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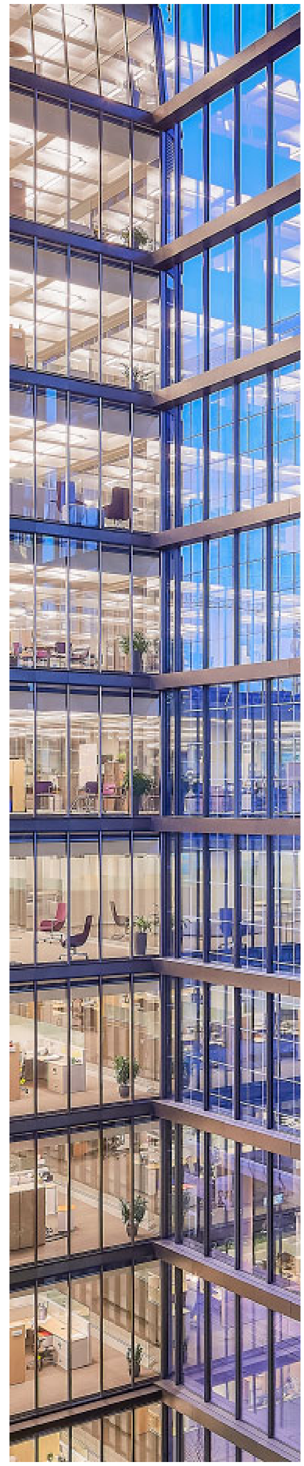

Canadian Financial Stress and Macroeconomic Conditions

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Abstract

I construct a new composite measure of systemic financial market stress for Canada. Compared with existing measures, it better captures the 1990 housing market correction and more accurately reflects the absence of diversification opportunities during systemic events. The index can be used for monitoring. For instance, it reached a peak during the COVID-19 pandemic second only to the 2008 global financial crisis. The index can also be used to introduce non-linear macrofinancial dynamics in empirical macroeconomic models of the Canadian economy. Macroeconomic conditions are shown to deteriorate significantly when the Canadian financial stress index is above its 90th percentile.

Topics: Central bank research; Financial markets; Financial stability; Monetary and financial indicators

JEL codes: C32, G01, E44

1 Introduction

Extreme financial market stress around the COVID-19 pandemic and the associated real economic damages highlight the importance of gauging the extent of macrofinancial spirals. I develop a new measure of financial market stress for Canada consistent with the narrative of stressful events and illustrate the role of financial stress as a non-linear propagation of shocks in the Canadian economy.

Periods of systemic financial stress are characterized by a sharp correction happening simultaneously on those key markets that provide the most important sources of funding to the Canadian economy. The Canadian financial stress index (CFSI) builds on the methodologies of Illing and Liu (2006), Hollo, Kremer, and Lo Duca (2012) and Duprey, Klaus, and Peltonen (2017). Using data from 1981 onward, I consider financial stress that spans seven market segments, namely the equity market, the Government of Canada bonds market, the foreign exchange market, the money market, the bank loans market, the corporate bonds market and the housing market. The system-wide nature of financial stress is reinforced by combining correlation and importance weights. Correlation weights ensure that the index only picks up episodes when several markets are severely impaired at the same time. Importance weights ensure that the markets most important for the funding of the Canadian economy contribute more to the stress index. In other words, the index emphasizes the periods where it is harder for investors and borrowers to substitute away assets that face market stress.

The innovation is twofold compared with the two existing measures of financial stress for Canada (Illing and Liu 2006; Cardarelli, Elekdag, and Lall 2011). First, they do not cover stress on the housing market, although it is a crucial source of shocks for the Canadian economy. Indeed, Canada experienced a major housing market correction in the 1990s. Because of its elevated imbalances, the housing market is an important source of concern for policy-makers in Canada (International Monetary Fund 2017). Second, existing indexes are computed as the sum of stress on individual markets and do not capture the co-movement across market segments when negative shocks hit: systemic stress should be greater than the sum of stress on individual markets (Duprey, Klaus, and Peltonen 2017). I show that the peaks of the CFSI are better aligned with episodes of stress that are most likely to affect the real economy. This is important for accurately quantifying the role of financial stress during periods of macroeconomic downturns.

The CFSI can be useful for at least two purposes. First, it is a useful metric for benchmarking the intensity of financial stress against historical episodes. For instance, the stress associated with the COVID-19 pandemic reached levels comparable only with the 2008 global financial crisis.[1] Second, financial market stress is often associated with non-linear macrofinancial dynamics that can amplify negative shocks. Above its 90th

[1]The April 2020 *Monetary Policy Report* features the CFSI (Chart 9, Bank of Canada 2020).

percentile, the CFSI is typically associated with more fragile macroeconomic conditions in Canada. I illustrate how financial stress and worsening macroeconomic conditions amplify each other in the context of a Bayesian threshold vector autoregressive model (Bayesian TVAR). The model explicitly relates episodes of high financial market stress, as captured by the CFSI, with a deeper correction of gross domestic product (GDP).

In practice, the CFSI is part of the tool kit for the risk management framework of the Bank of Canada (Poloz 2020). It is an input to non-linear macrofinancial models used to gauge risks, such as the risk amplification macroeconomic model (RAMM) (Traclet and MacDonald 2018) and the growth at risk model (Duprey and Ueberfeldt 2020). Indeed, non-linear macroeconomic models are becoming increasingly popular in an attempt to capture tail events by postulating the existence of different macroeconomic dynamics in periods of severe financial stress. In the context of a Bayesian TVAR, monetary policy has a more severe impact on output when financial conditions are tighter (for the United States: Balke 2000; for Canada: Li and St-Amant 2010). For the United Kingdom, Chatterjee et al. (2017) find support for a feedback loop between real and financial stress. Another strategy relies on a Markov-switching VAR, where the change in regime is driven by an unobserved Markov chain rather than an observable measure of financial stress, as in the Bayesian TVAR. For the United States, Hubrich and Tetlow (2015) show that regime changes into high financial stress line up with known crises episodes and are highly detrimental to real economic activity.

Section 2 presents the new CFSI. Section 3 highlights the advantages of the CFSI over alternative measures. Section 4 highlights the heightened macroeconomic costs associated with elevated financial market stress in Canada. Section 5 concludes.

2 Measuring financial stress in Canada

Financial stress is defined as simultaneous financial market turmoil among the most important asset classes and reflected by (i) the uncertainty in market prices, (ii) sharp corrections in market prices, (iii) a widening of spreads, and (iv) the degree of commonality across asset classes. Asset classes are split along several dimensions: equities or bonds, long-term assets or short-term commercial papers, financial or real assets (e.g., housing), denominated in Canadian dollars or foreign currencies.

2.1 Existing tools and limitations for Canada

The construction of an index of financial market stress relies on three fundamental steps.

Collecting measures of stress. The most common set of data relies on equity prices, government bond yields and exchange rates. A limited dataset such as the one used by Duprey, Klaus, and Peltonen (2017) allows for the inclusion of more than 50 years of data while ensuring a large cross-country comparability. However, some indexes that focus on specific countries embed much more data. For instance, the National Financial Conditions Index of the Federal Reserve Bank of Chicago (Brave and Butters 2011; Brave and Butters 2012) includes more than 100 different time series of financial activity with varying frequency, at the cost of a shorter time span. One major shortcoming common to most existing indexes is that they fail to directly capture developments in the housing markets. This is essential for Canada because one of the most stressful events occurred in the early 1990s, with a sharp correction of housing prices in Toronto, Ontario, and Vancouver, British Columbia. Likewise, this is a key concern in Canada moving forward because housing prices skyrocketed in Toronto and Vancouver in 2016–17. One of the early contributions to this literature, Illing and Liu (2006), develop an index for Canada, but it excludes housing.

Aggregating measures of stress. There are various aggregation methods that can be used to combine individual stress into a stress composite (for a survey, see Kliesen, Owyang, and Vermann 2012). The main methods rely on (i) the loadings to the first principal component (Hakkio and Keeton 2009; Kliesen and Smith 2010; Brave and Butters 2011), (ii) the relative weights of the different markets they represent (Illing and Liu 2006), (iii) variance-equal weights for standardized components (European Central Bank 2009; Cardarelli, Elekdag, and Lall 2011), or (iv) cross-correlations of the different subindexes (Oet et al. 2011; Hollo, Kremer, and Lo Duca 2012). Principal component analysis is the easiest method; it identifies the trend that is common to all underlying data to avoid "informationally redundant" data. But it does not necessarily embed the time-varying importance of each time series, and the first principal component may not be enough to capture all dynamics of financial stress. In addition, systemic stress should not be limited to the summation of individual stress (Allen and Carletti 2013). Among the various techniques mentioned above, the use of correlation weights is the only method that is consistent with the supra-additivity property of tail risk: during stressful periods, the overall level of financial market stress should be larger than the sum of financial stress on its constituent markets. This is the method favoured in this paper, although I combine it with sectoral weights similar to Illing and Liu (2006) to account for the relative importance of different sectors over time.

Backtesting measures of stress. Once a financial stress composite has been built successfully, its ability to capture known stress events should be backtested. Simple measures of financial stress such as the Country-Level Index of Financial Stress (CLIFS) of Duprey, Klaus, and Peltonen (2017) capture almost all of the known crises in Europe but react to additional stress events that were deemed not stressful enough to unfold into a full-fledged crisis. To ensure the financial stress composite is a fair representation of the sequence of financial crises, the aggregation technique could be optimized to capture a limited list of expert-identified events. To that extent, Chatterjee et al. (2017) suggest using information weights to avoid redundant data and discount those data that do not match the narrative of financial stress events. Unfortunately, these tools are of limited use in Canada, a country that never experienced a systemic banking crisis according to Laeven and Valencia (2013) because its financial system was much more resilient to the 2008 global financial crisis (Huang and Ratnovski 2009). As a result, there is less guidance about what an index of financial stress should look like in Canada. Therefore, I build on a narrow set of indicators from Duprey, Klaus, and Peltonen (2017) already backtested on European data, and I compare the CFSI to a 2003 Bank of Canada survey of stressful events.

2.2 Construction of the financial stress index for Canada

The current index of financial stress for Canada developed by Illing and Liu (2006) was optimized to fit stress events as of 2003 and does not include several important dimensions, such as housing or the supra-additivity property of systemic stress. Along seven market segments, the new monthly index combines 43 time series from 1981 onward (18 to measure market stress and 25 to measure market size), with some features from Duprey, Klaus, and Peltonen (2017) (market stress is supra-additive) and Illing and Liu (2006) (each market is weighted by quantities). The construction of the CFSI is represented in Figure 1.[2]

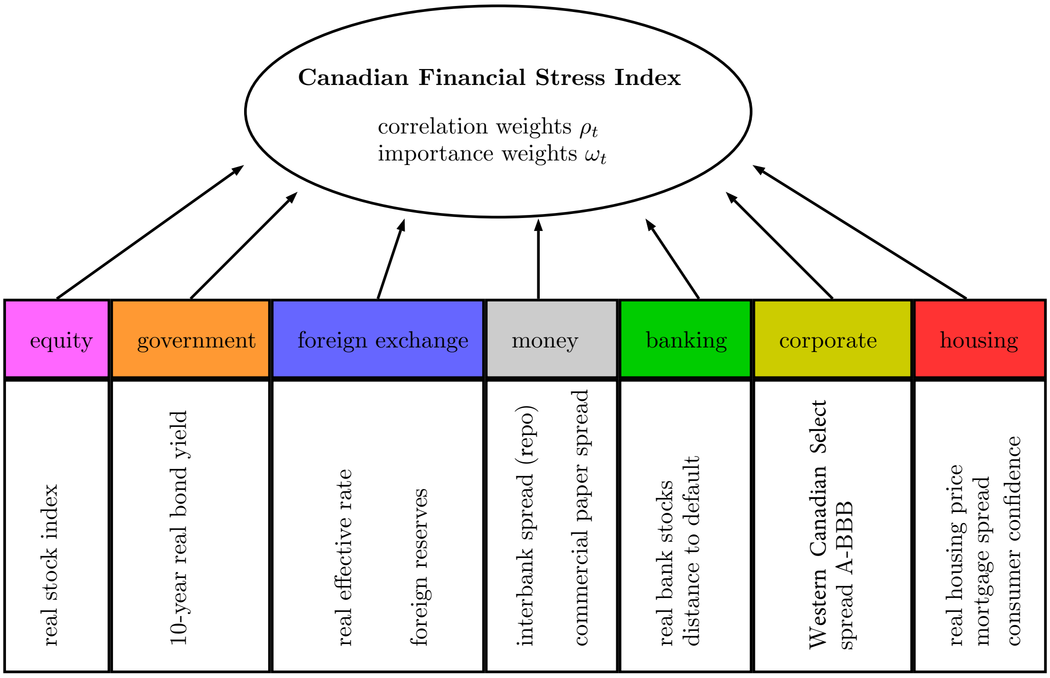
Seven different market segments. The proposed CFSI is composed of measures of financial stress capturing seven different markets. The parsimonious nature of the dataset—I use 18 time series to compute 19 stress indicators covering more than 7 markets—ensures that I capture different aspects of similar stress periods without having too much redundant information (see Table 2 for more details). In addition to the equity (EQU), government bonds (GOV) and foreign exchange (FOR) markets, captured in a way very similar to Duprey, Klaus, and Peltonen (2017), I consider the money market (MON), the bank loans market (BAN), the corporate sector (COR) and the housing sector (HOU).

Stress $s_{t,m}$ on each market segment $m = \{EQU, GOV, FOR, MON, BAN, COR, HOU\}$ is captured by the average of two ($I = 2$) or three ($I = 3$) raw stress measures $r_{t,m,i}$ that are transformations of the data, either realized volatilities, interest rate spreads or variations compared with a local maximum or minimum. Indeed, financial stress can be

[2] The index can also be computed at a higher frequency, e.g., weekly, with additional assumptions: some variables need to be interpolated, and instead of using realized volatilities, one may use instead a generalized autoregressive conditional heteroskedasticity (GARCH) model to ensure more stability of the estimate at a higher frequency.

Figure 1: **Construction of the Canadian financial stress index (CFSI)**

Note: Stress on each market segment corresponds to the average of two or three stress measures described in Table 2 and normalized using the empirical cumulative distribution over a backward expanding window, starting with fixed window until 1991 (i.e., 10 years since the start of the index in 1981).



characterized by larger volatilities, widening spreads over the risk-free rate or price corrections for large assets. I mostly use simple transformations but include a more complex measure, such as the distance to default, which is a standard measure of systemic banking risk, averaged over all Canadian financial institutions (MacDonald, Van Oordt, and Scott 2016).

The different raw stress indicators $r_{t,m,i}$ do not have the same unit, so an additional normalization is required before aggregating them into the seven market stress components $s_{t,m}$. Each raw stress indicator is normalized to lie in $[0;1]$ by using the empirical cumulative distribution (*rank*) over an expanding window (see e.g., Hollo, Kremer, and Lo Duca 2012; Duprey, Klaus, and Peltonen 2017).[3] New data are normalized against historical data in a recursive manner.[4]

Stress on each market segment is computed as the average of the I raw stress indicators

[3]Because high values are associated with more stress, most of the raw indicators are right-skewed. The use of ordinal ranking therefore implies that the relative magnitude of the stress events during periods of high stress is lost. In the meantime, there are fewer data points with very large stress, and it may be harder to find an appropriate benchmark without looking at other data points in the same neighbourhood of the quantile distribution rather thank looking at the actual distribution. However, the alternative—for instance, normalizing using variance-equal weights—is less robust to outliers with large values.

[4]The index is robust to using a backward expanding window, a rolling window or the whole sample to normalize the data.

$r_{t,m}$ for this market:

$$s_{t,m} = \sum_{i=1}^{I} \left\{ \text{rank}_{[0;t]} \left(r_{t,m,i} \right) \right\}. \tag{1}$$

Stress on each market segment is displayed in Figure 2. Equity market stress is high during the stock market crash of October 1987, the burst of the dot com bubble in the 2000s and the 2008 global financial crisis. Stress on the government bonds market is highest during the 1980s and early 1990s, when government debt was higher and Canada experienced two downgrades, in October 1992 by S&P and in February 1995 by Moody's. Moody's further downgraded Canada in April 2000, but it was quickly followed by better ratings from all three main rating agencies in the 2000s. Stress on the corporate bonds market was also high during the 1990s and in 2015 with the oil price shock that triggered a recession. Housing market stress is high in the early 1980s, in the early 1990s and in 2008. But the 1990s appear to be most stressful with a sustained decline in prices, while 2008 was partly driven by temporary loss of consumer confidence. Last, the foreign exchange market, the bank loans market and the money market also peak at the expected time, around the European exchange rate crisis of 1993, the aftermath of the Russian default and collapse of Long-Term Capital Management (LTCM) in the late 1990s or the 2008 global financial crisis.

Supra-additive aggregation method. Similar to Hollo, Kremer, and Lo Duca (2012) or Duprey, Klaus, and Peltonen (2017), I aggregate the different market segments by relying on a portfolio theory approach that weights each subindex $s_{t,m}$ by its cross-correlation $\rho_{t,m,m'}$ with the others, where $m' \neq m$. By aggregating correlated subindexes, I show the resulting index reflects increased systematic risk due to a stronger co-movement across market segments. In contrast, less correlated market segments result in a lower composite index because the risk can be diversified away across market segments. I compute the following time-varying cross-correlation matrix C_t using a pair-wise exponentially weighted moving average (EWMA) specification with smoothing parameter $\lambda = 0.85$ as in Duprey, Klaus, and Peltonen (2017):[5]

$$C_t = \begin{bmatrix} 1 & \rho_{t,EQU,GOV} & \rho_{t,EQU,FOR} & \rho_{t,EQU,MON} & \rho_{t,EQU,BAN} & \rho_{t,EQU,COR} & \rho_{t,EQU,HOU} \\ \rho_{t,GOV,EQU} & 1 & \rho_{t,GOV,FOR} & \rho_{t,GOV,MON} & \rho_{t,GOV,BAN} & \rho_{t,GOV,COR} & \rho_{t,GOV,HOU} \\ \rho_{t,FOR,EQU} & \rho_{t,FOR,GOV} & 1 & \rho_{t,FOR,MON} & \rho_{t,FOR,BAN} & \rho_{t,FOR,COR} & \rho_{t,FOR,HOU} \\ \rho_{t,MON,EQU} & \rho_{t,MON,GOV} & \rho_{t,MON,FOR} & 1 & \rho_{t,MON,BAN} & \rho_{t,MON,COR} & \rho_{t,MON,HOU} \\ \rho_{t,BAN,EQU} & \rho_{t,BAN,GOV} & \rho_{t,BAN,FOR} & \rho_{t,BAN,MON} & 1 & \rho_{t,BAN,COR} & \rho_{t,BAN,HOU} \\ \rho_{t,COR,EQU} & \rho_{t,COR,GOV} & \rho_{t,COR,FOR} & \rho_{t,COR,MON} & \rho_{t,COR,BAN} & 1 & \rho_{t,COR,HOU} \\ \rho_{t,HOU,EQU} & \rho_{t,HOU,GOV} & \rho_{t,HOU,FOR} & \rho_{t,HOU,MON} & \rho_{t,HOU,BAN} & \rho_{t,HOU,COR} & 1 \end{bmatrix}.$$

[5] Using bivariate or multivariate GARCH specifications obtains similar results but requires estimating additional parameters and increases model uncertainty.

The cross-correlations are presented in Figure 3. During stressful periods, around 1990, 1998, 2008 and 2015, cross-correlations tend to be positive. This means that there is little room for hedging across market segments. Most market segments tend to co-move, which is a key characteristic of systemic stress. In particular, the median pair-wise correlation across market segments started to increase from extremely low levels in 2003 and peaked in 2008.

Time-varying importance weights. Consistent with Illing and Liu (2006), I also weight each market segment m by its size in the overall Canadian economy $\omega_{t,m}$. For instance, the growing volume of residential mortgage loans should be reflected by a higher importance of the housing market stress in the overall financial stress composite. Each market segment is weighted by the volume of lending it is associated with (Table 3).

The equity market is weighted using equity finance by Canadian businesses. The government bonds market is weighted using the amount of outstanding government bonds with medium- to long-term maturities issued in Canadian dollars by the different levels of government. The foreign exchange market is weighted by the amount of funding for governments and corporations denominated in foreign currencies (loan, securities or bonds). The money market is weighted by the amount of short-term commercial papers issued in Canadian dollars by corporations and treasury bills issued in Canadian dollars by the different levels of government. The banking sector is weighted by the amount of business or consumer loans issued in Canadian dollars by chartered banks, excluding residential mortgages. The corporate bonds market is weighted by the amount of medium- to long-term bonds and debentures issued by Canadian businesses in Canadian dollars. Finally, the housing market is weighted by the amount of residential mortgages held on balance sheets by financial institutions, including chartered banks, credit unions, mortgage credit companies and financial trusts.

Figure 4 displays the evolution of the weights of each market segment over time $w_t = \{w_{t,EQU}, w_{t,GOV}, w_{t,FOR}, w_{t,BAN}, w_{t,HOU}, w_{t,COR}, w_{t,MON}\}$.

Overall financial stress index. The financial stress composite for Canada is computed as follows, where $\otimes$ denotes the element-wise Hadamard product:

$$CFSI_t = (w_t \otimes \mathbf{s}_t) \cdot C_t \cdot (w_t \otimes \mathbf{s}_t)' \tag{2}$$

where w_t is the 1×7 vector of market segment weights with $\sum_m w_{m,t} = 1$, s_t is the 1×7 vector of standardized stress bounded in $[0; 1]$ for each market segment m, and C_t is the 7×7 time-varying matrix of cross-correlation among all pairs of market segments. As a result, the CFSI is also bounded on $[0; 1]$.

Figure 2: **Normalized stress on each market segment**

Note: Stress on each market segment corresponds to the average of two or three stress measures described in Table 2 and normalized using the empirical cumulative distribution. Vertical bars for the government bonds market display downgrades and upgrades by rating agencies.

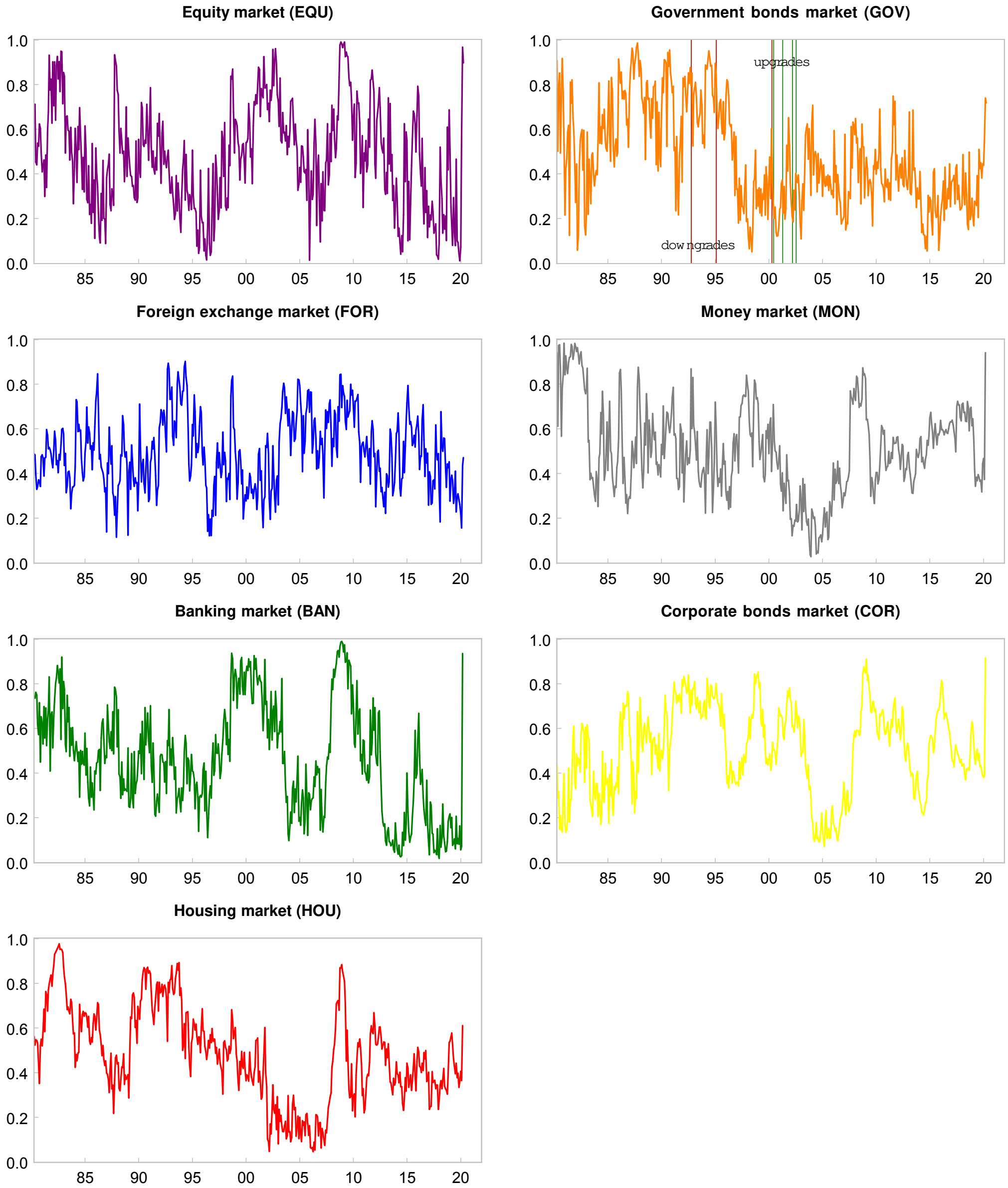


Figure 3: **Pair-wise correlation among all pairs of market segments**

Note: The dashed red line is the minimum value at each point in time of all pair-wise correlations, while the solid blue line is the median.

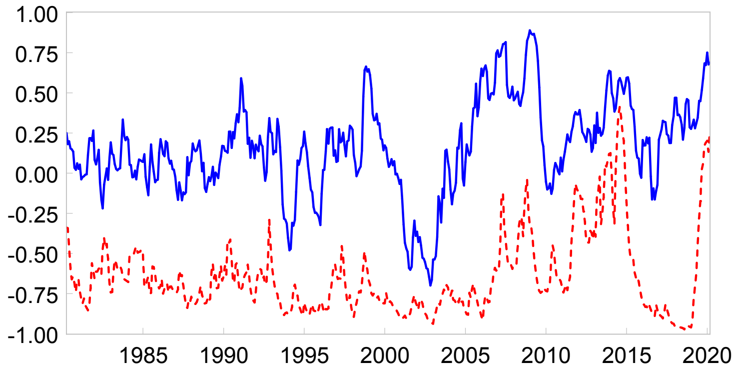
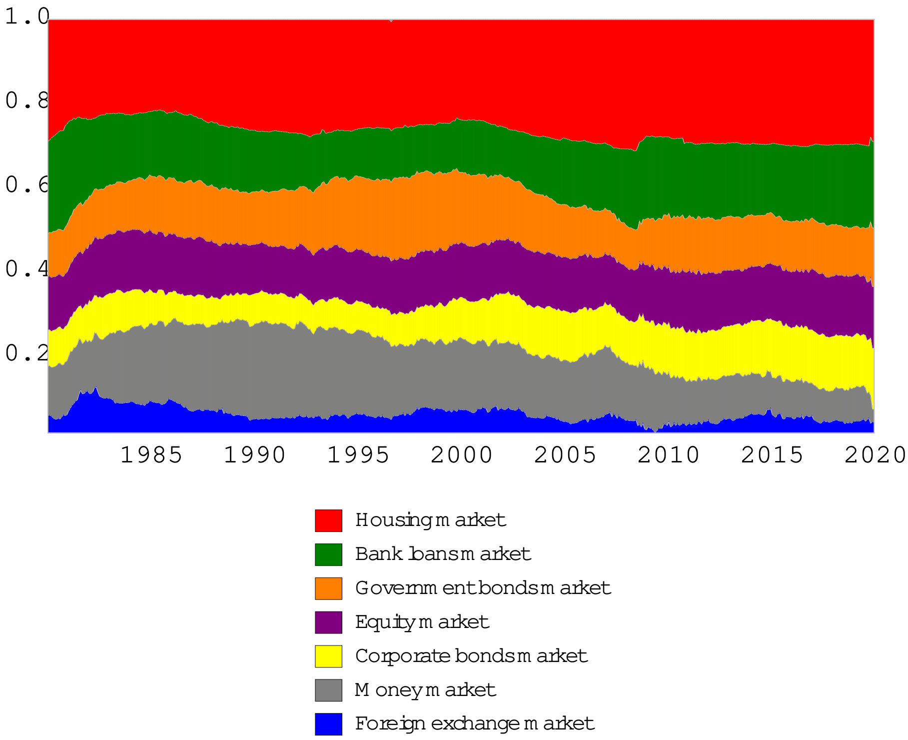


Figure 4: **Evolution of the shares of each market segment over time**

Note: The order of the legend from top to bottom corresponds to the areas in the chart from top to bottom. The precise definition of the share of each market segment is presented in Table 3. The historical levels are adjusted backward for the following three breaks. November 1981: changes in the treatment of foreign bank affiliates in the Bank of Canada statistics. January 1984: the volume of residential mortgages from trust and mortgage loan companies was not collected before. November 2011: change in accounting standards, from generally accepted accounting principles (GAAP) to International Financial Reporting Standards (IFRS). Under IFRS, securitized mortgages still held by the originating institution are no longer treated as items that are off balance sheets. Missing entries in the early 1980s for some items presented in Table 3 are extrapolated backward by keeping their percentage contribution to a given market fixed and equal to the last known value.



3 The CFSI reflects known stressful events

Next, I compare episodes of high financial stress with the narrative of episodes of financial stress in Canada.

3.1 The CFSI against a narrative of stressful events

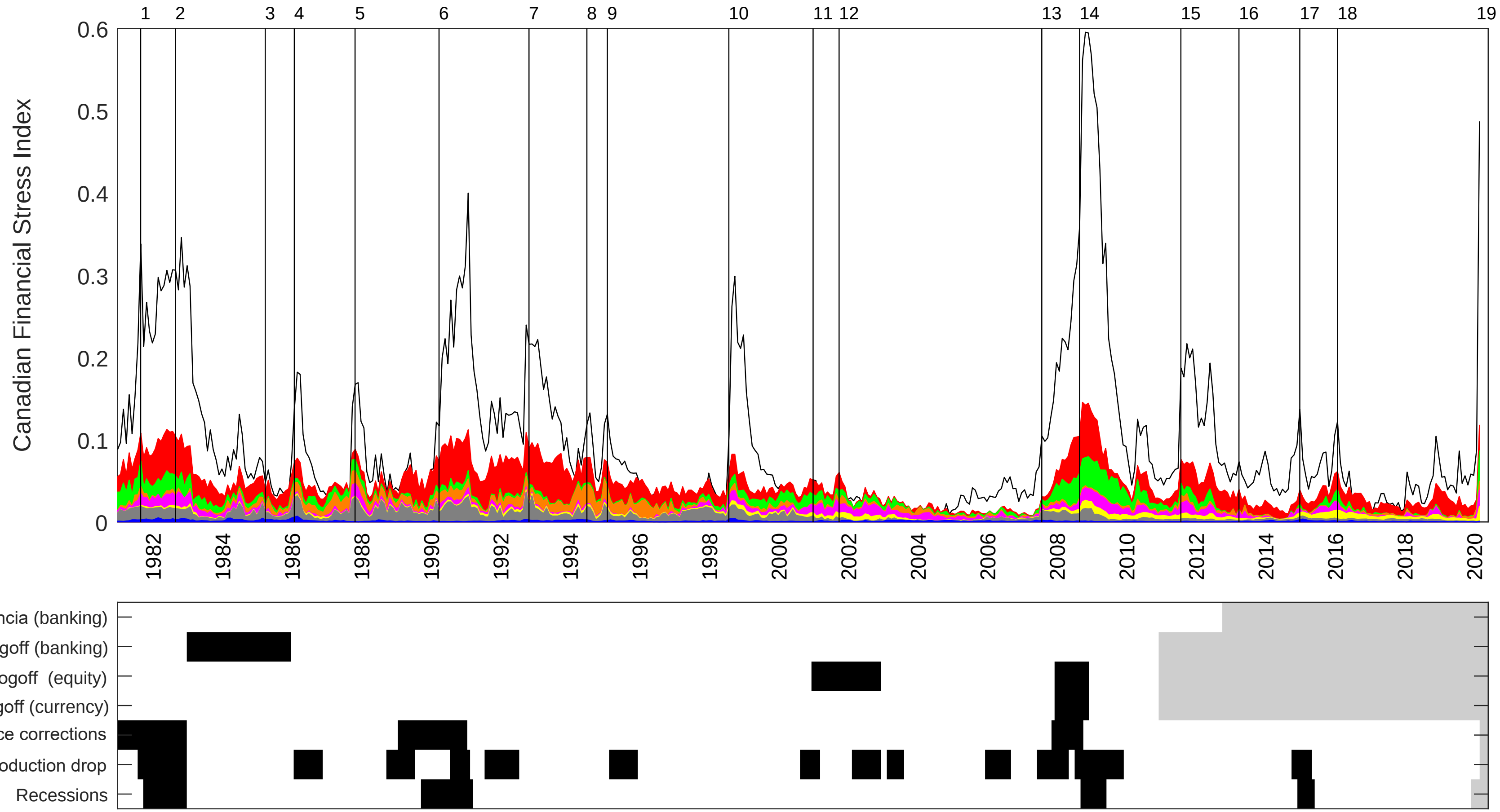
Figure 5 shows the contribution of each market segment to the CFSI. It emphasizes the role of cross-correlations in identifying episodes of heightened financial stress. Cross-correlations are represented by the area below the black CFSI line that does not have colours.

The peaks of the CFSI line up very well with known events of financial stress. The main spikes of financial stress, namely 1982, 1990 and 2008, coincide with periods of recessions and corrections in the industrial production and housing prices. The decomposition of financial stress shows that 1982 was driven by the housing, banking, equity and money markets; 1990 was driven by the housing, money and government bonds markets; 2008 was driven by the banking, housing, money and equity markets. In March 2020 during the COVID-19 pandemic, the CFSI had the strongest one-month increase, reaching a peak only second to the 2008 global financial crisis.

However, it is worth noting that financial market stress does not always bring macroeconomic underperformance, and macroeconomic underperformance does not always yield severe financial market stress. For instance, the banking crisis of 1985–86 with the bailout of the Canadian commercial banks (CCB) and the liquidation of Northland Bank of Canada (NBC) did not trigger a recession. This regional banking crisis did not spill over to the rest of the economy, in part thanks to the actions of the Bank of Canada and federal authorities. The default of Russia and associated collapse of LTCM in 1998 triggered an international financial market shock, with limited consequences for the Canadian real economy. The oil price shock of 2015 triggered a recession in Canada, with higher financial market stress driven by the corporate sector, but the disruption to the financial system was limited.

Figure 5: **The Canadian financial stress index: Known stressful events in Canada**

Note: The black line is the Canadian financial stress index (CFSI). The colours refer to the contribution of each market segment as in Figure 1. The white area below the black line corresponds to the contribution of the cross-correlations across market segments. The list of events for the upper chart is as follows: 1. spike in interest rates; 2. Mexican debt crisis; 3. Bailout of the Canadian Commercial Bank (CCB); 4. Liquidation of Northland bank; 5. Black Monday; 6. Start of the Vancouver housing crisis; 7. Downgrade by S&P; 8. Mexican crisis and bailout package; 9. Downgrade by Moody's; 10. Russian default and Long-Term Capital Management (LTCM) bailout; 11. Losses following the burst of the dot com bubble; 12. Terrorist attack in the United States; 13. Start of the subprime crisis; 14. Collapse of Lehman Brothers; 15. Greek bailout; 16. Taper tantrum; 17. The oil price (Western Canadian Select [WCS]) falls below Can$40; 18. The oil price (WCS) falls below Can$20; 19. COVID-19 crisis. The lower chart displays crises episodes. Laeven and Valencia (2013) and Reinhart and Rogoff (2011) identify crises of different types (banking, equity, currency). House price corrections correspond to periods characterized by more than 10% year-over-year drop in real housing prices from peak to trough. Industrial production drops correspond to drops in the seasonally adjusted index of industrial production of at least six months, possibly intertwined with one month of positive growth. Recessions are defined by at least two quarters of negative real output growth.



3.2 Visual inspection of the CFSI against alternative metrics

Next, I compare the CFSI to alternative financial stress measures for Canada (Figure 6).

Simple measures of financial stress usually capture stress on one specific segment of the market. The corporate bond spread in Figure 6(a) is sometimes used in the absence of financial stress composites. It captures well the 1982 and 2008 crises as well as the 2015 oil price shock. However, it does not capture well other events occurring more specifically in the banking sector (1985–86) or the housing market (1990). Alternatively, the VIX in Figure 6(b) is a broader measure of financial market stress that captures overall stock market volatility. As such, it places more emphasis on the stock market corrections, like the Black Monday in 1987, the Asian crisis of the late 1990s and the crash of the dot com bubble in the 2000s. The Senior Loan Officer Survey in Figure 6(c) reports the change in domestic credit conditions for business loans from 1999 onward. It does not reflect the possibility to arbitrage between bank loans and market finance and does not include consumer loans or mortgage lending.

Figure 6(d) displays a simple index of financial stress for Canada computed with the method of principal components on the same raw stress measures as the CFSI. This illustrates the issue with the principal component method. The first loading captures the 2008 global financial crisis particularly well, but not the other stress events, such as 1990 housing market shock, that would be captured by the other principal components. The principal component approach is not time-varying and does not necessarily combine multiple facets of financial stress into one single component.

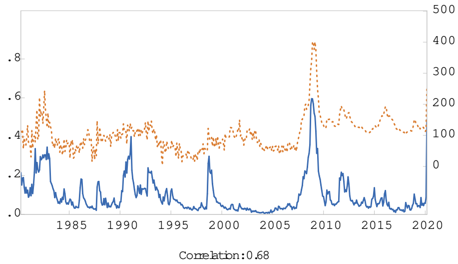
Two indexes of financial stress are already available for Canada. The index of Illing and Liu (2006) was constructed before the 2008 global financial crisis to coincide with pre-2008 stressful events specifically for Canada (Figure 6(e)). The index of Cardarelli, Elekdag, and Lall (2011) is available until 2010 for several countries, including Canada (Figure 6(f)). In addition, I report the CLIFS measure of Duprey and Klaus (2017), who expand the work of Duprey, Klaus, and Peltonen (2017) to other non-European countries (Figure 6(g)). This last index is reported for sake of comparison because the CFSI, although more complete, shares many similarities.[6] None of these alternative indexes for Canada include housing stress. The last one encompasses only a very limited set of input, and the first two do not satisfy the property of subadditivity of systemic financial stress. In addition, the index of Illing and Liu (2006) emphasizes the 1998 LTCM collapse as the most important event of financial stress for Canada. This event was deemed to be somewhat stressful for the Canadian financial markets in a survey conducted by the Bank of Canada in 2003, but the magnitude of stress appears at odds with the 2008 global financial crisis. The CFSI correlates most with the index of Cardarelli, Elekdag, and Lall (2011).

[6] I can backcast the CFSI with fewer time series to start in 1964 instead of 1981, ultimately getting close to the few time series used in Duprey and Klaus (2017) since 1964.

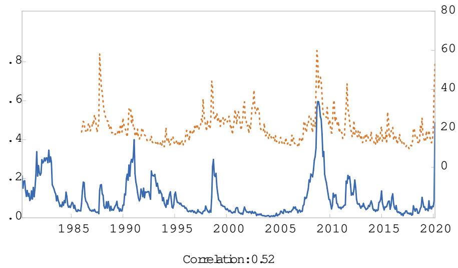
Figure 6: **Comparison with alternative financial stress indexes**

Note: The Canadian financial stress index (CFSI) is displayed in plain blue (left scale). The alternative index is displayed in dashed red (right scale, if the unit is different). The Senior Loan Officer Survey (SLOS) is a quarterly publication of the Bank of Canada that surveys senior loan officers on the change in credit conditions compared with the previous quarter. It reflects the number of weighted respondent reporting a tightening (positive number) or a loosening (negative number) but does not reflect the magnitude of the tightening. The volatility index (VIX) is a proxy for overall risk aversion on the global markets.

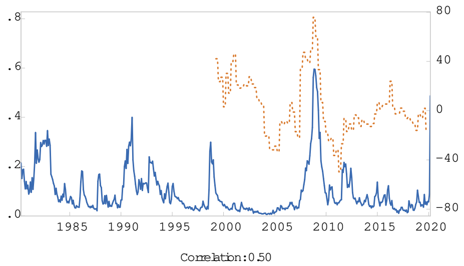
(a) Corporate bond spread



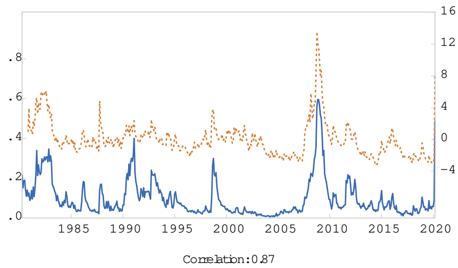
(b) VIX



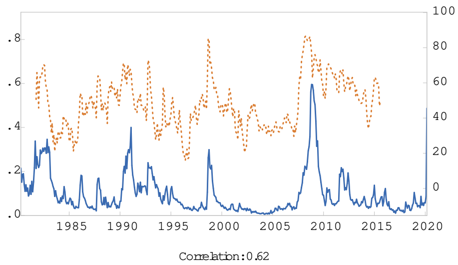
(c) SLOS



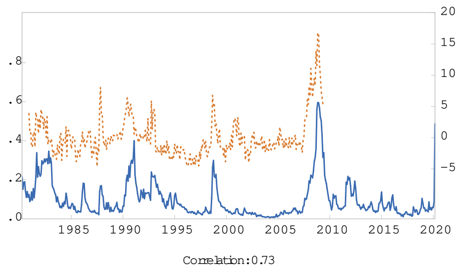
(d) First principal component



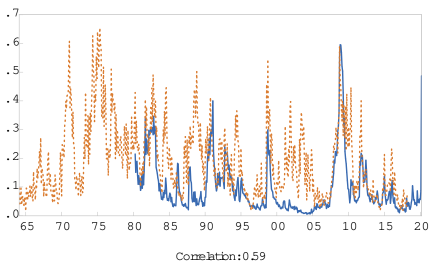
(e) Illing and Liu (2006)



(f) Cardarelli, Elekdag, and Lall (2011)



(g) Duprey and Klaus (2017)



3.3 Statistical coherence of financial stress composites

Finally, Table 1 compares the ability of the different financial stress indexes to line up well with episodes of financial stress. I consider the same list of financial stress episodes used by Illing and Liu (2006) when backtesting the validity of their index. They relied on a 2003 survey of 40 senior policy-makers and economists who were asked to identify the main financial stress events. In the absence of banking or financial crises reported for Canada, this survey—to which I add the stress episodes that occurred since 2003—is the main source of external validation.

I compute three different metrics. The area under the receiver operating characteristic curve (AUROC) reflects the ability of the peaks of the CFSI to match the stress events of the survey from 2003. An AUROC value greater than 0.5 indicates that the prediction is better than a random guess. An AUROC of 1 means that the CFSI provides a perfect match of the stress event.[7] The AUROC is a generalization of the noise-to-signal ratio for any given preferences of the regulator between missing crises (type 1 errors) and false signals (type 2 errors).[8] I also report the partial AUROC that restricts the AUROC to focus on a partial, and more plausible, range of preferences between type 1 and type 2 errors. Last, the usefulness measure of Alessi and Detken (2014) is computed conditional on a given preference parameter. It measures the ability of the stress index to better match the known episodes of stress as opposed to ignoring the stress index, i.e., assuming Canada either never or always faced financial stress.

When restricted to the period from 1981 to 2003 used by Illing and Liu (2006) (first set of rows in Table 1), the CFSI performs best according to the AUROC and partial AUROC. For balanced preferences ($\mu = 0.5$) or preferences slightly biased toward an aversion for false signals ($\mu = 0.4$), the CFSI also performs best. However, Illing and Liu (2006) reach a better usefulness when preferences are tilted toward an aversion for missing crises ($\mu = 0.6$). This last result is driven by the choice of stress events used to discriminate among the indexes of financial stress. In particular, the CFSI does not identify the dot com bubble as a major financial stress event, but rather as an event mostly driven by stress on the equity market. When I exclude the 1998 and 2000 stress events that were ranked only as only "somewhat" stressful in the survey, the CFSI performs best across all metrics. When the most recent periods are added, including the 2008 global financial crisis and the 2015 oil price shock or the 1990 housing crisis (not identified by the 2003 survey), the CFSI performs better than other indexes (second set of rows). The results are similar when excluding the 1998 and 2000 stress events (last set of rows).

[7]The AUROC is estimated non-parametrically. For more details, see, for example, Fawcett (2006) for a technical overview and Schularick and Taylor (2012) for an application to crises identification.

[8]It is also standard to use the noise-to-signal ratio of (Kaminsky, Lizondo, and Reinhart 1998). However the ratio implicitly embeds a given trade-off between noise and signal. It can lead to counter-intuitive results depending on the relative variation of the numerator or denominator. Therefore, we do not use this less robust method.

Table 1: Ability of the financial stress indexes to capture known stressful events

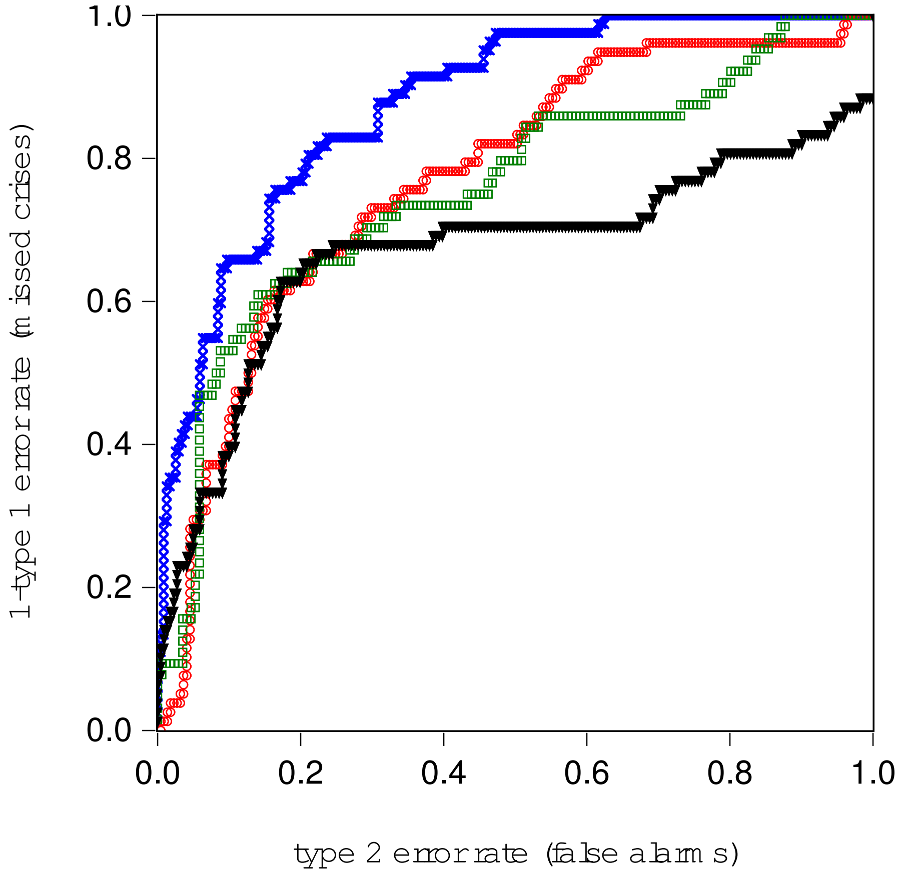
			μ=0.5			μ=0.6			μ=0.4		
	AUROC	pAUROC	T1	T2	U	T1	T2	U	T1	T2	U
Until 2003: dates as Illing and Liu (2006)											
CFSI	**0.78**	**0.75**	0.43	**0.11**	**0.46**	0.33	**0.21**	0.29	**0.43**	0.11	**0.41**
FSI of Illing and Liu (2006)	0.73	0.68	0.07	0.56	0.37	0.07	0.56	0.33	0.48	0.20	0.22
FSI of Cardarelli et al. (2011)	0.68	0.65	0.56	0.12	0.33	0.00	0.85	0.15	0.56	0.12	0.27
CLIFS of Duprey et al. (2017)	0.52	0.51	0.50	0.36	0.14	0.00	0.99	0.01	0.89	0.05	0.04
Dates as Illing and Liu (2006) + 2008 crisis + 2015 oil + 1990 housing											
CFSI	**0.82**	**0.76**	**0.32**	0.17	**0.51**	0.16	0.37	**0.38**	**0.41**	**0.10**	**0.44**
FSI of Illing and Liu (2006)	0.75	0.74	0.38	0.24	0.38	0.05	0.60	0.33	0.46	0.17	0.29
FSI of Cardarelli et al. (2011)	0.75	0.73	0.41	0.12	0.47	0.36	0.19	0.27	0.41	0.12	0.41
CLIFS of Duprey et al. (2017)	0.63	0.59	0.44	0.18	0.38	0.41	0.22	0.16	0.44	0.18	0.29
Dates as Illing and Liu (2006) + 2008 crisis + 2015 oil + 1990 housing - LTCM crisis - dotcom bubble											
CFSI	**0.86**	**0.82**	**0.26**	0.17	**0.57**	0.09	0.38	**0.48**	**0.35**	0.11	**0.49**
FSI of Illing and Liu (2006)	0.74	0.75	0.41	0.19	0.41	0.05	0.64	0.28	0.41	0.19	0.32
FSI of Cardarelli et al. (2011)	0.74	0.73	0.48	0.10	0.42	0.15	0.54	0.23	0.48	0.10	0.37
CLIFS of Duprey et al. (2017)	0.64	0.61	0.39	0.21	0.40	0.35	0.26	0.21	0.39	0.21	0.30

Note: This table displays summary statistics that show how well different Canadian financial stress indexes capture the stressful events identified in the 2003 survey used in Illing and Liu (2006). It consists of the following events: August 1981 spike in interest rates, Latin American debt crises (early 1980s), Canadian commercial bank and Northland failures (1985), October 1987 stock market crash, early-1990s bank losses, Mexican crisis (1994–1995), Asian crisis (1997–1998), Russian debt default and Long-Term Capital Management bailout (1998), the burst of the dot com bubble (2000), events of September 11, 2001. The 1998 and 2000 events were only assessed as "somewhat" stressful by most of the respondents. For other rows in the table, as robustness, additional events are either added or removed. AUROC is the area under the receiver characteristic curve, and it is associated with an informative signal when above 0.5, whatever the preferences of the regulator. pAUROC is the partial AUROC restricted to assess the informativeness of a signal under a subset of preferences of the regulator, in the range $\mu = [0.3; 0.7]$. μ is the cost associated with type 1 errors (T1), i.e., the share of missed crises. Conversely, $1 - \mu$ is the cost associated with type 2 errors (T2), i.e., the share of false signals. A higher μ is associated with an aversion to missing crises (thus a lower T1). U is the usefulness indicator of Alessi and Detken (2011) that measures the signal's ability to be informative under certain preferences μ. When computing the different measures, the 12 months after a stressful event are removed unless another stress event starts during this period. Otherwise, the assessment could be biased by the behaviour of the stress indexes during the recovery period. Numbers in bold correspond to the best metric in favour of the CFSI.

Figure 7 displays the receiver operating characteristic (ROC) curves of the different financial stress indexes. This is a visual representation of ability of the stress indexes to line up with the sequence of stress events referred to in the last set of rows of Table 1. The ROC of the CFSI shows that the CFSI always delivers a lower missed crisis rate than alternative stress indexes for any given false signal rate. The ROC curves of other indexes do not go as far in the top-left corner of the chart, meaning that they tend to misclassify more expert-identified stress events whatever the preference for type 1 or type 2 errors.

Figure 7: **Receiver operating characteristic curves for the different Canadian financial stress indexes**

Note: This figure displays the non-parametric receiver operating characteristic (ROC) curves computed for all four Canadian financial stress indexes. It summarizes the ability of each financial stress index to peak during the periods identified by experts as being stressful for the Canadian economy (a survey of economists conducted in 2003). When the curve gets closer to the top-left corner, it means that the peaks of the FSI coincide more with Canadian crises. Conversely, when the curve gets closer to the 45 degree line, it means that the peaks of the FSI do not coincide with the Canadian crises (the odds of the peaks of the FSI lining up with the crises is just a coin flip). The blue crosses represent the CFSI presented in this paper. The red circles represent the index of Illing and Liu (2006). The black triangles refer to the CLIFS of Duprey, Klaus, and Peltonen (2017). The green squares represent the ROC for the index of Cardarelli, Elekdag, and Lall (2011).

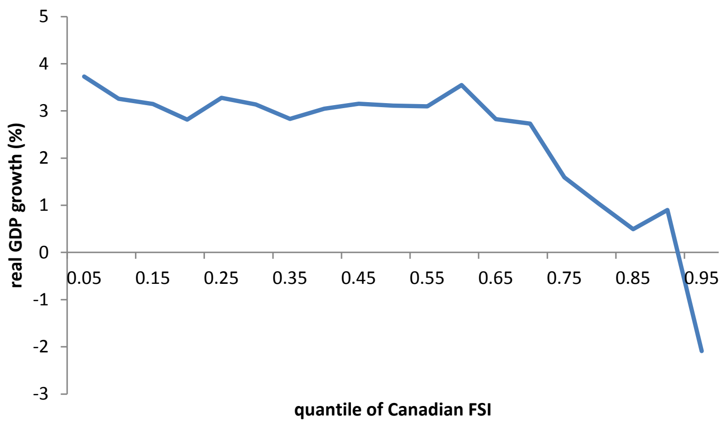


4 Financial stress and its macroeconomic impact

The previous sections described a new index of financial stress for Canada that improves on the existing measures. But the reason we care about financial stress is that it tends to be associated with a negative economic outcome. Figure 8 shows that high levels of financial stress above the 90th quantile of the CFSI are associated with negative real GDP growth.[9] In this section, I provide a simple framework to illustrate the negative relationship between financial stress and economic growth.

Figure 8: **Real GDP growth per quantile of Canadian financial stress index**

Note: The chart displays the average year-over-year GDP growth per quantile of the Canadian financial stress index (CFSI). It excludes the post-crisis periods (two quarters after each recession) because GDP growth and the CFSI may have different recovery speeds that would blur the relationship between increasing levels of financial stress and economic downturns.



4.1 A simple threshold vector autoregressive model

A Bayesian threshold vector autoregressive (Bayesian TVAR) model allows for macroeconomic dynamics to differ across regimes, identified by the level of an observed threshold variable. I use the CFSI as the threshold variable to make an explicit link between macroeconomic dynamics and known events of elevated financial stress for the Canadian market.

The model is estimated on monthly data from December 1981 to December 2019. It includes the seasonally adjusted annualized growth rate of real GDP ($gGDP_t$),[10] the seasonally adjusted annualized CPI inflation rate ($gCPI_t$), the three-month treasury bill rate (R_t) and the proposed measure of financial stress ($CFSI_t$). Defining the vector of

[9] This simple approach is consistent with the quantile regression framework of Adrian, Boyarchenko, and Giannone (2019) for the United States or Duprey and Ueberfeldt (2020) for Canada.

[10] In the beginning of the sample, no monthly GDP measure is available for Canada. I use the quarterly GDP measure spliced with the monthly seasonally adjusted index of industrial production. Similar results are obtained when using the monthly seasonally adjusted annualized growth rate of the industrial production index instead. But industrial production is a more narrow definition of economic activity.

endogenous variables $Y_t = [gGPD_t, gCPI_t, R_t, CFSI_t]$, the Bayesian TVAR with P lags and a constant μ is:

$$Y_t = \mu^{S_t} + \sum_{p=1}^{P} \left(\beta_p^{S_t} Y_{t-p} \right) + \Theta^{S_t} \epsilon_t^{S_t}. \tag{3}$$

The Bayesian TVAR model distinguishes between periods with significantly different macroeconomic elasticities (β^{S_t}) that depend on the state of the economy $S_t \in \{L; H\}$. The state of the economy is defined as being in a low (high) financial stress regime if the CFSI is below (above) an estimated percentile τ of the CFSI, possibly lagged by d periods. The Bayesian TVAR model can be thought of as a set of two VARs conditional on being above or below the cutoff level of financial stress τ.

$$S_t = \begin{cases} L & \text{if } CFSI_{t-d} < \tau \\ H & \text{if } CFSI_{t-d} \geq \tau \end{cases} \tag{4}$$

The Bayesian TVAR model is estimated with Bayesian techniques following Bruneau and Chapman (2017). The CFSI is normalized using its minimal and maximal value so that it lies between 0 and 1, and the prior for the threshold variable can be modelled as a gamma distribution. The estimation of the threshold requires at least 10 percent of the observations in the high-stress regime to have a meaningful estimation of the macroeconomic dynamics in the high-stress regime. The regime-specific decomposition Θ^{S_t} of structural shocks $\epsilon_t^{S_t}$ is the Cholesky matrix with the same order as in Y_t.[11] I choose a model specification with three lags $P = 3$ and one delay $d = 1$, as suggested by the information criterion.[12]

The log-likelihood of the Bayesian TVAR is highest for a cutoff level of financial stress τ in the 85 to 90 percent range. This means that episodes of high financial stress correspond mainly to the 2008 global financial crisis and the episode around 1990 with the correction in housing prices in Toronto and Vancouver.

4.2 Financial stress episodes damage the real economy

Negative real shocks increase financial stress. Figure 9 shows the impact of a real shock on GDP growth. It is more persistent in the high-stress regime and is associated with a larger increase in the CFSI. If a linear VAR is estimated instead, the two regimes of high and low financial stress are combined, and the impact of real shocks on the CFSI is diluted (black line).

[11] Similar results would be obtained with a signs restriction shock identification.

[12] The assumption of the absence of thresholds can be rejected: the data favour the Byesian TVAR over a standard VAR.

Positive financial stress shocks worsen GDP. Figure 10 shows the impact of a financial stress shock. It has a more persistent negative impact on real GDP growth in the high-stress regime. In the case of a linear VAR, the negative impact of financial stress shocks on real GDP growth may be underestimated (black line).

Figure 9: **Impulse response function: demand shock**

Note: The figure displays the response to an increase in the annualized real GDP growth by 1 percent. The black line corresponds to the median response in a linear vector autoregression (VAR). The red dashed (blue dotted) line corresponds to the median response in the threshold VAR when the economy is in the high-(low-)stress regime. The bootstrapped confidence bands correspond to the one-standard-deviation confidence bands.

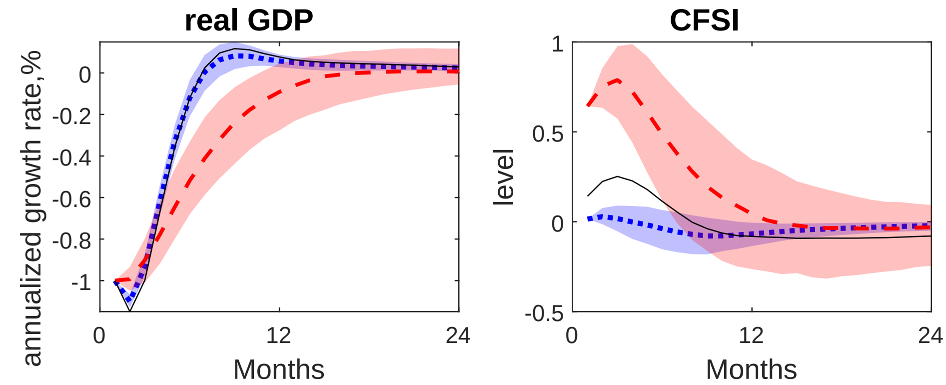
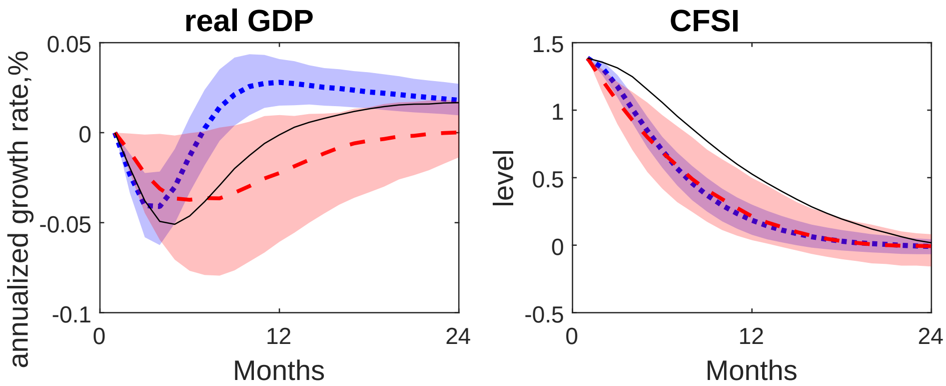


Figure 10: **Impulse response function: Canadian financial stress shock**

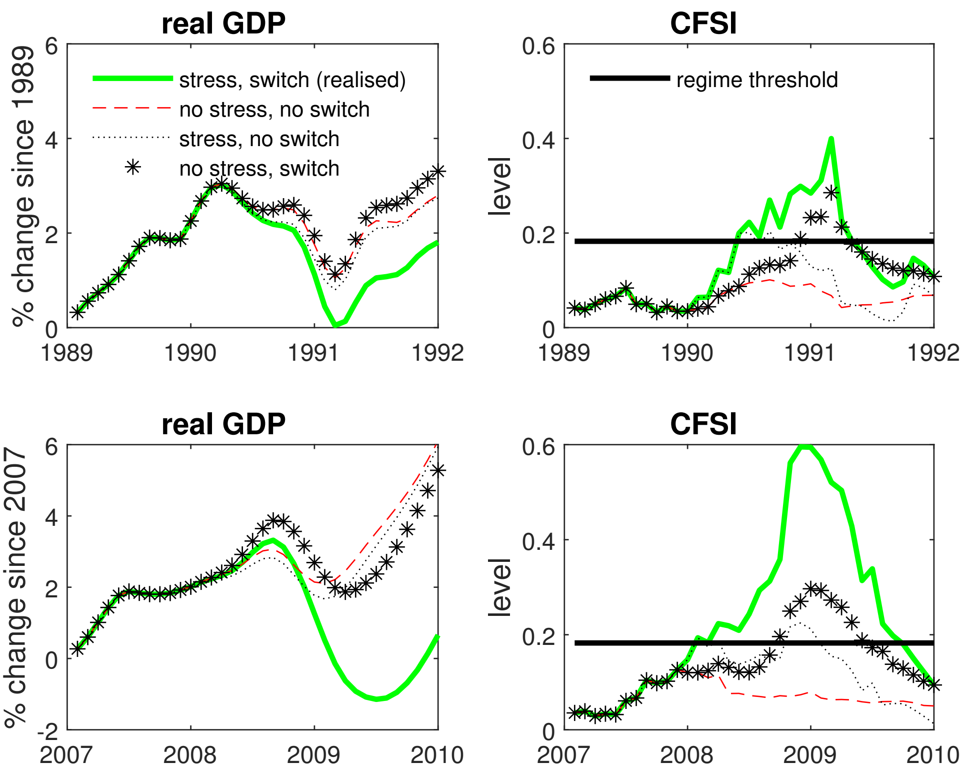
Note: The figure displays the response to an increase in the Canadian financial stress index (CFSI) by 0.1. The black line corresponds to the median response in a linear vector autoregression (VAR). The red dashed (blue dotted) line corresponds to the median response in the threshold VAR when the economy is in the high-(low-)stress regime. The bootstrapped confidence bands correspond to the one-standard-deviation confidence bands.



The combination of regime change and financial stress shocks act as an amplification mechanism. Figure 11 shows counterfactuals around two major episodes of financial stress: the housing market crash of the 1990s and the 2008 global financial crisis. I hold the policy rate at its historical value. I compute three counterfactuals and, together with the realized data, I obtain four cases: with or without financial stress shocks and with or without a transition from the low- to the high-stress regime. In all counterfactuals, real GDP would have been significantly higher. This suggests that financial stress has the greatest negative impact on GDP growth when there is a combination of financial stress shocks and a change to the high-stress regime. Financial stress shocks are an important source of concern for the macroeconomy mostly when they are amplified in the high-stress regime.[13]

Figure 11: **Counterfactuals around the 1990 housing crisis and the 2008 global financial crisis**

Note: Each row of the figure displays historical data (solid lines) and counterfactuals (other lines) around the stress events of 1990 and 2008, while still following the historical path for monetary policy. The three counterfactuals start after one year and are recovered from the estimated threshold vector autoregression with a Cholesky decomposition of the shocks. The figure shows a counterfactual without the financial stress shocks (dashed red), a counterfactual with the same financial stress shocks but without regime change (dotted black) and a counterfactual without the financial stress shocks but with regime change as in the data (black stars). The horizontal black line on the right column corresponds to the estimated threshold above which the economy falls into a regime of high financial stress with different macroeconomic elasticities. Real GDP is normalized to be 0 at the beginning of the period considered.



[13]This holds true for different lags or different delay parameters.

5 Conclusion

I construct a Canadian financial stress index (CFSI) that captures the intensity of financial market turmoil in Canada that spans seven market segments. The index emphasizes the periods where it is harder for investors and borrowers to substitute away assets that face market stress.

The innovation is twofold compared with the existing measures of financial stress. First, I include stress on the housing market. This is a crucial source of shocks for Canada—for instance, around the housing market correction of 1990. Second, compared with the two existing measures of financial stress for Canada (Illing and Liu 2006; Cardarelli, Elekdag, and Lall 2011), I capture the co-movement across market segments, which tends to be stronger during systemic events. Those improvements lead to an index that better reflects known episodes of financial stress in Canada.

The CFSI can be helpful for at least two purposes. First, it helps benchmark the intensity of financial stress against historical episodes. Second, financial market stress is often associated with non-linear macrofinancial dynamics that can amplify negative shocks. Above its 90th percentile, the CFSI is typically associated with more fragile macroeconomic conditions in Canada. I illustrate how financial stress and worsening macroeconomic conditions amplify each other in the context of a Bayesian threshold vector autoregressive model (Bayesian TVAR). The model explicitly relates episodes of elevated financial market stress, as captured by the CFSI, with a deeper correction of GDP.

The results suggest that using financial stress indexes to capture rapidly deteriorating financial conditions can be useful to better capture the deterioration of macroeconomic conditions when tail events materialize. Thus, the CFSI is included either in the risk amplification macroeconomic model (RAMM) (Traclet and MacDonald 2018) or the growth-at-risk model (Duprey and Ueberfeldt 2020), two models used in the risk management framework of the Bank of Canada (Poloz 2020) to weight risks to the outlook. Assessing macrofinancial risks and their real economic implications is especially relevant in the context of the COVID-19 pandemic, where financial stress reached levels comparable only to the 2008 global financial crisis.

A Data appendix

Table 2: **List of time series used in the computation of the index of financial stress**

market segment		raw data				transformation		Illing and Liu
		ticker	**data type**	**frequency**	**source**	**ticker**	**details**	**(2016)**
EQU	equity	TOTMKCN(PI)	TSX stock index	daily	Datastream	ABS_EQU	monthly average of the absolute value of daily log real returns	CMAX of the TSX index over a one-year window
						CMAX_EQU	cumulated maximum loss of the real stock index over a five-year window	
GOV	government	TRCN10T	10-year Government of Canada bond	daily	Datastream	ABS_GOV	monthly average of the absolute value of daily change in real bond yields	inverted slope of the yield curve; covered CA/US treasury bill spread ; treasury bills bid-offer spread
		TRUS10T	10 year US bond	daily	Datastream	CDIFF_GOV	difference between the real CA/US bond spread and its minimum over the previous five years	
FOR	foreign exchange	B156XRN@BIS	narrow real effective exchange rate	monthly	BIS	ABS_FOR	absolute value of the log rate	CMAX of the CA/US exchange rate
						CUMUL_FOR	absolute value of the average change in the rate over six months	
		RESTLM	Canada's Official International Reserves	monthly	Famemart	CMAX_FOR	cumulated maximum loss of official reserves over a five-year window	
MON	money market	CIDOR3M	3 months interbank rate	daily	Datastream	ABS_MON	monthly average of the absolute value of the overnight Repo rate	corporate paper minus treasury bill spread
		CNTBB3M	3 months treasury bills	daily	Datastream	SPR1_MON	interbank rate over the three month treasury bill	
		CP.CDN.90D.OPER	Prime corporate three months paper rate	daily	Famemart	SPR2_MON	three-month corporate paper rate over the three-month treasury bill	
BAN	banking	BANKSCN(PI)	Datastream banks price index	daily	Datastream	IDIO_BAN	idiosyncratic banking shocks: inverse of the residual from regressing real log bank stock returns over the real log stock market return, estimated on a two-year rolling window	beta between the banking sector index and the overall market index
			minus Distance-to-default (higher means more stress)	monthly	MacDonald at al. (2016)	IND_BAN	average distance to default of Canadian financial institutions	
		F0C2	Merrill Lynch option-adjusted spread on AA-rated businesses	daily	Merrill Lynch	CDIFF_BAN	difference between the funding spread of AA banks and its minimum over the previous five years	
COR	corporate	F0C3	Merrill Lynch option-adjusted spread on A-rated businesses	daily	Merrill Lynch	CDIFF_COR	difference between the funding spread of A-rated corporations and its minimum over the previous five years	corporate bond spread
		d.wcc	WCC oil price	monthly	Famemart	CMAX_COR	cumulated maximum drop of the WCC oil price over a five-year window	
		F0C4	Merrill Lynch option-adjusted spread on A-rated businesses	daily	Merrill Lynch	SPR_COR	spread between the funding cost of A and BBB-rated corporations	
HOU	housing	CACERPUM@CREA	Housing price deflated using CPI	monthly	Famemart	CMAX_HOU	cumulated maximum drop of the real housing price over a five-year window	
		BROKER_AVERAGE_5YRMORT	Average five-year fixed mortgage rate among national mortgage	monthly	Famemart	SPR_HOU	spread between the five-year mortgage rate and the five-year Government of Canada bond	
		v122540	five-year Government of Canada bond yield	monthly	Famemart			
		NCBI	Index of Consumer Confidence	quarterly	Conference Board	IND_HOU	negative of the consumer confidence index interpolated at monthly frequency	

Note: The EQU, GOV and FOR indicators are similar to those used by Duprey, Klaus, and Peltonen (2017), with the addition of the foreign reserves. The Canadian financial stress index is composed of measures of volatility (ABS), large variations (CMAX, CDIFF, CUMUL), spreads (SPR) and other, more complex indicators (IND, IDIO). For the formula used for ABS, CMAX, CDIFF, CUMUL, refer to Duprey, Klaus, and Peltonen (2017). The last column refers to the input used by Illing and Liu (2006).

Table 3: **List of time series when weighting each market segment**

market		**ticker**	**definition**
EQU	equity	V122642	Equity and warrants
		V36846	minus: Foreign currency securities to Canadian residents from chartered banks
GOV	government	V37342	Government of Canada direct and guaranteed securities and loans, total unmatured direct and guaranteed securities (excluding non-marketable)
		V37319	minus: Government of Canada direct and guaranteed securities and loans, marketable bonds and notes payable in foreign currencies
		V37331	minus: Government of Canada direct and guaranteed securities and loans, treasury bills
		V122256	minus: Provincial governments and their enterprises, treasury bills and other short-term paper
		V122257	minus: Municipal governments, treasury bills and other short-term paper
FOR	foreign exchange	V37319	Government of Canada direct and guaranteed securities and loans, Marketable bonds and notes in foreign currencies
		V122478	plus: Provincial bonds delivered abroad
		V122269	plus: Municipal bonds delivered abroad
		V122255	plus: Short-term commercial paper issued in US dollars, includes instruments with an original term of one year or less
		V122272	plus: Corporate bonds placed abroad, includes instruments with an original term to maturity of more than one year
		V36877	plus: Foreign currency loans to Canadian residents from chartered banks
		V36846	plus: Foreign currency securities to Canadian residents from chartered banks
		V36937-V36884	plus: Foreign currency liabilities minus foreign currency assets held by chartered banks
MON	money market	V122241	Total corporate short-term paper
		V37331	plus: Government of Canada direct and guaranteed securities and loans, treasury bills
		V122256	plus: Provincial governments and their enterprises, treasury bills and other short-term paper
		V122257	plus: Municipal governments, treasury bills and other short-term paper
		V36864	plus: Interbank loans
BAN	bank loans market	V36717	Total personal loans (including credit cards, lines of credit)
		V36863	plus: Business loans
		V36719	plus: Leasing receivables
		V36718	plus: Non-residential mortgages
		V36864	minus: Interbank loans
		V36877	minus: Foreign currency loans to Canadian residents from chartered banks
		V36937-V36884	minus: Foreign currency liabilities minus foreign currency assets held by chartered banks
COR	corporate	V122640	Bonds and debentures
		V122255	minus: Short-term commercial paper issued in US dollars, includes instruments with an original term of one year or less
		V122272	minus: Corporate bonds placed abroad, includes instruments with an original term to maturity of more than one year
HOU	housing	V36724	Total charted banks assets: residential mortgage
		V1404824	plus: Non-depository credit intermediation: residential mortgage
		V122577	plus: Local credit unions and caisses populaires: residential mortgage
		V37050	plus: Trust and mortgage loan companies excluding bank trust and mortgage subsidiaries: residential mortgage

Note: The weights for each market segment are normalized to sum to unity at each point in time. Data are monthly or monthly interpolation of quarterly data.

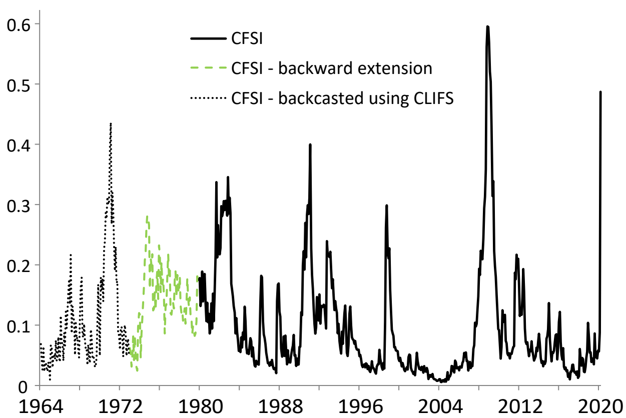
B Extension of the Canadian financial stress index

The benchmark CFSI starts in 1981. For any of these indexes of financial stress, the trade-off is between data quality and data coverage. The constraining variable is the Merton-type banking stress, but a few other variables are not available in the 1970s either. However, the CFSI can be extended backward by using proxies for missing variables or simply ignoring missing values. For banking stress, I backcast the distance to default of MacDonald, Van Oordt, and Scott (2016) by eight years using the marginal expected shortfall computed on the Datastream bank stock index returns for Canada, conditional on a large daily loss of the Toronto Stock Exchange. I also backcast the corporate bond spreads by three years using the spreads of other bond grades. Other variables are missing without proper substitutes, and I simply drop them when computing the average stress per sector. Interbank spreads, bank funding spreads, corporate spreads and households mortgage spreads are not available in the first few years. Before 1981, the market segments reflecting stress for money markets, banks, corporations and households comprises only one or two individual inputs instead of three to four.

Before 1973, data that capture stress on those markets are more limited, and one could use the CLIFS index of Duprey and Klaus (2017), who extend the country coverage of Duprey, Klaus, and Peltonen (2017) to further backcast the CFSI until 1964. The construction method of the CLIFS index for Canada shares similarities to the one of the CFSI, but it uses only three to five main time series to reflect stress on three to five market segments. The backcasted time series are presented in Figure 12, and the episodes of high financial stress are consistent with the narrative of stressful episodes, like the monetary crisis of 1971 or the oil price shocks of the 1970s.

Figure 12: **Backward extension of the CFSI**

Note: The CFSI is the plain black curve and starts in 1981. The backward extended CFSI follows the same construction as the CFSI, but a few time series are missing from 1973 to 1981 for four of the seven sectors covered. Before 1973, a few sectors have no available data, and the CFSI cannot be computed. I extend the stress index back to 1964 using the CLIFS metric of Duprey, Klaus, and Peltonen (2017) that follows a simplified (but similar) construction procedure but focuses only on equity, government, foreign exchange, banking and housing stress.



References

Adrian, Tobias, Nina Boyarchenko, and Domenico Giannone. 2019. "Vulnerable Growth". *American Economic Review* 109, no. 4 (): 1263–1289.

Alessi, Lucia, and Carsten Detken. 2014. "On policymakers' loss functions and the evaluation of early warning systems: Comment". *Economics Letters* 124 (3): 338–340.

— . 2011. "Real time early warning indicators for costly asset price boom/bust cycles: A role for global liquidity". *European Journal of Political Economy* 27 (3): 520–533.

Allen, Franklin, and Elena Carletti. 2013. "What Is Systemic Risk?" *Journal of Money, Credit and Banking* 45 (1): 121–127.

Balke, Nathan S. 2000. "Credit and Economic Activity: Credit Regimes and Nonlinear Propagation of Shocks". *The Review of Economics and Statistics* 82 (2): 344–349.

Bank of Canada. 2020. *Monetary Policy Report.* April.

Brave, Scott, and Andrew R. Butters. 2012. "Diagnosing the Financial System: Financial Conditions and Financial Stress". *International Journal of Central Banking* 8 (3): 191–239.

— . 2011. "Monitoring Financial Stability: A Financial Conditions Index Approach". *Economic Perspectives, Federal Reserve Bank of Chicago* 35 (1): 22–43.

Bruneau, Gabriel, and James Chapman. 2017. "A model For Financial System Risk Scenarios: The Nonlinear Macrofinancial Risk Model". Bank of Canada, mimeo.

Cardarelli, Roberto, Selim Ali Elekdag, and Subir Lall. 2011. "Financial Stress and Economic Contractions". *Journal of Financial Stability* 7 (2): 78–97.

Chatterjee, Somnath, Ching-Wai (Jeremy) Chiu, Thibaut Duprey, and Sinem Hacioglu Hoke. 2017. "A Financial Stress Index for the United Kingdom". Bank of England Working Paper No. 697.

Duprey, Thibaut, and Benjamin Klaus. 2017. "World Financial Stress Indices". Bank of Canada, mimeo.

Duprey, Thibaut, Benjamin Klaus, and Tuomas A. Peltonen. 2017. "Dating systemic financial stress episodes in the EU countries". *Journal of Financial Stability* 32:30–56.

Duprey, Thibaut, and Alexander Ueberfeldt. 2020. "Managing GDP Tail Risk". Bank of Canada Staff Working Paper No. 2020-03.

European Central Bank. 2009. "Box 1: A Global Index of Financial Turbulence". Financial Stability Review, December, 21-23.

Fawcett, Tom. 2006. "An introduction to roc analysis". *Pattern Recognition Letters* 27 (8): 861–874.

Hakkio, Craig S., and William R. Keeton. 2009. "Financial Stress: What is it, how can it be measured, and why does it matter?" *Economic Review, Federal Reserve Bank of Kansas City* 2:5–50.

Hollo, Daniel, Manfred Kremer, and Marco Lo Duca. 2012. "CISS - A Composite Indicator of Systemic Stress in the Financial System". ECB Working Paper No. 1426.

Huang, R., and L. Ratnovski. 2009. *Why Are Canadian Banks More Resilient?* IMF Working Papers 09/152. International Monetary Fund.

Hubrich, Kirstin, and Robert J. Tetlow. 2015. "Financial stress and economic dynamics: The transmission of crises". *Journal of Monetary Economics* 70 (1): 100–115.

Illing, Mark, and Ying Liu. 2006. "Measuring Financial Stress in a Developed Country: An Application to Canada". *Journal of Financial Stability* 2 (3): 243–265.

International Monetary Fund. 2017. *Article IV Consultation.* IMF Country Report No. 17/210.

Kaminsky, Graciela, Saul Lizondo, and Carmen M. Reinhart. 1998. "Leading Indicators of Currency Crises". *IMF Staff Papers* 45 (1): 1–48.

Kliesen, Kevin L., Michael T. Owyang, and Katarina E. Vermann. 2012. "Disentangling Diverse Measures: A Survey of Financial Stress Indexes". *Federal Reserve Bank of St. Louis Review* 94 (5): 369–398.

Kliesen, Kevin L., and Douglas C. Smith. 2010. "Measuring Financial Market Stress". *Economic Synopses, Federal Reserve Bank of St. Louis* 2.

Laeven, Luc, and Fabian Valencia. 2013. "Systemic Banking Crises Database". *IMF Economic Review* 61 (2): 225–270.

Li, Fuchun, and Pierre St-Amant. 2010. "Financial Stress, Monetary Policy, and Economic Activity". *Bank of Canada Review* 2010 (Autumn): 9–18.

MacDonald, Cameron, Maarten Van Oordt, and Robin Scott. 2016. "Implementing Market-Based Indicators to Monitor Vulnerabilities of Financial Institutions". Bank of Canada Staff Analytical Note, 5.

Oet, Mikhail V., Ryan Eiben, Timothy Bianco, Dieter Gramlich, and Stephen J. Ong. 2011. "The Financial Stress Index: Identification of Systemic Risk Conditions". Federal Reserve Bank of Cleveland Working Paper No. 11-30.

Poloz, Stephen. 2020. *Monetary policy in unknowable times.* Remarks by Stephen S. Poloz Governor of the Bank of Canada at the Eric J. Hanson Memorial Lecture at the University of Alberta, May 25.

Reinhart, Carmen M., and Kenneth S. Rogoff. 2011. "From Financial Crash to Debt Crisis". *American Economic Review* 101 (5): 1676–1706.

Schularick, Moritz H., and Alan M. Taylor. 2012. "Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008". *American Economic Review* 102 (2): 1029–1061.

Traclet, Virginie, and Cameron MacDonald. 2018. *The Framework for Risk Identification and Assessment.* Bank of Canada Technical Report No. 113.