DISCUSSION PAPER SERIES

No. 6693

FINANCIAL STABILITY, THE TRILEMMA, AND INTERNATIONAL RESERVES

Maurice Obstfeld, Jay C Shambaugh and Alan M Taylor

INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

www.cepr.org

Available online at: www.cepr.org/pubs/dps/DP6693.asp

ISSN 0265-8003

FINANCIAL STABILITY, THE TRILEMMA, AND INTERNATIONAL RESERVES

Maurice Obstfeld, University of California, Berkeley, NBER and CEPR
Jay C Shambaugh, Dartmouth College and NBER
Alan M Taylor, University of California, Davis, NBER and CEPR

Discussion Paper No. 6693
February 2008

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 6693

February 2008

ABSTRACT

Financial Stability, the Trilemma, and International Reserves*

The rapid growth of international reserves---a development concentrated in the emerging markets---remains a puzzle. In this paper we suggest that a model based on financial stability and financial openness goes far toward explaining reserve holdings in the modern era of globalized capital markets. The size of domestic financial liabilities that could potentially be converted into foreign currency (M2), financial openness, the ability to access foreign currency through debt markets, and exchange rate policy are all significant predictors of reserve stocks. Our empirical financial-stability model seems to outperform both traditional models and recent explanations based on external short-term debt.

JEL Classification: E44, E58, F21, F31, F36, F41, N10 and O24
Keywords: banking crises, capital flight, central banks, exchange rate regimes, financial development, foreign exchange, global imbalances, Guidotti-Greenspan rule, international liquidity, intervention, lender of last resort, net foreign assets, sterilization, sudden stop

Maurice Obstfeld
Department of Economics
University of California
508-1 Evans Hall
Berkeley CA 94720-3880
USA
Email: obstfeld@econ.berkeley.edu

Jay C Shambaugh
Department of Economics
Dartmouth College
6106 Rockefeller Hall
Hanover, NH 03755
USA
Email:
jay.c.shambaugh@dartmouth.edu

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=100662

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=160729

Alan M Taylor
Department of Economics
University of California
One Shields Avenue
Davis CA 95616-8578
USA
Email: amtaylor@ucdavis.edu

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=127083

* Financial support from the Fondation Banque de France through a grant administered by the CEPR is gratefully acknowledged. We also thank Sara Friesen and Seema Sangita for excellent research assistance. Sebastian Edwards graciously provided his unpublished data on financial openness (which update the indicator described in Edwards 2005). For helpful comments we thank scholars at Kansas, Manchester, Warwick, and the Santa Cruz Center for International Economics, 10th Annual International Economics Conference, and especially our discussant Michael Devereux. All errors are ours.

Submitted 30 January 2008

1 Introduction

Over the past decade, the international reserves held by monetary authorities have risen to very high levels relative to national outputs. More rapid reserve accumulation, primarily attributable to relatively poor countries, is thought to have affected the global patterns of exchange rates, of capital flows, and of real interest rates. Foreign official purchases of dollars have also financed an unprecedented level of external borrowing by the world's biggest economy, that of the United States. The upsurge in global reserve growth confronts economists with an important puzzle. What has driven it, and is it likely to endure?

The facts to be explained can be summarized as follows. Starting from the end of the Bretton Woods era, reserves as a fraction of GDP grew dramatically—up by a factor of 3.5 from less than 2 percent in 1960 to 6 percent in 1999—despite the supposed global shift toward more flexible exchange rate arrangements in 1973. Since 1999, reserve accumulation has accelerated sharply. Asian and some Latin American emerging markets, Japan among the industrial countries, and oil exporters, notably Russia, have been the primary drivers of this trend. Since 1990 advanced country reserves have held steady at about 4 percent of GDP, but emerging markets' reserves have more than quintupled, from 4 percent to over 20 percent of GDP.[1] These data present both a theoretical and an empirical challenge, but as yet there is little consensus and only modest success on either front. Indeed some have suggested that the current level of reserves is excessive—and hence, implicitly, beyond the explanatory powers of a rational economic framework.[2]

We argue that reserve accumulation is a key tool for managing domestic financial instability as well as exchange rates in a world of increasing financial globalization. We therefore build on the view—certainly not a new one—that a primary reason for a central bank to hold reserves is to protect the domestic banking sector, and domestic credit markets more broadly, while limiting external currency depreciation. The need for such protection increases given the multiplication of risks in more financially open economies, where potential currency mismatches and a combination of internal drains (runs from bank deposits to currency) and external drains (flight to foreign currency or banks) can place extraordinary demands on a central bank's foreign exchange reserves. In the empirically prevalent scenarios of "twin" internal and external drains, reserve backing falls when the central bank attempts to ease domestic illiquidity by acting as a lender of last resort (LLR). Especially for an emerging market in which domestic bond markets are thin and large-scale quasi-fiscal bailouts may spark fears of public insolvency, no practical short-run means of influencing the exchange rate other than reserve sales may be available.

[1] Figures are from Flood and Marion (2002) and Jeanne (2007).

[2] See, for example, Summers (2006). Bird and Rajan (2003) and Rodrik (2006) make the second-best argument that, rather than self-insuring against domestic economic vulnerabilities by incurring the costs of holding more reserves, countries should attack the sources of the vulnerabilities directly. We return to this point below. Levy Yeyati (2006) offers a critique of standard measures of reserve holding costs.

We first present a simple theoretical framework for understanding this mechanism. We then investigate the empirical determinants of reserve growth in a broad panel of developing, emerging, and advanced countries. We pursue a systematic empirical investigation to show that there has been a statistically robust and economically significant correlation of reserve levels (reserves/GDP) with financial openness (a measure of cross-border capital mobility), financial development (proxied by M2/GDP), and exchange rate policy (using peg indicators). The three factors are all important and they multiplicatively compound each other as a determinant of reserve/GDP ratios in our specification. This result again highlights the role of the trilemma, albeit in a different context. In previous papers we have emphasized how open capital markets and a fixed exchange rate limit monetary policy autonomy measured by interest rate independence (Obstfeld, Shambaugh, and Taylor 2004; 2005). In this paper we show how the same policy combination may dictate a large war chest of reserves for LLR purposes for some countries when there is a risk of capital flight.

These findings do not necessarily deny a role to more traditional determinants of reserve holdings, such as openness to international merchandise trade. In our simple conceptual framework, these other determinants may well act as complementary factors affecting the demand for reserves, and in our empirical work we are careful to control for them. As a matter of statistical significance, some of these traditional factors appear to matter (e.g., trade) but others do not (e.g., debt). Of course, the channels through which traditional variables such as trade influence reserve demand can be quite "nontraditional" in a financially globalized world.

As a matter of quantitative significance, however, we show through counterfactual analysis that the key to understanding the evolution of reserves, especially in recent years, is to include measures of financial openness and financial development. With the spread of globalization and growth of banking systems and financial markets, these variables have shifted profoundly in emerging markets since the early 1990s. By accounting for those shifts, we can much more successfully explain the changing patterns of reserve holdings. For example, we can show (using out of sample predictions) that there was no major deviation in this pattern after 1997. We can even go a long way toward explaining alleged outliers such as China. By this historical yardstick, current reserve holdings are neither inexplicable nor excessive—we find no major underprediction, at least not systematically, and not for the usual emerging-market suspects. China, and most of emerging Asia, hold reserves at levels close to those predicted by the model, and only in the last years of our sample (2003–04) does China start to leave some reserves unexplained. Among the very big reserve holders, Japan does appear to hold more reserves than the model suggests are necessary.

2 Earlier thinking on the demand for international reserves

A long literature has, at different times, emphasized various factors that help determine the demand for international reserves.

2.1 From the trade-based Bretton Woods view to sudden stops and precautionary accumulation

The modern study of optimal international reserves begins with Heller (1966), who viewed the demand for reserves by a monetary authority as reflecting optimization subject to a tradeoff between the benefits of reserves and the opportunity cost of holding them. Heller's work and the work that soon followed envisioned the benefits as relating to the level and variability of balance of payments flows, primarily imports and exports. Basically, reserves could buy time for more gradual balance of payment adjustment, so the demand for them was viewed as a positive function of both the cost of adjustment (through demand compression, devaluation, and so on) and the likelihood that such adjustment measures might become necessary at a low level of reserves. While such adjustment-based variables met with some empirical success, the proxies for reserve costs showed no robust relationship to reserve holdings, at least when countries were pooled.[3]

The collapse of the Bretton Woods regime after 1973 shifted the ground under the arguments about reserve holdings. At least in the advanced countries, a new resolution of the trilemma emerged—a move to a different "corner" with capital mobility and floating exchange rates. But it was unclear what this move meant for reserve holdings. On the one hand, a truly floating regime needs no reserves and a liberalized financial account would minimize the need for reserve changes to absorb a given set of balance-of-payments shocks. On the other hand, governments are far from indifferent to the exchange rate's level and a liberalized financial account might in and of itself generate more BOP instability, possibly augmenting reserve needs.

As if to support an array of confounding theoretical arguments, global international reserves did not decline noticeably relative to output after the shift to floating exchange rates. The exigencies of the 1980s debt crisis did lead to a decline in the growth rate of developing-country reserves during the 1980s. But the new wave of rich-to-poor capital flows starting in the 1990s led to new thinking on the role of international reserves in a financially globalized world, one in which currency crises originating in the financial account could inflict major reserve drains. An important study in this vein is that of Flood and Marion (2002). They showed that a parsimonious but successful specification based on earlier work by Frenkel and Jovanovic (1981) remained robust, and

[3] See Williamson's (1973) magisterial survey of the literature up to the close of the Bretton Woods system. More recent surveys include Wijnholds and Kapteyn (2001) and Bahmani-Oskooee and Brown (2002). Because proxies for reserve costs have generally performed so dismally in pooled samples, we do not include them in our empirical analysis below.

they reinterpreted the reserve-variability variable central to that specification in terms of the "shadow floating exchange rate" concept from the theoretical crisis literature. However, their work left open the possibility that variability in reserves is a proxy for more fundamental financial variables that generate reserve (or shadow exchange rate) variability.

Perhaps the most influential view was based on the role of short-term external debts in generating and helping to predict emerging-market currency crises. Wijnholds and Kapteyn (2001, n. 13) recount that in December 1997, after the Korean crisis erupted, the IMF board discussed a rule of thumb for reserve adequacy incorporating short-term foreign-currency debt. It came to be known as the Guidotti-Greenspan rule after policymakers Pablo Guidotti and Alan Greenspan both explicitly proposed the idea in 1999 (see Greenspan 1999).

The proposal came at a time of mounting concern about "sudden stops" in capital inflows (Calvo and Reinhart 2000), periods when access to foreign financing can dry up. A country may plan to pay interest on external debt, but it might not have the wherewithal to pay off a principal amount that it had expected to roll over. Guidotti suggested a rule of thumb whereby emerging markets should have sufficient reserves that they could cover full amortization for up to one year without access to foreign credit. The idea was supported by empirical research showing that short-term external debt appears to be a potent predictor of currency crises. It is not much of an exaggeration to say that on this view, the economy *itself* is a bank, and monetary (as opposed to credit) considerations are inessential.

Despite its recent notoriety, the Guidotti-Greenspan rule has a hallowed history going back at least a century. In the second volume of his *Treatise on Money* (1930), John Maynard Keynes discussed his view of the then-accepted principles governing the optimal level of free gold reserves. Because it is so very explicit and so clearly in line with current discussion (including consideration of financial integration), the relevant passage is worth quoting at length (Keynes 1971, pp. 247–8):

> The classical investigations directed to determining . . . the appropriate amount of a country's free reserves to meet an external drain are those which, twenty years ago, were the subject of memoranda by Sir Lionel Abrahams, the financial secretary of the India Office, who, faced with the difficult technical problems of preserving the exchange stability of the rupee, was led by hard experience to the true theoretical solution. He caused to be established the gold standard reserve, which was held separately from the currency note reserve in order that it might be at the unfettered disposal of the authorities to meet exchange emergencies. In deciding the right amount for this reserve he endeavoured to arrive at a reasoned estimate of the magnitude of the drain which India might have to meet through the sudden withdrawal of foreign funds, or through a sudden drop in the value of Indian exports (particularly jute and, secondarily, wheat) as a result of bad harvests or poor prices.

> This is the sort of calculation which every central bank ought to make. The bank of a country the exports of which are largely dependent on a small variety of crops highly variable in price and quantity—Brazil, for example—needs a larger free reserve than a country of varied trade, the aggregate volume of the exports and imports of which are fairly stable. The bank of a country doing a large international financial and banking business—Great Britain, for example—needs a larger free reserve than a country which is little concerned with such business, say Spain.

Notice that Keynes here focuses exclusively on external drains, and does not mention the causal influence of internal drain on external drain that would surely have appeared more important to him upon witnessing the global financial crisis that broke out in 1931, the year after the *Treatise*'s publication. In this respect his prescriptions mirror the Guidotti-Greenspan perspective, which likewise concentrates on external drains, largely ignoring the possible role of domestic residents' financial decisions. How does the Guidotti-Greenspan precautionary prescription hold up in practice?

Aizenman and Marion (2003) suggest a precautionary demand for reserves as a cause of the rising international reserves in East Asia following the Asian crisis. Aizenman and Lee (2006) estimate an empirical panel model in which precautionary factors, represented by dummy variables marking past crises, play an important role in explaining desired reserve levels. Like us, Aizenman and Lee (2006) find that China is not an obvious outlier. However, while the authors motivate their regression tests in terms of a theoretical model of insurance against sudden stops, their econometric results actually say nothing about the mechanism through which past crises have influenced subsequent reserve holdings.

In other recent work, Jeanne and Rancière (2006) and Jeanne (2007) estimate optimal international reserves in a model where the latter serve the role of allowing national consumption smoothing in the face of random sudden stops.[4] Consistent with Summers' (2006) observation, they find that countries hold reserves that are excessive relative to the Guidotti-Greenspan benchmark—in some cases multiples of short-term external debt. Were it not for this predictive failure, there would perhaps be no great puzzle over "excessive" reserves.

2.2 An alternative view based on the double drain

What then has been driving reserve accumulation since the late 1990s? To resolve the puzzle we consider the concerns of a government facing simultaneous currency and banking crises, with potential foreign reserve losses that are magnified by its domestic interventions as the lender of last resort. In this context the failure of trade and debt criteria to explain reserve holdings is perhaps understandable on an intuitive level. Trade and debt arguments for reserve holdings

[4] Durdu, Mendoza, and Terrones (2007) likewise focus on potential sudden stops as a motivation for reserve demand.

emphasize that a negative (capital outflow) balance-of-payments shock can emanate from the financial account when the *export of home assets to foreigners suddenly stops.* But we think it important to recall that similar shocks can arise when the *import of foreign assets by domestic residents suddenly starts.*[5]

Some illustrative calculations can illuminate the point. A typically "bad" trade deficit in a developing country might be, say, 5% of GDP, but if this had to be financed out of reserves in a sudden stop, the implied drain would only be about $\frac{1}{10}$% of GDP per week, a slow leak. To ratchet this drain up we might consider that an imminent crisis could lead to speculative arbitrage even on the current account side, either via "leads and lags," or even the outright hoarding of all hard-currency export receipts offshore. In that case, suppose exports and imports are, say, a not unreasonable 26% of GDP, so trade is balanced. A sudden stop (with no export receipts repatriated in the worst-case scenario) implies that a reserve drain of $\frac{1}{2}$% of GDP per week will ensue. Given current levels of emerging market reserve holdings, this faster drain would be a concern, but would not exhaust reserves very quickly.

What about the next rationale for reserves, short-term debt? If we suppose there is also a short-term debt equal to a not atypical 26% of GDP rolling over continuously, this could add a further $\frac{1}{2}$% of GDP in weekly financing needs, getting the reserve drain up to 1% of GDP a week. Conventional drains of this order of magnitude might be potentially worrying, but to rationalize current reserve holdings we think it is important to keep in mind the even more catastrophic double drains that can result from capital flight.

In the case that we focus on, domestic capital flight is financed through a drain of domestic bank deposits—so domestic financial stability is inescapably a central consideration in reserve management policy. To continue with intuition based on representative estimates, suppose M2 is 20% of GDP. If half of M2 decides to flee the country in a panic, this could happen in the space of a week or two, and hence reserves equal to 5%–10% of GDP per week might start to drain out of the country. That flow would be an order of magnitude larger than those likely to be triggered in a sudden stop by the debt or trade financing needs noted above. We think it is the threat of this type of drain that most worries emerging market policymakers, since, absent speedy and credible help from an international lender of last resort, rapid ouflows of this type would be difficult to manage without a large war chest.

In the new era of financial globalization, these flows are not just hypothetical. A good example of this kind of dynamic is provided by the events in Argentina. We look first at 1994–95, and developments in the wake of the Mexican "Tequila Crisis." Just before the crisis started in December 1994, Argentina's central bank reserves were about 11 billion pesos, out of a total money base (M0) of 15 billion pesos (with 1 peso equal to 1 U.S. dollar). M2 was about 50 billion pesos, or 20% of a GDP of roughly 250 billion pesos.

[5] For example, sudden stops and current account reversals are often classified using net balance of payments flow data, but this may obscure the underlying cause of the flow. However, as Rothenberg and Warnock (2006) note, many "sudden stop" episodes would be better described as "sudden flight" events of the kind we have in mind here.

After the crisis, a sudden stop occurred in emerging markets including Argentina. For the first few weeks no great problem arose in the Argentine domestic banking sector. But in early 1995 a bank run steadily developed. During this time, demand for money base or M0 held steady at about 14 to 15 billion pesos until mid-1995. However, the demand for M2 collapsed; bank depositors took their money to Miami or Montevideo in search of a safe haven. As they rushed for dollar liquidity in February/March the central bank's reserves drained, falling to a level of just 5 billion pesos by April 1995, meaning that about one eighth of M2 had been exchanged for central bank reserves (worth two fifths of M0) in the space of a few weeks.

If this kind of drain had continued, with no change in circumstances, then Argentina's reserves would have been quickly depleted, and the convertibility plan probably would have ended within weeks or even days. Yet the plan survived. Despite saying in 1994 that it would tolerate no more fiscal laxity from Argentina, the IMF (fearing global contagion) rolled out new loans as the bank run grew to critical proportions in early 1995. The new injection of dollars kept the plan afloat and was thought to have served a "catalytic" role in encouraging fresh inflows of private capital. The moment of crisis was narrowly averted.[6]

What would have happened without IMF intervention in 1995? It is likely that the 1995 counterfactual, with no IMF support, would have looked something like the actual events of 2001–02, when the withdrawal of IMF support in late November 2001 (in much tougher macroeconomic and fiscal circumstances) triggered a massive bank run. Already the year 2001 had seen a steady double drain, with the country losing 11.5 billion dollars of deposits and 10.9 billion in reserves from January to November. But in the two days after the IMF withdrew its backing, the drain intensified by an order of magnitude. On the single day of November 30, 1.4 billion dollars were withdrawn from the banking system; fully ten percent or 1.7 billion dollars of reserves were lost in the space of twenty four hours.[7]

The convertibility plan died a quick death. First, the "temporary" capital controls of the *corralito* were imposed within a couple of days of the IMF's departure, and starting in January the trilemma was resolved more definitively when the peso was allowed to depreciate (it was soon hovering around 4 pesos per dollar, before steadying at 3). And along the way Argentina suffered an historic economic and political meltdown.

In our view, emerging market policymakers now have exactly this type of double drain in mind, a rapid portfolio shift by domestic depositors which threatens to overwhelm the reserves of a central bank, even one that could be mistaken for a currency board. As large fractions of M2 decided to leave Argentina, it was clear that having near-complete backing of M0 would be of little help.

Based on this line of reasoning, and much more theory and evidence to follow, we think capital flight is at least as important, and perhaps more important than a sudden stop as a crisis trigger. We agree with Wijnholds and Kapteyn

[6]The Argentine experiences in 1994–95 and 2001–02 are recounted in great in detail Paul Blustein's (2005) book *And the Money Kept Rolling In (and Out)*.

[7]Figures from Levy Yeyati, Schmukler, and Van Horen (2004).

(2001, pp. 10–11), who argue that even the recent debt-based approaches to reserve demand, while considering financial globalization, have missed this vital element. We adopt this broader view of the financial stability concerns of a central bank faced with a double drain risk, and we and find that the broader view better fits the data.

Our conceptual framework therefore builds on crisis-inspired discussions of banking problems such as those of Velasco (1987), Calvo and Mendoza (1996), Sachs (1998), and Chang and Velasco (2001), in which a flight from domestic bank deposits into foreign exchange—a scenario of simultaneous internal and external drain that occurred in many of the 1990s crises—brings foreign reserves and the exchange rate under extreme pressure by putting the banking system into meltdown and activating the central bank's LLR role.[8]

Several papers have highlighted the double drain within the context of the historical gold standard. In a classic paper, Dornbusch and Frenkel (1984) employ a standard model of the money multiplier to derive a dynamic model of gold flows and reserves in a world of imperfect capital mobility. The risk of a double drain arises when the "confidence effect" is at work and higher interest rates cause a flight to cash rather than into deposits.[9] In an extension of this model, della Paolera and Taylor (2002, 2003) show that the model predicts a crisis outcome when a national bank, say, the "banking department" of a gold standard currency board or a parastatal bank, acts as a lender of last resort (loosening credit as its reserves fall in a credit crunch).

Even for present-day currency arrangements, we also emphasize that a drain which *originates* as purely an internal matter may spread to the exchange market if it sparks fears of government fiscal distress following a banking-sector rescue.[10] As Viner (1939, p. 263) puts it: "A drain ... which is distinctly of one type in its origin, may imperceptibly become a drain of another type, or may, by causing alarm, give rise to another type of drain as well." Following up on this view, we see M2, the quasi-liquid deposits of the banking system, as the variable most naturally tracking the potential pressure on reserves resulting from a flight out of domestic-currency bank deposits.[11]

This broader view of the utility of reserves also has a hallowed history—one that goes back at least to the British currency turbulence of the late eighteenth and early nineteenth centuries. Writing in his classic *Paper Credit of Great Britain* (1802) during Britain's 1797–1821 suspension of gold convertibility, Henry Thornton argued that gold reserves were necessary not only to meet fluctuations in the trade balance (external drains); they also were important

[8]More recent theoretical contributions to the "twin crisis" literature include Goldstein (2005) and Shin (2005), both of whom focus on the decisions of foreign bank creditors.

[9]For a related analysis, see Miller (1996).

[10]Miller (2000) sketches a scenario in which banking crises lead to currency crises.

[11]Keynes (1971, p. 247), again seeming to ignore the possibility of *domestic* financial instability, argues that the maximal sizes of the external shocks necessitating free foreign exchange reserves are not "likely to bear any stable relationship to the volume of money within the country, which will depend partly on the national income and partly on the national habits. They are governed, rather, by the magnitude and variability of the country's international business as traders, investors and financiers."

for positioning the Bank of England to head off or respond to internal drains without collapsing the home economy. He argued explicitly that at a time of domestic economic distress, attempts to attract gold by shrinking the Bank of England's note issue would be self defeating—gold can be accumulated only ex ante, not ex post.

Like Keynes, Thornton is worth quoting at length. After pointing out that some "interchange of gold for paper" is needed to regulate the real value of paper money, he states (Thornton 1939, pp. 111–2):

> In order to ensure that this interchange shall at all times take place, it is important that, generally speaking, a considerable fund of gold should be kept in the country, and there is in this kingdom no other depository for it but the Bank of England. This fund should be a provision not only against the common and more trifling fluctuations in the demand for coin, but also against the two following contingencies. First, it should serve to counteract the effects of an unfavourable balance of trade, for this infallibly will sometimes occur, and it is what one or more bad harvests cannot fail to cause. It is also desirable, secondly, that the reserve of gold should be sufficient to meet any extraordinary demand at home, though a demand in this quarter, if it should arise from great and sudden fright, may undoubtedly be so unreasonable and indefinite as to defy all calculation. If, moreover, alarm should ever happen at a period in which the stock of gold should have been reduced by the other great cause of its reduction, namely, that of a call having been recently made for gold to discharge an unfavourable balance of trade, the powers of any bank, however ample its general provision should have been, may easily be supposed to prove insufficient for this double purpose.

Later in *Paper Credit* Thornton spells out further his thinking on the role of reserves in supporting domestic financial markets along with the currency's foreign exchange value (Thornton 1939, p. 153):

> The more particular examination of this subject of an unfavourable exchange, brings us, therefore, to the same conclusion to which we were led in the former Chapter; namely, that the [Bank of England] ought to avoid too contracted an issue of bank notes. The absence of gold, though itself an evil, may prevent other evils of greater moment.... It should farther be remembered, that gold is an unproductive part of our capital: that the interest upon the sum exported is so much saved to the country: and that the export of gold serves, as far as it goes, to improve the exchange, by discharging the debt due on account of an unfavourable balance of trade; and to prevent the depreciation of our own paper currency, as compared with the current money payments of other countries.

Thornton's perspective affirms the close interplay between internal and external drains, and thus the interplay between domestic financial stability and currency stability.[12]

The credit-market turbulence that erupted in the summer of 2007 has vividly illustrated that in a world of deeply intertwined financial markets, the potential need for reserves to counter domestic financial instability is not limited to poorer countries. For example, a French bank operating in multiple currencies may well experience a need for dollar liquidity that the European Central Bank cannot directly meet by supplying euros.

If the ECB nonetheless supplies euro credit when dollars are wanted, the euros will be sold for dollars in the foreign exchange market, depressing the euro's dollar price and, contrary to the classical case of LLR support in a closed economy, incipiently raising euro-zone inflation. The ECB can avoid these pressures by purchasing the euros it has lent out with dollar reserves—in effect, carrying out a sterilized sale of dollars. But to do so readily, in the amounts that may be necessary, it may need to hold substantial dollar reserves. Recognizing such needs, the Federal Reserve's Open Market Committee, at its December 11, 2007 meeting, authorized the extension of substantial dollar credits to major foreign central banks.

This rationale for reserve holding even by developed countries is not entirely new, though it has been neglected in the recent discussion of reserve levels, perhaps because emerging-market crises have been much more frequent and salient than crises in the industrialized world. Writing more than two decades ago, Guttentag and Herring (1983, pp. 20–21) expressed concern about "banks located in countries that have adequate LLR facilities for banking activities denominated in domestic currencies but inadequate facilities for coping with foreign-currency difficulties. This category . . . may . . . include banks headquartered in countries with convertible currencies but meager foreign-exchange reserves."[13]

[12]Years later, Bagehot (1873) famously expanded on Thornton's themes. He observed, "Very large loans at very high rates are the best remedy for the worst malady of the money market when a foreign drain is added to a domestic drain. Any notion that money is not to be had, or that it may not be had at any price, only raises alarm to panic and enhances panic to madness...." Later still, Johnson (1958, p. 157) argued that a larger money supply would necessitate larger reserves, but he based his analysis on the monetary approach to the balance of payments rather than on the central bank's LLR role vis-à-vis the domestic banking system.

[13]Guttentag and Herring also note (p. 13) that "banks headquartered in countries with very large dollar reserves can attract Eurodollar deposits on more favorable terms than banks headquartered in countries with relatively small reserves . . . ." This "tiering" phenomenon, which in the 1970s was most evident in periods of international financial stress, could provide a collateral benefit to the banks of countries holding large reserves. We have seen no recent empirical work on this hypothesis, however. Fischer (1999) argues that the IMF, with the ability to provide liquidity in many currencies, can potentially act as an international LLR. Several factors, including the IMF's lack of any direct role in financial regulation and the conditionality of its loans, make its facilities an implausible substitute for national reserve holdings. Indeed the recent global reserve buildup has in part reflected reluctance to depend on the Fund, reluctance that in November 2003 led to discontinuation of the Fund's never-used Contingent Credit Lines, introduced in 1999.

2.3 Summary

Reserve adequacy should be judged relative to M2. In a simple model we illustrate why. Our empirical analysis then shows that a demand for reserves based on the size of M2 does seem to fit the data, and has greater explanatory power than the traditional factors in the long run—and even in the recent build up, where underprediction has been the norm until now.

One paper close in spirit to ours is Lane and Burke (2001). They estimate purely cross-sectional regressions on a 1981–95 sample. They do not find financial openness to be significant in their work, though their use of time averages limits them to using as an independent variable the fraction of time a country is open. In the cross section, financial depth is found to increase reserves significantly. Lane and Burke ascribe this finding to the possibility that some liabilities in the domestic financial system are denominated in foreign currency, directly generating a potential need for more reserves.[14] Our view is broader, and holds that regardless of the currency denomination of these domestic liabilities, they can add to the pressure on the reserves of a central bank that is concerned to limit currency depreciation. The Lane-Burke paper does not consider the recent surge in reserves, as its analysis ends in 1995, but it is a precursor of our paper in its examination of both financial openness and depth.[15]

Our findings have important policy implications. For example, Rodrik (2006) argues that, rather than accumulating costly reserves, countries should take direct measures that would reduce vulnerability to external drains (such as a Chilean-style *encaje*, or tax on short-term capital inflows). The task of substantially reducing the domestic banking system's vulnerability is a more demanding and time-consuming one, however. In the meantime, many countries might be ill advised indeed to forgo the insurance provided by their foreign exchange reserves.

3 Some theoretical motivation

Empirically and in theory, a major motivation for holding international reserves is to support the overall banking system while avoiding extreme currency depreciation. Given this motivation, and a country's vulnerability to portfolio shifts by domestic residents, its demand for international reserves may go far beyond what would be needed simply to insure against a "sudden stop" in foreign capital inflows.

[14] Obstfeld (2004) presents a model along these lines.

[15] Dominguez (2007) suggests that countries with less developed financial markets will tend to hold higher levels of reserves. In her empirical specification, financial development is proxied by the sum of portfolio debt plus equity external liabilities, measured as a share of GDP. Dominguez finds that variable to have a significant negative effect on reserve holdings. Our M2 measure of financial development, in contrast, focuses attention directly on the domestic banking system. Consistent with our interpretation, Dominguez finds that a higher level of private debt liabilities raises a country's reserve demand. Future research should seek to isolate more precisely how different aspects of a country's financial structure affect its demand for international reserves.

This section presents a simple heterogeneous-forecast model to illustrate the positive linkage between the size of the banking sector and a country's demand for international reserves. An appendix explains implications of our crisis scenario for the central bank's balance sheet. The theory provides the basic motivation for the empirical work that follows.

There are two periods in the model, periods 0 and 1. The exchange rate e on date 1 is given by the simple formula

$$e(\theta) = \alpha\theta,$$

where θ is an indicator of the future "state" of the home economy. The exchange rate is quoted as the foreign-currency price of domestic currency, so a fall in e is a depreciation of home currency and relatively low values of θ index relatively unfavorable states. Economic actors in the home country have divergent views of the fundamental that will materialize in period 1. For a given θ — which may or may not be an unbiased forecast of the true future fundamental — domestic agent i holds the expectation that the fundamental will be $\theta + \varepsilon_i$ on date 0, where the noise ε_i is uniformly distributed over the interval $[-\overline{\varepsilon}, \overline{\varepsilon}]$ and $\theta - \overline{\varepsilon} > 0$. Domestic agents are indexed by $i \in [0, 1]$.

We assume that, in period 0, there is already a "sudden stop" situation, in that foreigners are unwilling to purchase domestic currency in the foreign exchange market at any price. For simplicity, we assume that the foreigners no longer hold domestic currency at all. As a result, the exchange rate will be determined in a market involving domestic residents and the home central bank only. We also assume that the domestic authorities can prevent domestic interest rates from fully offsetting expected exchange-rate changes, or that interest-rate increases themselves are so damaging to financial-sector stability that domestic residents discount them. As a simplified way of capturing this situation, we simply ignore the interest that could potentially be earned on currency positions. Thus, what people fundamentally care about is the future exchange rate, $e(\theta)$, compared to today's exchange rate e. If θ is very low (the crisis is expected to continue and even intensify), the currency is very weak. But among domestic residents, there will be divergent opinions about how far the currency will fall.

Domestic residents hold money as domestic bank deposits. Each agent has one deposit whose size is proportional to the broad money supply M. Deposits are perfectly liquid, in that their owners may withdraw them without notice and sell the for foreign exchange. Bank assets are illiquid however — otherwise, as loans were called in, the debtors would cause M to shrink by repaying the banks. This means that the banks can repay depositors only if the receive liquidity assistance from the domestic central bank. (The model would have the same qualitative implications if some fraction of the assets banks held against their liabilities M were liquid.)

Given the preceding assumptions, agent i wishes to trade home money for foreign exchange provided $\mathrm{E}\left\{e(\theta) \mid \theta + \varepsilon_i\right\} = \alpha\left(\theta + \varepsilon_i\right) \leq e$. In words, domestic depositors wish to buy foreign exchange if they expect the home currency to fall below its current level. For a given e, the law of large numbers implies that, the measure of traders such that

$$\alpha\left(\theta+\varepsilon_i\right)\leq e$$

or, equivalently, that $\varepsilon_i \leq \frac{e}{\alpha} - \theta$ is

$$\frac{1}{2\overline{\varepsilon}}\int_{-\overline{\varepsilon}}^{\frac{e}{\alpha}-\theta}\mathrm{d}x=\frac{1}{2\overline{\varepsilon}}\left(\overline{\varepsilon}+\frac{e}{\alpha}-\theta\right).$$

Thus, at an exchange rate of e on date 0, the demand for foreign exchange (in terms of home currency) is

$$\frac{M}{2\overline{\varepsilon}}\left(\overline{\varepsilon}+\frac{e}{\alpha}-\theta\right).$$

As the home currency depreciates in period 0, the demand for foreign currency falls.

The central bank sells R in reserves (measured in foreign currency). Then the equilibrium in the foreign exchange market is given by the equality of domestic demand and supply:

$$\frac{M}{2\overline{\varepsilon}}\left(\overline{\varepsilon}+\frac{e}{\alpha}-\theta\right)=\frac{R}{e}.$$

The equilibrium exchange rate therefore satisfies the quadratic equation

$$e^2-\alpha\left(\theta-\overline{\varepsilon}\right)e-\frac{2\alpha\overline{\varepsilon}R}{M}=0,$$

with (positive) solution

$$e=\frac{\alpha\left(\theta-\overline{\varepsilon}\right)+\sqrt{\alpha^2\left(\theta-\overline{\varepsilon}\right)^2+\frac{8\alpha\overline{\varepsilon}R}{M}}}{2}.$$

This solution shows the role of both reserves and the banking system's liabilities in driving the exchange rate. As R rises the currency strengthens (e rises), and as M rises it weakens.[16]

We can summarize the model's main implications easily. Suppose there is a bad realization of θ (or simply adverse beliefs about θ) and therefore pressure on the currency as people withdraw bank deposits to speculate in foreign exchange. The central bank can moderate today's depreciation using its reserves. Given the central bank's exercise of its LLR role, however, the incipient pressure on the exchange rate will be greater if the size of the banking system, measured by M, is bigger.

Because the scope of the run out of domestic-currency deposits is proportional to the domestic banking system's liabilities under the preceding specification, it is most appropriate to take the size of the broad money supply M2

[16] If $R = 0$, currency would have to fall in period 0 until *everybody* expected an appreciation between dates 0 and 1, making the domestic demand for foreign exchange zero. The currency would overshoot to the level $\alpha\left(\theta-\overline{\varepsilon}\right)<\alpha\theta$.

as an indicator of the potential need for reserves. As we have noted, this is the theoretical approach taken by authors such as Velasco (1987), Calvo and Mendoza (1996), Sachs (1998), and Chang and Velasco (2001), and as we shall see, it receives strong empirical support from our estimates of the demand for foreign exchange reserves.

4 Empirical findings

We have argued on theoretical grounds—and based on historical policymaking best practice going back more than two centuries—that financial-sector protection has always been an important motivation for reserve accumulation when a country is trying to manage its exchange rate. Our goal now is to show empirically that the same holds true today. To foreshadow our main results: we find that the inclusion of financial stability variables greatly improves our ability to explain the great worldwide reserve build-up of recent years. We conclude that these financial stability factors should be at center stage in any empirical analysis of reserve behavior.

To make a case for a different empirical approach, we begin by comparing our proposed new financial-stability-based model of reserve accumulation with a state-of-the-art model of a more traditional kind. To provide such a benchmark we adopt a specification that is used in a recent IMF (2003) study.[17] It was the IMF's poor results using this traditional model that led Jeanne (2007) to conclude that there is no satisfactory linear regression framework that can explain current patterns of reserve accumulation.

In what follows we have two main goals: first, to do better than this traditional model; and second, to do so much better that we can claim to have a credible alternative model of international reserve demand by central banks. We do not argue that elements of the traditional model, or of other models such as the "buffer stock" or "mercantilist" models, are not also important as explanatory factors (Flood and Marion 2002; Aizenman and Lee 2006). If our empirical results prove to be robust, however, it will be important to include financial-stability considerations more explicitly into future research on the demand for international reserves.

4.1 Benchmark comparison: Financial stability versus the traditional model

To begin, we estimate and compare a *traditional* model along the lines of IMF (2003) and our new *financial stability* model. We use an up-to-date and complete data set, and we use a consistent (common) sample for a fair comparison of the

[17]See IMF (2003), chapter 3, table 2.3 for details. Due to the data constraints it puts on our sample, our specification does not currently include export volatility, which is in the IMF regression. In the IMF regression, though, the coefficient was almost exactly zero and was statistically insignificant, so we do not view excluding it as doing great damage to the spirit of that framework.

two specifications. Table 1 reports the results of this comparison using a simple pooled OLS specification with no fixed effects (no FE). The sample consists in each case of 2671 country-year observations. The unbalanced panel covers 26 years from 1980 to 2004 and includes 134 countries.[18]

In all our empirical work, the dependent variable will be the (natural) log of the reserves to GDP ratio (all data are WDI data, unless noted otherwise). In column 1 we present a traditional model of the IMF type, where the regressors are: log population, the log of the import to GDP ratio, exchange rate volatility (the standard deviation of the monthly percentage change in the exchange rate against the relevant base country over the current year, based on author calculations using IFS data), and the log of real GDP per capita (GDP per capita at PPP, that is, in current international dollars).

In column 2 we present our financial-stability based model, where the regressors are: financial openness (the Edwards 2005 index, scaled from 0 to 1), a pegged exchange rate dummy (based on the *de facto* Shambaugh 2004 coding[19]), a soft peg exchange rate dummy,[20] the log of M2 to GDP, the log of trade (imports plus exports) to GDP, and an advanced-country dummy.

The new model passes its initial inspection. Judging by the fit, the financial stability model outperforms the traditional model: the R^2 rises from 0.31 in Column 1 to 0.38 in Column 2. Aside from the peg dummy, all of the proposed explanatory variables are statistically significant.

Logic suggests that a country that cares more about exchange rate stability would be more worried about its ability to cover demands for foreign funds without allowing substantial currency depreciation. While the peg is not significant, we cannot reject that it is equal to the soft peg, so we do not claim harder pegs need fewer reserves, though we do find the soft peg has a larger coefficient in nearly all specifications. In alternative specifications (not shown)

[18] We have excluded dollarized countries and multilateral currency unions (such as the CFA, the Eastern Caribbean Currency Union, and EMU) where division of reserves or M2 across countries may be difficult and where the need for any one country to maintain reserves is different than for countries with their own currencies. EMU countries are included up until 1998, after which individual country M2 data disappear.

[19] A country is classified as pegged if its official exchange rate stays within a +/- 2% band with regards to its base country over the course of a year, or if its exchange rate has no change for 11 months and shows one discrete devaluation. To avoid "accidental" classifications, a country must stay pegged for 2 years to be considered pegged. See Shambaugh (2004) for extensive discussion.

[20] The soft peg classification is created by the authors for this project. A country is considered a soft peg if its exchange rate stays within +/- 5% bands of its base country or if its monthly exchange rate changes by less than 2% in every month. There are 1050 non pegs in the sample, 844 pegs, and 777 soft pegs (with pegs and soft pegs being mutually exclusive) with all but 25 of the soft pegs staying within the 5% bands. As with the peg classification, the system requires a country to be classified a soft peg 2 years in a row to be considered a soft peg. The soft pegs are generally crawling pegs, loose basket pegs, or tight managed floats. Of the 777 observations, 237 are declared as basket pegs, 111 are loose EMS member or tangential to the EMS, 107 are Latin American crawling pegs, 82 are East Asian soft de facto pegs, and 114 are East European soft pegs in the last decade (those five groups comprise 83% of the soft pegs). We note that Japan vs. the US dollar and Germany vs. the US dollar are never classified as soft pegs, demonstrating that countries that allow a fair bit of flexibility are never accidentally classified as soft pegs or pegs.

where we merge peg and soft peg into one indicator variable, it is statistically and quantitatively significant in nearly all cases where soft peg is significant.

The significance of the soft peg, and the fact that it is at least as strong as the peg variable, is sensible. Our previous work (Obstfeld, Shambaugh, and Taylor 2004; 2005) focused on strict peg definitions when examining monetary autonomy due to the fact that the wider the bands, the more monetary autonomy a country had. On the other hand, if a country holds reserves to ward off large devaluations in the face of a financial shock, any country with a preference for non-floating rates is equally exposed. Hence, both pegs and soft pegs may need more reserves than countries that float.[21]

The quantitative importance of financial openness and financial depth is clearly evident. When the financial openness index rises by 1 standard deviation (+0.243 in this sample), the model predicts that the reserve-to-GDP ratio rises by 0.16 log points. When the financial depth measure (log M2/GDP) index rises by 1 standard deviation (+0.674 in this sample), the model predicts that the reserve-to-GDP ratio rises by 0.21 log points. These are potentially large effects: for a developing country that went through a transition from 1 standard deviation below the mean on these two dimensions to 1 standard deviation above the mean, the model would predict that the reserve-to-GDP ratio would close to double, all else equal. The trilemma appears here: the impacts on the reserve/GDP ratio are magnified in countries that peg, where reserve levels are even higher, all else equal.

The contrast between the positive coefficient on GDP per capita in the traditional model and the negative coefficient on the advanced dummy in the financial stability model is worth noting. The advanced dummy in our model is intended to proxy for creditworthiness or ability to issue debt abroad in home currency (we include a variable to directly test the latter on a smaller data sample later). If we include GDP per capita in column 2, it is insignificant with or without the advanced dummy. GDP per capita is highly positively correlated with both M2/GDP and financial openness. The positive sign on this variable in the traditional model seems to come from its possible role as a proxy for the two excluded financial variables. Once these are controlled for, GDP per capita drops out of the regression.

Column 3 shows the financial stability model without including trade. Trade is highly correlated with all our right hand side variables, and we show the results without it to demonstrate that our results are not driven by cross-correlation. Instead, the positive correlation of the independent variables clearly biases the results against our hypothesis—the exclusion of the trade variable leads to larger and more significant results across the board. In particular, we see that the coefficient on pegs (which tend to trade more) moves up substantially.

One of our concerns throughout the empirical analysis will be to ensure that results are not driven by the major differences in patterns of reserve accumulation in advanced countries versus emerging markets and developing countries.

[21]The connection of pegging to reserves should also be weaker than for monetary autonomy as countries could simply follow the base country's interest rate perfectly in which case they may not need many reserves at all even if perfectly pegged.

To break the sample up into these three groups we use a standard classification.[22] Columns 4 through 6 repeat the regression exercise with the sample restricted to just the emerging market countries. The sample size is cut by more than 75%, and falls to just 646 country-year observations, so we can no longer expect estimates to be quite as precise. Nonetheless, the basic message from columns 1 and 2 is confirmed. The fit is better under the new model (and even better in this restricted sample), with an R^2 of 0.60 versus the traditional model's 0.53. Financial openness is statistically significant and the coefficient increases in estimated magnitude to 0.918. Peg remains insignificant and soft peg is now as well, suggesting a stronger relationship for the financial openness side of the trilemma and weaker for pegging for this group of countries. The M2/GDP coefficient falls slightly and the trade coefficient is essentially unchanged.

Table 1 shows that the new model has potentially good explanatory power in an absolute sense, and also relative to the current benchmark IMF model of reserve demand. We obviously need to do more checking for robustness, but these initial results serve as a comparison with the traditional model. They further illustrate the potentially large changes in reserves that could be induced by changes in financial openness and financial depth.

4.2 Robustness: Cross-section versus time-series identification

In this section we subject our benchmark financial stability model to various perturbations, both to check robustness and to identify whether the basic findings emanate from cross-sectional or time-series patterns in the data. Results are reported in Table 2. Columns 1 through 4 examine the maximal sample of data using the benchmark financial stability model. We have 2770 country-year observations, only a slight increase over the sample size underlying Table 1.[23]

In the first column of Table 2 we see that the modest sample enlargement makes little difference to the simple pooled OLS estimates: the coefficients in column 1 of Table 2 are very similar to those reported in column 2 of Table 1.

In the second column of Table 2 we introduce country fixed effects (CFE). This change sweeps out all cross-sectional means, so there is no between identification (and the advanced country dummy is also absorbed). All coefficients are now estimated from time-series variation within country units. The CFE obviously improve the fit (R^2 rises to 0.70). This weakens some but not all of the coefficient estimates. The financial openness coefficient actually increases in size. Peg and soft peg coefficients shrink and become insignificant. The M2 coefficient is cut in half and becomes statistically insignificant. The trade coeffi-

[22] IFS code $<$ 199 are advanced, with the exception of Malta and Turkey. Emerging countries are those in the Morgan Stanley emerging market index plus some eastern European countries.

[23] The sample size in Table 2 is slightly larger than in Table 1 because Table 1 is restricted to those observations with complete data for both the traditional model and the financial stability model. A small subset of countries lacks some data needed to estimate the traditional model (such as GDP per capita); these are added to the sample underlying Table 2.

cient increases. From these results we infer that the effects of pegs and financial deepening (M2) are most clearly manifested in the cross section when using annual data, but all other effects are clearly present in the time dimension.

This impression is confirmed when we switch to year-only fixed effects (YFE) in column 3. Compared with the pooled OLS results in column 1, year effects are statistically significant, but the coefficient estimates do not change by a large or statistically significant amount, and the fit is only modestly improved (R^2 is 0.38 in column 3 versus 0.37 in column 1).

Finally, in Column 4 we add both country and year fixed effects (CYFE). Now the financial openness variable is significant at the 10% level; however, quantitatively speaking its magnitude is still large, around 0.4. The M2 variable is no longer influential and has the wrong sign. In the most conservative CYFE specification, the trade variable appears to be the most robust to specification changes, and still takes a value around 0.6 that is yet again statistically significant at the 1% level.

We next investigate whether the results are sensitive to pooling across different groups of countries. They turn out to be very sensitive. Columns 5 to 10 split the sample up into three subsamples: advanced, emerging and developing, and to save space we compare the two extreme specifications: no fixed effects (no FE) and country-year fixed effects (CYFE). Results for the omitted cases of CFE and YFE are available on request.

For the advanced countries (columns 5 and 6) the sample size is 423 and the fit without fixed effects is similar to the full sample, with an R^2 of 0.44, rising to 0.84 with CYFE. In the emerging markets (columns 6 and 7) the sample size is 646, and fit is much better with no FE, 0.6 rising to 0.85 with CYFE. In developing countries the sample is largest but the fit is poorest with no FE, 0.30 rising to 0.70 with CYFE. The model's relatively strong performance for the EM sample is encouraging, in that the reserve accumulation puzzle is predominantly an emerging market phenomenon.

Several features of the split sample results stand out. First, most coefficients are not stable across these specifications. Second, the trade coefficient is the most robust across all these specifications (only in the Advanced CYFE does it drop out). Third, the M2 variable is significant in the no FE specifications for both the advanced and developing samples and is significant in both the no FE *and* the CYFE regressions for the emerging market sample. This suggests that the financial stability rationale for reserves is most strongly evident in the emerging market group of countries, as we noted in the arguments surrounding our theoretical model. In addition, the relationship is not purely cross-sectional, but shows up within countries even when year effects are included as well. Fourth, the significant role of the peg variables seem to be driven by variation within the developing countries in the sample, as well as pooling between the three subsamples. Within the subsamples, peg coefficients are close to zero and imprecisely estimated regardless of fixed effects in the advanced and emerging groups, but for developing countries soft peg is significant in the no FE specifications.

Fifth, and last, we note that the impact of financial openness is evident within countries in the advanced sample (column 6) but not between countries;

and it is evident between countries elsewhere (columns 7 and 9), but not so much within. We conjecture that this reflects the fact that most advanced countries have, in this sample period 1979–2004, rather quickly completed a nearly full transition through time to full financial openness, providing extensive within variation, but since most are now open, little between variation. In contrast, many emerging and developing countries have not opened, so within variation is more limited, even though the between variation is still substantial.

We further explore the source of identification in the model by examining our results across three broad eras where financial globalization may have been different. Thus, rather than rely on year to year variation, we can ask in which eras different variables appeared to be important and across which eras changes in variables appear to drive changes in reserves. We collapse our data into the 1980s, the pre Asian Crisis 1990s (1990-97), and the post Asian Crisis period (1998-2004). Table 3 shows the results. First, in column 1, we see that, as expected, using the period average data pooled with no fixed effects presents effectively the same results as table 1.

Next, in columns 2 through 4, we compare the between results in the three different eras, that is, we run the purely cross-sectional regression on each of the three eras. M2/GDP is highly significant across all eras with roughly the same coefficient.[24] Trade/GDP is highly significant but becomes less important quantitatively over time (in the most recent era, a larger percentage change in the trade to GDP ratio is needed to get a similar change in the reserves to GDP ratio). Financial openness is most important in the early era; by the last period, we see many countries with more open financial markets holding fewer reserves than their partially closed counterparts. As emerging market countries, many of whom are only partly open to financial flows, have increased reserves this variable is weaker in the full sample cross section. Alternately, pegging and soft pegging are more important lately.[25]

Turning to what explains changes in reserves to GDP ratios across eras, we include country fixed effects in column 5. Thus, country means are removed and all identification comes from changes in variables over time. Financial liberalization, financial depth, and trade all remain economically and statistically important. Thus, when we ask why reserves are higher now than the 1980s, all these factors would seem to be part of the explanation.

Looking across specific eras, we see in columns 6 through 8 that financial depth is a very important variable when explaining changes from the early 1990s to today. It has much less of an explanatory role early in the sample. Thus, it appears financial depth is a variable that has grown in importance as financial markets have opened and financial globalization has grown. Financial liberalization appears most strongly explaining changes in reserves from the early 1980s to today. That is, countries which liberalized in the late 1980s and

[24] Looking just at emerging market countries in annual panels divided by era, we see a growing importance of financial depth over time, suggesting it is even more important in a cross-section of emerging market countries than it was in earlier years.

[25] These results are very similar if one runs regressions on annual data without fixed effects on these eras one at a time

into the 1990s now hold substantially more reserves than in the past. Thus, while year to year variation is not always easy to pin down, looking across broad eras demonstrates the importance of the financial model for explaining how reserves demand has evolved.

4.3 Dollarization and debt: Is the Guidotti-Greenspan rule relevant?

Our next concern is omitted variables related to debt. There are two sets of issues to consider here. First, the ideas of Guidotti and Greenspan have now coalesced into a widely cited rule of thumb, which judges emerging-market reserve adequacy relative to a country's short-term external foreign-currency debt liabilities. The standard benchmark level is 100% of short-term debt coming due within one year. Second, the "original sin" approach focuses on the ability of a country to issue domestic-currency debt to foreigners (Eichengreen, Hausmann, and Panizza 2005). Rather than considering only the overall value of a country's external debt, we also focus on "sin," or the share of internationally issued debt in foreign currency. Thus, while the Guidotti-Greenspan (GG) rule focuses on the possibility of an external run on a country—a sudden stop—our sin variable directly addresses the ability to access foreign exchange in exchange for domestic currency on world markets.

We now test to see whether foreign-currency debts or the ability to issue debt in local currency —measured by either the GG or the sin criterion—play any role in the pattern of reserve accumulation. The results are shown in Tables 4 and 5. We use two samples to examine these questions based on data availability. Short-term foreign-currency external debt data from the Global Finance Database of the World Bank are used to test whether countries follow the GG rule. These data are available only for emerging and developing countries.

The first column of Table 4 estimates the core model on this more limited sample. Results are similar to those previously shown for the emerging markets sample. The results for the GG rule (in columns 2 through 5) are weak. The coefficient is never significantly positive, and is in fact always negative regardless of what type of fixed effects are included.[26] We also considered the debt service burden of countries (column 6) but there was no apparent effect.

Arguably, this is why the rule was promulgated: to get countries to try to follow a new rule that they were not following already. On the other hand, as Summers (2006) has noted, many countries hold reserves far in excess of short-term external foreign-currency debt. Looking more closely at the data, we find that only 290 of the 1935 observations are close to following the GG rule (these are countries where the short-term external debt/reserves ratio is between 75% and 125%). In fact, 1366 have more reserves than short-term foreign-currency debt – but as the regressions show, the level of short-term debt is not a good predictor of the level of reserves. According to the estimates, the more debt a country has, the *fewer* reserves it holds. Thus, while our focus in on financial

[26] Lane and Burke (2001) also find a negative correlation between external debt and reserves.

stability, the focus on external debt or a sudden stop does not receive much support from the regression analysis.[27]

When we turn to the question of the currency of issue on international markets, data availability leaves a sample of only 770 country-year observations, with 168 advanced, 331 emerging, and 271 developing economies included (data are only available from 1993). Our two debt measures are SIN1 (the fraction of internationally issued securities issued in foreign currency) and the log of the ratio to GDP of all external liabilities in foreign currency. Both variables are based on authors' calculations using data from Eichengreen, Hausmann, and Panizza (2005). These results are shown in Table 5. The results show that the "original sin" hypothesis fares better than the Greenspan-Guidotti guideline. While the foreign-currency debt variable that we use here does not allow a pure test of GG, we again see that it fails to show up in a statistically significant manner consistent with the policy prescription. However, the SIN1 variable is significantly positive in 3 cases. It is important to understand why. The SIN1 variable has very little temporal variation, and the time dimension is already very small. For nearly all emerging market or developing countries the original sin measure is very nearly constant (and close to 100%).

Two things follow from these observations. First, SIN1 is essentially a cross-sectional variable. It is therefore driven to insignificance by any specification that includes country fixed effects (such as columns 2 and 4). Second, SIN1 is close to 1 in all but the advanced countries, so there is no variation in the cross-sectional dimension within emerging and developing samples. Hence, the variable is also driven to insignificance by samples that exclude the advanced countries (we thus only report the regressions on the advanced sample, where there is some variation). The results seen in columns 1, 3, and 5 do show that here SIN1 is highly significant—when it varies, it seems to matter quite a bit. Further, it isn't simply a proxy for advanced country status (which presumably entails more effective prudential oversight of the financial markets): as we can see from columns 1 and 3, both Advanced and SIN1 are significant. Thus, from the point of view of economizing on reserves, it is good to be advanced, but it is even better to be a country without sin. Again, these results support the general notion of our theoretical motivation. The concern does not appear to be the size of foreign liabilities (which in general are much smaller than M2), but rather the ability to access foreign currency if necessary.

Finally, in columns 6 and 7 we expand the specification to see whether our results on debt and original sin remain robust across eras. They do. Whether before or after the Asia crisis, the coefficient on SIN1 is statistically significant in full samples that span advanced and other countries (it is not significant otherwise). But the debt variable is never significant, showing that foreign currency debt is not relevant in any period, despite the fact that countries might be more wary of a sudden stop after the Asian Crisis. Again, the sample size is much reduced, but the trade and M2 coefficients are quite stable in magnitude and remain significant at the 1% level.

[27] These results hold if we split the emerging and developing samples apart.

4.4 Then versus now: Have we entered a new era?

We now return to the question of model stability across time. Specifically, we must address the suggestion (discussed in our introduction) that the recent wave of reserve accumulation implies that we have entered a new era, one where the pattern of reserve accumulation shows a pronounced break from that seen in the past. We have already examined the financial model across eras, but now we turn to see if something unexplainable has happened since the Asian Crisis—from either the traditional model's perspective or from the financial model's perspective. It is argued that after the Asian Crisis, poorer countries set out to augment their war chests in ways that regression models cannot predict.

In Table 6, we included specific dummies to examine an issue, explored in Aizenmann and Lee, whether there is a significant shift in the unexplained reserves after crises in the region where a crisis strikes. Specifically, we examine whether there is a shift in East Asian emerging economies after the Asian crisis, and compare this unexplained portion in the financial stability model and the traditional model. We include dummies for post 1997, East Asian Emerging, and the interaction of the two. The first column shows that the traditional model underestimates East Asian reserves significantly in general, underestimates reserves after 1997 and further underestimates the interaction. The combined effect suggests that East Asian reserves are underestimated by 0.849 log points in the traditional model. Column 2, on the other hand, shows that East Asian reserves show no persistent underestimate in the financial model. The model is unable to explain some of the post 1997 surge in reserves and even more for East Asia in that period, with the combined underestimation of 0.376 log points—substantially smaller than for the traditional model.

Including year effects in columns 3 and 4 drops the post 1997 dummy, now the combined underestimation for the traditional model is 0.6 while the underestimate for the financial model is only 0.19 and is not statistically significantly different from zero. Thus, the financial stability model is much better able to explain East Asian reserves in general, and in particular after the Asian Crisis. More importantly, it does not appear that a gaping hole is emerging in our ability to predict reserve levels. We revisit this issue in our out of sample predictions below.

4.5 Does money increase reserve demand or vice versa?

While our estimates support the idea that increased financial depth will generate higher reserve demand, we need to confirm that it is not simply a result of the fact that a central bank increasing its reserves may increase its money supply as a consequence (absent sterilization). Technically, the central bank can determine reserves and money independently, simply sterilizing any transaction in which they change reserve levels with offsetting purchases or sales of domestic assets. Still, we turn in table 7 to verify that it is the size of the banking system or M2 that matters for reserves as opposed to a more limited monetary aggregate like M0.

Our first approach is to change the scaling of reserves. Rather than look at reserves scaled to GDP, we scale reserves by M0 and look at the traditional model and the financial stability model. Column 1 shows that reserves to M0 ratios are higher when imports to GDP is higher and lower when exchange rate volatility is higher. Column 2 demonstrates that much like our previous results, financial openness, pegging, and financial depth (measured by M2/M0) are positively correlated with reserves and an advanced dummy is negative. The financial stability model has a much higher R-squared than the traditional model and is quite similar to the main specification when scaling by GDP.

We can further test the question by simply including M0/GDP in our standard regression specification. We find that M0/GDP is not at all correlated with reserves when controlling for the other independent variables in the financial stability model.[28] More importantly, the M2/GDP coefficient is still the same size (slightly larger) than in our main regressions in table 1. It is not the case that the connection between money and reserves stems from increased money causing reserves to grow. Instead, even controlling for the base money (M0), growth in the financial sector (M2) generates reserves growth.

4.6 In-sample and out-of-sample prediction: Are current reserves excessive?

As noted above, it is often alleged that current reserve holdings are excessive or "unexplainable" based on traditional or debt-level explanations. When considering whether the financial stability models can better explain recent behavior, we can consider two types of tests. First we can use our model within our data sample to try to explain why reserves have been changing. Alternatively, we can stop our model in 2000 and try to use the more recent values of our independent variables to predict reserve holdings in 2001–04 (out of sample) and compare the result to actual reserves.

4.6.1 In-sample prediction

Figure 1 (a-b) shows the growth in emerging market reserves over the past 25 years. We use two models, our basic financial stability model and the "traditional" model.[29] The height of the columns represents the actual amount of reserves year by year in emerging markets. The columns' subsections use the model to explain the growth of reserves over time. The bottom subsection is the amount predicted in 1980 (constant over time). Other subsections allow for changes in one variable at a time. The second lowest is simply the change

[28] The two variables are weakly positively correlated, but with all the financial stability variables included, the relationship is effectively zero. Removing M2/GDP only moves the coefficient to positive but not statistically significantly different from zero.

[29] Our basic financial stability model is like the one in Table 1 column 3 (with trade excluded). We remove trade to clearly separate the financial stability model from the traditional model and to see how far a purely financial stability and trilemma oriented model can go. Further, the regressions used for this figure use a somewhat smaller sample as we must enforce a balanced panel to make sure that changes in the sample are not moving the reserves total.

in GDP assuming all other variables remain constant, etc. The dark shaded subsection represents the amount that cannot be explained by the model (it is the top section when there is an under prediction and under zero if there is over prediction, implying the unexplained portion is negative). As can be seen in Figure 1a, using a financial stability model, growth in GDP alone (assuming a constant reserve/GDP ratio) explains a considerable amount of reserve growth, but beyond that, financial openness and the size of the financial sector explain a considerable amount of additional reserve growth. The model has no trouble predicting the growth in reserves from \$180 billion in 1980 to \$800 billion in 2001. Since then, a gap has opened, but the model still predicts reserves at over \$1.1 trillion by 2004. In contrast, the traditional model in Figure 1b predicts lower levels of reserves in emerging markets broadly and in particular is leaving a considerable volume of reserves unexplained by the mid 1990's. By 2004 the traditional model predicts roughly \$880 billion of reserves and leaves \$700 billion unexplained. Figure 2 provides the same exercise for China alone and paints a very similar picture.

Since projecting forward from 1980 may be a stretch for any model, Figure 3 (a-h) repeats the exercise on a shorter timescale, and with reserves now shown as a ratio to GDP. It provides country examples utilizing the full model including an original sin variable. To generate these figures, we estimate our model on data from 1996–2004.[30] Next, we calculate the predicted values for 1996 and consider that the baseline. We then allow each variable, one by one, to be set equal to its actual value while holding other variables at their 1996 values and consider the difference. Thus, we can check how much of the changing reserves to GDP ratio is generated by changes in each of the independent variables. The figures also show the amount of unexplained reserve holdings as a ratio to GDP (the difference between actual and predicted).

For example, Figure 3a shows that in 1996, China was holding too few reserves relative to our benchmark (unexplained reserves were negative). Over time, the M2 portion of the columns continues to grow, in the end justifying an increase in the reserve/GDP ratio of 7 percentage points. Financial opening in 2004 justifies another small increase in reserves. The United States, in contrast, has not changed its reserve/GDP ratio by much, and the model suggests that this is appropriate.

Japan, on the other hand, has greatly increased its ratio of reserves to GDP in recent years, with little motivation from the financial stability model. Emerging Asia is predicted to hold roughly 20% of GDP in reserves, but in recent years, reserve growth has outpaced our model's benchmark (though not substantially).

For the remaining groups shown, the model does a fair job of explaining the ratios. The model predicts both emerging and developing Latin American countries within a few percentage points of GDP. Recent surges in Emerging EU countries are left somewhat unexplained, but this amounts to about 7% of GDP. The model is able to explain why emerging Latin American countries hold

[30]Data constraints when using sin and foreign currency debt necessitate starting at the later date

fewer reserves than emerging Asia. Both hold a few percent over predicted in 2004, but emerging Asia's predicted reserves are on average 20% of GDP (even with China taken out) and emerging Latin America is predicted to hold reserves equal to 12% of GDP.

4.6.2 Out-of-sample prediction

Instead of trying to understand how what is driving the changes in reserves over time, we may also want to test how well we are able to predict reserves out of sample. Jeanne (2007) suggests that despite acceptable in-sample projections, regressions are unable to explain the recent surge in reserves. The in-sample figures above showed that a considerable amount of the level and ratio to GDP of reserves can be explained using a financial stability model, but these were all in-sample explanations, not pure predictions. We also estimate our model on data from 1993 (the first year for which we have sin data) to 2000, and then try to predict reserves a number of years out (2004 being the last year for which we have a full set of independent variables).[31] Figure 4a shows actual reserves on the vertical axis and compares them to the reserves level that the financial stability model predicts for 2004. The points cluster relatively close to the 45-degree line (where actual and predicted reserves coincide), and many controversial cases (such as that of China) are rather close to it. (China is marked by an arrow.) In contrast, Figure 4b shows the same scatter, but using the traditional model to make the reserve predictions. The scatter is more dispersed relative to the 45-degree line, and in particular, more countries are far away from the line. (China is now considerably farther away from the diagonal.)

One way to compare the two figures is to note that the R^2 of a regression of actual reserves/GDP on the predicted using the financial stability model is 0.52, and the slope coefficient is 1.33. Thus, on average, our model underpredicts some at the high end, but the amount is not glaring. In contrast, using the traditional model, the R^2 is only 0.41 and the slope coefficient is 1.81, suggesting a more severe underprediction of the largest reserve holdings using the traditional model.[32]

Rather than focus on 2004, we can also show the performance of the model over time. We again run the regressions on data from 1993–2000 and we present in Figure 5 the actual, financial-stability-predicted, and traditional-predicted reserve/GDP ratios for a number of countries or country groups.[33] The financial stability model is able to largely explain the rise of reserves in China (at least

[31] In contrast to Figure 3 which generates a slightly larger sample by sacrificing some early years (1993-5), in this exercise, we use the years 1993-5 and report on fewer countries due to the need for a sufficient time series before our cutoff date, 2000.

[32] Removing the large outlier Singapore improves the performance of the financial model, shifting the R^2 up to 0.68 and lowering the slope coefficient to 1.23. For the traditional model, the effect is mixed. Removing Singapore lowers the R^2 down to 0.32, but it also lowers the slope coefficient closer to 1 (from 1.81 down to 1.38).

[33] The number of groups is smaller than in Figure 3 due to the need for a balanced panel in both the traditional and financial stability models.

until the last year of the sample, 2004).[34] The financial stability model does quite a bit better for the United States than does a traditional model. For the three emerging market country groups, the financial stability model is always closer to actual than the traditional model, though in the most recent years, the gap between predicted and actual reserves is growing in emerging Asia.[35] Finally, though, we see that no model can explain the massive run up in reserves for Japan. One could suggest many reasons for its large reserves: attempts to prevent deflation by buying foreign assets, attempts to prevent appreciation, taking advantage of low home interest rates and higher United States rates, but neither the financial stability nor the traditional model captures these effects.

In general, we find that the financial stability model can predict with reasonable accuracy the official reserve holding behavior of the last decade. There are notable exceptions (Japan, Singapore, and to some degree China in the last two years), but in light of the financial stability model that we have proposed, the puzzle appears far less dramatic than traditional models or models based on foreign debt and sudden stops would suggest.

5 Conclusion

The recent and rapid accumulation of reserves by emerging markets with pegged or quasi-pegged exchange rates is often considered inexplicable. The practice of emerging central banks seems far ahead of any coherent theory—and hence an economic puzzle, if not a policy problem. Puzzling it may be in terms of the prevailing models of reserve accumulation from the 1960s and 1970s, and even the more recent Guidotti-Greenspan rule of the 1990s, which emerged from the Asian Crisis of 1997.

However, in terms of operational rules devised in the 1790s, following the Panic of 1797, the current trends make more sense. In the eighteenth and nineteenth centuries the Bank of England found itself with the responsibilities of a Lender of Last Resort, under a Gold Standard system, in an economy undergoing rapid financial development. And in that era too, as noted by T. S. Ashton, practice preceded theory (Kindleberger 2000, p. 162).

A visionary thinker realized that with a fixed exchange rate and a growing base of bank deposits to worry about, a central bank needed to grow its reserves if it were to face down the threat of external and internal drains. Thus, reserve adequacy had to be gauged against the size of the banking sector. It took quite some time for Henry Thornton's ideas to be fully appreciated in 19th century England; they appear to have been much more rapidly grasped in 21st century China.

[34] As in Figure 3, the 1993ff sample does a better job of predicting China's holdings in the early 2000s than a full 1980ff sample because the 1980s had a weaker coefficient on financial variables (as shown in Table 4).

[35] Malaysia and Thailand seem to be important drivers of this result.

Appendix:
Twin crises and the central bank balance sheet

At the center of the financial system is the central bank. Its balance sheet identity has the form

$$H + Currency + CBC = D + \bar{E}R,$$

where H denotes banking-system deposits (high-powered money), $Currency$ denotes currency (assumed held outside the central bank), CBC is central-bank capital, D denotes domestic assets of the central bank, $\bar{E}$ is the domestic-currency price of foreign exchange, and R denotes international reserves (measured in foreign currency). We assume for simplicity that the exchange rate is fixed, although, as noted earlier, matters are not much different if the rate is flexible and the authorities simply wish to limit depreciation.

The private banking system's liabilities M constitute the money supply (not including currency), whereas its assets are high-powered central bank deposits H and illiquid loans L. If PBC denotes private bank capital, the private banking system's balance sheet identity is

$$M + PBC = H + L.$$

We wish to consider a scenario of simultaneous internal and external drain, in which residents attempt to convert bank deposits M into foreign exchange. Our assumption is that currency holdings are not responsive to depreciation expectations—perhaps they are determined by a relatively interest inelastic cash-in-advance demand. The demand for bank deposits is, however, elastic with respect to the nominal domestic bond rate i, with a Cagan-type demand given by

$$lnM - lnP = \mu - \lambda i.$$

Now suppose that there is a sudden rise in the market's depreciation expectations, such that the bond rate i doubles. If the interest elasticity of money demand is 0.5, then the volume of deposits demanded will fall by 25 percent. If the banking system cannot liquidate loans in the short run, it must pay off these deposits using central-bank deposits—so H as well as central bank international reserves fall by $0.25M$.

If central-bank foreign reserves cannot cover the capital outflow, and measures other than intervention are unavailable to support the exchange rate, there will be a depreciation. Let us suppose for the moment that international reserves are sufficient, however. It is still possible, given the importance of currency in the overall monetary base, that banking-system liquidity cannot cover desired withdrawals: $H < 0.25M$ In this case the central bank will act as a lender of last resort, effectively purchasing debt instruments worth $0.25M - H$ from the banking system in exchange for newly issued high-powered money. At the end of the day, the central bank's balance sheet has become

$$\begin{aligned} Currency + CBC &= (D + .25M - H) + \bar{E}R - H - (.25M - H) \\ &= (D + .25M - H) + (\bar{E}R - .25M). \end{aligned}$$

The second line emphasizes that domestic assets are higher by the amount of the LLR support, whereas reserves are lower by $0.25M$. The private banking system is illiquid and its balance sheet is

$$.75M + PBC = L - (.25M - H).$$

Now let us consider, realistically, that such an operation might stretch the central bank's international reserves. What options are available to the central bank if it wishes to control the exchange rate? At this stage, much of the central bank's domestic assets may consist of banking system loans that it will be unable to market except at a steep loss. At a time of uncertainty the line between illiquidity and insolvency may be blurred, if it is visible at all. This is, after all, why the LLR is needed in the first place. But with the banks' loans (now passed on to the central bank directly or as collateral) being difficult to value, it may be uncertain ex ante whether the liquidity provision is a loan or a subsidy. If the latter, a large prospective (or actual) bailout may endanger central bank capital and, in fact, pose a possible drain on the public-sector finances more generally.

Matters are not much better if the authorities seek merely to limit, rather than stop, depreciation. The considerations making a large reserve stock essential are basically the same. The ability of domestic residents to switch into foreign-currency deposits offered by the domestic banking system also helps little, because banks will be under interest-rate pressure and will wish to buy central bank foreign reserves so as to avoid an increasing currency mismatch on their own books.

References

Aizenman, Joshua, and Jaewoo Lee. 2006. "International Reserves: Precautionary versus Mercantilist Views, Theory and Evidence." Photocopy. UC-Santa Cruz and International Monetary Fund (March).

Aizenman, Joshua, and Nancy Marion. 2003. "The High Demand for International Reserves in the Far East: What's Going On?" *Journal of the Japanese and International Economies* 17 (September): 370–400.

Baek, Seung-Gwan, and Changkyu Choi. 2004. "Exchange Rate regimes and International Reserves." Photocopy. Myongji University and Hongik University (August).

Bagehot, Walter. 1873. *Lombard Street: A Description of the Money Market.* London: Kegan, Paul & Co.

Bahmani-Oskooee, M., and F. Brown. 2002. "Demand for International Reserves: A Review Article." *Applied Economics* 34 (July): 1209–26.

Bird, Graham, and Ramkishen Rajan. 2003. "Too Much of a Good Thing? The Adequacy of International Reserves in the Aftermath of Crises." *World Economy* 86 (June): 873–91.

Blustein, Paul. 2005. *And the Money Kept Rolling In (And Out): Wall Street, the IMF, and the Bankrupting of Argentina.* New York: Public Affairs.

Calvo, Guillermo A., and Enrique G. Mendoza. 1996. "Mexico's Balance-of-Payments Crisis: A Chronicle of a Death Foretold." *Journal of International Economics* 41 (November): 235–64.

Calvo, Guillermo A., and Carmen M. Reinhart. 2000. "When Capital Flows Come to a Sudden Stop: Consequences and Policy." In *Reforming the International Monetary and Financial System*, edited by Peter B. Kenen and Alexander K. Swoboda. Washington, D.C.: International Monetary Fund.

Chang, Roberto, and Andrés Velasco. 2001. "Financial Crises in Emerging Markets: A Canonical Model." *Quarterly Journal of Economics* 116: 489–517.

della Paolera, Gerardo, and Alan M. Taylor. 2002. "Internal Versus External Convertibility and Emerging-Market Crises: Lessons from Argentine History." *Explorations in Economic History* 39 (4): 357–89.

della Paolera, Gerardo, and Alan M. Taylor. 2003. "Gaucho Banking Redux." *Economía* 3: 1–42.

Dominguez, Kathryn M. E. 2007. "International Reserves and Underdeveloped Capital Markets." Photocopy. University of Michigan (October).

Dornbusch, Rudiger, and Jacob A. Frenkel. 1984. "The Gold Standard and the Bank of England in the Crisis of 1847." In *A Retrospective on the Classical Gold Standard, 1821–1931*, edited by M. D. Bordo and A. J. Schwartz. Chicago: University of Chicago Press.

Durdu, Ceyhun Bora, Enrique G. Mendoza, and Marco Terrones. 2007. "Precautionary Demand for Foreign Assets in Sudden Stop Economies: An Assessment of the New Merchantilism." IMF Working Paper WP/07/146 (June).

Edwards, Sebastian. 2005. "Capital Controls, Sudden Stops, and Current Account Reversals." Working Paper 11170, National Bureau of Economic Research.

Eichengreen, Barry, Ricardo Hausmann, and Ugo Panizza. 2005. "The Pain of Original Sin." In *Other Peoples' Money*, edited by Barry Eichengreen and Ricardo Hausmann. Chicago: University of Chicago Press, pp. 13–47.

Fischer, Stanley. 1999. "On the Need for an International Lender of Last Resort." *Journal of Economic Perspectives* 13 (Fall): 85–104.

Flood, Robert, and Nancy Marion. 2002. "Holding International Reserves in an Era of High Capital Mobility." In Susan M. Collins and Dani Rodrik, eds. *Brookings Trade Forum 2001.* Washington, D.C.: Brookings Institution, pp. 1–68.

Frenkel, Jacob A., and Boyan Jovanovic. 1981. "Optimal International Reserves: A Stochastic Framework." *Economic Journal* 91 (June): 507–14.

Goldstein, Itay. 2005. "Strategic Complementarities and the Twin Crises." *Economic Journal* 115 (April): 368–90.

Greenspan, Alan. 1999. "Currency Reserves and Debt." Remarks before the World Bank Conference on Recent Trends in Reserves Management, Washington, D.C. (April 29). http://www.federalreserve.gov/boardDocs/speeches/1999/19990429.htm.

Guttentag, Jack, and Richard Herring. 1983. "The Lender-of-Last-Resort Function in an International Context." *Princeton Essays in International Finance* 151 (May).

Heller, H. Robert. 1966. "Optimal International Reserves." *Economic Journal* 76 (June): 296–311.

IMF. 2003. *World Economic Outlook 2003.* Washington, D.C: International Monetary Fund.

Jeanne, Olivier. 2007. "International Reserves in Emerging Market Countries: Too Much of a Good Thing?" *Brookings Papers on Economic Activity* 1: 1–79.

Jeanne, Olivier, and Romain Rancière. 2006. "The Optimal Level of International Reserves for Emerging Market Countries: Formulas and Applications." IMF Working Paper WP/06/229 (October).

Johnson, Harry G. 1958. "Towards a General Theory of the Balance of Payments." In *International Trade and Economic Growth.* London: George Allen and Unwin.

Keynes, John Maynard. 1971. *A Treatise on Money. Volume 2: The Applied Theory of Money.* In *The Collected Writings of John Maynard Keynes, Volume VI.* London: Macmillan (for the Royal Economic Society).

Kindleberger, Charles P. 2000. *Manias, Panics, and Crashes: A History of Financial Crises,* 4^{th} ed. New York: Wiley.

Klein, Michael W., and Jay C. Shambaugh. 2006. "The Nature of Exchange Rate Regimes." Working Paper 12729, National Bureau of Economic Research.

Lane, Philip R., and Dominic Burke. 2001. "The Empirics of Foreign Reserves." *Open Economies Review* 12 (October): 423–34.

Levy Yeyati, Eduardo. 2006. "The Cost of Reserves." Documento de Trabajo 10/2006, Centro de Investigación en Finanzas, Universidad Torcuato Di Tella (July).

Levy Yeyati, Eduardo, Sergio L. Schmukler, and Neeltje Van Horen. 2004. "The Price of Inconvertible Deposits: The Stock Market Boom During the Argentine Crisis." *Economics Letters* 83(1): 7–13.

Miller, Victoria. 1996. "Speculative Currency Attacks with Endogenously Induced Commercial Bank Crises." *Journal of International Money and Finance* 15 (June): 383–403.

Miller, Victoria. 2000. "Central Bank Reactions to Banking Crises in Fixed Exchange Rate Regimes." *Journal of Development Economics* 63 (December): 451–72.

Obstfeld, Maurice. 2004. "Globalization. Macroeconomic Performance, and the Exchange Rates of Emerging Economies." *Monetary and Economic Studies* 22 (December): 29–55.

Obstfeld, Maurice, Jay C. Shambaugh, and Alan M. Taylor. 2004. "Monetary Sovereignty, Exchange Rates, and Capital Controls: The Trilemma in the Interwar Period." *IMF Staff Papers* 51: 75–108.

Obstfeld, Maurice, Jay C. Shambaugh, and Alan M. Taylor. 2005. "The Trilemma in History: Tradeoffs among Exchange Rates, Monetary Policies, and Capital Mobility." *Review of Economics and Statistics* 87 (August): 423–38.

Reinhart, Carmen M., and Kenneth S. Rogoff. 2004. "The Modern History of Exchange Rate Arrangements: A Reinterpretation." *Quarterly Journal of Economics* 119 (February): 1–48.

Rodrik, Dani, 2006. "The Social Cost of Foreign Exchange Reserves." *International Economic Journal* 20 (September): 253–66.

Rothenberg, Alexander D., and Francis E. Warnock. 2006. "Sudden Flight and True Sudden Stops." Working Paper 12726, National Bureau of Economic Research.

Sachs, Jeffrey D. 1998. "Creditor Panics: Causes and Remedies." Photocopy. Harvard University (October). http://www.cid.harvard.edu/archive/hiid/papers/cato.pdf.

Shambaugh, Jay C. 2004. "The Effects of Fixed Exchange Rates on Monetary Policy." *Quarterly Journal of Economics* 119 (February): 301–52.

Shin, Hyun Song. 2005. "Liquidity and Twin Crises." *Economic Notes* 34 (3):257–277.

Summers, Lawrence H. 2006. "Reflections on Global Account Imbalances and Emerging Markets Reserve Accumulation." L. K. Jha Memorial Lecture, Reserve Bank of India (March). http://www.president.harvard.edu/speeches/ 2006/0324_rbi.html.

Thornton, Henry. 1939. *An Enquiry into the Nature and Effects of the Paper Credit of Great Britain (1802)*, edited with an introduction by F. A. von Hayek. London: George Allen and Unwin.

Velasco, Andrés. 1987. "Financial Crises and Balance of Payments Crises: A Simple Model of Southern Cone Experience." *Journal of Development Economics* 27: 263–83.

Viner, Jacob. 1937. *Studies in the Theory of International Trade.* New York: Harper & Brothers.

Wijnholds, J. Onno de Beaufort, and Arend Kapteyn. 2001. "Reserve Adequacy in Emerging Market Economies." IMF Working Paper WP/01/43 (September).

Williamson, John. 1973. "Surveys in Applied Economics: International Liquidity." *Economic Journal* 83 (September): 685–746.

Table 1: Traditional and Financial Stability Models of Reserve Demand

	1 Traditional	2 Financial stability	3 Financial stability	4 Traditional	5 Financial stability	6 Financial stability
ln(Population)	0.021			0.034		
	0.035			*0.068*		
ln(Imports/GDP)	0.806			0.790		
	*0.097***			*0.131***		
Exch. Rate Volatility	-0.011			0.092		
	0.009			*0.143*		
ln(GDP/Population)	0.158			0.149		
	*0.042***			*0.088*		
Financial openness		0.671	1.035		0.918	1.632
		*0.174***	*0.212***		*0.186***	*0.337***
Peg		0.095	0.246		0.023	0.022
		0.077	*0.093***		*0.118*	*0.127*
Soft peg		0.167	0.289		-0.012	0.065
		*0.060***	*0.078***		*0.115*	*0.124*
ln(M2/GDP)		0.311	0.444		0.238	0.569
		*0.072***	*0.086***		*0.118+*	*0.117***
ln(Trade/GDP)		0.583			0.570	
		*0.071***			*0.075***	
Advanced		-0.554	-0.858			
		*0.125***	*0.161***			
Constant	-6.818	-6.253	-4.538	-6.731	-5.904	-5.242
	*0.911***	*0.360***	*0.288***	*1.958***	*0.424***	*0.491***
Observations	2671	2671	2671	646	646	646
R-squared	0.31	0.38	0.27	0.53	0.60	0.49
Sample	Full	Full	Full	Emerging	Emerging	Emerging

Standard errors clustered at country level in italics.
+ significant at 10%; * significant at 5%; ** significant at 1%.
No fixed effects in these regressions.
Dependent variable: ln(reserves/GDP).

Table 2: The Financial Stability Model across Samples and Fixed Effects

	1	2	3	4	5	6	7	8	9	10
Financial Openness	0.555	0.708	0.413	0.378	-0.374	1.013	0.918	0.121	0.596	0.438
	*0.179***	*0.206***	*0.191**	*0.214+*	*0.42*	*0.419**	*0.186***	*0.206*	*0.237**	*0.329*
Peg	0.117	0.037	0.114	0.013	0.005	0.028	0.023	0.071	0.166	0.029
	0.084	*0.066*	*0.085*	*0.062*	*0.157*	*0.103*	*0.118*	*0.063*	*0.112*	*0.084*
Soft peg	0.172	0.068	0.151	0.046	0.101	0.006	-0.012	0.023	0.239	0.066
	*0.060***	*0.046*	*0.061**	*0.043*	*0.124*	*0.085*	*0.115*	*0.079*	*0.076***	*0.058*
ln(M2/GDP)	0.323	0.174	0.319	-0.028	0.617	0.283	0.238	0.348	0.327	-0.156
	*0.072***	*0.107*	*0.073***	*0.109*	*0.229**	*0.231*	*0.118+*	*0.121***	*0.106***	*0.132*
ln(Trade/GDP)	0.584	0.748	0.570	0.601	0.992	-0.375	0.570	0.604	0.562	0.605
	*0.070***	*0.149***	*0.073***	*0.145***	*0.179***	*0.359*	*0.075***	*0.177***	*0.111***	*0.205***
Advanced	-0.545		-0.462							
	*0.123***		*0.133***							
Constant	-6.230	-6.499	-6.082	-4.590	-8.836	-2.933	-5.904	-5.764	-6.241	-4.734
	*0.358***	*0.638***	*0.378***	*0.697***	*1.445***	*2.333*	*0.424***	*0.868***	*0.505***	*0.958***
Observations	2770	2770	2770	2770	423	423	646	646	1701	1701
R-squared	0.37	0.70	0.38	0.73	0.44	0.84	0.60	0.85	0.30	0.70
Sample	Full	Full	Full	Full	Advanced	Advanced	Emerging	Emerging	Developing	Developing
Year fixed effects			x	x		x		x		x
Country fixed effects		x		x		x		x		x

Standard errors clustered at country level in italics.

+ significant at 10%; * significant at 5%; ** significant at 1%.

Dependent variable: ln(Reserves/GDP).

Table 3: The Financial Stability Model across Eras

	1	2	3	4	5	6	7	8
Financial openness	0.449	0.936	0.332	-0.139	0.668	0.259	0.488	0.987
	*0.206**	*0.389**	*0.314*	*0.237*	*0.235***	*0.246*	*0.332*	*0.304***
Peg	0.159	0.053	0.232	0.286	-0.062	0.193	-0.060	-0.352
	0.119	*0.214*	*0.153*	*0.151+*	*0.135*	*0.153*	*0.23*	*0.189+*
Soft peg	0.281	0.132	0.202	0.498	0.070	0.266	-0.091	-0.121
	*0.138**	*0.305*	*0.172*	*0.189***	*0.147*	*0.156+*	*0.235*	*0.23*
ln(M2/GDP)	0.385	0.372	0.387	0.363	0.284	0.483	0.042	0.345
	*0.078***	*0.138***	*0.080***	*0.079***	*0.165+*	*0.164***	*0.259*	*0.209*
ln(trade/GDP)	0.521	0.587	0.490	0.350	0.762	0.754	0.889	0.567
	*0.072***	*0.151***	*0.104***	*0.103***	*0.202***	*0.224***	*0.355**	*0.217***
Advanced	-0.658	-0.432	-0.714	-0.752				
	*0.132***	*0.224+*	*0.186***	*0.171***				
Constant	-6.101	-6.586	-5.954	-4.877	-6.853	-7.409	-6.434	-6.243
	*0.359***	*0.571***	*0.429***	*0.483***	*0.786***	*0.802***	*1.358***	*0.880***
Observations	370	104	134	132	370	266	238	236
R-squared	0.43	0.43	0.47	0.40	0.82	0.91	0.88	0.84
Sample	Full	1980-89	1990-97	1998-2004	Full	90-97/98-04	80-89/90-97	80-89/98-04
Country fixed effects					x	x	x	x

Standard errors clustered at country level in italics.
+ significant at 10%; * significant at 5%; ** significant at 1%.
Dependent variable: ln(reserves/GDP).
Observations are collapsed into the three eras: 1980-89, 1990-97, 1998-2004. Thus, there are 3 observations per country in column 1 and 5, 1 observation per country in columns 2-4, and 2 observations per country in 6-8.

Table 4: The Impact of Short-Term External Debt (the Guidoitti-Greenspan Rule)

	1	2	3	4	5	6
Financial openness	0.861	0.912	0.760	0.637	0.217	0.845
	*0.191***	*0.193***	*0.219***	*0.224***	*0.235*	*0.189***
Peg	0.152	0.100	0.090	0.100	0.066	0.132
	0.088+	*0.085*	*0.076*	*0.084*	*0.071*	*0.083*
Soft peg	0.163	0.120	0.110	0.086	0.072	0.150
	*0.061***	*0.055**	*0.050**	*0.056*	*0.047*	*0.059**
ln(M2/GDP)	0.295	0.327	0.172	0.325	-0.045	0.302
	*0.082***	*0.078***	*0.121*	*0.080***	*0.124*	*0.081***
ln(trade/GDP)	0.470	0.492	0.814	0.448	0.596	0.491
	*0.079***	*0.081***	*0.172***	*0.086***	*0.170***	*0.088***
Ln(Short Term Ext. Debt/GDP)		-0.111	-0.111	-0.098	-0.088	
		*0.053**	*0.038***	*0.056+*	*0.034**	
Ln(DebtService/GNI)						-0.052
						0.065
Constant	-5.839	-6.390	-7.111	-6.001	-5.175	-5.860
	*0.396***	*0.484***	*0.712***	*0.518***	*0.752***	*0.405***
Observations	1935	1935	1935	1935	1935	1922
R-squared	0.31	0.33	0.66	0.36	0.69	0.31
Sample	limited by data	limited by data	limited by data	limited by data	limited by data	limited by data
Year fixed effects				x	x	
Country fixed effects			x		x	

Standard errors clustered at country level in italics.

+ significant at 10%; * significant at 5%; ** significant at 1%.

Dependent variable: ln(reserves/GDP).

No advanced countries in the samples.

Table 5: The Role of "Sin"

	1	2	3	4	5	6	7
Financial openness	0.413	-0.046	0.409	-0.037	0.073	0.590	0.261
	0.229+	*0.217*	*0.228+*	*0.19*	*0.657*	*0.309+*	*0.22*
Peg	0.082	0.225	0.073	0.165	0.242	0.042	0.119
	0.091	*0.078***	*0.092*	*0.069**	*0.148*	*0.105*	*0.114*
Soft peg	0.078	0.063	0.068	0.057	0.155	-0.030	0.156
	0.062	*0.05*	*0.062*	*0.048*	*0.123*	*0.09*	*0.086+*
ln(M2/GDP)	0.548	0.535	0.540	0.301	0.696	0.437	0.607
	*0.086***	*0.198***	*0.088***	*0.184*	*0.222***	*0.115***	*0.084***
ln(trade/GDP)	0.376	0.818	0.376	0.570	0.457	0.460	0.310
	*0.098***	*0.175***	*0.102***	*0.169***	*0.288*	*0.113***	*0.107***
Advanced	-0.712		-0.643			-0.457	-0.780
	*0.148***		*0.166***			*0.194**	*0.183***
Sin1	1.354	-0.621	1.438	-0.281	2.122	1.666	1.311
	*0.402***	*1.123*	*0.411***	*1.032*	*0.648***	*0.485***	*0.521**
ln(Foreign Curr. Debt/GDP)	0.035	-0.007	0.015	-0.076	-0.238	-0.030	0.051
	0.03	*0.031*	*0.035*	*0.031**	*0.158*	*0.057*	*0.032*
Constant	-7.228	-7.174	-7.342	-5.855	-9.845	-7.855	-6.978
	*0.627***	*1.452***	*0.639***	*1.491***	*1.510***	*0.878***	*0.737***
Observations	770	770	770	770	168	306	464
R-squared	0.58	0.89	0.58	0.90	0.57	0.52	0.61
Sample	limited by data	limited by data	limited by data	limited by data	Advanced	1990-97	1998-2004
Year fixed effects			x	x			
Country fixed effects		x		x			

Standard errors clustered at country level in italics.

+ significant at 10%; * significant at 5%; ** significant at 1%.

Dependent variable: ln(reserves/GDP).

Table 6: Changes After the Asia Crisis

	1	2	3	4
	Traditional	Financial stability	Traditional	Financial stability
ln(Population)	-0.032		-0.039	
	0.04		*0.04*	
ln(Imports/GDP)	0.661		0.638	
	*0.098***		*0.100***	
Exch. Rate Volatility	-0.009		-0.007	
	0.008		*0.006*	
ln(GDP/Population)	0.146		0.141	
	*0.041***		*0.042***	
Financial openness		0.571		0.551
		*0.178***		*0.184***
Peg		0.107		0.093
		0.077		*0.078*
Soft peg		0.168		0.150
		*0.058***		*0.059**
ln(M2/GDP)		0.299		0.302
		*0.081***		*0.081***
ln(Trade/GDP)		0.571		0.569
		*0.073***		*0.074***
Advanced		-0.489		-0.480
		*0.137***		*0.141***
Constant	-5.484	-6.176	-5.169	-6.100
	*0.968***	*0.374***	*0.980***	*0.384***
Post 97	0.273	0.187		
	*0.054***	*0.060***		
East Asia EM	0.315	-0.047	0.332	-0.043
	0.187+	*0.145*	*0.189+*	*0.146*
East Asia EM x Post 97	0.261	0.236	0.261	0.228
	*0.128**	*0.124+*	*0.128**	*0.124+*
Observations	2671	2671	2671	2671
R-squared	0.34	0.39	0.35	0.40
Fixed effects	None	None	Year	Year
Sum of dummies	0.849	0.376	0.593	0.185

Standard errors clustered at country level in italics.
+ significant at 10%; * significant at 5%; ** significant at 1%.

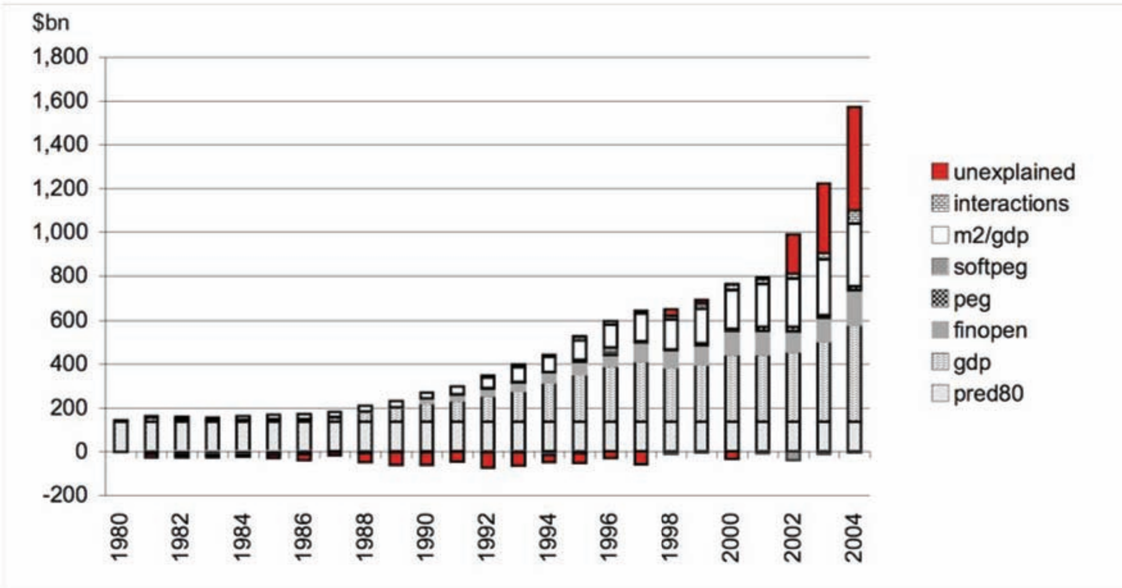
Table 7: The Monetary Base and M2

	1	2	3	4
	Traditional	Fin Stability	Fin Stability	Fin Stability
Dependent variable	ln(res/M0)	ln(res/M0)	ln(res/M0)	ln(res/GDP)
ln(Population)	-0.019			
	0.043			
ln(Imports/GDP)	0.635			
	*0.131***			
Exch. Rate Volatility	-0.028			
	*0.008***			
ln(GDP/Population)	0.094			
	0.049+			
Financial openness		0.599	0.906	0.629
		*0.203***	*0.220***	*0.165***
Peg		-0.012	0.151	0.100
		0.096	*0.105*	*0.078*
Soft peg		0.117	0.238	0.165
		0.064+	*0.080***	*0.060***
ln(M2/M0)		0.688	0.746	
		*0.076***	*0.076***	
ln(Trade/GDP)		0.473		0.587
		*0.082***		*0.071***
Advanced		-0.851	-1.048	-0.542
		*0.144***	*0.178***	*0.124***
ln(M2/GDP)				0.352
				*0.080***
ln(M0/GDP)				-0.089
				0.084
Constant	-3.15	-3.318	-1.623	-6.158
	*1.110***	*0.348***	*0.144***	*0.377***
Observations	2664	2763	2763	2665
R-squared	0.18	0.36	0.3	0.38

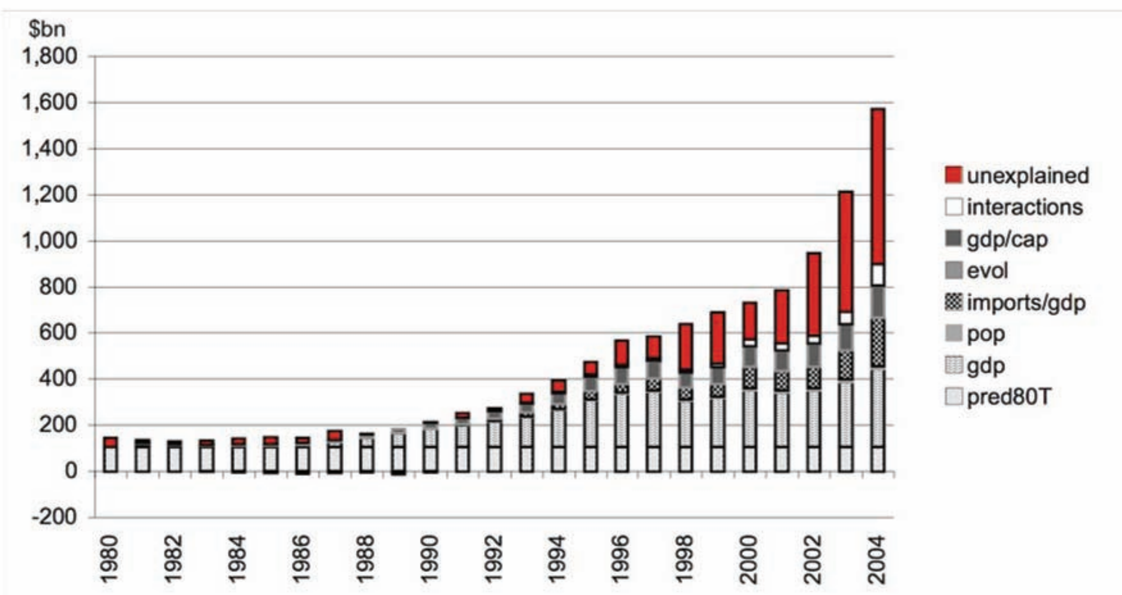
Standard errors clustered at country level in italics.
+ significant at 10%; * significant at 5%; ** significant at 1%.
No fixed effects in these regressions.

Figure 1: In-Sample: What Explains Post-1980 Increases in Emerging Market Reserves?

(a) Emerging Market Sample: Financial Stability Model



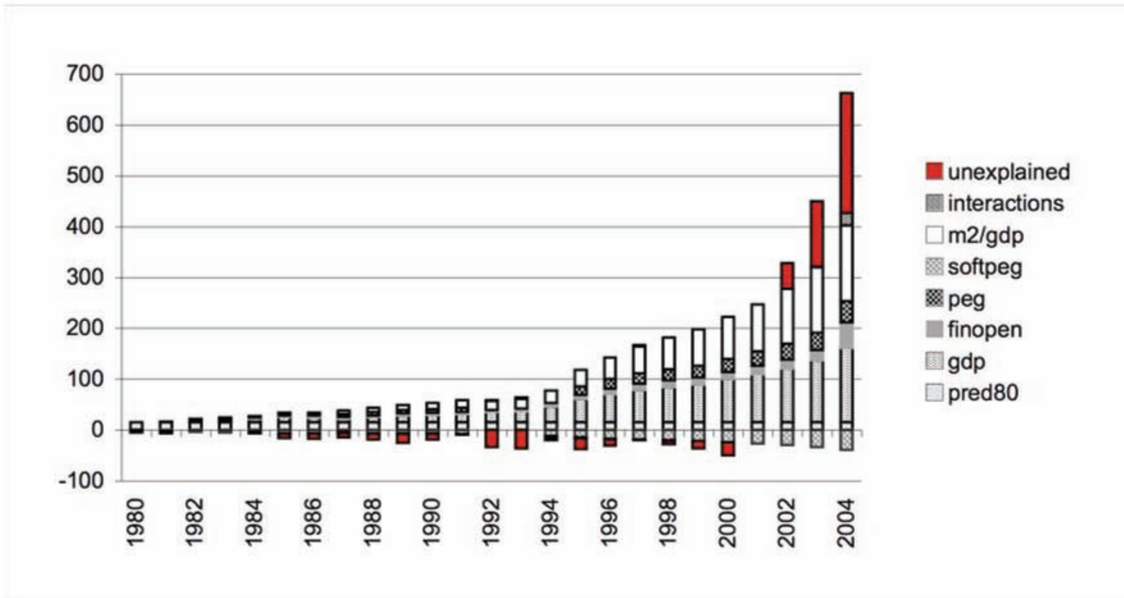
(b) Emerging Market Sample: Traditional Model



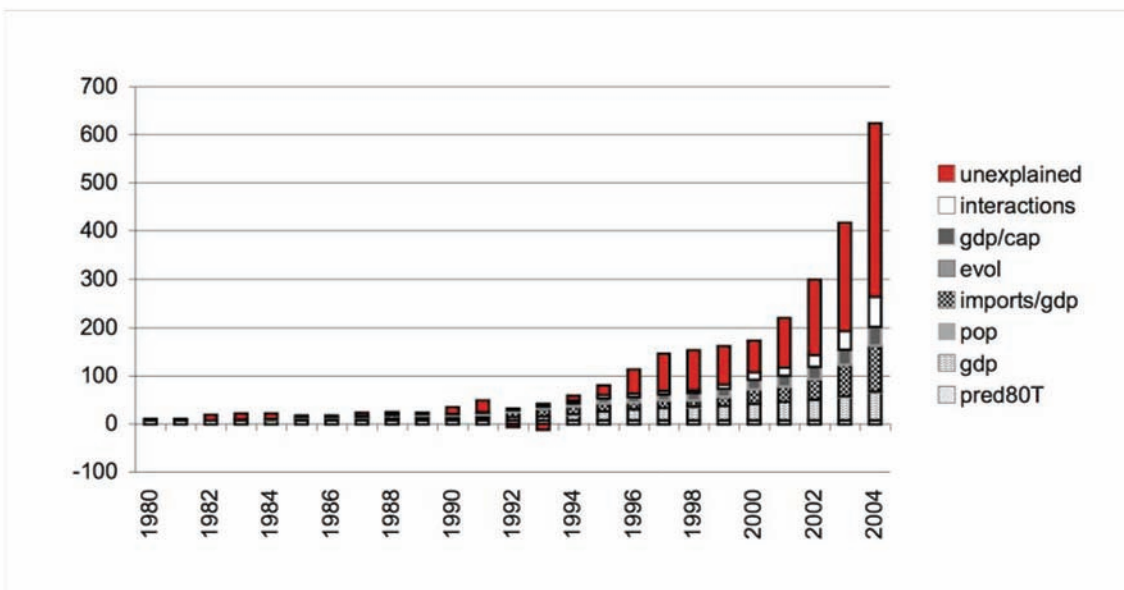
Note: these two figures show the increase in reserves over 25 years for emerging market countries in billions of current US dollars. The sub-sections of the bars represent the explanators of the growth. The bottom bar is the amount predicted in 1980 (constant over time). Other sub-sections allow for changes in 1 variable at a time. The second lowest is simply the change in GDP assuming all other variables remain constant, etc. The top section represents the amount that cannot be explained by the model.

Figure 2: In-Sample: What Explains Post-1980 Increases in China's Reserves?

(a) China: Financial Stability Model



(b) China: Traditional Model



Note: these two figures show the increase in reserves over 25 years for China in billions of current US dollars. The sub-sections of the bars represent the explanators of the growth. The bottom bar is the amount predicted in 1980 (constant over time). Other sub-sections allow for changes in 1 variable at a time. The second lowest is simply the change in GDP assuming all other variables remain constant, etc. The top section represents the amount that cannot be explained by the model.

Figure 3: In-Sample: What Explains Recent Increases in Reserves/GDP? Examples

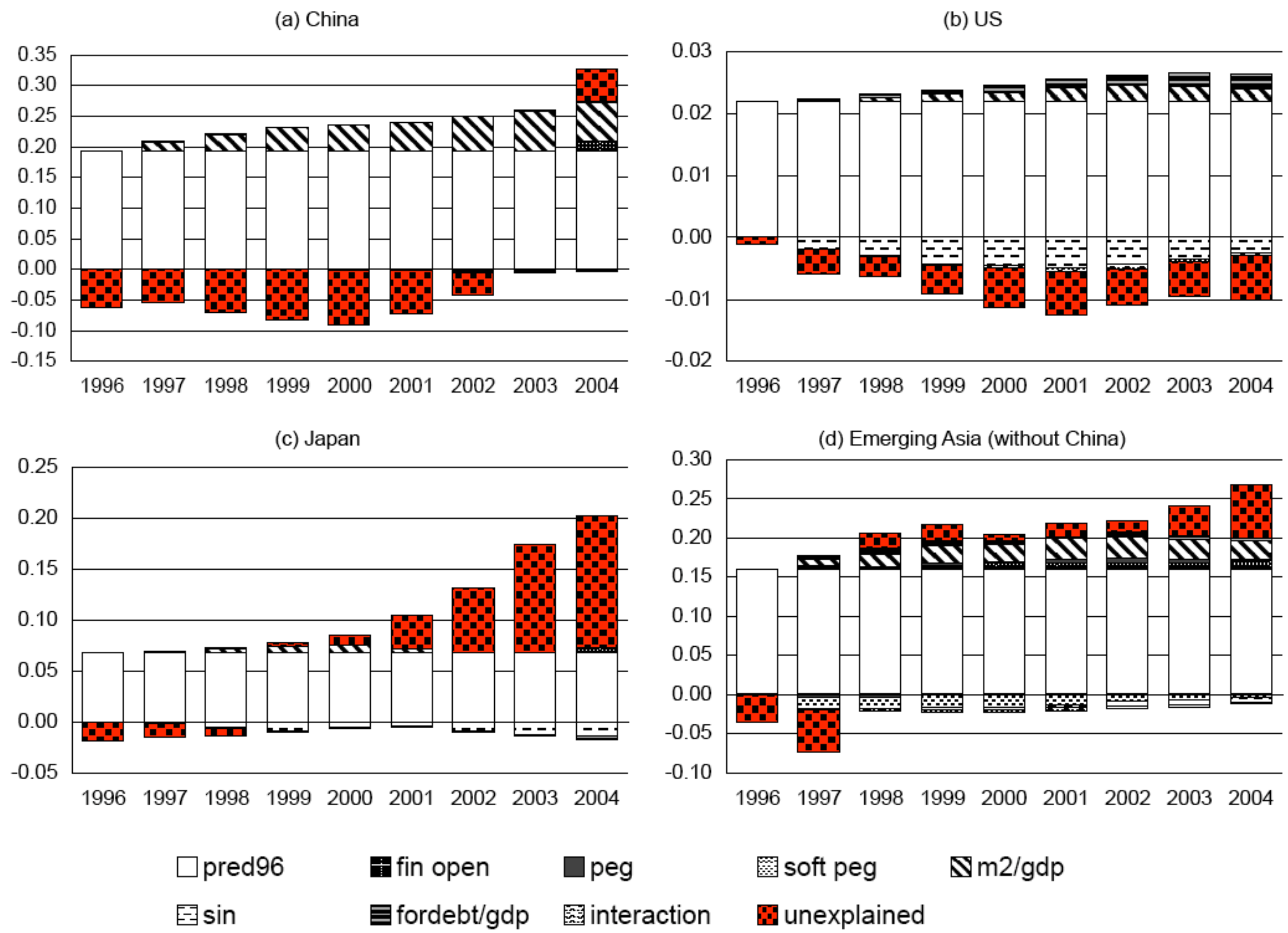
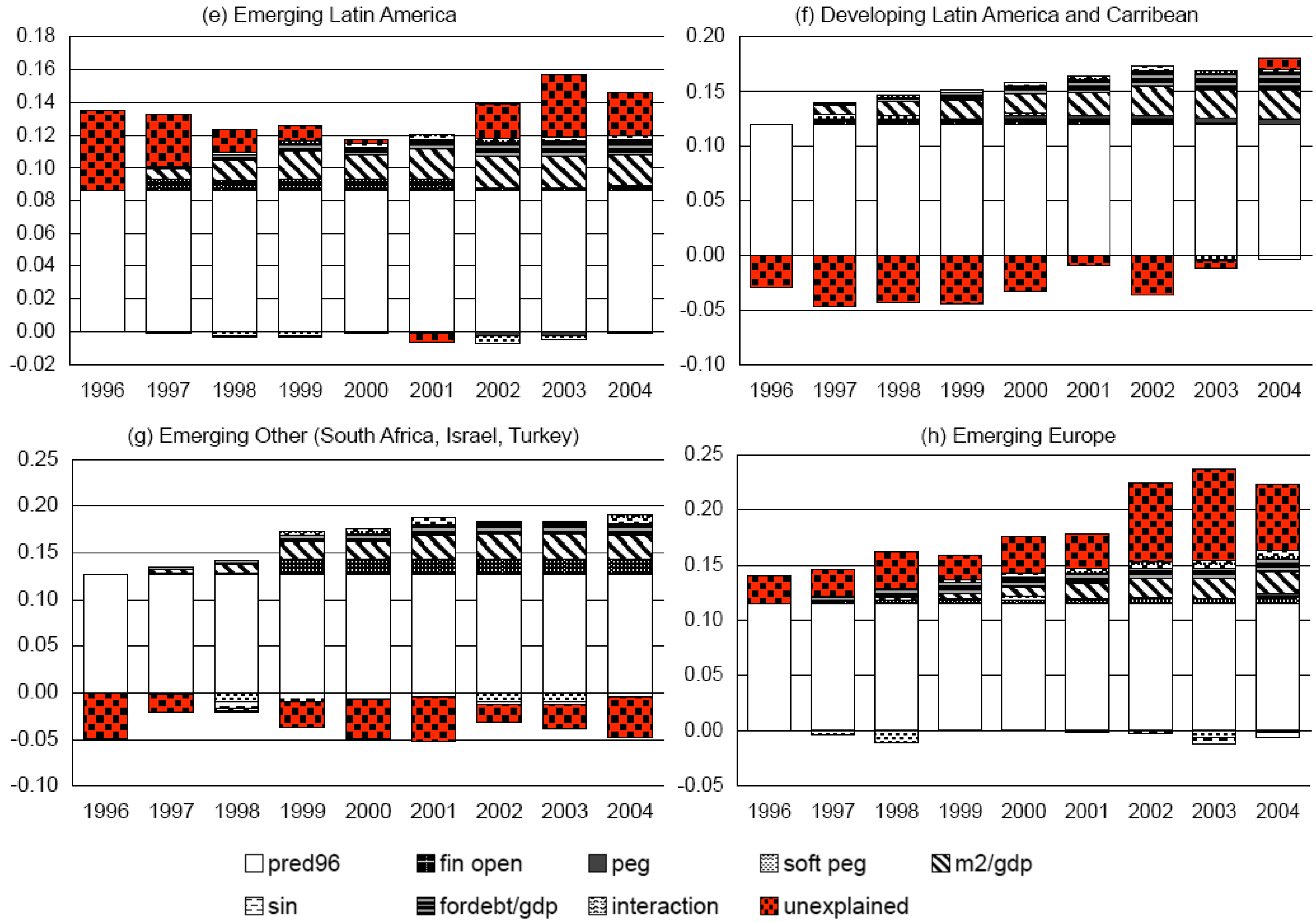


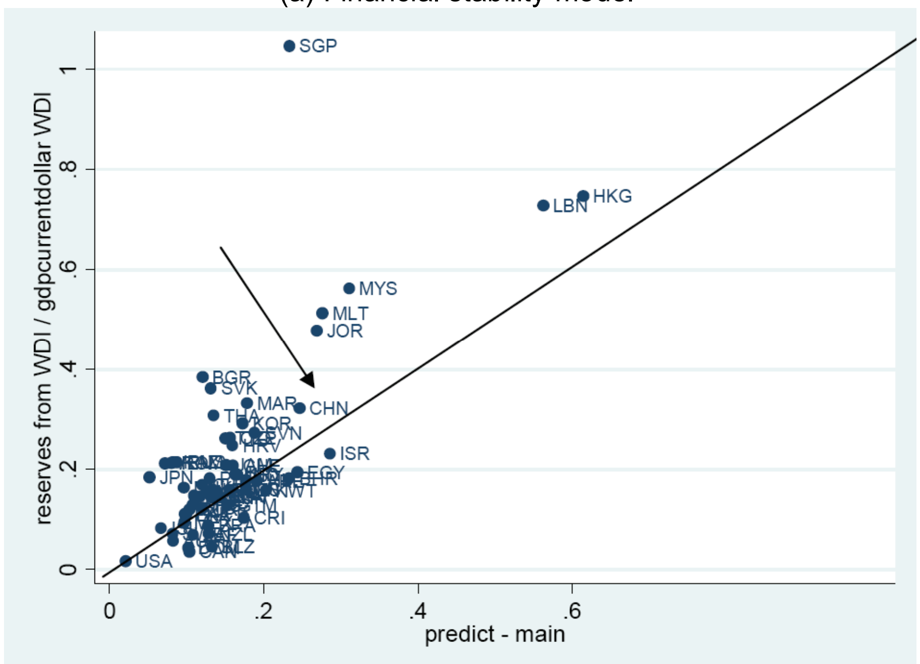
Figure 3: Continued



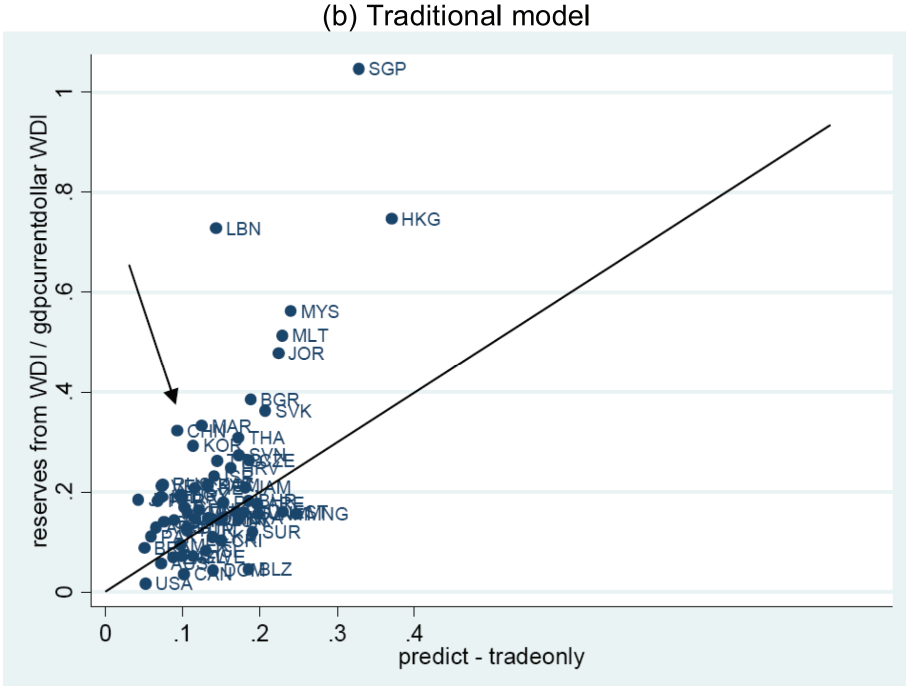
Note: these figures show the increase in reserve/GDP ratios over 9 years. The sub-sections of the bars represent the explanators of the growth. The bottom bar is the amount predicted in 1996 (constant over time). Other sub-sections allow for changes in 1 variable at a time. The second lowest is simply the change in GDP assuming all other variables remain constant, etc. The top section represents the amount that cannot be explained by the model.

Figure 4: Out-of-Sample Predictions: 2004 projected from 1993–2000

(a) Financial stability model



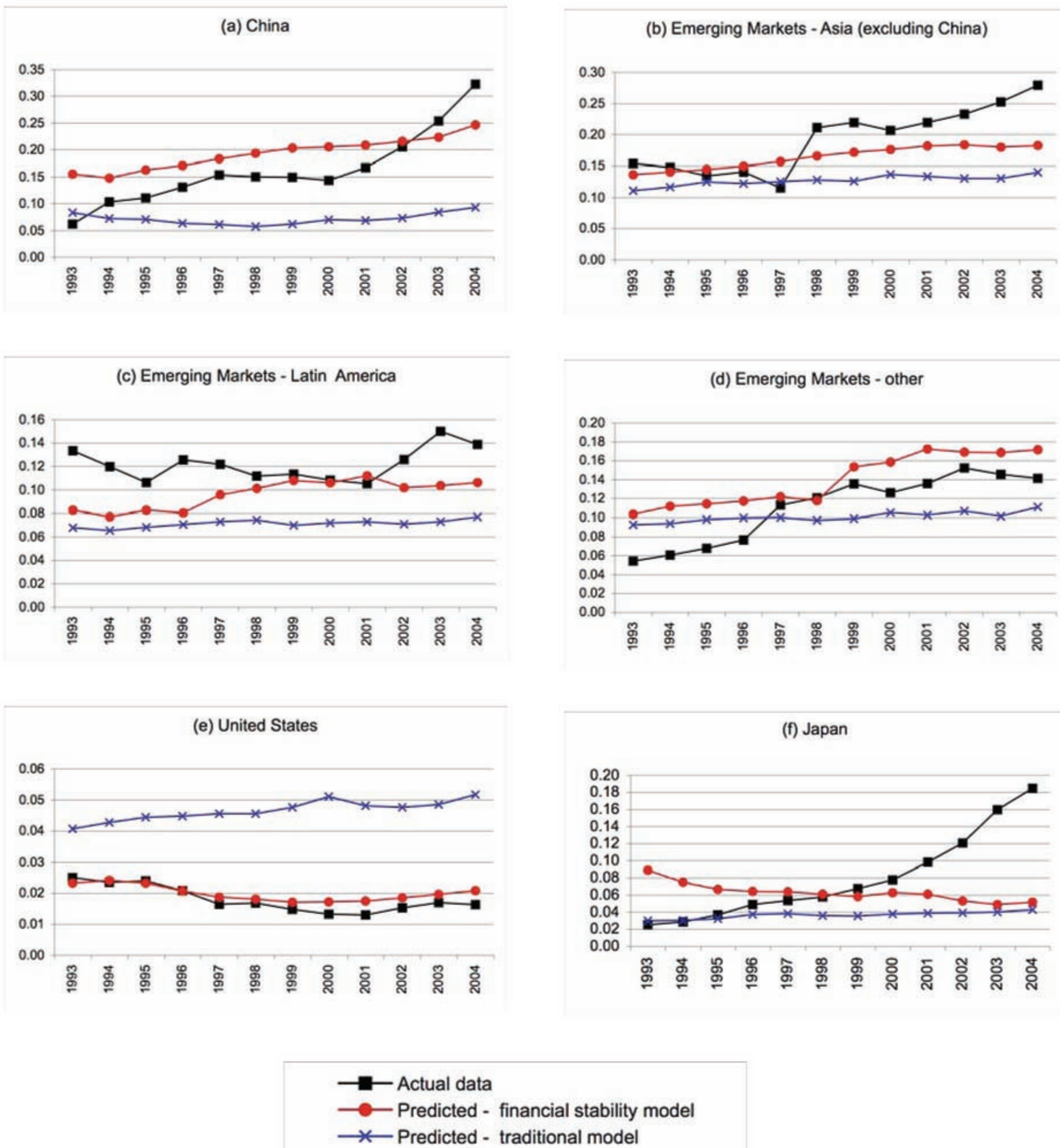
(b) Traditional model



Note: Figure (a) shows actual (y-axis) vs. predicted (x-axis) reserve/GDP ratios in 2004. Predicted values come from the financial stability model (with sin and foreign debt) estimated for 1993-2000. A regression of actual reserves on predicted yields a coefficient of 1.33 (s.e. 0.16) and R^2 of 0.52. The arrow points to China.

Figure (b) shows actual (y-axis) vs. predicted (x-axis) reserves/GDP in 2004. Predicted values come from the traditional model estimated for 1993-2000. Samples in the two figures are the same. A regression of actual reserves on predicted yields a coefficient of 1.81 (s.e. 0.28) and R^2 of 0.41. The arrow again points to China.

Figure 5: Out-of-Sample Predictions over Time



Note: These figures show the actual reserve/GDP ratios; those predicted by a financial stability model (including Sin and foreign currency debt) along the lines of Table 4, column 1 without trade included; and those predicted by a traditional one as shown in Table 1, column 1. Both models are estimated for 1993-2000. For the figures showing a combination of countries within a group, the same countries are used for all three lines and the panels are balanced (no countries enter or exit).