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An IS-LM Analysis of the Zero-Bound Problem

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An IS-LM Analysis of the Zero-Bound Problem

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Abstract

Policy options for stimulating real activity are limited once short-term interest rates have been driven to zero. Monetary policy makers face the difficult challenge of preventing or reversing declines in near-term inflation expectations while preserving confidence in the central bank's commitment to long-term price stability. Fiscal policy makers must commit to a credible plan for maintaining or raising near-term government purchases while minimizing increases in future marginal tax rates.

JEL codes: E12, E31, E52, E63
Keywords: IS-LM, zero bound, monetary policy, fiscal policy

The views expressed herein are exclusively those of the author and do not necessarily reflect those of the Federal Reserve Bank of Dallas or the Federal Reserve System.

As of this writing (January 2011), the unemployment rate stands at 9.4 percent. The trimmed-mean measure of trend personal consumption expenditure (PCE) inflation has plunged by more than two-thirds, from 2.8 percent to 0.9 percent, in a little over two years (from July 2008 to December 2010).[1] PCE inflation excluding food and energy has fallen from 2.6 percent to 0.8 percent over the same period. The Federal Reserve's Federal Open Market Committee (FOMC) has noted that "currently, the unemployment rate is elevated, and measures of underlying inflation are somewhat low, relative to levels that the Committee judges to be consistent, over the longer run, with its dual mandate [to foster maximum employment and price stability]."[2] Ordinarily, the FOMC would direct the Open Market Trading Desk at the Federal Reserve Bank of New York to drive down short-term interest rates in this situation, in an effort to stimulate demand. However, the FOMC's main policy rate was cut to near-zero levels back in December 2008, leaving essentially no room for further reductions. What is there left for policymakers to do, should they wish to encourage a more rapid economic recovery? This note uses an updated version of an old analytical tool—the IS-LM model—to shed light on possible answers to this question.[3] The main conclusions are as follows:

- With short-term interest rates constrained by the zero bound, monetary policy's only impact on the current economy is through near-term inflation expectations. Policy impedes economic recovery if it allows these expectations to fall. It encourages recovery if it succeeds in getting these expectations to increase. The policy challenge is to raise near-term inflation expectations without eroding confidence in the Federal Reserve's commitment to long-term price stability.
- The Fed raises near-term inflation expectations by either committing to maintain faster growth of its balance sheet over an extended period or committing to a once-and-for-all upward shift in the expected path of its balance sheet. The first option risks raising inflation beyond the near term, violating the Fed's price-stability mandate.
- An increase in the current size of the Fed's balance sheet that leaves expected future balance-sheet levels unchanged has no impact at all, except to increase idle bank reserves and/or idle cash balances.
- Increases in government purchases have a greater than one-for-one effect on aggregate demand at the zero interest-rate bound if it is believed that they will be financed through cuts in future government purchases. Increased current purchases have an exact one-for-one effect on current demand if they are financed through a broadening of the tax base that leaves marginal tax rates unchanged. Increased purchases have a less than one-for-one effect if it is thought that they will result in a higher future marginal tax rate.

1. A LITTLE HISTORY OF THOUGHT

The original IS-LM macro model was developed by Sir John Hicks as a formalization of the ideas put forward by J.M. Keynes in his *General Theory of Employment, Interest, and Money* (Hicks 1937). Hicks' graphical apparatus dominated graduate and undergraduate macro textbooks well into the 1980s and is the most frequently taught macro model at the undergraduate level even today.

At the model's core are two relationships: (1) a negative relationship between current desired expenditure and the real interest rate that reflects the incentive to defer spending when the real return on saving is high, for given expectations of future income or expenditure (this is the IS curve); and (2) a positive relationship between expenditure and the nominal interest rate that reflects the tendency for a given quantity of money to circulate more rapidly the higher is the opportunity cost of holding cash (this is the LM curve). Note that it's the real interest rate that matters in the IS-curve relationship and the nominal interest rate that matters in the LM-curve relationship. For given inflation expectations, though, there's no problem moving between real and nominal yields, allowing the IS and LM equations to be solved for the current level of expenditure and the current real or nominal interest rate.

The LM relationship is relatively uncontroversial, though some people prefer to think of the Fed as choosing the nominal interest rate rather than choosing the money supply. One simply treats the nominal interest rate as the policy variable and solves the LM equation for the associated money supply, rather than the other way around. A new complicating factor is that the Federal Reserve has begun paying interest on bank reserves—an innovation that has affected the demand for reserves relative to cash.

The IS relationship is more problematic. Textbook expositions treat the expectations that enter the IS equation as exogenously fixed, but that approach is quite limiting and unrealistic. Except at the undergrad-

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[1] For a description of this inflation measure, see Dolmas (2005).

[2] FOMC statement released December 14, 2010.

[3] The approach is developed in more detail in Koenig (1993a and 1993b). A variant is applied to the Japanse economy by Krugman (1998), who emphasizes implications for monetary policy.

uate level, expectations are now nearly always assumed to be "model consistent" or "rational." The result is that current demand depends not just on current policy, but also on the policies that people believe will be followed in the future. Today, these "feed-forward" policy effects are of critical importance. By changing private-sector expectations of how monetary policy will be conducted in the future, the FOMC can hope to affect current demand despite the zero-bound constraint on the funds rate. Similarly, the extent to which today's increases in government purchases are stimulative depends very much on how people believe the additional spending will ultimately be financed.

2. THE IS CURVE

The simplest case is an economy without capital investment.[4] Then, the IS equation comes from households' choice between current and future consumption. Theory and intuition tell us that this decision will be sensitive to the real interest rate:

$$Ec_{t+1} - c_t = \sigma(r_t - \rho), \tag{1}$$

where r_t is the short-term real interest rate, c_t is (the logarithm of) current real consumption, Ec_{t+1} is planned or expected consumption next period, and ρ and σ are fixed, positive parameters.[5] (The former parameter is called the "elasticity of intertemporal substitution" and measures the sensitivity of the timing of consumer spending to the real interest rate. The latter parameter is the "pure rate of time preference" and reflects households' tendency to prefer current over future consumption.) Equation 1 says that the higher is the real return on saving, relative to the rate of time preference, the greater is the incentive for households to defer consumption.

To get the equation of the IS curve, you just rearrange Equation 1 to put the real interest rate on the left-hand side:

$$r_t = \rho + \frac{Ec_{t+1} - c_t}{\sigma}. \tag{2}$$

For given expectations of future consumption, this equation defines a downward-sloping line in $c \times r$ space, with vertical intercept $\rho + \frac{Ec_{t+1}}{\sigma}$ and slope -$\frac{1}{\sigma}$. Alternatively, one can write the IS equation as a relationship between the short-term *nominal* interest rate and current consumption, given expected future consumption and expected inflation:

$$R_t = \rho + (Ep_{t+1} - p_t) + \frac{Ec_{t+1} - c_t}{\sigma}, \tag{IS}$$

where p_t is (the logarithm of) the current price level and Ep_{t+1} is the price level expected next period. This version of the IS curve is a downward-sloping line in $c \times R$ space (*Figure 1*). Changes in expected inflation, $E\pi_{t+1} \equiv Ep_{t+1} - p_t$, shift the line vertically, one for one (*Figure 2A*). Increases in expected future consumption, Ec_{t+1}, shift the line horizontally, one for one (*Figure 2B*). The key to moving today's IS curve is to increase one or the other of these expectations.

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[4] For the extension to an economy with investment, see Koenig (1993b).

[5] See Hall (1978). Equation 1 assumes that households are able to borrow and lend at the market interest rate. If credit markets are impaired, some households' spending may be constrained by current income (Campbell and Mankiw 1989). Koenig (1993a) considers the possibility that the consumption of some households might be tied to current income.

Figure 1: The IS curve is a negative relationship between current consumption and the nominal interest rate.

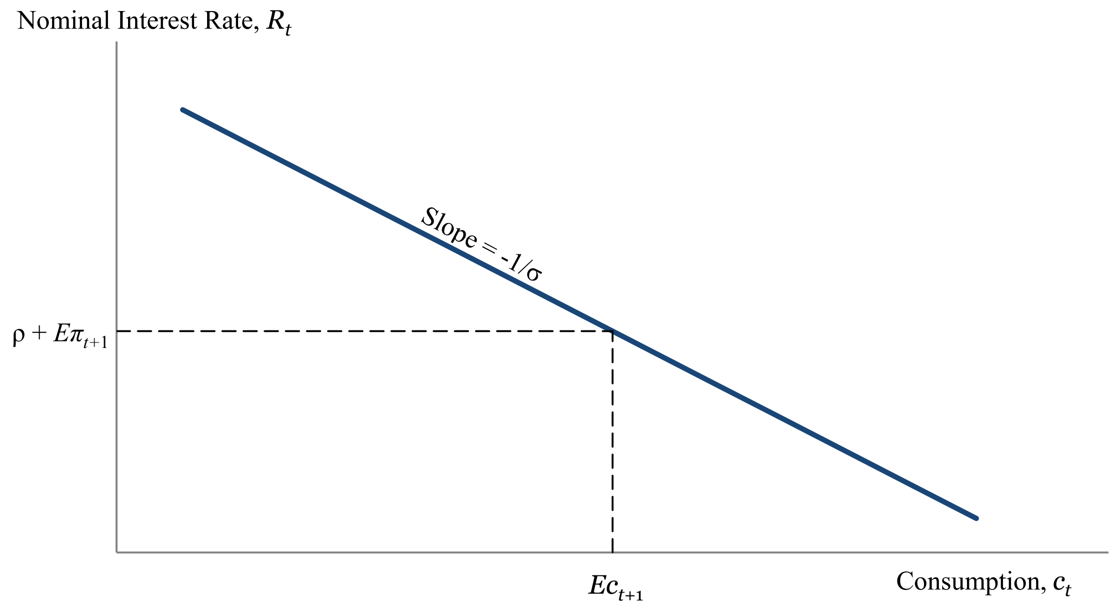


Figure 2A: Increases in expected inflation shift the IS curve vertically, one for one.

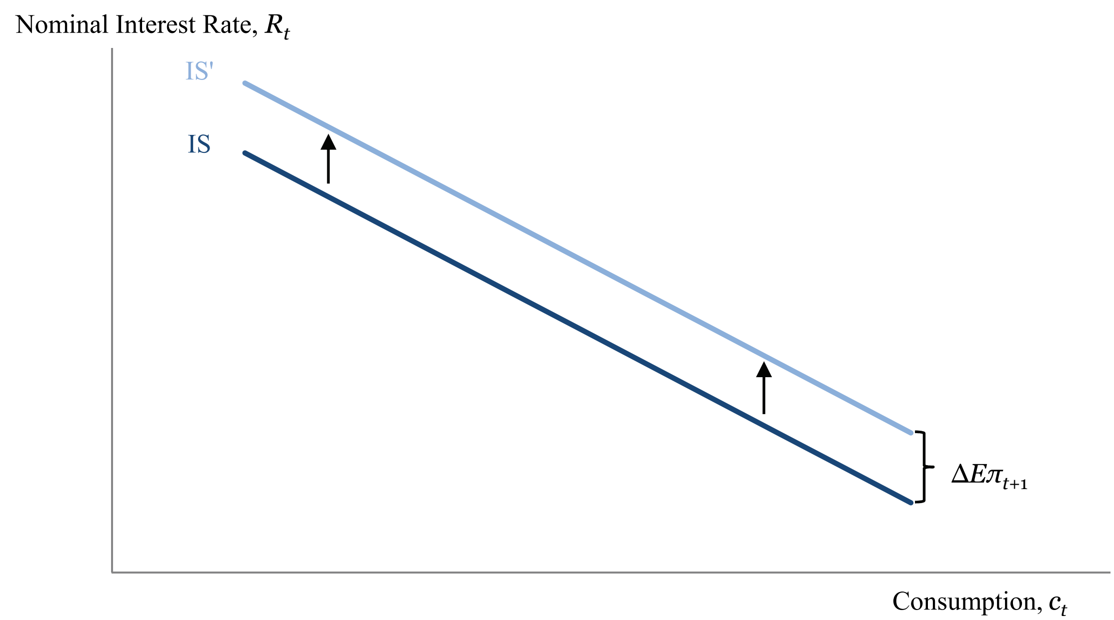
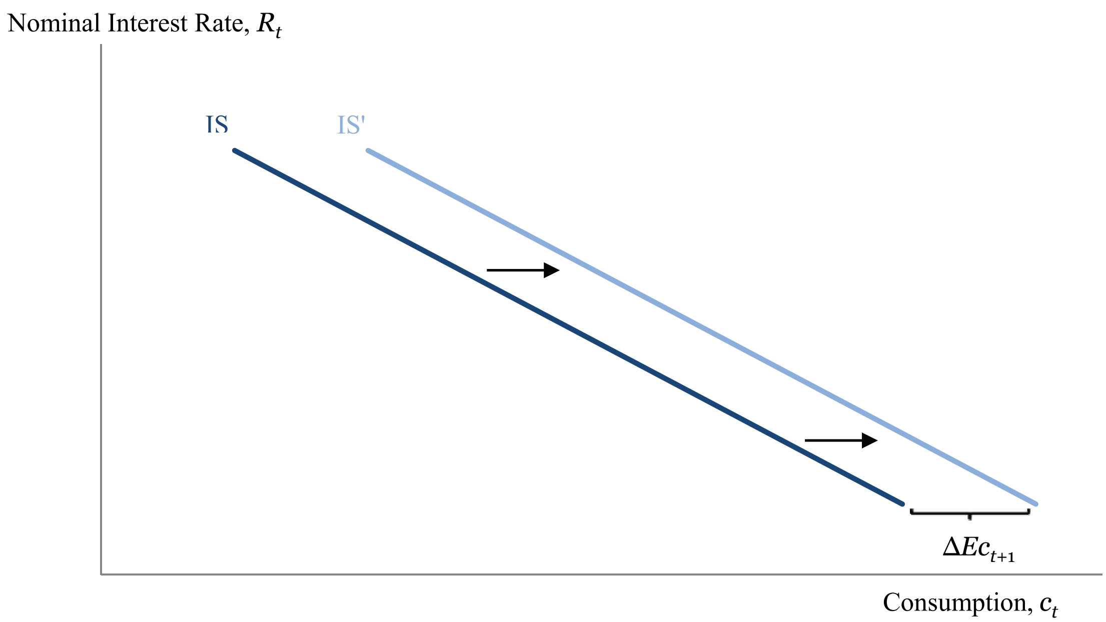


Figure 2B: Increases in expected future consumption shift the IS curve horizontally, one for one.



In the special case where $\sigma = 1$, the IS equation reduces to

$$R_t = \rho + E(p_{t+1} + c_{t+1}) - (p_t + c_t). \tag{IS$'$}$$

Now, the IS curve has a slope of -1, and the only way to shift it to the right (or, equivalently, upward) is to increase expected growth in nominal spending.

3. THE LM CURVE

How about the LM schedule? As noted above, the LM equation captures the fact that the velocity of money is increasing in the opportunity cost of holding money. Equivalently, it captures the requirement that the demand for base money (cash, plus bank reserves held at the Fed) equal the supply of base money. Prior to October 2008, the cost of holding base money of all sorts was just the short-term interest rate, R_t, because the return on holding both cash and reserves was zero. However, the Emergency Stabilization Act of 2008, signed into law on October 3, 2008, authorized the payment of interest on noncash bank reserves at a rate $IR_t \leq R_t$, set by the Board of Governors. So, now the opportunity cost of holding cash is R_t, while the opportunity cost of holding noncash reserves is $R_t - IR_t$. With little loss of realism, suppose that the demand for noncash reserves is zero whenever $IR_t < R_t$ and that banks are indifferent as to their noncash reserve holdings whenever $IR_t = R_t$.[6] Meanwhile, the demand for cash is positively related to (the logarithm of) household expenditure, $p_t + c_t$, and negatively related to the nominal interest rate.

Whenever $0 \leq IR_t < R_t$, only cash is demanded, and the demand for base money is equal to the supply of base money if, and only if,

$$p_t + c_t - \alpha R_t = m_t, \tag{3}$$

where α is the interest semi-elasticity of the demand for cash, $p_t + c_t - R_t$ is the (logarithm of the) demand for cash, and m_t is (the logarithm of) the money supply. Equivalently,

$$p_t + c_t - m_t = \alpha R_t. \tag{3$'$}$$

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[6] In practice, banks are required to hold a minimum level of reserves that is tied to their liabilities to depositors. For convenience, these nondiscretionary reserves are lumped together with currency and coin as "cash" in the discussion that follows. "Noncash reserve holdings," therefore, are reserves in excess of required reserves. Prior to the financial crisis, when $0 = IR_t < R_t$, these excess reserves were only 0.2 percent of base money. Thus, assuming that "noncash reserves" are *de minimis* whenever the opportunity cost of holding such reserves is positive is not unrealistic. An alternative modeling approach—which does not lead to conclusions substantially different from those obtained here—is to assume that currency is elastically supplied. What is referred to as "cash" in the main text can then be reinterpreted as required reserves. "Noncash reserve holdings" remain the same thing as excess reserves. Following this approach, the LM curve is those combinations of consumption and the interest rate at which the demand for bank reserves and the supply of bank reserves are equal.

In words, the velocity of money is increasing in the nominal interest rate.

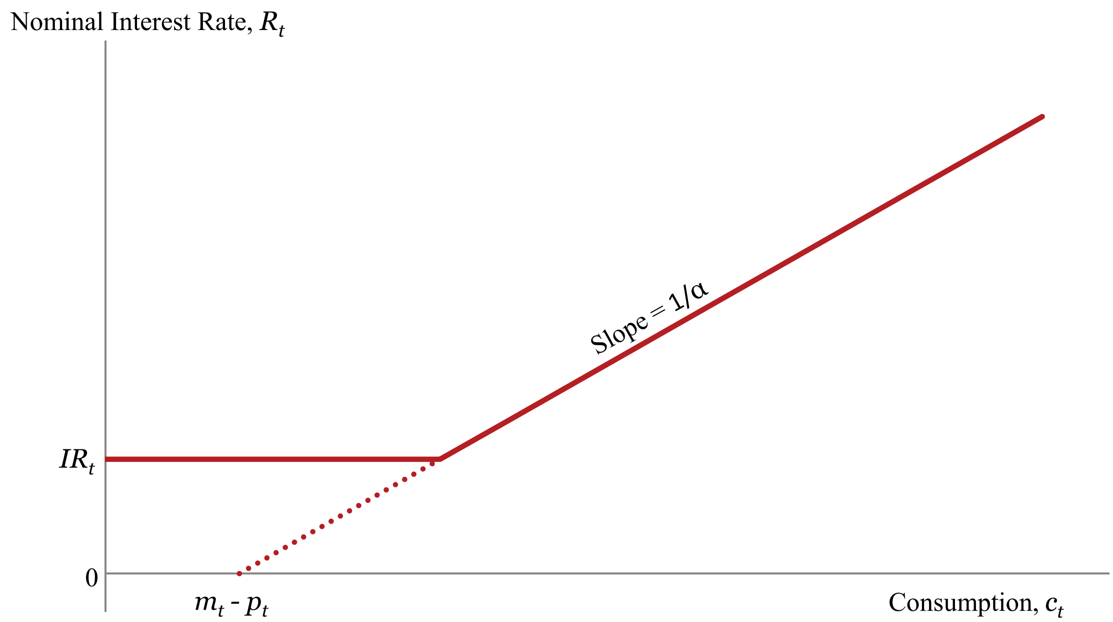
There are two other cases to consider: $0 < IR_t = R_t$ and $0 = IR_t = R_t$. In the former case, the opportunity cost of holding cash is positive, but that of holding bank reserves is zero. Consequently, the demand for cash is $p_t + c_t - \alpha R_t$, exactly as before, while banks are indifferent as to the level of their reserves and end up holding as excess reserves whatever portion of the money supply is not held as cash. In the latter case ($0 = IR_t = R_t$), the opportunity cost of holding base money of all types is zero. With banks and households both indifferent between money and short-term Treasury securities, the money supply is divided between reserves and cash in a manner that is indeterminate.

Solving for the nominal interest rate gives the equation for the LM schedule:

$$R_t = \max\{IR_t,\ \frac{p_t + c_t - m_t}{\alpha}\}. \tag{LM}$$

Plotted in $c \times R$ space, the LM curve has a kink (*Figure 3*). At low levels of consumption the LM curve is horizontal, with $R_t = IR_t$. At higher levels the nominal interest rate is increasing in consumption, so that the LM schedule is upward sloping.[7] An increase in the real money supply, $m_t - p_t$, shifts the LM curve to the right, one for one (*Figure 4A*). A cut in the interest rate on reserves, IR_t, shifts the horizontal portion of the LM curve down, one for one (*Figure 4B*).

Figure 3: The LM curve is a generally positive relationship between current consumption and the nominal interest rate.



[7] If the Federal Reserve stands ready to lend freely to banks at discount rate $DR_t \geq IR_t$, then arbitrage will keep $R_t \leq DR_t$. Graphically, the LM curve will have a lower horizontal segment at $R_t = IR_t$ and an upper horizontal segment at $R_t = DR_t$ and be upward sloping in between. In practice, there is a stigma attached to discount-window borrowing, so that discount rate is not a firm ceiling on R_t.

Figure 4A: Increases in the real money supply shift the LM curve horizontally, one for one.

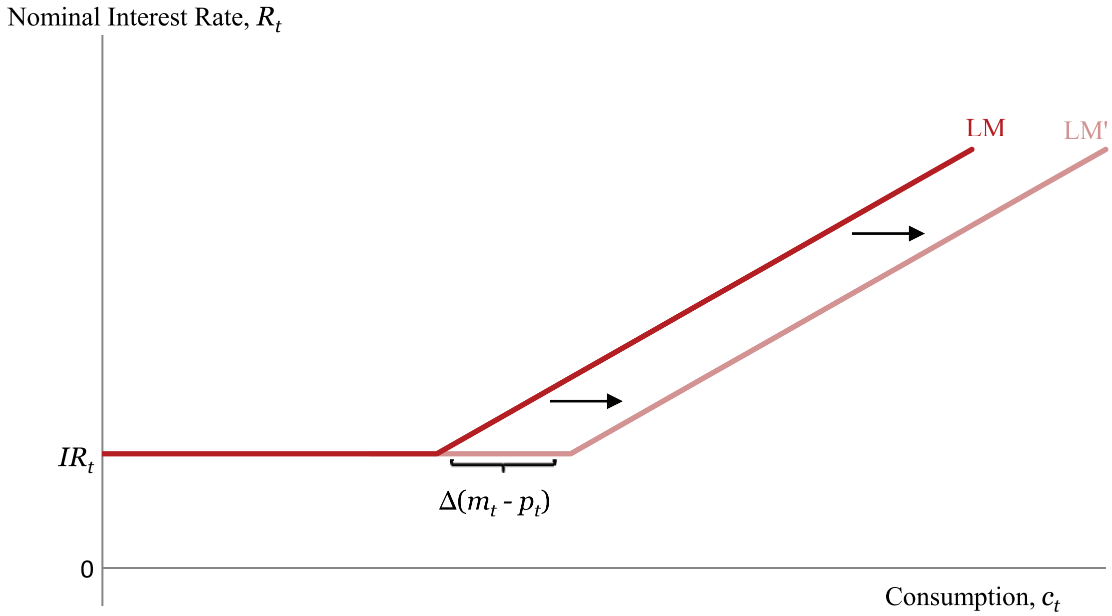
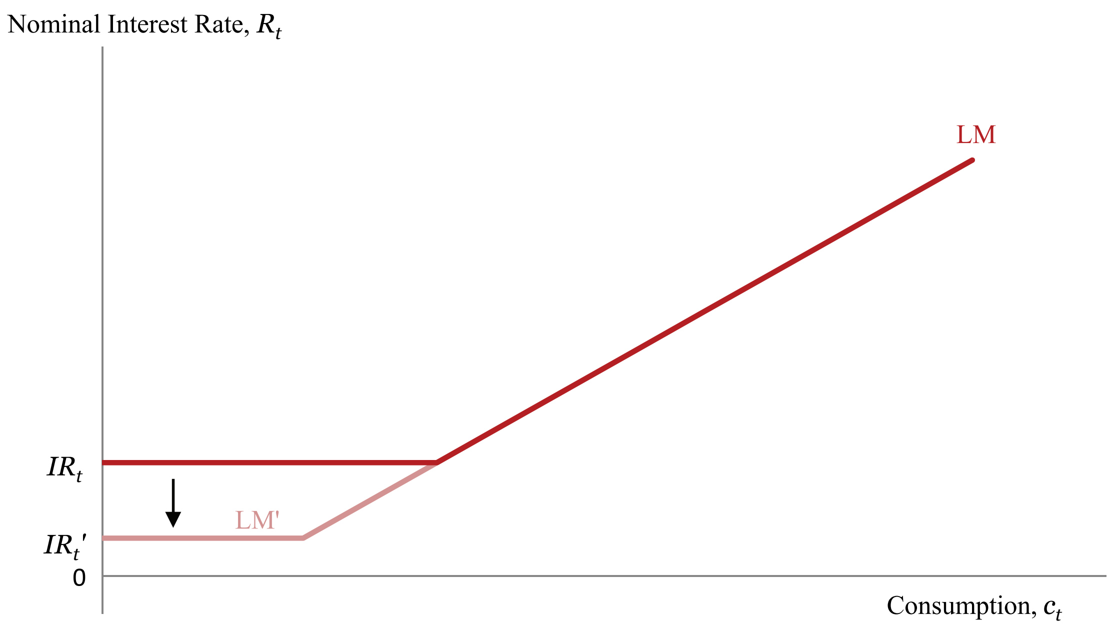


Figure 4B: Reductions in the interest paid on reserves shift the horizontal section of the LM curve downward, one for one.

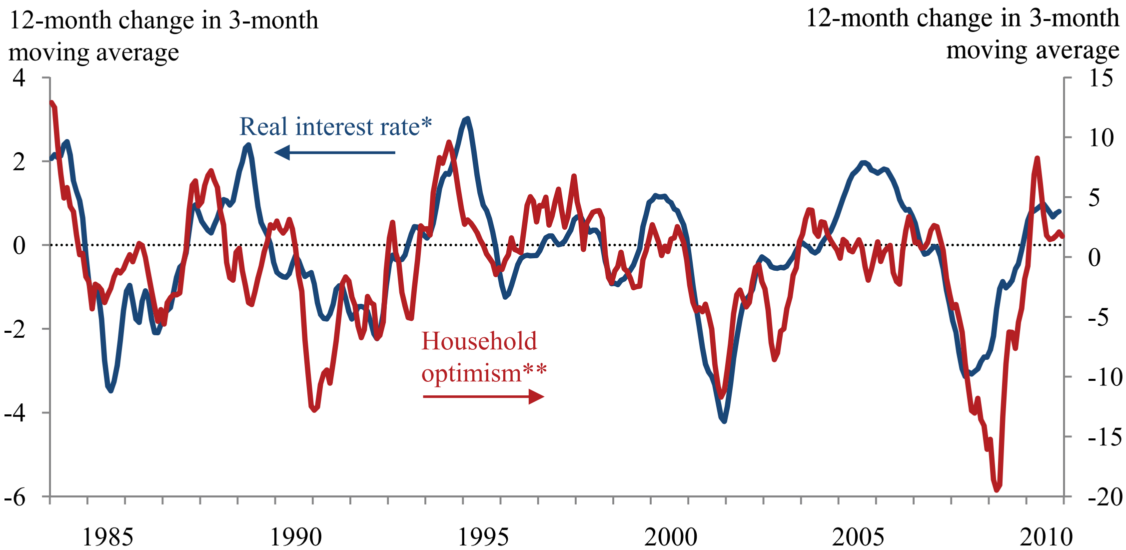


4. IS THE MODEL CONSISTENT WITH THE DATA?

The basic idea behind the IS curve—specifically, Equation 2—is that households will bid up the real short-term interest rate if they expect times to be better in the future than they are today: Households would all want to borrow against their future prosperity in the absence of a rate increase. Conversely, households will bid down the real interest rate if they expect relatively bad times ahead, as they all try to save for the coming "rainy day." There does, indeed, appear to be a strong positive relationship between real short-term interest rates and the typical household's assessment of its future prosperity relative to its current condition. Specifically, the greater is the net fraction of households expecting their incomes to rise over the next six months, the higher tends to be the six-month Treasury bill rate, relative to trend inflation. Figure 5 shows this connection in first-difference form: As the net percentage of households expecting income gains increases, so does the six-month Treasury rate, relative to trend inflation.[8]

[8] Both series trend downward in levels, which exaggerates their correlation. By taking differences, this potentially misleading common trend is eliminated from the data.

Figure 5: Changes in the real interest rate are closely linked to changes in households' optimism.



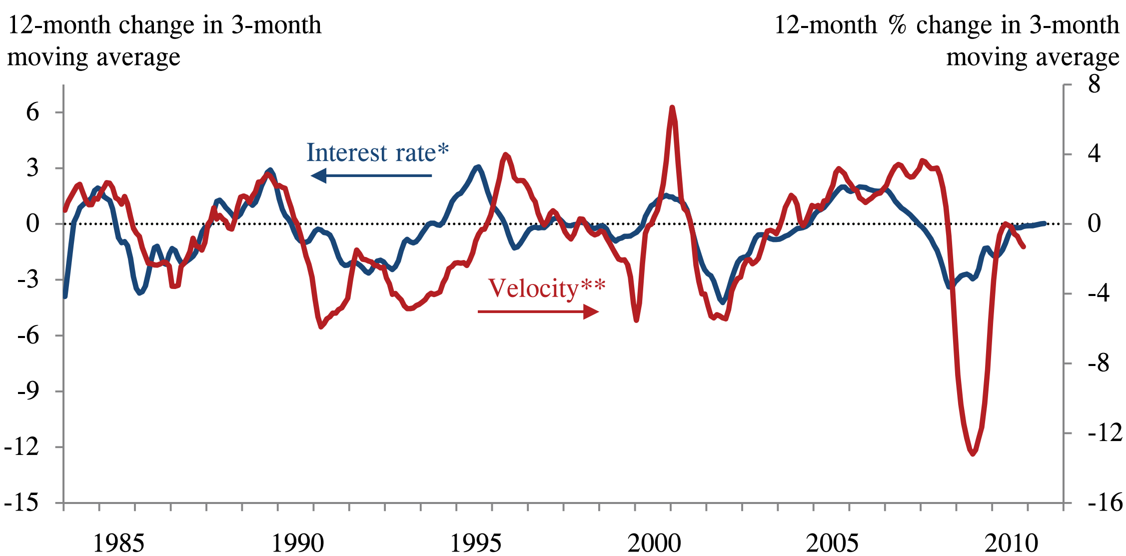
*6-month Treasury yield less 12-month trimmed mean PCE inflation rate

** Net percentage of consumers expecting an increase in income

SOURCES: The Conference Board; Federal Reserve Board; Federal Reserve Bank of Dallas; author's calculations.

Up through the middle of 2008 there also appears to be a strong, positive relationship between changes in the level of short-term nominal interest rates and subsequent changes in the velocity of cash, consistent with a first-difference version of Equation 3′ (*Figure 6*).[9] In the wake of Lehman Brothers' collapse in September 2008, however, short-term interest rates quickly fell to negligible levels, so that households were largely indifferent as to their cash holdings. The velocity of cash collapsed. This collapse does not contradict the IS-LM model. It merely confirms that the LM curve overlaps with the horizontal axis at $R = 0$.

Figure 6: The velocity of money responds (with a lag) to changes in the short-term interest rate.



*6-month Treasury yield shifted forward 6 months

**Velocity = (Nominal PCE)/(monetary base - excess reserves)

SOURCES: Federal Reserve Board; Bureau of Economic Analysis; author's calculations.

Bottom line: The IS and LM equations match up reasonably well with relevant data.

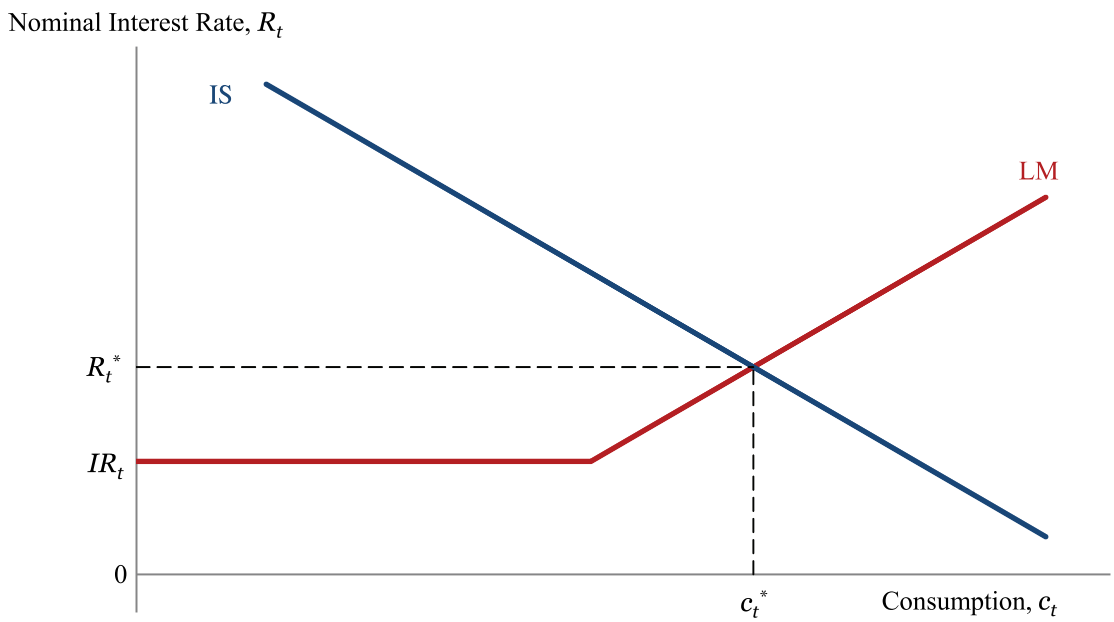
[9] The rationale for looking at differences rather than levels is the same as in Figure 5.

5. EQUILIBRIUM

The simplest way to close the IS-LM model is to assume that prices are set one period in advance, at levels it is believed are consistent with market clearing.[10] With the current price level fixed, the central bank controls the position of the LM curve through its choice of the current-period money supply and interest paid on reserves. The expected future levels of consumption and the price level that determine the position of the IS curve are those implied by a standard real-business-cycle model, given future monetary and fiscal policies. Current-period equilibrium occurs where the IS and LM schedules intersect. There are three cases to consider.

First, the IS and LM schedules may meet along the upward-sloping portion of the LM curve (*Figure 7A*). In this case, anything that shifts the IS schedule upward (an increase in expected inflation) or to the right (an increase in expected future consumption) moves the economy up to the northeast along the LM curve, raising both current consumption, c_t, and the current nominal interest rate, R_t. Anything that shifts the LM schedule to the right (an increase in the money supply) moves the economy to the southeast along the IS curve, raising c_t and lowering R_t. Changes in the interest paid on reserves, IR_t, have no marginal economic effects whatsoever.

Figure 7A: Equilibrium occurs where the IS and LM schedules intersect.



Second, the IS and LM schedules may meet along the horizontal segment of the LM curve (*Figure 7B*). In this case, a rightward or upward shift in the IS schedule (due to an increase in expected future consumption or in expected inflation) increases current consumption without changing the interest rate. An expansion of the money supply shifts the LM schedule horizontally, but has no substantive marginal economic effects at all—it simply increases idle bank reserves. A cut in the interest paid on reserves, by lowering the horizontal segment of the LM curve, moves the economy to the southeast along the IS schedule, raising current consumption and reducing the current interest rate. The exception, of course, is when the economy begins with interest rates already at zero (*Figure 7C*). In these circumstances, there is no room for further cuts in IR_t, so conventional monetary policy—if by "conventional" one means LM-curve shifts—is powerless to stimulate the economy.

[10] "One period" probably corresponds to between six months and one year for the U.S. economy. For rigorous treatment of dynamics in an economy with more-gradual price adjustment, see Koenig (1990) or McCallum and Nelson (1999).

Figure 7B: When the IS curve intersects the horizontal segment of the LM curve, changes in the current money supply are ineffective.

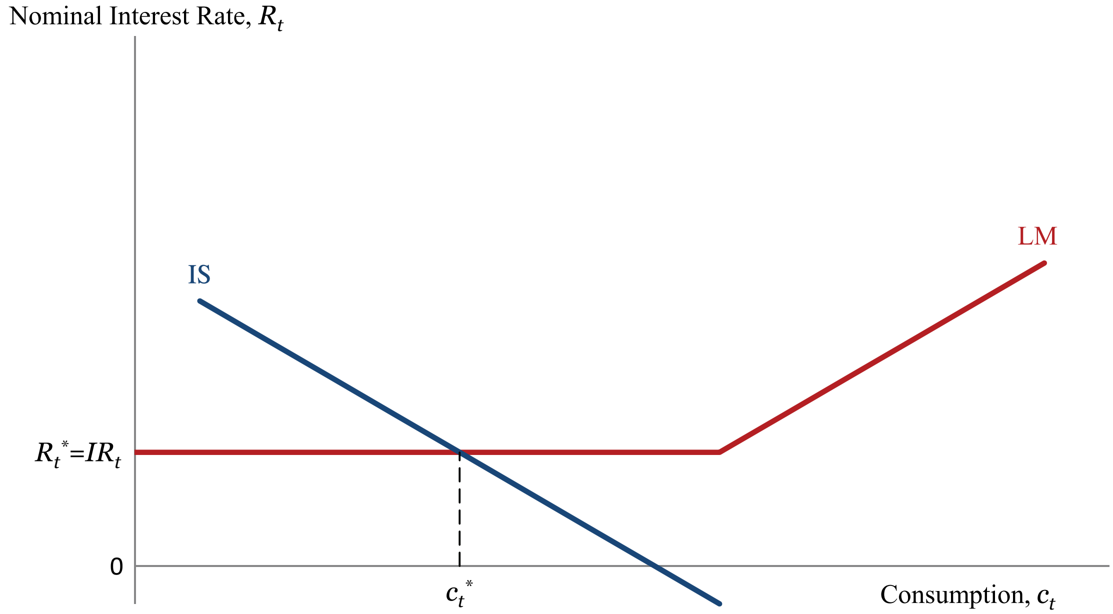
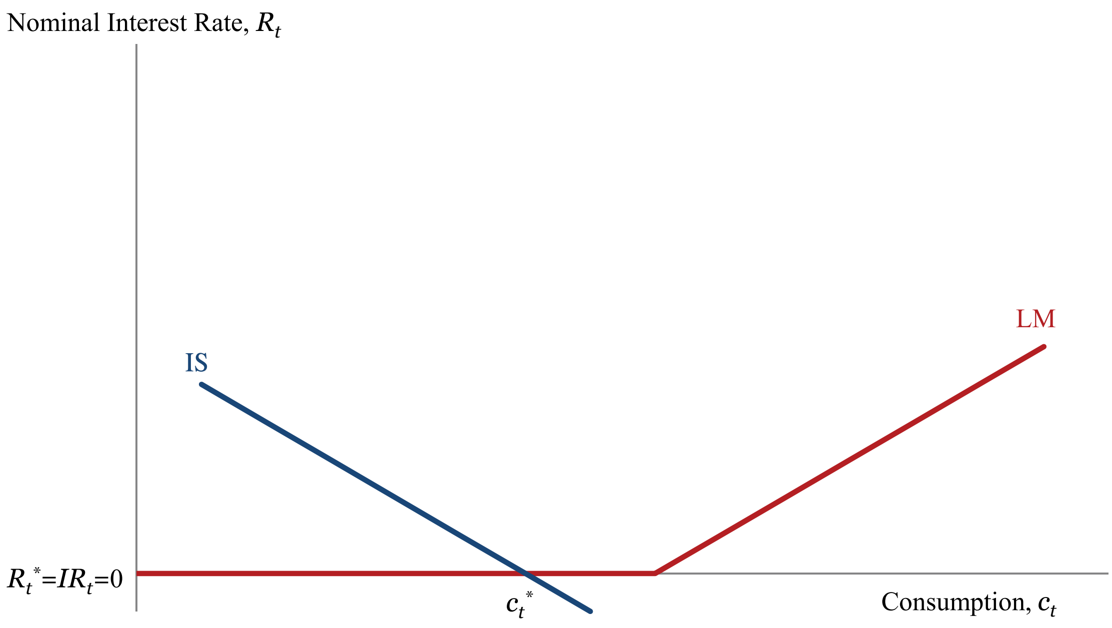


Figure 7C: At the zero bound, conventional monetary policy is powerless to stimulate the economy.



6. RECENT EXPERIENCE

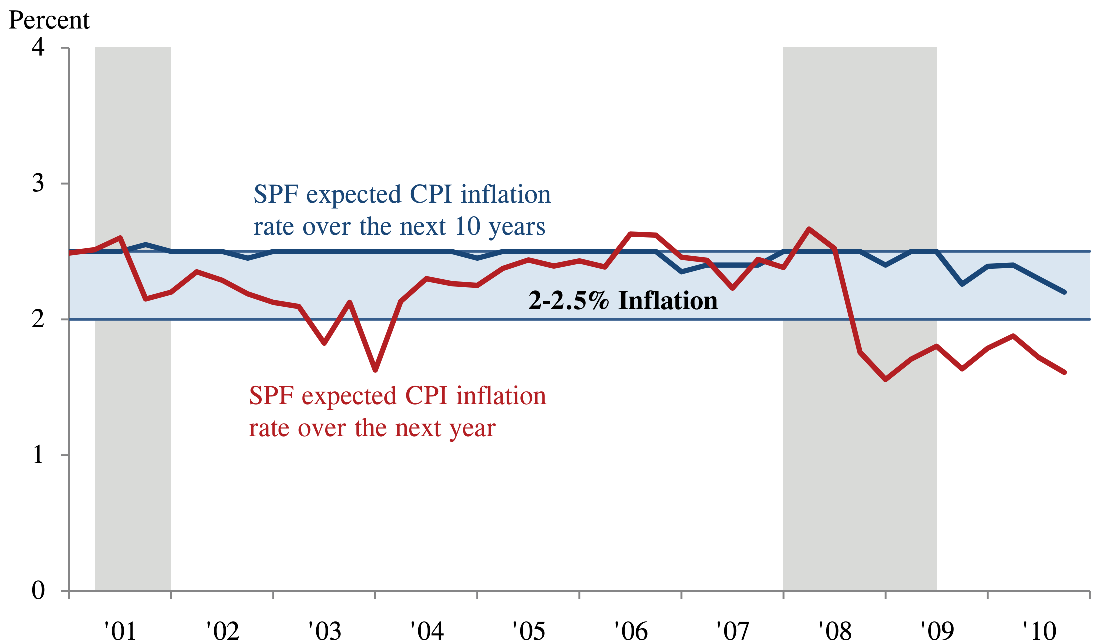
Between 2007:Q2 (at the eve of financial turmoil and two quarters before the peak of the business cycle) and 2009:Q2 (the business-cycle trough), real personal consumption expenditures fell 7.1 percent relative to trend, and short-term interest rates fell from just over 5 percent to almost zero.[11] Excess reserves (bank reserves in excess of required reserves) increased 500 fold, from 0.2 percent to 46.5 percent of the money supply. In short, the economy moved from an equilibrium like that depicted in Figure 7A to an equilibrium like that depicted in Figure 7C. How did this happen?

[11] The Congressional Budget Office, similarly, estimates that real GDP was 0.3 percent above trend in 2007:Q2 and 6.9 percent below trend in 2009:Q2, for a total relative GDP decline of 7.1 percent.

Consider, first, changes over time in expectations of future consumption. In the years leading up to 2007:Q2, one-year-ahead expected real consumption (as measured by the Survey of Professional Forecasters, or "SPF") rose steadily at an average annual rate of 2.8 percent. Between 2007:Q2 and 2008:Q2, however, these expectations *fell* by 0.05 percent, and between 2008:Q2 and 2009:Q2 they fell by an additional 2.37 percent. We know that changes in expected future consumption shift the IS schedule horizontally in the same direction, one for one, so these figures mean that the normal rightward drift in the IS curve was first halted, then thrown into reverse as households became increasingly pessimistic about their prospects. Intuitively, growing household pessimism translated into a desire to shed rather than accumulate debt, which acted to restrain current consumption demand and put downward pressure on real interest rates.

Consider, next, changes in inflation expectations. One-year-ahead SPF expectations of CPI inflation rose slightly, from 2.4 percent to 2.7 percent, between 2007:Q2 and 2008:Q2. Between 2008:Q2 and 2009:Q2, however, one-year inflation expectations reversed course and dropped to 1.7 percent (*Figure 8*). Changes in inflation expectations shift the IS curve vertically, one-for-one, in the same direction. So, the fall in inflation expectations that followed Lehman Brothers' collapse shifted the IS curve downward by a full percentage point, reinforcing the leftward shift caused by households' increased pessimism.

Figure 8: One-year inflation expectations tumbled during the financial crisis; ten-year expectations have drifted lower.

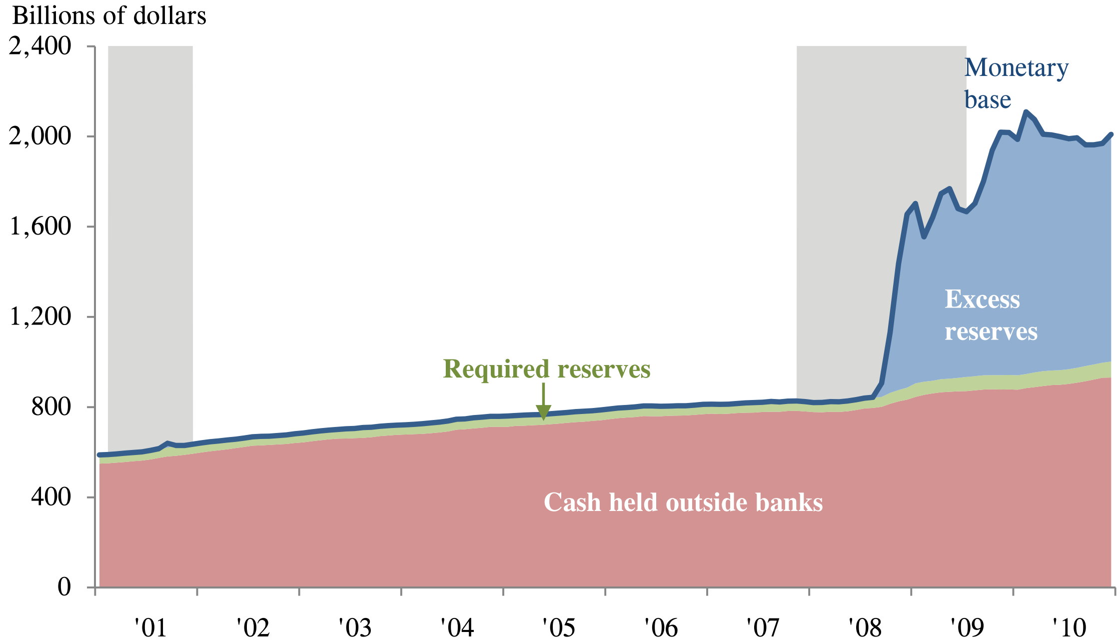


SOURCES: Federal Reserve Bank of Philadelphia; author's calculations.

How about the LM curve? Base-money growth slowed steadily from 9.9 percent over the four quarters ending 2002:Q2 to 1.8 percent over the four quarters ending 2007:Q2 to 1.2 percent over the four quarters ending 2008:Q2. Judging by Figure 6, the velocity of cash behaved pretty much as one would have expected, given the path of short-term interest rates. The implication is that the LM schedule was shifting rightward between 2002:Q2 and 2007:Q2, but at a slower and slower pace.

The LM-curve story over the four quarters ending 2009:Q2 was *very* different. As previously mentioned, the velocity of cash fell out of proportion to any decline in short-term interest rates following the collapse of Lehman Brothers in 2008:Q3 as cash became a perfect substitute for short-term Treasury securities. On the supply side, base money grew by a whopping 109.2 percent between 2008:Q2 and 2009:Q2. However, whatever portion of the increase wasn't added to holdings of cash flowed into excess bank reserves (*Figure 9*). So, although the LM schedule shifted sharply to the right between 2008:Q2 and 2009:Q2, the vast bulk of the shift occurred with the economy already in a situation like that depicted in Figure 7C, where rightward LM shifts are ineffective.

Figure 9: FOMC doubled the money supply during the financial crisis, but most of the increase flowed into excess reserves.



SOURCES: Federal Reserve Board; author's calculations.

7. POLICY AT THE ZERO BOUND

Increases in today's money supply have no effect on real activity when the short-term interest rate is constrained by the zero bound. Are there policies that *are* effective in current circumstances? Yes. First off, certain fiscal policies are capable of providing stimulus. To see this, note that if the fraction of real GDP purchased by the government is denoted by g_t, then

$$y_t = c_t + g_t, \tag{4}$$

approximately, where y_t is (the logarithm of) real GDP.[12] With c_t determined by the intersection of the IS and LM schedules, independent of g_t, it would seem that increases in government purchases as a percentage of GDP must translate one for one into percentage increases in real GDP.[13] This conclusion is correct in the special case where the increase in g_t is implemented without changes to expected future marginal tax rates or expected future government purchases.[14] Any rise in expected future marginal tax rates, however, will lower expected future consumption, Ec_{t+1}, which will shift the current IS schedule to the left.[15] With the LM curve horizontal at the zero bound, c_t will fall one for one with Ec_{t+1}, offsetting some of the stimulus to GDP provided by increased government purchases. In brief, *an increase in current government purchases that people believe is to be financed through future tax-rate increases will crowd out private consumption today, so that current output rises less than one for one with the increase in government purchases.*

Suppose that people believe that the increase in g_t will be financed by cuts in *future* government purchases. With government purchases absorbing less of future output, Ec_{t+1} will increase, shifting the current IS schedule to the right by an equal amount. Thus, the positive direct effect of g_t on y_t is reinforced by increased current consumption, c_t. *An increase in current government purchases that people believe will be financed through cuts in future purchases has a multiplier effect on current output: Output rises by more than one for one with the increase in government purchases.* Here again, the feed-forward effect is strongest

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[12] See the appendix for a derivation.

[13] For example, if g_t rises from 0.21 to 0.22, then real GDP ought to rise by $100\times(0.22 - 0.21) = 1.0$ percent, approximately. Throughout this discussion, it is assumed that government purchases have no direct effects on the marginal utility derived from consumption, leisure, or money balances.

[14] Most real-world efforts to "broaden the tax base" by eliminating deductions, credits, or exemptions push at least some individuals into higher tax brackets and, so, have disincentive effects.

[15] The appendix derives how the economy will respond to various policy changes in period $t+1$, when the price level has had a chance to adjust.

when the economy is on the horizontal portion of the LM schedule, for then any horizontal shift in the IS schedule due to a change in expected future consumption is fully reflected in current consumption.[16]

Is there anything the *monetary authority* can do to provide stimulus at the zero bound? Yes, monetary policy makers will shift the current IS curve upward, raising current consumption and output, if they can increase expected near-term inflation, $E\pi_{t+1}$. One way to raise expected near-term inflation is by reducing next period's demand for real cash balances, which will tend to raise next period's price level. This is accomplished by committing to a sustained period of more-rapid money supply growth, so that long-term inflation expectations rise and put upward pressure on expected future nominal interest rates. (For details, see the appendix to this article.) Another way to increase expected near-term inflation is by promising an increase in next period's money supply. One rationale for Fed purchases of longer-term Treasury securities is that such purchases may help convince the public that the FOMC intends to maintain an enlarged balance sheet for long enough that the additional liquidity has a chance to show up in future prices.

8. COMMENTARY

A sustained period of more-rapid money growth obviously has the potential to weaken the credibility of the Fed's commitment to long-term price stability. Even a rise in *near*-term inflation expectations above rates considered consistent with long-term price stability is regarded as problematic by some.[17] Given the current elevated rate of unemployment and less-than-robust jobs growth prospects, however, the FOMC clearly fails in meeting its dual mandate if it allows inflation expectations to fall significantly *below* rates consistent with its long-run inflation objective. Survey data suggest that, indeed, it is a shortfall in inflation expectations that ought to be of concern at present, rather than any threat of an increase. Thus, after adjusting for the normal differential between CPI and PCE inflation, the 1.6 percent CPI inflation expected by professional forecasters as of 2010:Q4 (*Figure 8*) is roughly 0.4 percentage points below the central tendency of FOMC participants' stated long-run inflation goals.[18] Meanwhile, long-term inflation expectations are well within the range consistent with price stability and have been drifting downward, not upward (*Figure 8, again*).

Arguably, there are ways of communicating policy at the zero bound that would give Fed policymakers flexibility to allow near-term inflation expectations to increase without eroding confidence in the commitment to long-term price stability. One such approach is nominal-spending targeting. Recall that when $\sigma = 1$ (reasonable as a rough approximation), the IS curve reduces to Equation IS′ (*page 5*). The key to controlling the IS curve, in this case, is controlling expected nominal spending. In fact, with short-term interest rates constrained by the zero bound, the *only* way to provide current stimulus is by increasing expectations of future spending. The adoption of an explicit spending or spending-growth target might positively influence these expectations. An advantage of such a target is that the amount of monetary intervention is automatically scaled back if the real growth outlook improves—as might happen, for example, in response to fiscal stimulus. If the real growth outlook deteriorates, however, monetary policy makers have license to pursue higher inflation in the near term. At all times, long-term inflation expectations are anchored by the difference between target spending growth and the economy's long-term real growth potential.

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[16] These results on fiscal multiplier and crowding-out effects take expected near-term inflation as given. The situation is rather more complicated if, instead, one takes the expected future money supply as given. See the appendix for details.

[17] Based on such concerns, the European Central Bank at all times seeks to keep inflation close to its 2.0 percent long-run goal, without allowing it to exceed that goal.

[18] Four times per year, each FOMC participant reveals the PCE inflation rate that he or she believe is most consistent, over the long term, with the Federal Reserve's mandate. As of November 2010, the central tendency of these rates extended from 1.6 to 2.0 percent. (The central tendency excludes the three highest and three lowest responses.) However, PCE inflation runs between 40 and 50 basis points below CPI inflation on average, over the long term. So, if the normal differential holds, the central tendency for a CPI inflation objective would be 2.0 to 2.5 percent, approximately.

APPENDIX: The Flexible-Price Equilibrium and "Feed-Forward" Effects on Today's Economy

This appendix derives the equilibrium of a competitive economy with flexible wages and prices. In the absence of new shocks, it is this equilibrium that the economy described in the body of this paper will achieve once wages and prices have had a chance to adjust. Accordingly, under rational expectations it is also this equilibrium that governs the "next-period" expectations of households in the IS-LM model. For convenience, the functions that characterize technology and tastes are chosen so that utility-maximization, profit-maximization, and other equilibrium conditions are all linear in logarithms. However, the important results go through, qualitatively, under much less stringent conditions. (Chiefly, leisure and consumption must be "normal" goods, and the utility function of the representative household must be separable, in each period, between consumption, leisure, and real cash balances.)

The Real Economy. Much as in Koenig (1996), the production function of the representative firm is assumed to take the form:

$$Y = \frac{\Theta N^{1-\beta}}{1-\beta}, \tag{A.1}$$

where Y and N are output per person and labor-hours per person, respectively, $0 \leq \beta < 1$ is a fixed parameter, and $\Theta > 0$ is an exogenously varying productivity variable. Taking logarithms:

$$y = \theta + (1-\beta)n - \ln(1-\beta) \approx \beta + \theta + (1-\beta)n, \tag{A.2}$$

where $y \equiv \ln(Y)$, $\theta \equiv \ln(\Theta)$, and $n \equiv \ln(N)$. The approximation is accurate for realistically small values of β. Profit maximization implies that the firm will demand labor up to the point where the marginal product of labor equals the real wage:

$$\theta - \beta n = w - p, \tag{A.3}$$

where w and p are the logarithms of the wage rate and price level, respectively. Equation A.3 defines a downward-sloping labor demand schedule with vertical intercept θ and slope $-\beta$.

The representative household is assumed to have a utility function of the form:

$$\mathrm{U}(C,N) = \frac{C^{1-\frac{1}{\sigma}} - 1}{1-\frac{1}{\sigma}} - \frac{N^{1+\lambda}}{1+\lambda}, \tag{A.4}$$

where C is consumption, $\sigma > 0$ is the elasticity of intertemporal substitution, and $\lambda > 0$ is a fixed parameter. Utility maximization implies (among other things) that the marginal rate of substitution between consumption and leisure equals the real after-tax wage. Taking logarithms:

$$\lambda n + \frac{c}{\sigma} = w - p + \ln(1-\tau) \approx w - p - \tau, \tag{A.5}$$

where the approximation is accurate provided that the tax rate applicable to labor income, τ, is not too large. Importantly, Equation A.5 is derived assuming that the individual takes the tax rate as "given" in much the same way that it takes the wage rate and price level as given.

Finally, the economy is subject to a resource constraint:

$$C = Y(1-g), \tag{A.6}$$

where $g \equiv \frac{G}{Y}$ is the fraction of output consumed by the government. Taking logarithms:

$$c = y + \ln(1-g) \approx y - g. \tag{A.7}$$

The approximation is accurate provided g is not too large. The analysis that follows treats g as an exogenous fiscal-policy variable, so that government purchases per person are proportional to output per person. It is important that government purchases per person depend on the *economy-wide average* of output per person, so that the labor-supply decision of any one household has a negligible effect on G.

Equations A.2, A.3, A.5 and A.7 are readily solved for the equilibrium values of output, labor hours, consumption, and the real wage as functions of productivity, the tax rate, and the fraction of output purchased by the government:

$$y^* = \frac{(1+\lambda)\theta + (1-\beta)\frac{g}{\sigma} + (\beta+\lambda)\beta - (1-\beta)\tau}{\Delta} \tag{A.8}$$

$$n^* = \frac{(1-\frac{1}{\sigma})\theta + \frac{g}{\sigma} - \frac{\beta}{\sigma} - \tau}{\Delta} \tag{A.9}$$

$$c^* = \frac{(1+\lambda)\theta - (\beta+\lambda)g + (\beta+\lambda)\beta - (1-\beta)\tau}{\Delta} \tag{A.10}$$

$$(w-p)^* = \frac{(\frac{1}{\sigma}+\lambda)\theta - \beta\frac{g}{\sigma} + \frac{\beta^2}{\sigma} + \beta\tau}{\Delta} \tag{A.11}$$

where

$$\Delta \equiv \lambda + \beta + \frac{1-\beta}{\sigma} > 0. \tag{A.12}$$

For the purposes of this paper, what's important is that equilibrium consumption is decreasing in both the fraction of output purchased by the government and the tax rate. If, in period t, people expect markets will clear in $t+1$, then:

$$Ec_{t+1} = Ec^*_{t+1} = \frac{E[(1+\lambda)\theta_{t+1} - (\beta+\lambda)g_{t+1} + (\beta+\lambda)\beta - (1-\beta)\tau_{t+1}]}{\Delta}. \tag{A.13}$$

Hence, given near-term inflation expectations, the period-t IS curve will shift to the right in response to expected higher future productivity, smaller government, or a lower tax rate—precisely as claimed in our discussion of the feed-forward effects of alternative methods for financing fiscal stimulus.

The Future Price Level. As discussed in the main text, monetary policy makers can affect the short-run (fixed-price) equilibrium of the economy at the zero bound if they can change people's perceptions of what the price level will be once it has had a chance to adjust: the higher is the expected future price level relative to the current (fixed) price level, the higher is today's IS curve, and the greater are today's output, consumption, and employment.

For simplicity, suppose that consumption is expected to grow at a constant rate, γ^*, once the price level has become flexible, and that the money supply is expected to grow steadily at rate μ^*. Equations 2 and 3 imply that[19]

$$r^* = \rho + \frac{\gamma^*}{\sigma} \tag{A.14}$$

and

$$\mu^* = \pi + \gamma^* - \alpha\frac{\mathrm{d}R}{\mathrm{d}t}. \tag{A.15}$$

However, $R = r + \pi$, so

$$\frac{\mathrm{d}R}{\mathrm{d}t} = \frac{\mathrm{d}r}{\mathrm{d}t} + \frac{\mathrm{d}\pi}{\mathrm{d}t} = \frac{\mathrm{d}\pi}{\mathrm{d}t}. \tag{A.16}$$

Combining A.15 and A.16:

$$\mu^* = \pi + \gamma^* - \alpha\frac{\mathrm{d}\pi}{\mathrm{d}t}, \tag{A.17}$$

which has a unique nonexplosive solution:

$$\pi^* = \mu^* - \gamma^*. \tag{A.18}$$

In words, inflation equals the difference between money growth and real output growth. It follows that the equilibrium nominal interest rate must be:

$$R^* = r^* + \pi^* = \rho + \mu^* + (\frac{1}{\sigma} - 1)\gamma^*. \tag{A.19}$$

Note that the zero bound is not an issue provided that $R^* > 0$, which the monetary authority can always achieve by choosing a sufficiently high rate of money growth, μ^*.

The position of the period-t IS curve, we know, is influenced by expected inflation, which is determined by the price level expected next period, Ep_{t+1}. Using Equations 3 and A.19, if people believe that markets will clear in $t+1$, then

$$Ep_{t+1} = E[m_{t+1} - c^*_{t+1} + \alpha R^*] = E\{m_{t+1} - c^*_{t+1} + \alpha[\rho + \mu^* + (\frac{1}{\sigma} - 1)\gamma^*]\}. \tag{A.20}$$

[19] Equation 3 (hence also Equation A.15) assumes that $IR < R$, so that banks hold negligible excess reserves.

For given expectations of future productivity, $E\theta_{t+1}$, and future fiscal policy, Eg_{t+1} and $E\tau_{t+1}$ —which together determine Ec^*_{t+1} —the monetary authority can increase expected inflation and, hence, shift the period-t IS schedule upward by increasing either the expected future money supply, Em_{t+1}, or expected future money growth, $E\mu^*$. The latter policy has the disadvantage that it raises expected long-term inflation, $E\pi^*$ (*c.f.* Equation A.18). This disadvantage is made clear if A.18 and A.20 are combined to yield:

$$Ep_{t+1} = E[m_{t+1} - c^*_{t+1} + \alpha(\rho + \pi^* + \frac{\gamma^*}{\sigma})]. \tag{A.20$'$}$$

The import of Equation A.20$'$ is that if monetary policy makers want to help the economy today without jeopardizing long-run price stability, they must increase Em_{t+1} relative to Ec^*_{t+1}.

An Alternative View of Policy. The above analysis follows the main text in assuming that the monetary authority targets the expected future price level (Ep_{t+1}) and expected long-run inflation (π^*). An alternative approach has the monetary authority target the expected future size of its balance sheet (Em_{t+1}) and π^*. From Equations A.10 and A.20$'$, an implication of this approach is that the fiscal authority, through its budget decisions (specifically, through its influence on Eg_{t+1} and $E\tau_{t+1}$ and, hence, on Ec^*_{t+1}) has as much control over the expected future price level as does the monetary authority. In return, the monetary authority becomes the dominant influence on current household demand. To see this, recall that shifting the IS curve is the only way to stimulate household demand when monetary policy is constrained by the zero bound. In turn, the only way to shift the IS curve is by changing $E[p_{t+1} + \frac{c_{t+1}}{\sigma}]$ (*c.f.* Equation IS). From A.20$'$, though,

$$E[p_{t+1} + \frac{c_{t+1}}{\sigma}] = E[m_{t+1} + (\frac{1}{\sigma} - 1)c^*_{t+1} + \alpha(\rho + \pi^* + \frac{\gamma^*}{\sigma})]. \tag{A.21}$$

For a given expected money supply and given long-run inflation target, the impact of changes in expected consumption—and, hence, of changes in expected fiscal policy—is ambiguous. In the special case where σ = 1, *the current position of the IS curve is completely independent of current or future fiscal policy.* (The exception: If there are government tax and/or spending and/or regulatory policies that raise the economy's long-run real growth rate, γ^*, these will feed forward and shift the IS schedule rightward.) Of course, even if its influence on current household demand is suspect, the fiscal authority still directly influences current aggregate economic activity through its control of government purchases, g_t.

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