What Is the Effect of Financial Stress on Economic Activity?

By Troy Davig and Craig Hakkio

Financial stress recently pushed the U.S. economy into its most severe recession since the Great Depression. Despite the apparent risk financial stress poses to the real economy, the relationship between financial stress and economic activity is complex and not well understood. The experience of the United States and other countries has shown that businesses and households often pull back on new investments and purchases in response to the tighter credit conditions and greater uncertainty caused by financial stress. But important gaps remain in our understanding of this critical relationship.

One potential complication in understanding the relationship is that it may change when financial stress is elevated and the economy is in a recession. Over the last 20 years, the U.S. economy has shown a tendency to switch between two very distinct states—a normal state in which economic activity is high and financial stress is low, and a distressed state in which economic activity is low and financial stress is high. Does the impact of financial stress on economic activity depend on which of these two states currently prevails? And how do changes in

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financial stress and economic activity affect the likelihood of switching from one state to the other?

This article examines these questions. A key finding is that, over the last two decades, increases in financial stress have had a much stronger effect on the real economy when the economy is in a distressed state. In addition, rising financial stress plays a role in eventually tipping a strong economy into a distressed state. As a result, policymakers should monitor financial conditions closely, both in good as well as bad times.

The first section explores the theoretical links between financial stress and economic activity. The second section examines the empirical relationship, taking into account whether the economy and financial system are in the normal or distressed states. The third section explores the dynamic linkages between financial stress and economic activity across the different states.

I.   THE IMPACT OF FINANCIAL STRESS ON ECONOMIC ACTIVITY: THEORETICAL FRAMEWORKS

To gain insight into how financial stress influences real economic activity, this section discusses two prominent economic theories. The first comes from research on "real options," which incorporates uncertainty into the decision of whether to, for example, invest in a new manufacturing plant today, or postpone the decision for a while to see how the uncertainty is resolved. The second theory shows how an increase in financial stress—that is, a worsening of financial conditions—affects the real economy by directly tying the cost of borrowing to the financial condition of firms. In this setting, a "financial accelerator" arises through which a deterioration in the financial condition of firms raises their cost of borrowing funds and thus leads to less investment. In turn, a decrease in investment will lower profits and further impair the financial condition of firms. Both theories, the real option and financial accelerator, indicate that high financial stress, as reflected primarily through heightened uncertainty, is associated with lower economic activity.

The real option framework

A central element of the real option theory is that it incorporates the value of waiting, allowing uncertainty to be resolved, before making

a new, irreversible investment.[1] For example, a new manufacturing plant may be profitable in the future if the price of its output rises, but it may lose money if prices fall. By waiting, the firm has more information about its economic prospects and can then make a more informed choice about whether to proceed with an investment. Thus, the term *real option* pertains to the option a firm has of waiting to make a real investment. Importantly, this option has value that firms should consider when undertaking a new investment.

A key result from the real option framework is that when uncertainty rises, waiting to make a new investment is often optimal. Low uncertainty generally means there is a small probability of an extreme outcome, including one so bad that the investment would prove unprofitable. As a result, there is not much to be gained from waiting for additional information before making the investment. In this case, firms are likely to invest today, given the investment is deemed to be profitable on average. However, when uncertainty is high—that is, when the probability of an extreme outcome is high—the firm will often find it optimal not to invest today but to wait until the uncertainty is resolved. Then, in the future, if the bad outcome appears certain, the firm will forego the investment. Alternatively, if it appears certain the bad outcome will not to occur, the firm will go ahead with the investment. In other words, high levels of uncertainty lead to reduced investment today and, depending on how the uncertainty is resolved, may lead to increased investment in the future.[2]

Focusing on the effect of uncertainty, the real option theory suggests that financial stress will lead to less investment spending.[3] This occurs because financial stress often reflects heightened financial market volatility and greater uncertainty about the future performance of the economy. Thus, firms may interpret a sudden jump in financial market volatility as a reflection of more uncertain economic conditions in the future and will pull back on new investment.

The financial accelerator model

When financial stress is low, financial markets operate smoothly. Thus, low financial stress can be viewed as "greasing the wheels" of economic transactions and facilitating economic growth by efficiently transferring funds from savers to borrowers. Savers are willing to extend

credit to firms in exchange for an expected positive return on their savings. Risk is always present, but during normal times, savers may perceive they have a firm grasp on the risks they face. In this case, financial markets provide a valuable function by efficiently pricing such risks and appropriately compensating savers. Funds then flow to borrowers, and riskier borrowers pay a higher interest rate, or risk premium, on what they borrow.

If financial markets become significantly impaired and financial conditions become stressful, however, obtaining funds from savers becomes more difficult and costly for firms and consumers. The premium that riskier borrowers have to pay increases, and the riskiest borrowers may be unable to obtain credit on any terms. If firms or consumers are unable to obtain funds to finance investment spending or purchase consumer durables, then both types of spending will fall. Such a response was particularly evident during the recent financial crisis when many financial markets simply stopped operating.

The workhorse model often used to address the impact of financial conditions on the real economy is the *financial accelerator* framework developed by Bernanke, Gertler and Gilchrist (1999). In this setting, firms that need to borrow from external sources, or obtain external financing, pay a premium to borrow that depends on their financial position.[4] For example, firms with high debt levels must pay a higher interest rate on the funds they borrow to undertake an investment compared to an identical investment by a firm with less debt. This premium is referred to as the "external finance premium." It represents the cost difference of financing a new investment by raising funds externally, such as by borrowing from a bank, versus using internal funds, such as the opportunity cost of using cash on hand.

The term financial accelerator arises from a feedback mechanism in the model. When the economy is booming, firms post higher profits and have stronger balance sheets. As a consequence, they appear to be less risky, so banks charge them a lower external finance premium. In turn, the lower external finance premium induces firms to make more new investments, which further contributes to economic growth. This mechanism works in good times, when the economy is growing rapidly, but also works in reverse, generating an "adverse feedback loop."[5] In this case, weakening economic conditions cause profits to decline

and balance sheets to weaken. In response, banks charge a higher external finance premium, which causes firms to invest less.

If uncertainty increases, banks respond by raising the average external finance premium because they expect more firms to go bankrupt.[6] If a firm files for bankruptcy, the bank will have to incur a cost to verify that the firm has insufficient assets to repay its loan and claim the firm's remaining assets. In response, banks charge a higher average premium on firms that borrow funds as compensation for the higher rate of expected bankruptcies. Consequently, the higher average external finance premium causes the average level of investment to decline.
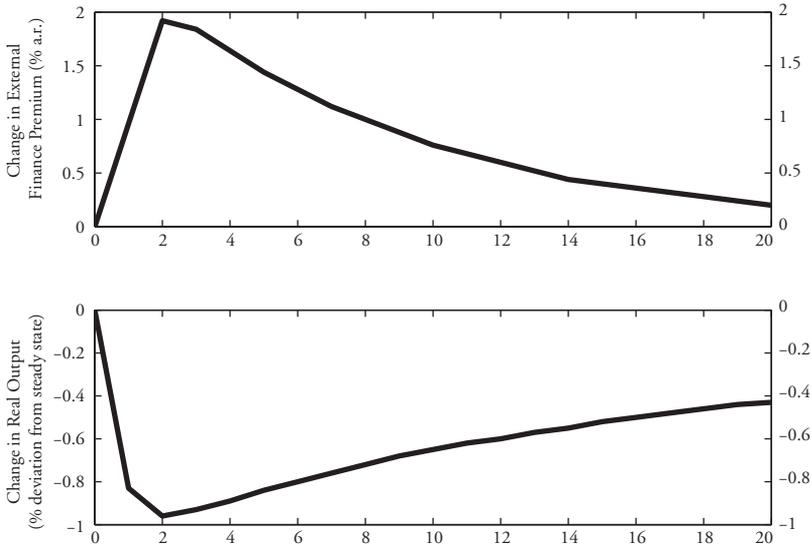
In the financial accelerator model, various shocks to the economy can cause further fluctuations in the external finance premium and, in turn, investment. For example, a sudden shift in investor sentiment may cause asset prices to fall for reasons unrelated to economic fundamentals, leading to a decrease in the net worth of firms. Such an unexpected drop in the net wealth of firms will sharply increase the external finance premium and generate what is typically thought of as financial stress.[7] Chart 1 shows the estimated response of the external financial premium and real economic activity to a 5 percent decline in net worth based on a particular version of the financial accelerator model. (Appendix A describes the model and assumptions about parameter values.) The decline in net worth weakens firms' balance sheets, so banks charge them a higher external finance premium to borrow. In response, firms invest less, causing economic activity to fall. Over time, the impact of the shock wears off and the economy recovers.

An important aspect of the financial accelerator model is that the strength of the relationship between a firm's net worth and the premium it must pay to borrow depends on the uncertainty of its profitability. Under heightened uncertainty, the premium becomes more sensitive to a firm's financial condition.[8] During such times, credit spreads become more sensitive to changes in the financial conditions of firms, causing firms to make larger adjustments to their investment plans. The following equation describes a mechanism that links the strength of the firm's balance sheet to the external finance premium:

Change in the external finance premium =
-v* (Change in the ratio of a firm's net worth to its capital stock).

Chart 1

RESPONSE OF REAL ECONOMY AND EXTERNAL FINANCE PREMIUM TO A DECLINE IN THE NET WEALTH OF FIRMS

Note: Assumes a 5 percent decline in net wealth. Details of the model are in Appendix A.
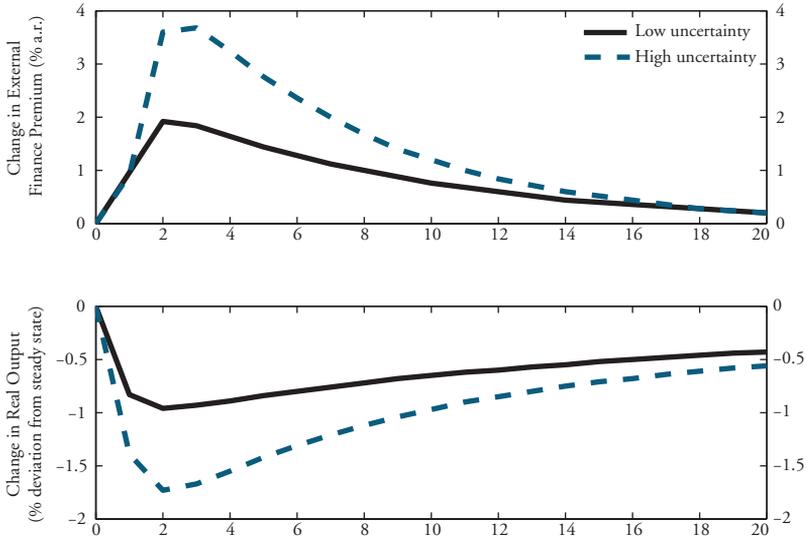Source: Authors' calculations

The premium decreases as the ratio of the firm's net worth to capital stock rises. Importantly, the strength of the response of the external finance premium to such changes, v, depends on the level of uncertainty in the economy. As uncertainty rises, so does the value of v. That is, the external finance premium becomes more sensitive to the financial condition of firms. For example, the gap between the premium paid by a firm with a low ratio of net worth to capital and a firm with a high ratio will be greater in a highly uncertain environment than in a more tranquil one.

To illustrate, Chart 2 compares the response of the economy and external finance premium to a decline in net worth in the baseline scenario, given in Chart 1, to the response in a period of heightened uncertainty.[9] Under higher uncertainty, the external finance premium becomes more sensitive to the net wealth of firms, causing a larger and longer-lasting decline in economic activity.

Chart 2

RESPONSE OF REAL ECONOMY AND EXTERNAL FINANCE PREMIUM TO A DECLINE IN THE NET WEALTH OF FIRMS: LOW VS. HIGH UNCERTAINTY

Note: Assumes a 5 percent decline in net wealth. Details of the model are in Appendix A.
Source: Authors' calculations

The financial accelerator framework suggests that, when uncertainty is high, the economy becomes more susceptible to financial shocks, such as a decline in the net worth of firms. In contrast, when uncertainty is low, the economy is better equipped to contend with financial shocks. This comparison will be made again later in the article, when the effects of financial stress on economic activity are measured using U.S. data.

II. FINANCIAL STRESS AND ECONOMIC ACTIVITY: AN EMPIRICAL FRAMEWORK

The theories discussed in the previous section suggest a strong relationship between financial stress and economic activity. This section examines the relationship using an empirical framework and data that includes several recent periods of financial stress in the U.S. economy.

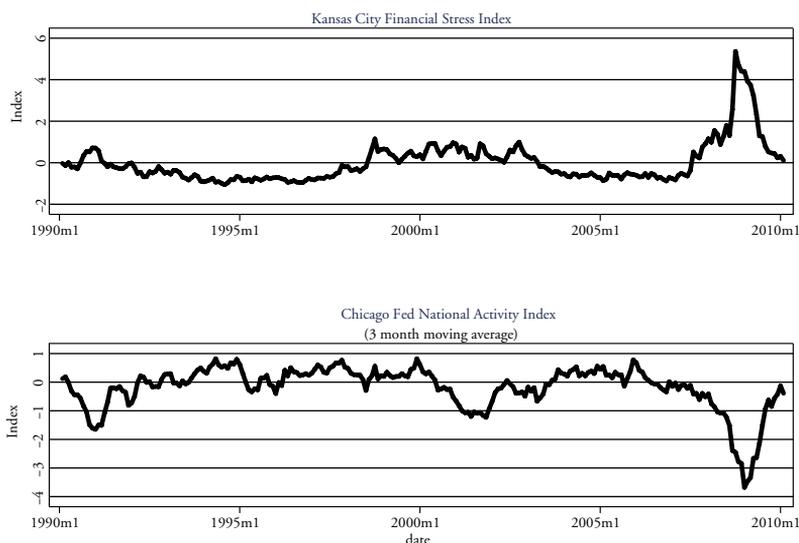*Measuring financial stress and economic activity*

Financial stress is measured using the Kansas City Federal Reserve's Financial Stress Index (KCFSI). This monthly index combines 11 variables that provide a range of economic signals of financial stress (Hakkio and Keeton). The variables fall into two broad categories: credit and liquidity spreads and measures based on the actual or expected behavior of asset prices.[10] A key aspect of the KCSFI is that periods of financial stress are episodic (Chart 3, top panel). For example, there appear to be at least three distinct episodes of financial stress, as the index was clearly elevated around 1991, 1998-2002, and during the recent financial crisis.[11]

Economic activity is measured using the Chicago Fed National Activity Index (CFNAI) (Chart 3, bottom panel). The CFNAI is constructed in a similar way to the KCFSI, combining a series of 85 macroeconomic data that provide a broad range of measures of economic activity. The CFNAI is more useful than real gross domestic product (GDP) as a measure of economic activity in this context because it is available monthly, in contrast to the quarterly release of real GDP. Other economic indicators, such as nonfarm payrolls, are also available monthly but focus on a single aspect of the economy, such as the labor market, while the CFNAI incorporates data from several categories of macroeconomic data.

Both the KCFSI and CFNAI have a mean of zero and a standard deviation of one. Thus, when the KCFSI exceeds zero, financial conditions are more stressed than average. Similarly, when the CFNAI exceeds zero, the economy is expanding faster than average.

Simple inspection of Chart 3 reveals two aspects of the relationship between financial stress and economic activity that are important when choosing and specifying an economic model. First, periods of heightened financial stress and weak economic activity are episodic. Financial conditions are generally benign for extended periods of time–but can suddenly spike. Similarly, economic activity generally grows at or above trend for extended periods of time–but can suddenly drop. Second, episodes of heightened financial stress and weak economic activity generally coincide. For example, the 1990-91, 2001, and recent recessions are clearly visible in the chart and roughly coincide with heightened financial stress.

Chart 3
THE KCFSI AND CFNAI

Source: Federal Reserve Bank of Chicago and Federal Reserve Bank of Kansas City
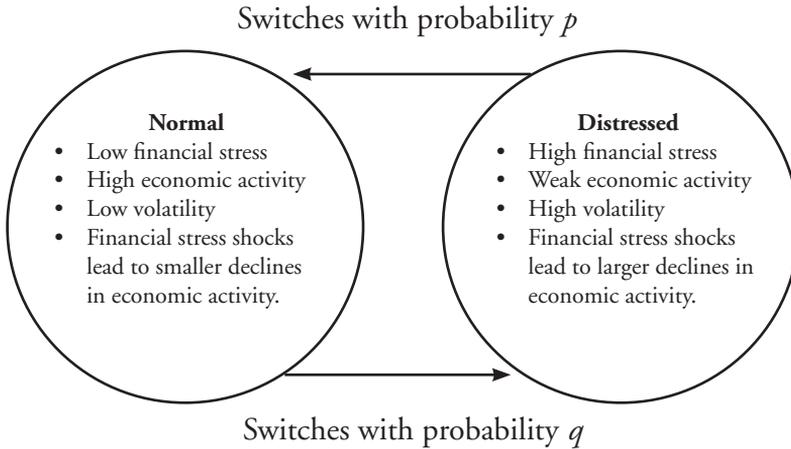
A regime-switching model

Since periods of elevated financial stress and weak economic activity are episodic, any empirical model should ideally be able to capture abrupt changes in these data. One way to capture such changes is through a regime-switching model.[12] The core elements of the model are described in Figure 1, with details given in Appendix B.

As shown in the figure, the regime-switching model developed for this analysis has two regimes, referred to as the normal and distressed regimes. For most of the sample, the economy is in the normal regime with low financial stress and high economic activity. Occasionally, the economy switches to the distressed regime, with high financial stress and low economic activity.[13]

A regime-switching model provides a rich framework in which to study how financial stress affects economic activity. In particular, this model captures different channels through which financial stress and economic activity interact. As Figure 1 shows, the defining character-

Figure 1
DIAGRAM OF THE REGIME-SWITCHING MODEL

Switches with probability *p*

Normal
- Low financial stress
- High economic activity
- Low volatility
- Financial stress shocks lead to smaller declines in economic activity.

Distressed
- High financial stress
- Weak economic activity
- High volatility
- Financial stress shocks lead to larger declines in economic activity.

Switches with probability *q*

istic of each regime is its average level of financial stress and economic activity, as well as its volatility.

This model also allows the dynamic interaction between financial stress and economic activity to vary across the two regimes. The financial accelerator model from the last section suggests that certain financial shocks have a larger impact on economic activity when uncertainty is high. Thus, the financial accelerator model suggests that financial shocks in a distressed regime should have a larger impact on output than in a normal one. As explained in detail in the next section, the U.S. data confirm this prediction.
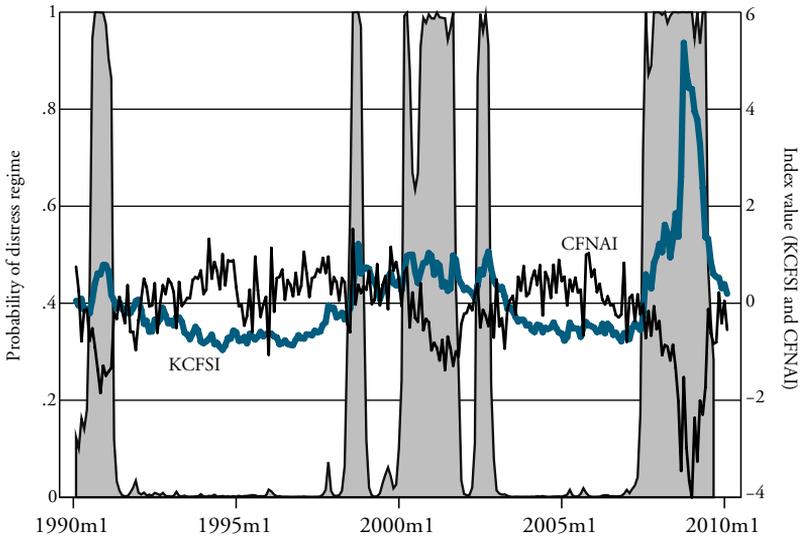
Finally, while the baseline model assumes that the probability of moving between the normal and distressed regimes (*p* and *q* in Figure 1) is constant, this assumption can be relaxed in a regime-shifting model. In particular, it is plausible that the probability of moving between regimes may itself depend on the level of financial stress and economic activity.

Normal and distressed regimes: Timing and summary statistics

Estimation of the regime-switching model determines the properties of each regime. Such properties include the average level of each variable and volatility, as well as the likelihood of being in one regime

Chart 4
PROBABILITY THE ECONOMY IS IN THE DISTRESSED REGIME

Source: Federal Reserve Bank of Chicago, Federal Reserve Bank of Kansas City and authors' calculations.

or the other. Specifically, the model only estimates the *probability* of being in a particular regime, not whether the economy is actually, or definitely, in a particular regime. Thus, the two regimes are determined solely by the data and are not imposed on the results.

The shaded area in Chart 4 shows the probability that the economy was in the distressed regime at each point in the sample period, from 1990 to September 2009. When the probability approaches one, the regime-switching model indicates that the economy was most likely in the distressed regime. The timing of this regime is generally consistent with slowdowns in economic activity and spikes in financial stress, as shown by the values of the KCFSI and CFNAI superimposed on the chart. The first episode of high financial stress occurred around 1991, when the U.S. banking system was suffering an array of difficulties due to real estate losses and the overall economy was in recession. The second episode occurred at the time of the Russian bond default and the ensuing problems in the financial sector. The third episode occurred amid the dot-com bubble collapse, the 2001 recession, and the September 11 ter-

rorist attacks. The fourth episode occurred amid the accounting scandals and sluggish recovery following the 2001 recession. The final episode reflects the recent recession and financial crisis of 2007-09.
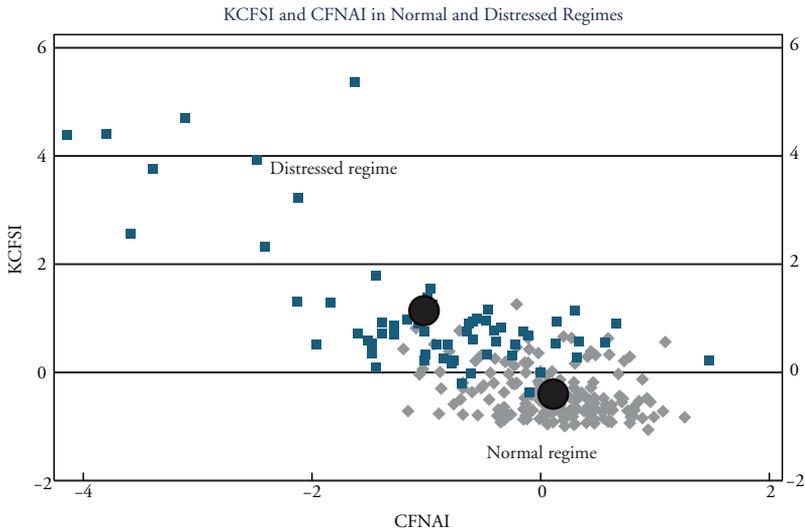
Thus, the timing of the distressed regime is generally consistent with negative economic and financial events over the past 20 years. Overall, the regime-switching model indicates that the economy was in the normal regime about 74 percent of the time and in the distressed regime the remaining 26 percent of the time.[14]

A scatter plot of financial stress and economic activity in the two regimes suggests three negative relationships (Chart 5). In the chart, the blue squares show values of financial stress and economic activity in the distressed regime, and the grey diamonds show these values in the normal regime. The blue squares show the first negative relationship: Financial stress and economic activity are negatively related in the distressed regime (simple correlation of -0.8). The grey diamonds show the second negative relationship: Financial stress and economic activity are negatively related in the normal regime, though to a much lesser degree (simple correlation of -0.3). Finally, the two large circles show the third negative relationship: Financial stress and economic activity tend to move in opposite directions when the economy switches from one regime to the other. The circles indicate the average values of financial stress and economic activity in each regime. The circle for the distressed regime lies above and to the left of the circle for the normal regime, implying that average economic activity is lower in the distressed regime and average financial stress is higher in the distressed regime.

In addition to differences in the average values of financial stress and economic activity, the volatility is higher in the distressed regime than in the normal regime. In the distressed regime, the standard deviation of economic activity is over two times larger, and the standard deviation of financial stress is nearly three times larger, than in the normal regime. This difference in volatility is consistent with the scatter plot shown in Chart 5. The grey diamonds in Chart 5 are tightly packed, while the blue squares are spread apart. In some respects, though, these results understate the rise in uncertainty because the KCFSI already incorporates at least two measures of volatility.[15] Therefore, not only does higher volatility lead to higher financial stress in the KCFSI, but when the economy is in the distressed regime, the volatility of financial stress is also higher.

Chart 5

RELATIONSHIP BETWEEN FINANCIAL STRESS AND ECONOMIC ACTIVITY

KCFSI and CFNAI in Normal and Distressed Regimes

Note: The average values for KCFSI is -0.40 in the normal regime and 1.14 in the distressed regime. The average values for CFNAI is 0.11 in the normal regime and -1.02 in the distressed regime.
Source: Federal Reserve Bank of Chicago, Federal Reserve Bank of Kansas City and authors' calculations.

III. THE IMPACT OF FINANCIAL STRESS ON ECONOMIC ACTIVITY: DYNAMIC INTERACTIONS

Not only is the average level of financial stress and economic activity across regimes negatively correlated, but the negative impact of a financial shock is larger and longer-lasting in the distressed regime. This section explores the dynamic interaction between financial stress and economic activity within each regime, as well as the role of financial stress in tipping the economy from one regime into another.

The dynamic impact of financial stress on economic activity in different regimes

To assess the extent of the differences across regimes, impulse-response functions are estimated to measure the impact of additional financial stress (the impulse) on economic activity (the response).[16] The additional financial stress is taken to be exogenous, so is similar

to the financial shock in the financial accelerator model (Chart 2).[17] To produce the impulse responses, a change in financial stress is allowed to affect real activity with a one-month delay, but changes in economic activity are assumed to affect financial markets immediately. These assumptions capture the rapidity with which financial markets can adjust to incoming data, whereas real capital investment and hiring decisions respond more sluggishly to changing conditions.
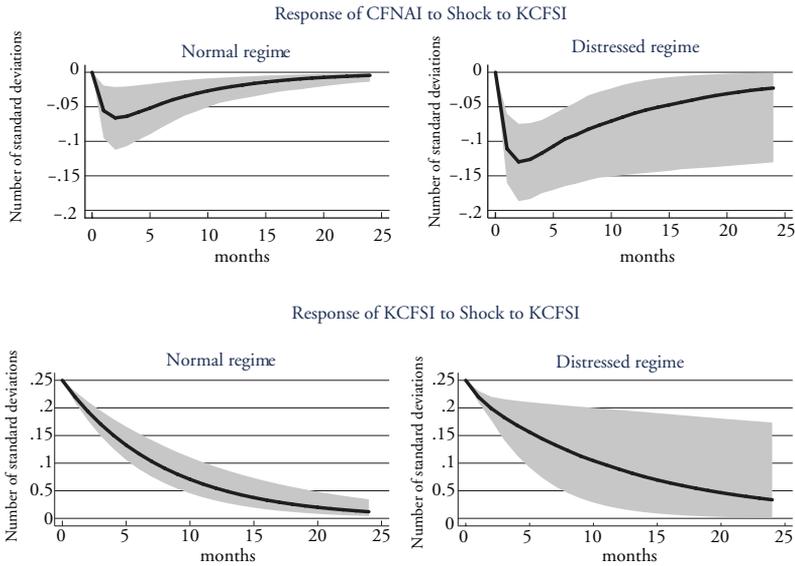
To gain insight into the role of financial stress, the effects of a financial stress shock on economic activity and on financial stress in each regime are shown in Chart 6.[18] The top half of the chart shows the response (with 95 percent confidence bands) of economic activity to a financial stress shock, measured in terms of standard deviations from the average level of economic activity in each regime. For comparability across regimes, the size of the financial shock in both regimes is the same. The first result, not surprisingly, is that a shock causing financial stress leads to a statistically significant decline in economic activity that lasts for several months, in both the normal regime and distressed regime. In addition, the differences in responses are statistically different across regimes.[19] The second result is also consistent with the Bernanke, Gertler, and Gilchrest model, namely that the effect is larger and longer-lasting in the distressed regime. Specifically, the impact of an increase in financial stress on economic activity is about 50 percent larger when the economy is distressed. In addition, the negative effect of higher stress on economic activity lasts longer. For example, after two years, the impact of the shock has nearly dissipated in the normal regime, whereas in the distressed regime the effects are still lingering (Chart 6).

The bottom half of Chart 6 shows the response of financial stress to a financial stress shock, also measured in terms of standard deviations from the average level of economic activity in each regime. The effect of a financial stress shock on future values of financial stress is more persistent and lasts longer in the distressed regime because the KCFSI returns to its average level more slowly in the distressed regime. The slower rate of decay in this regime is what persistently holds down economic activity and might suggest that financial markets could be slower to heal and repair themselves in an elevated state of stress.

In many respects, however, the responses of activity in Chart 6 understate the differences between the two regimes. The average size of a

Chart 6
IMPACT OF A SHOCK TO FINANCIAL STRESS

Response of CFNAI to Shock to KCFSI

Response of KCFSI to Shock to KCFSI

Note: The size of the shock to KCFSI is the same in both regimes.
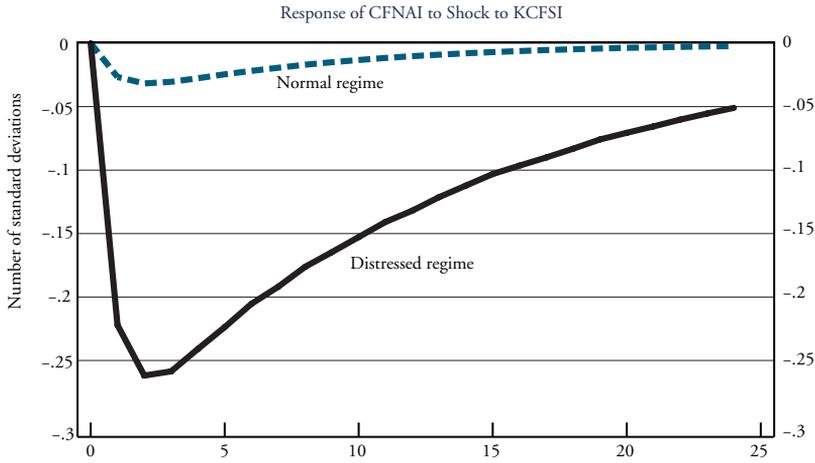Source: Authors' calculations

financial stress shock in the distressed regime is more than four times that in the normal regime. Chart 6 shows the response to a shock to the KCFSI in each regime, assuming the shock was the same size in both the normal and distressed regimes. Chart 7, however, allows the size of the shocks to differ in a way that reflects the greater volatility in the distressed regime. Not surprisingly, the effect of a one standard-deviation financial stress shock—which is larger in the distressed regime than in the normal regime—is even larger and lasts longer than in the distressed regime.

The effect of financial stress on the probability of moving to the distressed regime

While financial stress may affect economic activity within a regime, financial stress and economic activity may also affect the probability of moving between regimes. This effect is measured by extending the previous model to allow the probability of switching between regimes to depend on the level of financial stress and economic activity.

Chart 7

IMPACT OF A REGIME-SPECIFIC ONE-STANDARD DEVIATION SHOCK TO FINANCIAL STRESS

Response of CFNAI to Shock to KCFSI

Note: Assumes a one standard deviation shock to KCFSI, where the standard deviation is calculated separately for each regime.
Source: Authors' calculations

The key empirical result from estimating the regime-switching model with this modification is that rising financial stress does indeed play an important role in tipping the economy into the distressed regime. From both statistical and economic standpoints, the effects are significant. The probability of switching regimes can be written as follows:[20]

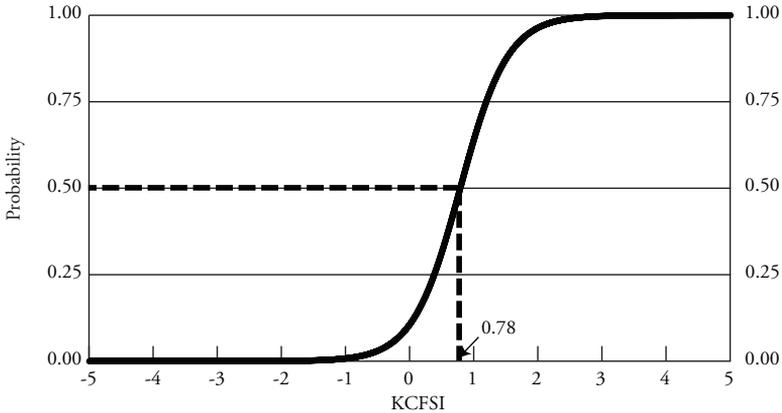$$q = f(\alpha_0 + \alpha_1 KCFSI_{t-1} + \alpha_2 CFNAI_{t-1})$$

$$p = g(\beta_0 + \beta_1 KCFSI_{t-1} + \beta_2 CFNAI_{t-1}),$$

where *f(.)* and *g(.)* are increasing functions. The only coefficient that is statistically significant is α_1, which is estimated to be a positive number. The other coefficients are statistically indistinguishable from zero. So as the KCFSI rises, the probability of the economy tipping from the normal regime into the distressed regime, *q*, increases.

More specifically, Chart 8 shows how the probability of the economy moving into the distressed regime, given that it is currently in the normal regime, depends on the value of financial stress. For example, when the KCFSI is below -1, the probability of moving to the

Chart 8

PROBABILIY OF MOVING FROM THE NORMAL REGIME TO THE DISTRESSED REGIME

Source: Author's calculations

distressed regime is near zero, and, equivalently, the probability of re-maining in the normal regime is near one. However, as financial stress rises, the probability that the economy moves into the distressed regime also begins rising. In particular, if the KCFSI breaches 0.78, the probabil-ity of moving into the distressed regime becomes greater than 50 percent.

In addition, the increase in probability is dramatic. For example, when the KCFSI is 0.38, the probability of switching to the distressed regime is 0.25. However, if the KCFSI makes a modest increase from 0.38 to 0.78, the probability of moving to the distressed regime increas-es to 50 percent. A further increase in the KCFSI from 0.78 to 1.19 increases the probability of moving to the distressed regime to 0.75.

This result provides evidence on how financial stress can have a particularly severe effect on economic activity. Suppose the economy is currently in the normal regime—sometime before the financial market disruptions that began in August 2007. While in the normal regime, financial stress is low, economic activity is high, and volatility is low. In addition, while financial stress shocks lead to declines in economic ac-tivity, the declines are relatively modest. However, if the economy is hit by a series of financial stress shocks, or by one large shock, the probabil-ity of moving from the normal regime to the distressed regime begins to

increase. If the shocks are cumulatively large enough, the economy may be tipped into the distressed regime. The effect is then dramatic. The average level of financial stress is higher, the average level of economic activity is lower, and the volatility of both is higher.

Interestingly, the results indicate that when the economy is in the distressed regime, financial conditions do not play a significant role in raising the probability that the economy returns to the normal regime. Similarly, the results indicate changes in the level of economic activity do not play a significant role in moving the economy between the normal and distressed regimes.[21] For example, analogous to Chart 8, the activity index on the horizontal axis would simply be a straight, horizontal line.

These results suggest that a rise in financial stress poses a risk the economy may enter a distressed regime. Consequently, policymakers should monitor financial conditions closely even when the economy appears to be functioning normally.

IV.   CONCLUSIONS

The recent financial and economic crisis illustrated the sharp relationship between financial stress and economic activity. However, such a tight connection is not always so obvious, since the economy also passes through several years where financial conditions appear to play a tangential role in driving economic activity. To assess how the effects of financial conditions vary over time, this article considers whether the influence of financial stress on economic activity depends on broader economic and financial conditions.

The article finds that the U.S. economy fluctuates between a normal regime, in which financial stress is low and economic activity is high, and a distressed regime, in which financial stress is high and economic activity is low. In the distressed regime, the effect of financial stress on economic activity can be quite large compared to the normal regime. Thus, when financial stress becomes elevated, policymakers should pursue policies to alleviate it, since the economy appears to be particularly susceptible to further increases in financial stress.

During less stressful times, policymakers also need to monitor financial stress closely, but for a slightly different reason. An event that triggers higher financial stress, even if the overall level is generally low,

will raise the probability the economy will enter a distressed state. Thus, even when financial conditions are normal, policymakers should closely monitor financial conditions.

APPENDIX A

The financial accelerator model is from Bernanke, Gertler and Gilchrist (1999), modified along the lines of Nolan and Thoenissen (2009) to incorporate a shock to the net worth of firms. The complete log-linearized model is as follows, where capital letters denote steady state values and lower case letters denote log deviations.

$$y_t = \frac{C}{Y}c_t + \frac{C^e}{Y}c_t^e + \frac{I}{Y}i_t \tag{1}$$

$$c_t = -r_t + E_t c_{t+1} \tag{2}$$

$$c_t^e = n_t \tag{3}$$

$$E_t r_{t+1}^k - r_t = -\upsilon\left(n_{t+1} - q_t - k_{t+1}\right) \tag{4}$$

$$r_{t+1}^k = (1-\epsilon)\left(y_{t+1} - k_{t+1} - x_{t+1}\right) + \epsilon q_{t+1} - q_t \tag{5}$$

$$q_t = \varphi\left(i_t - k_t\right) \tag{6}$$

$$y_t = \alpha k_t + \Omega h_t \tag{7}$$

$$y_t - h_t - x_t - c_t = \eta^{-1} h_t \tag{8}$$

$$\pi_t = \beta E_t \pi_{t+1} - \kappa x_t \tag{9}$$

$$k_{t+1} = \delta i_t + (1-\delta) k_t \tag{10}$$

$$n_t = \frac{\gamma}{\beta} n_{t-1} + \left(\frac{\gamma}{\beta} - \frac{\gamma K}{\beta N}\right) r_{t-1} + \left(\frac{\gamma K R}{N}\right) r_{t-1}^k + v_t \tag{11}$$

$$R_t = \phi \pi_t \tag{12}$$

$$R_t = r_t + E_t \pi_{t+1} \tag{13}$$

$$v_t = \rho v_{t-1} + e_t \tag{14}$$

Equation (1) is the aggregate resource constraint, indicating that log deviations in output(y_t) reflect deviations in consumption of non-entrepreneurs (c_t), consumption of entrepreneurs (c_t^e) and investment (i_t). Equation (2) is the consumption Euler equation, which indicates consumption of non-entrepreneurs depends on the current real interest rate (r_t) and expected future consumption. Equation (3) indicates that changes in the consumption of entrepreneurs reflects changes in their net worth (n_t). Equation (4) describes the external finance premium (i.e. $E_t r_{t+1}^k - r_t$), which depends on the firm's net worth relative to the value of its capital available for production in the following period, $q_t + k_{t+1}$. Deviations in the price of capital are given by q_t and deviations in the amount of capital available for production in the following period are given by k_{t+1}. Equation (5) describes the return to capital (r_{t+1}^k) in terms of next period's marginal product of capital and expected capital gains. Equation (6) describes investment (i_t) in terms of the price of capital and current capital stock. Equation (7) describes

how aggregate production (y_t) depends on capital and hours worked (h_t). Equation (8) describes equilibrium in the labor market and equation (9) is the forward-looking Phillips curve relation, where current inflation (π_t) varies with expected inflation and the markup of retails goods over wholesale goods (x_t): This markup varies inversely with aggregate demand, so an increase in aggregate demand creates price pressures that feed through to higher inflation. Equation (10) is the law of motion for capital, and equation (11) is the law of motion for net wealth, where the net wealth shock is given by v_t. Equation (12) is the monetary policy rule, and equation (13) is the Fisher equation.

Using a quarterly frequency and following Bernanke, Gertler and Gilchrist (1999), the following parametric values are used to compute the impulse response in Charts 1 and 2 : α = .35 (capital share); β = .99 (household discount factor); δ = .025 (capital depreciation rate); Ω = .64 (household labor share), and γ = .9728 (survival rate of entrepreneurs). The elasticity of the external finance premium with respect to the firms net worth, υ, is calculated from a model of the loan contracting problem as described in Bernanke, Gertler and Gilchrist (1999). In this model, the verification cost incurred by banks in the event of default is assumed to be a fraction μ = .12 of the firms remaining assets. Also, two alternative assumptions are made about the variance of the idiosyncratic shocks that hit firms. In the baseline case, the variance of the idiosyncratic shocks is .28, the same as in Bernanke, Gertler and Gilchrist (1999), and implies υ = .09 and R^k/R = 1.014. Under the alternative parameterization, which is intended to capture a state of heightened uncertainty, the variance is 1.5 and implies υ = .21 and R^k/R = 1.0183. The serial correlation in the net wealth shock, ρ, is set to .9. The remaining parameters in the above model are as follows: C/Y = .65 (steady-state consumption-to-output ratio), I/Y = .14 (steady-state investment-to-output ratio), C^e/C = .01 (steady-state entrepreneurial consumption-to-output ratio), η = 3 (labor supply elasticity), φ = .25 (elasticity of the price of capital with respect to the investment-capital ratio), κ = .09 (slope of the forward-looking Phillips curve), and ϕ = 1.5 (reaction of the nominal interest rate to inflation). Other parameters that vary across the two parameterizations are as follows: ϵ = .9515 and K/N = 1.52 under the parameterization with low idiosyncratic productivity shocks and ϵ = .9479 and K/N = 1.11 under the

parameterization with high idiosyncratic productivity shocks. These variables vary because they are a function of the steady-state capital stock, which depends on the steady-state external finance premium.

APPENDIX B

The regime-switching vector autoregression specification is as follows

$$y_t = B\left(s_t\right) y_{t-1} + A\left(s_t\right) \Sigma\left(s_t\right) \varepsilon_t$$

where $y_t = \left[x_t, fs_t\right]'$ and ε_t denote structural innovations that are normally distributed with a mean of zero and variance of unity: x_t denotes the Chicago Fed National Activity Index, and fs_t denotes the Kansas City Fed Financial Stress Index. Also,

$$A\left(s_t\right) = \begin{bmatrix} 1 & 0 \\ a\left(s_t\right) & 1 \end{bmatrix},$$

$$B\left(s_t\right) = \begin{bmatrix} b_{11} & b_{12}\left(s_t\right) \\ b_{21}\left(s_t\right) & b_{22} \end{bmatrix},$$

and

$$\Sigma\left(s_t\right) = \begin{bmatrix} \sigma_x\left(s_t\right) & 0 \\ 0 & \sigma_{fs}\left(s_t\right) \end{bmatrix}.$$

In the benchmark version of the model, the transition probabilities are constant, so s_t evolves according to

$$P = \begin{bmatrix} 1-p & p \\ q & 1-q \end{bmatrix}.$$

In the version of the model that allows time-varying probabilities, the transition probabilities are parameterized as follows

$$1 - p = \frac{\exp(\gamma_0 + \gamma_1 fs_{t-1} + \gamma_2 x_{t-1})}{1 + \exp(\gamma_0 + \gamma_1 fs_{t-1} + \gamma_2 x_{t-1})},$$

$$1 - q = \frac{\exp(\delta_0 + \delta_1 fs_{t-1} + \delta_2 x_{t-1})}{1 + \exp(\delta_0 + \delta_1 fs_{t-1} + \delta_2 x_{t-1})}.$$

To estimate the model, the likelihood function is constructed using the methods in Kim and Nelson (1999) then numerically maximized.

ENDNOTES

[1]For example, see Bernanke (1983), Dixit and Pindyck (1994), and Bloom (2009).

[2]This argument is an example of what Bernanke (1983, page 91) called the "bad news principle of irreversible investments." When deciding whether or not to wait before investing, the only thing that matters is bad news. When the firm chooses to not invest today, it foregoes earning returns today. In exchange for this sacrifice, the firm has the "option" to invest next period if the opportunity is profitable. As a result, today's option will be worthless next period if the good outcome occurs but is valuable if the bad outcome occurs. As a result, if additional bad news is more likely in the future, the incentive to not invest today and wait until next year is greater.

[3]Some references lending support to this claim include Leahy and Whited (1996), Guiso and Parigi (1999) and Bloom (2009).

[4]In this setting, there is asymmetric information, which means that borrowers have greater knowledge regarding the returns to their projects than banks. To structure a contract that minimizes the costs associated with this asymmetric information, banks issue debt to firms that borrow funds. If the firm fails to repay the full loan amount plus interest, then the bank pays a bankruptcy cost and claims whatever assets the firm has available.

[5]Bernanke (2007) discusses the adverse feedback loop in the context of the recent financial crisis.

[6]In the context of the Bernanke, Gertler and Gilchrist (1999) model, heightened uncertainty refers to an increase in the variance of the idiosyncratic productivity shock impinging on firms.

[7]For example, Christiano, Motto and Rostagno (2007) interpret this shock as capturing movements in the net wealth of firms that does not reflect movements in economic fundamentals. This shock can also be interpreted as an exogenous shock to the external finance premium. See also Leahy and Gilchrist (2002) or Nolan and Thoenissen (2009) for further analysis of the net wealth shock in a financial accelerator framework.

[8]See Hall and Wetherilt (2002) for details concerning how varying degrees of uncertainty affect the sensitivity of the external finance premium to balance sheet conditions.

[9]Under this scenario, the standard deviation of the idiosyncratic productivity shock mentioned in footnote 6 is slightly more than twice as large than under the baseline case.

[10]The index is calculated using principal component analysis, which estimates the coefficients on the 11 variables so that the index explains the maximum possible amount of total variation in the variables from February 1990 through the current month.

[11]Hakkio and Keeton (2009) review in detail the various events associated with movements in the KCFSI.

[12]Various types of regime-switching models have been used to study the interaction between financial conditions, output and monetary policy, such as Balke (2000), Atanasova (2003), Lo and Piger (2005), and Calza and Sousa (2006). Of course, there exists a large literature that broadly addresses the impact of financial conditions on economic activity – as just a few recent examples, see Guichard and Turner (2008), Gilchrist, Yankov and Zakrajsek (2009), and Hatzius et al (2010).

[13]The coincident timing in changes to financial stress and economic activity, discussed earlier, motivates the use of two regimes in the regime-switching model. The unusual nature of the recent crisis and recession suggests that this episode could be categorized as a separate regime, suggesting a three-regime switching model. However, estimation indicates that the early episodes share characteristics with the recent crisis. If this were not the case, then the two-regime switching model would identify the recent crisis as a separate regime, given its extreme nature, and categorize all other points in the sample as a single regime. The specification of two regimes is suggested by simply inspecting the data. An alternative specification could allow two regimes for financial stress and two for economic activity. But specifying four regimes, corresponding to the four possible combinations, would be unnecessarily complicated. Specifying two regimes is more parsimonious and captures the basic properties of the data-primarily that the episodic shifts in financial stress and economic activity roughly coincide.

[14]The economy is considered to be in the normal regime if the probability of being there is greater than 0.5.

[15]KCFSI includes the implied volatility of overall stock prices (as measured by the VIX) and it includes a variable that measures the idiosyncratic volatility of bank stock prices.

[16]Hakkio and Keeton (2009) also estimate a VAR for KCFSI and CFNAI and plot impulse response functions. The model in this paper assumes two regimes, while the Hakkio and Keeton results assume there is a single regime. Even so, their results are consistent with those reported here in the sense that their results can be roughly interpreted as an average response across the two regimes.

[17]The shock in the regime-switching model, however, is not exactly the same shock in the financial accelerator model, since the shock to the KCFSI is a composite of several different financial variables.

[18]That is, the impulse responses in Chart 6 assume that the economy remains in either the normal or distressed regime every period, even though the potential exists for the economy to shift between the different regimes.

[19]To assess whether the differences in the responses are statistically significant, a 90 percent confidence band for the mean difference in responses was calculated using Monte Carlo simulations drawing from the variance-covariance matrix of parameter estimates. The upper band of this confidence band is below zero for roughly 2 years.

[20]These relationships are only for building intuition regarding how the probabilities vary with financial and economic conditions. The exact relationships are given in Appendix B.

[21]This result is reminiscent of the finding in Hakkio and Keeton (2009) that the CFNAI does not help predict the KCFSI.

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