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Quantitative Easing: Entrance and Exit Strategies

Alan S. Blinder

Apparently, it *can* happen here. On December 16, 2008, the Federal Open Market Committee (FOMC), in an effort to fight what was shaping up to be the worst recession since 1937-38, reduced the federal funds rate to nearly zero.[1] From then on, with all its conventional ammunition spent, the Federal Reserve was squarely in the brave new world of *quantitative easing*. Chairman Ben Bernanke tried to call the Fed's new policies "credit easing," probably to differentiate them from actions taken by the Bank of Japan (BOJ) earlier in the decade, but the label did not stick.[2]

Roughly speaking, quantitative easing refers to changes in the composition and/or size of a central bank's balance sheet that are designed to ease liquidity and/or credit conditions. Presumably, reversing these policies constitutes "quantitative tightening," but nobody seems to use that terminology. The discussion refers instead to the bank's "exit strategy," indicating that quantitative easing is something aberrant. I adhere to that nomenclature here.

I begin by sketching the conceptual basis for quantitative easing: why it might be appropriate and how it is supposed to work. I then turn to the Fed's *entrance* strategy—which is presumably in the past, and then to the Fed's *exit* strategy—which is still mostly in the future. Both strategies invite some brief comparisons with the Japanese experience between 2001 and 2006. Finally, I address some questions about central bank independence raised by quantitative easing before briefly wrapping up.

THE CONCEPTUAL BASIS FOR QUANTITATIVE EASING: THE LIQUIDITY TRAP

To begin with the obvious, I think every student of monetary policy believes that the central bank's conventional policy instrument—the overnight interest rate (the "federal funds" rate in the United States)—is more powerful and reliable than quantitative easing. So why would any rational central banker ever resort to quantitative easing? The answer is pretty clear: Under

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[1] Specifically, the FOMC cut the funds rate to a range between zero and 25 basis points. In practice, funds have mostly traded around 10 to 15 basis points ever since.

[2] As will be clear later, the Fed's approach and the BoJ's approach *were* different.

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extremely adverse circumstances, a central bank can cut the nominal interest rate all the way to zero and still be unable to stimulate its economy sufficiently.[3] Such a situation, in which the nominal rate hits its zero lower bound, has come to be called a "liquidity trap" (Krugman, 1998), although that terminology differs somewhat from Keynes's original meaning.[4]

Let's review the underlying logic. The presumption is that real interest rates (r), not nominal interest rates (i), are what mainly matter for, say, aggregate demand. In deep recessions, monetary policymakers may need to push real rates ($r = i - \pi$, where π is the rate of inflation) into negative territory.[5] But once i hits zero, the central bank cannot force it down any farther, which leaves r "stuck" at $-\pi$, which is small or possibly even positive. In any case, once $i = 0$, conventional monetary policy is "out of bullets."

Actually, the situation is even worse than that. Recall Milton Friedman's (1968) warning about the perils of fixing the *nominal* interest rate when inflation is either rising or falling: Doing so invites dynamic instability. Well, once the nominal rate is stuck at zero, it is, of course, fixed. If inflation then falls, the real interest rate will rise farther, thereby squeezing the economy even more. This is a recipe for deflationary implosion.

Enter quantitative easing. Suppose that, even though the *riskless overnight* rate is constrained to zero, the central bank has some unconventional policy instruments that it can use to reduce interest rate *spreads*—such as term premiums and/or risk premiums. If flattening the yield curve and/or shrinking risk premiums can boost aggregate demand, then monetary policy is not powerless, even at the zero lower bound.[6] In that case, a cen-

tral bank that pursues quantitative easing with sufficient vigor can break the potentially vicious downward cycle of deflation, weaker aggregate demand, more deflation, and so on.

What unconventional weapons might be contained in such an arsenal? The following list is hypothetical and conceptual, but every item has a clear counterpart in something the Federal Reserve has actually done.

First, suppose the central bank's objective is to flatten the yield curve, perhaps because long rates have more powerful effects on spending than short rates. There are two main options. One is to use "open mouth policy." The central bank can commit to keeping the overnight rate at or near zero either for, say, "an extended period" (or some such phrase) or until, say, inflation rises above a certain level. To the extent that the (rational) expectations theory of the term structure is valid and the commitment is credible, doing so should reduce long rates and thereby stimulate demand.[7] But such verbal commitments would not normally be considered quantitative easing because no *quantity* on the central bank's balance sheet is affected. So I will not discuss them further.

The quantitative easing approach to the term structure is straightforward: Use otherwise-conventional open market purchases to acquire longer-term government securities instead of the short-term bills that central banks normally buy. If arbitrage along the yield curve is imperfect, perhaps because asset holders have "preferred habitats," then such operations can push long rates down by shrinking term premiums.[8]

The other likely target of quantitative easing is risk or liquidity spreads. Every private debt instrument, even a bank deposit or a AAA-rated bond, pays some spread over Treasuries for one

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[3] Another argument is that a central bank might want to "save its bullets" for an even more dire situation. However, this argument was effectively debunked by Reifschneider and Williams (2002).

[4] The Keynesian liquidity trap arises at the point where the demand function for money becomes infinitely elastic, which could happen at a nonzero interest rate.

[5] The difference between ex ante expected inflation and ex post actual inflation is not important for this purpose.

[6] Here I exclude exchange rate policy from monetary policy. Depreciating the exchange rate may be another option (see Svensson, 2003), though not when the whole world is in a slump.

[7] While the expectations theory of the term structure with rational expectations fails every empirical test (see, for example, Blinder, 2004, Chap. 3), long rates do seem to move in the right direction, if not by the right amount.

[8] The preferred habitat theory is attributed to Modigliani and Sutch (1966). It was one rationale, for example, for "Operation Twist," which sought to lower long rates while raising short rates in the early 1960s. Operation Twist, however, was not widely viewed as successful.

or both of these reasons.[9] Since private borrowing, lending, and spending decisions presumably depend on (risky) non-Treasury rates, reducing their spreads over (riskless) Treasuries reduces the interest rates that matter for actual transactions *even if riskless rates are unchanged.*

How might a central bank accomplish that? The most obvious approach is to buy one of the risky and/or less-liquid assets, paying either by (i) selling some Treasuries from its portfolio, which would change the *composition* of its balance sheet, or (ii) creating new base money, which would increase the *size* of its balance sheet.[10] Either variant can be said to constitute quantitative easing, and its effectiveness depends on the degree of substitutability across the assets being traded. As we know, buying X and selling Y does nothing if X and Y are perfect substitutes.[11] Fortunately, it seems unlikely that, say, mortgage-backed securities (MBS) are perfect substitutes for Treasuries—certainly not in a crisis.

THE FED'S ENTRANCE STRATEGY

With this conceptual framework in mind, I turn now to what the Federal Reserve actually did as it embarked on its new strategy of quantitative easing. Because the messy failure of Lehman Brothers in mid-September 2008 was such a watershed, I begin the story before that event.

Reacting somewhat late to the onset of the financial crisis in the summer of 2007, the FOMC began cutting the federal funds rate on September 18, 2007—starting from an initial target of 5.25 percent. While it cut rates rapidly by historical standards, the Fed did not signal any great sense of urgency. It was not until April 30,

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[9] In practice, it can be difficult to distinguish between spreads related to risk and spreads related to illiquidity. After all, illiquidity is one element of the riskiness of an asset. Hereafter, I simply refer to "risk spreads."

[10] Alternatively, if it has the legal authority, the central bank could (partially or totally) guarantee some of the risky assets or make loans to private parties who agree to buy the assets.

[11] Curdia and Woodford (2010) argue that the effectiveness of quantitative easing depends on the existence of "credit market frictions" rather than on imperfect substitutability. I think this difference is mostly terminological.

Federal Reserve Balance Sheet

Assets	Liabilities and Net Worth
Treasury securities	Currency
Less-liquid assets	Bank reserves
Loans	Treasury deposits
	Capital

2008, that the target funds rate got down to 2 percent, where the FOMC decided to keep it while awaiting further developments (Figure 1). Perhaps more germane to the quantitative easing story, the Fed was neither expanding its balance sheet (Figure 2) nor increasing bank reserves (Figure 3) much over this period.

However, the Fed was already engaging in several forms of quantitative easing, even apart from emergency interventions such as the Bear Stearns rescue. To understand these brands of quantitative easing, it is useful to refer to the oversimplified central bank balance sheet in the box. Because other balance sheet items are inessential to my story, I omit them.

The first type of quantitative easing showed up entirely on the assets side. Early in 2008, the Fed started selling its holdings of Treasuries and buying other, less-liquid assets instead (see Figure 2). This change in the *composition* of the Fed's portfolio was clearly intended to provide more liquidity (especially more T-bills) to markets that were thirsting for it. The goal was to reduce what were seen as liquidity premiums. But, of course, the underlying financial situation was deteriorating all the while, and the markets' real problems may have been fears of insolvency, not illiquidity—to the extent you can distinguish between the two.[12]

The second sort of early quantitative easing operations began on the liabilities side of the Fed's balance sheet. To assist the Fed, the Treasury

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[12] See, for example, Taylor and Williams (2009).

Figure 1

Effective Federal Funds Rate

Percentage Points
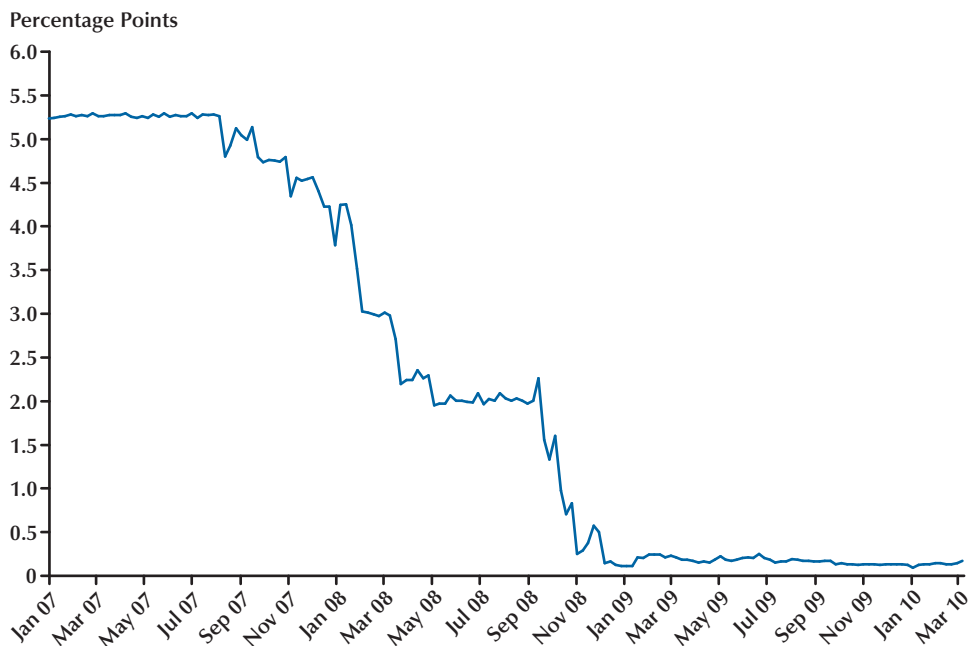
SOURCE: Federal Reserve.

started borrowing in advance of its needs (which were not yet as ample as they would become later) and depositing the excess funds in its accounts at the central bank. These were clearly *fiscal* operations, but they enabled the Fed to increase its assets—by purchasing more securities and making more discount window loans (e.g., through the Term Auction Facility [TAF])—*without* increasing bank reserves (see Figure 3). That is very helpful to a central bank that is still a bit timid about stimulating aggregate demand and/or is worried about running out of T-bills to sell— both of which were probably true of the Fed at the time. But notice that these operations marked the first breaching, however minor, of the wall between fiscal and monetary policy. In addition, the Fed began lending to (nonbank) primary dealers in the immediate aftermath of the Bear Stearns rescue in March 2008.

Six months later came the failure of Lehman Brothers, and everything changed—including

the Fed's monetary policy. The FOMC resumed cutting interest rates at its October 10, 2008, meeting, eventually pushing the funds rate all the way down to virtually zero by December 16 (see Figure 1). More germane to the quantitative easing story, the Fed started expanding its balance sheet, its lending operations, and bank reserves immediately and dramatically (see Figures 2 and 3).[13] By the last quarter of 2008, any reservations at the Fed about boosting aggregate demand were gone. It was "battle stations."

Total Federal Reserve assets skyrocketed from $907 billion on September 3, 2008, to $2.214 *trillion* on November 12, 2008[14] (see Figure 2). As this was happening, the Fed was acquiring a

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[13] Taylor (2010) correctly points out that the Fed began expanding its balance sheet substantially even *before* the federal funds rate hit zero.

[14] Federal Reserve System balance sheets are published weekly and are available on the Board's website.

Figure 2

Composition of the Fed's Balance Sheet: Assets Side
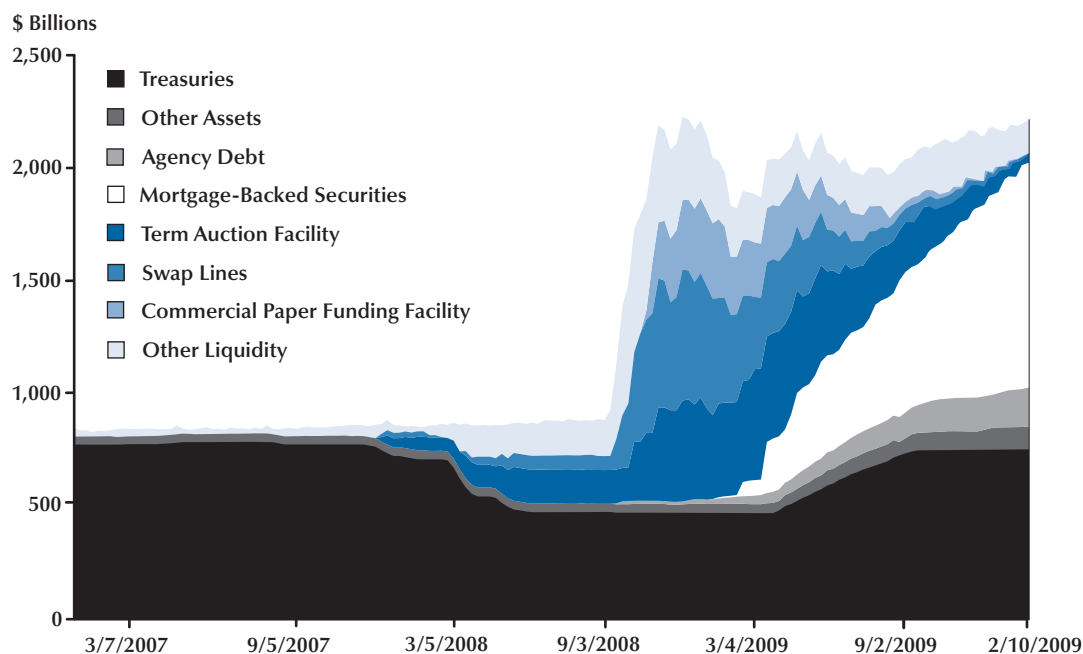
SOURCE: Federal Reserve Bank of New York.

wide variety of securities that it had not owned before (e.g., commercial paper) and making types of loans that it had not made before (e.g., to nonbanks). On the liabilities side of the balance sheet, bank reserves ballooned from about $11 billion to an astounding $594 billion over that same period—and then to $860 billion on the last day of 2008 (see Figure 3). Almost all of this expansion signified increased *excess* reserves, which were a negligible $2 billion in the month before Lehman collapsed (August) but soared to $767 billion by December.[15] Since the Fed's capital barely changed over this short period, its balance sheet became extremely leveraged in the process. Specifically, the Fed's leverage (assets divided by capital) soared from about 22:1 to about 53:1.

It was a new world, Tevye.[16]

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[15] These figures are monthly averages.

[16] A central bank can operate with negative net worth. Still, it is an uncomfortable position for the central bank.

The early stages of the quantitative easing policy were ad hoc, reactive, and *institution based*. The Fed was making things up on the fly, often acquiring assets in the context of rescue operations for specific companies on very short notice (e.g., the Maiden Lane facilities for Bear Stearns and American International Group [AIG]). Soon enough, however, the Fed's innovative parade of purchase, lending, and guarantee programs took on a more systematic, thoughtful, and *market-based* flavor—starting with the Commercial Paper Funding Facility (CPFF, begun in September 2008) and continuing with the MBS purchase program (announced November 2008), the Term Asset-Backed Securities Loan Facility (TALF, started in March 2009), and others. The goal became not so much to save faltering institutions, although that potential need remained, but rather to push down risk premiums, which had soared to dizzying heights during the panic-

Figure 3

Total Reserves of Depository Institutions
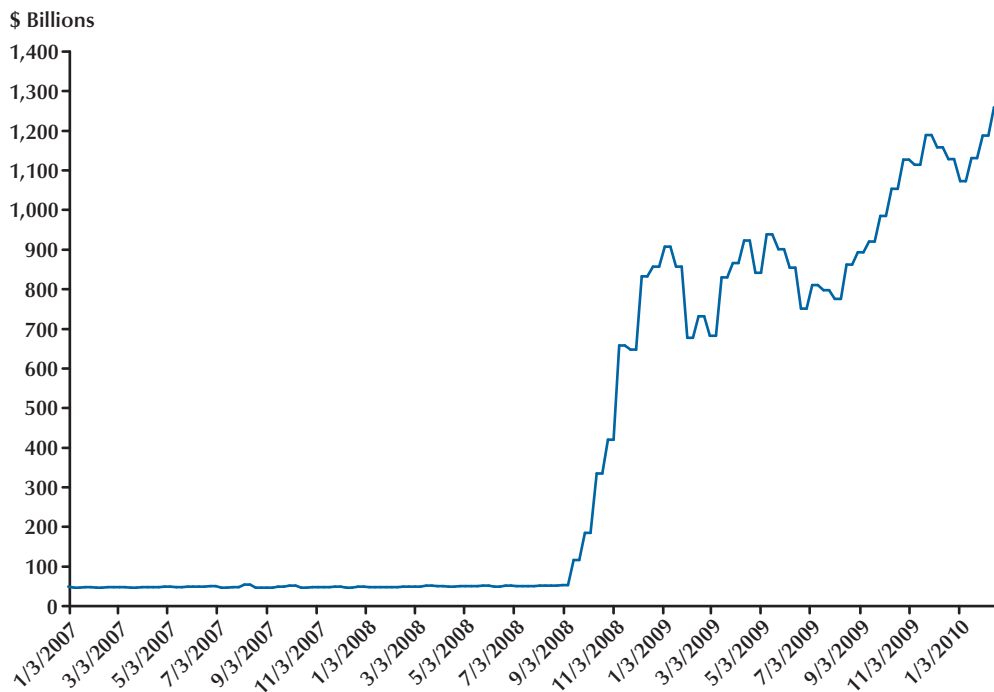
SOURCE: Federal Reserve.

stricken months of September through November 2008.[17]

This change in focus was both notable and smart. As mentioned earlier, riskless rates per se are almost irrelevant to economic activity. The traditional power of the funds rate derives from the fact that risk premiums between it and the (risky) rates that actually matter—rates on business and consumer loans, mortgages, corporate bonds, and so on—do not change much in normal times. Think of the interest rate on instrument j, say R_j, as being composed of the corresponding riskless rate, r, plus a risk premium specific to that instrument, say ρ_j. Thus $R_j = r + \rho_j$. If the ρ_j changes little, then control of r is a powerful tool for manipulating the interest rates that matter—and hence aggregate demand. That is the normal

case. But when the ρ_j moves around a lot—in this case, rising—the funds rate becomes a weak policy instrument. During the most panicky periods, in fact, most of the R_js were rising even though r was either constant or falling.

While I will say more about the Japanese experience later, one sharp contrast between quantitative easing in the United States and quantitative easing in Japan is worth pointing out right here. The BOJ concentrated its quantitative easing on reducing *term* premiums, mainly by buying long-term Japanese government bonds. By contrast, until it started purchasing long-term Treasuries in March 2009, the Fed's quantitative easing efforts concentrated on reducing *risk* premiums, which involved a potpourri of market-by-market policies. It was far more complicated, to be sure, but in my view, also far more effective.

In fact, the one aspect of the Fed's quantitative easing campaign of which I have been critical

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[17] As Michael Woodford pointed out to me, saving faltering institutions would also be expected to reduce risk spreads.

is its purchases of Treasury bonds. The problem in many markets was that the sum $r + \rho_j$ was too high—but mainly because of sky-high risk premiums, not high risk-free rates. Thus the true target of opportunity was clearly ρ_j, not r, which was already very low. Furthermore, a steep yield curve provides profitable opportunities for banks to recapitalize themselves without taxpayer assistance. Why undermine that?

In any case, the Fed's quantitative easing attack on interest rate spreads appears to have been successful, at least in part. Figures 4 and 5 display two different interest rate spreads, one short term and the other long term. Figure 4 shows the spread between the interest rates on 3-month financial commercial paper and 3-month Treasury bills; Figure 5 shows the spread between Moody's Baa-rated corporate bonds and 10-year Treasury notes. The diagrams differ in details—for example, with short rates much more volatile than long rates. But both convey the same basic message: Once the Fed embarked on quantitative easing in a major way, spreads tumbled dramatically. Admittedly, other things were changing in markets at the same time; so this was far from a controlled experiment. Still, the "coincidence" in timing is suggestive.

THE FED'S EXIT STRATEGY

The Fed's exit is still in its infancy. Chairman Bernanke first outlined the major components of its strategy in his July 2009 Congressional testimony, followed by a speech in October 2009 and further testimonies in February and March 2010.[18] So by now we have a pretty good picture of the Fed's *planned* exit strategy. Here are the key elements, listed in what may or may not prove to be the correct temporal order[19]:

1. "In designing its [extraordinary liquidity] facilities, [the Fed] incorporated features… aimed at encouraging borrowers to reduce their use of the facilities as financial conditions returned to normal" (p. 4, note).

2. "normalizing the terms of regular discount window loans" (p. 4).

3. "passively redeeming agency debt and MBS as they mature or are repaid" (p. 9).

4. "increasing the interest on reserves" (p. 7).[20]

5. "offer to depository institutions term deposits, which…could not be counted as reserves" (p. 8).

6. "reducing the quantity of reserves" via "reverse repurchase agreements" (p. 7).

7. "redeeming or selling securities" (p. 8) in conventional open-market operations.

Notice that this list deftly omits any mention of raising the federal funds rate. But the funds rate will presumably not wait until all the other steps have been completed. Indeed, Bernanke (2010a) noted that "the federal funds rate could for a time become a less reliable indicator than usual of conditions in short-term money markets," so that instead "it is possible that the Federal Reserve could for a time use the interest rate paid on reserves…as a guide to its policy stance" (p. 10). I will return to this not-so-subtle hint shortly.

The first and third items on this list are the parts of "quantitative tightening" that the Fed gets for free, analogous to letting assets run off naturally. As the Fed has noted repeatedly, its special liquidity facilities were designed to be unattractive in normal times, and Item 1 is by now almost complete. The Fed's two commercial paper facilities (one designed to save the money market mutual funds) outlived their usefulness, saw their usage drop to zero, and were officially closed on February 1, 2010. The same was true of the lending facility for primary dealers, the Term Securities Lending Facility, and the extraordinary swap arrangements with foreign central banks. The TAF and the MBS purchase program had been recently completed at that time,[21] and the TALF was slated to follow suit at the end of June 2010.

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[18] Bernanke (2009a,b; 2010a,b).

[19] The quoted material is from Bernanke's February 2010 testimony.

[20] Congress authorized the payment of interest on bank reserves as part of its October 2008 emergency package.

[21] This article is based on a lecture given on April 1, 2010; see the title page footnote.

Figure 4

Commercial Paper Versus T-Bill Risk Spread

Percentage Points
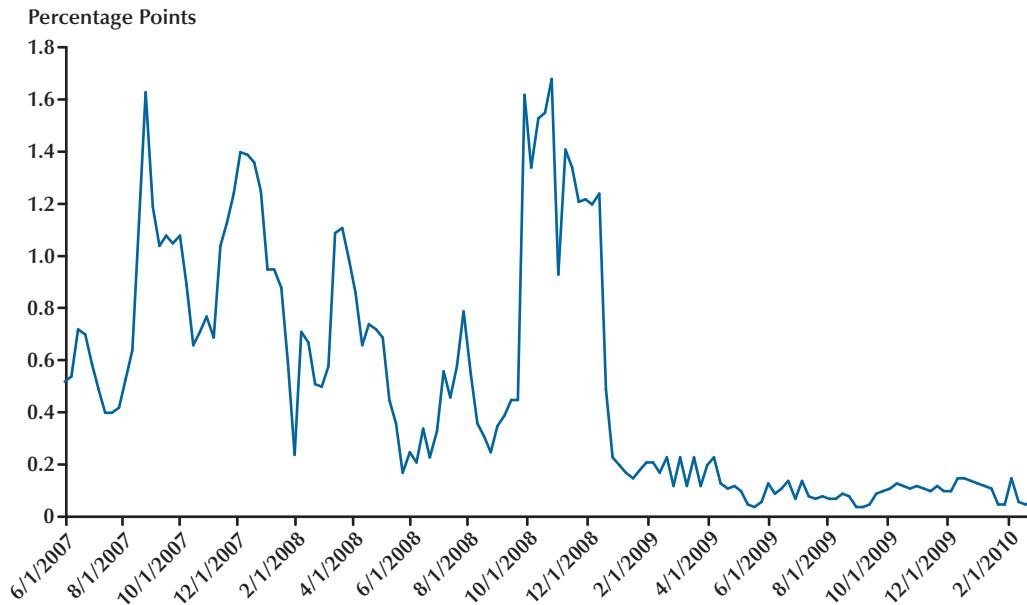
SOURCE: Federal Reserve.

Figure 5

Corporate Bond Versus T-Note Risk Spread

Percentage Points
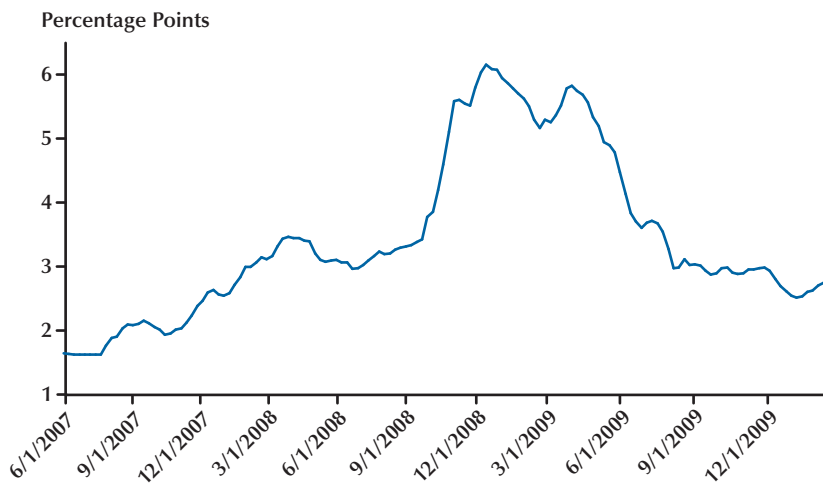
SOURCE: Federal Reserve.

Item 2 on this list (raising the discount rate) is necessary to supplement Item 1 (making borrowing less attractive), and the Fed began doing so with a surprise *intermeeting* move on February 18, 2010. A higher discount rate is also needed if the Fed is to shift to the "corridor" system discussed later.

Note, however, that all these adjustments in liquidity facilities will still leave the Fed's balance sheet with the Bear Stearns and AIG assets and huge volumes of MBS and government-sponsored enterprise debt. Now that new purchases have stopped, the stocks of these two asset classes will gradually dwindle (Item 3 on the list). But unless there are aggressive open market sales, it will be a long time before the Fed's balance sheet resembles the status quo ante.

That brings me to Items 6 and 7 on Bernanke's list, which are two types of conventional *contractionary* open market operations, achieved either by reverse repurchases (repos) (and thus temporary) or by outright sales (and thus permanent). Transactions such as these have long been familiar to anyone who pays attention to monetary policy, as are their normal effects on interest rates.

However, there is a key distinction between Items 1 and 3 (lending facilities), on the one hand, and Items 6 and 7 (open market operations), on the other, when it comes to degree of difficulty. Quantitative easing under Item 1, in particular, wears off naturally on the markets' own rhythm: These special liquidity facilities fall into disuse as and when the markets no longer need them. From the point of view of the central bank, this is ideal because the exit is perfectly timed, almost by definition.

Items 6 and 7 are different. The FOMC will have to decide on the pace of its open market sales, just as it does in any tightening cycle. But this time, both the volume and the variety of assets to be sold will probably be huge. Of course, the FOMC will get the usual market and macro signals: movements in asset prices and interest rates, the changing macro outlook, inflation and inflationary expectations, and so on. But its decisionmaking will be more difficult, and more consequential, than usual because of the enormous scale of the tightening. If the Fed tightens too

quickly, it may stunt or even abort the recovery. If it waits too long, inflation may gather steam. Once the Fed's policy rates are lifted off zero, short-term interest rates will presumably be the Fed's main guidepost once again—more or less as in the past.

This discussion leads naturally to Item 5 on Bernanke's list, the novel plan to offer banks new types of accounts "which are roughly analogous to certificates of deposit" (p. 8). That is, instead of just having a "checking account" at the Fed, as at present, banks will be offered the option of buying various certificates of deposit (CDs) as well. But here's the wrinkle: Unlike their checking account balances at the Fed, the CDs will *not* count as official reserves. Thus, when a bank transfers money from its checking account to its saving account, *bank reserves will simply vanish*.

The potential utility of this new instrument to a central bank wanting to drain reserves is evident, and the Fed has announced its intention to auction off fixed volumes of CDs of various maturities, probably ranging from one to six months. Such auctions would give it perfect control over the *quantities* but leave the corresponding *interest rates* to be determined by the market. Frankly, I wonder why banks would find these new fixed-income instruments attractive since they cannot be withdrawn before maturity, they do not constitute reserves, and they cannot serve as clearing balances. As a consequence, the new CDs may have to bear interest rates higher than those on Treasury bills. We'll see.

I come, finally, to the instrument that Bernanke and the Fed seem to view as most central to their exit strategy: the interest rate paid on bank reserves. Fed officials seem to view paying interest on reserves as something akin to the magic bullet. I hope they are right, but confess to being a bit worried. Everyone recognizes that the Fed's quantitative easing operations have created a veritable mountain of excess reserves (shown in Figure 3), which U.S. banks are currently holding voluntarily, despite the paltry rates paid by the Fed. The question is this: How urgent is it—or will it become—to whittle this mountain down to size?

One view sees all those excess reserves as potential financial kindling that will prove infla-

Figure 6

Interest Rate Floor System

Figure 7

Interest Rate Corridor System
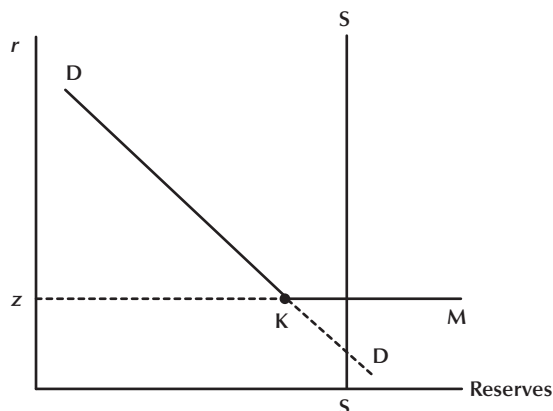
tionary unless withdrawn from the system as financial conditions normalize.[22] We know that under normal circumstances—before interest was paid on reserves—banks' demand for excess reserves was virtually zero. But now that reserves earn interest, say at rate z, which the Fed sets, banks probably will not want to reduce their reserves all the way back to zero. Instead, excess reserves now compete with other very short-term safe assets, such as T-bills, in banks' asset portfolios.[23] Indeed, one can argue that, for banks, reserves are now almost-perfect substitutes for T-bills. So excess reserve holdings will not need to fall all the way back to zero. Rather, the Fed's looming task will be to reduce the *supply* of excess reserves at the same pace that banks reduce their *demands* for them. The questions are how fast that pace will be and how far the process will go. Remember that as the Fed's liabilities shrink, so must its assets. So as the Fed reduces bank reserves, it must also reduce some of the loans and/or less-liquid assets now on its balance sheet.

There is, however, an alternative view that argues that the large apparent "overhang" of excess reserves is nothing to worry about. Specifically,

once the relevant market interest rate (r) falls to the interest rate paid on reserves (z), the demand for excess reserves becomes infinitely elastic (horizontal) at an opportunity cost of zero ($r - z = 0$), making the effective demand curve in Figure 6 DKM rather than DD.[24] Another way to state the point is to note that banks will not supply federal funds to the marketplace at a rate below z because they can always earn z by depositing those funds with the Fed.

As Figure 6 shows, as long as the (vertical) supply curve of reserves, SS, which the Fed controls, cuts the demand curve in its horizontal segment, KM, *the quantity of reserves should have no effect on the market interest rate*, which is stuck at z. Therefore, the quantity of reserves should presumably have no effects on anything else either. Infinitely elastic demand presumably means that *any* volume of reserves can remain on banks' balance sheets indefinitely without kindling inflation. It also means that the Fed's exit decisions should concentrate on how quickly to shrink the *assets* side of its balance sheet. The *liabilities* side, in this view, is a passive partner that matters little per se.

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[22] See, for example, Meltzer (2010) and Taylor (2009).

[23] They will soon also compete with the new CDs just discussed.

[24] See, for example, Keister, Martin, and McAndrews (2008) or Keister and McAndrews (2009).

The idea of establishing either an interest rate *floor*, as depicted in Figure 6, or an interest rate *corridor*, as depicted in Figure 7, may become the Fed's new operating procedure.[25] The corridor system starts with the floor (just explained) and adds a *ceiling* above which the funds rate cannot go. That ceiling is the Fed's discount rate, d, because no bank will pay more than d to borrow federal funds in the marketplace if it can borrow at rate d from the Fed.[26] The Fed's policymakers can then set the upper and lower bounds of the corridor (d and z) and let the funds rate float—whether freely or managed—between these two limits. Under such a system, the lower bound—the rate paid on reserves, z—could easily become the Fed's active policy instrument, with the discount rate set mechanically, say, 100 basis points or so higher.[27]

If the federal funds rate were free to float within the corridor, rather than remaining stuck at the floor or ceiling, the Fed could use it as a valuable information variable. If the funds rate traded up too rapidly, that might indicate the Fed was withdrawing reserves too quickly, creating more scarcity than it wants. If funds traded down too far, that might indicate that reserves were too abundant—that is, the Fed was withdrawing them too slowly. Such information should help the Fed time its exit.

QUANTITATIVE EASING AND TIGHTENING IN JAPAN

Quantitative easing in Japan, the only relevant historical precursor, began in March 2001 and ended in March 2006 (Figure 8). The BOJ drove the overnight interest rate to zero and then pledged to keep it there until deflation ended, mainly by flooding the banking system with excess reserves.

To create all those new reserves, the BOJ bought mostly Japanese government bonds, as mentioned earlier. The central idea behind quantitative easing in Japan was to stimulate the economy by proliferating reserves and flattening the (risk-free) yield curve, not by decreasing risk spreads.[28]

In fact, long bond rates did fall. But it is difficult to know how much of the decline was due to the BOJ's purchases and how much was due to its pledge to keep short rates near zero for a long while. Ugai's (2006) survey of empirical research on the effects of Japan's quantitative easing programs concluded that the evidence "confirms a clear effect" of the commitment policy on short- and medium-term interest rates but offers only "mixed" evidence that "expansion of the monetary base and altering the composition of the BOJ's balance sheet" had much effect.[29]

In any case, one of the more interesting and instructive aspects of quantitative easing in Japan may be how quickly it was withdrawn. Figure 8 shows that banks' excess reserves climbed gradually from about 5 trillion yen to about 33 trillion yen over the course of about two and a half years, but then fell back to only about 8 trillion yen over just a few months in 2006. Such an abrupt withdrawal of central bank money was, I suppose, driven by fears of incipient inflation—which was curious given Japan's recent deflationary history. In any case, inflation never showed up. While the suddenness of the BOJ's exit did not kill the economy, whether it hampered Japan's ability to stage a strong recovery is an open question.

In the case of the Fed, the massive increase in bank reserves after the Lehman bankruptcy came very quickly, as Figure 3 shows. The shrinkage, of course, has yet to begin. But my guess is that it will be gradual. If so, the Fed's pattern (up fast, down slow) will be just the opposite of the BOJ's (up slow, down fast). My second guess is that the Fed's more gradual withdrawal of quantitative easing will not unleash strong inflationary forces. And if that is correct, my third guess

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[25] Bernanke (2010a, p. 9 note) elucidates the corridor idea.

[26] Obviously, this requires that discount window lending is neither rationed by, for example, window guidance nor limited by "stigma."

[27] There is an interesting sidelight here for Fed aficionados: At present, the authority to set the discount rate and the rate paid on reserves resides with the Board of Governors, not the FOMC, which sets the funds rate.

[28] There were some purchases of private assets, but the BOJ concentrated on Japanese government bonds.

[29] The quoted material is from the paper's abstract.

Figure 8

Quantitative Easing in Japan
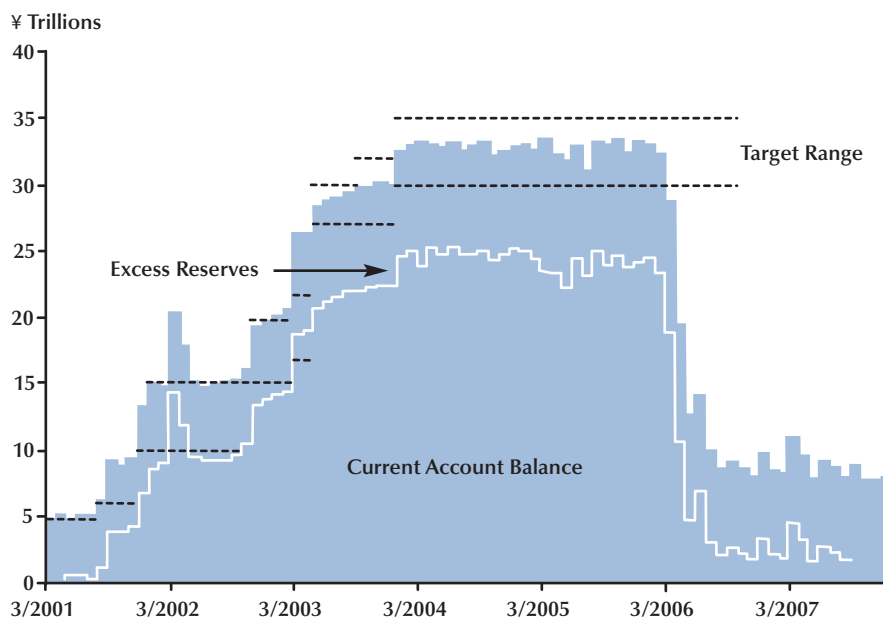
SOURCE: Bank of Japan.

follows: History will judge the Fed's course the wiser one. But all this is in the realm of conjecture right now. History will unfold at its own pace.

IMPLICATIONS FOR CENTRAL BANK INDEPENDENCE

Because many of the Fed's unorthodox quantitative easing policies put taxpayer money at risk, these policies constituted quasi-fiscal operations—equivalent to investing government funds in risky assets.[30] But there was one big difference: Congress did not appropriate any money for this purpose. Some congressmen and senators are quietly happy that the Fed took these extraordinary actions on its own initiative. After all, doing so saved them from some politically horrific votes. ("Would you please vote $180 billion for AIG, Senator?") But others complain bitterly that

the Fed usurped authority that the Constitution reserves for Congress.

On that last point, it is worth quoting Section 13(3) of the Federal Reserve Act at some length, for it was invoked to justify these actions. It reads[31]:

> In **unusual and exigent circumstances**, the Board of Governors of the Federal Reserve System, by the affirmative vote of not less than five members, may authorize any Federal reserve bank, during such periods as the said board may determine…to discount **for any individual, partnership, or corporation**, notes, drafts, and bills of exchange when such notes, drafts, and bills of exchange are indorsed or otherwise secured **to the satisfaction of the Federal Reserve bank** (emphasis added).

The three bold-faced phrases emphasize the three salient features of this section. First, the

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[30] At the margin, every dollar the Fed loses is the taxpayers' money.

[31] Section 13(3) was added to the Federal Reserve Act in 1932 and last amended in 1991.

circumstances must be extraordinary ("unusual and exigent"). Second, the law allows the Fed to lend to pretty much anyone, without restriction, as long as it takes good collateral. Third, the Fed itself gets to judge whether the collateral is good. In a system of government founded on checks and balances, that provision constitutes an extraordinary grant of power. But reading the law does at least answer one narrow question: The Fed did *not* overstep its legal authority; that authority was and is extremely broad.

The real question is whether Section 13(3) grants the central bank too much unbridled power. My tentative answer is yes, especially since Section 13(3) interventions tend to put taxpayer funds at risk and to be institution specific—two characteristics that make them inherently political. Still, getting timely congressional votes to address "unusual and exigent" circumstances can be very difficult. Remember, the Troubled Asset Relief Program (TARP) failed on the first vote. Balancing those two considerations leads me to recommend something similar to the provisions in the House and Senate bills: In order to invoke Section 13(3) powers, the Fed should need approval from some other authority, such as the Secretary of the Treasury, acting on behalf of the president.[32] Then, as soon as is practicable, the Fed should report to the two banking committees of Congress on exactly what it did, why it made those decisions, and whether it expects to incur any losses on the transactions.[33] Those two steps would go a long way toward filling the democracy deficit.[34]

But the broader question is this: How far *beyond* conventional monetary policy should the doctrine of central bank independence be extended? Remember, the Federal Reserve has never had nearly as much independence in the sphere of bank supervision and regulation, where it shares power with three other federal banking agencies, as it has in monetary policy. So, for example, if the Fed were to be made the systemic risk regulator, should it be as independent in that role as it is in monetary policy? Or should it be given something more like *primus inter pares* status? It's a fair question, without a clear answer.

Another variant of the same question arises when some of the quasi-fiscal operations justified by Section 13(3) come to constitute all or most of the Fed's monetary policy. Such a situation is, of course, not hypothetical. Since December 2008, the FOMC's undisputed control of the federal funds rate has given it no leverage over the economy whatsoever because the funds rate is constrained to essentially zero, and hence immobilized. Indeed, one might argue that, until just recently, the Fed's most important monetary policy instruments were its asset purchases.[35]

WRAPPING UP

When the FOMC met on August 7, 2007, and declared that inflation was still a bigger threat than unemployment, no one could have guessed what the coming years would bring. When the FOMC met on September 16, 2008, the day after the Lehman bankruptcy, probably no one imagined what the Fed would wind up doing over the next six months. The quantitative easing policies that began as a trickle in 2007, but became a flood after the Lehman failure, may have changed the Fed forever. They have certainly raised numerous questions about its policy options, its operating procedures, and its position within the U.S. government.

The Fed's entrance strategy into quantitative easing was ad hoc and crisis driven at first, but it became more orderly and thoughtful as time went by. It was a wonderful example of learning by doing. But the Fed now finds itself on an alien planet, with a near-zero funds rate, a two-trillion-

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[32] Both bills require the approval of the proposed Financial Stability Oversight Council, which is to be chaired by the Secretary of the Treasury. The House bill also requires explicit approval from the Treasury secretary.

[33] This report should probably be kept confidential for a while, as both bills recognize.

[34] The Dodd-Frank Act was passed several months (July 21, 2010) after this lecture was given.

[35] Both the House and Senate bills draw sharp distinctions between Section 13(3) lending to specific institutions, which would be prohibited, and more generic Section 13(3) lending aimed at markets, which would be allowed. The latter is, arguably (unconventional) monetary policy.

dollar balance sheet, a variety of dodgy assets, holes in the wall separating the Fed from the Treasury, Congress up in arms, and its regulatory role up in the air.

Your mission, Mr. Bernanke, since you've chosen to accept it, is to steer the Federal Reserve back to planet Earth, using as principal aspects of your exit strategy some new instruments you have never tried before. As always, should you or any member of the Fed fail, the Secretary and Congress will disavow any knowledge of your actions. This lecture will self-destruct in five seconds. Good luck, Ben.

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Doubling Your Monetary Base and Surviving: Some International Experience

Richard G. Anderson, Charles S. Gascon, and Yang Liu

The authors examine the experience of selected central banks that have used large-scale balance-sheet expansion, frequently referred to as "quantitative easing," as a monetary policy instrument. The case studies focus on central banks responding to the recent financial crisis and Nordic central banks during the banking crises of the 1990s; others are provided for comparison purposes. The authors conclude that large-scale balance-sheet increases are a viable monetary policy tool provided the public believes the increase will be appropriately reversed. (JEL E40, E52, E58)

The recent financial crisis has challenged monetary policymakers around the world on a scale that has not been seen since the 1930s. In normal times, the monetary policy for most central banks is implemented by (i) targeting an overnight interest rate and (ii) holding as assets securities issued by the country's own national treasury. In some cases, a central bank's assets also include foreign exchange or other nations' sovereign debt. When large shocks occur and in response the policy rate has already been reduced to (near) zero, some central banks have aggressively expanded their balance sheet, a policy widely referred to as *quantitative easing*.[1] In the United States, for example, the Federal Reserve's mid-2010 balance sheet was approximately *triple* its size of two years earlier.

The essence of quantitative easing policies is the purchase of assets from the private sector with newly created central bank deposits; such exchanges promise to reduce both risk and term premia in longer-term interest rates.[2] The cur-

rently sparse empirical evidence suggests that quantitative easing actions likely must be large because the private-sector's substitution elasticities among high-quality financial assets are small.

In this article, we examine the experience of selected central banks that have used large-scale balance-sheet expansion as a policy instrument. We conclude that such increases are a viable monetary policy tool for central banks with significant independence and credibility, assuming the public believes the increase will be appropriately reversed.

To some analysts, large balance-sheet increases raise the specter of higher inflation. Historically, an absence of fiscal discipline was the cause of large-scale increases in central bank balance sheets. Sargent (1982), for example, reviews cases of hyperinflation and Meltzer (2005) reviews monetary policy in the United States dur-

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[1]   See Bernanke and Reinhart (2004).

[2]   See Bernanke, Reinhart, and Sack (2004). Purchasing lower-quality assets raises discussion of the boundary between monetary and fiscal policy. Recent academic papers include those by Jeanne and Svensson (2007), Cúrdia and Woodford (2010a,b), Gertler and Karadi (2009), Reis (2009), Borio and Disyatat (2009), and Söderström and Westermark (2009).

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ing the late 1960s and 1970s. Recent actions in the United States, United Kingdom, Switzerland, Australia, and others have *proactively* used massive balance-sheet changes as a policy tool while sustaining a commitment to avoid rapid inflation.

SOME MACROECONOMIC THEORY

Our principal lesson—that large, visible money injections made in response to special events can increase near-term economic activity without increasing inflation if policymakers credibly commit to reverse the increase at a later date—arises in a variety of macro models. The key element is that inflation expectations are little affected by increases in central bank balance sheets that are perceived as temporary. Goodfriend and King (1981) showed this result in the context of Barro's (1976) rational expectations model by introducing a central bank that credibly commits to a long-run path for the money stock even while sharply increasing the near-term money supply.[3] Recently Berentsen and Waller (2009) showed the same result in a search-theoretic real business cycle model.[4] In contrast, many early rational expectations macroeconomic models (during the 1970s) specified that all changes in the money supply were unanticipated and permanent—that is, the money stock followed a random walk. In such models, changes in the money stock, because they were anticipated to be permanent, caused the price level to jump and real economic activity to remain unchanged. Similar results arise in the classical long-run equilibria of New Keynesian models that contain incomplete information and

adjustment costs, although there may be interim increases in economic activity.[5]

A central bank's promise to reverse a large-scale balance-sheet increase in a timely fashion lacks credibility if the central bank is not sufficiently independent of the political process. Although earlier studies tended to be equivocal regarding a negative correlation between inflation and central bank independence, more recent research using longer sample periods and broader measures has found stronger correlations (Crowe and Meade, 2008). Central banks that have used quantitative easing successfully rank high on measures of independence, transparency, and accountability. Laurens, Arnone, and Segalotto (2009), for example, ranked 98 central banks on these characteristics—successful central banks (except Australia) tended to rank at or above the 15th percentile. The Sveriges Riksbank (Sweden) and the Swiss National Bank (SNB) are ranked 4th and 5th, respectively. The Reserve Bank of Australia (RBA), however, ranked 48th.

CASE STUDIES: SUCCESSFUL LARGE-SCALE BALANCE-SHEET INCREASES

This section explores the practical use of large-scale balance-sheet increases as a policy instrument. Selected countries with recent large-scale central bank balance-sheet increases are shown in Table 1.[6] A subset of these countries is explored in greater detail. The countries loosely fall into three groups: (i) countries that responded in a temporary manner to the recent financial crisis, (ii) the Nordic countries during the banking

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[3] Specifically, Goodfriend and King (1981, p 382) outline a mechanism by which "for a given wealth, an individual who suffers an anticipated temporary reduction in measured real balances might shift expenditure from present to future periods, in order to take advantage of lower net costs of transactions in these periods." Presumably a sharp but temporary increase in money balances provided by the central bank might induce individuals to shift expenditure to present from future periods to take advantage of now-lower costs in the present period.

[4] The Berentsen-Waller model (2009) is based on the Lagos-Wright double coincidence of wants framework. Monetary policy is assumed to have short-run and long-run components, the former focused on stabilizing real activity (in the presence of shocks) and the latter on the long-run inflation trend.

[5] See, for example, Woodford (2003) and Clarida, Galí, and Gertler (1999). Among the differences in these papers noted by Berentsen and Waller (2009, p. 2) is that New Keynesian models rely on "nominal rigidities, such as price or wage stickiness, that allows monetary policy to have real effects" and that the models "are 'cashless' in the sense that there are no monetary trading frictions." In their general equilibrium real business cycle model, all prices are flexible but money overcomes trading frictions. Hence, in New Keynesian models, ad hoc stickiness may allow real effects of monetary shocks even under complete information.

[6] The currency symbols used throughout the text are listed in Table 1. Unless otherwise indicated, monetary values are listed as U.S. dollars.

Table 1

Selected Countries with Major Increases in Their Monetary Base

Country/Currency (code, symbol)	Period of increase	Peak date	Peak quantity	Percent increase
Argentina/peso (ARS, $)	February 2002–Present	January 2010	121.7 billion ARS	778.9
Australia/dollar (AUD, $)	October 2008–February 2009	December 2008	73.6 billion AUD	45.9
Belgium/euro (EUR, €)	September 2008–July 2009	September 2008	166.3 billion EUR	83.9
Brazil/real (BRL, RS)	December 2005–Present	September 2008	254.9 billion BRL	56.9
China/yuan (CNY, ¥)	December 2006–Present	December 2009	14.4 trillion CNY	109.1
Czech Republic/koruny (CZK, Kč)	April 1993–December 2001	November 2001	545.3 billion CZK	494.7
Denmark/krone (DKK, kr)	June 1993–June 2000	December 1999	192.9 billion DKK	300.3
Finland/euro (EUR, €)	January 1994–October 1997	March 1997	11.5 billion EUR	80.7
Egypt/pound (EGP, £)	August 2005–Present	July 2008	362.4 billion EGP	150.4
Iceland/krona (ISK, kr)	April 2007–Present	July 2009	173.9 billion ISK	252.7
Ireland/euro (EUR, €)	September 2008–Present	June 2009	132.5 billion EUR	184.7
Japan/yen (JPY, ¥)	March 2001–April 2006	July 2008	116.6 trillion JPY	76.5
Korea/won (KRW, ₩)	December 2006–Present	March 2009	71.7 trillion KRW	80.5
The Netherlands/euro (EUR, €)	September 2008–Present	October 2008	113.5 billion EUR	94.0
New Zealand/dollar (NZD, NZ$)	July 2006–December 2006	December 2006	12.8 billion NZD	140.8
Poland/zlotych (PLN, zł)	January 2006–Present	December 2009	139.3 billion PLN	93.6
Russia/ruble (RUB, руб)	September 1998–May 2007	May 2007	5,350.8 billion RUB	2,510.0
Sweden/krona (SEK, kr)	November 1993–January 1997	June 1994	208.3 billion SEK	118.0
	October 2009–Present	December 2008	319.1 billion SEK	201.2
Switzerland/franc (CHF)	October 2008–Present	April 2009	117.0 billion CHF	203.0
United Arab Emirates/dirham (AED, د.إ)	February 2007–Present	March 2008	279.7 billion AED	214.2
United Kingdom/pound (GBP, £)	February 2009–Present	January 2010	208.9 billion GBP	204.1
United States/dollar (USD, $)	September 2008–Present	February 2010	2,150.9 billion USD	146.8

NOTE: The table includes advanced and larger emerging-market economies wherein the monetary base significantly increased during the past 20 years. We omit the large number of developing and smaller emerging-market economies with similar or, often larger, increases. The "Period of increase" is the time interval (in our judgment) during which the monetary base increased rapidly, was elevated, and (if applicable) decreased to a more-typical level. Measures of the monetary base vary by country. The central banks of Argentina, Brazil, Iceland, Japan, Russian, Sweden, Switzerland, and the United States publish monetary base measures, and we use those data. The Central Bank of the Russian Federation (Bank of Russia) did not publish its monetary base until 2002; therefore, "reserve money" data published by the International Monetary Fund (IMF) are used. Sweden's monetary base is measured using the Riksbank's traditional definition (notes and coins in circulation plus liabilities to monetary policy counterparties); we omit the Riksbank's changed definition in late 2008 when it added special deposits from banks and debt certificates issued by the Riksbank. The monetary bases for Belgium, Finland, Ireland, and The Netherlands are measured as the sum of currency in circulation plus liabilities to banking institutions. For other countries, the monetary base is the series "reserve money" published by the IMF.

SOURCE: Central Bank of Argentina, Banco Central do Brasil, International Monetary Fund, Central Bank of Iceland, Bank of Israel, Bank of Japan, Bank of Russia, Sveriges Riksbank, Statistics Sweden, Swiss National Bank, Federal Reserve Bank of St. Louis, and authors' calculations.

Figure 1

Doubling of the Monetary Base in Selected Countries
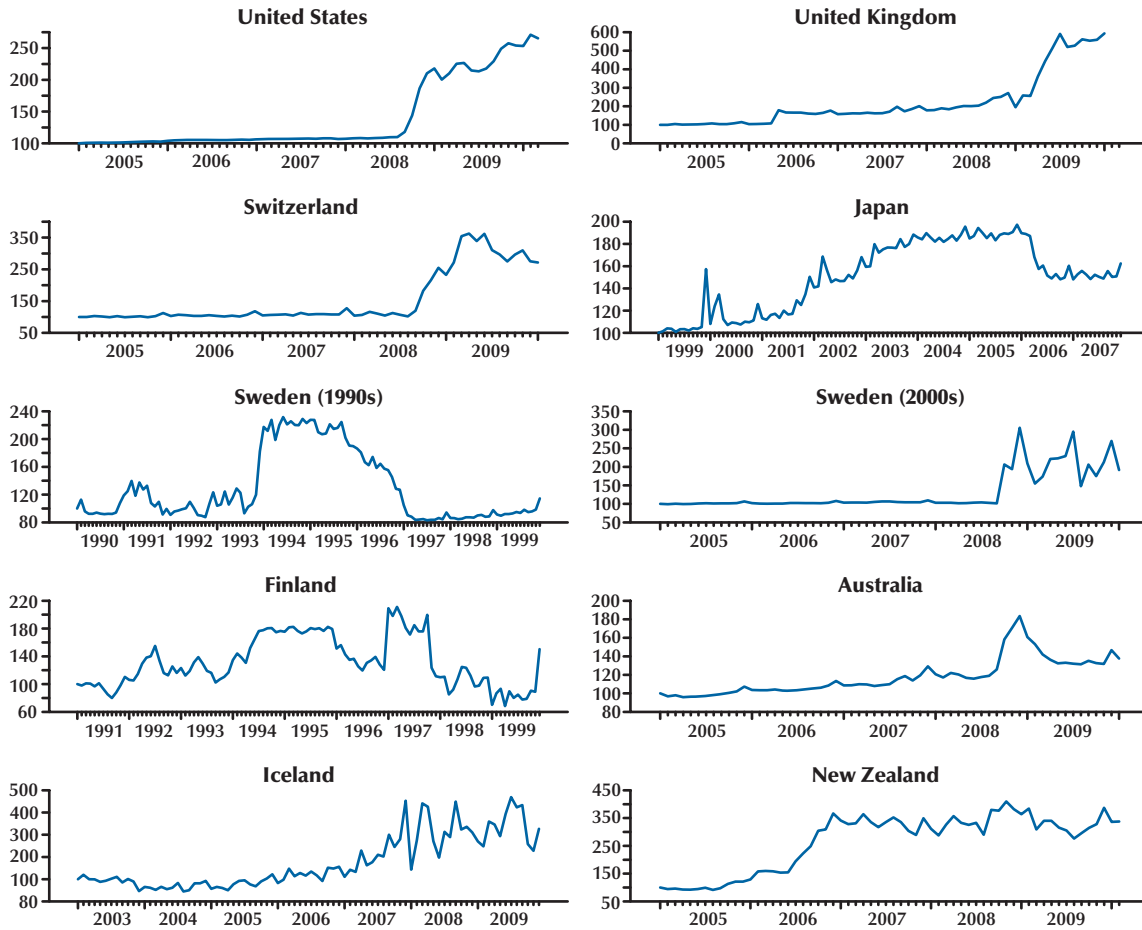
NOTE: The figure displays 10 cases of extraordinary monetary base changes in nine countries. To illustrate clearly the magnitude of the change, in each panel the monetary base series is indexed (normalized) to 100 at the first observation. The horizontal (time) scale varies by country, reflecting primarily four different episodes. Changes in the United States, the United Kingdom, Switzerland, Sweden (2000s), Iceland, and Australia reflect the 2008 global financial crisis. Changes in Finland and Sweden during the 1990s reflect the Nordic banking crisis. Changes in Japan reflect its quantitative easing from 2001-06. Finally, New Zealand increased its monetary base permanently in 2006 to improve operation of its payment system.

SOURCE: Federal Reserve Board, Bank of England, Swiss National Bank, Bank of Japan, Sveriges Riksbank, International Monetary Fund, Central Bank of Iceland, Reserve Bank of Australia, and Reserve Bank of New Zealand.

Figure 2

Central Bank Policy Rates
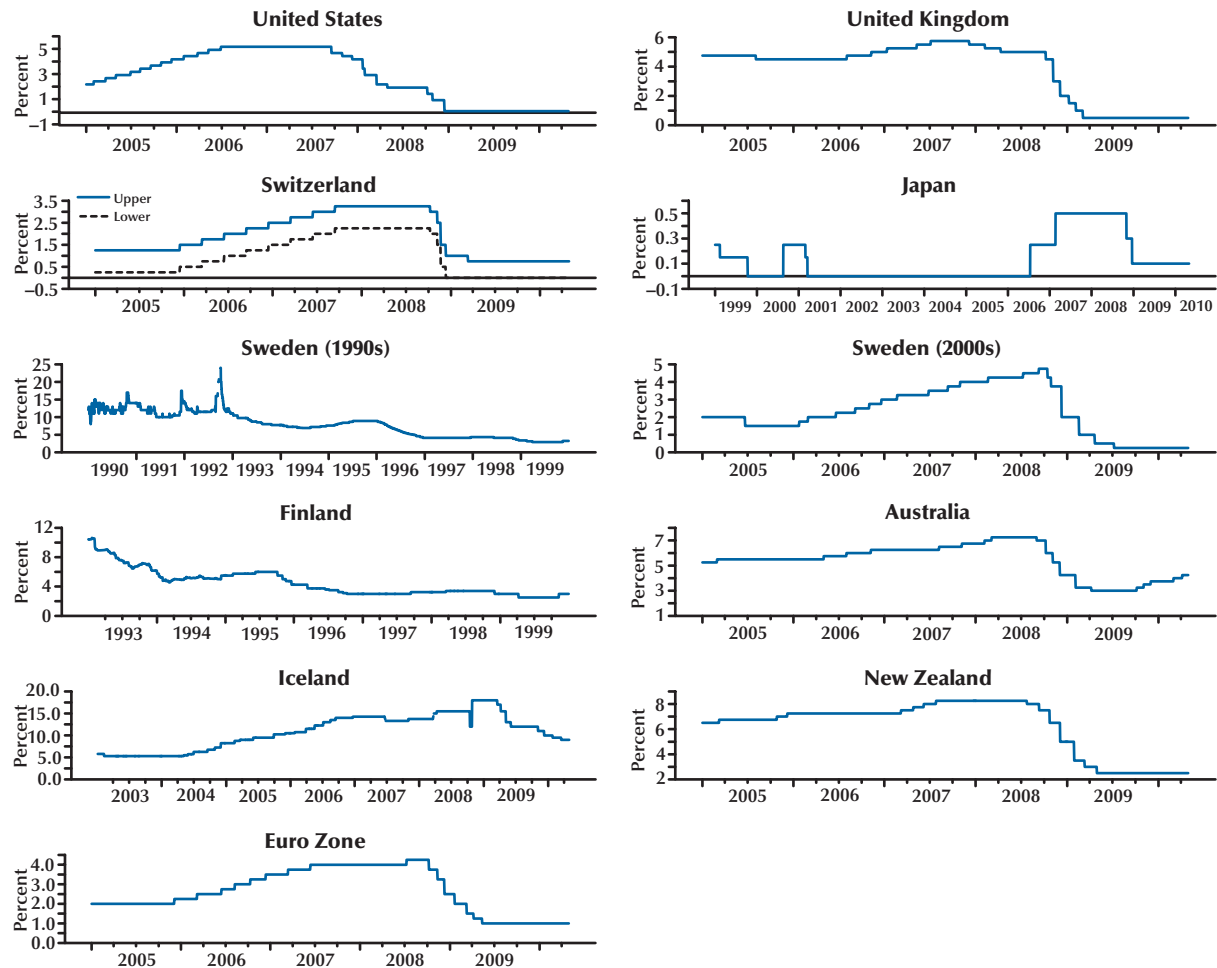
NOTE: The figure displays central bank policy rates in nine countries and the euro zone. In some cases, dramatic decreases in policy target rates accompanied expansions of the monetary base. In others, changes were modest (e.g, Australia and New Zealand). In the 1990s, foreign exchange crises occasionally caused sharp increases in policy rates not accompanied closely by changes in the monetary base (e.g., Sweden and Finland). The Bank of Japan kept the uncollateralized overnight call rate as low as 0 percent during the quantitative easing period.

Rates shown (daily data): United States, federal funds rate; United Kingdom, Bank Rate; Switzerland, target range of 3-month LIBOR rate; Japan, uncollateralized overnight call rate; Sweden, marginal rate (January 1990–May 1994), and repo rate (June 1994–present); Finland, tender rate (January 1993–December 1998), and minimum bid rate of the European Central Bank's main financing operation (January 1999–present); Australia, interbank overnight cash rate; Iceland, nominal discount rate; New Zealand, Official Cash Rate; euro zone, minimum bid rate of the European Central Bank's main financing operation. Sweden's official interest rate topped 50 percent in September 1992 as the result of the Riksbank's exchange rate defense. We omit observations of Sweden's marginal rate that are higher than 24 percent.

SOURCE: Federal Reserve Board, Central Bank of Iceland, Bank of England, Swiss National Bank, Bank of Finland, Bank of Japan, European Central Bank, Bank of Russia, Riksbank, Reserve Bank of Australia, Reserve Bank of New Zealand.

Figure 3

Actual and Expected Inflation

— Consumer Price Inflation: Year-over-year increase in consumer prices (monthly)
--- Expected Inflation: Anticipated change in consumer prices during the next 12 months (monthly)
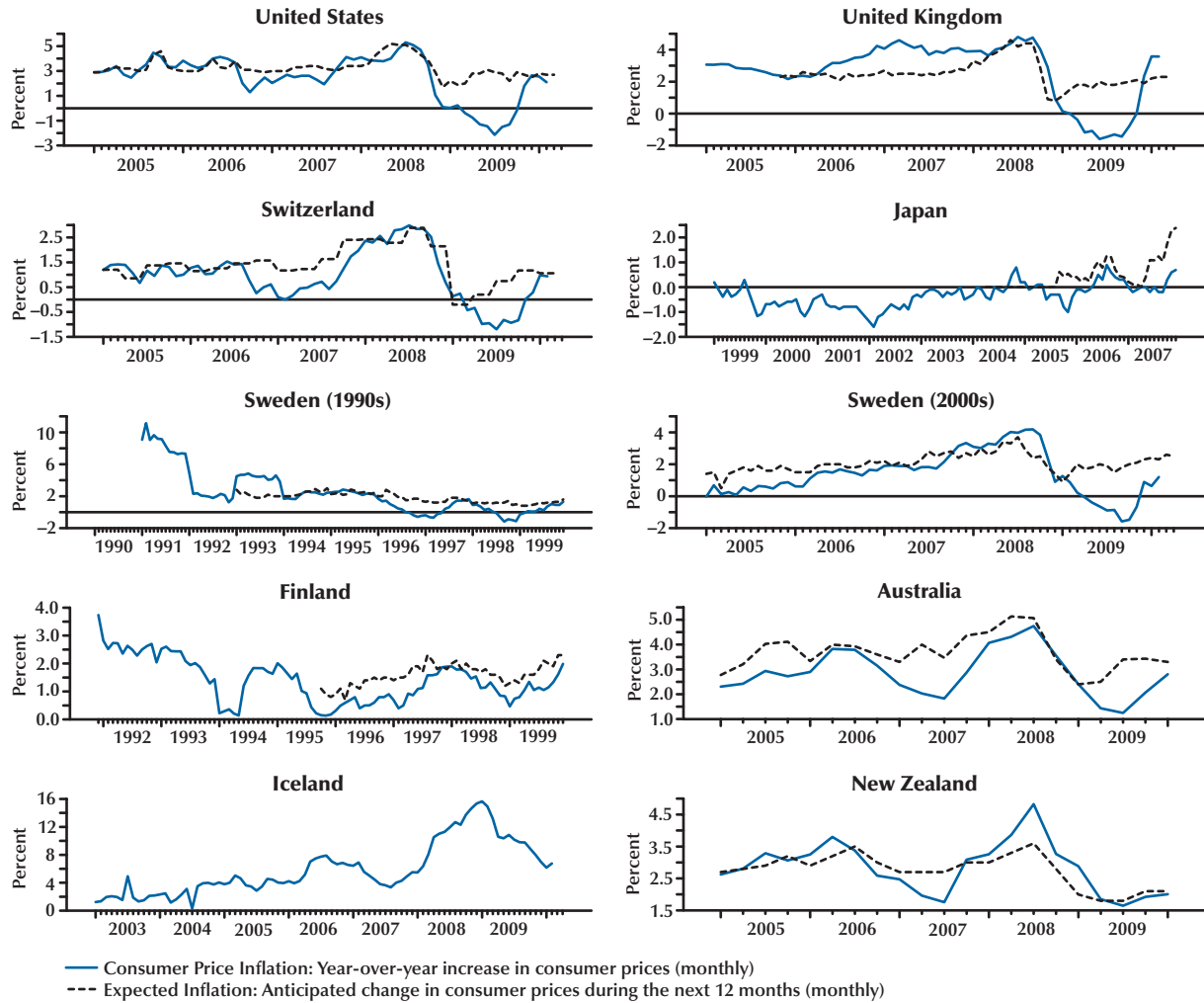
SOURCE: United States, Survey of Consumers conducted by Thomson Reuters and the University of Michigan; United Kingdom, Citigroup Inflation Tracker conducted by YouGov and Citigroup; Australia, Melbourne Institute Survey of Consumer Inflationary Expectations conducted by the Melbourne Institute of Applied Economic and Social Research; New Zealand, *Survey of Expectations* conducted by the Reserve Bank of New Zealand; Sweden, Consumer Tendency Survey conducted by the National Institute of Economic Research; Finland, *Consumer Survey* conducted by Statistics Finland; Japan, Consumer Confidence Survey conducted by the Economic and Social Research Institute. Values of expected inflation in Japan are calculated using the median of the anticipated change in consumer prices during the next 12 months. Switzerland, *Consumer Confidence Survey* by the State Secretariat for Economic Affairs. Switzerland's *Consumer Confidence Survey* reports an index of expected inflation. Data are transformed into an index with a mean equal to the mean consumer price inflation series over the observed period.

INFLATION EXPECTATIONS

Well-anchored inflation expectations are crucial to the success of unconventional monetary policy actions, including large increases in central bank balance sheets. Figure 3 shows both consumer price inflation and expected inflation for selected countries that have experienced such increases. Actual inflation is measured as the year-over-year increase in consumer prices. Expected inflation is the anticipated change in consumer prices during the next 12 months as determined from household surveys. We selected household surveys based on their availability across countries. Other surveys are available. A cross-country comparison of inflation expectations is routinely included in the IMF's *World Economic Outlook*. The Reserve Bank of New Zealand's Survey of Expectations is a market-based survey, whereas all other surveys are household based. A comparison of household surveys and market surveys can be found in Batchelor and Dua (1989).

The onset of financial crisis and recession typically reduces both actual and expected inflation. At the same time, if expansionary monetary policies are anticipated to stimulate economic activity, households might expect that actual inflation will return to its long-run trend in the near future. This pattern is evident in most of the countries we surveyed.

During 2008, for example, the United States, the United Kingdom, Switzerland, Sweden, and Australia experienced sharp decreases in actual and expected inflation. At the end of 2008, expected inflation generally stabilized (albeit at a lower rate than the recent trend) even as actual inflation continued to fall. As economic activity stabilized during 2009, inflation expectations increased (particularly in the second quarter), even while actual inflation continued to ease. Higher expectations were somewhat validated by higher inflation during the second half of 2009. It appears that both actual and expected inflation had returned to the long-run trends by the end of 2009.

The 1990s Nordic banking crisis is another example. Inflation in Sweden and Finland was high in 1990 and 1991. As Swedish and Finnish central banks and governments pursued aggressive expansionary policy, consumer price inflation declined below these central banks' inflation targets. The National Institute of Economic Research in Sweden and Statistics Finland started to survey inflation expectations in 1993 and 1995, respectively. In both countries, expected inflation was stable around the respective central bank's inflation target.

crisis of the 1990s, and (iii) selected other countries, for comparison, with (apparently) permanent increases. Figure 1 shows changes in the monetary base of these countries during periods of quantitative easing (each country's series is normalized to 100 at the date when major balance-sheet expansion began).[7] Sweden's monetary base during the Nordic banking crisis of the 1990s, for example, rapidly doubled and remained at that level for two years before slowly returning to its pre-expansion level. Japan's monetary base increased slowly starting in 2001 and fell rapidly

in 2006 when the Bank of Japan (BOJ) reversed policy. New Zealand, in a cooperative agreement with its banks to improve operation of the payment system, doubled its monetary base to a new, sustained level.

Large-scale balance-sheet increases in response to financial crises often occur after policymakers have reduced their target interest rate to (near) zero; the paths of central bank policy rates are shown in Figure 2. During December 2008, for example, the BOJ reduced its target overnight interest rate to 0.1 percent and the Federal Reserve reduced its target federal funds rate to a range between zero and 0.25 percent. Exceptions are Australia and Iceland, which are discussed later.

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[7] Generally, the *monetary base* is defined as the sum of currency in circulation outside the central bank plus deposits of financial institutions at the central bank. Variations for individual countries are noted in the case studies.

The inflation experience in these countries is shown in Figure 3, which displays both actual inflation and survey-based measures of expected inflation. Consistent with the visibility of the financial crisis and high credibility levels of these central banks, inflation expectations moved little, if at all, as balance sheets increased—indeed, the time series for actual and anticipated inflation are nearly indistinguishable.

The United States[8]

Before September 2008, the size of the Federal Reserve's balance sheet had changed little during the financial crisis of 2007-08 because holdings of Treasury securities decreased as lending through credit-market programs increased (Figure 4). In September, the Fed ceased shrinking its Treasury portfolio and large-scale balance-sheet increases began. In turn, the federal funds rate slipped steadily; on December 16, 2008, the Federal Open Market Committee (FOMC) set a target range for the federal funds rate of 0 to 0.025 percent. On November 25, 2008, the Federal Reserve announced that it would purchase up to $100 billion of debt issued by the Federal Home Loan Banks, FNMA, and FHLMC, plus up to $500 billion of mortgage-backed securities (MBS) backed by FNMA, FHLMC, and GNMA with the stated purpose to "reduce the cost and increase the availability of credit for the purchase of houses."[9] Purchases began in January 2009.

As of late January 2009, the Federal Reserve's total assets and liabilities were approximately $2 trillion versus $900 billion in late August 2008; purchases of housing-related debt and MBS accounted algebraically for about one-third of the increase and a variety of credit and lending programs accounted for the rest.

At its March 17-18, 2009, meeting the FOMC announced its intent to purchase by year-end 2009 up to $1.25 trillion of agency MBS and up to $200 billion of agency debt, plus up to $300 billion in longer-term Treasury securities during the next six months. These purchases, later referred to as the *Large-Scale Asset Purchase program*, sustained the size of the Fed balance sheet even as various credit and lending programs closed. As of the April 2010 FOMC meeting, total assets were $2.34 trillion.

United Kingdom

Rapid expansion of the U.K.'s monetary base began in February 2009, eventually tripling to £208.04 billion in July 2009 from £68.69 billion in January 2009. Motivating aggressive increases in the monetary base was a sharp slowing in economic activity: Real output during 2008:Q4 and 2009:Q1 fell at 7 percent and 10 percent annual rates, respectively. The Bank of England (BOE)'s Monetary Policy Committee (MPC) had reduced its policy rate (Bank Rate) from 5 percent in October 2008 to 1 percent in February 2009.[10] Yet, forecasts suggested an increased risk that inflation might undershoot the MPC's 2 percent target.

In March, the MPC decided to ease monetary conditions in the United Kingdom by reducing Bank Rate to 0.5 percent and to begin aggressive expansion of its balance sheet. The Bank's first purchase was £75 billion of government bonds (gilts) during the first week of March. During March, the Bank purchased £982 million of commercial paper, £128 million of commercial bonds, and £12.9 billion of gilts. The monetary base rose to £90.12 billion by the end of March.[11] By the end of May, additional purchases pushed the BOE's total assets close to £300 billion and the monetary base to £156.14 billion.

Figure 5 shows the impact of these programs on the BOE's balance sheet and the monetary base.

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[8] See Bernanke (2009) for a summary of the U.S. experience.

[9] GNMA (Government National Mortgage Association, or "Ginnie Mae"), part of the U.S. Department of Housing and Urban Develop - ment, issues no debt but does issue MBS on which it guarantees payment of principal and interest. FNMA (Federal National Mortgage Association, or "Fannie Mae") and FHLMC (Federal Home Loan Mortgage Corporation, or "Freddie Mac") issue both debt and MBS on which they guarantee the timely payment of principal and interest.

[10] Before March 5, 2008, the U.K. Asset Purchase Facility (APF) purchased £986 million in commercial paper. Because these purchases were financed by the sale to the public of Treasury bills, and hence had little impact on the monetary base, we omit them from our analysis. For details of the APF's operation, see BOE (2009a,b).

[11] In 2006 the BOE discontinued publication of its monetary base, referred to as M0. Here, we calculate the monetary base as the sum of BOE banknotes in circulation plus deposits of banks at the BOE (reserves).

Figure 4

Composition of Federal Reserve Balance Sheet

$ Billions **Assets**

■ Short-Term Lending to Financial Firms and Markets
■ Rescue Operations
□ Operations Focused on Longer-Term Credit Conditions
■ Traditional Portfolio

$ Billions **Liabilities**

■ Source Base
□ Treasury Financing Account
■ Traditional Liabilities and Capital Account
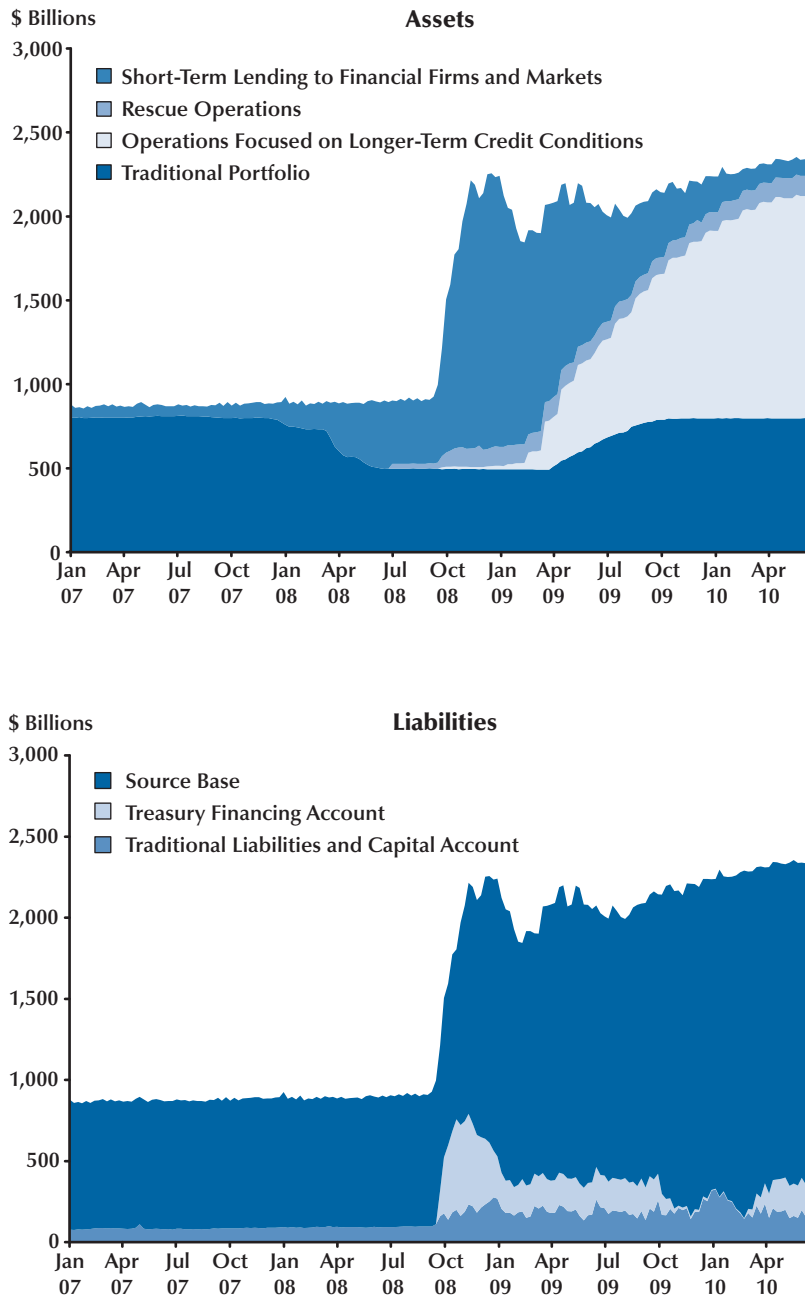
NOTE: See Federal Reserve Bank of St. Louis, U.S. Financial Data, for a description of chart categories.

SOURCE: Federal Reserve Board, Federal Reserve Statistical Release H.4.1.

Figure 5

Composition of Bank of England Balance Sheet

£ Billions   **Assets**

- Other Assests
- Long-Term Reverse Repo
- Bonds and Securities Purchased
- Advance to HM Government
- Short-Term Market Operations

£ Billions   **Liabilities**

- Other Liabilities
- Short-Term Market Operations
- Reserves
- Notes in Circulation
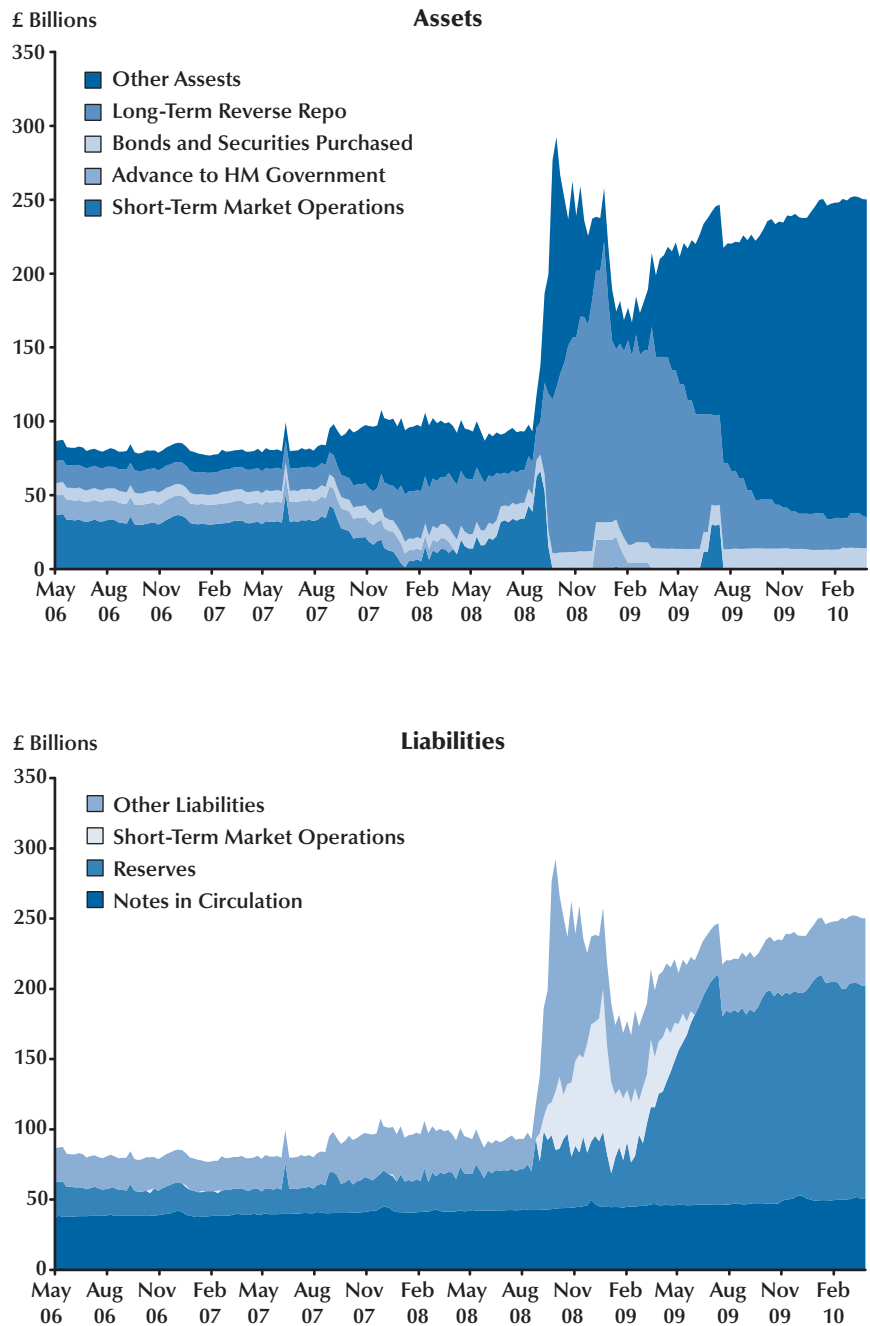
SOURCE: Bank of England (www.bankofengland.co.uk/markets/balancesheet/).

On the asset side of the balance sheet, the large increase in the "Long-Term Reverse Repo" category reflects the assets acquired by expanding the types of collateral that may be pledged on traditional lending facilities. The later increase in the "Other Assets" category reflects the BOE's increase in dollar lending and assets purchased under the Asset Purchase Facility. On the liabilities side of the BOE's balance sheet, the monetary base is measured as the sum of "Notes in Circulation" plus "Reserves" at the BOE. Note that the BOE issues liabilities (BOE bills) that are not part of the monetary base as we have measured it in this analysis. During the fall of 2008, the BOE issued 1-week maturity bills to finance expanded lending to banks. The BOE shifted away from using its own bills for financing during 2009, causing liabilities in the "Short-Term Market Operations" category to decline and bank reserves to increase.

The BOE reports that balance-sheet actions reduced yields on medium- and long-dated government bonds, as well as spreads of commercial paper and commercial bonds over overnight index swaps. Yields on 10-year U.K. bonds fell when purchase programs were announced and subsequently drifted upward as purchases occurred. Inflation expectations plummeted from a high of 4.5 percent in September 2008 to a low of 1 percent (see the dashed line in Figure 3) before later drifting and leveling off near 2 percent.

Switzerland

The impact of the global financial crisis on Switzerland has been modest, albeit sufficient to result in recession. During 2008:Q4 and 2009:Q1, real gross domestic product (GDP) declined at an annual rate of 2.5 percent and 3.5 percent, respectively. The Swiss National Bank's (SNB) 2009 *Financial Stability Report* describes the steps they took.[12] In October 2008 the SNB reduced its target for the 3-month Swiss franc London Interbank offering rate (LIBOR) and began expanding its balance sheet. The SNB also began participating in foreign currency swaps with the Federal
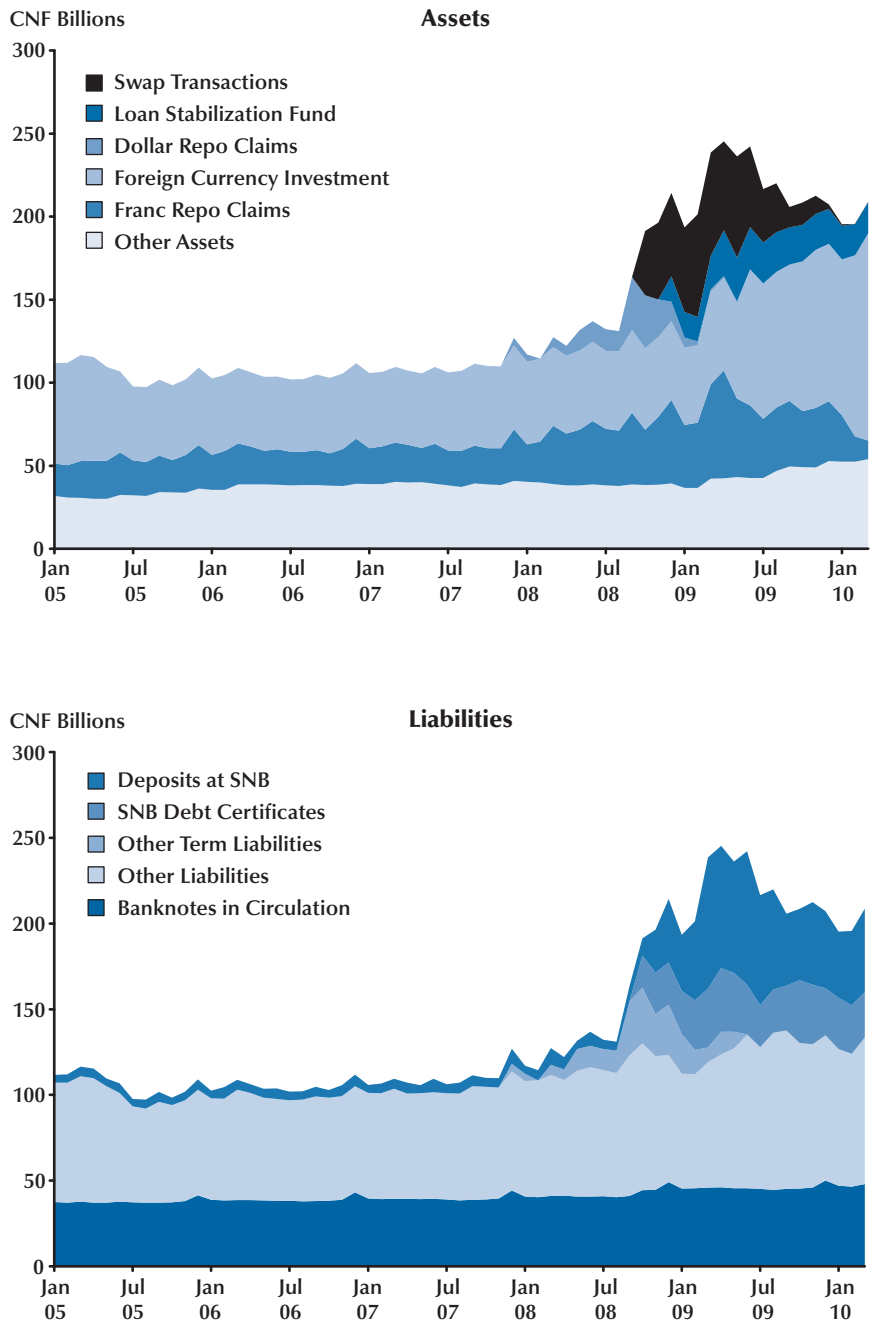
Reserve in October 2008, eventually reaching more than CHF 60 billion in March 2009. In December 2008 the SNB created a loan stabilization fund to "finance the acquisition of illiquid assets from UBS, largely composed of assets backed by US residential and commercial mortgages." Under terms of the loan, UBS, among other financial institutions, will make partial payments extending up to 12 years. (Assets in this program were CHF 22 billion as of September 2009.) Between October 2008 and April 2009, the Swiss monetary base approximately tripled, reaching CHF 117 billion in April 2009. On March 12, 2009, the SNB announced a policy shift toward foreign exchange market intervention, saying the appreciation of the Swiss franc "represents an inappropriate tightening of monetary conditions."

The SNB's unconventional policies sharply increased the size of its balance sheet and the Swiss monetary base. Figure 6 shows the growth and changing composition of the SNB assets and liabilities. The largest increase among assets is in foreign currency swap transactions. On the liabilities side, the largest increase is in bank deposits at the SNB (top category on the graph)—from an average of CHF 6 billion in 2007 to more than CHF 75 billion in March 2009. To temper the increase in the monetary base and "absorb liquidity in the market" resulting from unconventional monetary policies, the SNB began issuing its own debt in October 2008 (labeled as "SNB Debt Certificates" in Figure 6). As of September 2009, the SNB had CHF 25 billion outstanding in SNB notes. These notes have a maximum maturity of one month.

Although we cannot yet assess the impact, if any, of the monetary base expansion on inflation, it seems reasonable to explore the SNB's inflation forecasts underlying its policy actions. In March 2009, the SNB forecast deflation for most of 2009 and close to zero inflation in 2010 and 2011. The forecast six months later projects deflation only in early 2009 and 2 percent inflation by the end of 2011. Perhaps tripling the monetary base has forestalled further undesired decreases in inflation (or even deflation): Inflation expectations plummeted in mid-2008, reaching close to zero

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[12] For additional details, see Swiss National Bank (2009); all quotations in this section are from this report.

Figure 6

Composition of the Swiss National Bank Balance Sheet

CNF Billions　　　　　　　　　　　　　　**Assets**

Legend:
- ■ Swap Transactions
- ■ Loan Stabilization Fund
- ■ Dollar Repo Claims
- ■ Foreign Currency Investment
- ■ Franc Repo Claims
- □ Other Assets

CNF Billions　　　　　　　　　　　　　　**Liabilities**

Legend:
- ■ Deposits at SNB
- ■ SNB Debt Certificates
- ■ Other Term Liabilities
- □ Other Liabilities
- ■ Banknotes in Circulation

SOURCE: Swiss National Bank.

percent by March 2009 (see Figure 3). Expected inflation has been positive and slowly trending upward since the SNB began quantitative easing.

Japan

Japan's economic growth has slowed sharply since the bursting of the asset price bubble in the early 1990s—from a 5.1 percent annual rate during the latter half of the 1980s, to a 1.5 percent annual rate during the 1990s, to a less than 0.5 percent annual rate since 2000.[13] Here, we review three episodes of BOJ quantitative easing efforts—the zero interest rate policy of the 1990s, a quantitative easing policy from 2001 to 2006, and its actions in response to the most recent financial crisis.

During the 1990s, the BOJ adopted the "zero interest rate policy" regime in which the policy target rate (overnight call rate) was set at 0.1 percent. The BOJ maintained its balance sheet at a level just sufficient to sustain the overnight call rate (near) zero. Nevertheless, real GDP growth during the decade averaged only 1.5 percent per year and the economy was stagnant at the decade's end. Worse, the threat of deflation had not eased—year-over-year consumer price index (CPI) inflation was negative (see Figure 3).

In March 2001, with a policy rate at zero, the BOJ initiated a quantitative easing policy in which it would maintain the call rate at zero until the year-over-year increase in the CPI "became positive on a sustained basis."[14] The expansion of the balance sheet was regulated by a targeted level of current account balances held by banks at the BOJ. To achieve its targets, the BOJ purchased government securities and bank bills backed by eligible collateral (i.e., corporate bonds or commercial paper). The BOJ more or less smoothly increased its holdings of long-term Japanese government bonds (JGBs); its holdings doubled by 2006 to roughly ¥90 trillion. In contrast, the BOJ purchased bank bills to quickly increase its bal-

ance sheet, reaching roughly ¥40 trillion in 2006 (Figure 7). The BOJ began a two-tier exit strategy in 2006 when the CPI displayed signs of steady increase, allowing its holdings of bank bills and long-term government securities (JGBs) to run off. Empirical studies have concluded that the BOJ's policy actions reduced longer-term rates, thereby flattening the yield curve, and had a positive, but small, effect on economic growth (Ugai, 2007).

In response to the current financial crisis, the BOJ reduced its policy target rate to 0.3 percent from 0.5 percent on October 31, 2008, and to 0.1 percent on December 19, 2008, and has initiated or expanded several programs to provide funds to the market.[15] Commercial paper was purchased outright during 2009:Q1 (¥1.6 trillion) but a rapid runoff occurred during the second quarter, and corporate bond purchases were made during the third quarter (¥400 billion). In addition, approximately ¥4 trillion of commercial paper was purchased during the first quarter under repo, and approximately ¥6 trillion in "special funds" was provided to banks as advances against corporate debt as collateral. These combined actions were modest relative to the size of the BOJ's balance sheet (see Figure 7).

In November 2009, the BOJ declared that the economy had officially entered a period of deflation with a negative year-over-year change in the CPI. On December 1, 2009, the BOJ announced a new liquidity supply initiative to fight weak economic activity, deflation, and a rising yen exchange rate. This program calls for the BOJ to furnish up to ¥10 trillion in 3-month loans to banks at the 0.1 percent target level of the policy rate (overnight unsecured call rate) against a variety of collateral, including JGBs, corporate bonds, and commercial paper. The BOJ said the program should "further enhance easy monetary conditions" and "encourage a further decline in longer term interest rates." Deflation continues in Japan, however, with a pace of −1 percent per year as of April 2010 (see Nishimura, 2010).

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[13] Shirakawa (2010) argues that quantitative easing policy actions successfully boosted Japanese economic activity and the story of "The Lost Decade" is myth.

[14] For details, see Oda and Ueda (2007) or Maeda et al. (2005). Humpage and Shenk (2008) provide a very readable summary. Shiratsuka (2009) summarizes recent thought.

[15] The BOJ's actions as of April 2010 are well summarized in "The Bank of Japan's Policy Measures in the Current Financial Crisis" (www.boj.or.jp/en/type/exp/seisaku_cfc/index.htm).

Figure 7

Composition of Bank of Japan Balance Sheet

Yen Trillions **Assets**

□ Bills Purchased
□ Loans and Discounts
□ Receivables under Resale Agreement
■ Government Securities
■ Foreign Currency Assets
■ Other

Yen Trillions **Liabilities**

□ Deposits of the Government
□ Payables under Repurchase Agreement
■ Deposits
■ Bank Notes
□ Other
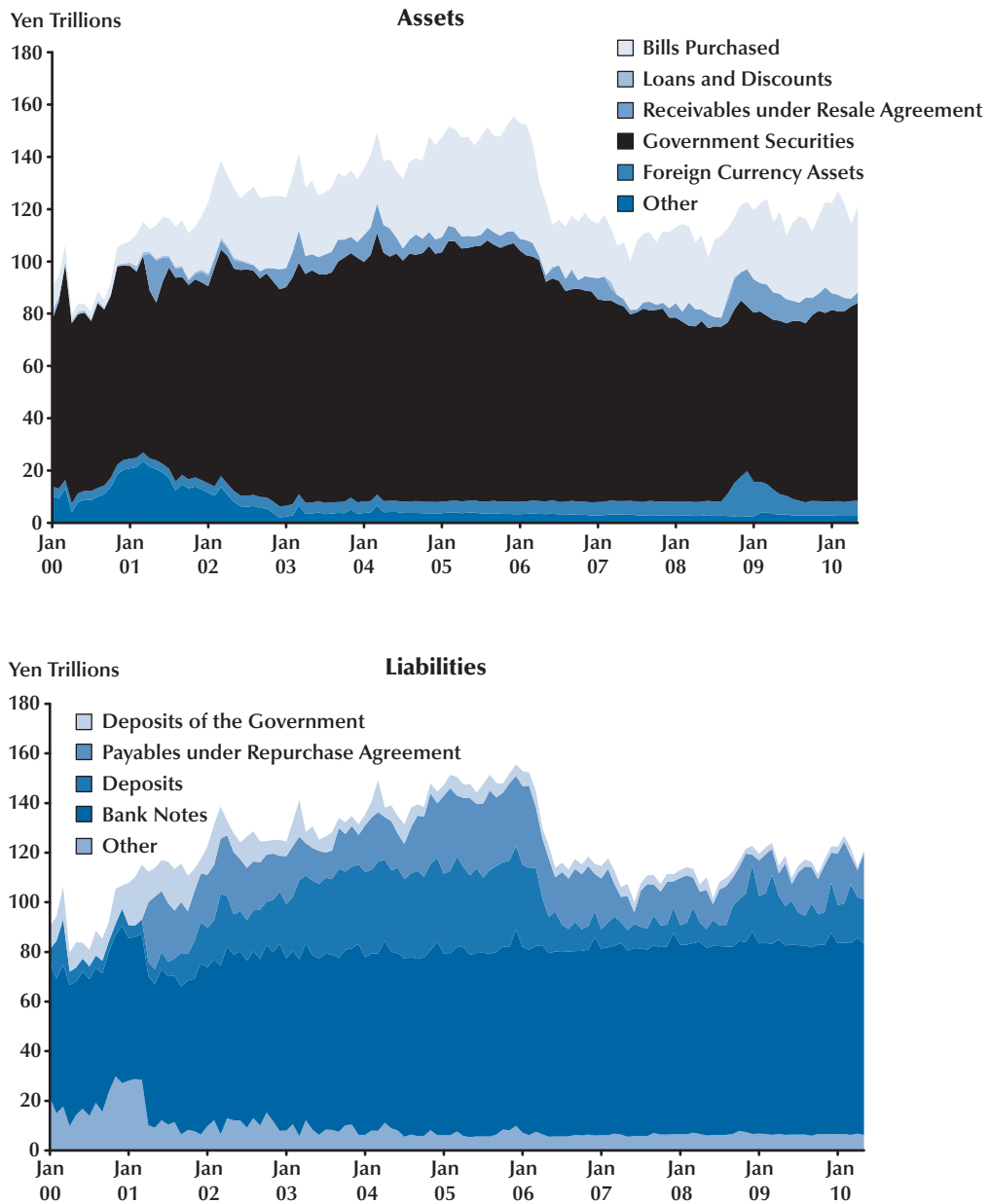
NOTE: The monetary base of Japan is approximately the sum of banknotes in circulation outside the BOJ plus deposits held by banks at the BOJ.

SOURCE: Bank of Japan.

Scandinavia

Sweden and Finland provide a unique set of cases because they have each undergone two episodes of quantitative easing during the past two decades: once during the banking crisis of the 1990s and more recently during the 2007-09 financial crisis. They are excellent case studies of *how to do it right.*

Sweden. Sweden was affected by two severe financial crises during the past two decades: the 1990s Nordic banking crisis and the 2007-08 global financial crisis. Each time, the Riksbank used large-scale increases in its balance sheet as a policy tool; the monetary base more than doubled during the Nordic banking crisis and has *tripled* during the most recent global financial crisis.

The Nordic banking crisis of the early 1990s affected all Scandinavian countries.[16] In each country, central bank support to the banking system sharply increased the nation's monetary base. Starting in 1992, the Riksbank used its foreign currency reserves to provide liquidity support to banks. Because the government had guaranteed all bank debt, the Riksbank allowed banks to borrow freely through normal liquidity facilities. The monetary base more than doubled within 10 months—from SEK 83.73 billion in August 1993 to SEK 208.26 billion in June 1994. When conditions stabilized, the monetary base decreased rapidly to SEK 81.11 billion by February 1997. Although inflation did not increase significantly during or after the monetary base expansion period, CPI inflation during 1994 was more than double the Riksbank's 2 percent inflation target and inflation expectations increased modestly as the Riksbank expanded its balance sheet. As a result, even with the monetary base at elevated levels, the Riksbank gradually increased its policy target rate during 1994 and 1995. The inflation rate returned to a 2 percent pace by late 1995, slipping negatively the following year. Inflation expectations retreated below the Riksbank's 2 percent inflation target to near 1.5 percent.

Policy actions by the Riksbank during the recent financial crisis resemble those during the 1990s. The growth and composition of the Riksbank's balance sheet are shown in Figure 8. In September 2008, the Riksbank created a loan facility that provided access to U.S. dollars, funded by currency swap agreements with the Federal Reserve.[17] This program increased the balance-sheet asset item "Claims on Residents inside Sweden Denominated in Foreign Currency" and the liability item "Liabilities outside Sweden Denominated in Kronor." To further assist banks, in October 2008 the Riksbank created an additional loan facility designed to accept collateral with maturities longer than those accepted at its traditional lending facilities.

To fund some lending programs, the Riksbank issued debt—*Riksbank certificates*—with a maturity of one week. The Riksbank, unlike other central banks, includes these certificates in its measure of the monetary base (see Figure 8).[18] Based on this measure, Sweden's monetary base increased almost fivefold from SEK 105.92 billion in September 2008 to a peak in November 2009. Alternatively, measured using the commonplace definition of the monetary base as the sum of currency in circulation plus the deposits held by financial institutions at the central bank, Sweden's monetary base tripled to peak of SEK 319 billion in December 2008.

Finland. Finland likely was the country most severely affected by the Nordic banking crisis, recording decreases in real GDP growth for three consecutive years (1990:Q3–1993:Q3).[19] From 1992 to 1997, strong government intervention included equity investments in the nation's

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[16] Honkapohja (2009) and Anderson (2009) discuss causes and the policy response; see also the references cited therein.

[17] For details, see Öberg (2009).

[18] For comparison purposes, the data in Figure 1 report a measure of the monetary base without Riksbank certificates.

[19] The Bank of Finland's takeover of the shaky commercial bank Skopbank in the fall of 1991 perhaps was the climax of the country's financial crisis. Skopbank was one of the pillars of Finland's commercial banking industry, widely referred to as the "central bank" for the country's savings banks. The takeover is reported to have eventually cost FIM 15 billion, the equivalent of 3 percent of GDP in 1991 (Sandal, 2004). The eventual resolution of the crisis and unwinding of government support programs cost Finland an amount equal to approximately 6 percent of one year's GDP; for Sweden and Norway, the eventual cost was near zero. For additional details, see Anderson (2009).

Figure 8

Composition of the Riksbank's Balance Sheet

SEK Billions   **Assets**

- Claims on Residents Inside Sweden Denominated in Foreign Currency
- Lending to Monetary Policy Counterparties
- Claims on Residents Outside Sweden Denominated in Foreign Currency
- Gold and Other Assets

SEK Billions   **Liabilities**

- Other Liabilites and Capital
- Liabilities Outside Sweden in SEK
- Riksbank Certificates
- Bank Deposits
- Currency in Circulation
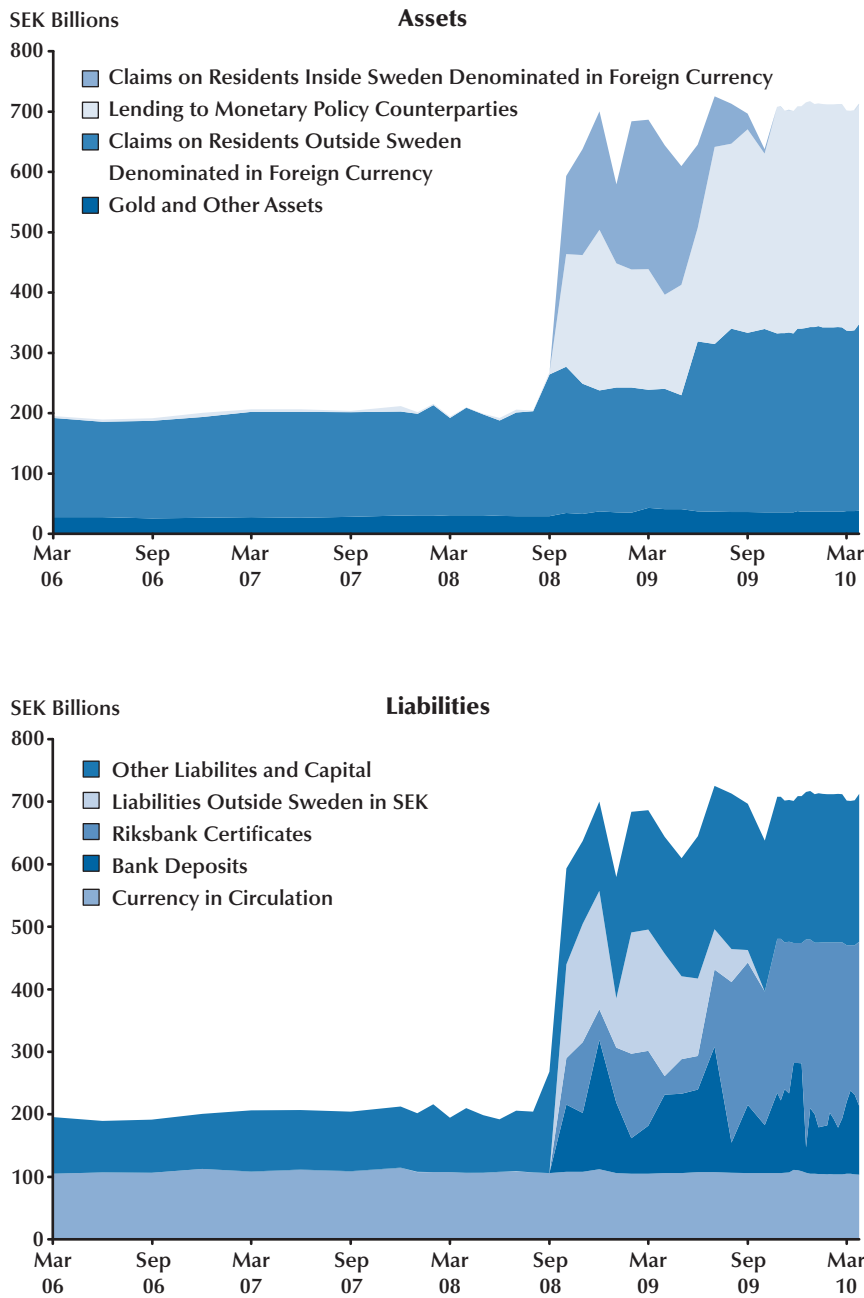
NOTE: The Riksbank defines Sweden's monetary base as "Currency in Circulation" plus "Bank Deposits" and "Riksbank Certificates."
SOURCE: The Riksbank.

Figure 9

Composition of Bank of Finland's Balance Sheet

FIM Billions   **Assets**

■ Other Assets
■ Gold and Foreign Currency Claims
■ Claims on Financial Institutions
■ Loans for Stabilizing the Money Market
□ Capitalized Expenditures Due to
     Stabilizing the Money Market

FIM Billions   **Liabilities**

□ Other Liabilities and Capital
■ CDs
■ Liabilities to Financial Institutions
■ Notes and Coin in Circulation
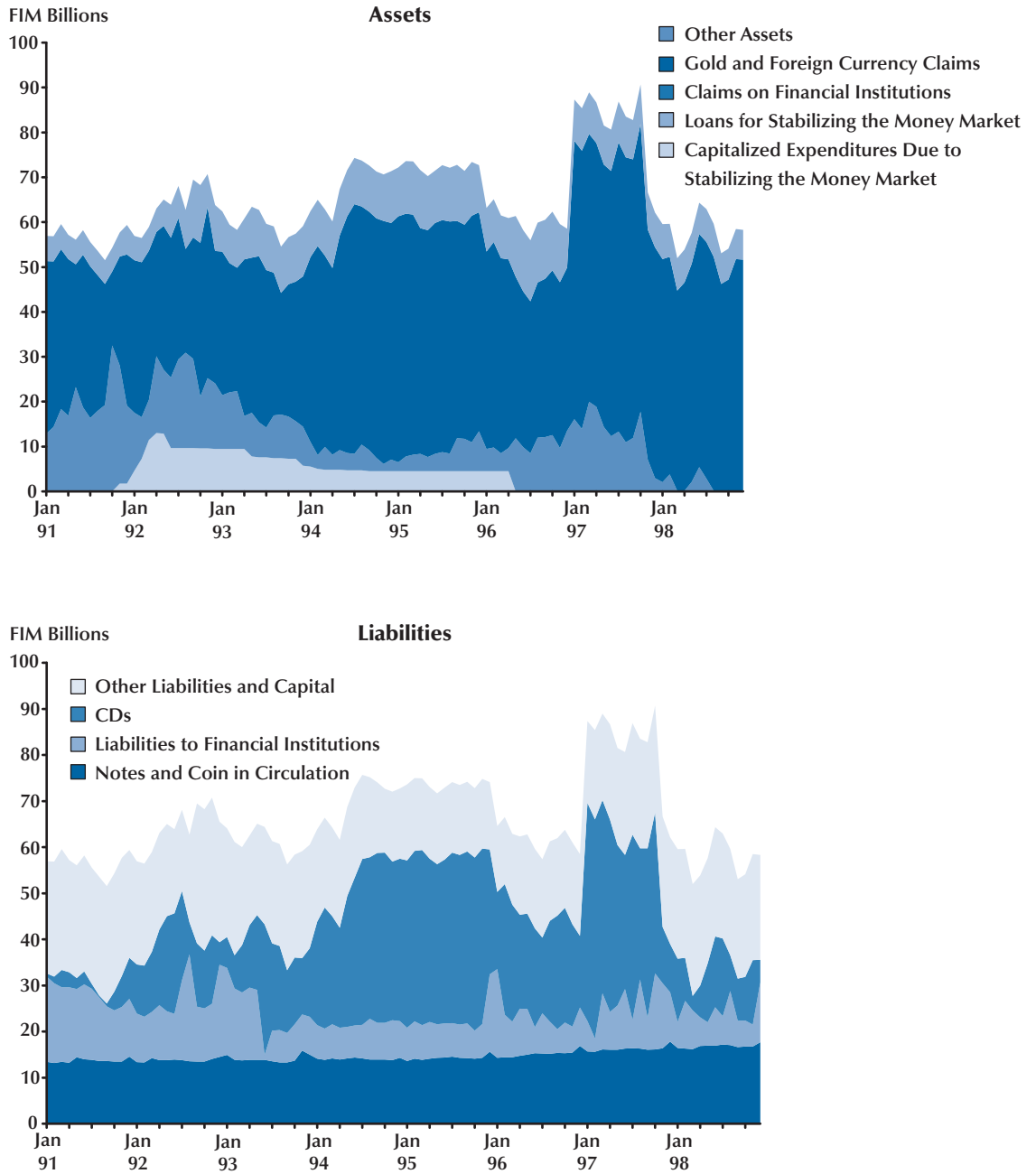
SOURCE: Bank of Finland.

banks and in a government-funded bank guarantee fund. By the end of 1997, the government had extended FIM 43 billion in direct bank support.[20] The Finnish monetary base expanded from FIM 34.5 billion in January 1992 to FIM 68.7 billion in March 1997 (Figure 9). Banking institutions started repaying the government in October 1997; thereafter, the monetary base decreased rapidly to FIM 36.2 billion in December 1997.

Inflation in Finland was high before the banking crisis started: The monthly year-over-year CPI rate topped 7 percent in spring 1990 and stayed above 5 percent during 1990. Inflation subsided as the crisis deepened; the year-over-year rate fell below 2 percent (the Bank of Finland's inflation target) in mid-1993. Inflation remained low for the remainder of the 1990s and inflation expectations remained anchored between 2 and 2.5 percent.

Finland adopted the euro in 1999, and hence during the financial crisis of 2007-09 exercised no independent monetary policy. Its response has been limited to banking supervision and support (Liikanen, 2009). Perhaps the largest country-specific impact was the spinoff of the Finnish operations of the Icelandic bank Glitnir into a new Finnish corporation in October 2008.

OTHER CASES OF LARGE-SCALE BALANCE-SHEET INCREASES

In this section, we briefly examine the experiences of three other countries with recent large-scale central bank balance-sheet increases.

Australia

Australia experienced a sharp but mild recession during late 2008 and early 2009, caused in part by reduced export demand and weaker consumer confidence. Stevens (2009) notes that the Reserve Bank of Australia had started easing policy in early September due to moderating demand, reducing its target overnight rate from 7.25 percent to 7 percent. Easing accelerated after the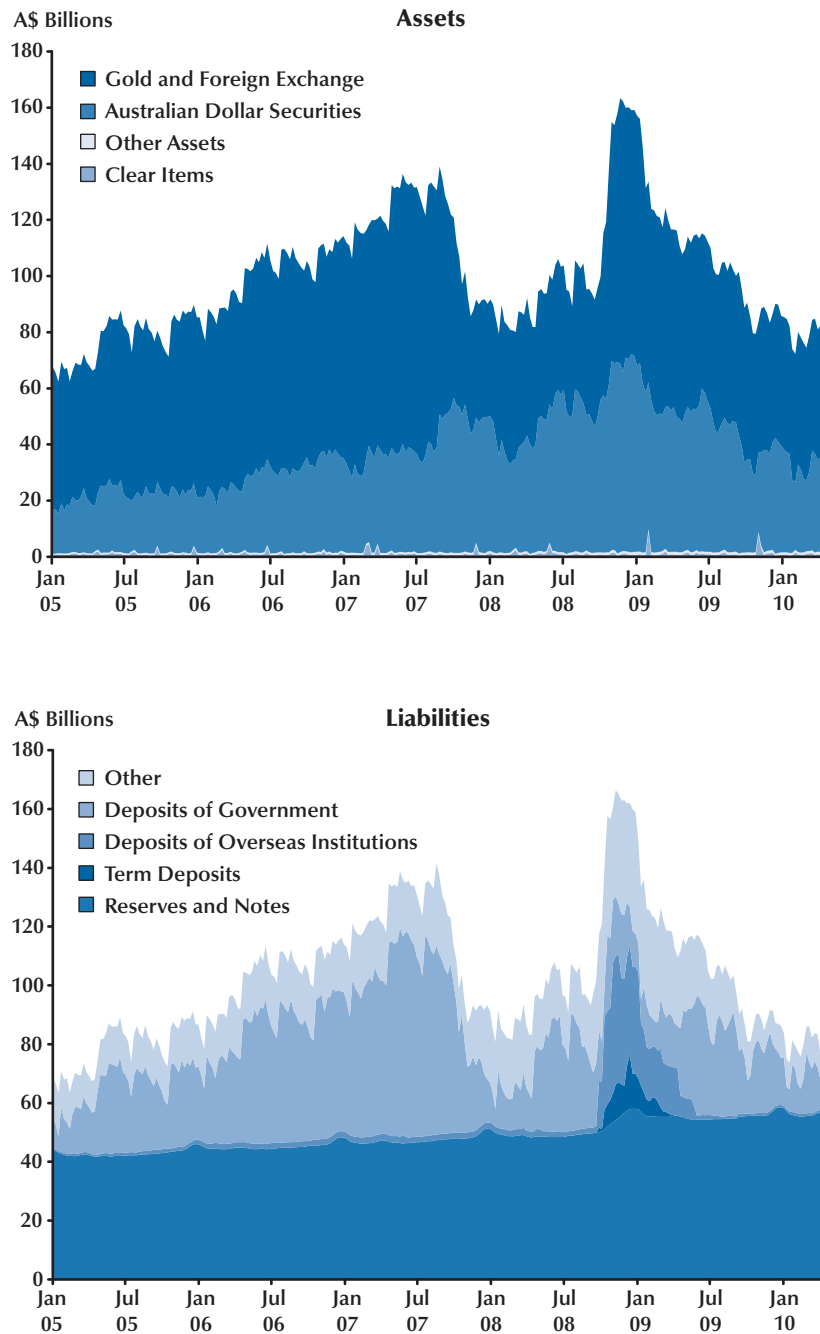 Lehman Brothers failure; the target was reduced by 300 basis points during the last four months of 2008 (including a 100-basis-point cut on October 8, 2008, coordinated with 50-basis-point or larger reductions by other G-10 central banks). Private net capital flows were negative in the third and fourth quarters of 2008, in part because Australian banks found Federal Reserve foreign currency swap lines a lower-cost source of funds than alternatives, particularly in 2008:Q4.[21] By mid-2009, global short-term credit markets were normalizing and Australian banks were obtaining funds in the market below the cost of the Fed's swap facility. The policy target rate reached its low of 3 percent on April 8, 2009, and on October 7, 2009, the Research Bank of Australia (RBA) started the process of increasing its target rate toward "a more normal setting" with a 25-basis-point increase.

The RBA's policy actions do not merit the label "quantitative easing" because the policy target rate never reached zero during mid-2009. Yet, the RBA balance sheet expanded sharply between August and December 2008, resulting in a 54 percent increase in the monetary base (measured as the sum of "Reserves and Notes" plus "Term Deposits"). Figure 10 shows the growth and changing composition of the RBA balance sheet. A number of domestic programs affected the balance sheet, including (i) broadening the pool of eligible collateral accepted by the RBA, (ii) conducting open market operations at longer maturities to increase the impact on longer-term yields, and (iii) offering term deposits at the RBA.[22] Deposits obtained by the RBA under the Federal Reserve's swap lines are included in the asset "Gold and Foreign Exchange," whereas the Australian dollars held as collateral by the Federal Reserve are included in the liability item "Deposits of Overseas Institutions." Interestingly, the RBA unwound its balance-sheet expansion in the first half of 2009 without rapid increases in its policy target rate: By May 2009, the level of the monetary base had returned approximately to its trend with the policy target rate at 4.25 percent.

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[20] For details, see Mutikainen (1998).

[21] D'Arcy and Ossolinski (2009) report that some Australian banks, successful bidders for U.S. dollars at RBA auctions, apparently reloaned the dollar funds to foreign parents.

[22] For additional details, see Stevens (2010) and Debelle (2008).

Figure 10

Composition of Reserve Bank of Australia Balance Sheet

A$ Billions   **Assets**

- ■ Gold and Foreign Exchange
- ■ Australian Dollar Securities
- □ Other Assets
- ■ Clear Items

A$ Billions   **Liabilities**

- □ Other
- ■ Deposits of Government
- ■ Deposits of Overseas Institutions
- ■ Term Deposits
- ■ Reserves and Notes

NOTE: The monetary base of Australia is approximately equal to "Reserves and Notes" plus "Term Deposits."

SOURCE: Reserve Bank of Australia.

There is no evidence that the RBA's actions affected inflation. Before the crisis, the Australian economy had experienced year-over-year growth in consumer prices averaging just under 3 percent, within the RBA's target range of 2 to 3 percent. Inflation expectations, however, reached as high as 6 percent as Australia's business cycle peaked in May 2008 (see Figure 3), but the late 2008 disturbances in financial markets caused inflation expectations to decline precipitously. Unlike in the United States, United Kingdom, and Japan, inflation expectations in Australia never raised the specter of deflation. A prompt unwinding of its balance sheet appears to have protected inflation stability.

Iceland

We mention Iceland primarily because of its widely reported role in the banking crises of several European nations. Iceland is unusual, in this analysis, because its policy target rate and central bank balance sheet increased simultaneously.

Iceland's financial system was seriously harmed by the recent financial crisis. Three of the country's largest commercial banks failed in October 2008; the government assumed the role as insurer of their deposits and replaced each board of directors.[23] These banks, however, had customer liabilities with other countries in addition to Iceland, equal to roughly 10 times Iceland's annual gross national product (see Central Bank of Iceland [CBI], 2009b, p. 13). As a result of the bank failures, Iceland's exchange rate fell sharply in October 2008; Iceland obtained a $2.1 billion loan from the International Monetary Fund (IMF) to stabilize its financial system.

Before receiving the IMF loan to stabilize the country's economy, in January 2008 the CBI had expanded the list of eligible collateral at its regular lending facilities to include bonds issued in dollars, euros, or British pounds but continued to require that at least 50 percent of collateral be denominated in kronor. By August 2008, the CBI went a step further, expanding the list of eligible collateral to include asset-backed securities and

reducing the krona requirement to 30 percent. Bank runs began the first week of October: Currency in circulation increased 53 percent that week (see Central Bank of Iceland, 2009b, pp. 24-25). The CBI used its reserves—even old banknotes no longer intended for circulation—to meet public demand. The combination of increased loans to banks[24] and currency in circulation caused the CBI's balance sheet to increase rapidly during the fall of 2008. At its peak, Iceland's monetary base had increased by 70 percent with highly volatile swings from month to month.

The CBI sought to distinguish its traditional approach to monetary policy (targeting the discount rate) from its balance-sheet actions. In October 2008, for example, the CBI increased its policy rate (the nominal discount rate) from 12 percent to 18 percent. At this time, year-over-year inflation had been steadily increasing since 2007 and was close to 15 percent. In pursuing its inflation target of 2.5 percent, the CBI had held its policy rate above 10 percent since 2005.[25] The CBI changed course in March 2009 after inflation began to subside (albeit still at high levels). The nominal discount rate dropped to 11 percent in November 2009. Because inflation was well above the target at the beginning of the crisis, it is difficult to assess whether the balance-sheet expansion affected either actual or expected inflation. However, the CBI forecasts that inflation will reach its target of 2.5 percent sometime in early 2011 (Central Bank of Iceland, 2009b), suggesting that the monetary base increases are not anticipated to increase inflation pressures.
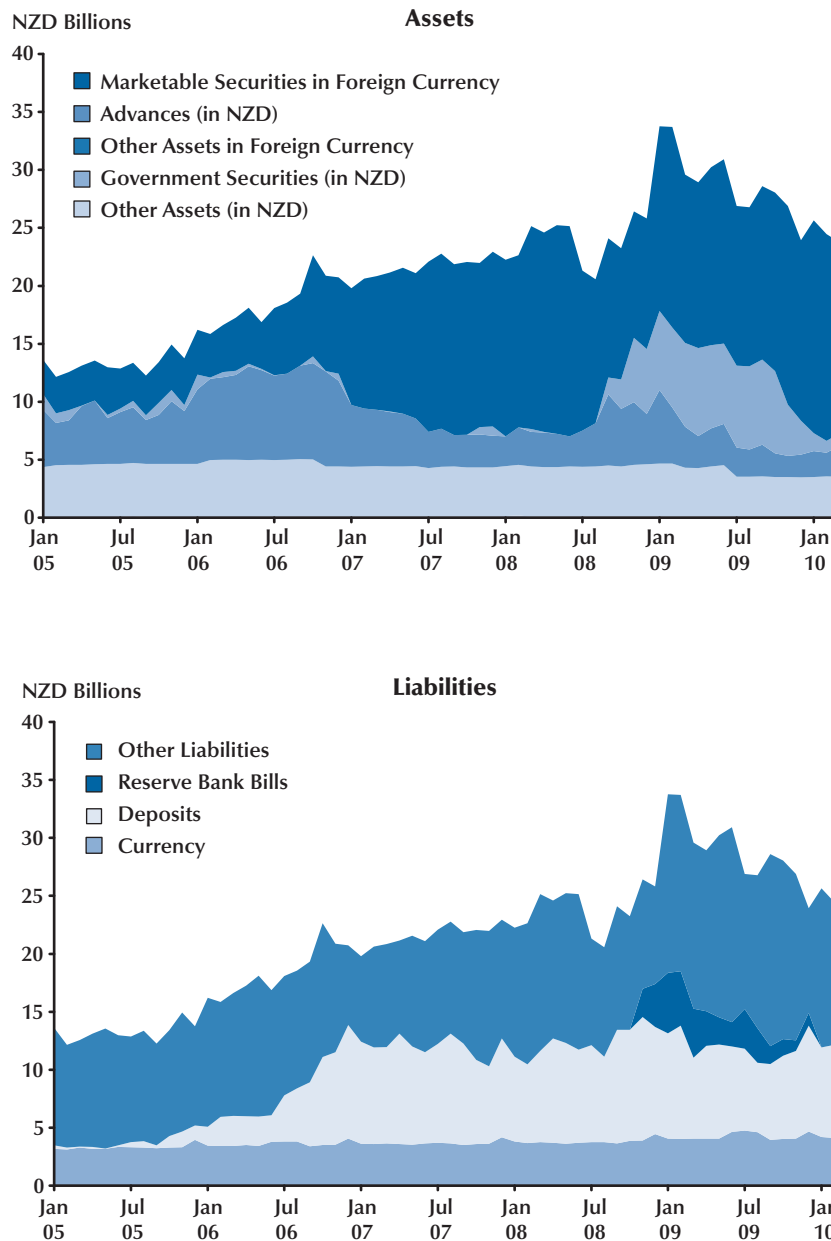
New Zealand[26]

New Zealand's monetary base increased 138 percent between July and December 2006. No adverse "shock" to the economy caused the Reserve Bank of New Zealand (RBNZ) to increase its monetary base. Rather, the increase was the

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[23] For additional details, see Central Bank of Iceland (2009a).

[24] Iceland's treasury purchased a 75 percent share in one bank (Glitnir) for €600 million and a week later the CBI loaned €500 million to another bank (Kaupthing) for four days.

[25] The CBI adopted an inflation target in March 2001.

[26] For additional details, see Nield (2008).

Figure 11

Composition of Reserve Bank of New Zealand Balance Sheet

NZD Billions **Assets**

Marketable Securities in Foreign Currency
Advances (in NZD)
Other Assets in Foreign Currency
Government Securities (in NZD)
Other Assets (in NZD)

NZD Billions **Liabilities**

Other Liabilities
Reserve Bank Bills
Deposits
Currency

NOTE: The Reserve Bank of New Zealand does not publish a series on the monetary base. It does publish data on settlement institution deposits at the RBNZ and currency in circulation, the sum of which is a measure of the monetary base.

SOURCE: Reserve Bank of New Zealand.

culmination of a collaborative project between the Reserve Bank and the settlement banks to improve the payment system to "reduce risk and enhance certainty in the financial system" (Nield, 2008, p. 10). The RBNZ-operated payment system does not permit daylight overdrafts (i.e., payments on behalf of a bank that exceed the bank's available account balance at the RBNZ). Increased settlement balances at the RBNZ significantly reduced delays in the payment system. The RBNZ also began paying interest on its settlement balances to increase the acceptance of the system and to discourage banks from using these reserve balances to fund new lending.

The new settlement system was implemented between August and October 2006. The RBNZ expected the monetary base would increase to between NZ$7 billion and NZ$10 billion (Nield, 2008) as banks gradually unwound Treasury bill holdings and used foreign exchange swaps to purchase New Zealand dollars. The RBNZ determined that since the cash was purchased at rates consistent with the policy rate, there would be no inflationary pressures. In fact, year-over-year growth in consumer prices fell from 3.4 percent in 2006:Q3 to 1.8 percent in 2007:Q3. It did, however, increase to 5 percent in 2008:Q3 only to again drop under 2 percent in 2009:Q2. Over the same period, inflation expectations remained well anchored around 3 percent.

The financial crisis hit New Zealand in mid-2008. Between July 2008 and April 2009, as inflation expectations plummeted, the RBNZ reduced its target for the official cash rate to 2.5 percent from 8.25 percent. Although the RBNZ has not emphasized increases in its balance sheet as part of its policy, Figure 11 shows clearly that large balance-sheet increases did occur. More recently, the RBNZ balance sheet has contracted somewhat as the crisis has eased, although a weak economic outlook has caused the RBNZ to sustain a low policy target rate.

CONCLUSION

During the past two decades, large increases— and decreases—in central bank balance sheets have become a viable monetary policy tool. Historically, doubling or tripling a country's monetary base was a recipe for certain higher inflation. Often such increases occurred only as part of a failed fiscal policy or, perhaps, as part of a policy to defend the exchange rate. Both economic models and central bank experience during the past two decades suggest that such changes are useful policy tools if the public understands the increase is temporary and if the central bank has some credibility with respect to desiring a low, stable rate of inflation. We find little increased inflation impact from such expansions.

For monetary policy, our study suggests several findings:

(i) A large increase in a nation's balance sheet over a short time can be stimulative.

(ii) The reasons for the action should be communicated. Inflation expectations do not move if households and firms understand the reason(s) for policy actions so long as the central bank can credibly commit to unwinding the expansion when appropriate.

(iii) The type of assets purchased matters less than the balance-sheet expansion.

(iv) When the crisis has passed, the balance sheet should be unwound promptly.

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Haircuts

Gary Gorton and Andrew Metrick

"When confidence is lost, liquidity dries up." The authors investigate the meaning of "confidence" and "liquidity" in the context of the recent financial crisis, which they maintain is a manifestation of an age-old problem with private money creation: banking panics. The authors explain this problem and provide some evidence with respect to the recent crisis. (JEL G1, E3)

It is commonly stated that the outbreak of a crisis is due to a lack of confidence—as if the lack of confidence was not itself the very thing which needs to be explained.

—Edwin Seligman (1908, p. xi)

Markets with heavy trading are often described as "liquid" markets. The financial crisis of 2007-09 was a banking panic in the **sale and repurchase agreement** (repo) market, a highly liquid market that shrank dramatically when the "depositors" withdrew their money, as we explain later (see Gorton, 2010, and Gorton and Metrick, 2009).[1] The average daily trading volume in the repo market was about $7.11 trillion in 2008, compared with the New York Stock Exchange, where the average daily trading volume in 2008 was around $80 billion.[2]

Repos are considered part of the money supply—like demand deposits or private bank notes before the Civil War[3]—and, like other forms of money, they involve trillions of dollars in exchanges without extensive due diligence. As with past U.S. banking panics, the core of the recent financial crisis was a problem of private money creation, which has always been difficult. In banking crises private markets fail to function; "liquidity dries up" because of a "loss of confidence." In this paper, we investigate this liquidity problem in the context of the recent financial crisis and provide evidence for our explanation.

Traditional banking is centered on creating demand deposits (checking accounts), which are part of the money supply. Demand deposits are a form of debt that allows the depositor the right to withdraw cash at any time (i.e., the deposits have a very short maturity); they are backed by the assets of the bank, including reserves and

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[1] Terms in **bold** may be unfamiliar to some readers and are defined in the glossary.

[2] On the repo markets, see Securities Industry and Financial Markets Association (SIFMA, 2008, p. 9), and on the stock market, see "Daily NYSE Group Volume in NYSE Listed" (www.nyxdata.com/nysedata/asp/factbook/viewer_edition.asp?mode=table&key=3002&category=3). The SIFMA number includes repo and reverse repo; half of $7.11 trillion would be $3.56 trillion.

[3] It has long been recognized that repo is a form of money; it was counted in the Federal Reserve System's monetary aggregate M3, which was discontinued in mid-2006.

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loans. Checks are in demand because they are easily transferable; and since they now are insured by the federal government, their value is never in question. Before the 1934 adoption of deposit insurance in the United States, demand deposits were designed to try to privately create confidence in their value. The idea was to create a medium of exchange—that is, a security that would be easily accepted in transactions, without the need for extensive and costly due diligence on the bank's part. With a successful design, checks could be used with confidence in their value without extensive due diligence. The traditional problem with demand deposits was that sometimes this confidence quickly disappeared. The 1930s saw many banking panics, events in which depositors ran en masse to their banks and demanded cash for their checking accounts. Banks, having lent the money, had illiquid loans and could not honor the demands of their depositors: The banking system was insolvent. This problem is exactly what deposit insurance solved.

In our paper, we focus on this specific type of private money—repos—which, as we explain below, are a kind of money used by institutional investors and nonfinancial firms that need a way to safely store cash, earn some interest, and have ready access to the cash should the need arise. In a repo transaction a "depositor" deposits money at a financial institution and receives collateral, valued at market prices. The transaction is short term, so the depositor can "withdraw" the money at any time. The deposit is backed by the bonds received as collateral from the institution where the money is deposited. Overcollateralization can occur if the market value of the bonds received exceeds the deposit. For example, if $90 million is deposited and $100 million of bonds is received as collateral, then there is a "**haircut**" or initial margin of 10 percent. This haircut is akin to bank capital or a reserve fund as the 10 percent is junior in seniority to the depositor's 90 percent claim.

Historically, securities that function as money have certain specific properties. These securities are debt that is short term and backed by diversified portfolios. Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2010a) have described the production of this type of debt as

the creation of information-insensitive securities. "Information insensitivity" means that the securities are immune from adverse selection when traded. This property defines a liquid market: Trading can occur quickly without loss to insiders. In a liquid market, no agent finds it profitable to produce private information about these securities. In short, you can trade and not be taken advantage of. However, if an economic shock is large enough, then debt that was information-insensitive becomes information-sensitive. This creates a loss of confidence, a fear of adverse selection that reduces liquidity. In this paper, we further investigate some of the details of this argument.

PANICS IN U.S. HISTORY

In U.S. history, periodic banking panics have been the norm. These panics can offer some useful insights for understanding the recent crisis. For example, during the U.S. national banking era (1863-1913), there were seven nationwide banking panics.[4] And, of course, there was the Great Depression in the 1930s. A banking panic starts at the peak of the business cycle when macroeconomic information signals a coming recession. The signal or economic shock causes concerns about the value of demand deposits that previously were considered completely safe. Upon learning of the coming downturn, depositors run to their banks to withdraw cash, concerned that banks will fail in the coming recession. In the nineteenth century, the news that arrived was an unexpected increase in the liabilities of failed businesses, a leading indicator of recession. See Gorton (1988) and Calomiris and Gorton (1991).

Faced with massive demands for cash, the banking system becomes insolvent because it cannot honor these contractual demands with respect to demand deposits. The money has been lent and cannot be recalled, and the loans cannot be sold. There is no private agent capable of buying the assets of the banking system at a price that allows banks to honor their contractual demands. This is the essence of a systemic event.

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4   There were also panics before the Civil War, notably in 1837 and 1857.

The information that the nineteenth-century depositors received was aggregate information, not bank-specific information about individual banks. People knew only that a recession was coming and that some banks were likely to fail; but no one knew which banks. So, the precautionary action of withdrawing funds from all banks was rational. The information shock about the coming recession was large enough to cause a panic.

Banks try to produce securities that are useful for transacting—namely, bank debt such as demand deposits. But during a bank panic, people lose confidence in the value of bank debt. Bank debt that was previously considered "safe" becomes suspect. In this context, "safe" means two related things. First, the value of the bank debt does not change much: A ten-dollar check is pretty much always worth ten dollars. Second, it does not benefit anyone to produce private information about the value of the bank debt and speculate on that information.

During the national banking era, there was no central bank to act as a lender of last resort. So, what happened during bank panics? During the nineteenth and early twentieth centuries, the banks themselves developed increasingly sophisticated ways to respond to panics. The response was centered on private bank clearinghouses. Originally organized as an efficient way to clear checks, these coalitions or clubs of banks evolved into much more. Clearinghouses tried to recreate the information-insensitivity of demand deposits by increasing the diversity of the portfolio backing demand deposits. First, in response to a panic, banks would jointly suspend convertibility of deposits into currency. Coincident with this move, clearinghouse member banks joined to form a new entity overseen by the clearinghouse committee. The clearinghouse would also cease the publication of individual bank accounting information (which banks were normally required by the clearinghouse to publish in the local newspapers) and would instead publish only the aggregate information of all the members. Finally, the clearinghouse issued new money called "clearinghouse loan certificates" directly to the public in small denominations (see Gorton, 1985, and Gorton and Mullineaux, 1987). The certificates were *joint* liabilities of the clearinghouse members—not of any individual bank—and provided a kind of deposit insurance. The clearinghouse loan certificate was a remarkable innovation that resulted from individual private banks finding a way to essentially become a single institution, responsible for each other's obligations during a panic and issuing a hand-to-hand currency.

SECURITIZED BANKING AND REPOS AS MONEY

The limits on the amount protected by deposit insurance make bank accounts inadequate for large depositors, such as institutional investors or nonfinancial firms. These investors and firms need a short-term, safe, interest-bearing place to store money. A repo is a financial contract used by market participants to meet short- and long-term liquidity needs. Repo transactions have two parties: essentially the bank (or borrower) and another party, the depositor (or lender). The depositor deposits money, and in exchange for the cash, the bank provides bonds as collateral to back the deposit. The depositor earns interest—the repo rate. Repos are typically short-term, often overnight transactions, so the money can be withdrawn easily by not renewing or "rolling" the repo.

Because FDIC insurance does not cover repos, the safety of the bank (typically a dealer bank) is insured privately with the collateral, which is valued at market prices. Depositors take delivery of the collateral so it is in their possession. The depositor in the repo is protected (in principle) from the bank's failure because he can sell the collateral in the market to recover the value of the deposit. That is, the nondefaulting party can unilaterally terminate the repo and sell the collateral if the bank becomes insolvent or keep the money if the depositor becomes insolvent. In other words, repo transactions are excluded from the U.S. bankruptcy code.[5]

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[5] Repos are exempt from the automatic stay provision of the bankruptcy code and aggrieved parties do not have to enter Chapter 11 to try to recover the value. The nondefaulting party to a repurchase can unilaterally terminate the transaction and sell the collateral or keep the cash, depending on which side of the repo they are on. See, e.g., Schroeder (1996).

Another important feature of repos is that the bonds the depositor receives as collateral can be "spent"—they can be used as collateral in another, unrelated, transaction. For example, the bonds could be posted as collateral against a derivatives position. This reuse of collateral is called "**rehypothecation**." Rehypothecation means that there is a money velocity associated with the collateral. In other words, the same collateral can support multiple transactions, just as one dollar of cash can lead to a multiple of demand deposits at a bank. The collateral is functioning like cash.

In what follows, "haircuts" play an important role. To reiterate, the previous example involves a large investor who may deposit $100 million and receive bonds worth $100 million. This is a case of a zero haircut. If the depositor deposits only $90 million and takes $100 million (market value) of bonds as collateral, there is a 10 percent haircut. In that case, the bank must finance the other $10 million in some other way, issuing new liabilities. Haircuts are determined by participants in the market and can change.

Traditional banking is the taking of deposits (paying, say, 3 percent interest) and lending the money at a higher rate (say, 6 percent interest). Repos work the same way. Deposits are taken and the repo rate is paid—say, 3 percent. The collateral is provided to make the deposit safe, but the return on the collateral—say, 6 percent—accrues to the bank, not the depositor. The bond collateral takes the place of the loan. But as we will see below, the collateral is often securitized bonds (claims on portfolios of loans).

Despite the apparent similarities between repo and demand deposits,[6] the Fed counted only those repo transactions completed by the primary security dealers that trade with the Fed, not the entire market. These transactions are the only repos for which the government collects data.

According to Fed data, primary dealers reported financing $4.5 trillion in fixed-income securities with repos as of March 4, 2008. But there are no official statistics on the overall size of the repo market. However, it is likely to be about $12 trillion, compared with the total assets in the U.S. banking system of $10 trillion[7] (see Gorton, 2010). Hördahl and King (2008) report that the amount traded in repo markets has doubled since 2002, "with gross amounts outstanding at year-end 2007 of roughly $10 trillion in each of the U.S. and euro markets, and another $1 trillion in the UK repo market" (p. 37). They report that the U.S. repo market exceeded $10 trillion in mid-2008, including double counting. According to Hördahl and King (2008), "the (former) top U.S. investment banks funded roughly half of their assets using repo markets, with additional exposure due to off-balance sheet financing of their customers" (p. 39; also see King, 2008).

An important feature of the repo market is that the collateral often consisted of securitized bonds.[8] These are the liabilities of a **special purpose vehicle** (SPV), which finances a large portfolio of loans (e.g., home mortgages, auto loans, credit card receivables) by issuing tranches (bonds) in the capital markets. The tranches are based on seniority, but all tranches are investment grade. The sponsoring firm—the originator of the loans in the underlying portfolio—holds the equity residual, and there may be other credit enhancements to ensure that the tranches are investment grade (see Gorton and Souleles, 2006). While the internal structure of these transactions is complicated, the tranches were designed to, in effect, be information insensitive. This securitization of non-mortgage loans creates a group of assets called **asset-backed securities** (ABS), while portfolios of residential mortgages are **residential mortgage–backed securities** (RMBS). Similarly,

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[6] Indeed, the Federal Reserve counted repo transactions as money in a monetary aggregate called M3. "M3 did not appear to convey any additional information about economic activity that was not already embodied in M2. Consequently, the Board judged that the costs of collecting the data and publishing M3 outweigh the benefits." M3 was discontinued on March 23, 2006. For more information, see "The Money Supply" (www.ny.frb.org/aboutthefed/fedpoint/fed49.html) and "Discontinuation of M3" (www.federalreserve.gov/releases/h6/discm3.htm).

[7] Triparty repos peaked at $2.8 trillion and are estimated to be between 10 and 15 percent of the overall repo market. This gives a range for repos between $18.7 trillion and $28 trillion.

[8] There was a shortage of collateral because collateral is needed for derivatives positions and clearing and settlement in addition to repos. Roughly 40 percent of U.S. debt of all types is held abroad and may not be available for use as collateral.

commercial mortgage–backed securities (CMBS) are claims on portfolios of commercial mortgages.

One asset class that was securitized was subprime mortgages. As explained by Gorton (2008), the product innovation with these mortgages was to structure the mortgages to effectively make the maturity two or three years. This structuring was accomplished with a fixed interest rate for the initial period, but with a significant rate increase at the "reset date," which essentially required the borrower to refinance the mortgage. With rising home prices, borrowers in the subprime market could build equity in their homes and would be able to refinance. For 2001 through 2006, subprime mortgage originations totaled about $2.5 trillion.[9] In 2005 and 2006, they totaled $1.2 trillion. A large portion of these later mortgages likely consisted of refinancings of previous mortgages. An important part of the subprime mortgage innovation was the financing method for the mortgages. In 2005 and 2006, about 80 percent of the subprime mortgages were financed through securitization—that is, the mortgages were sold in RMBS, which involves pooling thousands of mortgages and selling the pool to an SPV, which finances the purchase of the mortgage pool by issuing securities with different seniorities in the capital markets.

Securitization is an important sector of U.S. capital markets. Figure 1 shows the annual issuance amounts of all U.S. corporate debt (investment-grade and below–investment-grade) and all private securitization issuance. The effects of the crisis are also apparent, a manifestation of the loss of confidence discussed later.

Gorton and Metrick (2009) label institutions that finance their portfolios of securitized bonds through repos as "securitized banks" to distinguish them from the traditional depository institutions, which are regulated. Securitized banks were largely the old investment banks. To conduct repo business, these firms had to hold portfolios of assets that could be used as collateral. As explained previously, the collateral is like the loan in traditional banking.

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[9]   See Inside Mortgage Finance (2006) and Joint Economic Committee (October 2007).

Figure 1

U.S. Corporate Debt and Securitization Issuance ($ billions)
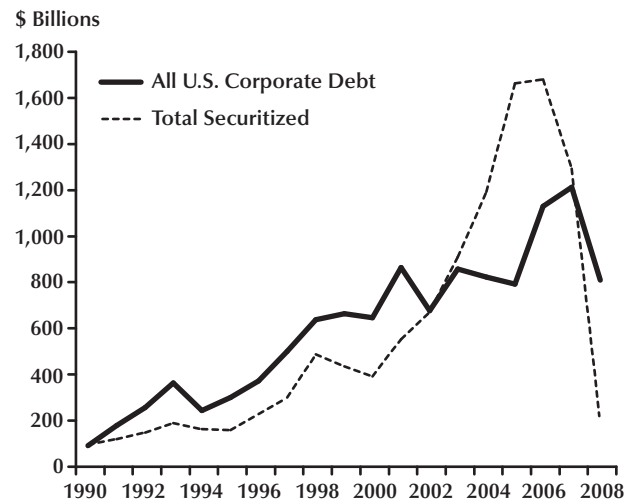
SOURCE: Thomson Reuters.

We now turn to the question of the vulnerability of securitized banks to runs.

REPO HAIRCUTS: TRYING TO RECREATE INFORMATION INSENSITIVITY AND, HENCE, LIQUIDITY

How could problems with subprime mortgages have caused a global financial crisis? Subprime mortgages were mostly securitized (about 80 percent were financed this way), but the amounts were not large enough to cause a systemic event. Gorton (2010) likens the subprime situation to an *E. coli* outbreak: Even a small outbreak in very specific foods can frighten many people into avoiding a wide array of similar foods. The problem with subprime, as with *E. coli*, was that no one knew where the risks actually were, so there was no certainty about which counterparties would fail. (And, unlike food, subprime mortgages cannot be recalled.) In the pre-Fed era, depositors knew that not all banks would fail in

a recession. But they did not know which banks were more likely to fail, and so there were runs on *all* banks. In this section we provide some analysis of the run on repos.

When a sufficiently bad economic shock occurs, debt cannot be traded without creating adverse selection or the fear of adverse selection. As discussed later, the dynamics of the recent crisis appear to be somewhat different from the panics of the nineteenth and early twentieth centuries. In analyzing the recent crisis, we see that it started small, grew, and was prolonged. It is hard to pin down the initial shock. Certain things were known: (i) Subprime mortgages were deteriorating during the first half of 2007, (ii) the house price bubble had burst, and (iii) some of the subprime mortgage originators were in trouble. The accumulation and aggregation of this information seems to have led to the start of the panic, which then worsened as more news arrived and the crisis exploded with the Lehman Brothers failure. But this scenario is conjecture and a subject for further research.

In the recent crisis, repo depositors did not know which securitized banks were most likely to fail (or whether the Fed would let them fail). More specifically, the concern was not directly about the bank defaulting, because repos are collateralized, but about the ability to recover the collateral value when sold in the market if the bank did default. Gorton (2010) and Gorton and Metrick (2009) argue that the financial crisis of 2007-08 was a banking *panic*. The panic corresponds to increasing repo haircuts, which caused massive deleveraging. The collapse of the repo market was the systemic event.

The panic corresponds to information-insensitive securities becoming information-sensitive, thereby creating a loss of confidence. Information "sensitive" means that traders then have an incentive to produce information. If that happens, then trade is reduced because of a fear of adverse selection. Liquidity dries up. One way to partially overcome this problem is for traders to recreate information-insensitive securities by taking a senior tranche of the original bond. In the repo market this concretely corresponds to a haircut. The bank taking the deposit must over-

collateralize the deposit. And this implies that the bank must hold more equity in the collateral.

A key point to remember is that the collateral offered in repos is valued at market prices. If the bonds become riskier and their prices go down, then they are valued at the lower prices. Furthermore, if their future price is uncertain, that added risk can be addressed with a higher repo rate. Repo rates can and did go up (see Gorton and Metrick, 2009). Why should repo collateral involve haircuts? And why should these haircuts go up? Our answer (following Dang, Gorton, and Holmström, 2010a,b) is that a haircut amounts to tranching the collateral to recreate an information-*in*sensitive security and thereby improve its liquidity.

The most relevant risk is not related to the usual worries about the payoff (i.e., possible risk) on the security but is endogenous to the *trading process*, separate from the risk of loss due to default. A haircut addresses the risk that if the holder of the bond in repo (the depositor) must sell a bond in the market to get the cash back, the trader to whom the bond is sold may be better informed, resulting in a loss (relative to the true value of the security). Consequently, the price cannot adjust to address this risk.

One way to protect against this endogenous adverse selection risk is to require overcollateralization—that is, to increase the haircut. The depositor deposits less than the market value of the bond but has the bond as collateral. For the bank—the entity funding the bond—this means that for a bond worth $100, only a lesser amount can be borrowed, perhaps $95 (i.e., a haircut of 5 percent). We examine this proposition in cross section by looking at the haircuts during the crisis for different categories of structured products, particularly examining whether the "closer" the security is to subprime the sooner and the higher the repo haircut on that collateral. The haircuts should be higher for asset classes that are more prone to be sensitive to subprime mortgage risk.

During the crisis, repo haircuts varied for different asset classes—in particular, different categories of structured products, including ABS, RMBS, CMBS, **collateralized loan obligations** (CLOs), and **collateralized debt obligations**

(CDOs). CDOs are SPVs that issue long-dated liabilities in the form of rated tranches in the capital markets and use the proceeds to purchase structured products for assets, especially ABS. CDOs purchased significant amounts of subprime RMBS bonds (see Gorton, 2008).
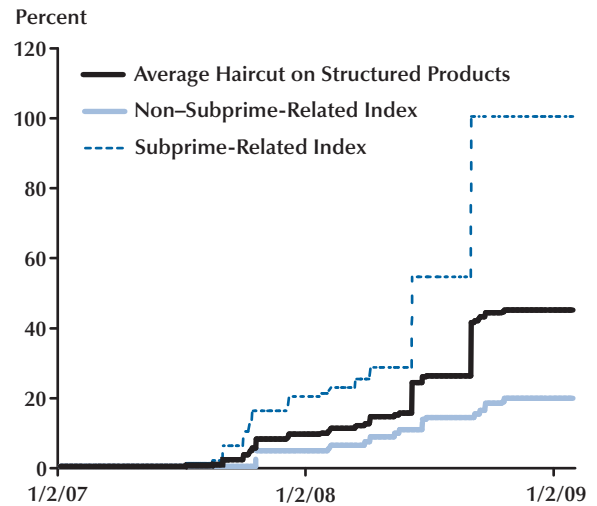
We examine haircut data from one broker-dealer engaging in repo transactions with other banks in the interbank market. Haircuts are a function of the default probabilities of the two parties to the transaction and the information sensitivity of the collateral (see Dang, Gorton, and Holmström, 2010b). So, haircuts are not uniform across asset classes. We cannot say that our data are representative because we do not have data from other banks, but the bank that provided the data to us anonymously is a large, well-known institution. We know of no other large datasets of haircuts.[10]

The data we examine are the interbank repo haircuts on the following asset classes, further characterized by their ratings: (1) A-AAA ABS (auto/credit cards/student loans); (2) AA-AAA RMBS/CMBS; (3) below-A RMBS/CMBS; (4) AA-AAA CLO; (5) unpriced ABS/MBS/all sub-prime; (6) AA-AAA CDOs; (7) unpriced CLOs/CDOs. "Unpriced" means that public pricing for the collateral is not listed on Reuters or Bloomberg. Of these categories, those numbered (1) through (4) are not subprime related; they do not contain subprime mortgages. We label this group "non–subprime related." The RMBS in categories (2) and (3) are prime mortgages, not subprime. Categories (5) through (7) are either directly subprime or contain subprime mortgages. CDOs, in particular, contain some subprime mortgages. We use all seven categories to construct an equally weighted average repo-haircut index for structured bonds.

In the pre-crisis period, haircuts were zero for all asset classes; this is consistent with the repo market being based on information-insensitive assets backing deposits. Figure 2 shows the hair-

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[10] Except for another dataset that we have obtained of haircuts on collateral used for loans to hedge funds by one dealer bank. Holding the asset class and rating of the collateral constant, these haircuts are larger but follow the same pattern of increase over the crisis as discussed. The Bank for International Settlements (2010) has a small amount of survey-based data from June 2007 and June 2009.

Figure 2

**Repo Haircuts on Different Categories of Structured Products**

cuts for the non–subprime-related and subprime-related groups and the average of all the categories. This figure and the others that follow essentially document the unfolding of the bank panic. An increase in repo haircuts corresponds to the withdrawals from this banking system, leading to massive deleveraging (see Gorton, 2010, and Gorton and Metrick, 2009). A notable feature of this run is that there was not a *single* shock, leading to one jump in the haircuts, but a prolonged *series* of increases in haircuts during the crisis. These dynamics of the crisis are discussed further by Gorton, Metrick, and Xie (2010).

Figure 2 confirms that haircuts were higher on subprime-related asset classes. In fact, the haircut eventually went to 100 percent—that is, these assets were not acceptable as collateral in repo. The non–subprime-related asset classes reached a maximum of a 20 percent haircut.

To reiterate the argument, if these asset classes simply became financially riskier in the usual sense, then that would be reflected in their market prices, which are the starting basis for the collateral. So, that reasoning does not explain these haircuts. Instead, the haircuts are consistent with

Figure 3

Average Haircuts on Structured Products versus Investment-Grade Corporate Bonds
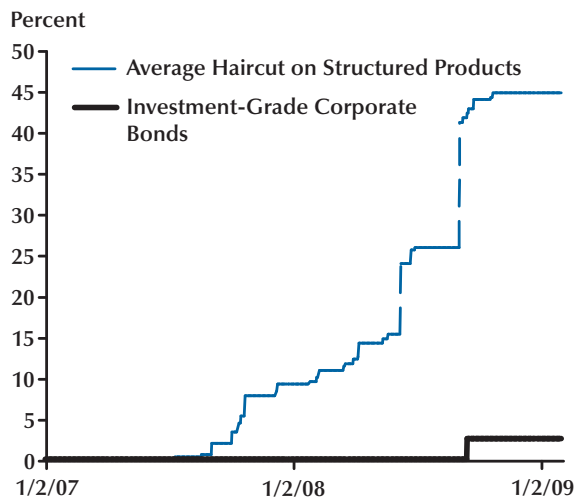
the idea that depositors want collateral that is "safe" in the very specific sense that it is immune to adverse selection and is hence liquid.

The panic portrayed in Figure 2 is the securitized-bank "run on repo." Each depositor imposes a haircut to protect against the possible effects of adverse selection. For the system as a whole, however, the implications are devastating. To understand the impact of this run on repo, take the estimate of the size of the repo market to be $10 trillion, the same size as the total assets in the regulated banking sector.[11] If the average haircut goes from zero (pre-crisis) to, say, an average of 20 percent during the crisis, then $2 trillion is the amount that the securitized banking system must find from other sources to fund its assets. Obviously, if the average haircut goes to 40 percent, then $4 trillion has to be raised. The only route available for these banks to make up the difference was asset sales, which caused a further downward movement in the prices of these asset classes, making them less usable as collateral, causing further sales, and so on. The securitized-

bank system is then effectively insolvent, as was the banking system during the pre-Fed panics.

Figure 2 also displays a loss of confidence in the sense that the non–subprime-related group faced significant haircuts even though it had nothing to do with subprime mortgages. Its only fault is that it is also "securitized." The situation is similar to sales of bagged lettuce dropping when the Food and Drug Administration announces that there is *E. coli* in bagged spinach. To show this loss of confidence, we compare the average haircut on structured products with the haircut on corporate bonds (Figure 3).

All investment-grade corporate bonds were treated the same with regard to haircuts. Corporate bonds are clearly not claims on portfolios of loans as are structured securitized bonds; so, in that sense maybe they are riskier. The point here is that despite no contagious effect of subprime on corporate bonds, the bond haircuts did go from zero to a peak of 2½ percent.

The previous discussion addresses why haircuts increased. In the context of traditional finance, there is no explanation. Corporate debt is, in a way, a kind of haircut on the firm's assets. In fact, the idea of creating information-insensitive debt in this way is quite familiar. The distinction between information-sensitive and information-insensitive has a familiar counterpart—namely, the distinction between investment-grade debt and below–investment-grade debt. While investment-grade debt is not money, it is well-known that, by many measures such as spread and likelihood of default, there is a large gap between these two broad rating categories. This difference has been confirmed empirically. Studies of corporate bond returns and bond yield changes have mainly concluded that (i) investment-grade bonds behave like Treasury bonds—they react to (riskless) interest rate movements and (ii) below–investment-grade bonds (junk bonds) are more sensitive to stock returns—they react to information about the firm.[12] Corporate debt is not money, but the

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[11] This is the number that most repo traders give as an estimate.

[12] Studies of the relation between stock and bond returns at the aggregate level include, e.g., Keim and Stambaugh (1986) and Fama and French (1989, 1993); at the portfolio and firm level, see, e.g., Blume, Keim, and Patel (1991) and Cornell and Green (1991); at the individual level, see, e.g., Kwan (1996a).

gap between investment grade and below–investment grade suggests an important informational line. Senior corporate debt has some features of the type of debt needed for transactions; it is an intermediate case. Kwan (1996b) writes: "It appears that AAA-rated bonds may have so little default risk relative to stocks that they are insensitive to information about the issuing firm."

The preceding analysis suggests that the line between information sensitivity and insensitivity has moved because of the subprime shock. Previously information-insensitive tranches are now sensitive. If this is the case, then we should see the effects in terms of prices or spreads. In other words, the spreads on some securitized asset class tranches should be much higher and remain higher. We can examine this issue by looking at what happened to the difference in spreads on different levels of seniority within the same asset class. We study the difference between the spread on the BBB-rated and the AAA-rated tranches of 5-year credit card ABS. We compare that with the spread difference between the BBB-rated industrial firm bond spread and the AAA-rated industrial firm bond spread at the 5-year horizon. The spread differences are expressed in **basis points**. (These are on-the-run bonds.) Finally, we look at the spread difference between the **LIBOR** and the **overnight index swap** rate. This last spread difference is a proxy for counterparty risk in the interbank market. The LIBOR minus OIS spread (LIB-OIS) should be zero to eliminate arbitrage profits (see Gorton and Metrick, 2009). But, if there is counterparty risk, it can become positive.

Figure 4 shows that the difference between BBB-rated industrial bond spreads and AAA-rated industrial bond spreads moved with the measure of counterparty risk: The spread was lower after the LIB-OIS came down. But this is not true for the credit card ABS spread differential between the BBB-rated and the AAA-rated tranches. This case suggests—but is clearly not definitive—that a kind of regime switch occurred whereby (in this example) the BBB-rated tranche of structured products became permanently information-sensitive.

Figure 4

Spread Differences by Asset Class (basis points)
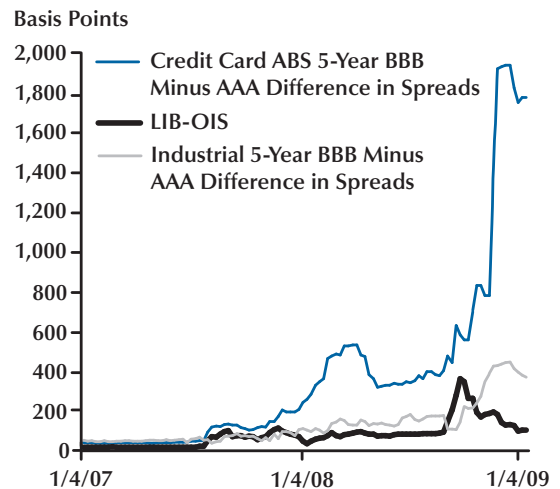
DISCUSSION AND CONCLUSION

Increases in repo haircuts are withdrawals from securitized banks—that is, a bank run. When all investors act in the run and the haircuts become high enough, the securitized banking system cannot finance itself and is forced to sell assets, driving down asset prices. The assets become information-sensitive; liquidity dries up. As with the panics of the nineteenth and early twentieth centuries, the system is insolvent.

Liquidity requires symmetric information, which is easiest to achieve when everyone is ignorant. This determines the design of many securities, including the design of debt and securitization. The goal is to design securities such that it does not pay to speculate in these bonds. They are information-insensitive debt instruments. Then they are easy to trade; they are liquid. This idea (from Dang, Gorton, and Holmström, 2010a,b) is the basis of our study of some repo haircut data. When the asymmetric information about the holders of subprime risks became pressing, increasing haircuts provided a way to recreate (through retranching) information-insensitive debt. This situation applied mostly to subprime-

related asset classes but also occurred with non–subprime-related structured asset classes. The spreads seem to reflect the now information-sensitive status of formerly investment-grade tranches of ABS.

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GLOSSARY

Asset-Backed Securities (ABS): An asset-backed security is a bond backed by the cash flows from a pool of specified assets in a **special purpose vehicle** rather than the general credit of a corporation. The asset pools may be residential mortgages, in which case the asset-backed security is a **residential mortgage–backed security** (RMBS); commercial mortgages, in which case it is a **commercial mortgage– backed security** (CMBS); automobile loans, credit card receivables, student loans, aircraft leases, royalty payments, and many other asset classes. See Gorton and Souleles (2006).

Basis Point (bp): A basis point is one-hundredth of a percentage point (0.01 percent).

Collateralized Debt Obligations (CDOs): A CDO is a **special purpose vehicle** that buys a portfolio of fixed-income assets and finances the purchase of the portfolio by issuing different tranches of risk in the capital markets. These tranches are senior tranches rated Aaa/AAA, mezzanine tranches rated Aa/AA to Ba/BB, and equity tranches (unrated). ABS CDOs are CDOs with underlying portfolios consisting of **asset-backed securities** (ABS), including **residential mortgage–backed securities** (RMBS), and **commercial mortgage–backed securities** (CMBS).

Collateralized Loan Obligations (CLOs): A CLO is a **special purpose vehicle** that buys a portfolio of bank loans and finances the purchase of the portfolio by issuing different tranches of risk in the capital markets. These tranches are senior tranches rated Aaa/AAA, mezzanine tranches rated Aa/AA to Ba/BB, and equity tranches (unrated).

Commercial Mortgage–Backed Securities (CMBS): See asset-backed securities, above.

Haircut or **Initial Margin**: The percentage by which an asset's market value is reduced for the purpose of calculating the amount of overcollateralization of the repo agreement.

LIBOR: The London Interbank Offered Rate (LIBOR) is a series of interest rates, of different maturities and currencies, at which banks offer to lend funds to each other. These rates are calculated by the British Bankers' Association as the averages of quotes contributed by a panel of banks and are announced at 11:00 AM local time in England. This is called the rate "fixing." Quotes are ranked, and the top and bottom quartiles are discarded. The LIBOR is fixed for 15 different maturities (from overnight to one year) and in 10 international currencies. Similar fixing arrangements exist in many markets around the world. See Gyntelberg and Wooldridge (2008).

Overnight Index Swap (OIS): An OIS is a fixed/floating interest rate swap in which the floating leg of the swap is tied to a published index of a daily overnight rate reference. The term can range from one week to two years—and sometimes more. At maturity, the two parties agree to exchange the difference between the interest accrued at the agreed fixed rate and interest accrued through geometric averaging of the floating index rate on the agreed notional amount. This means that the floating rate calculation replicates the accrual on an amount (principal plus interest) rolled at the index rate every business day over the term of the swap. If cash can be borrowed by the swap receiver on the same maturity as the swap and at the same rate and lent back every day in the market at the index rate, the cash payoff at maturity will exactly match the swap payout: The OIS acts as a perfect hedge for a cash instrument. Since indices are generally constructed on the basis of the average of actual transactions, the index is generally achievable by borrowers and lenders. Economically, receiving the fixed rate in an OIS is like lending cash. Paying the fixed rate in an OIS is like borrowing cash. Settlement occurs net on the earliest practical date. There is no exchange of principal. The index rate used is typically the weighted average rate for overnight transactions as published by the central bank (e.g., the effective federal funds rate).

Rehypothecation: "Hypothecate" means to pledge collateral. Rehypothecation is the practice of reusing (or repledging) collateral received in one transaction with an unrelated third party in an unrelated transaction. See Singh and Aitken (2009) and Johnson (1997).

Residential Mortgage–Backed Securities (RMBS): See asset-backed securities.

Sale and Repurchase Agreement (repo): A sale and repurchase agreement (known as a "repo" for short) is a sale of a security combined with an agreement to repurchase the same security at a specified price at the end of the contract. Economically, a repo is a secured or collateralized loan—that is, a loan of cash against a security as collateral. From the point of view of the borrower of the cash (who is putting up the security as collateral), it is a reverse repurchase agreement, or "reverse repo." The collateral pledged by the borrower toward the repo sometimes has a haircut (or initial margin) applied, which means the collateral is valued at slightly less than market value. This haircut reflects the perceived underlying risk of the collateral and protects the lender against a change in its value. Haircuts vary for different asset classes and ratings.

Securitization: The process of financing by segregating specified cash flows from loans originated by a firm (the "sponsor") and selling claims specifically linked to these specified cash flows. This is accomplished by setting up another company, called a **special purpose vehicle** or special purpose entity, and then selling the specified cash flows to this company, which purchases the rights to the cash flows by issuing (rated) securities into the capital market. The sponsor services the cash flows— that is, it makes sure that the cash flows are arriving and so on.

Special Purpose Vehicle (SPV): An SPV or special purpose entity (SPE) is a legal entity that has been set up for a specific, limited purpose by another entity, the sponsoring firm. An SPV can take the form of a corporation, trust, partnership, or a limited liability company. The SPV may be a subsidiary of the sponsoring firm or it may be an "orphan" SPV—one that is not consolidated with the sponsoring firm for tax, accounting, or legal purposes (or it may be consolidated for some purposes but not others). An SPV can carry out only some specific purpose, circumscribed activity, or a series of such transactions. The SPV is not an operating company in the usual sense. It is more of a completely rules-based company in that there is no managerial discretion needed. It has no employees or physical location. An essential feature of an SPV is that it must be "bankruptcy remote"—that is, the SPV can never become legally bankrupt. The most straightforward way to achieve this stipulation is for the SPV to waive its right to file a voluntary bankruptcy petition, but this is legally unenforceable. The only way to completely eliminate the risk of either voluntary or involuntary bankruptcy is to create the SPV in a legal form ineligible as a debtor under the U.S. bankruptcy code. See Gorton and Souleles (2006).

Forecasting with Mixed Frequencies

Michelle T. Armesto, Kristie M. Engemann, and Michael T. Owyang

A dilemma faced by forecasters is that data are not all sampled at the same frequency. Most macroeconomic data are sampled monthly (e.g., employment) or quarterly (e.g., GDP). Most financial variables (e.g., interest rates and asset prices), on the other hand, are sampled daily or even more frequently. The challenge is how to best use available data. To that end, the authors survey some common methods for dealing with mixed-frequency data. They show that, in some cases, simply averaging the higher-frequency data produces no discernible disadvantage. In other cases, however, explicitly modeling the flow of data (e.g., using mixed data sampling as in Ghysels, Santa-Clara, and Valkanov, 2004) may be more beneficial to the forecaster, especially if the forecaster is interested in constructing intra-period forecasts. (JEL C32)

Forecasting macroeconomic variables is an important task for central banks, financial firms, and any other entity whose outcome depends on business cycle conditions. Unfortunately, many important macroeconomic indicators are not sampled at the same frequency. For example, gross domestic product (GDP) data are sampled quarterly, employment and inflation data are sampled monthly, and most interest rate data are sampled daily. Forecasting models, however, generally require data to be of the same frequency. This presents a small, yet manageable, problem for the econometrician, for which several solutions are available.

In this article, we examine a few common solutions to the mixed-frequency problem. In most cases, forecasters time-aggregate higher-frequency data to match the sampling rate of lower-frequency data. For example, a forecaster may time-aggregate three monthly samples of employment data into a single observation for each quarterly sample of GDP data. One way to do this is to take a simple average of the three monthly samples. The higher-frequency data would then be entered into the regression as a simple average along with the lower-frequency data.

Such simple averaging is the most common method of time-aggregating higher-frequency variables; however, in principle, one could use any (normalized) weighting function. For example, each intra-quarter observation could be assigned a different coefficient (henceforth, step weighting). While this may be tractable when mixing quarterly and monthly observations, other sampling frequencies may be problematic. With parsimony in mind, Ghysels, Santa-Clara, and Valkanov (2004) propose a general framework called mixed data sampling (MIDAS) to use when a forecaster wants to estimate a small number of hyperparameters relative to the sampling rate of the higher-frequency vari-

able (in particular, daily versus monthly sampling). Ghysels, Santa-Clara, and Valkanov (2004) employ (exogenously chosen) distributed lag polynomials as weighting functions.

MIDAS models have been used to forecast quarterly series using monthly or weekly data. For example, Clements and Galvão (2008) introduced a common factor to the MIDAS model with an autoregressive (AR) component. They found that their model provided better forecasts at short horizons—especially within-quarter horizons—than a benchmark AR or an AR distributed-lag model. Kuzin, Marcellino, and Schumacher (2009) used monthly series to forecast euro-area quarterly GDP. They compared the performance of the AR-MIDAS model of Clements and Galvão (2008) to a vector autoregression (VAR) and found that the AR-MIDAS model performed better near one-quarter horizons, while the VAR model performed better near three-quarter horizons. Galvão (2007) included a MIDAS framework in a smooth-transition autoregression to allow for changes in a higher-frequency variable's forecasting ability. Her model improved forecasts of quarterly GDP when using weekly short-term interest rate and stock returns data along with term spread data, sometimes up to horizons of two or three years.

Other studies have used daily or intra-daily data to forecast quarterly data. Tay (2006) used daily stock returns in three models to forecast quarterly GDP growth: an AR model and a MIDAS model, which both included higher-frequency data, and a benchmark model. He found that for the early 2000s, his MIDAS model outperformed his benchmark model by 20 to 30 percent, while his AR model using stock returns over a specified period performed even better. Ghysels, Santa-Clara, and Valkanov (2006) used daily and intra-daily stock returns in a MIDAS model to predict future stock-return volatility. Compared with their benchmark model, using high-frequency returns (especially the sum of 5-minute absolute returns data) improved the forecasts by up to 30 percent for horizons of up to four weeks. Ghysels and Wright (2009) included changes in daily interest rates in a MIDAS model to predict upcoming quarterly releases from the Survey of Professional Forecasters. Andreou, Ghysels, and Kourtellos

(2010a) found that incorporating daily factors (obtained from using financial data in a dynamic factor model) improved the forecasting ability of their MIDAS model for some horizons.

There are other methods for mixing frequencies. Although we will not examine them all in detail, we note a few. For example, one could treat the lower-frequency series as though the data existed but were missing, that is, conduct the forecasting regression at the higher frequency and use forecasted observations of the lower-frequency variable for dates with no actual observation. The obvious question, though, is how to construct the missing data. Fernández (1981), for example, suggests interpolation. Recently, Eraker et al. (2008) used similar methods in a Bayesian framework. One could also employ the Kalman filter to construct the missing data (e.g., Fulton, Bitmead, and Williamson, 2001) or construct factors (e.g., Giannone, Reichlin, and Small, 2008; Aruoba, Diebold, and Scotti, 2009; and Camacho and Perez-Quiros, 2010). Bai, Ghysels, and Wright (2010) discuss the link between the MIDAS regressions covered in this article and the Kalman filter.

In this article, we use simple time averaging, a step-weighting function, and exponential Almon polynomial MIDAS to forecast the following variables using the noted data as the predictor: (i) quarterly GDP growth, using its own lags and monthly employment growth rates, (ii) monthly inflation, using its own lags and daily interest rates, (iii) monthly industrial production (IP) growth, using its own lags and daily interest rates, and (iv) monthly employment growth, using its own lags and daily interest rates. These cases demonstrate how the three methods differ when the difference between the higher and lower sampling frequencies is increased. We then test these forecasts out-of-sample to provide a rough assessment of the performance of each method.

The balance of the paper is constructed as follows: The next section describes the data and forecasting environment and introduces the notation. The following section describes the three forecasting methods used. The subsequent two sections present results from the forecasting experiments: The first compares the performance of the three methods using end-of-period data;

the second evaluates the performance of MIDAS using intra-period data. The final section offers some concluding remarks.

THE FORECASTING ENVIRONMENT AND NOTATION

Before proceeding, a number of essential elements must be addressed: notation, forecast evaluation techniques, and the data.

The problem of mixed sampling frequencies is exemplified in Figures 1 and 2. Figure 1 shows quarterly GDP and monthly employment growth rates for the period 1980 to mid-2009: As is typical, the monthly employment observations fluctuate between the quarterly GDP observations. Figure 2 shows how daily federal funds rate observations similarly fluctuate between monthly consumer price index (CPI) inflation observations.

When comparing across modeling environments, it is important to use common notation. In the econometric procedures that follow, our objective is to forecast a lower-frequency variable, Y, sampled at periods denoted by time index t. Past realizations of the lower-frequency variable are denoted by the lag operator, L. For example, if Y_t is the monthly inflation rate, then the inflation rate one month prior would be the first lag of Y_t, $LY_t = Y_{t-1}$, two months prior would be $L^2 Y_t = Y_{t-2}$, and so on.

In addition to lags of Y, we are interested in the information content of a higher-frequency variable, X, sampled m times between samples of Y (e.g., between $t-1$ and t).[1] L_{HF} denotes the lag operator for the higher-frequency variable. If X_t is the daily federal funds rate, then $L_{HF} X_t$ denotes the one-day-before-t realization of the federal funds rate (i.e., the last day of the previous month). If X_t is monthly employment growth used to forecast quarterly GDP, then $L_{HF} X_t$ denotes the employment growth rate of the last month of the previous quarter.

Figure 3 depicts the forecast timeline, which for simplicity shows one-period-ahead forecasts.

Generalization to longer horizons should be obvious. Assume that at time t we are interested in forecasting Y_{t+1}, the circled observation on the timeline. Standard forecasting experiments would use data available through time t; this is depicted in the gray section of the timeline. We perform such end-of-period forecasting experiments using each of the three methods noted above. The blue section of the timeline depicts information that becomes available during the $t+1$ period (i.e., leads); this information may be relevant for forecasting Y_{t+1}. Using the MIDAS method, we perform intra-period forecasting experiments using both the data specified in the gray section and that in the blue section. For the end-of-period and intra-period forecasting experiments, we provide results from a rolling-window scheme (i.e., the in-sample estimation period is a fixed number of periods, T) and results from a recursive scheme (i.e., the in-sample estimation uses all available data up to period t). We compute root mean-squared errors (RMSEs) to compare across forecasts.

Data

To compare the three methods for time-aggregating higher-frequency data, we use two different sets of sampling rates (i.e., monthly data to forecast quarterly data and daily data to forecast monthly data). In all cases, we use lags of the forecasted variable in addition to a single predictor. Generalization to multiple predictors is straightforward. First, we compare forecasts of the quarterly GDP growth rate using the monthly payroll employment growth rate as the predictor. Then, we compare forecasts of the monthly CPI inflation growth rate, monthly IP growth rate, and monthly employment growth rate using daily predictors: the daily effective federal funds rate for CPI inflation and the daily term spread (which is the difference between the 10-year Treasury note yield and the 3-month Treasury bill yield) for IP and employment. Each vintage of real-time data is seasonally adjusted and thus uses a different set of seasonal factors.

In most forecasting experiments, one wishes to use data available at the time the forecaster would have constructed the forecasts, thus, prior
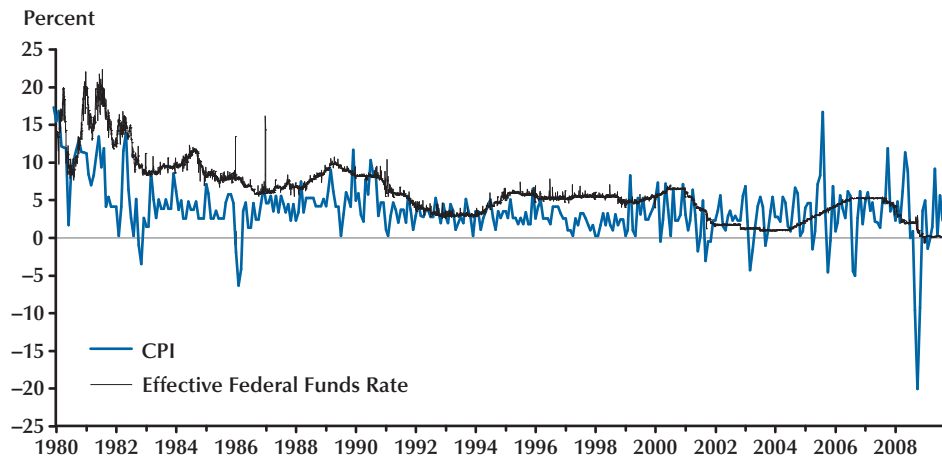
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[1] The extension to include other exogenous variables sampled at the same frequency as Y is obvious and will not be explicitly explored here.

Figure 1

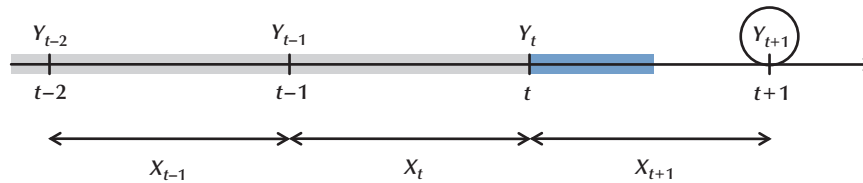**Quarterly GDP and Monthly Employment Growth Rates**
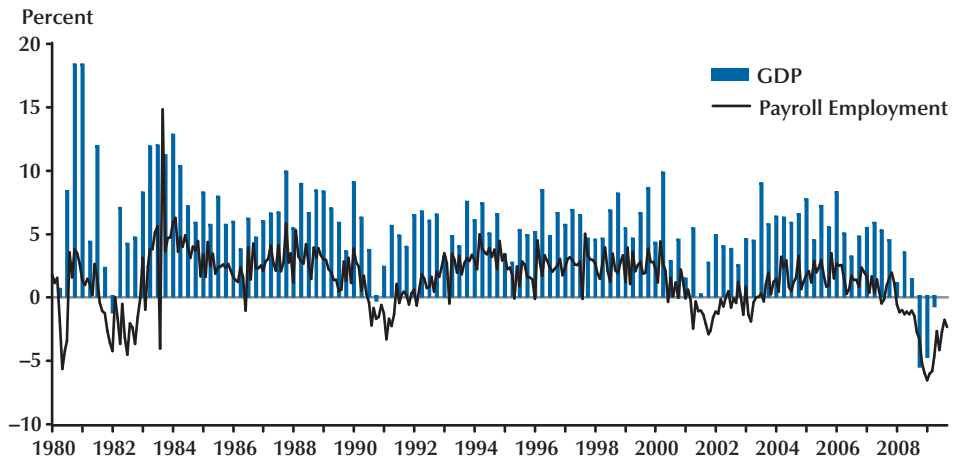
NOTE: Annualized log growth rates.

Figure 2

Monthly CPI Growth Rate and Daily Federal Funds Rate

NOTE: CPI is the annualized log growth rate.

Figure 3

Forecast Timeline

NOTE: The timeline shows information available for forecasting Y_{t+1}.

to potential revisions (see, for example, Croushore, 2005 and 2006; and Croushore and Stark, 2001). We, therefore, use real-time data (detailed below) for the GDP growth rate, employment growth rate, CPI inflation rate, and IP growth rate. Interest rates are not revised, thus their initial data releases are used. We assume that the goal of the forecaster is to predict the true values of the variables. We also assume that the most recent data vintages of the variables are the true value and use these vintages to compute the forecast errors.[2]

For our forecasting experiments, the data we use are log growth rates of the seasonally adjusted annual rate of nominal GDP from the Bureau of Economic Analysis, seasonally adjusted nonfarm payroll employment and seasonally adjusted CPI from the Bureau of Labor Statistics, and seasonally adjusted IP from the Board of Governors of the Federal Reserve System. We also use interest rate data from the Board of Governors. The real-time data vintages (from ArchivaL Federal Reserve Economic Data) used are December 1990 through September 2009. For the monthly forecasts using daily data, our initial in-sample estimations run from July 1975 to November 1990 and the out-of-sample forecasts begin in December 1990. For the GDP forecasts using employment data, our in-sample estimations run from the third quarter of 1975 to the fourth quarter of 1990 and the out-of-sample forecasts begin in the first quarter of 1991.

---

[2] This choice is made with some caveats. For example, IP is reindexed three times during the full sample period. This might introduce mild distortions in the RMSEs for the 1992, 1997, and 2002 periods.

TIME AGGREGATION

This section describes the three methods we use to time-aggregate higher-frequency data for use in forecasting lower-frequency variables.

Time Averaging

One solution to the problem of mixed sampling frequencies is to convert higher-frequency data to match the sampling rate of the lower-frequency data. The simplest method is to compute the simple average of the observations of X that occur between samples of the lower-frequency variable:

$$\overline{X}_t = \frac{1}{m}\sum_{k=1}^{m}L_{HF}^k X_t.$$

With the two variables Y_t and $\overline{X}_t$ in the same time domain, our regression approach is simply

$$(1) \qquad Y_t = \alpha + \sum_{i=1}^{p}\beta_i L^i Y_t + \sum_{j=1}^{n}\gamma_j L^j \overline{X}_t + \varepsilon_t,$$

where the γ_js are the slope coefficient on the time-averaged Xs. Notice that the third term in equation (1) employs the higher-frequency lag operator, indicating that we are using, for example, the prior jth month's average of daily X_ts.

Step Weighting

The previous method assumes the slope coefficients on each of the individual observations of X are equal. Alternatively, one could assume

that each of the slope coefficients for each k sampling of X are unique. This model, including one lag of the predictor X ($n = 1$), is

$$(2) \qquad Y_t = \alpha + \sum_{i=1}^{p} \beta_i L^i Y_t + \sum_{k=1}^{m} \gamma_k L_{HF}^k X_t + \varepsilon_t,$$

where $\{\gamma_k\}_{k=1}^{m}$ represents a set of slope coefficients for all k.

This representation has two potential difficulties. First, the pattern of slope coefficients (and, thus, the weights on each of the lagged intermediate samplings) is unconstrained. One might have the prior belief, for example, that more weight should be given to the samples of X that are more contemporaneous to the observed Y.[3] Second, as the sampling rate, m, increases, equation (2) leads to parameter proliferation. For example, for data sampled at a monthly frequency for use in a quarterly model with one lag, $m = 3$, and the number of parameters is manageable. In contrast, for data sampled at a daily frequency for use in a monthly model with one lag, assuming $m = 20$, for instance, means that 20 different slope coefficients must be estimated.

Thus, once the model is extended to multiple lags, the number of parameters could become quite large. The most general model is

$$(3) \qquad Y_t = \alpha + \sum_{i=1}^{p} \beta_i L^i Y_t + \sum_{k=1}^{n \times m} \gamma_k L_{HF}^k X_t + \varepsilon_t,$$

which allows for up to n lower-frequency lags. This means we would have to estimate $n \times m = 4 \times 20 = 80$ parameters in the third term alone to forecast a monthly variable using four monthly lags of daily data. An alternative formulation preserves the within-month effects but allows for different effects across months:

$$(4) \qquad Y_t = \alpha + \sum_{i=1}^{p} \beta_i L^i Y_t + \sum_{j=1}^{n} \Gamma_j L^j \sum_{k=1}^{m} \gamma_k L_{HF}^k X_t + \varepsilon_t.$$

For the same forecasting problem as above (i.e., using four monthly lags of daily data), equation (4)

would have 24 parameters in the third term. Although these are fewer parameters than needed for equation (3), this number is large compared with that needed for equation (1) (our time-averaging model) and could lead to overfitting. Corsi (2009, p. 181, footnote 11) provides an example of the use of step-weighting functions. Andreou, Ghysels, and Kourtellos (2010b) also discuss potential issues of step weighting (e.g., asymptotic biases and inefficiencies).

MIDAS

The time-averaging model is parsimonious but discards any information about the timing of innovations to higher-frequency data. The step-weighting model preserves the timing information but requires the user to estimate a potentially large number of parameters. To solve the problem of parameter proliferation while preserving some timing information, Ghysels, Santa-Clara, and Valkanov (2004) propose this MIDAS model:

$$(5) \qquad Y_t = \alpha + \sum_{i=1}^{p} \beta_i L^i Y_t + \gamma \sum_{k=1}^{m} \Phi(k; \boldsymbol{\theta}) L_{HF}^k X_t + \varepsilon_t,$$

where the function $\Phi(k; \boldsymbol{\theta})$ is a polynomial that determines the weights for temporal aggregation.

The weighting function, $\Phi(k; \boldsymbol{\theta})$, can have any number of functional forms; the desire here is to achieve flexibility while maintaining parsimony. Ghysels, Santa-Clara, and Valkanov (2004, 2005, and 2006) suggest, for example, a beta formulation:

$$(6) \qquad \Phi(k; \theta_1, \theta_2) = \frac{f\left(\frac{k}{m}, \theta_1, \theta_2\right)}{\sum_{j=1}^{m} f\left(\frac{j}{m}, \theta_1, \theta_2\right)}$$
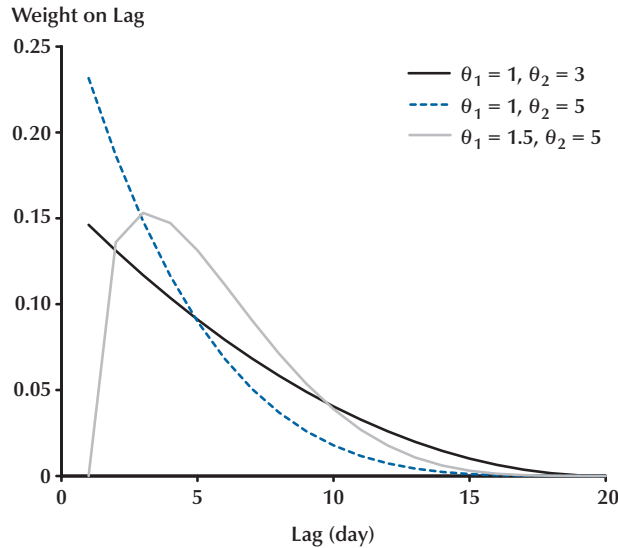
where

$$f(i, \theta_1, \theta_2) = \frac{i^{\theta_1 - 1}(1 - i)^{\theta_2 - 1} \Gamma(\theta_1 + \theta_2)}{\Gamma(\theta_1) \Gamma(\theta_2)},$$

θ_1 and θ_2 are hyperparameters governing the shape of the weighting function, and

$$\Gamma(\theta_p) = \int_0^\infty e^{-i} i^{\theta_p - 1} di$$

---

[3] This is similar in flavor to a number of priors used to estimate VARs, including the Minnesota prior and the Sims-Zha (1998) prior.

Figure 4

Beta Polynomial Weighting Function

Figure 5

Exponential Almon Polynomial Weighting Function

is the standard gamma function. Figure 4 shows a few parameterizations of the beta polynomial weighting function. In particular, note that various parameterizations can obtain strictly decreasing or humped-shaped weighting functions. In addition, the rate of decay is governed by the parameterization. Simple time averaging is obtained when $\theta_1 = \theta_2 = 1$.

Ghysels, Santa-Clara, and Valkanov (2005) and Ghysels, Sinko, and Valkanov (2007) also suggest an exponential Almon specification:
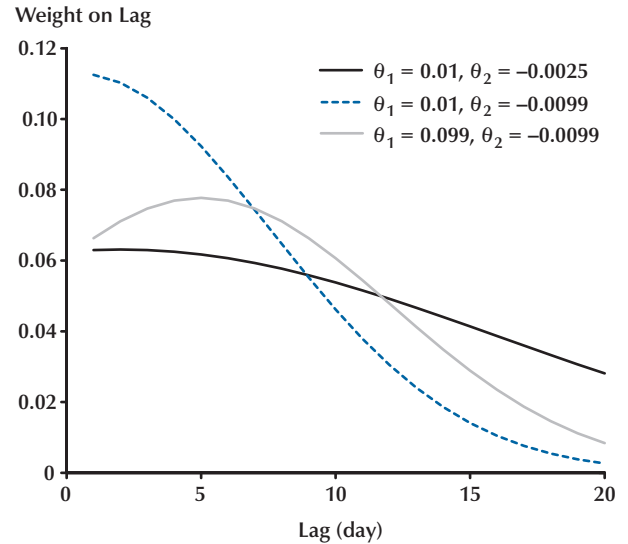
$$\Phi\left(k;\theta_1,\theta_2\right) = \frac{\exp\left(\theta_1 k + \theta_2 k^2\right)}{\sum_{j=1}^{m}\exp\left(\theta_1 j + \theta_2 j^2\right)}.$$

In this case, simple time averaging is obtained when $\theta_1 = \theta_2 = 0$. Figure 5 shows various parameterizations of the exponential Almon polynomial weighting function.

We can generalize the MIDAS specification to multiple lags of the predictor X:

$$(7) \qquad Y_t = \alpha + \sum_{i=1}^{p}\beta_i L^i Y_t + \gamma \sum_{k=1}^{M}\Phi\left(k;\boldsymbol{\theta}\right)L_{HF}^k X_t + \varepsilon_t,$$

where $M = m \times n$. In this case, lags of the predictor are incorporated by expanding the weighting polynomial. Obviously, this restricts the manner in which the predictor influences the forecast; however, if we believe the influence of the predictor should decay monotonically after a certain period, equation (7) is a useful representation with the additional benefit of being extremely parsimonious.[4]

END-OF-PERIOD FORECASTING RESULTS

The preceding two sections propose a few solutions to the mixed-frequency problem. As with most forecasting problems, the efficacy of the model depends heavily on the nature of the forecasted data and the information available to the forecaster. Even across the models described here for time-aggregating higher-frequency data,

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4 Although the two weighting schemes can produce many of the same shapes, we choose to present results using the exponential Almon polynomial weighting function.

one might expect each model's efficacy to depend on, among other things, the difference in the sampling rate and the number of variables included. For example, in models that rely on a large number of explanatory variables, the problem of parameter proliferation might be more evident; thus, the more-parsimonious models, time averaging (equation (1)) and MIDAS (equation (5)), may be favored. When sampling frequencies vary widely, one might expect the step-weighting model (equation (2)) to suffer from parameter proliferation and the time-averaging model (equation (1)) to suffer from a poor approximation to the truth. We test the three models' ability to forecast four macroeconomic variables using the noted data as the predictor: (i) quarterly GDP growth, using monthly employment growth data, (ii) monthly CPI inflation, using daily federal funds data, (iii) monthly IP growth, using daily term spread data, and (iv) monthly employment growth, using daily interest rate data.

Tables 1 and 2 show the results at various horizons from our end-of-period forecasting experiments using a rolling-window scheme and a recursive scheme, respectively. For these experiments, we use only data up through the end of the previous month (when forecasting IP or employment) or quarter (when forecasting GDP). At the shortest horizon, the MIDAS and time-averaging models are almost identical except for forecasting GDP, for which MIDAS slightly outperforms time averaging. In contrast, MIDAS outperforms step weighting in all cases, even more so when using the term spread as a predictor rather than the federal funds rate. At longer horizons, the models are essentially equivalent. Altering the lag length did not substantially change the results. Obviously, as the lag length increases, the viability of the step-weighting model breaks down. This is especially true for models forecasting monthly variables using daily data.

INTRA-PERIOD FORECASTING RESULTS

One advantage of MIDAS over time averaging and step weighting is that MIDAS can forecast within periods. Suppose we want to forecast CPI

inflation for time t. At the beginning of month t, we have information on CPI inflation for month $t-1$ and daily interest rate data for month $t-1$. With this data, we can construct forecasts for the four noted variables, as we did in the previous section. However, because information that may have predictive power—specifically, month-t daily interest rate data—comes in before the end of month t, we can update our forecast of period-t inflation daily throughout the month. Such an intra-period forecasting experiment would include both the gray and blue sections on the Figure 3 timeline, with the latter depicting the intra-period information.[5]

One way to perform this intra-period forecasting experiment is to simply include the new observations of the higher-frequency data in the regression. For the dth day of the month, the regression is

$$
\begin{aligned}
\hat{Y}_{tld} = \alpha \\
(8) \quad + \sum_{i=1}^{p}\beta_i L^i Y_t + \gamma^{LEAD}\sum_{j=m-d+1}^{m}\Phi\left(j;\boldsymbol{\theta}^{LEAD}\right)L_{HF}^{j}X_{t+1} \\
+ \gamma^{LAG}\sum_{k=1}^{m}\Phi\left(k;\boldsymbol{\theta}^{LAG}\right)L_{HF}^{k}X_{t} + \varepsilon_t,
\end{aligned}
$$

which has some advantages if we believed there were some within-month calendar effects. Without the third term, equation (8) is identical to the MIDAS regression (7). The third term reflects the effect of the current month's data.

Equation (8) is actually a set of day-dependent forecasting models—we would have a different regression for each day of the month. Another alternative is to make the following restrictions in equation (8):

$$
(9) \quad \begin{aligned}
\gamma^{LEAD} = \gamma^{LAG}, \\
\boldsymbol{\theta}^{LEAD} = \boldsymbol{\theta}^{LAG}.
\end{aligned}
$$

This means that forecasts do not differentiate between current- and past-month data—that is, we do not treat the new data as special. There are additional options; however, we do not explore them here.

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[5] The discussion here concerns the forecast of the $h = 0$ horizon of Y. Generalization to different horizons, again, should be obvious.

Table 1

RMSEs from End-of-Period Forecasts, Rolling Window

	Forecasted variable											
	GDP, h quarters ahead			CPI, h months ahead			IP, h months ahead			Employment, h months ahead		
Forecasting experiment	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$
1 Quarterly lag of Y,												
3 Monthly lags of employment												
Model: average	0.5683	0.6307	0.7012									
Model: step weighting	0.5702	0.6457	0.7073									
Model: MIDAS	0.5480	0.6315	0.7042									
1 Monthly lag of Y, 30 daily lags of fed funds rate												
Model: average				0.2537	0.2771	0.2803						
Model: step weighting				0.2623	0.3129	0.2748						
Model: MIDAS				0.2536	0.2769	0.2801						
1 Monthly lag of Y, 22 daily lags of term spread												
Model: average							0.6688	0.6559	0.6589	0.1122	0.1175	0.1353
Model: step weighting							0.7357	0.6664	0.6586	0.1288	0.1247	0.1319
Model: MIDAS							0.6682	0.6590	0.6591	0.1126	0.1177	0.1348

Table 2

RMSEs from End-of-Period Forecasts, Recursive

Forecasting experiment	GDP, h quarters ahead			CPI, h months ahead			IP, h months ahead			Employment, h months ahead		
	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$
1 Quarterly lag of Y, 3 Monthly lags of employment												
Model: average	0.5972	0.7090	0.7669									
Model: step weighting	0.5857	0.7416	0.7717									
Model: MIDAS	0.5669	0.6903	0.7635									
1 Monthly lag of Y, 30 daily lags of fed funds rate												
Model: average				0.2586	0.2987	0.3067						
Model: step weighting				0.2602	0.3017	0.2991						
Model: MIDAS				0.2577	0.2986	0.3086						
1 Monthly lag of Y, 22 daily lags of term spread												
Model: average							0.6588	0.6576	0.6679	0.1208	0.1240	0.1456
Model: step weighting							0.6812	0.6745	0.6873	0.1343	0.1371	0.1453
Model: MIDAS							0.6619	0.6588	0.6717	0.1212	0.1232	0.1450

Forecasted variable

Table 3
RMSEs from MIDAS Intra-period Forecasts, Rolling Window

	Forecasted variable											
	GDP, h quarters ahead			CPI, h months ahead			IP, h months ahead			Employment, h months ahead		
Forecasting experiment	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$
1 Quarterly lag of Y, 3 Monthly lags of employment + d leads												
$d=1$	0.5637	0.5995	0.6987									
$d=2$	0.5470	0.5990	0.6917									
$d=3$	0.5489	0.5585	0.6930									
1 Monthly lag of Y, 30 daily lags of fed funds rate + d leads												
$d=10$				0.2534	0.2757	0.2790						
$d=20$				0.2533	0.2753	0.2789						
$d=30$				0.2533	0.2757	0.2786						
1 Monthly lag of Y, 22 daily lags of term spread + d leads												
$d=5$							0.6693	0.6560	0.6625	0.1119	0.1177	0.1371
$d=15$							0.6693	0.6571	0.6627	0.1118	0.1178	0.1376
$d=22$							0.6691	0.6575	0.6627	0.1119	0.1179	0.1378

Table 4

RMSEs from MIDAS Intra-period Forecasts, Recursive

	Forecasted variable											
	GDP, h quarters ahead			CPI, h months ahead			IP, h months ahead			Employment, h months ahead		
Forecasting experiment	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$	$h=1$	$h=2$	$h=5$
1 Quarterly lag of Y, 3 Monthly lags of employment + d leads												
$d=1$	0.5918	0.6380	0.7681									
$d=2$	0.5245	0.6375	0.7648									
$d=3$	0.4931	0.5969	0.7628									
1 Monthly lag of Y, 30 daily lags of fed funds rate + d leads												
$d=10$				0.2564	0.2939	0.3055						
$d=20$				0.2560	0.2928	0.3057						
$d=30$				0.2561	0.2930	0.3058						
1 Monthly lag of Y, 22 daily lags of term spread + d leads												
$d=5$							0.6569	0.6576	0.6755	0.1206	0.1255	0.1487
$d=15$							0.6565	0.6575	0.6750	0.1206	0.1255	0.1492
$d=22$							0.6564	0.6575	0.6758	0.1207	0.1255	0.1495

Figure 6

RMSEs for Leads (One-Period-Ahead Forecasts, Rolling Window)
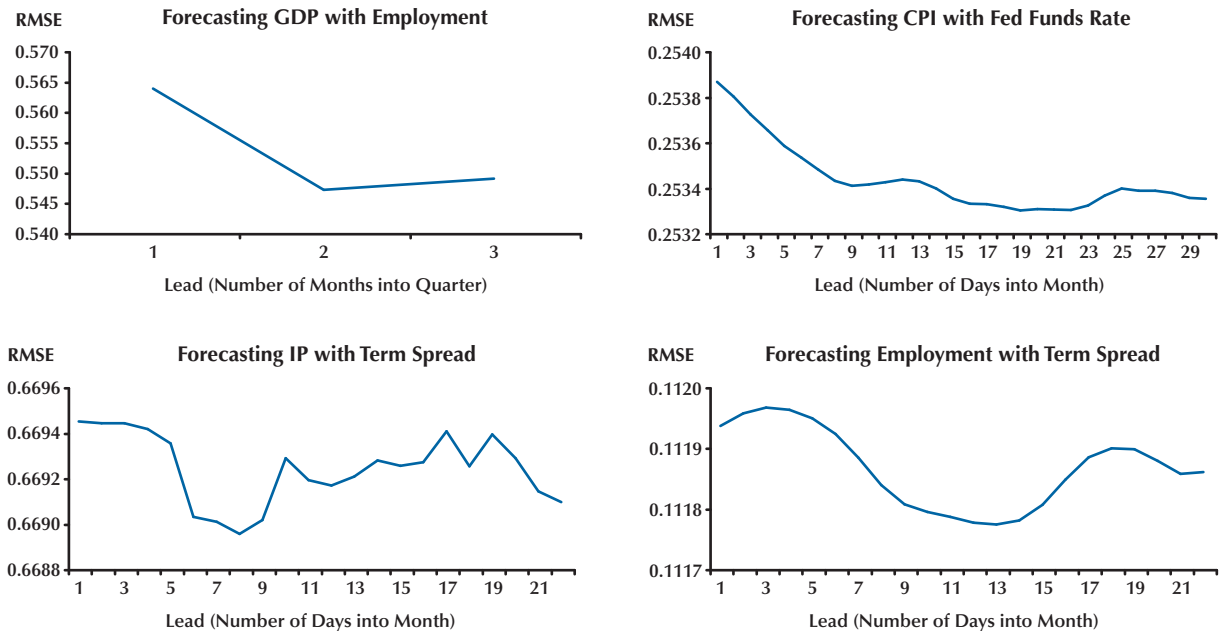
Tables 3 and 4 show the results from our intra-period forecasting experiments (with restriction (9) imposed) using a rolling-window scheme and a recursive scheme, respectively. Compared with the results from Tables 1 and 2, those from Tables 3 and 4 show the benefit of including additional intra-period information. Roughly two-thirds of the RMSEs in Tables 3 and 4 are lower than those of the MIDAS forecasts in Tables 1 and 2. In Tables 3 and 4, for forecasting CPI inflation with the federal funds rate, the RMSE declines over at least the first two-thirds of the month. A similar result holds for forecasting GDP growth with intra-quarter employment growth. The gain is less apparent for forecasting real variables (IP and employment)—as opposed to nominal variables—using the daily term spread; here it appears the RMSEs rise when we take into account the term spread late in the month. This may be because information for real variables reacts more slowly to changes in monetary policy.

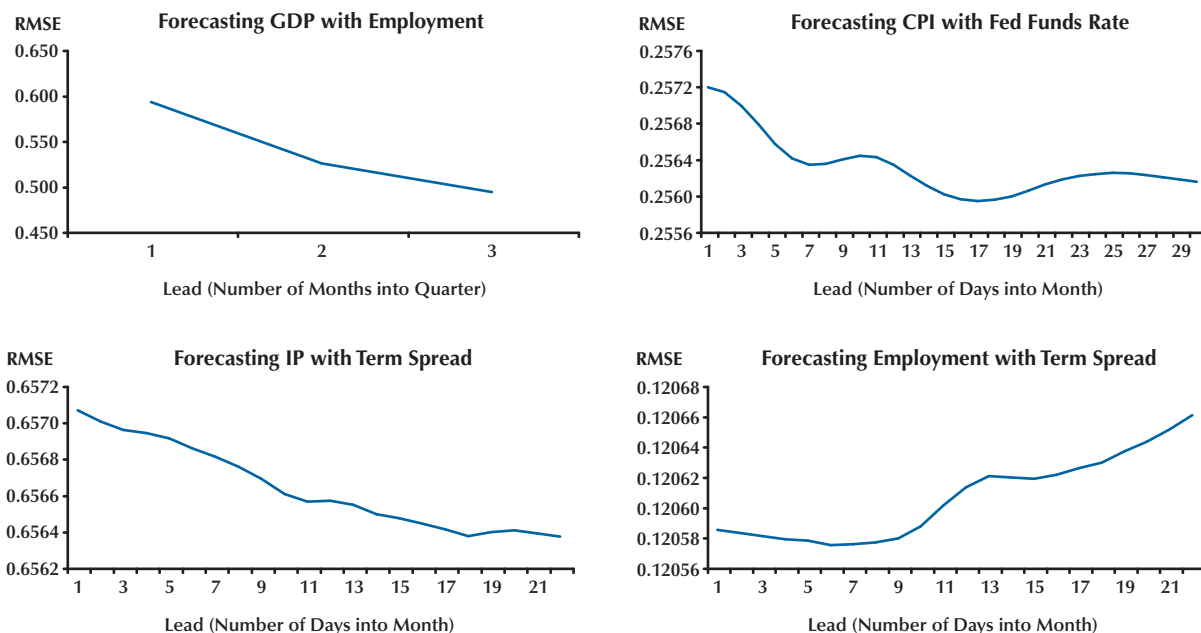Figures 6 and 7 further demonstrate these results by showing the change in the RMSEs for forecasts of the four variables over a quarter or month. The *x*-axis shows the number of months into the quarter or days into the month that the forecast is computed. In Figure 6, the RMSE for the CPI declines almost monotonically over the current month. This is not true, however, for IP and employment, where the RMSEs decline for early leads but then increase later in the month. For forecasts of one-quarter-ahead GDP, the RMSE across different leads initially declines but then increases slightly. In contrast, Figure 7 shows that the RMSEs for both IP and GDP decline over the given period, whereas the RMSE for employment increases almost monotonically over the month.

SUMMARY AND CONCLUSIONS

Forecasting is important for making policy and financial decisions. In some cases, however, forecasters are often confronted with the problem of mixing data frequencies. Macroeconomic data typically are sampled monthly (e.g., employment,

Figure 7

RMSEs for Leads (One-Period-Ahead Forecasts, Recursive)

RMSE **Forecasting GDP with Employment**

Lead (Number of Months into Quarter)

RMSE **Forecasting CPI with Fed Funds Rate**

Lead (Number of Days into Month)

RMSE **Forecasting IP with Term Spread**

Lead (Number of Days into Month)

RMSE **Forecasting Employment with Term Spread**

Lead (Number of Days into Month)

CPI, IP) or quarterly (e.g., GDP); financial data (e.g., interest rates, asset prices) typically are sampled daily (or even more frequently). In this paper, we demonstrated some common approaches to the mixed-frequency problem. In particular, we demonstrated time aggregation, which transforms by means of summation—either weighted or unweighted—higher-frequency data to allow standard regression techniques to be used.

For a simple set of experiments, we found that the performances of different time-aggregation approaches vary—that is, there does not appear to be a golden rule. There may be trade-offs between parsimony (i.e., avoiding overfitting) and flexibility at different horizons and for different sets of data. We refer the reader to the extant literature for a more detailed discussion.[6]

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[6] Much of the code used here is available in the Matlab Toolbox for MIDAS regressions. The toolbox is described in Sinko, Sockin, and Ghysels (2010), and the code is available at www.unc.edu/~eghysels/Software_datasets.html.

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