. This estimation technique has strong advantages over the previously employed techniques on international reserves demand equations.

The use of a static reserve demand equation estimated by OLS (or GLS) fixed effects has been the common practice among empirical papers on this subject.[6] This means these papers are assuming that central banks change their desired levels of reserves instantaneously when one of the determinants varies. But this is not a realistic assumption. As we will see, reserves stocks changes slowly from one year to another, and thus partial

[3] For a seminal contribution see Sachs et al. (1996).

[4] Dooley et al. (2003) and Dooley and Garber (2005).

[5] Precautionary vs. mercantilist objectives in terms of Aizenman and Lee (2005).

[6] For instance Garcia (1999), Lane and Burke (2001), Flood and Marion (2002), Aizenman y Marion (2003, 2004), Aizenman y Lee (2004), and Soto et al. (2004).

adjustments to the desired level are the rule rather than the exception. The correct way to estimate this kind of relationship must include the dynamic component in the international reserves demand adding the first lag of the dependent variable as a regresor to avoid misspecifications.

Moreover, as noted by Bond (2002), even when the coefficient of lagged dependent variable is not the focus of interest, allowing for dynamics in the underlying process may be crucial for recovering consistent estimates of other parameters i.e. reserves demand determinants.

However, the introduction of this variable in the demand equation causes endogenity problems that need a careful treatment. Consider the following model

$$(1) \qquad y_{i,t} = \gamma y_{i,t-1} + x'_{i,t}\beta + \eta_i + \varepsilon_{i,t}$$

where $x_{i,t}$ is, for the moment, a set of exogenous variables in the sense that $E(x_{i,t}, \varepsilon_{j,s}) = 0 \ \forall i,t,j,s$; η_i is an individual effect that capture the unobservable heterogeneity among countries and $\varepsilon_{i,t}$ is an unobserved homoscedastic disturbance term that satisfies the following conditions: i) $E(\varepsilon_{i,t}, \varepsilon_{j,s}) = 0 \ \ i \neq j \ \text{o} \ t \neq s$ which states that errors terms are mutually uncorrelated; and ii) $E(\eta_i, \varepsilon_{j,s}) = 0 \ \forall i,j,s$ that is, errors are uncorrelated with the unobserved heterogeneity.

There are a variety of econometric techniques to estimate a model like (1). The first possibility is to apply OLS or GLS to a fixed effect model ignoring that the inclusion of $y_{i,t-1}$ cause biased and inconsistent estimators since $y_{i,t-1} - \bar{y}_i$ is correlated with $\varepsilon_{it} - \bar{\varepsilon}_i$. As is well documented by Nikell (1981) and Kiviet (1995) the fixed effect estimator is downwards biased. A second alternative is to conduct an estimation using a simple OLS (ignoring individual heterogeneity) but in this case the result would be an upwards biased autoregressive coefficient (Hsiao, 1986). The fact that the previous estimators are likely to be biased in opposite direction gives us a useful hint about the range in which the consistent estimation is expected to be.

An alternative procedure was suggested by Anderson and Hsiao (1981) consisting in differentiating equation (1) and hence removing the η_i component to obtain

$$(2) \qquad (y_{i,t} - y_{i,t-1}) = \gamma(y_{i,t-1} - y_{i,t-2}) + (x_{i,t} - x_{i,t-1})'\beta + (\varepsilon_{i,t} - \varepsilon_{i,t-1})$$

Taking advantage of the absence of correlation between $(\varepsilon_{i,t} - \varepsilon_{i,t-1})$ and $y_{i,t-2}$ or $(y_{i,t-2} - y_{i,t-3})$, the authors recommend using them as "internal" instruments for equation (4).[7]

However, the Anderson-Hsiao estimator is a special case of the family of estimators within the generalized method of moments (GMM)[8]. More general GMM estimators, for instance those proposed by Arellano and Bond (1991), are superior for at least two reasons. On the one hand, they gain efficiency by using as instruments all the available lags of the right side variables. On the other hand, they allow to take into consideration the potential endogenity of other variables different to $y_{i,t-1}$.

[7] Arellano (1989) demonstrates the convenience of $y_{i,t-2}$ as an instrument since employing the lagged difference results in an estimator with a very high variance. This is confirmed by Arellano and Bond (1991) and Kiviet (1995).

[8] See Hansen (1982).

The "Differences GMM" estimator of Arellano and Bond (1991) exploits linear[9] moment conditions of the form $E(y_{i,t-s}\Delta\varepsilon_{it})=0$ for $t=3,...,T$ and $2\le s\le t-1$ and also allows to incorporate weakly endogenous covariates which are instrumented by the lagged levels dated at $t-1$.[10] This estimator is consistent for $N\to\infty$ and fixed T.

However, there is a problem with this methodology which is the lack of power of the internal instruments in the context of high persistency of the endogenous variables. As is emphasized by Blundell and Bond (1998), Bond et al. (2001), Blundell el al. (2000) among others, lagged levels are weak instruments when the dependent variable is highly persistent i.e. $\alpha\to 1$ or when the variance of the individual effects η_i increases relative to variance of $\varepsilon_{i,t}$. To mitigate this problem it has been proposed to add the following extra assumption over the initial conditions: $E(\eta_i\Delta y_{i2})=0$ which implies that there is no correlation between the error term $\varepsilon_{i,t}$ and $\Delta y_{i,t-1}$ for $t=4,5,...,T$.[11] In this new setting it is possible to estimate a level equation which is instrumented by proper lagged differences. The so-called System GMM estimator is a linear combination of the differences and levels estimators in which the weight given to the levels estimators increases when there are weak instruments caused by high persistency series. We think the latter is the more probable scenario regarding international reserves stocks.

An additional possibility to deal with the dynamic specification of equation (2) and tackle the bias induced by the inclusion of y_{t-1} is to correct the D-LSDV model. Such a line of research has been followed by Kiviet (1995). The author highlights the high variance of the GMM consistent estimators and the contrast with the dynamic fixed effect estimator which, though biased, is much more efficient. The bias correction of Kiviet (1995) (D-LSDVC estimator) provides us an unbiased efficient estimation. Unfortunately, this methodology does not solve the problem generated by endogenous $x_{i,t}$ variables. Nevertheless, it will be useful to compute the D-LSDVC consistent estimator of the autoregressive variable to compare its results with those obtained with the System GMM estimator.

Summing up, the proper study of foreign reserves demand requires the simultaneous solving of the problems posed by adding dynamics, the strong persistency that characterizes reserves and the potentially endogenous $x_{i,t}$ regressors. As we have previously discussed, the most suitable instrument to deal with these problems is the System GMM estimator.

3. The control set: classic and new determinants

In this section we briefly describe the variables employed in our empirical model. The dependent variable is the log of the ratio of international reserves to GDP which is the common practice among empirical papers.

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[9] The baseline assumptions of Arellano and Bond (1991) imply extra linear and nonlinear moment conditions that could be employed to gain precision throughout a nonlinear GMM (Ahn and Schmidt, 1995).

[10] If the $x_{i,t}$ is endogenously determined the available moment conditions are $E(x_{i,t-s}\Delta\varepsilon_{it})=0$ for $t=3,...,T$ and $2\le s\le t-1$. When $x_{i,t}$ is predetermined then it is valid that: $E(x_{i,s}\Delta\varepsilon_{it})=0$ for $t=3,...,T$ and $1\le s\le t-1$. In the case that $x_{i,t}$ is strictly exogenous we have that $E(x_{i,s}\Delta\varepsilon_{it})=0$ for $t=3,...,T$ and $1\le s\le T$.

[11] Blundell et al. (2000) demonstrate that the later condition is satisfied under mean stationarity of the $y_{i,t}$ process. The result can be extended to the endogenity case of the $x_{i,t}$ process.

From the traditional literature revisited in the theoretical section we select three variables: the opportunity cost of holding international reserves[12], the volatility of commercial transactions[13] and the propensity to import which also acts as a proxy of trade openness.[14] We expect a positive sign of the coefficient of the opportunity cost and a negative sign in the case of volatility and trade openness variables.

Considering the insights of the general discussion of recent models on international reserves, we add three important covariates. In the first place, the degree of openness of the capital account measured by volume of capital inflows relative to GDP. In the second place a volatility measure of these capitals inflows[15]. In both cases we would expect to find positive coefficients in the regression analysis. Finally, a dummy variable from 1990 to 2003 captures the structural break regarding financial openness in a large number of developed and emerging countries.

As previously discussed, it is possible that the exchange rate regime in place influences the demand for international reserves. We control for this using a *de facto* classification of exchange rate regimes developed by Coudert and Dubert (2005). This classification was originally applied to Asian economies. We have replicated this methodology to cover the 139 countries and 29 years of our dataset.

This classification is based on three steps. The first one consists on the estimation of an annual trend in the (monthly) nominal exchange rate in order to distinguish crawling peg from peg regimes. The second criterion makes it possible to separate fixed regimes (pegs and crawling peg) from flexible ones (managed and pure floating) by constructing a comparison test of annual nominal exchange rate variance between each country and a benchmark group of floating currencies (Pound Sterling, German Deutsche Mark and Yen) against the Dollar. In a third step a comparison test is performed on the variance of monthly changes of international reserves against the benchmark group in order to differentiate managed from pure floating. At the end, we finish with five dummy variables that identify pegs, crawling pegs, managed floating, pure floating and unidentified (due to missing data).

Up to this point it is clear we are dealing with variables that, in one way or another, were previously treated in empirical research on international reserves. However, we think it is important to expand the control set to tackle two main issues.

The first issue is the relationship between reserves holdings and the level of economic development. We believe there is a strong link between these variables in an inverted U-shaped form. There are two alternatives but complementary explanations for this. The first argument is as follow. Since middle-income countries are more prone to financial crisis than rich or poor countries, they are more interested in using reserves as a precautionary buffer against sudden stops and financial volatility. These countries do not have a fully developed institutional framework to deal with external shocks such as developed countries have. They usually experience “fear of floating”[16] and cannot rely on exchange rate flexibility as a shock absorber. Additionally, they do not have full access to international credit markets when a shock hits their economies and cannot count on a reliable international lender of last resort.

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[12] Measured only by the yield of the ten-year US Treasury bond since it is very difficult to find a representative rate of return for each country due to data imperfections in constructing the interest rate differential.

[13] Calculated by the coefficient of variation of exports levels using a three-year rolling window.

[14] The traditional literature emphasized the relevance of the propensity to import as a measure of the costs of an external adjustment. As a consequence, it was expected a negative relationship between reserves and propensity to import. However in empirical research it was systematically found a positive association which was endorsed to the fact that propensity to import is a proxy of trade openness.

[15] Constructed in the same way that in the case of trade volatility.

[16] Calvo and Reinhart (2002).

Besides, poor countries are not financially integrated and have far greater priorities than stockpiling reserves even if we assume they have the ability to generate regular balance of payments surpluses. That is, the social return of an alternative use of international reserves is much higher than in middle-income countries.

Our second argument recognizes the fact that successful *export-led-growth* policies allows countries go through a caching up process and so, it is more plausible that they tend to be placed near the middle of the world (per capita) income distribution rather than in the tails. Real exchange rate is an important component of *export-led-growth* policy. A target on this variable would be difficult to maintain without accumulating reserves when this policy is successful, i.e. when this policy do generate substantial current account surpluses. Put in a nutshell, going successfully through *export-led-growth* entails high reserves and a higher probability of an intermediate income level. This effect could generate a U-shaped relationship between these variables in the whole sample if there is an important number of countries with such a strategy.

For these reasons we incorporate to our regression analysis the level and square of the GDP PPP per capita in constant dollars.

The second variable we wish to introduce measures the degree of "herd behaviour" among regional neighbours. There are, again, two reasons for a country to partially replicate the actions of its neighbours of similar characteristics. In both cases there is an argument of strategic behaviour underlying in game theory.

On the one hand, it can be argued that there exists a relationship between reserves and risk. A country with more reserves is perceived to be less risky than a neighbour by credit risk agencies (and so by the international financial community in general) all things being equal. It is possible to imagine a Nash equilibrium with high levels of reserves in which each country tries to increase its reserves relative to similar countries to reduce perceived risk, but finally none succeed in effectively reduce such risk. This is the story of the "battle of reserves" emphasized in recent literature.[17]

On the other hand, it is possible to find another Nash equilibrium scenario with high levels of reserves in those regions pursuing *export-led-growth* policies. Here the idea is that countries do not want to lose competitiveness and thus they are reluctant to allow real appreciation *vis a vis* their neighbours. To partially avoid this appreciation central banks in *export-led-growth* countries probably have to stockpile reserves (generally in a sterilized fashion) and probably maintain some type of capital controls.

The variable included to estimate the degree of regional imitation is the percentage of countries of each region[18] that increased their reserves in the previous year.

4. Main Results

The econometric results are presented in a sequential way to illustrate the shortcomings of previous empirical work and its consequences on the results interpretation. The sequence finishes with a robust estimation technique. The results are presented in Table 2.

[17] See Turner and Moreno (2004).

[18] The considered regions are: East Asia and Pacific, South Asia, Europe and Central Asia, Latin America and Caribbean, North America, Middle East and North Africa, and Sub-Saharan Africa.

Table 2. Econometric estimations

Variables	LSDV	D-LSDV	Pooled DOLS	D-LSDVC	Diff GMM	System GMM
$(Reserves/GDP)_{t-1}$	-	0.7559164 ***	0.8977117 ***	0.8318187 ***	0.5750452 ***	0.8424973 ***
		(0.0000)	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*
GDP PPP pc	0.000069 ***	-0.000007	0.000009 ***	-0.000005	-0.000068	0.000015 *
	(0.0000)	*(0.5150)*	*(0.0090)*	*(0.8030)*	*(0.1990)*	*(0.0560)*
GDP PPP pc^2	-2.68E-09 ***	-4.05E-10 *	-4.60E-10 ***	-1.83E-10	6.22E-10	-7.94E-10 ***
	(0.0000)	*(0.0760)*	*(0.0000)*	*(0.7250)*	*(0.5530)*	*(0.0090)*
Trade Openness	0.542952 ***	0.079828	0.050413 **	0.052800	0.281634	0.084611 *
	(0.0000)	*(0.1370)*	*(0.0260)*	*(0.3380)*	*(0.1310)*	*(0.0640)*
Financial Openness	0.030920	0.041104 ***	0.021177	0.043892 ***	0.051827 **	0.043882 *
	(0.1540)	*(0.0060)*	*(0.1050)*	*(0.0040)*	*(0.0480)*	*(0.0580)*
Trade Volatility	0.034670 *	-0.005780	-0.011611	-0.006609	-0.029488 *	-0.017700
	(0.0520)	*(0.6200)*	*(0.3960)*	*(0.6400)*	*(0.0780)*	*(0.3330)*
Financial Volatility	-0.067406 ***	-0.014221	0.003558	-0.007028	-0.022344	-0.005985
	(0.0020)	*(0.3910)*	*(0.8120)*	*(0.6750)*	*(0.3240)*	*(0.7950)*
Opportunity Cost	-0.489491 ***	-0.101554 **	-0.021962	-0.118326 **	-0.168893 **	-0.040146
	(0.0000)	*(0.0400)*	*(0.6310)*	*(0.0430)*	*(0.0160)*	*(0.4460)*
Regional Imitation	0.002340 ***	0.003967 ***	0.004328 ***	0.003983 ***	0.003783 ***	0.004236 ***
	(0.0030)	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*
Pure Floating	0.070955	0.042020	0.019377	0.053248	0.025436	0.012962
	(0.1260)	*(0.1470)*	*(0.3250)*	*(0.1910)*	*(0.3860)*	*(0.6520)*
Managed Floating	-0.143473 ***	0.061733 **	0.042603 *	0.072102 **	0.040516	0.028047
	(0.0010)	*(0.0360)*	*(0.0530)*	*(0.0500)*	*(0.2250)*	*(0.3020)*
Crawling Peg	-0.041565	0.004777	0.021618	0.007890	-0.006485	-0.012590
	(0.3420)	*(0.8660)*	*(0.3090)*	*(0.8420)*	*(0.8240)*	*(0.6450)*
Inconclusive ERR	-0.429794 ***	0.036638	0.049990	0.066631	0.074741	0.111994
	(0.0020)	*(0.7330)*	*(0.6200)*	*(0.5280)*	*(0.6120)*	*(0.5490)*
Dummy Shift 1990	0.169444 ***	0.103273 ***	0.075075 **	0.086324 **	0.078026 *	0.078765 ***
	(0.0000)	*(0.0010)*	*(0.0130)*	*(0.0130)*	*(0.0760)*	*(0.0060)*
Constant	-1.440011 ***	-0.488057 ***	-0.464674 ***	-	-	-0.474552 ***
	(0.0000)	*(0.0050)*	*(0.0010)*			*(0.0010)*
Countries	139	139	-	138	138	139
Observations	2646	2638	2638	2469	2469	2638
Adj. R^2	0.6721	0.8504	0.8428	-	-	-
F-Test	0.0000 ***	0.0000 ***	0.0000 ***	-	0.0000 ***	0.0000 ***
Hansen Test	-	-	-	-	1.0000	1.0000
AB test for AR(1)	-	-	-	-	0.0000 ***	0.0000 ***
AB test for AR(2)	-	-	-	-	0.8020	0.8430

Notes: dependent variable is the log of the ratio of total international reserves to GDP.

*statistically significant at 10% level, **statistically significant at 5% level, *** statistically significant at 1% level.

Instrumented variables: $(Reserves/GDP)_{t-1}$, GPD PPP per capita, square of GDP PPP per capita, trade openness, financial openness, trade volatility, financial volatility, regional imitation.

We start by estimating the static fixed effect model with the objective of establishing a benchmark case with similar shortcomings to those found in several papers on this subject.[19]

The first column of Table 2 shows the least squares dummy variable estimator (LSDV). The result to highlight here is the high level of statistic significance of the included covariates. In

[19] For instance, Azienman and Marion (2004)

fact, it could be tempting to draw many conclusions such as “reserves increases in managed floating regimes with respect to pegged ones“. But these conclusions could be wrong. We need to control for bias and inconsistency problems caused by ignoring the dynamic specification of reserves demand.

Columns 2 and 3 of Table 2 are the fixed effect and pooled OLS dynamic estimations (D-LSDV and Pooled DOLS respectively). These two methodologies produce biased (in opposite direction) autoregressive coefficients. However, they are useful for two reasons.

In the first place, they illustrate the important consequences of introducing dynamics in terms of both signs and statistical significance levels of the right hand side variables. It is clear from columns 2 and 3 of Table 2 that the inclusion of the lagged dependent variable captures a large part of the effect of others persistent variables like GDP or trade openness in both pooled and fixed effects OLS dynamic models. Hence the first relevant result is that previous papers on this subject have based their empirical conclusions on an incorrect basis since they neglect the inertia in reserves stocks which causes bias and inconsistency.

The second conclusion we could draw from these estimations is that the autoregressive parameter shows a high level of persistency. A consistent estimation of this coefficient should lie between 0.756 (D-LSDV) and 0.898 (Pooled DOLS) as explained in the methodological section. This is the case of the dynamic least square dummy variable corrected (D-LSDVC) presented in column 4 of Table 2.

Next we turn to GMM type estimators. Column 5 of Table 2 is the traditional difference estimator of Arellano and Bond (1991). We opt for the two-step variant of the difference GMM estimator with the finite sample variance correction of Windmeijer (2005).[20] The results of the Hansen test of overidentification restrictions and the second order residual autocorrelation test do not reject the validity of instruments. All the control variables are treated as endogenous with the exception of exchange rate regime variables and the dummy shift of 1990. It is easily observed from column 5 that there is a problem of weak instruments which causes an important sample bias. In this case, the coefficient of lagged reserves is lower than the value founded on the pooled dynamic OLS estimation, and besides the difference is quite high (0.575 vs. 0.756, more than 25%). In relation to this, the lack of significance of almost all regressors could be indicating two things. It could be suggesting that in a consistent estimation most of the traditional determinants do not have the expected behaviour, challenging much of the current state of the arts in this subject. An alternative explanation is that the instruments employed are so weak as to be incapable of detecting the original relationships. As we see in column 6 (Table 2), the system GMM methodology reveals a mixture of these two effects.

As in the previous case, the Hansen and the second order autocorrelation test do no reject the validity of the proposed instrumental set. The coefficient of the lagged dependent variable increases considerably (0.842) and lies between the result of OLS and FE dynamic models. This confirms that high persistency in reserves stocks causes that endogenous covariates are weak instruments in the difference GMM. The economic interpretation of such a coefficient dated back to the pioneering first generation models of reserves adequacy that stressed stochastic time series properties of reserves adjustments.[21]

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[20] The two-step GMM estimator is efficient but the estimated asymptotic standards errors could be severely downward biased in small samples. For this reason the common practice was to sacrifice some precision (using the one-step GMM estimator) in order to avoid large inference mistakes. Windmeijer (2005) demonstrates that the presence of estimated parameters on the weight matrix accounts for much of the divergence between finite sample and the usual asymptotic variance of the two-step GMM estimator. This divergence can be estimated resulting in a finite sample corrected variance that approximates fairly well the sample variance and thus conduce to a more accurate inference.

[21] For instance Kenen and Yudin (1965), Heller (1966), Clark (1970) or Frenkel and Jovanovic (1981).

Concerning the remaining endogenous covariates, there are many interesting findings.

Regarding traditional explanatory variables, only the propensity to import results statistically significant with the expected positive sign. Neither the opportunity cost nor the trade volatility seems to be significant at the conventional levels. This could be indicating both that the available information is too poor to construct good proxies of these variables[22] or that traditional determinants are no longer important to explain current reserve hoarding.

Interestingly, the financial opening variable is statistically significant and the corresponding financial flows volatility is not. We suspect that this important effect is captured by the dummy variable for the period 1990-2005 which was characterized by worldwide capital account deregulation.

In conjunction, the results of trade and financial openness and trade and financial volatility seem to indicate that for accumulation purposes it is more important to cover the exposure to external shock rather than the magnitude of the shocks itself.

There is strong evidence that the new proposed regressors (the income level and its square and the regional imitation) are relevant. The signs of the first two variables implied an inverted U-shaped relationship between reserves and the income level. We have previously proposed two complementary explanations to this singular functional form.

The sign and significance of the regional imitation variable suggest reserve accumulation strategies could be viewed as a non cooperative game in which each participant is trying to not fall behind a competitor in term of international risk perception and/or real exchange rate competitiveness.

The last paragraph is devoted to the exchange rate variables. The omitted category is the fixed regime variable and surprisingly, none of the dummies are statistically significant. Concerning flexible regimes, this result could be reflecting no more than the fear of floating highlighted by Calvo and Reinhart (2002). Regarding the intermediate cases, the results are more difficult to interpret. But in a sense, the lack of significance of exchange rate regime is a corroboration of the paradoxical result that more flexibility does not necessarily entail less reserves. In fact, these results give support to the idea that stockpiling reserves and allowing exchange rate fluctuations is a complementary strategy to be followed by emerging countries in order to minimize volatility and reduce crisis probability.

5. Conclusions

Since the nineties the interest in international reserves has been growing and in fact it is nowadays very different from the view prevailing during the 1960-1980 period. However, the main reason to demand international liquidity is basically the same: precaution. But what has actually been changing is the source of uncertainty that motivates this precautionary behaviour.

This paper proposes to recover the spirit of traditional models which highlight the adjustments cost of current and desired reserves stocks. The latter naturally leads to a framework characterized by persistence in the time series and this reflects the actual behaviour of central banks. We have demonstrated that ignoring reserve demand dynamics is a potential flaw of recent empirical papers that tends to be intensified in high persistency scenarios.

But introducing dynamics is costly. A proper study of foreign reserves demand requires solving simultaneously two problems: the strong persistency that characterizes reserves and the potentially endogenous $x_{i,t}$ regressors. According to our evaluation of latest

[22] This reason was previously used in Soto et al. (2004) to explain the counterintuitive negative effect of the opportunity cost (interest rate differential) over international reserve holdings.

econometrics advances, the most suitable instrument to deal with these problems is the System GMM estimator.

Based on the methodological discussion, we estimate a foreign reserve demand equation in a panel data of 139 countries and 30 years and compare the performance of different estimators.

The sequence of estimators reveals serious bias and inconsistency problems in previous papers that tend to invalidate the economic interpretations of the explanatory variables.

In order to specifically answer why countries accumulate reserves, we have proposed a series of traditional and new control variables anchored in classical and modern theoretical grounds. We confirm it is correct to recover the dynamic notion of international reserves demand, the only traditional variable that remains significant is the trade openness while trade and financial volatility are not statistically significant. Other significant variables are those proposed in the paper: financial openness, regional imitation, and the 1990 step dummy. We also verify a U-shape relationship between international reserves and the level of development. Surprisingly, exchange rate regimes are not important to explain reserves hoarding. Contrary to previous papers, we do not find that pegged regimes are more prone to reserve accumulation.

This paper has two main contributions. Firstly, it proposes a correct empirical approach to start evaluating competing theoretical models. Secondly, it incorporates more suitable variables to explain the specific behaviour of several central banks in this flourishing field of international macroeconomics.

The policy implications of our findings suggest a triangular relationship between foreign reserves, financial flows globalization and exchange rate regimes. Traditionally, it was thought that exchange rate flexibility was a substitute for reserve accumulation. However, we have seen that when countries are in an intermediate stage of development and they are increasing their exposure to capital flows, reserve accumulations could be considered as an important tool in order to obtain a successful integration. This attitude is highly rational in a world where there is no clear lender of last resort to deal with financial and currency crisis. Finally, for some countries, reserve accumulation could have another externality, which is avoiding excessive exchange rate appreciation.

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