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Financial Stability, the Trilemma, and International Reserves

By MAURICE OBSTFELD, JAY C. SHAMBAUGH, AND ALAN M. TAYLOR*

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*: E44, E58, F21, F31, F36, F41, N10, O24.)

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, global international reserve holdings as a fraction of world GDP grew dramatically—up by a factor of 3.5 from less than 2 percent in 1960 to 6 percent in 1999—despite the 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, the average advanced country ratio of reserves to GDP has held steady at

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about 4 percent, but the emerging markets' average reserve ratio has 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.[3] 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 (Kaminsky and Reinhart 1999), 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 official bailouts may spark fears of public insolvency, no practical short-run means of managing the exchange rate other than reserve sales may be available.

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 (captured by 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 open-economy monetary policy trilemma, albeit in a different context. In previous papers we have emphasized how open capital markets and an exchange-rate target limit monetary policy autonomy measured by interest rate independence (Obstfeld, Shambaugh, and Taylor 2004, 2005). In this paper we show that the same policy environment may dictate a large war chest of reserves for LLR purposes 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 (for example, trade) but others do

[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.

[3]See, inter alia, Feldstein (1999) and Calvo (2006). Later in this paper we trace the argument back to Thornton (1802).

not (for example, foreign 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 the 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 our model start to leave a substantial fraction of China's reserves unexplained. Among the very big reserve holders, Japan does appear to hold more reserves than the model suggests are necessary.

I. Earlier Thinking on the Demand for International Reserves

A long literature has, at different times, emphasized various motives for holding international reserves.

A. 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 payments 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.[4]

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 "vertex" with capital mobility and floating exchange rates. But

[4]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 poorly in pooled samples, we do not include them in our empirical analysis below; one notable exception, however, was Edwards (1985), who used long-term sovereign spreads rather than short-term money market spreads.

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 balance-of-payments 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 they reinterpreted the balance-of-payments variability regressor 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 has been one based on the role of short-term external debts as drivers and predictors of 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 be able to pay interest on external debt, but lack the wherewithal to repay a principal balance that it had expected to roll over. Guidotti suggested a rule of thumb whereby emerging markets should have sufficient reserves to 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, facing the primary risk of a run by external depositors.

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:

> 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. (Keynes 1971, pp. 247–8)

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 for reserves as precautionary saving 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? Both theory and econometrics have been brought to bear on the question. Regressions by Aizenman and Marion (2003) find rising international reserves in East Asia following the Asian crisis. However, while the authors motivate their regression tests in terms of a theoretical model of insurance against sudden stops, their econometric results say little about the mechanism through which past crises have influenced subsequent reserve holdings.[5] 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.[6] 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 of the sudden stop theory, there would perhaps be no great puzzle over "excessive" reserves.

B. 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 operating a fixed exchange rate and facing simultaneous currency and banking crises, with potential foreign reserve losses that are magnified by its

[5] 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 (2007) find that China is not an obvious outlier.

[6] Durdu, Mendoza, and Terrones (2009) likewise focus on potential sudden stops as a motivation for reserve demand.

domestic interventions as the lender of last resort. In this context the failure of debt criteria to explain reserve holdings is more understandable. External debt arguments for reserve holdings 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*.[7]

Some illustrative calculations clarify why neither trade nor debt criteria can explain large reserve holdings. 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 be only 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 are worrisome, but to rationalize current reserve holdings fully we think it is important to keep in mind the even more catastrophic double drains that can result from capital flight.

In a double drain scenario, domestic capital flight is financed through withdrawals 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 trade or debt financing channels noted above. It is the threat of this type of drain, we argue, that most worries emerging market policymakers. Absent speedy and credible help from an international lender of last resort, rapid outflows of this size would be difficult to withstand without a very large war chest.

In the new era of financial globalization, these flows are not just hypothetical. A good example of this dynamic is provided by events in Argentina. Consider first the 1994–95 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 monetary base (M0) of 15 billion pesos (with 1 peso equal to 1 U.S. dollar). Broad money, M2, was about 50 billion pesos, or 20 percent of a GDP of roughly 250 billion pesos.

After the crisis, a sudden stop occurred in emerging markets including Argentina. For the first

[7]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.

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 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 places like Miami or Montevideo in search of a safe haven. As they rushed for dollar liquidity in February and March the central bank's reserves bled away, 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 the drain had continued, Argentina's existing reserves would have been quickly depleted and convertibility would have ended within weeks or even days. Yet convertibility survived. Despite a 1994 statement 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 rescued the peso-dollar peg and was thought to have served a "catalytic" role in encouraging fresh inflows of private capital. A currency collapse was narrowly averted.[8]

What would have happened without IMF intervention in 1995? The 1995 counterfactual, with no IMF support, probably 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 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.[9]

Convertibility 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.

Beyond this specific example, Rothenberg and Warnock (2006) show that nearly half of all sudden stops (defined based on net flows) are really cases where domestic entities initiated rapid capital flight, often billions of dollars in short time spans. Within the sample we will use for empirical analysis below, the median annual net purchase of foreign assets by private domestic entities, what we shall call "private domestic outflows," is roughly 1 percent of GDP, but the 95th percentile is 15 percent of GDP.[10] Thus, a nontrivial amount of assets can leave the country in a given year in extreme circumstances. In emerging market countries since 1997, the 95th percentile of private domestic outflows is 20 percent of GDP. In many cases, the outflow is harmless and may even represent beneficial mutually risk sharing. In a financial center like Singapore, for example, domestic private outflows are often over 40 percent of GDP and offsetting foreign in-

[8]The Argentine experiences in 1994–95 and 2001–02 are recounted in great detail by Paul Blustein (2005).

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

[10]As in Rothenberg and Warnock, we define private domestic outflows as the sum of direct investment, non-reserve portfolio investment abroad, and other investment (largely bank flows), based on IMF International Financial Statistics data lines 78bdd, 78bfd, and 78bhd. Symmetrically, foreign inflows are the remaining items in the nonreserve financial account.

flows are roughly 30 percent of GDP. But in some other cases, a substantial amount of money has left a country even when none is flowing in. In 1998, Singapore saw 20 percent of GDP in private net domestic outflows offset by zero private foreign inflows. In Argentina in 2002, net private domestic outflows totaled 8 percent of GDP while net private foreign inflows were negative (as foreigners joined the run). Malaysia saw private domestic outflows of 7 and 11 percent of GDP in 1998 and 1999. Korea's private domestic outflows were 3 percent of GDP in 1997, Thailand's 3 percent of GDP in 1998, and Russia's 6 percent of GDP in 1998, all set against little or no private foreign inflows. In some cases (notably that of Malaysia), capital controls were deployed in an attempt to stem capital flight, but sizable private domestic outflows appeared regardless. We should also note that in every case mentioned, financial accounts are more open now than at the date of these capital flight events.

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. As noted by Wijnholds and Kapteyn (2001, pp. 10–11), debt-based approaches to reserve demand, while considering financial globalization, have missed a vital element, the financial stability concerns of a central bank facing a double drain risk. We argue that this 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 (1996, 2006), 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.[11]

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 account 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.[12] 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 under present-day currency arrangements, a drain that *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.[13] 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 best proxy for the potential pressure on reserves resulting from a flight out of the domestic banking system.[14]

[11]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.

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

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

[14]Keynes (1971, p. 247), again seeming to ignore the possibility of *domestic* financial instability, argues that the maximal sizes of the shocks necessitating free foreign exchange reserves are not "likely to bear any stable relationship

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 observed that gold reserves were necessary not only to meet fluctuations in the trade balance (external drains); they also were important 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.

Thornton considered the example of a real shock such as a harvest failure, which simultaneously produces an external gold drain and domestic economic distress. Rather than tightening domestic monetary conditions so as to keep gold at home, he suggested, the Bank of England should use its gold reserves to finance the adverse trade balance. For this purpose it should hold a large enough precautionary gold reserve to allow it to maintain the domestic money supply while limiting currency depreciation. Like Keynes, Thornton is worth quoting at length:

> 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 1802, p. 153)

Thornton's perspective affirms the close interplay between internal and external drains, and thus the interplay between domestic financial stability and currency stability.[15]

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 but lacking access to Federal Reserve lending facilities 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

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."

[15] 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.

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 Open Market Committee on December 11, 2007 authorized the extension of substantial dollar credit lines to major foreign central banks. These facilities were subsequently enlarged in size and extended to more countries.

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 dollar shortages in emerging-market crises have been—until recently—much more common than in industrial-country crises. Writing more than a quarter-century 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."[16]

C. 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 buildup, 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 (measured by M2, the measure we will also use below) 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. 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. Very much in line with our analysis, Rodrik (2006) argues that since emerging-market

[16]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. But several factors, including the IMF's lack of any direct role in financial regulation and the conditionality of its loans, have long made its facilities an implausible substitute for national reserve holdings. Indeed the recent global reserve buildup has in part reflected reluctance to rely on the Fund, reluctance that in November 2003 led to discontinuation of the Fund's never-used Contingent Credit Lines, introduced in 1999. Decisions in early 2009 to expand Fund resources and to make access to them more flexible may allow the Fund more easily to play an important future role as an international LLR. See Obstfeld (2009) for a discussion.

countries began to embark on financial liberalization starting in the early 1990s, their reserve accumulation has been driven empirically by the size of the domestic financial sector rather than by real magnitudes such as trade flows.[17]

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 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.

II. 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.

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. We do not purport to explicitly model every aspect of reserve demand and test it in a structural sense. Rather this section demonstrates how the a larger banking sector can generate greater official demand for foreign reserves if the authorities prefers some degree of exchange rate stability (as many countries do). An appendix to a working paper version (Obstfeld, Shambaugh, and Taylor 2008) 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 here is the foreign-currency price of domestic currency, so a fall in e is a depreciation of home currency. Thus lower values of θ index more unfavorable states. Economic actors in the home country have divergent views of the fundamental that will materialize in period 1. For a given θ—not necessarily 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 $i \in [0,1]$ and all of them are risk neutral.[18]

[17]See Figure 3 in Rodrik (2006), which shows ratios of M2 to reserves. 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.

[18]If instead of assuming exogenously heterogeneous market forecasts we assumed idiosyncratic heterogeneous signals

We posit 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, $e_1 = e(\theta)$, compared to today's exchange rate e_0. There are no transaction costs of foreign exchange trading, though they could easily be introduced. If θ is very low (the crisis is expected to continue and even intensify), then the average market forecast is for continuing currency weakness. But among domestic residents, there will be divergent opinions about how weak the currency will be.

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 them 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 they receive liquidity assistance from the domestic central bank. (The model would have the same qualitative implications if some proper 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 $\mathrm{E}\{e_1 \mid \theta+\varepsilon_i\} = \alpha(\theta+\varepsilon_i) \le e_0$. In words, domestic depositors wish to buy foreign exchange if they expect the home currency to fall below its current level. For a given date 0 exchange rate e, the measure of agents such that

$$\alpha(\theta+\varepsilon_i) \le e$$

or, equivalently, such that $\varepsilon_i \le \frac{e}{\alpha} - \theta$, 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). The equilibrium in the foreign exchange market at date 0 is then given by the equality of domestic demand for foreign

about future fundamentals, then agents would be able to extract information about the true value of future fundamentals from their observation of the date 0 equilibrium exchange rate. That is not the case here. An alternative assumption yields a model isomorphic to ours: agents know the true future value of θ but have a distribution of costs of trading in the foreign exchange market.

exchange and its supply by the central bank:

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

The equilibrium exchange rate at date 0 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

$$e_0=\frac{\alpha\left(\theta-\overline{\varepsilon}\right)+\sqrt{\alpha^2\left(\theta-\overline{\varepsilon}\right)^2+\frac{8\alpha\overline{\varepsilon}R}{M}}}{2}.$$

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_0 rises), and as M rises it weakens.[19]

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

III. 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 financial stability variables are strongly correlated with reserve holdings and 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 benchmark model of a more tra-

[19]If $R=0$, the value of the 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 drop to the level $\alpha\left(\theta-\overline{\varepsilon}\right)$.

ditional kind. 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. 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 2007). 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.

A. *Benchmark Comparison: Financial Stability versus the Traditional Model*

To begin, we estimate and compare a *traditional* model and our new *financial stability* model. As a benchmark traditional model we adopt a specification proposed in a recent IMF (2003) study.[20] It was the IMF's poor results using this traditional model that led Jeanne (2007) to conclude that no satisfactory linear regression framework can explain current patterns of reserve accumulation.

In all of our empirical equations, the dependent variable is the (natural) logarithm of the ratio of official international reserves to GDP. [21] (All data are from the World Bank's World Development Indicators unless otherwise noted.) The explanatory variables in the "traditional model" are:

- the log of population;
- the log of the ratio of foreign trade (imports plus exports) to GDP; [22]
- 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 authors' calculations using IFS data);
- the log of real GDP per person (converted at PPP exchange rates, in current international dollars).

Alternatively, we consider our "financial stability model," which is based on the insights discussed above. The financial stability model includes as regressors:

- the log of the ratio of M2 to GDP;
- a measure of financial openness (based on the Edwards 2007 index, scaled from 0 to 1);

[20]See IMF (2003), Chapter 3, Table 2.3 for details. Because of data constraints for our sample of countries, our specification does not include export volatility, a variable included in the IMF framework. In the IMF regression, however, the coefficient on export volatility was almost exactly zero and statistically insignificant, so we believe that excluding this variable does no great damage to the spirit of the IMF approach. The same section of the IMF study experiments with some other variables in purely bivariate regressions. The specification we highlight, however, is based on the final multivariate regression specification that the IMF reports.

[21]The reserve measure does not include the assets of sovereign wealth funds.

[22]Many traditional models use the ratio of imports to GDP instead of trade to GDP. We use trade instead of imports because we want to have the same trade variable across the traditional and financial stability specifications. Using trade rather than imports makes virtually no difference and slightly strengthens the traditional specification.

- a pegged exchange rate dummy (based on the *de facto* Shambaugh 2004 coding, with annual ±2% bands);[23]
- a soft-peg exchange rate dummy (similar, but based on ±5% bands);[24]
- an advanced country dummy;[25]
- the log of the ratio of foreign trade (imports plus exports) to GDP.

The inclusion of M2 is directly motivated by the model. In addition, we note that if financial flows cannot move across borders, the likelihood of a bank run becoming a balance of payments crisis is much reduced, and thus we include the Edwards measure of financial openness. Further, as noted above, a central bank that is not concerned by exchange rate movements may simply expand domestic credit in a banking crisis and allow the exchange rate to move if necessary. Thus we include peg and soft peg exchange rate dummies.[26] It may happen, however, that some countries accumulate more reserves simply as a result of pegging—or lose them for that reason. Reversing the direction of causality, one sees the possibility that countries choose to peg when reserves are ample. These possibilities suggest caution in interpreting the role of the peg indicators.

In addition, a number of features (stable banking systems and the ability to borrow in one's own currency, for example) may mean that advanced economies need fewer reserves, and this is the motivation for the inclusion of an advanced country dummy, which we would expect to have a negative sign. Finally, we have included the log of trade as a control because of its robustness as an explanatory variable in other empirical studies.

We use a consistent (common) sample for a fair comparison of the two specifications. Table 1 reports the results of this comparison using a simple pooled OLS specification, in which no fixed effects are allowed for the moment. As is often done in the literature, we scale reserves by GDP to make the dependent variable stationary. The resulting series is still positively autocorrelated.

[23]A country is classified as pegged if its official exchange rate stays within a ±2% band with respect to its base country—the country to which it would ostensibly peg—over the course of a year; *or* if its exchange rate has no change in 11 out of 12 months and shows at most one discrete devaluation. Furthermore, to avoid "accidental" classifications, a country must stay pegged for two years to be considered pegged. See Shambaugh (2004) for extensive discussion.

[24]The soft peg classification has been created for this project by the authors. A country is considered a soft peg if its exchange rate stays within a ±5% band with respect to its base country, or if its exchange rate changes by less than 2% in every month. There are 1,050 nonpegs in the sample, 844 pegs, and 777 soft pegs (with pegs and soft pegs being mutually exclusive). All but 25 of the soft pegs stay within the ±5% bands. As with the preceding peg classification, a country classified as a soft peg must satisfy one of the criteria set out above for two years in a row to be considered a soft peg. The soft pegs are generally crawling pegs, loose basket pegs, or tightly managed floats. Of the 777 observations, 237 are declared as basket pegs, 111 pertain to loose EMS members or rates in countries that shadowed the EMS, 107 are Latin American crawling pegs, 82 are East Asian soft de facto pegs, and 114 are Eastern European soft pegs in the last decade. In fact, these five groups make up 83 percent of the soft peg observations. We note that the Japan-U.S. dollar and Germany-U.S. dollar rates are never classified as soft pegs, which suggests that countries that allow a fair bit of flexibility are unlikely to be accidentally classified as soft pegs or pegs under our algorithm.

[25]Other than Malta and Turkey, countries with IMF IFS codes less than 199 are classified as advanced.

[26]Baek and Choi (2008) examine the link between reserves and various exchange-rate regime classifications, based on the data asembled by Reinhart and Rogoff (2004). They conclude that countries with intermediate regimes demand more reserves than countries with polar regimes, although there is no scaling of the reserves in their paper (which makes comparisons difficult and raises some potential econometric problems).

TABLE 1: TRADITIONAL AND FINANCIAL STABILITY MODELS OF RESERVES DEMAND.

Specification	(1) Traditional	(2) Add fin. openness	(3) Add peg	(4) Add M2	(5) Horserace	(6) Financial stability	(7) Financial only
ln(population)	0.000	-0.001	0.004	-0.014	-0.012		
	(0.035)	(0.035)	(0.034)	(0.033)	(0.032)		
ln(trade/GDP)	0.78	0.752	0.75	0.706	0.544	0.583	
	(0.094)**	(0.095)**	(0.094)**	(0.096)**	(0.084)**	(0.071)**	
Exch. rate vol.	-0.009	-0.006	-0.004	-0.006	-0.001		
	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)		
ln(GDP/person)	0.101	0.046	0.092	0.015	0.063		
	(0.042)*	(0.045)	(0.040)*	(0.053)	(0.055)		
Financial openness		0.477			0.599	0.671	1.035
		(0.205)*			(0.171)**	(0.174)**	(0.212)**
Peg			0.154		0.09	0.095	0.246
			(0.083)+		(0.077)	(0.077)	(0.093)**
Soft peg			0.207		0.161	0.167	0.289
			(0.064)**		(0.059)**	(0.060)**	(0.078)**
ln(M2/GDP)				0.263	0.284	0.311	0.444
				(0.095)**	(0.087)**	(0.072)**	(0.086)**
Advanced					-0.625	-0.554	-0.858
					(0.145)**	(0.125)**	(0.161)**
Constant	-6.414	-6.099	-6.379	-6.111	-6.265	-6.253	-4.538
	(0.895)**	(0.896)**	(0.877)**	(0.871)**	(0.788)**	(0.360)**	(0.288)**
Observations	2671	2671	2671	2671	2671	2671	2671
R^2	0.31	0.32	0.32	0.33	0.38	0.38	0.27

Note: Robust standard errors clustered by country in parentheses. Significant at + 10%; * 5%; ** 1%.

We therefore cluster the standard errors by country to allow for heteroskedasticity across countries and, more importantly, to allow for an unstructured serial correlation in the error term within countries.[27] Even at this point it is worth noting that our results hold in a pure cross section (a between-groups panel estimation), so serial correlation is in no way driving the results or generating spurious-regression effects. (See section 4.3 for more details.) Our data sample consists in each case of 2,671 country-year observations. The unbalanced panel covers 26 years from 1980 to 2004 and includes 134 countries. The countries in our sample are listed in an appendix.[28]

Column 1 reports results for the traditional model. Countries that trade more and are richer tend to hold more reserves. In columns 2 through 4, we add to the first specification the main financial variables—relating to the fixity of the exchange rate, the openness of the financial account, and domestic financial depth. All estimates of these variables' coefficients are positive and significant, as expected. The trade coefficient remains positive and significant, but including the M2/GDP

[27] Bertrand et al. (2004) discuss how clustering can correct properly for serial correlation biases.

[28] We have excluded dollarized countries and multilateral currency unions (such as the CFA, the Eastern Caribbean Currency Union, the period during the breakup of the ruble in former Soviet Union countries, and the eurozone) where the allocation of reserves or M2 across countries may be ambiguous and where the need for any one country to maintain reserves is different than for countries with their own currencies. Eurozone members are included individually through 1998, after which individual member-country M2 data disappear. As the country list shows, we do have some small countries in the sample but the results are robust to dropping all countries with population below one million. Outliers do not drive the results either, as partial scatters of financial depth (measured by M2/GDP) or financial openness against reserve ratios show no strong outlier observations.

ratio reduces the coefficient of the per capita GDP variable to insignificance. GDP per person is positively correlated with financial openness and financial depth, and may act as a proxy for them when they are omitted. We never find exchange-rate volatility to be important in this sample. In any case that variable is endogenous because the size of a country's reserve holdings may affect its ability to manage the exchange rate, in part through an expectations channel.

In column 5 we run a horserace between the two sets of variables. All the financial variables remain significant with the exception of the (hard) peg variable. (In particular, the soft peg variable is still positive and significant.) The result suggests that a model based on financial motives (and including trade) should be a better predictor of reserve holdings than one ignoring these factors. Column 6 reports estimates of the financial-stability based model. Dropping the insignificant traditional variables has essentially no impact on the other variables, and a formal test that nests the two models favors our financial model against the traditional model.[29]

Finally, we examine a "financial only" specification that drops trade (column 7). Trade is positively correlated with all the financial variables (especially pegging, because economies that are more open to trade are more likely to manage their exchange rates). We show a regression that omits trade to demonstrate that the inclusion of trade only biases the results against our hypothesis. Exclusion of the trade variable leads to larger and more significant estimated coefficients on all of the financial variables. In particular, the coefficients on both peg variables increase Substantially, as one would expect.

The estimated partial correlations with pegs deserve some discussion. A country that cares more about exchange-rate stability would plausibly be more worried about its ability to cover demands for foreign funds without allowing substantial currency depreciation. While the (hard) peg variable is not statistically significant in the full model, it is economically significant and we cannot reject the hypothesis that its effect is the same as the coefficient on the soft peg variable. Thus, we do not claim that countries with harder pegs hold fewer reserves than those with soft pegs, though we do find that the soft peg variable has a larger coefficient in nearly all specifications. In alternative specifications (not shown) in which we merge peg and soft peg into a single indicator variable, the resulting composite indicator is statistically and quantitatively significant in nearly all cases where soft peg is significant.[30]

It makes sense that the soft peg variable is significant, with a positive relationship to reserve

[29]We perform tests suggested by Davidson and Mackinnon (1981). First, we include the fitted value based on the financial stability model of column 6 in a regression equation including the traditional model of column 1. The coefficient on the fitted value regressor is highly statistically significant. This suggests that omitting the financial variables excludes important information: the tradtional model is misspecified. The same holds true when using the fitted value from a regression like column 7 that includes *only* our financial variables. Alternatively, when including the fitted value from a regression like column 1 as an additional regressor in the specification of column 6, the coefficient on the fitted value is not significantly different from zero, even at the 10 percent level. This result suggests that the traditional model adds no information once the variables in our financial stability model are included.

[30]Eliminating the set of Reinhart and Rogoff (2004) "freely falling" countries makes no difference to the results. Shifting the exchange-regime classification entirely to Reinhart-Rogoff does make a difference, though, in large part due to a change in the country sample. As noted in the next section, the coefficient on pegging is mainly driven by the developing country subsample. Far more of these countries are missing data in the Reinhart and Rogoff classification. Estimating our specification on the Reinhart-Rogoff country sample leads to very similar results to simply applying the Reinhart-Rogoff classification to our full sample. Because the Reinhart Rogoff coding mixes information about exchange-rate system and financial openness through its use of black-market exchange rates to identify regimes, we view the Shambaugh (2004) classification and our soft peg classification as more pertinent in the present context.

demand that is at least as strong as that of the (hard) peg variable. Our previous work (Obstfeld, Shambaugh, and Taylor 2004, 2005) focused on strict peg definitions when examining monetary policy autonomy in the form of interest-rate independence, arguing that the wider the allowed currency fluctuation bands, the more monetary autonomy a country has. On the other hand, if a country holds reserves to ward off large devaluations following financial shocks, any country with a preference for non-floating rates is equally exposed, whether its preferred band is large or small. Hence, both pegs and soft pegs may mandate higher reserves than countries that are indifferent to the exchange rate's level would choose to hold. We do not expect only reserve demand by pegged countries to be influenced by M2 or financial openness (in which case only interaction terms with the peg variable would be significant). On the contrary, nearly all countries will prefer to have the means to resist very large depreciations. Hence, higher M2 and financial openness are expected to matter even when a country is normally freely floating.

Our findings on financial depth and openness also appear to be quantitatively important. In the financial stability model (column 6), for example, when financial openness rises by one 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, ln(M2/GDP), rises by one 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 one standard deviation below the mean on these two dimensions to one standard deviation above the mean, the model predicts that the reserve-to-GDP ratio would close to double, all else equal (+0.74 log points). The trilemma also appears here: the impacts of all variables on the reserve/GDP ratio are magnified in countries that peg, given the logarithmic specification.

The contrast between the positive coefficient on per capita GDP 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 capability to issue debt abroad in home currency. (Below we examine the latter "original sin" factor directly using a smaller data sample.) As expected, advanced-country status has a strong negative effect. The positive sign of GDP per person in the traditional model may reflect that variable's possible role as a proxy for the excluded financial variables. Once these are added, GDP per capita drops out of the regression.

B. Robustness: Subsamples and Short-Term Debt

Table 1 shows that the new model has potentially good explanatory power in an absolute sense, as judged by the R^2 statistic.[31] The model also performs well relative to the current benchmark, the IMF's "traditional" model of reserve demand. Furthermore, our initial results illustrate the potentially large changes in reserves that could be induced by changes in financial openness and financial depth. On the other hand, much of the interest lately has centered on the behavior of emerging markets. Hence, in Table 2 we consider the subsample of emerging markets only. Particularly in the context of these poorer countries, recent policy debate has put great emphasis on the importance of short-term external debt as an indicator of financial vulnerability. Thanks

[31] Here and elsewhere we report the standard, unadjusted R^2 statistic. Because we have a large number of observations relative to the number of regressors, the adjusted and unadjusted R^2 are always identical to two decimal places.

TABLE 2: EMERGING MARKETS SAMPLE.

Specification	(1) Traditional	(2) Horserace	(3) Fin. stability	(4) Fin. only	(5) Add debt	(6) Fin. and debt
ln(population)	0.025	-0.043			-0.095	
	(0.062)	(0.056)			(0.066)	
ln(trade/GDP)	0.83	0.491	0.57		0.428	0.59
	(0.122)**	(0.108)**	(0.075)**		(0.088)**	(0.090)**
Exch. rate vol.	-0.004	0.328			0.314	
	(0.125)	(0.164)+			(0.154)+	
ln(GDP/person)	0.092	-0.017			0.075	
	(0.084)	(0.086)			(0.105)	
Financial openness		0.93	0.918	1.632	0.589	0.701
		(0.238)**	(0.186)**	(0.337)**	(0.219)*	(0.191)**
Peg		0.036	0.023	0.022	0.098	0.07
		(0.119)	(0.118)	(0.127)	(0.117)	(0.104)
Soft peg		0.006	-0.012	0.065	0.035	0.009
		(0.111)	(0.115)	(0.124)	(0.085)	(0.09)
ln(M2/GDP)		0.299	0.238	0.569	0.337	0.198
		(0.123)*	(0.118)+	(0.117)**	(0.114)**	(0.113)+
ln(short ext. debt/GDP)					-0.129	-0.048
					(0.076)	(0.068)
Constant	-6.788	-4.935	-5.904	-5.242	-4.82	-5.816
	(1.820)**	(1.644)**	(0.424)**	(0.491)**	(1.894)*	(0.559)**
Observations	646	646	646	646	504	504
R^2	0.55	0.61	0.6	0.49	0.54	0.51

Note: Robust standard errors clustered by country in parentheses. Significant at + 10%; * 5%; ** 1%.

to the World Bank's Global Development Finance database we have consistent series for this variable for emerging-market countries, so we introduce it into our analysis of that subsample.

To divide the total country sample into advanced, emerging, and developing groups we use a standard classification.[32] Table 2 (columns 1 through 4) repeats the regression exercise of Table 1 with the sample restricted to just the emerging markets. The basic message of Table 1 is confirmed. The fit is better under the new approach, with an R^2 of 0.60 for the financial-stability model (column 3) versus the traditional model's 0.55 (column 1). The financial variables again have the expected signs and significance levels in column 2, that is, in the horserace between the two sets of variables.[33] The peg variables provide exceptions, however. Both are roughly zero for the emerging sample. Most of the identification for these variables in the full sample seems to come from differences between the emerging and developed samples, and from within the developing-country sample, and these effects are excluded from the emerging-only sample underlying Table 2.[34] Looking at our financial stability model (column 3), financial openness

[32]As noted above, codes less than 199 with the exceptions of Malta and Turkey are classified as advanced. Emerging countries are those in the Morgan Stanley emerging-market index plus some Eastern European countries. Generally countries in the developing group are even poorer than the emerging markets, and there are no emerging countries with populations below one million. We are left with 646 observations for this sample

[33]As before, Davidson-Mackinnon (1981) tests allow a statistical comparison. The coefficient on the fitted value from a traditional regression is insignificant if included in the financial-stability model (this is true with or without short-term external debt added to the traditional model). In contrast, the fitted value from the financial-stability model does have a statistically significant coefficient when added to a traditional regression.

[34]On the other hand, a simple bivariate regression shows that the peg variables are positively associated with reserve

is statistically significant and the coefficient increases in estimated magnitude to 0.918. The M2/GDP coefficient falls slightly and the trade coefficient is essentially unchanged. Excluding the trade variable (column 4) results in larger estimated coefficients on financial variables, as in Table 1.[35]

Columns 5 and 6 of Table 2 add the log ratio of short-term foreign-currency external debt to GDP as an additional variable. The ideas of Guidotti and Greenspan have now coalesced into a widely cited rule of thumb, which judges emerging-market reserve adequacy relative to the potential demand for repayment connected with a country's short-term external foreign-currency borrowing. However, the empirical results are poor. The estimated coefficients on debt in columns 5 and 6 are negative and insignificant. Thus, it appears there is a weak tendency for emerging countries to hold *fewer* reserves when they have more short-term debt.[36] We also considered the role of the debt service burden but found no effect. The lack of evidence that countries follow the Guidotti-Greenspan rule is consistent with the observation of Summers (2006) that many countries now hold reserves far in excess of short-term external foreign-currency debt.[37]

C. 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. If we expect to explain an increase in reserves for emerging markets, we need to see our results confirmed not just in the cross-section but within countries over time as well. Results are reported in Table 3. Column 1 simply reproduces column 3 from Table 2 for comparison (moving the trade regressor to the end of the list).

In the second column of Table 3 we introduce country fixed effects (CFE). This change sweeps out all cross-sectional means, so there is no "between" identification, only "within." All coefficients are now estimated from time-series variation within country units. The country fixed effects obviously improve the fit (R^2 rises to 0.82), and they weaken some but not all of the coefficient estimates. The financial openness coefficient decreases in size, and is now significant only at the 10 percent level. The peg and soft peg coefficients remain insignificant. The trade

holdings. In multivariate regressions, however, the cross-correlation with other variables dominates in this particular sample.

[35]For the emerging sample, the positive coefficient on exchange-rate volatility is driven by a very few extreme outliers in the sample, so we disregard it. Specifically, the coefficient becomes statistically insignificant if we exclude merely the three out of 646 observations on exchange-rate volatility that lie more than eight standard deviations from the overall sample mean. Omitting a mere seven outlying observations (a one percent trim) turns the estimated coefficient negative and insignificant.

[36]Lane and Burke (2001) find a negative partial correlation between reserves and an array of external debt indicators, viz. short-term debt, total debt, and the share of short-term in total debt. They suggest that the governments of countries with bigger short-term or total foreign debts might face higher borrowing costs. In that case, retirement of public debt using reserves would reduce the public-sector interest burden. Of course, endogeneity bias is a likely factor. Countries that have accumulated sizable reserve stocks typically have also run current account surpluses and thereby reduced their external debts.

[37]Looking at the consolidated emerging and developing-country sample, we find that only 290 of the 1,935 observations are close to following the Guidotti-Greenspan rule (these are countries where the short-term foreign-currency external debt-to-reserves ratio is between 75 percent and 125 percent). In contrast, 1,366 observations display ratios above 100 percent.

TABLE 3: SOURCE OF IDENTIFICATION FOR THE EMERGING-MARKETS SAMPLE

	(1)	(2)	(3)	(4)	(5)
Specification	No FE	CFE	YFE	YFE & CFE	Between
Financial openness	0.918	0.393	0.789	0.121	1.6
	(0.186)**	(0.213)+	(0.249)**	(0.206)	(0.757)*
Peg	0.023	0.054	0.029	0.071	-0.24
	(0.118)	(0.081)	(0.125)	(0.063)	(0.338)
Soft peg	-0.012	0.046	-0.034	0.023	-0.137
	(0.115)	(0.086)	(0.111)	(0.079)	(0.37)
ln(M2/GDP)	0.238	0.492	0.215	0.348	0.351
	(0.118)+	(0.130)**	(0.114)+	(0.121)**	(0.180)+
ln(trade/GDP)	0.57	0.8	0.574	0.604	0.392
	(0.075)**	(0.120)**	(0.080)**	(0.177)**	(0.213)+
Constant	-5.904	-7.504	-5.756	-5.764	-5.894
	(0.424)**	(0.451)**	(0.456)**	(0.868)**	(0.543)**
Observations	646	646	646	646	646
R^2	0.6	0.82	0.62	0.85	0.73

Note: Robust standard errors clustered by country in parentheses. Significant at + 10%; * 5%; ** 1%. In column 5, the regresssion is a between groups panel regression; There are 31 country groups, within R^2 is 0.30, between is 0.73, and overall is 0.57.

coefficient remains large and significant. Importantly, though, the M2 coefficient increases both in magnitude and in statistical significance.

In column 3 we omit country fixed effects but add year-only fixed effects (YFE). The year effects are statistically significant, but compared with the pooled OLS results in column 1, the coefficient estimates do not change by a large or statistically significant amount, and the fit is only modestly improved.

In column 4 we add both country and year fixed effects (CFE and YFE). In this specification the estimated coefficient of the financial openness variable is now insignificant. More of the estimated effect of financial openness in the EM sample seems to come from cross-section than from time-series variation. The M2 and trade variables, though, remain positive and significant, even after controlling for both year and country effects.

Finally, in Column 5, we remove all time-series identification and look at between-country panel estimation (running regressions across panel averages for each country). Our results are strikingly similar to the regressions without country fixed effects. Countries that are on average more financially open tend to hold more reserves; countries that have larger M2 to GDP ratios and larger trade to GDP ratios also tend to hold more reserves. The peg variables do not have significant coefficients in the between regression for the emerging-market sample, though they do in between regressions on the full or developing-country samples.

D. Original Sin

The finding of a negative advanced dummy coefficient in Table 1 could reflect the possibility that poorer countries, unable to issue foreign debt denominated in their own currencies, may need to hold more reserves. We now explore the influence of "original sin" directly.

Given the limited information available, however, analysis is restricted to a subset of only 770 country-year observations, including 168 advanced, 331 emerging, and 271 developing, with

TABLE 4: ORIGINAL SIN

	(1)	(2)	(3)	(4)
Sample	Full sample	Emerging markets	Full sample	Emerging markets
Financial openness	0.413	0.871	0.46	0.851
	(0.229)+	(0.321)*	(0.202)*	(0.299)**
Peg	0.082	-0.079	0.233	0.019
	(0.091)	(0.119)	(0.081)**	(0.154)
Soft peg	0.078	0.021	0.237	0.027
	(0.062)	(0.084)	(0.068)**	(0.103)
ln(M2/GDP)	0.548	0.343	0.318	0.306
	(0.086)**	(0.104)**	(0.081)**	(0.113)*
ln(trade/GDP)	0.376	0.517	0.489	0.512
	(0.098)**	(0.082)**	(0.087)**	(0.107)**
Advanced	-0.712		-0.883	
	(0.148)**		(0.134)**	
Original sin (SIN1)	1.354	-0.901		
	(0.402)**	(2.211)		
ln(foreign currency debt/GDP)	0.035	0.003		
	(0.03)	(0.044)		
Foreign currency exposure			0.334	0.184
			(0.223)	(0.372)
Constant	-7.228	-5.089	-5.632	-5.811
	(0.627)**	(2.275)*	(0.483)**	(0.684)**
Observations	770	331	1227	408
R^2	0.58	0.63	0.44	0.6

Note: Robust standard errors clustered by country in parentheses. Significant at + 10%; * 5%; ** 1%. Foreign currency exposure is the net national foreign currency position (gross external foreign currency assets less gross external foreign currency liabilities), excluding official international reserves, from Lane and Shambaugh (2009).

data starting in 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). Findings are reported in Table 4.

These results show that the "original sin" hypothesis actually fares better than the Guidotti-Greenspan guideline. While the second foreign-currency debt measure that we use here does not allow a test of the strict version of Guidotti-Greenspan, it fails to show up in an economically or statistically significant manner consistent with that policy prescription. The SIN1 variable, however, is significantly positive in the full sample (column 1): countries issuing a higher fraction of debt in foreign currency hold higher foreign reserves. Our financial-stability model still performs well when augmented with the SIN1 variable. Its core variables remain positive and, for the most part, significant.[38]

If country fixed effects are added, SIN1 loses significance and carries a perverse sign because the variable has very little time variation. (We omit the detailed results.) For nearly all emerging-market and developing countries, the original sin measure is very nearly constant and close to 100 percent. This feature of the data also ensures that SIN1 is insignificant in samples that

[38]Neither peg nor soft peg are now statistically significant. However, the sample is now much smaller. Moreover, a considerable portion of the developing-country sample is excluded by the use of SIN1 as a regressor, and, as we have seen, it is in developing countries that the exchange rate regime variables seem to matter most for reserve demand.

exclude the advanced countries, even when there are no country fixed effects. Column 2 shows these results for the emerging-market sample. Importantly, though, SIN1 is not simply a proxy for advanced country status (which may entail additional structural advantages such as better prudential oversight of the financial markets). Advanced and SIN1 are individually significant even when both appear as regressors. 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 with less sin.

The inability to issue debt in one's own currency may induce a country to hold more reserves to balance its currency profile. Countries with large external foreign currency debt may hold reserves to balance their currency position, but the failure of the Greenspan-Guidotti variables suggests this is not the entire story. On the other hand, one may also want to consider the full national external balance sheet, not just the size of liabilities. Lane and Shambaugh (2009) have assembled a new data set on international currency exposures that is suitable for this purpose.

The Lane-Shambaugh variable gives the net foreign currency position implied by a country's external balance sheet (after subtracting out reserve positions). When we include this variable in the full or emerging sample, we find that a more negative net foreign currency exposure does not lead a country to hold more reserves. Thus, reserves do not seem to function as a hedge against foreign-currency liabilities elsewhere in the national balance sheet.[39]

To conclude, our full data sample exhibits a positive correlation between reserves and original sin, but there is no correlation within the emerging-market subsample. Our main concern here, however, is to show that our core results are unaffected by this modification of the empirical specification. Nonetheless, the causal relationship between reserves and original sin may warrant further scrutiny in future research. It may be that sin causes reserves, in that a larger stock of foreign-currency debt, all else equal, requires larger reserve cover in the event of a sudden stop. But it is equally possible that some reverse causation is at work, with larger reserves at the central bank assuring the private sector that the peg is more likely to hold, and hence encouraging greater domestic issuance of foreign-currency debt.

E. Then versus Now: Have We Entered a New Era?

We next consider the model's stability over time. Specifically, we address the suggestion that the recent wave of reserve accumulation reflects a pronounced break from the central bank behavior of the past. To do this we examine how the model performs in three broad eras.

We divide our sample into three periods: the 1980s, the pre-Asian crisis 1990s (1990-97), and the post-Asian crisis years (1998-2004). The first three columns of Table 5 shows our findings for the emerging-market sample. Financial openness and trade have fairly consistent estimated effects over time, but financial depth appears not to have been a factor in the 1980s (column 1) and only recently has become quite important (column 3). Over time, the trade/GDP ratio becomes less important for the emerging-market sample while financial depth becomes increasingly important.

[39]We have also experimented with measures of bank quality and bank regulation (due to Ross Levine and his coauthors). Countries with shakier banks might hold more reserves against the higher probability of financial instability. The bank quality measures, like original sin, lack substantial time variation. While in some specifications they are statistically significant with the expected sign, they are not particulary robust and do not affect the other core variables of our financial-stability model.

TABLE 5: FINANCIAL STABILITY MODEL ACROSS ERAS

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Emerging	Emerging	Emerging	Full	Full	Full
	1980s	Pre-Asia 1990–97	Post-Asia	1980s	Pre-Asia 1990–97	Post-Asia
Financial openness	0.923	0.829	0.648	0.782	0.43	0.024
	(0.490)+	(0.419)+	(0.253)*	(0.299)*	(0.232)+	(0.214)
Peg	0.177	0.081	-0.089	0.027	0.18	0.213
	(0.195)	(0.201)	(0.116)	(0.133)	(0.109)	(0.108+)
Soft peg	-0.087	-0.002	0.101	0.13	0.153	0.243
	(0.229)	(0.112)	(0.089)	(0.106)	(0.078)+	(0.074)**
ln(M2/GDP)	0.000	0.154	0.45	0.22	0.34	0.386
	(0.193)	(0.172)	(0.101)**	(0.142)	(0.083)**	(0.072)**
ln(trade/GDP)	0.625	0.614	0.479	0.638	0.57	0.379
	(0.172)**	(0.147)**	(0.069)**	(0.105)**	(0.083)**	(0.097)**
Advanced				-0.218	-0.662	-0.831
				(0.163)	(0.154)**	(0.182)**
Constant	-5.327	-5.807	-6.07	-6.298	-6.197	-5.114
	(0.605)**	(0.516)**	(0.456)**	(0.610)**	(0.368)**	(0.458)**
Observations	217	212	217	976	930	864
R^2	0.54	0.51	0.71	0.33	0.4	0.35

Note: Robust standard errors clustered by country in parentheses. Significant at + 10%; * 5%; ** 1%. No fixed effects.

The pattern is similar for the full sample (columns 4 through 6), although M2/GDP is positive and significant in the early 1990s as well. Thus, the emerging-market countries seem to be coming more into line with the overall patterns in the full sample. In fact, M2/GDP is positively correlated with reserves in the emerging-market sample in each period, but the partial correlation increases and the pertinent standard error falls as time goes by. In the full sample financial openness is insignificant in the post-Asian crisis period, perhaps due to the absence of variation (over time or space) among the advanced countries. Another feature of the full sample is that the importance of peg indicators seems to rise over time. This pattern is most likely due to the secular increase in the reserves of the emerging-market countries, which are more likely than industrial countries to manage their exchange rates.

These findings suggest that the growth in the importance of M2/GDP for emerging market countries started just as these countries were becoming progressively more fully integrated into world financial markets. The findings provide further support for our argument that M2 has been a key driver of recent reserve growth and that it should not be overlooked when trying to predict reserve behavior going forward.

These results as well as theoretical analysis both suggest that interaction terms may be relevant. In practice, we found that an interaction between financial openness and financial depth is not statistically significant, and the noninteracted variables retain their signs.

F. Does Money Increase Reserve Demand or Vice Versa?

Our estimates are consistent with the idea that increased financial depth in the form of higher M2 generates higher reserve demand. But the results might instead reflect a different pattern of causation. High-powered money could be a common causal factor, because the broad money supply M2 and international reserves might simultaneously rise in response to a rise in the monetary

TABLE 6: THE MONETARY BASE AND M2

	(1)	(2)	(3)	(4)
Dependent variable	Traditional ln(reserves/M0)	Financial Stability ln(reseves/M0)	Financial Stability ln(reserves/M0)	Financial Stability ln(reserves/GDP)
ln(population)	-0.067			
	(0.087)			
ln(trade/GDP)	0.364	0.278		0.571
	(0.151)*	(0.072)**		(0.077)**
Exch. rate vol.	-0.088			
	(0.29)			
ln(GDP/person)	0.328			
	(0.153)*			
ln(M2/M0)		0.726	0.81	
		(0.114)**	(0.113)**	
Peg		-0.222	-0.144	0.046
		(0.141)	(0.133)	(0.14)
Soft peg		-0.066	0.014	-0.004
		(0.114)	(0.114)	(0.122)
Financial openness		1.407	1.777	0.894
		(0.235)**	(0.289)**	(0.196)**
ln(M2/GDP)				0.261
				(0.113)*
ln(M0/GDP)				-0.06
				(0.123)
Constant	-3.341	-2.928	-2.155	-5.831
	(2.579)	(0.372)**	(0.287)**	(0.467)**
Observations	646	646	646	646
R^2	0.36	0.57	0.54	0.60

Note: Robust standard errors clustered by country in parentheses. Significant at + 10%; * 5%; ** 1%.

base M0. In principle, a central bank can determine the composition and size of its balance sheet independently through sterilized intervention. In practice, however, causality could run from M0 to reserves and M2 jointly. For example, the central bank might pursue a reserve management policy of keeping the reserves/M0 ratio fixed (constant backing of the monetary base, including the case of a currency board); in that environment, an increase in the demand for M0 could then spill over into both an increase in reserves (an endogenous central bank response) and an increase in M2 (for a given money multiplier, via the banking sector's creation of broad money).

We investigate this possibility in Table 6, but the results suggest that the hypothesized effect of base money on reserves and M2 is *not* driving our results. (Table 6 reports results for the emerging-market sample. Results based on the full country sample are quite similar, the main difference being that in the full sample, pegging is positively correlated with the ratio of reserves to M0.) Our first approach is to change the scaling of reserves. Rather than looking at reserves divided by GDP, we scale reserves by M0 in alternative versions of the traditional and financial stability models. Column 1, the rescaled traditional model, shows that ratios of reserves to M0 are higher when the trade/GDP ratio and per capita GDP are higher. Column 2 demonstrates that, much as in our previous results, financial openness and financial depth (the latter measured as M2/M0) are still positively correlated with reserves. As in the earlier tables, the peg variables are not significant for the emerging-market sample. Even when rescaled by M0 rather than GDP, the financial stability model still produces a higher R^2 than the traditional model.

For a different approach, in column 4, we scale by GDP as before but also include the ratio M0/GDP in the regression as an additional control variable. When so added, M0/GDP is uncorrelated with the ratio of reserves to GDP, conditional on the other independent variables in the financial stability model. More importantly, the M2/GDP coefficient is still the same size (slightly larger) than in the comparable estimates of Table 2, column 3. The connection between broad money M2 and reserves apparently is not due to causality running through M0. Even controlling for base money (M0), growth in the financial sector (M2) is significantly correlated with reserve growth.

A particular pattern one may be concerned with is that high current account surplus countries might try to avoid appreciation by buying reserves, as in, say, the "new mercantilist" view. If this also led to money-supply growth (with purchases of reserves directly increasing M0, as under incomplete sterilization), one might mistakenly misinterpret side effects of exchange rate policy for deliberate backstopping of the banking system. Yet, as Table 6 shows, we do not see reserves rising with M0. Instead, the size of the banking system, scaled either by M0 or GDP, appears to drive reserve ratios. Beyond these observations, though, we have experimented with a wide variety of current account controls in our regressions and they do not affect our results. In particular, including the ratio of the current account surplus to GDP (or lagged ratios) in our annual specifications typically results in positive and significant coefficients, but these modifications do not alter the coefficients or significance levels of the other variables at all.[40]

G. *In-Sample and Out-of-Sample Prediction: Are Current Reserves Excessive?*

The considerations suggested by previous thinkers such as Thornton and expressed in our theoretical model do appear to matter empirically for reserve demand. As financial depth increases, the central bank will worry more about an internal-external double drain, and will hold more reserves. This will especially be true if the country is financially open and perhaps if its currency is pegged.[41] Financial depth is important even in just the time series dimension (within estimates) for emerging markets, and it has become more important lately as emerging-market countries have grown more open financially. These findings suggest that M2 is potentially a key to understanding recent reserve growth.

We now turn from a focus on model selection and statistical significance to evaluations based on model fit and quantitative significance. As we have noted above, it is often alleged that current

[40]We have also experimented with cross-sectional regressions over different eras to see if countries with high current account balances over a five to ten year period have higher reserves. The rationale is that we do not expect the level of the current account in a given year to affect reserves as much as the cumulative current account over a number of years. Here again, the current account does appear to have a positive relationship to reserve holdings, but its addition does not affect the other coefficients. In the emerging-market sample the impact of the current account surplus is strongest in the last decade, but that effect is driven by Singapore, Venezuela, and Russia, all which have had large current account surpluses and have higher reserve ratios than expected based on other variables. We have also examined country fixed effect regressions. With fixed effects added, countries still seem to have higher reserve levels when they have higher current account surpluses. But again, adding the current account has virtually no impact on the estimated coefficients of the other variables, nor does the overall explanatory power of the regression change much at all.

[41]Unconditionally, exchange rate pegging seems positively and significantly correlated with reserve holding, but that correlation may reflect omitted variables such as trade. It is possible that one reason for the weakness of this variable is that even countries that are floating at a given point in time expect to peg again soon (see Klein and Shambaugh 2008). In that case, they will not necessarily hold fewer reserves while they are not pegging.

reserve holdings are excessive or "inexplicable" based on traditional or external-debt explanations. We now present both in-sample and out-of-sample predictions to show that our financial stability model can provide a better account of recent reserve accumulation behavior.

IN-SAMPLE PREDICTION. — The two panels of Figure 1 show the growth in total emerging market reserves over the 25 year sample period. For this period we conduct an in-sample comparison of the financial stability model specification and the traditional specification.[42] The heights of the columns represent actual values of reserves year by year in emerging markets. The columns' subsections illustrate how changes in the model variables explain the growth of reserves over time. The bottom subsection is the amount that a model predicts for the year 1980 (constant over time). The other subsections of each column depict in turn the predicted changes since 1980 due to each regressor. The second lowest, for example, shows the effects of changes in per capita GDP assuming all other variables had remained constant at their 1980 values. The total predicted effect, however, is not merely the sum of all those columns: the column section labeled "interaction" captures the multiplicative (nonlinear) effect of all variables changing simultaneously, given the log functional form we have used. Finally, the dark shaded subsection represents the amount that cannot be explained by the model: it is the top section when there is an underprediction and below the horizontal zero axis if there is overprediction, so that the unexplained portion is negative.

Figure 1a shows that when one uses a financial stability specification, growth in per capita GDP alone (assuming a constant reserve/per capita GDP ratio) explains a considerable amount of reserve growth. Beyond that, however, financial openness and the size of the financial sector explain considerable 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 specification in Figure 1b predicts lower levels of reserves in emerging markets broadly and in particular it leaves a considerable volume of reserves unexplained starting in the middle 1990s. By 2004 the traditional specification predicts only about $880 billion in reserves and leaves $700 billion unexplained. Figure 2, which presents the in-sample predictions for China alone, paints a very similar picture.[43]

The case of the world's largest reserve holder, China, warrants a brief separate discussion. As the contribution of M2 in the figure suggests, China's M2 has grown considerably over time (from 27 percent of GDP in 1979 to 150 percent of GDP in 2004). Thus, financial deepening provided a basic motivation for reserve growth long before discussions of the renminbi's undervalued exchange rate became prominent. While China is not generally regarded as very open economy financially, it has nonetheless grown increasingly so by objective measures (from a score of zero in 1979 to 0.5 in 2004 on a scale of 0 to 1, based on Edwards' 2007 metric and

[42]The financial stability specification that we use is the one in Table 1, column 7, which excludes the trade variable. We remove trade to separate clearly the financial stability specification from the traditional specification: we would like to see how far financial stability factors alone can go. Further, the estimates underlying Figure 1 come from a restricted, balanced sample. Otherwise, changes in the country sample would in part drive our predicted reserve totals.

[43]In a working paper version, we present additional in-sample predictions over shorter horizons that allow us to include more countries in a balanced panel as well as "sin" data (Obstfeld, Shambaugh, and Taylor 2008). The results again show that a financial stability specification does quite well at explaining rising reserves to GDP ratios in the last decade and in particular does better than specifications relying on trade alone.

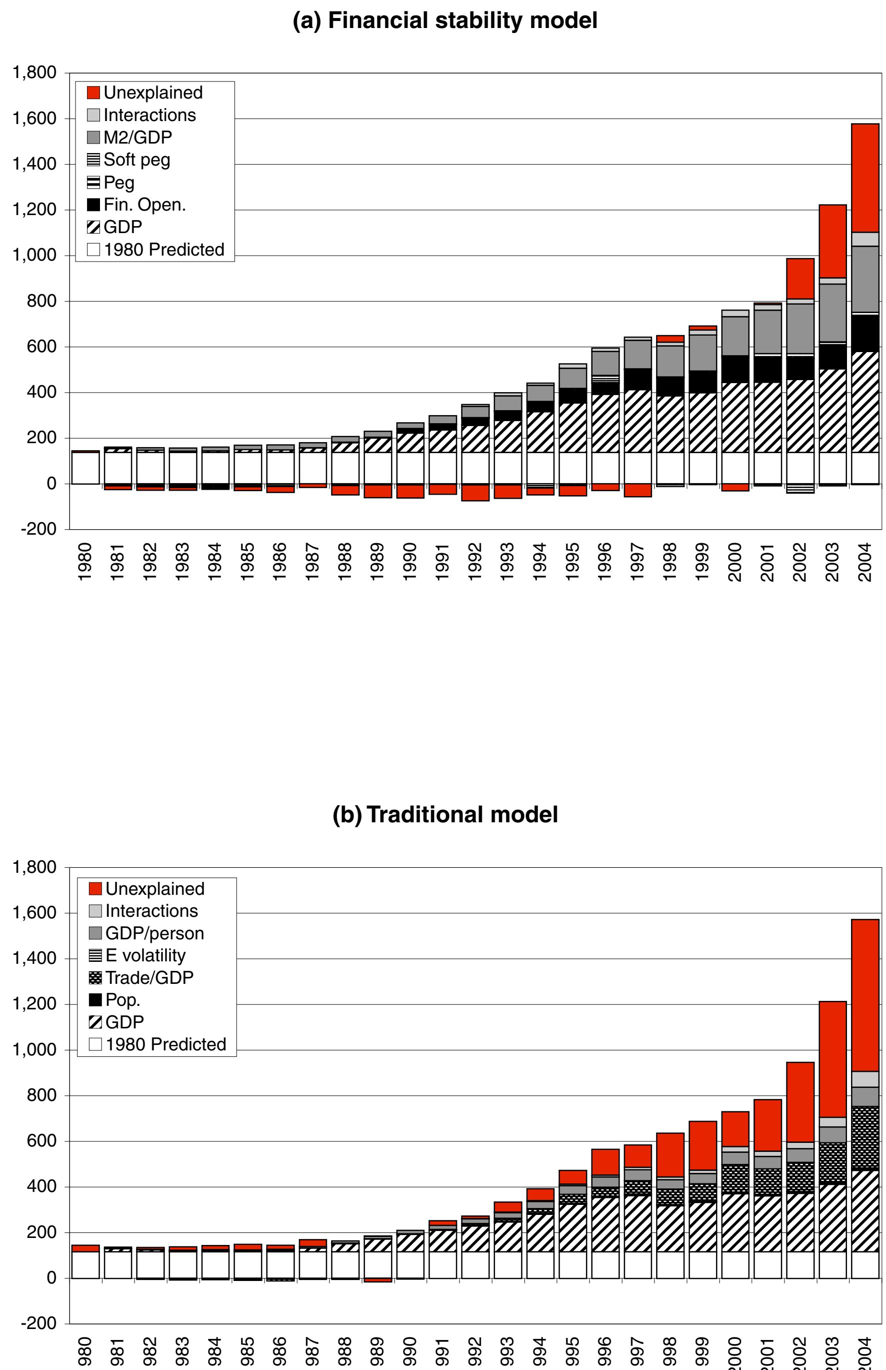
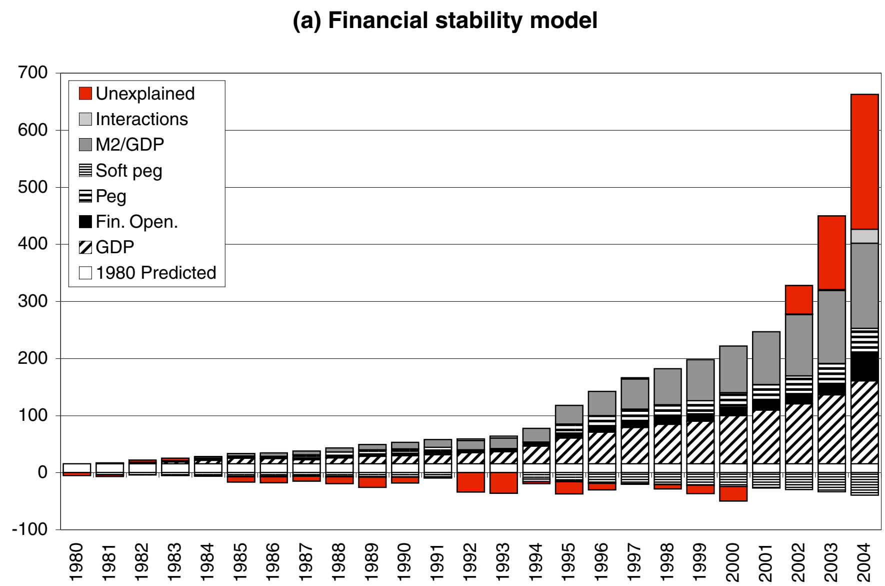


FIGURE 1: IN-SAMPLE: WHAT EXPLAINS POST-1980 INCREASES IN EMERGING MARKET RESERVES?



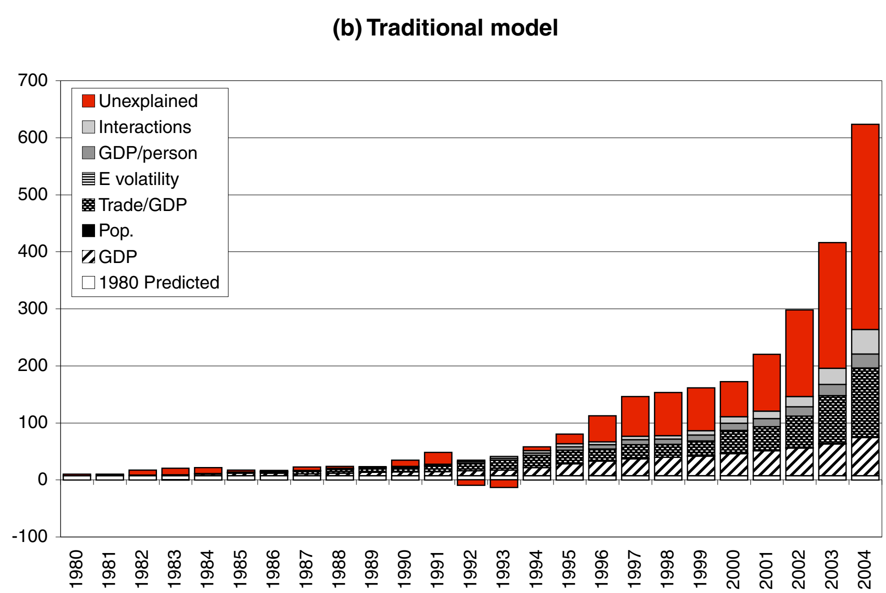


FIGURE 2: IN-SAMPLE: WHAT EXPLAINS POST-1980 INCREASES IN CHINA'S RESERVES?

data). Its nonreserve outflows have exceeded 4 percent of GDP a number of times in the last decade. Furthermore, China has used international reserves to recapitalize domestic banks in past years and the high level of non-performing loans held by Chinese banks is sometimes cited as a reason for its large holdings of reserves.[44] If further bank bailouts are unavoidable, or if China moves toward greater financial openness—two trends that seemed likely to materialize in recent years—then more reserves will be needed. A considerable amount of Chinese reserve accumulation thus seems explicable in our specification. As the next section shows, China does not appear to be an extreme outlier even in out-of-sample forecasts, at least up to the end of our data sample in 2004.

OUT-OF-SAMPLE PREDICTION. — In addition to asking what drives reserve changes over time, one might ask how well the model predicts reserves out-of-sample. Jeanne (2007) suggests that despite providing acceptable in-sample accounting, econometric equations estimated over past subsamples are unable to predict the surge in reserves in the most recent years.

We have seen that the financial stability specification likewise explains reserves well on an in-sample basis, so we now turn to its out-of-sample performance. We estimate the financial-only model on data from 1993 (the first year for which there are "original sin" data) up to 2000, and then try to predict reserves in subsequent years (2004 being the last year for which we have a full set of independent variables).

Figure 3a shows actual reserves on the vertical axis and compares them to the reserve levels 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. In contrast, Figure 3b shows the same scatter but instead uses the traditional model to make the out-of-sample reserve predictions for 2004. This scatter is much more dispersed relative to the 45-degree line and, in particular, more countries are far distant from the line. (China is now well above 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 ratio using the financial stability model is 0.52, and the slope coefficient is 1.30. 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 0.37 and the slope coefficient is 1.84, suggesting a more severe underprediction of the largest reserve holdings if one uses the traditional model.[45]

Figure 4 illustrates the model's performance over time for a selection of countries and country groups. We again estimate using 1993–2000 data and graph actual reserve/GDP ratios against the out-of-sample predictions of the financial stability and traditional specifications.[46] The financial stability specification is able to explain most of the rise in the reserves of China, at least until the last year of the sample, 2004.[47] The financial stability specification does quite a bit better

[44] See Prasad and Wei (2007). In 2003, China used $45 billion from its reserves to recapitalize two state banks.

[45] Removing the large outlier Singapore improves the performance of the financial stability model, raising 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 to 0.32, but it also lowers the slope coefficient from 1.81 to 1.38.

[46] The number of groups is smaller than in Figure 3 because of the need for balanced panels.

[47] As in Figure 3, an equation based on 1993–2000 data does a better job of predicting China's holdings in the early

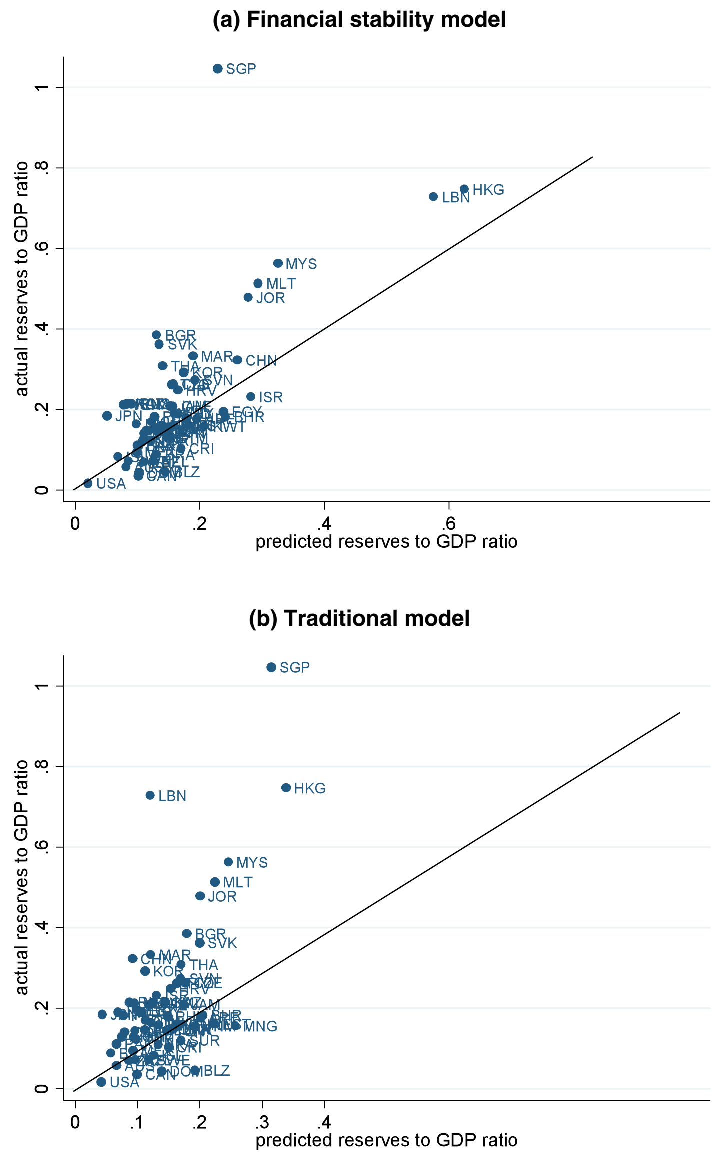


FIGURE 3: OUT-OF-SAMPLE PREDICTIONS: 2004 PROJECTED FROM 1993–2000

for the United States than does a traditional specification. For the three emerging market country groups, the financial stability model is always more accurate than the traditional model, though in the most recent years, the gap between predicted and actual reserves is growing in emerging Asia.[48] Finally, though, we see that neither model can explain the massive run up in Japan's reserves. One could hypothesize many potential reasons for that country's high reserves: attempts to prevent deflation by buying foreign assets, attempts to prevent appreciation, or a government desire to conduct carry trades. Neither the financial stability nor the traditional model captures these effects, however.

In general, we find that the financial stability specification can predict with reasonable accuracy the official reserve holdings in our sample. There are notable exceptions (Japan, Singapore, and to some degree China beginning in 2004), but in light of the financial stability specification that we have proposed, the reserve accumulation puzzle appears far less dramatic than either traditional models or models based on foreign debt and sudden stops would suggest.

IV. 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 appears to be 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 following Britain's 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).

More than two centuries ago Henry Thornton perceived that with a fixed exchange rate and a growing base of bank deposits to worry about, a central bank needed to accumulate 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. Over the past two decades, Thornton's insight has become an important key to understanding global patterns of demand for international reserves.

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2000s than one based on the full time sample because the 1980s data give less weight to financial variables (as shown in Table 4).

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

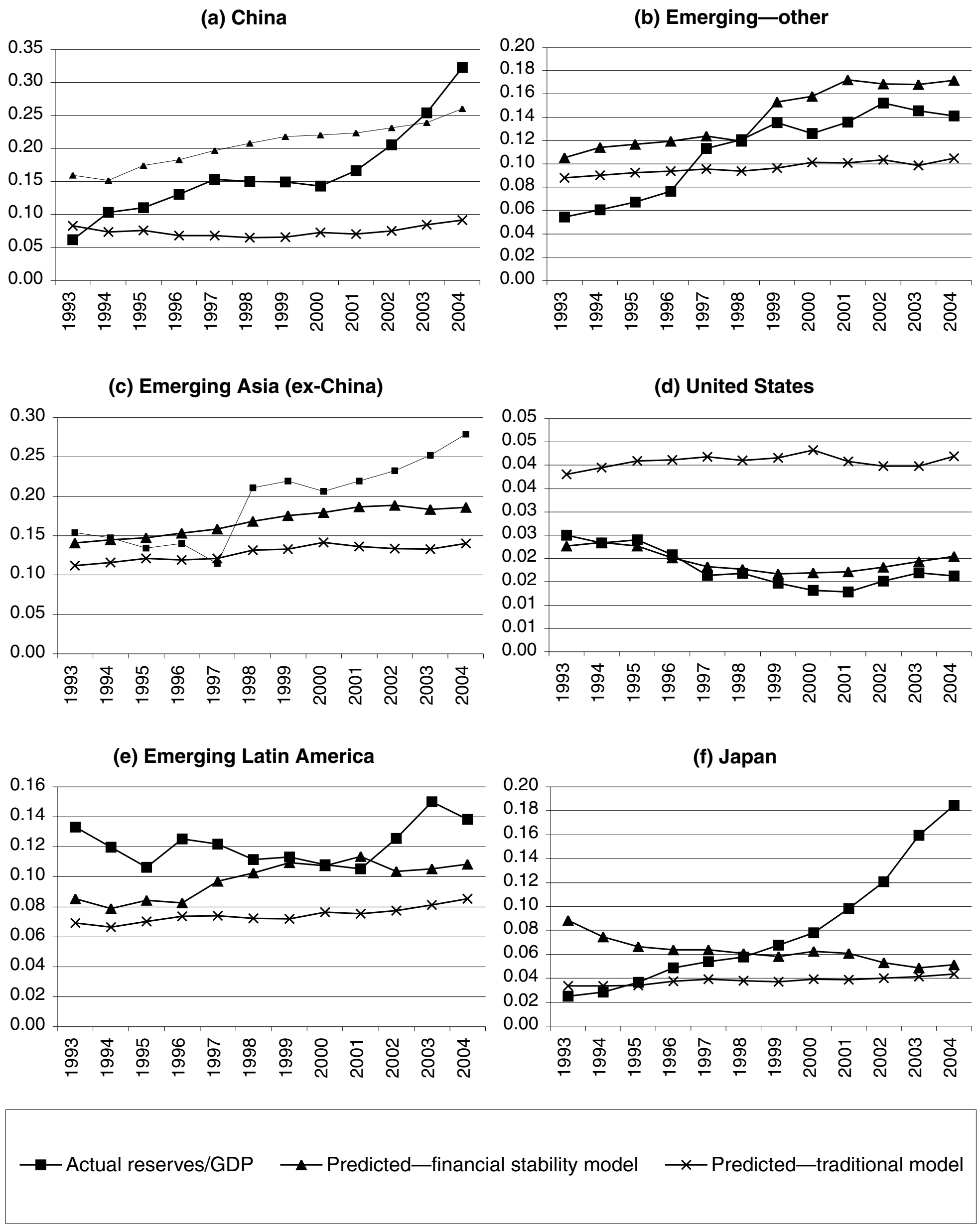

FIGURE 4: OUT-OF-SAMPLE PREDICTIONS OVER TIME

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