The Fisher Effect and the Financial Crisis of 2008

David Glasner

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Abstract

This paper uses the Fisher equation relating the nominal interest rate to the real interest rate and expected inflation to provide a deeper explanation of the financial crisis of 2008 and the subsequent recovery than attributing it to the bursting of the housing-price bubble. The paper interprets the Fisher equation as an equilibrium condition in which expected returns from holding real assets and cash are equalized. When inflation expectations decline, the return to holding cash rises relative to holding real assets. If nominal interest rates are above the zero lower bound, equilibrium is easily restored by adjustments in nominal interest rates and asset prices. But at the zero lower bound, nominal interest rates cannot fall, forcing the entire adjustment onto falling asset prices, thereby raising the expected real return from holding assets. Such an adjustment seems to have triggered the financial crisis of 2008, when the Federal Reserve delayed reducing nominal interest rates out of a misplaced fear of inflation in the summer of 2008 when the economy was already contracting rapidly. Using stock market price data and inflation-adjusted US Treasury securities data, the paper finds that, unlike the 2003–2007 period, when stock prices were uncorrelated with expected inflation, from 2008 through at least 2016, stock prices have been consistently and positively correlated with expected inflation.

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Author's Note

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I. Introduction

The 2008 financial crisis is widely attributed to the bursting of the housing bubble.[1] However, the housing bubble seems to have peaked in early 2006, with prices not falling until late 2006 or early 2007, so the bursting of the housing bubble preceded the financial crisis by at least a year and a half. Undoubtedly, the bursting of the housing bubble was related to the subsequent weakness in the financial sector, but the lag between the end of the bubble and the onset of the crisis suggests that other factors may have helped cause the crisis. The possibility that factors other than the housing bubble were implicated in the financial crisis invites further exploration.

I argue that demand-side factors also contributed to the onset of the financial crisis in 2008 and that the Fisher equation relating the nominal and real interest rates via the expected rate of inflation can serve as a tool by which to identify those factors. As usually interpreted, the Fisher equation treats the real rate of interest as exogenously determined by the "fundamental" factors of productivity and time preference laid out in Fisher's canonical treatments of the subject (Fisher 1896, 1907, 1930). Under standard assumptions about the neutrality and superneutrality of money,[2] the independence of the real rate from monetary factors, including expected inflation, is easily shown. Accordingly, the Fisher equation implies that changes in

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[1] Opinions differ about whether there indeed was a housing bubble. I am agnostic on that subject and simply use the term to refer to a class of explanations of the 2008 financial crisis that focuses on structural problems with the financial system that produced systemic financial instabilities, thereby triggering a financial crisis and an economic downturn. Under this approach, the direction of causation was from financial instability to macroeconomic instability. My approach is to emphasize that macroeconomic instability can produce financial instability, so that causation can—and in 2008 certainly did—operate in both directions.

[2] Neutrality means that a change in the demand for or stock of money has no effect on relative prices or output. Superneutrality means that changes in the rate of change in the demand for or stock of money have no effect on relative prices or output.

expected inflation should cause equal changes in the equilibrium nominal rate of interest (Hirshleifer 1970, 135–38).

Rather than focusing on the effect of increases in expected inflation in raising nominal interest rates, I examine the Fisher equation from the opposite perspective: the effect of a reduction in expected inflation at the zero lower bound when nominal interest rates cannot adjust to reflect the change in expected inflation. With the nominal rate of interest bounded from below at or near zero, the Fisher equation seemingly cannot be satisfied if the expected rate of deflation exceeds the real rate of interest.

So it may be instructive to spell out the adjustment process whereby an exogenous reduction in expected inflation at the zero lower bound could lead to a new equilibrium. In equilibrium, the expected yields from holding all assets must be equal, so decreased expected inflation, by raising the expected yield of money above the expected yield from holding any real asset or combination of real assets (i.e., any feasible real investment project), would induce asset holders to shift from holding real assets to holding money. If expected inflation is sufficiently low, or negative, equilibrium cannot be restored unless real asset values fall, thereby raising the expected return from holding real assets. Thus, given an exogenous reduction in expected inflation, the asset-market equilibrium corresponding to satisfaction of the Fisher equation requires the real rate of interest to increase to match the increased expected rate of deflation.

If inflation expectations are treated as an exogenous variable, then the existence of a new equilibrium with reduced asset prices and an increased real rate of interest can be achieved by a straightforward, albeit painful, adjustment process. But if inflation expectations are endogenous, a negative shock to expected inflation could lead to an adjustment process in which inflation expectations interact with asset prices, thereby creating a positive feedback loop of falling asset

prices and intensifying deflation expectations. Such perverse dynamics may characterize the panics and financial crises with which asset-price crashes are associated. In such situations, an exogenous commitment to stabilizing asset prices may be an essential condition for restoring asset-market equilibrium (Farmer 2016).

Thus, at the zero lower bound, a generalized Fisher relation can be written as follows:

$$i = 0 \geq r + p^e, \tag{1}$$

where i is the nominal rate of interest, r the real rate of interest (ex ante or prospective), and p^e the expected rate of inflation.[3] The important point is that, in contrast to the conventional interpretation of the Fisher equation, the brunt of the adjustment to a change in expected inflation is shifted from the nominal rate of interest to the real rate.

The specific hypothesis tested in this paper is that, in the summer of 2008, a drop in expected inflation, attributable to concerns voiced by the Federal Reserve Open Market Committee about the eroding credibility of its inflation target even as the economic contraction that started in December 2007 was accelerating, raised the expected yield from holding money above the expected yield from holding real assets. The misplaced focus on an illusory inflation threat in a contracting economy implied a tightening of monetary policy, creating the conditions for an asset-price crash and financial crisis.

I test this hypothesis by regressing asset prices on real interest rates and expected inflation. Historically, the main obstacle to extracting estimates of expected inflation and real interest rates from observed nominal interest rates has been the lack of any market-based measures of expected inflation. But the active trading of inflation-indexed instruments, in

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[3] When understood as an equilibrium condition rather than a definition, the real interest in the Fisher equation rate must refer to the prospective yield asset holders are expecting to earn from holding assets, and the inflation rate is the expected inflation rate. When understood as a definition, the real rate in the Fisher equation is the realized real rate after adjustment for inflation, and inflation is the actual, not expected, rate.

particular inflation-adjusted US Treasury securities (TIPS), provides easily accessible market data on real (inflation-adjusted) interest rates from which inferences can be drawn about the inflation expectations of holders of such securities. Although inferences about inflation expectations over a particular time horizon can be extracted from the difference between yields on TIPS and conventional Treasury securities of a corresponding duration, the inflation adjustment received by holders of TIPS implies that the estimates of expected inflation and real interest rates are imperfect and possibly biased (Grischenko, Vandem, and Zhang 2016).

By most measures, the price level during the financial crisis of 2008–2009 actually fell, and short- and medium-term inflation expectations (as reflected in TIPS spreads) turned negative during the crisis, so the interaction of inflation expectations with asset prices over time can now be observed. It is therefore possible to determine whether the observed market dynamics are consistent with the dynamics implied by the Fisher equation when nominal interest rates are at or near their lower bound.[4]

Regressions for successive six-month periods from 2003 through 2016 show a positive and statistically significant relationship between asset prices and inflation expectations beginning in the first half of 2008. In the period from 2003 through the first half of 2007, by contrast, a statistically significant positive correlation was found only in the first half of 2003. The consistently positive correlation between expected inflation and asset prices in the run-up to the financial crisis and its aftermath supports the theoretical intuition that, as nominal interest rates approach the zero lower bound, a decline in expected inflation may trigger a decline in asset

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[4] Even if expected inflation is positive, the perverse dynamics associated with an expected rate of deflation greater than the real rate can also occur if the expected yield on capital is negative and exceeds (in absolute value) expected inflation.

prices as the expected yield from holding cash equals and surpasses the expected yield from holding real assets.

The next section presents the theory of asset pricing underlying the subsequent empirical analysis. Under *normal* conditions (i.e., nonrecession periods with low to moderate expected inflation and nominal interest rates above the zero lower bound), expected inflation may affect asset prices in several ways, so that, at least at low or moderate levels, there is no strong a priori reason for expected inflation and asset prices to be correlated.[5] Depending on the underlying factors affecting real interest rates, real rates have an ambiguous relationship with asset prices.[6] In normal periods, there seems to be no a priori basis for hypothesizing a strong correlation between asset prices and either real interest rates or expected inflation. But at or near the zero lower bound, the Fisher relationship, owing to asset-market disequilibrium, may not be satisfied as an equality. In such a disequilibrium, increases in expected inflation tend to raise asset prices, as the correlation between expected inflation and asset prices overwhelms other causal relationships between expected inflation and asset prices.

Section III presents the results of regressing asset prices on proxies for real interest rates and expected inflation from 2003 through 2016. The results show that from 2003 to 2007, when interest rates were substantially above the zero lower bound, there was almost no evidence of a statistically significant relationship between asset prices and either real interest rates or expected inflation. However, after the economy fell into recession at the end of 2007, the correlation

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[5] However, it does not follow that the coefficient on the expected inflation term under normal conditions would be zero. Rather, given the multiplicity of forces by which expected inflation could affect asset prices, there is no a priori reason why any one or any combination of forces would predominate or cancel each other out. But an observed positive or negative coefficient would not be surprising.

[6] In fact, both expected inflation and the real rate of interest are endogenous variables, so that the relationships between asset prices and inflation expectations and between asset prices and real interest rates are not true structural relationships but reduced form relationships. However, because inflation expectations are directly affected by monetary-policy decisions, the relationship between asset prices and policy decisions affecting inflation expectations can be estimated empirically as a relationship between asset prices and inflation expectations.

between the daily change in the Standard and Poor's 500 (S&P 500) and both real interest rates and inflation expectations became strongly positive. The strongly positive correlation between changes in asset prices and changes in expected inflation began to emerge soon after an economic downturn began at the end of 2007, continuing with few exceptions until the end of 2016. Thus, from the prelude to the financial crisis of 2008 until well into the recovery phase, increases in expected inflation have been strongly favorable to stock prices, possibly presaging subsequent increases in economic activity. The meaning and significance of the regression results are discussed in section IV, and some concluding remarks are offered in section V.

II. Asset Prices and Inflation Expectations

Asset values reflect expectations of the future cash or service flows associated with those assets, appropriately discounted to the present. If the market portfolio of assets is taken as a benchmark, changes in the value of that portfolio correspond to changes in either the size or the time profile of expected future cash flows—closely, although imperfectly, correlated with expectations of aggregate future output—or in the level, or term structure, of the discount factors by which future cash flows are converted to present values.

In this simple framework, expected inflation implies offsetting effects on expected cash flows and (via the Fisher equation) on discount factors. However, by raising the nominal rate of interest, thereby reducing the quantity of money demanded (at least the quantity demanded of non-interest-bearing money), expected inflation might indirectly affect asset values because the consequent shift from money to real assets causes a once-and-for-all increase in asset prices (by

either raising expected future cash flows or reducing the real interest rate).[7] A decrease in expected inflation, according to this line of reasoning, would reduce asset prices. This effect, well known since the 1960s literature on inflation and growth, refers to the tendency of expected inflation to induce a shift from money into real assets, thereby encouraging capital accumulation and stimulating growth (Tobin 1965, Johnson 1967). However, that literature may have overstated the growth-enhancing property of inflation in failing to distinguish either between inside and outside money or between interest-bearing and non-interest-bearing money and failing to recognize that holding money may economize on the use of real resources.

Thus, under normal conditions (when nominal rates are above the zero lower bound[8]), a policy-induced increase in expected inflation would likely not raise asset prices substantially, and the subsequent—presumably small—shift from cash into assets would reflect a marginal adjustment of asset portfolios. Plausible arguments for why expected inflation, especially at rates above some threshold, could depress asset values include the taxation of the nominal appreciation of capital and inflation-induced resource misallocations. However, when the real rate of interest is low enough, or expected deflation high enough, for nominal interest rates to approach zero, the incentive to shift from holding real assets to holding cash implies that expected inflation and asset prices are positively correlated. With nominal interest rates at or

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[7] A subtle theoretical point arises in this context. Does a fully anticipated increase in the rate of inflation imply a shift out of money into real assets? If money is interest bearing, there would seem to be no reason to shift out of holding money. However, if some money—that is, currency or banknotes—is non-interest-bearing, there might be some shift out of money into real assets—although a shift from currency to deposits is also possible. The shift from holding currency to holding real assets would tend to increase the value of such assets, implying a corresponding reduction in the expected yield from those assets.

[8] The real interest rate need not always be positive. If the real interest rate is negative, then the condition for avoiding a reverse Fisher effect is that the expected inflation rate exceeds the real interest rate. In other words, if the real rate is −2 percent, inflation must exceed 2 percent to avoid asset market disequilibrium and a flight from real assets into money—a crash in asset prices.

near the zero lower bound, the Fisher relation implies a positive correlation between changes in expected inflation and changes in asset values.

Whether real interest rates are correlated with asset prices is also relevant. Under normal conditions, the relationship between real interest rates and asset prices seems ambiguous because, in theory, real interest rates are determined by the interaction of a variety of fundamental causes, each with a distinct effect on asset values. For example, real interest rates might rise because rapid technological progress is expected to increase future economic growth, causing expectations of future cash flows to rise. With unchanged expectations of future cash flows, increased real interest rates would reduce asset prices, but if real interest rates rise because future cash flows are expected to increase, asset prices may rise in anticipation of those cash flows despite being discounted at increased rates. However, if increased real interest rates reflect heightened time preference, with unchanged expectations of future technological progress and future cash flows, increased real rates would imply falling asset prices. So, without information about changes in expected future cash flows or changes in time preference, there is no basis on which to predict whether asset prices and real interest rates are correlated.

Before the US Treasury began issuing TIPS in 2003, there were no market-generated estimates of inflation expectations. But with the advent of TIPS in durations matching those of conventional Treasury bonds, a breakeven spread between the yields on TIPS and on conventional Treasuries of matching durations could be calculated. Under the assumptions that (1) the yield on TIPS of a given duration corresponds to the real rate of interest for that duration and (2) the Fisher equation holds, the breakeven spread serves as a market estimate of expected inflation over that duration.

However, if the Fisher equation is viewed as an equilibrium condition rather than a tautology, then it is not necessary for the nominal interest rate always to equal the sum of the real rate and the expected rate of inflation. In particular, if expected deflation exceeds the ex ante real interest rate in absolute value, the Fisher equation cannot be satisfied at the zero lower bound, in which case the breakeven spread between TIPS and conventional Treasuries must exceed the actual "market" expected inflation.[9] I know of at least three other reasons why the TIPS yield and the TIPS spread may be imperfect estimates of their theoretical counterparts in the Fisher equation.

First, because TIPS promises to compensate bearers for any loss of principal at maturity owing to inflation over the duration of the bond but does not deduct any increase in principal owing to deflation, a deflation option is embedded in the TIPS, thereby increasing the value of a TIPS, reducing its yield, and understating (overstating) expected inflation (deflation). The value of the option increases, and the distortion in estimates of expected deflation increases, as the probability of deflation increases (Grischenko, Vandem, and Zhang 2016).

Second, during periods of financial turbulence, investors may be willing to pay an added liquidity premium to acquire conventional Treasuries, thereby reducing the yields on conventional Treasuries and reducing the breakeven TIPS spread. The yields on TIPS may be increased correspondingly because of the relative illiquidity of TIPS in periods of financial distress, thereby exaggerating the breakeven TIPS spread and understating the implied estimate of expected inflation. Thus, this imperfection in the TIPS spread may, to some extent, offset the first imperfection mentioned above.

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[9] In other words, at the zero lower bound, unless the yield on TIPS is negative, the breakeven TIPS spread would understate (in absolute value) the expected rate of deflation.

Third, the breakeven spread between TIPS and conventional Treasuries reflects not only the expected rate of inflation, but also the willingness to bear inflation uncertainty. For a given TIPS spread, the less willing agents are to bear uncertainty, the smaller the implied rate of expected inflation.

The above imperfections can be mitigated, at least over the time period covered by the data for this paper, by focusing on long-term interest rates and TIPS spreads. While yields on short-term Treasuries have approached the zero lower bound at various times for durations as long as two years since 2008, yields on 10-year Treasuries have never sunk below 1.3 percent over the entire period covered by this study. Thus, the previously mentioned distortions associated with the zero lower bound do not affect the TIPS spread at 10-year maturities. However, because the 10-year TIPS spread reflects the geometric average of expected inflation over a 10-year horizon, and because short-term inflation expectations tend to be more volatile than longer-term inflation expectations, the 10-year TIPS spread likely understates the variation in the short-term inflation expectations; on average, and probably consistently since 2008, that spread has overstated the short-term expectation of inflation. But because changes in the 10-year TIPS spread are probably closely correlated with changes in short-term inflation expectations, it seems reasonable to use the 10-year TIPS spread as a proxy for short-term inflation expectations in view of the problems with alternative measures of expected inflation.

III. Expected Inflation and Asset Prices from 2003 to 2016

In the previous section, I suggested that the relationship between asset prices and inflation expectations is asymmetric. Under normal conditions, there is no strong a priori reason to expect asset prices to be correlated with inflation expectations. However, when inflation expectations

are near or below zero, pulling nominal interest rates toward the zero lower bound, a strongly positively correlation emerges between asset prices and inflation expectations. The level of real interest rates also matters, because the lower the real interest rate, the higher the rate of expected inflation at which the zero lower bound is reached.

The asymmetrical relationship between asset prices and expected inflation implies that in a regression of asset prices on real interest rates and expected inflation, coefficient estimates would differ substantially depending on whether nominal interest rates are close to or substantially above the zero lower bound. With nominal rates above the zero lower bound, coefficient estimates of the expected-inflation variable would likely be close to zero and statistically insignificant. Conversely, with nominal rates close to zero, coefficient estimates would be positive and statistically significant.

To test this hypothesis, I used daily data on the S&P 500,[10] which serves as a proxy for asset prices in general, and regressed the daily change in the natural log of the S&P 500 on the daily change in estimates of expected inflation and in real interest rates from 2003 through 2016. As discussed in the previous section, I used the yield on 10-year constant-duration TIPS as a proxy for the real interest rate and the breakeven TIPS spread for a constant 10-year duration as a proxy for expected inflation.[11]

As an additional indicator of inflationary expectations, I also added the dollar-to-euro exchange rate as an independent variable,[12] inasmuch as many investment portfolios included

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[10] Data for the S&P 500 are available at Federal Reserve Bank of St. Louis, "S&P 500," accessed July 6, 2018, https://fred.stlouisfed.org/series/SP500.

[11] Data for the yield on 10-year constant-duration TIPS are available at Federal Reserve Bank of St. Louis, "10-Year Treasury Inflation-Indexed Security, Constant Maturity," accessed July 6, 2018, https://fred.stlouisfed.org/series /DFII10. Data for the breakeven TIPS spread for a constant 10-year duration are available at Federal Reserve Bank of St. Louis, "10-Year Treasury Constant Maturity Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series /DGS10.

[12] Data for the dollar-to-euro exchange rate are available at Federal Reserve Bank of St. Louis, "U.S. / Euro Foreign Exchange Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series/DEXUSEU.

both dollar and euro assets with the relative proportions of dollars and euros depending on expectations of future movements in the dollar-to-euro exchange rate, movements reflecting expectations of relative future rates of inflation in dollars and euros. Furthermore, the dollar-to-euro exchange rate may, under certain conditions, also reflect expectations about future monetary policy. (See section IV for further discussion of influence of the dollar-to-euro exchange rate.)

The empirical model takes the following form:

$$\Delta Ln(S\&P500)_t = a_0 + a_1 \Delta TIPS_t + a_2 \Delta TIPSspread_t + a_3 \Delta(euro\_ex)_t + \varepsilon_t. \tag{2}$$

where Δ represents the daily change in the corresponding variable. The natural log of the S&P 500 from the beginning of 2003 until the end of 2016 and the dollar-to-euro exchange rate are plotted in figure 1, and the 10-year TIPS and the 10-year breakeven TIPS spread are plotted over the same period in figure 2. Because of the rising trend of the S&P 500, which almost doubled between 2003 and 2016, albeit with a sharp downturn in 2008–2009, and because of a downward trend in the yield on 10-year TIPS over the period, the regression estimates in levels are likely spurious.[13]

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[13] The estimated regression in levels was

$$Ln(S\&P500)_t = 7.88 - 0.152\,TIPS_t + 0.067\,TIPSspread_t - 0.490(euro\_ex),$$

with the *t*-values of all variables indicating statistical significance at less than 1 percent. The *R*-squared equaled 0.354.

Figure 1. Natural Logarithm S&P 500 and Dollar-to-Euro Exchange Rate, 2003–2006
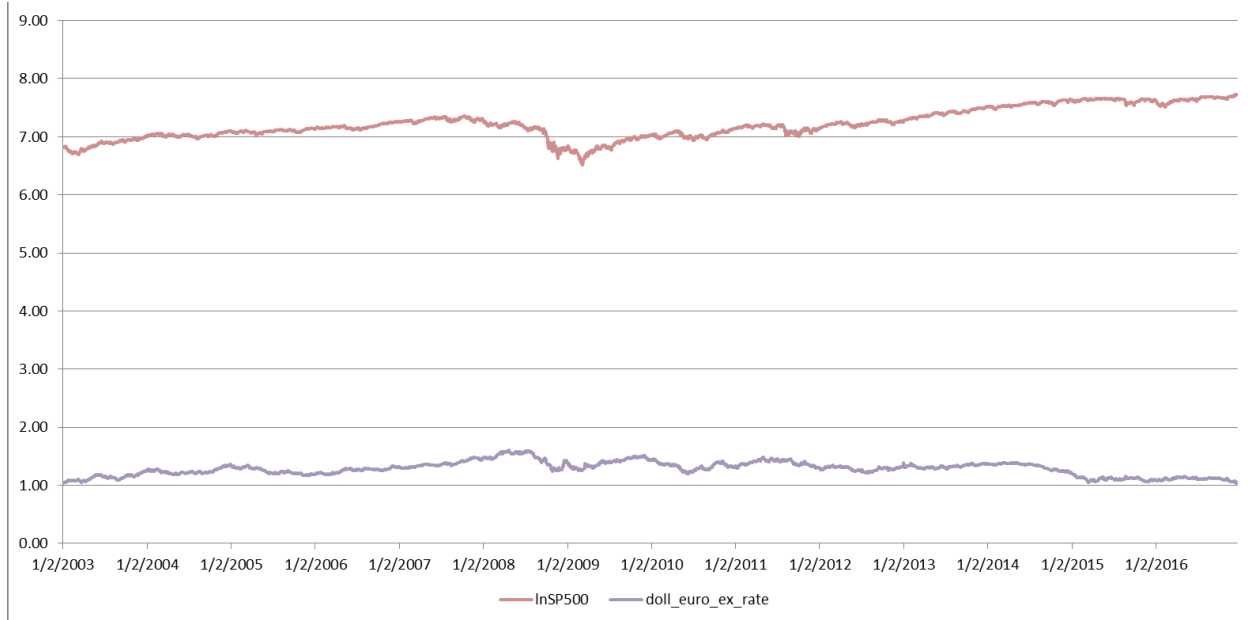
Sources: Federal Reserve Bank of St. Louis, "S&P 500," accessed July 6, 2018, https://fred.stlouisfed.org/series /SP500; Federal Reserve Bank of St. Louis, "U.S. / Euro Foreign Exchange Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series/DEXUSEU.

Figure 2. 10-Year TIPS and 10-Year TIPS Spread, 2003–2006

Sources: Federal Reserve Bank of St. Louis, "10-Year Treasury Inflation-Indexed Security, Constant Maturity," accessed July 6, 2018, https://fred.stlouisfed.org/series/DFII10; Federal Reserve Bank of St. Louis, "10-Year Treasury Constant Maturity Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series/DGS10.

I therefore detrended the data by taking first differences to arrive at the daily change in each variable.[14] Estimated coefficients of the regression on the daily changes in the variables over the entire 2003–2016 period are reported in table 1,[15] with coefficient estimates and standard errors for the three independent variables showing that all the estimated coefficients in the regression over the entire period are significant based on the standard *t*-test.[16]

Table 1. Regression Results for Entire Period (2003–2016) and Two Subperiods

Time period	Constant	DC10_TIPS	DC10_TIPSspread	DC_euro	*R*-squared
01/03–12/16	.0002 (.0001)	**.0598*** (.0047)	**.1073*** (.0067)	**.2009*** (.0318)	.178
01/03–06/07	.0004* (.0002)	**.0215*** (.0448)	.1067 (.0073)	−.0330 (.0360)	.023
07/07–12/16		**.0722*** (.0060)	**.1310*** (.0076)	**.2160*** (.0395)	.239

Notes: DC10_TIPS is the daily change in yield on 10-year constant maturity TIPS. DC10_TIPSspread is the daily change in the 10-year constant maturity breakeven TIPS spread. DC_euro is the daily change in the dollar-to-euro exchange rate. Significant coefficients are in bold. * indicates significance at the 10 percent level; ** indicates significance at the 5 percent level; *** indicates significance at the 1 percent level.

Sources: Federal Reserve Bank of St. Louis, "S&P 500," accessed July 6, 2018, https://fred.stlouisfed.org/series /SP500; Federal Reserve Bank of St. Louis, "10-Year Treasury Inflation-Indexed Security, Constant Maturity," accessed July 6, 2018, https://fred.stlouisfed.org/series/DFII10; Federal Reserve Bank of St. Louis, "10-Year Treasury Constant Maturity Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series/DGS10; Federal Reserve Bank of St. Louis, "U.S. / Euro Foreign Exchange Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series /DEXUSEU.

The upshot of my analysis of the Fisher equation in the previous section is that, when nominal interest rates are above the zero lower bound, the response of asset prices to changes in inflation expectations is very different from the response when nominal interest rates are at or near

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[14] Augmented Dickey-Fuller and Kwiatowski-Phillips-Schmidt-Shinn tests show that the order of integration is one for all four series, so that coefficient estimates by ordinary least squares are not spurious.

[15] In some cases in which some but not all markets were closed owing to holidays, I used two-day changes for those markets in which there was holiday trading.

[16] A Breusch-Pagan test for heteroscedasticity showed that, over the entire sample, the hypothesis of homoscedasticity was rejected at more than a 99 percent confidence level. However, the data exhibit little heteroscedasticity in the first subperiod (January 2003 through June 2007), with the hypothesis homoscedasticity not rejected at even a 70 percent confidence level. The reported standard errors are robust vce standard errors.

the zero lower bound.[17] The latter part of the period from 2003 to 2016 having been characterized by persistently low nominal short-term interest rates at or near the zero lower bound, the analysis of the preceding section suggests that a regression estimated over the entire 2003–2016 time period would exhibit a structural break at some time before the financial crisis of 2008.

I therefore performed the estat sbsingle test in Stata for the existence of an unknown structural break in the data. The test determined that there was a break and that the timing of the break occurred at approximately July 6, 2007. The supremum Wald test reports a test statistic that implies that the probability of the null hypothesis of no structural break is less than 1 in 10,000.

Given the likely structural break in the data, I estimated the regression separately on the two subperiods (January 2003 through June 2007 and July 2007 through December 2016). The results for the separate regressions are presented in table 1. In the first subperiod, the constant term is positive and weakly significant at the 10 percent level. The constant term can be interpreted as an estimate of the average daily upward trend in the S&P 500 over the first subperiod. Of the estimated coefficients of the independent variables, only the positive TIPS coefficient is significant (at the 1 percent level); the *R*-squared is 0.02, indicating that the regression has minimal explanatory power. This result is consistent with my earlier conjecture that in normal periods, neither the real interest rate nor expected inflation has a strong unidirectional influence on asset prices. However, in the regression for the latter period, the constant term is positive but not statistically significant (presumably reflecting the small net increase in the S&P 500 between the beginning and end of the second subperiod), while all three

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[17] I have not attempted to estimate how closely the nominal interest rate must approach zero for the effects I am describing in this paper to become significant. In any event, no single estimate would be applicable in every case because of the sensitivity of those effects to the liquidity premium that may be embedded in the short-term interest rate. But if the liquidity premium is low, a nominal short-term interest rate within 50 basis points of zero would seem likely to give rise the effects under discussion.

coefficients of the independent variables are positive and significant at the 1 percent level. The structural break in early July 2007 supports my conjecture that, at the zero lower bound, expected inflation, for which both the TIPS spread and the euro exchange rate are proxies, is positively correlated with asset prices.

In addition to dividing 2003–2016 into two periods corresponding to the structural break in mid-2007, I divided the entire period into successive six-month periods. Results for the six-month regressions before the structural break are reported in table 2; results for the six-month periods following the break are reported in table 3.

Table 2. Six-Month Regressions, January 2003 through June 2007

Time period	Constant	DC10_TIPS	DC10_TIPSspread	DC_euro	*R*-squared
01/03–06/03	.0013 (.0010)	**.1093*** (.0210)	**.0702** (.0298)	−.2660 (.1987)	.279
07/03–12/03	.0012 (.0008)	.0031 (.0117)	.0217 (.0212)	**−.3367*** (.1156)	.087
01/04–06/04	.0002 (.0007)	−.0102 (.0136)	.0228 (.0189)	.1394 (.0936)	.042
07/04–12/04	.0006 (.0006)	**.0613*** (.0154)	−.0253 (.0224)	.1601 (.1144)	.139
01/05–06/05	−.0002 (.0006)	−.0026 (.0176)	.0044 (.0267)	−.0765 (.1182)	.004
07/05–12/05	.0004 (.0006)	−.0060 (.0136)	.0010 (.0217)	.0214 (.0881)	.003
01/06–06/06	.0002 (.0006)	−.0234 (.0195)	.0073 (.0295)	.0368 (.1240	.018
07/06–12/06	.0008 (.0005)	−.0178 (.0156)	**−.0549** (.0269)	−.1121 (.1189)	.039
01/07–06/07	.0004 (.0007)	.0135 (.0347)	.0022 (.0298)	−.0158 (.2276)	.005

Notes: DC10_TIPS is the daily change in yield on 10-year constant maturity TIPS. DC10_TIPSspread is the daily change in the 10-year constant maturity breakeven TIPS spread. DC_euro is the daily change in the dollar-to-euro exchange rate. Significant coefficients are in bold. * indicates significance at the 10 percent level; ** indicates significance at the 5 percent level; *** indicates significance at the 1 percent level.

Sources: Federal Reserve Bank of St. Louis, "S&P 500," accessed July 6, 2018, https://fred.stlouisfed.org/series /SP500; Federal Reserve Bank of St. Louis, "10-Year Treasury Inflation-Indexed Security, Constant Maturity," accessed July 6, 2018, https://fred.stlouisfed.org/series/DFII10; Federal Reserve Bank of St. Louis, "10-Year Treasury Constant Maturity Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series/DGS10; Federal Reserve Bank of St. Louis, "U.S. / Euro Foreign Exchange Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series /DEXUSEU.

Table 3. Six-Month Regressions, July 2007 through December 2016

Time period	Constant	DC10_TIPS	DC10_TIPSspread	DC_euro	*R*-squared
07/07–12/07	.0006 (.0009)	**.1237***** (.0155)	.0652 (.0583)	.1941 (.2804)	.378
01/08–06/08	.0010 (.0010)	**.0899***** (.0154)	**.0945**** (.0393)	−.1322 (.1991)	.308
07/08–12/08	.0011 (.0028)	**.1530***** (.0358)	**.2376***** (.0379)	.1740 (.2728)	.290
01/09–06/09	.0010 (.0018)	.0266 (.0204)	**.0840***** (.0288)	**.5371**** (.2144)	.162
07/09–12/09	.0011 (.0008)	**.0368*** (.0212)	**.0801***** (.0187)	**.6188***** (.1262)	.354
01/10–06/10	.0009 (.0008)	**.0650***** (.0191)	**.1968***** (.0258)	**.3911***** (.1360)	.541
07/10–12/10	.0009 (.0007)	**.0266**** (.0114)	**.0962***** (.0233)	**.5069***** (.1084	.346
01/11–06/11	.0030 (.0006)	**.0827***** (.0140)	**.0838***** (.0158)	**.2450***** (.0833)	.403
07/11–12/11	.0015 (.0012)	**.1197**** (.0463)	**.1415***** (.0406)	**.6872***** (.2469)	.476
01/12–06/12	.0007 (.0006)	**.0703***** (.0185)	**.1557***** (.0222)	**.2627**** (.1106)	.483
07/12–12/12	.0000 (.0005)	**.0800***** (.0187)	**.1150***** (.0296)	**.2392***** (.547)	.414
01/13–06/13	**.0013**** (.0006)	.0250 (.0185)	**.1604***** (.0296)	−.0059 (.1656)	.230
07/13–12/13	**.0010*** (.0006)	.0043 (.0151)	.0444 (.280)	.1374 (.1570)	.030
01/14–06/14	.0008 (.0005)	**.0806***** (.0194)	**.1194***** (.0245)	.0434 (.1694)	.256
07/14–12/14	.0005 (.0007)	**.0859***** (.0185)	**.1020***** (.0333)	−.1729 (.1606)	.246
01/15–06/15	.0000 (.0001)	**.0377**** (.0156)	.0363 (.268)	.1136 (.0845)	.097
07/15–12/15	.0002 (.0008)	**.0531**** (.248)	**.1629***** (.368)	**−.4079**** (.1580)	.302
01/16–06/16	.0009 (.0007)	**.0820***** (.0198)	**.2093***** (.0203)	−.0448 (.1380)	.451
07/16–12/16	.0005 (.0005)	−.0228 (.0173)	**.0503**** (.0205)	**−.1698*** (.1013)	.099

Notes: DC10_TIPS is the daily change in yield on 10-year constant maturity TIPS. DC10_TIPSspread is the daily change in the 10-year constant maturity breakeven TIPS spread. DC_euro is the daily change in the dollar-to-euro exchange rate. Significant coefficients are in bold. * indicates significance at the 10 percent level; ** indicates significance at the 5 percent level; *** indicates significance at the 1 percent level.

Sources: Federal Reserve Bank of St. Louis, "S&P 500," accessed July 6, 2018, https://fred.stlouisfed.org/series /SP500; Federal Reserve Bank of St. Louis, "10-Year Treasury Inflation-Indexed Security, Constant Maturity," accessed July 6, 2018, https://fred.stlouisfed.org/series/DFII10; Federal Reserve Bank of St. Louis, "10-Year Treasury Constant Maturity Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series/DGS10; Federal Reserve Bank of St. Louis, "U.S. / Euro Foreign Exchange Rate," accessed July 6, 2018, https://fred.stlouisfed.org/series /DEXUSEU.

In the first subperiod after the structural break (July–December 2007), the coefficient of the TIPS variable is positive and significant, but the coefficient of the TIPS spread variable is small and insignificant, as was the coefficient of the dollar-to-euro exchange rate variable. Only in the next subperiod (January–June 2008) was the estimated coefficient on the TIPS spread variable positive and significant.

No specific event occurred in early July 2007 that can be associated with a break between the two periods. The housing bubble burst in early 2007, but stock prices did not dip until August 2007. However, economic conditions were deteriorating during 2007–2008, as housing prices began falling after years of rapid increases. The stock market briefly recovered after its August dip before peaking in October 2007, and the National Bureau of Economic Research chronology dates the start of the economic downturn in December. So even if there was no economically noteworthy event in July 2007, the early summer of 2007 still plausibly marks a transition point from normalcy to abnormality.

Table 2 shows only a handful of statistically significant regression coefficients, two of which occur in the January–June 2003 subperiod—the United States invaded Iraq in March 2003—when the aftereffects of the 2001 recession were still being felt, with nominal interest rates still unusually low and perhaps more similar to the period after the statistical break than it was to the rest of the 2003–2007 period.[18] However, as shown in table 3, starting after the structural break in the second half of 2007, the TIPS spread (the inflation-expectations variable) did have a statistically significant positive coefficient. In the first half of 2008, coefficients on both TIPS and the TIPS spread were positive and significant, while the coefficient on the euro

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[18] Two of the other three statistically significant coefficients (one on the expected inflation variable and the other on the dollar-to-euro exchange rate variable) had negative signs in contrast to the positive coefficients characterizing the second subperiod. The remaining significant coefficient was a positive coefficient on the real interest rate variable.

was negative and insignificant. From the first half of 2008 through the last half of 2012, the estimated coefficients of TIPS and the TIPS spread were positive and significant in each six-month subperiod. And from the first half of 2009 through the last half of 2012, the estimated coefficient of the euro was positive and significant in each six-month period.

From the beginning of 2013 to the end of 2016, the estimated coefficient of the TIPS spread has been positive and significant in each period except 2013-II and 2015-I, although the estimated coefficient of TIPS was not significant in 2013-I, 2013-II, and 2016-II. The estimated coefficient on the euro has not been positive and significant in any period since 2012-II (but was negative and significant in 2015-II).

IV. Discussion

The idea underlying this paper is that, understood as an equilibrium condition, the Fisher equation can be satisfied by way of two distinct processes. The first operates when the nominal interest rate is sufficiently above the zero lower bound. In that circumstance, changes in inflation expectations mainly—although perhaps not exclusively—affect the nominal interest rates. The supposed dichotomy between expected inflation and the real rate of interest determined purely by real factors is inferred from a comparative-statics exercise in which an exogenous change in inflation expectations does not alter the underlying real equilibrium—an exercise whose relevance to the actual fluctuations of real and nominal interest rates is doubtful.

The second process operates when the nominal rate is at—or close to—the zero lower bound. Because a decrease in expected inflation cannot affect the nominal rate at the zero lower bound, the Fisherian equilibrium condition can be satisfied only by means of a corresponding increase in the real rate.

Away from the zero lower bound, the usual presumption is that a change in expected inflation causes a corresponding change in the compensation received by lenders from borrowers, so that nominal interest rates adjust with little or no change in the real value of the repayment terms. However, at (or near) the zero lower bound, the nominal interest rate, being stuck at zero, cannot adjust to a decline in expected inflation. A decline in expected inflation must then work itself out through the choices asset holders make between holding real assets or cash.

Thus, by reducing the demand to hold real assets, thereby depressing real-asset values, falling expected inflation at the zero lower bound raises expected real-asset yields. With unchanged expected real cash flows from those assets, reduced expected inflation at the zero lower bound implies an increase in the ex ante real interest rate, thereby tending to restore the Fisher equilibrium condition. But if reduced expected inflation negatively affects expected real cash flows and if falling asset prices cause further reductions in expected inflation, then the adjustment of real interest rates to reduced expected inflation at the zero lower bound may not lead directly to a new Fisher equilibrium at the zero lower bound with reduced expected inflation matched by a correspondingly increased real rate of interest. Instead, an exogenous reduction in expected inflation at the zero lower bound may trigger a vicious downward spiral of falling asset prices and falling expected inflation with no restoration of the Fisher equilibrium condition.[19]

The upshot of these reflections is that although there is no compelling reason under normal conditions to expect asset prices and expected inflation to be correlated, there is a compelling reason for asset prices and expected inflation to be positively correlated at the zero lower bound. The structural break in the regression of the daily change in the logarithm of the S&P 500 on the daily changes in the estimated real interest rate, estimated inflation expectation,

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[19] See Thompson (1977) for a derivation of such a scenario in a standard neoclassical model.

and the dollar-to-euro exchange rate is consistent with the hypothesis that asset prices and expected inflation are positively correlated at the zero lower bound but are only ambiguously correlated away from the zero lower bound. Before the structural break in mid-2007, nominal interest rates were substantially above the zero lower bound; nominal interest rates could have fallen to accommodate reductions in expected inflation without any fall in asset prices.

However, after an economic downturn started in late 2007 and deepened in 2008, expected returns from holding real assets began to fall. The federal funds target was gradually reduced from 5.25 percent in December 2007 to 2 percent in May 2008. The Federal Reserve (Fed), becoming increasingly concerned about reported rising inflation driven by a spike in oil prices, refused to reduce the federal funds target further, ignoring mounting evidence of economic contraction and rising unemployment. As financial conditions become increasingly unsettled in the late summer of 2008, the credit demands of financially distressed borrowers were driving up the liquidity premium on cash (as reflected in the London euro deposit market rates, which rose from 2.6 percent in August to 4.9 percent in October) even as expected yields on real assets were falling. The collapse of Lehman Brothers over the second weekend in September transformed financial distress into a full-blown panic.[20] The crash in asset prices occurred even before the nominal interest rate, temporarily elevated by the abnormal liquidity premium on cash characteristic of a financial crisis, fell to the zero lower bound.

It might be thought that a crash in asset values occurring before nominal interest rates fall to the zero lower bound is inconsistent with the theory of asset-price dynamics based on the Fisher equation advanced in this paper. However, the Fisher equation can be generalized to

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[20] As observed above, during periods of financial distress, estimates of inflation expectations and real interest rates inferred from the Fisher equilibrium condition are subject to significant bias. With financial markets seemingly in disequilibrium, the nominal interest rate was above zero and exceeded the sum of the ex ante real interest rate and expected inflation only because of an abnormally high liquidity premium on cash.

incorporate a Keynesian liquidity premium. In the augmented Keynesian version of the Fisher equation, the disequilibrium dynamics described above come into play whenever the liquidity premium on cash rises sufficiently to raise the expected yield from holding money above the expected yield from holding real assets (Glasner 2018).

Because the expected returns from all assets must be equal in equilibrium, any net liquidity services provided (at the margin) by money must be offset by an expected carrying cost of holding money, thereby sufficiently reducing the expected yield from holding money to induce people to hold other assets as well as money. But if the expected return from holding real assets is falling and the liquidity services of money are increasing, people will seek to shift from holding real assets to holding money even though the nominal interest rate exceeds the zero lower bound.

Using the notation of Keynes (1936, chapter 17), we must have in equilibrium

$$q = l - c = r = i - p^e, \tag{3}$$

where q represents the pure real return from holding a real asset providing no expected appreciation and involving no carrying cost, l represents the liquidity services provided by money, c represents the carrying cost of holding money (i.e., expected inflation), r represents the pure financial return expected from holding a financial asset providing no liquidity service and no carrying cost (including loss of purchasing power), i represents the nominal interest rate on bonds or other fixed-income securities, and p^e represents expected inflation.

In this framework, equilibrium requires that the expected return from holding money ($l - c$) just equals both the expected return on holding real assets (q) and the expected return from holding bonds ($i - p^e$). A shift from real assets into money occasioned by an increase in the

liquidity premium could occur even while the expected return from holding bonds is positive, especially those bonds that provide some liquidity services (e.g., nearly riskless Treasury bonds).

But the empirical results raise a deeper question: What mechanism can account for the observed positive correlation between expected inflation and stock prices? During an asset-price crash induced by an attempt to switch from real assets to cash, declining expected inflation (or a rising liquidity premium) raises the expected yield from holding money above the expected yield from holding real assets. However, the observed positive correlation between asset values and inflation expectations is not confined to the relatively short periods of falling asset prices; the positive correlation was observed in 16 of the 18 six-month periods from the beginning of 2008 until the end of 2016. The dynamic process that causes asset prices to decline when falling inflation expectations force nominal interest rates down to the zero lower bound is straightforward, but what is the process that could cause asset prices to rise along with expected inflation when nominal interest rates are at or near the zero lower bound? To what extent are the process of asset-price collapse and asset-price recovery symmetrical?

Given a deflationary expectational shock at the zero lower bound, the burden of adjustment must be reflected in the ex ante real interest rate. The equilibrating mechanism requires asset prices to fall sufficiently to restore equality between the expected yields on all assets. But the asset-price crash of 2008–2009 did not lead to the stabilization of asset prices at a reduced level with ex ante real rates rising to match the reduced rate of expected inflation. Instead, after a fall of nearly 60 percent between September 2008 and March 2009, asset prices began a rapid recovery marked by modestly rising inflation expectations and falling ex ante real

interest rates.[21] Thus, the adjustment to the asset-price crash appears to have been caused not by the automatic readjustment of the ex ante real rate to reduced expected inflation, but by policy actions taken by the monetary authorities to raise expected inflation.[22]

When the S&P 500 bottomed out in March 2009, nominal short-term interest rates were at or near the zero lower bound. The Fed's announcement of a large-scale program of open-market purchases (quantitative easing) almost immediately lifted expected inflation as measured by the TIPS spread. At longer durations, nominal interest rates were not at zero, so there was room for longer-term real interest rates, as reflected in TIPS, to fall. Nevertheless, the increase in stock prices seems too large to be explained by reduced real interest rates, which suggests that expected future cash flows must also have increased. An expectation of increasing future cash flows would, by itself, tend to increase, not depress, the real interest rates at which future cash flows are discounted by investors. In a standard time-preference model, reduced real interest rates, if related to future cash flows at all, would be associated with decreased future incomes relative to present incomes. Thus, the most plausible explanation of increasing expected future cash flows would be that they were occasioned by an increase in expected inflation

That the 2008–2009 asset-price crash was followed by what appears to have been a policy-induced increase in expected inflation and a corresponding decline in the real interest rate suggests that no error-correction mechanism associated with co-integration of the independent variables was operating. The only equilibrating, error-correction mechanism consistent with the adjustment dynamics implied by the Fisher equation would have entailed further reductions in asset prices, with real interest rates rising correspondingly—the exact opposite of the actual

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[21] To simplify the narrative, I ignore the role of the liquidity premium during the crash of asset prices. Clearly, the high liquidity premium was a precipitating cause of the crash, and the decline of the premium had the same effect as an increase in expected inflation or an increase in reducing the return on holding cash.
[22] And, perhaps just as important, by actions taken to reduce the liquidity premium.

adjustment in which real asset prices were rising and real interest rates were falling. The observed

response of rising inflation expectations and rising asset prices therefore seems to reflect an

exogenous policy response, not an endogenous equilibrating or error-correction response.

Finally, a comment about the dollar-to-euro variable may be in order. The dollar-to-euro

exchange rate had a positive and statistically significant coefficient in only eight of the 28 six-

month periods for which the regression in differences was estimated. These eight periods

occurred consecutively from January 2009 through December 2012. In every other time period,

except one, the estimated coefficients were insignificant, the one exception being the second half

of 2015, when the estimated coefficient was negative and significant. The most plausible

explanation for the observed positive coefficients from 2009 to 2012 seems to be that is that the

dollar-to-euro exchange rate was associated with an expectation of monetary easing by the Fed,

leading to a depreciation of the dollar relative to the euro.[23] In 2015, I conjecture that the

negative coefficient was associated with an expectation of monetary easing by the European

Central Bank, which enhanced expectations of future cash flows and therefore led to an increase

in asset values.

V. Conclusion

My results point to two important conclusions. First and most obviously, when ex ante real

interest rates are low, sharp downturns in asset prices are associated with steep drops in expected

inflation and rising liquidity premiums. If a recession is associated with falling ex ante real

interest rates, bringing nominal rates close to the zero lower bound, then tightening monetary

policy to counter perceived inflationary pressures amplifies the risks of an asset-price crash and a

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[23] The dollar-to-euro exchange rate is measured as the dollar price of one euro. Thus, an increase in the dollar-to-euro exchange rate corresponds to a depreciation of the dollar in terms of euros.

financial crisis, either by causing expected inflation to fall or by causing the liquidity premium to rise. Second, once asset prices start to fall rapidly, monetary policies aimed at increasing expected inflation and making liquidity readily available to reduce the liquidity premium can stabilize asset prices and promote recovery. The Bagehot (1873) maxim to lend freely at a penalty rate is counterproductive if it forces distressed borrowers to liquidate their asset positions—reinforcing an asset-price crash—because they are unable to borrow at penalty rates.

This is not to say that inflation is always desirable. The case for inflation as a strategy for monetary policy depends on a very low or negative real rate of interest, which seems to be an exceptional circumstance. Moreover, my results also suggest that the danger of deflation, which has led monetary authorities to generally aim at a low but steady rate of inflation, is misplaced for two reasons. First, deflation becomes dangerous only in an environment of low real interest rates, in which nominal rates are at or near the zero lower bound. In an environment of rapid growth with correspondingly high real interest rates, mild deflation need not pose any downside risk. Second, targeting the rate of inflation regardless of economic conditions is likely to be destabilizing in the face of adverse supply shocks, which reduce real output and depress profit expectations and real interest rates even as expected inflation rises. A monetary policy that aims at keeping inflation and expected inflation constant during a supply shock can reduce profit expectations and real interest rates even further while restricting liquidity and raising the liquidity premium.

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