Using Policy Intervention to Identify Financial Stress [1]

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Abstract

This paper describes the construction of a financial stress index. Our index incorporates the level, volatility, and co-movement of a variety of financial series, rather than a single dimension of the data. To determine which time periods are ones of notable financial stress, and thus the relevant for determining the role of the level, volatility, and co-movement of our financial series, we use actions taken by policymakers. In addition to describing the construction of our financial stress index, we spend time discussing issues relevant to the general construction of stress indexes such as how a financial stress index differs from a financial conditions index, the challenges of combining different financial series into a single measure, and the role historical experience plays in index construction.

Key words: Financial Stress, Financial Markets, Financial Institutions

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1 Introduction

The purpose of this paper is two-fold. First, we describe the construction of a financial stress index. There have been a number of such indexes introduced in the past few years, such as Brave and Butters (2011), Hakkio and Keeton (2009), Illing and Liu (2006), Kliesen and Smith (2010), Kritzman, Li, Page, and Rigobon (2010), Oet, Eiben, and Bianco (2011), and Bank of America Merrill Lynch (2010). Nevertheless, the measure discussed here has some novel features which make it a useful addition to the literature. The second purpose of this paper is to provide a more detailed discussion of some of the issues regarding how financial stress indexes are constructed. [2]

The stress index described in this paper builds on the index introduced by Nelson and Perli (2005). That index is based on the behavior of 12 financial series that in turn capture market measures of risk pricing, uncertainty, and liquidity. To construct their overall index, Nelson and Perli first calculate three sub-indexes based on the level, speed of change, and co-movement of the series. They then select historical crisis periods and, using a logistic regression framework, relate the three sub-indexes to an indicator of being in a crisis period or a normal period. The results of the logit regression are used to convert the sub-indexes into an overall stress index.

The stress index described here follows the same general procedure used by Nelson and Perli, but make some adjustments. The most substantive change is the way crisis periods are selected. Nelson and Perli choose crisis periods based on opinion regarding when financial markets were under stress, a method similar to Illing and Liu (2006). In this paper, we base crisis periods on whether policymakers responsible for regulating financial institutions intervened in financial markets out of concern about systemic risks posed by troubles at a U.S. financial institution or impaired functioning in a U.S. financial market. As such, the financial stress index presented in this paper can be interpreted as indicating the degree to which conditions in financial markets are similar to periods when policymakers were concerned enough about systemic risks to intervene. While this procedural shift does not have much practical impact on the resulting index, it does mark a consequential shift in interpretation. We make a few other changes to the index described by Nelson and Perli, such as making adjustments to the volatility sub-index and modifying the composition of the 12 underlying financial series. All these changes are noted below.

[2] In other words, we intend to wax philosophical.

The structure of the stress index presented here differs somewhat from other stress indexes described in the literature and is a useful vehicle for discussing some issues related to the construction of the stress indexes. The first issue we consider is the role of a financial stress index versus a financial conditions index. A financial conditions index provides some information on the price or non-price costs of obtaining credit. A financial stress index provides more information on whether markets are functioning or behaving in a typical fashion. Both sets of information are important yet quite different; it is necessary to consider what a particular index is capturing to determine which should be applied in a particular setting.

The second issue is which characteristics of asset prices matter. Many stress indexes focus on levels of different variables, whereas the measure described here incorporates multiple dimensions. We argue that behavioral differences in markets that reflect different levels of stress indicate that looking at more than just the level is useful.

The third issue follows from the second. When more than one financial series is used, those series need to be combined in some fashion. While a variety of weighting mechanisms have been employed, principal-component based approaches and market-size weighting schemes have been the most common. The approach here draws more heavily on historical experience to determine appropriate weights.

The fourth issue is the use of historical experience to develop any stress index. Many stress indexes incorporate history to some extent by using history as guide for looking at which financial series to use in the construction of the index. The measure in this paper involves greater use of the historical experience. We use historical crisis episodes and policymaker responses to financial market stresses to gauge the importance of our sub-indexes in the construction of an overall metric of stress.

Related to the use of history as a guide is the role of updating, our fifth issue. As more time passes and the underlying series used to construct the stress index have either more placid periods or more volatile periods, one might re-interpret history. In particular, periods that might have looked stressful prior to the experience of the fall of 2008 may no longer look particularly problematic. The issue of updating impacts all financial stress indexes, but may have a larger impact on the index described here given the procedure that is used.

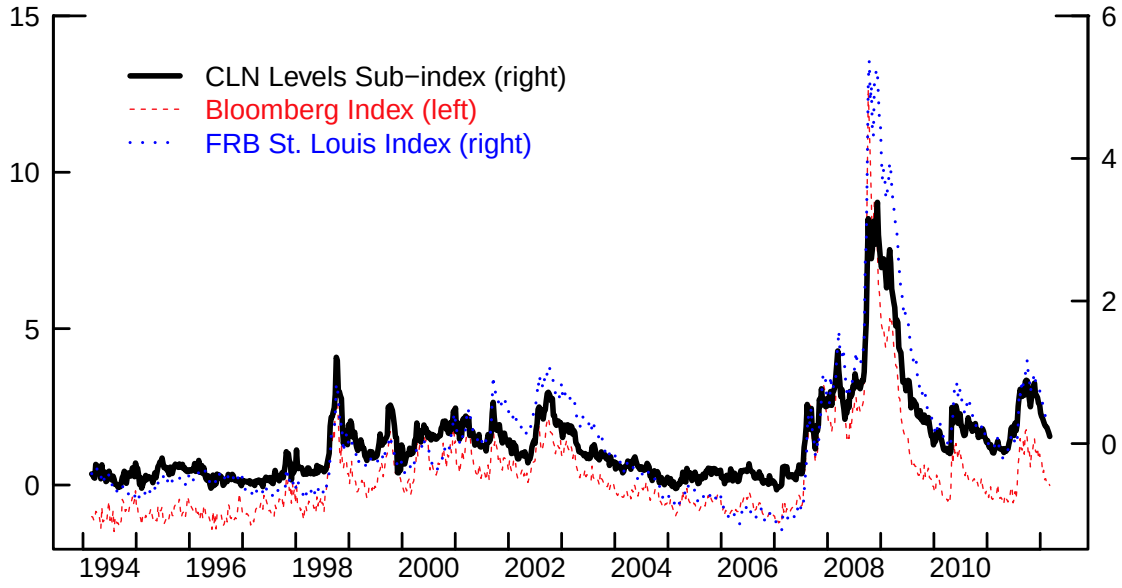
The paper is organized as follows. In section two, we describe the construction of the financial stress index. In section three, we discuss each of the issues noted here and compare our approach to other stress indexes. Section four concludes.

2 Development of the Financial Stress Index

As in Nelson and Perli (2005), the financial stress index described here is a composite of three sub-indexes, each of which in turn describes a specific aggregate characteristic of twelve underlying data series. Here, we present the basic building blocks and review the steps taken to convert these into an overall stress index. The underlying data consist of twelve financial series that cover market liquidity, risk pricing, and uncertainty.[3] All of these series would be expected to respond to financial stress. To make the series comparable, we standardize each variable. We examine the data at a daily frequency.

2.1 The Levels Sub-index

Fig. 1. Levels sub-index



Note. This series is the average of the twelve standardized variables, which are each expressed as the number of standard deviations they each are from their own long run means. The series from Bloomberg and the Federal Reserve Bank of St. Louis are in different units, and the Bloomberg index has been inverted to facilitate comparison.

In most measures of financial market stress or strain, the focus is squarely on the level of various financial market indicators, which is captured here in the first sub-index. This

[3] These variables are listed in appendix A. These 12 variables use in this paper differ slightly from those used by Nelson and Perli (2005) as we replace a few series measuring uncertainty with additional measures of stress in funding markets. These variables are similar to the financial series included in other financial stress measures such as Hakkio and Keeton (2009).

sub-index is simply the average of the twelve standardized series, plotted as the black line in Figure 1. The series are standardized such that each value is the number of standard deviations that variable's level is away from its long-run mean. As might be expected, the series is higher during periods often considered to be stressful, such as the one around the Russian default/collapse of Long Term Capital Management (LTCM) in late 1998 or during the recent financial crisis period from 2007-2009.

In constructing any one of the other recent stress indexes, authors have used many different variables as well as several different aggregation strategies. The index here uses a modest number of variables and a basic aggregation methodology for reasons of relative parsimony. We argue that this simple average provides most of the information regarding the level of the various series, and that these series capture the majority of the distinct movements associated with financial stress. Some other financial stress indexes have used more complex aggregation methods, for example principal components, rather than the average to combine series. Doing so here would have little material effect. Similarly, some indexes use many more variables in their effort to characterize financial stress. As shown in Figure 1, two other stress indexes that use more variables and different aggregation methods yield largely similar results.[4] Our point is not that our choice of variables or simple averaging approach is superior, rather that there appears to be something of a consensus regarding measures of the aggregate level of financial market variables and that our first sub-index yields the results found by other researchers and organizations.

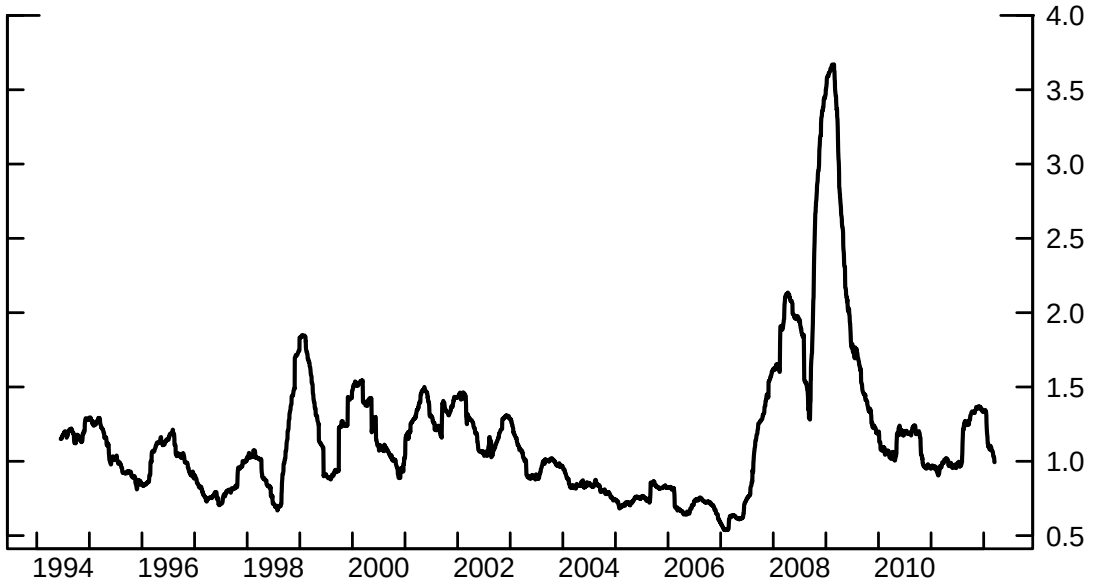
2.2 The Volatility Sub-Index

Not only do the levels of measures of risk, uncertainty, and liquidity premia tend to increase during periods of financial stress, their volatility increases as well. Typically, during the onset of a crisis, prices of risky or illiquid assets plunge, which causes risk spreads and liquidity spreads to widen sharply. Other scholars, such as Kritzman, Li, Page, and Rigobon (2010) have noted that the prices of risk assets remains especially sensitive to news as the crisis continues. This idea motivates the construction of the second sub-index, a volatility sub-index, shown in figure 2.[5] This sub-index is again an average across the twelve underlying

[4] These indexes are only two of a number of available indexes. These have the virtue of being easily available via Bloomberg under the tickers "BFCIUS Index" (Bloomberg Index) and "SLF FSI Index" (FRB St. Louis Index).

[5] Nelson and Perli (2005) use the rate of change in the 12 financial variables which captures quite well the initial plunge in asset prices and widening of risk and liquidity spreads. Focusing

Fig. 2. Volatility sub-index



Note. This series is the average across the 12 series of the square root of the sum of squared daily changes over a 4-month rolling window and is used to assess changes in the level of volatility in the twelve underlying financial market variables.

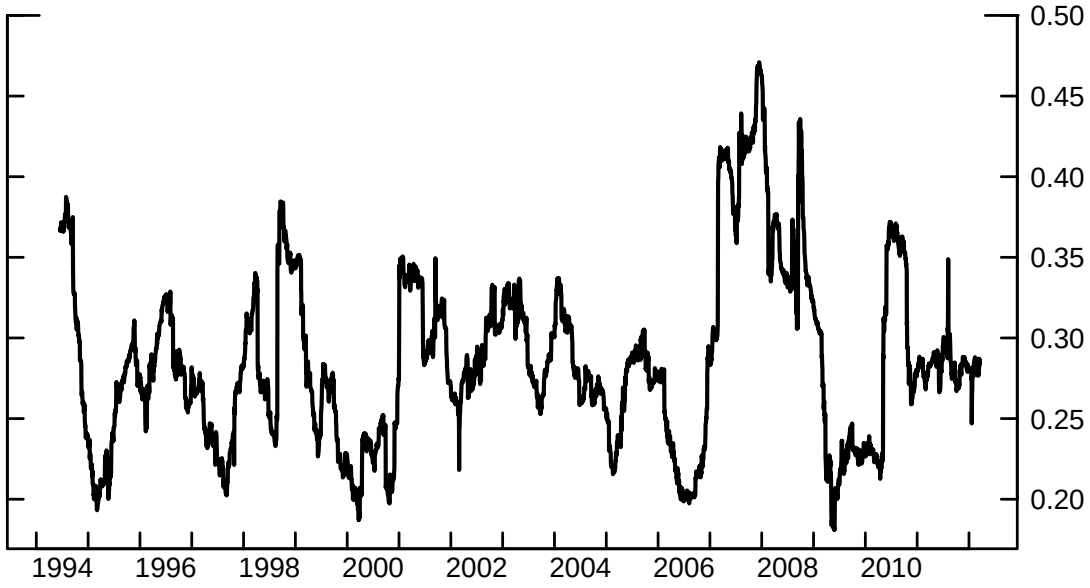
financial variables, this time looking at the sum of squared daily changes over an 4-month rolling window.[6] Changes in volatility are expected to correspond to shifts between more stressful and less stressful periods.

Our measure of realized volatility allows us to assess changes in asset price volatility that may not be as forward-looking as changes in implied volatility exercises, but give us the ability to look further back in time than options-based metrics would. The series in Figure 2 demonstrates changes in volatility during several peak stress events, most notably in the time immediately following the Lehman Brothers failure in late 2008.

on volatility tends to do a better job capturing dynamics in situations where financial stress is sustained over a longer period.

[6] Other analysis of volatility of financial series have also employed a cumulative sums of squares approach such as Inclan and Tiao (1994), who use cumulative sums of squares to detect changes in volatility in backward-looking statistical analysis. We discuss the sensitivity of our results to parameter choices such as window-size in section 2.5.1

Fig. 3. Comovement sub-index



Note. This series looks at the percentage of changes in the 12 underlying series that can be explained by a single common factor over a 4-month rolling window.

2.3 The Comovement Sub-Index

Finally, during financial stress episodes, asset prices tend to move together more; "the correlation goes to one" in colloquial terms. The third sub-index looks at the time-varying level of comovement among the variables. To capture the changing co-movement, we again follow Nelson and Perli (2005) and calculate the principal components of the changes in the twelve series using 4-month rolling windows. The comovement sub-index is the share of total variation explained by the first principal component in each window. The higher this measure, the more of the changes in the underlying series can be explained by a single common factor. This sub-index is plotted in Figure 3.

The data in Figure 3 show that the percentage of variation explained by a single common factor was also at its peak during the financial crisis of 2007-2009, but that the events of 2007-2009 were less of an outlier than was the case in the other sub-indexes.

2.4 Historical Stress Episodes

To combine the three sub-indexes into a single index, it is useful to consider how they behaved during historical stress episodes. To determine what constituted a stress event, we start by

identifying interventions by policymakers that occurred out of concern that troubles at a U.S. financial institution or the impairment in functioning of a U.S. financial market might present systemic risks to financial stability and have negative consequences for economic activity. The policymakers we look at include the Federal Reserve, the Federal Deposit Insurance Corporation, and the Treasury Department; although, in the final analysis, interventions by the Federal Reserve end up being far more common than those of other agencies. The types of interventions that qualify are fairly broad, as our rule is to include all actions taken by policymakers that are done specifically to protect financial market functioning. For example, the action by the Federal Reserve to convene a conference of the heads of major financial firms to organize the rescue of Long Term Capital Management counts as an intervention, as does the extraordinary provision of liquidity by the Federal Reserve on and in the days following September 11, 2001, and of course the facilities of the three agencies designed to confront the market functioning concerns of 2007-2009. We count as an intervention the announcement of any new action, or any escalation of previous interventions, but we do not count the implementation of a given action. [7] The complete list of interventions is provided in Appendix B. We do not consider changes in monetary policy to be interventions, as the motivating factor for that action is considered to be more macroeconomic, and less in consideration of financial market functioning, per se. [8]

We consider the stress episodes to be the periods extending from four weeks before an intervention is announced to four weeks after this announcement (an eight week window). [9] This time frame is meant to capture the majority of the period in which the stress built to a level that resulted in policymaker action, as well as a period following the action that includes a lag for implementation of the policy. A sensitivity analysis of the choice of window size demonstrates that the size of the total window around the policy announcement date only becomes a significant factor if it is shrunk down to four weeks or below. Windows of five to sixteen weeks produce similar results, so a choice was made to remain on the smaller end of the spectrum to avoid false positives.

Some of the interventions we consider are ones that occur over a short period of time, such as

[7] For example, we include the announcement of the Federal Reserve's Term Auction Facility (TAF), as well as announcements of increases in its size or maturity structure, we do not include individual TAF auctions themselves.

[8] We also do not include actions taken to prevent stresses related to the century date change. This episode is an idiosyncratic period in which the timing of a potentially stressful event was perfectly forecastable so the announcement of programs occurred well in advance of any realized stress.

[9] The exception is September 11, where given the nature of the event, there was no build-up of market stress. Thus we include only a four-week window following the event.

the intervention following the attacks of 9/11, while other interventions resulted in facilities that were in use for some time, such as the Term Auction Facility. In both cases, we look only at the eight week window surrounding the announcement. By looking at that eight-week window, even in cases in which the announcement concerned the creation of a facility that would be in place for some time, we focus on conditions that prevailed in financial markets around the time that the policymakers decided to intervene.

We treat periods outside those policy intervention windows as "normal." In order to follow our rule for determining stress period, we do not classify the last 4 weeks of the data as either a stress period or a normal period; this is explained further in Section 3.5. The twelve underlying series are all available consistently since early 1994. Given the rolling window structure of the data, all three sub-indexes become available starting in July of 1994. The last observation used here is from March 16, 2012. [10]

2.5 Logistic Regression Model

To look at how the sub-indexes behaved in the stress periods, we use a logistic regression framework and regress a stress episode indicator on our three sub-indexes, levels (L), changes in volatility (V), and comovement (C). The regression takes the form:

$$p_t = P\left(\beta_0 + \beta_L L + \beta_V V + \beta_C C\right) \tag{2.1}$$

The results appear in Table 1. Higher levels of all three of the sub-indexes are associated with being in a stress period. It is notable that, despite the common spike across each of the three sub-indexes in the financial crisis of 2007-2009, each of these sub-indexes remains statistically and economically important in helping us to define an overall index of financial stress. After taking account of the different variances in the sub-indexes, changes in the sub-index capturing the co-movement of the different variables appears most strongly associated with the shift from a normal to a stress period, while the sub-index capturing the change in asset market volatility has the smallest, though still significant, relative impact in determining a stress period.

[10] The most up-to-date version of the stress index series is available from the authors upon request.

Table 1: Logistic regression model estimation results

	Estimate	Std. Error	z value	$Pr(>\|z\|)$
Intercept	-10.2878	0.5382	-19.115	$< 10^{-15}$
Levels (L)	4.5623	0.2611	17.473	$< 10^{-15}$
Volatility (V)	0.8399	0.2495	3.366	0.000763
Comovement (C)	18.6486	1.2607	14.792	$< 10^{-15}$

2.5.1 Possible Multicollinearity Issues

The significance of the volatility subindex (V) within the logistic regression estimated in equation 2.1 is sensitive to changes in underlying structure of the index calculations, particularly to the window size used in the volatility calculation. This appears to be an issue of multicollinearity due to the similarity between the levels and the volatility measure, driven in part by the large spike in both associated with the 2008-2009 peak of the recent financial crisis. The correlation between the series under the current specifications is high at this point in time.

Table 2: Correlation of Three Subindexes

	Levels (L)	Volatility (V)	Comovement (C)
Levels (L)	1	0.861	0.250
Volatility (V)	0.861	1	0.181
Comovement (C)	0.250	0.181	1

However, this is being driven in part by the two years at the peak of the recent financial crisis, and was less a concern prior to that point. Measures of severity of multicollinearity are somewhat challenging, because all samples possess some degree of multicollinearity. [11]

[11] Several papers examine the difficulties of attempting to qualify the severity of the impact of multicollinearity in economics and statistics samples; a brief critique of some of this work is O'Hagan

While the results remain sensitive to this aspect of construction, we believe that the level and the volatility both play an important roll in measuring financial market stress and elect to continue using both subindexes. As discussed in more detail in section 3.5, the index values for the present time will be altered as more data and more events accumulate in the future. The concern of multicollinearity is expected to diminish over time.

2.6 Index Construction

We can use the coefficients from the logistic regression in equation (2.1) in at least one of two ways. The first method would be to simply use the coefficients as weights to combine the three sub-indexes that describe the three characteristics of the data we feel help to describe financial stress:

$$S_1 = \beta_L L + \beta_V V + \beta_C C \tag{2.2}$$

This version of the index is shown in Figure 4. [12]

As we use a logistic regression framework to derive the coefficients it is also natural to express the financial index as the estimated probability of being in a period of stress. This estimated probability is given as:

$$S_2 = \frac{e^{(\beta_0 + S_1)}}{1 + e^{(\beta_0 + S_1)}}, \tag{2.3}$$

and is shown in Figure 5.

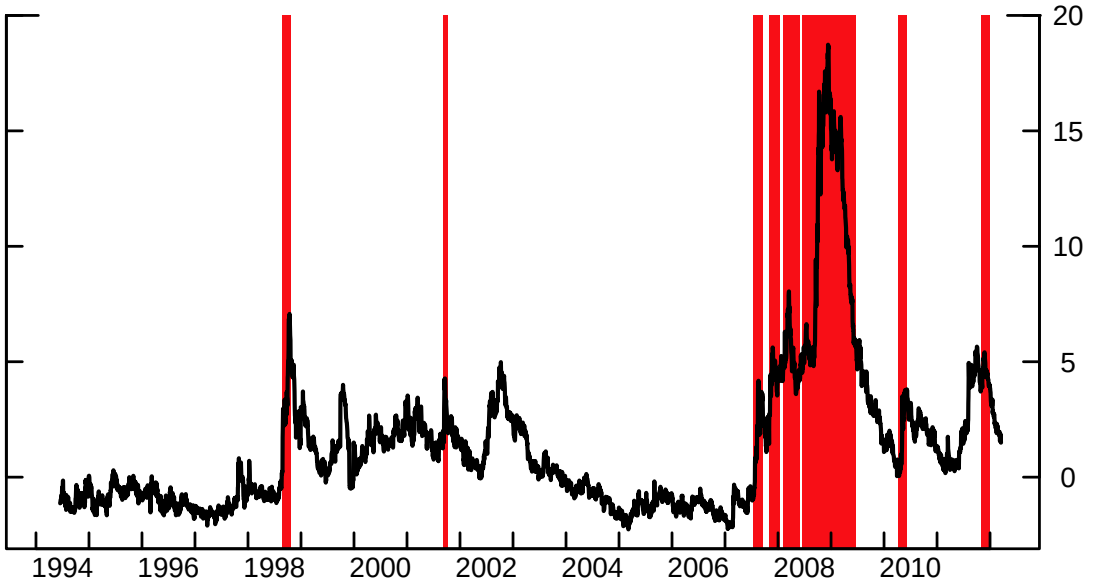
2.7 Interpreting the output

To be clear, the sense in which this index is expressing a probability is limited to the context of identifying current conditions. The probability in Figure 5 is the probability that financial

and McCabe (1975), and a short summary is available in Greene (2002).

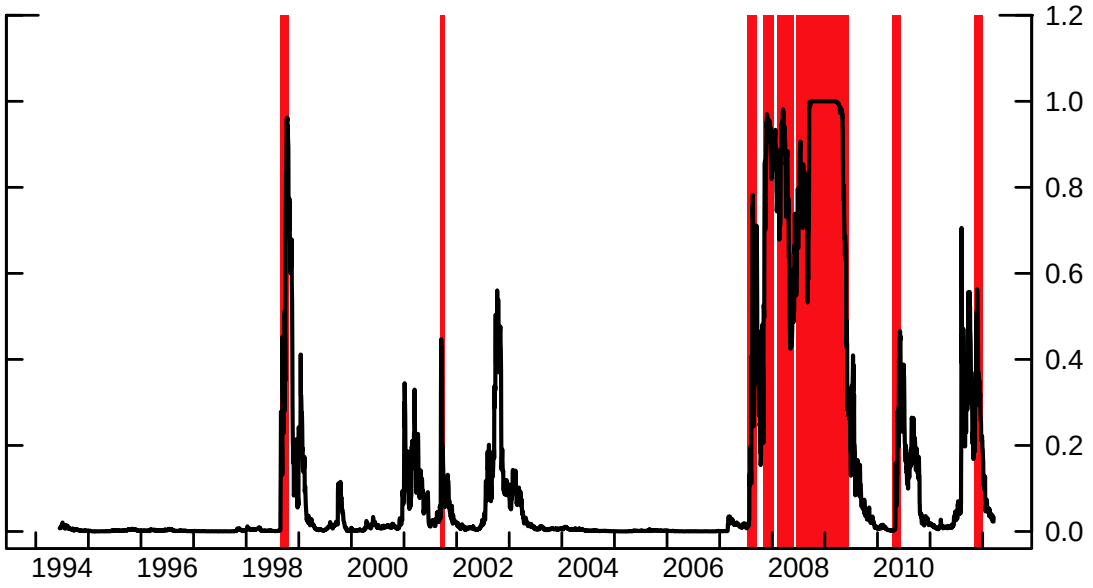
[12] There are various arguments about using a continuous measure as opposed to a more discrete one. Oet, Eiben, and Bianco (2011) assert that is it easier to identify emerging pressures using a more continuous measure, and they argue that stress tends to come in varying degrees, so more continuous measures reflect that variation.

Fig. 4. Weighted-sum Financial Stress Index



Note. This index is built using equation (2.2) *and is the more continuous measure of stress of the two we generate. The red bars indicate policy intervention windows.*

Fig. 5. Probabilistic Financial Stress Index



Note. This index is built using equation (2.3) *and is the more discrete measure of stress generated. The red bars indicate policy intervention windows.*

markets are currently experiencing conditions identical to those identified as stress episodes.

Of course, policymakers have access to the information entering the analysis in real time

anyway, so they would likely know if there was a financial crisis or not. What this index provides is a sense of historical context for those opinions. Rather than thinking of this as a probability of stress episode, one should think of it as a statistical measure of the similarity between current conditions, and those that prevailed at a time already identified as a crisis. The more continuous measure in Figure 4 is simply a smoother interpretation of the same information, which is useful to researchers in need of a more continuous series to study effects of stress on other areas of the macroeconomy.

We emphasize that the stress index presented here is descriptive of financial conditions and is not designed as an early warning system (i.e. it is a coincident indicator). Specifically it does not provide an indication of the likelihood of a financial crisis over any particular time horizon.

3 Issues related to the construction of a financial stress index

This section covers the issues related to construction of any financial stability index by describing in broad terms what they are and what they are not and describing a few features of our index that enable it to provide accurate and timely analysis with a minimum of subjectivity moving forward.

3.1 Financial Stress versus Financial Condition

A financial stress index (FSI) is meant to capture something about the functioning or fragility of financial markets. [13] Impaired functioning might take the form of increased difficulty in executing transactions or an inability of intermediaries to fund their market-making operations at usual tenors. Fragility might take the form of exceptionally heightened sensitivity to new information or shocks (as in Kritzman, Li, Page, and Rigobon (2010)). Hakkio and Keeton (2009) note that financial stress tends to be associated with increased uncertainty about the fundamental value of assets, increased uncertainty about the behavior of other investors, increased asymmetry of information, flights to quality, and flights to liquidity; all of these items would reduce functioning in markets and might result in market dislocations. A financial stress index is a device to distill the information about financial market functioning

[13] See De Brandy and Hartmann (2000) for a detailed survey of issues related to systemic risk.

and fragility. [14]

Having a measure of the stress in financial markets and being able to identify difficulties early can enhance policymakers' ability to take steps to alleviate the crisis (International Monetary Fund (2009)). In this regard, our index might be particularly apt as it provides a comparison of current conditions to periods when policymakers opted to intervene out of concern regarding financial stability.

A financial conditions index (FCI), by contrast, is more useful in assessing the macroeconomic implications of developments in the financial sector (see English, Tsatsaronis, and Zoli (2005)). Information about such things as the cost of borrowing for households, cost of capital for business, real exchange rates, and household wealth, has implications for spending, investment, output, and inflation. An FCI extracts information from a wide variety of indicators about these items and condenses it into a single measure. One way to construct an FCI is to extract one or more principal components from a large number of financial series that reflect items such as borrowing costs and wealth. Researchers sometimes adjust the underlying financial series to remove the impact of lagged real economic conditions prior to the principal component computation. By constructing the FCIs in this way, it is hoped that they provide an indication about some financial conditions that cannot be measured directly, such as risk aversion and sentiment. As shown by English, Tsatsaronis, and Zoli (2005) and Hatzius, Hooper, Mishkin, Schoenholtz, and Watson (2010), FCIs can be useful in forecasting economic activity. Thus, such indexes are also useful for policymakers, but more in connection with setting monetary (or fiscal) policy.

FSIs and FCIs serve quite different purposes; however, such distinctions are not always clear in the literature. [15] Clouding the issue, FSIs and FCIs may be constructed in similar ways and

[14] It is also useful to that financial stress indexes are distinct from indexes that measure stress of individual institutions. Market and institutional stress are highly related but may play different roles in economic interactions and may require different policy responses. For examples of indicators of stress at individual institutions see, for example, Acharya, Pedersen, Philippon, and Richardson (2010), Adrian and Brunnermeier (2011), and Carlson, King, and Lewis (2011).

[15] Some, such as Borio and Lowe (2002) have argued that there may ultimately be an indirect connection between the two. They argue that easier financial conditions can promote more rapid credit growth and increased leverage that increase the likelihood of a crisis/high stress period. Hakkio and Keeton (2009) find that their financial stress index is correlated with changes in bank lending standards as reported on the Federal Reserve's Senior Loan Officer Opinion Survey. Others have taken the stance that financial instability matters only to the extent that it affects the real economy and stress indexes ought therefore to be based on the size of the shock provided to the real economy, as in De Nicolò and Lucchetta (2011); this approach complicates the distinction between credit conditions and financial stress. Finally, financial stress and conditions must be related in the

may include some similar indicators. For example, a number of such indexes are constructed using principal component analysis. The spread between yields on corporate bonds and Treasury bonds serves as a measure of risk and the cost of financing and is often included in both FSIs and FCIs. However, as noted above, other items can differ. FCIs often include other measures of the cost of funding, such as indicators of lending standards, or measures of household wealth. FSIs often include some measures of liquidity in financial markets and of uncertainty. It is important for the creators and users of these FSIs and FCIs to be careful in considering how they are constructed and what they measure to effectively use and interpret them. In constructing the index in this paper, we have tried to select underlying series that reflect the functioning and fragility of markets.

More importantly, we focus on policy interventions that related to strains in financial markets or on financial institutions. These interventions focus on market functioning concerns that we associate with financial stress. We specifically exclude monetary policy actions from our list of policy interventions as these actions focus more on the cost of credit and thus financial conditions. Given the types of periods we view as related to financial stress, as well as the underlying financial series we use, we consider our index to be clearly tied to financial stress.

3.2 Dimensions of asset price developments

Many financial stress indexes focus on the level of variables such as risk spreads, spreads that are indicative of liquidity premia, and indicators of the level of uncertainty such as measures of implied volatility. These factors certainly matter and they are included here as well.

However, as noted above, asset prices are often described as displaying additional characteristics during financial crises. A stress episode is often characterized by rapid changes in asset prices. Hakkio and Keeton (2009) argue that greater volatility in the market prices of the assets reflects the heightened uncertainty about fundamental values that generally accompanies financial stress. News and economic shocks can thus result in large reactions in asset prices. Often episodes of financial stress are associated with an initial sharp plunge in asset prices, but large movements in asset prices may continue as long as strains in markets persist. The sub-index based on the volatility of asset prices is meant to capture this dynamic of financial stress. As indicated by the logit analysis in Table 1, this measure of asset price movements is indeed generally associated with periods considered to be stressful.

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extreme in that when markets stop functioning, funding conditions are presumably very tight.

Another characteristic of financial stress periods is that asset prices tend to move more together. The increased co-movement may reflect heightened concerns about macroeconomic or other broad factors that will impact a wide range of asset prices. The International Monetary Fund (2009) suggests that tail risk dependence can boost co-movement and be a measure of systemic risk. Heightened co-movement could also be related to more microeconomic issues such as increased use of quantitative risk models that are similar across financial institutions and thus point to common responses to asset price changes (Hendricks, Kambhu, and Mosser (2007)); such common responses may be more pronounced during periods when institutions are looking to reduce risk and de-leverage. the sub-index based on the share of the movement in the twelve series explained by the first principal component is meant to capture this increased co-movement. Kritzman, Li, Page, and Rigobon (2010) also propose measuring the share of variation in markets explained (or "absorbed") by a limited number of factors as an indicator of systemic risk. They argue that this measure indicates the extent to which markets have become tightly coupled and thus more fragile in the sense that negative shocks can propagate more quickly and broadly. Both their measure and our measure tend to rise during stress periods.[16] The logit analysis also shows that a higher degree of co-movement is associated with a crisis episode.

We consider the addition of measures of the volatility and co-movement of asset prices to be an important contribution to the literature on the construction of financial stability indexes.

3.3 Weighting Different Series

When using different series, it is necessary to weight them. Depending on the number of series, these weighting schemes can be quite complex; Brave and Butters (2011) use over 100 different series that are available at different frequencies. There are a variety of weighting options available and many alternatives have been used in the literature on financial stress indexes (and in the literature on financial conditions indexes). Equal weightings would imply using a simple average, but such a scheme is not commonly used. A more common approach is to use a principal component analysis so that series that move more together are given more

[16] While the co-movement measure proposed by Kritzman, Li, Page, and Rigobon (2010) and the one calculated here attempt to capture similar ideas, they are constructed somewhat differently. Kritzman, Li, Page, and Rigobon (2010) focus on co-movement of assets within the same market, such as equity price indexes for a range of industry groups, whereas our measure looks across markets (equity, fixed income, funding). Additionally, our measure is looking not at the comovement of the levels of the variables, but of the changes in the variables. Both measures use rolling windows, but our measure uses a much shorter time horizon (4 months as opposed to 500 days).

"weight" in the overall index while series that display idiosyncratic movements are given lower weights (Hakkio and Keeton (2009), Kliesen and Smith (2010)). Illing and Liu (2006) discuss a variety of weighing schemes including principal components, market size weights, variance-equal weights, and weights using the position within the variables cumulative distribution functions; then find that the credit weights perform the best among the schemes they test.

Some schemes construct sub-indexes based on different markets or themes and then combine these sub-indexes into an aggregate index. Generally underlying financial series are included in only one sub-index. Oet, Eiben, and Bianco (2011) use such a modular technique that combines several series related to a particular market into a sub-index and then combine these sub-indexes using a weighting scheme based on Flow of Funds credit data (a market size approach). The Bank of America Merrill Lynch (2010) financial stress index is constructed using sub-indexes based around different themes, such as risk, skews, and flows (and sub-sub-indexes are created within these). Component series are converted to z-scores, measuring distance from historical norms, in order to produce the aggregate series.

In the financial stress index described in this paper, there are essentially two weighting schemes. In the construction of the sub-indexes, each of the twelve underlying financial series is given equal weight. (This is true even for the co-movement indicator that uses principal components as it is based on the share of the twelve series explained by the first principal component rather than the first principal component itself.) We use the same twelve series in the creation of each of the three sub-indexes and focus on different dimensions of the price movements. In the construction of the overall index, we use historical experience and logit analysis to weight the sub-indexes. Thus, this weighing scheme involves looking more at which pricing dimensions' levels, volatility, co-movement's are more relevant for signaling stress than it does in determining which particular asset prices are better at providing signals of stress.

3.4 Use of Historical Experience

Historical experience plays a role in many financial stress indexes. Sometimes the role history plays is subtle. When constructing a financial stress index, it is impossible to base such an index on the universe of financial asset prices. Thus, scholars generally limit the series examined in the construction of a financial stress index to those series that reacted notably during the crisis.

History is used as a guide in other ways as well. In order to assess the performance of a stress index, the creators of the stress index will check to see how strongly it is associated with historical stress episodes.[17] Sometimes these stress episodes are determined quantitatively or according to some rule: Demirguc-Kunt and Detragiache (1998) look at whether problem assets in the banking sector reach a particular threshold or there is a large-scale nationalization of the banking system, Bordo and Schwartz (2000) focus on the inability of sovereign nations or the private sector to service debts, while Reinhart and Rogoff (2009) use bank runs or emergency measure taken to assist the banking system.

In other cases, the stress episodes are determined more subjectively. Illing and Liu (2006) use an internal survey of Bank of Canada staff to determine stressful episodes in Canadian history. More than just using historical episodes to judge the quality of a proposed index, Illing and Liu use the historical episodes to select the most preferred stress index from among a number of potential candidate series (where these candidate series reflect different ways of combining different financial series). Blix Grimaldi (2010) uses the prevalence of selected words in European Central Bank Monthly Bulletins as a guide for whether periods ought be be characterized by more normal or stressful financial conditions. This approach, like Illing and Liu, also draws on assessments by central bank staff though more indirectly.[18] While there is some subjectivity in terms of which words are selected as keywords, the counting process provides a rule-based framework.

Thus, use of historical episodes has played an important role in the development of other financial stress index. The procedure used here involves history to a slightly greater degree in that we use historical episodes to judge and weight the importance of our sub-indexes. Historical stress episodes are determined based entirely the actions of policy makers in reaction to events in financial markets; the procedure somewhat similar to Illing and Liu but based on a more rigid assessment criteria: policymaker action.

In the absence of the framework used here, it is not immediately obvious how one might combine these three sub-indexes given their different nature. However, using history in this way has trade-offs. On the positive side, it provides a framework for weighting the three sub-indexes that describe different facets of the data with minimal subjective decision-making in favor of a rules-based system for assessing stress periods. One limitation of this framework

[17] In an interesting contrast, Oet, Eiben, and Bianco (2011) do not benchmark to historical episodes but to measures of implied volatility.

[18] Grimaldi then uses a methodology similar to the one used here and by Nelson and Perli (2005) where she uses a logistic regression to test whether composite sub-indexes reflecting levels and rate-of-change of underlying financial series are associated with normal versus stressful periods.

is that, by construction, no shades of gray exist in the definition of a stress episode. A policy intervention is a policy intervention, so to speak. For example, a reduction in the Federal Reserve's primary credit spread receives the same weight as the introduction of the FDIC's program to guarantee the debt of banks and bank holding companies, two actions which would appear to differ substantially as to the underlying stress they indicate.

At a finer level of distinction, the construction of an index based on the logit regression assumes that the financial system is either in a crisis or not in a crisis, when it fact the degree of stress may produce many more shades of gray (see, for example, Oet, Eiben, and Bianco (2011)). In particular, some near crisis episodes that provide information on asset price behavior during stress may be missed. However, as argued by some, such as Kritzman, Lowry, and Van Royen (2001), International Monetary Fund (2009), and González-Hermosillo and Hesse (2011), models of regime shifts seem to fit asset price developments during stress episodes fairly well, which would suggest our more dichotomous approach may be reasonable. [19] We could allow for some gradation in the severity of financial crises by using an ordered logit and distinguishing between major stress episodes and minor stress episodes, but there is a practical limit to the granularity with which episodes can be classified. Moreover, the interventions by policymakers on which we base our index are more easily thought of as dichotomous–whether an intervention has occurred or not–rather than a continuous measure. [20] Note that this drawback relates to the construction of our index and not to the resulting output. We can construct a financial stress index as the (coefficient) weighted sum of the sub-indexes that can be continuous–either untransformed or transformed using a logit conversion. Moreover our sub-indexes are continuous measures. Nevertheless, the discrete nature of the crisis classification used in the construction of the stress index might have the propensity to emphasize particular factors more than others.

[19] Further, Hendricks, Kambhu, and Mosser (2007) argue that financial crises are characterized by market gridlock amid a coordination failure. Such a characterization is also suggestive of a more dichotomous regime shift.

[20] Our indicator of policymaker intervention includes both the period shortly before and shortly after the action. Interventions have typically not immediately soothed markets so we argue that it is appropriate to include the post-intervention period. Nevertheless, it should be kept in mind that the market developments during this period do include any response to policymaker action. Boyd, De Nicolò, and Loukoianova (2010) provide some further discussion of this point.

3.5 Role of updating

Over time, new information can have an impact on the financial stress index. Depending on the type of weighting scheme used to compare different sub-series, new data or shifting correlations can impact the financial stress index. Sullivan, Peterson, and Waltenbaugh (2010) provide some evidence regarding how the distribution of many asset prices, especially with respect to the tails of the distribution, changed with the addition of asset price movements in late 2008 following the failure of Lehman Brothers. This new data can have a large impact on measures of financial stress. If the creation of the financial stress index uses principal component analysis over the whole sample period, then shifting correlations may result in shifting weights being applied to the series and alter the resulting first principal component over the life of the series. There are some approaches, such as using principal components over rolling windows, a dynamic principal components analysis as in Brave and Butters (2011) or market size weighting schemes such as Oet, Eiben, and Bianco (2011), that alleviates this issue in part or in whole.

Another related issue is that if standardized series are used then the addition of exceptionally volatile or calm periods can shift the standardization parameters in such a way as to shift the stress index over time. This adjustment is necessary because the means and variance of the underlying series will evolve.

Given the use of history in the construction of the stress index presented here, there is an additional channel through which new information can impact the stress index. Each time data is updated it must be re-standardized, then the logit must be re-estimated to determine how the new sub-series are related to the crisis episodes. In doing so, we must also update whether any new periods covered in the data were crisis periods or not such that there is correspondence between the period used to standardize the data and the period used in the logit estimation. Over time, as new crisis and normal periods are added, the commonalities between stress periods in the behavior of the levels, rate of change, and co-movement of different asset prices may vary. These changes may result in changes to the coefficients in our logit regression. Thus, the history of the financial stress index will change over time as new information arrives.

One benefit of the rules-based structure of this index helps to ease the challenges of updating. Because the rule stipulates a 4-week window on either side of a policy action, we can always know whether or not any period of time–up to 4 weeks prior to the current date–is a stress episode or not. Thus, our decision rule keeps us from having to repeatedly have a conversation

about whether or not the current period should be labeled a stress period or not.

4 Conclusion

This paper describes a financial stress index that incorporates the level, volatility, and co-movement of asset prices. Historical experience is used as a guide about the relative importance of these particular factors. The use of history and three factors has advantages and disadvantages. The trade-offs involved are discussed in depth in the context of more general construction of financial stability indexes. In general, we view the approach taken here as an important compliment to the construction of financial stability indexes by others.

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A Underlying Data Series

The data used to build the index are:

- Liquidity
  - On-the-run liquidity premium for the 2-year Treasury
  - On-the-run liquidity premium for the 10-year Treasury
  - Federal funds target – yield on the two-year Treasury
  - Spread between the rate on 3-month certificates of deposit and 1-month certificates of deposit
- Risk Spreads
  - Yield spread between AA-rated corporate bonds and Treasury securities
  - Yield spread between BBB-rated corporate bonds and Treasury securities
  - Yield spread between high-yield corporate bonds (7-year) and Treasury securities
  - Spread between the 3-month LIBOR and the 3-month Treasury rate
  - (12-month ahead earnings/S&P 500 earnings) – yield on 10-year Treasury (a measure of the equity premium for stocks
- Investor Uncertainty
  - 180-day Eurodollar implied volatility
  - Implied volatility on the 10-year Treasury note
  - S&P100 implied volatility (VXO)

B Policy Intervention Events

This list contains the policy intervention events used in the logistic regression in section 2.5.

Date	Intervention Event
September 23, 1998	Federal Reserve coordinates purchase of LTCM by consortium of 14 firms
September 11, 2001	Federal Reserve responds to liquidity shortages caused by the physical limitations of 9/11
August 10, 2007	Federal Reserve adds $38 billion in reserves and issues a statement reaffirming its commitment to provide liquidity
August 17, 2007	Federal Reserve reduces primary credit spread by 50 basis points and allows 30-day term financing
August 21, 2007	Federal Reserve reduced minimum fee rate for SOMA securities lending
November 26, 2007	Federal Reserve eases terms on SOMA lending
December 12, 2007	Federal Reserve announced creation of the TAF
March 7, 2008	Federal Reserve announces it is expanding the size of the next two TAF auctions
March 11, 2008	Federal Reserve announces the creation of the TSLF
March 14, 2008	Federal Reserve lends to Bear Stearns
March 16, 2008	Federal Reserve facilitates purchase of Bear Stearns by JPMC and creates PDCF
May 2, 2008	Federal Reserve increases the size of TAF auctions
July 13, 2008	Federal Reserve authorizes the Federal Reserve Bank of New York to lend to Fannie and Freddie should lending prove necessary
July 30, 2008	Federal Reserve extends term lending on TAF to 84 days
September 7, 2008	Treasury places Fannie and Freddie into conservatorship & provides liquidity backstops for GSEs
September 15, 2008	Federal Reserve expands PDCF eligible assets & conducts two open market operations
September 16, 2008	Federal Reserve extends line of credit to AIG
September 19, 2008	Federal Reserve announces AMLF & Treasury guaranties MMMFs
September 28, 2008	FDIC announces assistance for Wachovia merger & Federal Reserve increase size of TAF
October 6, 2008	Federal Reserve further expands size of TAF
October 7, 2008	Federal Reserve announces creation of the CPFF
October 8, 2008	Federal Reserve decreases fees on SOMA lending
October 14, 2008	Treasury announces $250 billion for preferred stock purchases & FDIC announces TLGP
October 21, 2008	Federal Reserve announces the creation of the MMIFF
November 23, 2008	Federal Reserve, Treasury and FDIC agree to provide Citigroup a package of guarantees, liquidity access, and capital
November 25, 2008	Federal Reserve announces the TALF
December 30, 2008	Treasury announces the purchase of preferred stock in GMAC
January 7, 2009	Federal Reserve expands set of institutions eligible to borrow under the MMIFF
January 16, 2009	Treasury, FDIC and Federal Reserve announce a rescue package offer for BofA similar to the one for Citigroup
January 30, 2009	Federal Reserve liberalizes rules related to AMLF
February 25, 2009	Federal Reserve, OCC, FDIC, and OTS announce details of the Capital Assistance Program
March 23, 2009	Treasury announces the details of the public-partnership investment plan.
May 1, 2009	Federal Reserve announces the inclusion of the CMBS in the TALF
May 7, 2009	Bank stress test results and capital-raising requirements for SCAP firms officially announced
May 19, 2009	Federal Reserve further expands collateral eligible under the TALF
May 11, 2010	Federal Reserve agrees with foreign central banks to reestablish temporary dollar swap facilities
November 30, 2011	Federal Reserve agrees with foreign central banks to lower the cost of temporary dollar swap facilities