The Contagion of Financial Crises:

A Threshold VAR Analysis

by

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1 Introduction

Since the 2008 financial crisis there has been an increased interest in research exploring the nonlinearities associated with financial stress and the impact of financial stress on the real economy. The financial crisis was a period of high financial stress and uncertainty and despite beginning in the US, the crisis spread to the rest of the world. The impact of stress emanating from the US financial system not only had serious implications on financial systems around the world, but led to prolonged weakness within the real economy. With advancements in information technology, the global economy we live in today has become increasingly interconnected. But, the aftermath of the 2008 financial crisis and its effect on national economies around the world raises the question whether policy makers can effectively implement policy actions to address domestic conditions.

Throughout history, the Canadian financial system has been largely exposed to developments within the US financial system.[1] While Canada did not experience a systemic financial crisis like the US did during 2007-2009 (Laeven and Valencia, 2013), Canada experienced significant declines in real gross domestic product. The primary focus of this paper is to model empirically the nonlinearities of financial stress shocks from the US to Canada under high and low US financial stress conditions, and to investigate whether or not these conditions have significant impacts on monetary policy in helping stimulate the Canadian economy. This relationship between financial stress and real economic activity has historically been difficult to uncover due to the episodic nature of financial stress events and data restrictions (Hubrich and

[1] Historically, 50% of corporate debt issued in Canada has been in USD (Thomson Reuters IFR). The correlation of daily stock returns from 1972 to 2017 between the TSX and S&P500 is 0.69 (Bloomberg).

Tetlow, 2014). We use a Threshold Vector Autoregressive (TVAR) model in order to examine the differing dynamics between high and low US financial stress.

Previous literature has shown that linear VAR models do not adequately capture the importance of financial conditions to the real economy due to the nonlinearities that exist between high and low financial stress conditions (see Davig & Hakkio (2010), Li & St-Amant (2012), Hubrich & Tetlow (2014)). This paper intends to expand the existing literature by investigating the nonlinear relationship between the US and Canadian economies as well as the resulting impacts on policy makers within Canada. The transmission of financial crises from the US to the Canadian economy, and whether or not policy makers lose control over domestic conditions as a result is important to understand for several reasons: The results have implications not only on policy decisions moving forward but in designing and implementing accurate stress tests for the Canadian economy.

This paper makes use of a unique index for financial stress for both the US and Canadian financial systems. The index used focuses on cross country comparability as well as adequately capturing all financial market segments; including developments within the housing sector.

Through the Threshold VAR model and the use of impulse response functions, we come to the conclusion that under high US financial stress; additional shocks to the financial system have significantly stronger negative impacts on the Canadian real economy compared to those within the low stress regime or predicted by a linear VAR model. Secondly, we find that Canadian monetary policy becomes a much weaker tool in stimulating the Canadian real economy. Lastly, through a counterfactual experiment conducted around the 2008 financial crisis, we find that by forcing our model into the low stress regime, US financial shocks are less severe and are less impactful to the Canadian economy. Around 67% of the drop in industrial production over the 2008 financial crisis can be attributed to the change in dynamics between the high and low financial stress regimes as opposed to the actual size of the financial shocks.

The remainder of the paper is structured as follows; Section 2 reviews the literature related to the theoretical framework behind the transmission of financial stress to the real economy as well as a review of related empirical research. Section 3 discusses the existing measures of financial stress and the choice of our measure for US and Canadian financial stress, as well as the other variables within our model. Section 4 provides an overview of model estimation and testing for significance. Section 5 presents the main results from impulse response analysis as well as test for the robustness of our results. Section 6 presents the results of our counterfactual simulations during the 2008 financial crisis to determine the importance of switching regimes. Section 7 concludes.

2 Related Literature

Over the last two decades' financial markets have experienced periodic episodes of heightened stress which have had real impacts on output. From the collapse of Long-Term Capital Management, to the bursting of the Dot-com bubble in 2001, to the 2008 financial crisis. We will briefly highlight some of the literatures that we found provided insightful research into this relationship between financial stress and the economy and helped to influence our work.

The role which financial frictions play in slowing down growth within the real economy stem from two major theories, the real options framework and the financial accelerator model. The real options framework states that given the uncertainty of future cash flows within times of high financial stress, the value of waiting for more information about future conditions may outweigh the expected value of current investments. When uncertainty rises, the variance of expected cash flows rise, leading to the possibility of losses on investment. Given this uncertainty, it is often optimal for businesses to forego irreversible investments today and wait for more certainty. This can lead to less investment overall and as a result slow down growth within the real economy.

Bernanke, Gertler and Gilchrist (1999) developed the initial financial accelerator model which helps to explain why it is that financial market stress can amplify both real and nominal shocks within the economy. Bernanke et al (1999) introduce into their dynamic general equilibrium model a "financial accelerator" which allows for endogenous developments within the credit market to amplify shocks to the economy. The financial accelerator model works by linking the "external finance premium" (the difference in the cost of raising external funds versus the opportunity cost of funds internal to the firm) and the net worth of potential borrowers. Davig and Hakkio (2010) provide a good summary of how the model works to amplify shocks; during good times, borrowers have stronger balance sheets which allow them to more easily obtain financing for investments at favourable interest rates. However, bad times may cause a weakening in borrower's balance sheets and as such increase the external financing premium paid, resulting in lower levels of investment or no investment at all. As uncertainty in the profitability of borrower's increase and the risk of bankruptcy rises, higher premiums are required for external financing. As a result, shocks to the economy which negatively affect a firm's balance sheet are amplified by the feedback from rises in the average cost of external financing to the average level of investment which ultimately causes the average level of economic activity to decline. These two frameworks help to explain theoretically why economies react differently between low financial stress and high financial stress regimes.

Davig and Hakkio (2010) make use of a regime-switching model in order to assess the nonlinear dynamics between high and low financial stress regimes within the United States. They make use of the Kansas City Federal Reserve's Financial Stress Index to monitor financial stress and the Chicago Fed National Activity Index (an index for macroeconomic activity based off of 85 macroeconomic variables). They estimate the probability, given the level of financial stress and macroeconomic activity, that the economy will switch to the distressed regime. In order to assess the differing dynamics across regimes, Davig and Hakkio use impulse response functions to examine the real effects of a shock to US financial stress. They find that within both regimes, shocks to financial stress lead to significant declines in real activity. However, within the high stress regime, the decline in real activity is 50% larger and longer lasting than within the low stress regime. Davig and Hakkio conclude by showing that financial stress within the US not only has real effects on the economy but also increases the probability of pushing the economy into a distressed regime. Davig and Hakkio develop a simple model which effectively captures the nonlinearities between regime. However, they do not touch on the implications for policy.

Li and St-Amant (2012) expand upon the simple framework by using a Threshold VAR model in order to assess the impact of shocks to Canadian financial stress on the real economy as well as the asymmetric effects of monetary policy within both a low and high Canadian stress regime. Li and St-Amant seek to answer the questions; does there exist symmetric effects between contractionary and expansionary monetary policy? What are the effects of large versus small shocks? And does monetary policy have the same effect on the real economy in a low financial stress regime as it does in a high stress regime? Using an index for financial stress developed by Illing and Liu (2006), quarterly real GDP growth, core inflation, and the real overnight rate, Li and St-Amant estimate a 'structural' Threshold VAR model for the Canadian economy. In order to assess the asymmetries between contractionary and expansionary monetary policy under stress, the authors estimate nonlinear impulse response functions for a one standard deviation shock to the real overnight rate. They find that (1) contractionary monetary policy shocks have a stronger effect on output growth than expansionary shocks and (2) there is little response of the financial stress index to monetary policy actions. Li and St-Amant go on to investigate the effects of large and small shocks within each regime where they find the difference in the size of the shock to be insignificant. Contrary to previous research, Li and St-Amant find that expansionary shocks have larger effects within the high stress regime as opposed to the low financial stress regime. Lastly, Li and St-Amant find that by using expansionary monetary policy there is a higher probability of pushing the economy back into the low financial stress regime. Our model is largely based off the work done by Li and St-Amant, adding to their model the transmission of stress from the US to Canada.

Although Li and St-Amant show that monetary policy remains effective given high levels of domestic stress, the issue of countries ability to counteract financial instability emanating from other economies was a focus of the recent April 2017 Global Financial Stability Report published by the International Monetary Fund (IMF). With a newly constructed index for global/US financial stress, researchers use a linear VAR model in order to attempt to answer the question; are countries losing control over their domestic financial conditions? The IMF outlines several reasons why it is that increased global financial linkages may limit the ability for monetary policy to stimulate the economy. Firstly, as we become more connected, financial conditions are more likely to be affected by foreign shocks. And secondly, this integration may weaken the transmission channels of monetary policy. If long-term bond yields are set in international markets they may be more influenced by changes in investor sentiment and less responsive to short-term rates. Using their global financial stress index, consumer prices, the domestic policy rate, and domestic financial stress index, the IMF uses impulse response functions to assess the ability of domestic policy in easing foreign shocks to financial stress. On average, the IMF finds that domestic policy makers still maintain some control over their domestic conditions. However, they find that domestic financial conditions react faster to global financial shocks than to monetary policy. As a result, given large, persistent global financial shocks, domestic policy makers may begin to lose control over financial conditions. We expand upon this work by using a Threshold VAR model as well as a slightly more elaborate index for US and Canadian financial stress.

Lastly, Hubrich and Tetlow (2014) examine the changing dynamics between high and low financial stress regimes. The authors use a Markov-switching VAR model, estimated with Bayesian methods, in order to empirically estimate the differing dynamics between regime as well as the importance of shocks versus changes in regime. Hubrich and Tetlow use the Federal Reserve Board's Index for Financial Stress in order to estimate a Markov-switching VAR for the US economy. Their model differs from previous papers in that, thanks to Bayesian estimation techniques, they are able to estimate a low stress, medium stress, and high stress regime. Hubrich and Tetlow go on to perform counterfactual experiments in order to investigate the effects of financial shocks and changes in regime on the US economy. Of relevance to our work are two specific counterfactuals; firstly, they run a counterfactual experiment starting in August 1998, over the period of the Long-Term Capital Management crisis in which they force financial stress to remain low, at a constant level throughout the crisis. Compared to the historical path, Hubrich and Tetlow find that as a result, monetary policy is not required to react by easing, and output growth grows marginally. The second counterfactual experiment of interest to our work is performed through the 2008 financial crisis. From 2007 until the end of 2009, Hubrich and Tetlow simulate the US experience given that the economy follows the same exact sequence of historical shocks but are restricted to staying within the low stress regime; that is, all that changes within the simulation are the relative coefficients of the regime. As a result, compared to the historical path, given that the economy remains within the low stress regime; (1) financial stress is lower than historical levels, (2) the need for large monetary policy actions are avoided, (3) output growth rises substantially and (4) money growth would have been lower. We use these counterfactuals as a starting point for our experiment; examining the importance of shocks versus changes in regime.

The amount of literature focusing on the dynamic interaction between financial stress, the real economy, and the implications on monetary policy has grown since the financial crisis. We add to the literature by using a Threshold VAR model to focus on the transmission of stress from US to Canada and the implications this has on monetary policy.

3 Measuring Financial Stress

Since the 2008 financial crisis a number of market based indicators for banking stress have been developed, as well as different financial stress indices. While there are an increasing number of proxies and indices for financial stress, this raises the question; how does one define financial stress? Duprey et al. (2015) define financial stress as “simultaneous financial market turmoil across a wide range of assets”. Financial stress episodes include not only uncertainty and sharp corrections in market prices, but also a widening of spreads, as well as an increase in the commonality between asset classes. Financial crises are complex, and in order to effectively measure financial stress, indices must be able to take into account the different facets of stress which exist within our system (Kliesen and Smith, 2010).

Several Federal Reserve Banks have developed financial stress indices for the United States by combining different time series using the principal component approach in order capture the components which explain most of the common variation. For instance, Hakkio and Keeton

(2009) construct the Kansas City Federal Reserve's Financial Stress Index. The index uses market prices and yields, available at a monthly frequency. However, the index starts in 1990. Another popular index is the St. Louis Federal Reserve's Financial Stress Index from Kliesen and Smith (2010). This weekly index is available from 1993 only. Last, the Chicago Federal Reserve's National Financial Conditions Index (Brave and Butters, 2011) is a monthly index that combines up to 105 time series and measures risk, liquidity and leverage in money markets and debt and equity markets as well as in the traditional and "shadow" banking systems.

For Canada, Illing and Liu (2006) developed a financial stress index utilizing data from the banking sector, foreign exchange markets, debt markets, and equity markets. Their work was an early contribution to this literature, but their index was optimized on the pre-crisis period, and the index is a mere summation of stress on individual markets.

Instead we use the Country-Level Index of Financial Stress (CLIFS) of Duprey and Klaus (2017) that extends the dataset of Duprey et al. (2017) who initially focusses on EU countries. This somewhat less data intensive approach has three advantages over the previous indices.

First the construction method directly encompasses the supra-additivity property of systemic stress by using cross-correlation weights. That is to say the overall level of financial stress should be higher than the sum of individual markets stress. This concept is important to understanding the 2008 financial crisis argues Allen and Carletti (2013) as, prior to the 2008 financial crisis, most regulations and risk analysis was performed on an individual firms and bank level, failing to capture this supra-additivity property of financial risk. Allen and Carletti claim that the view that risk within financial systems is the summation of individual risks within the system fails to incorporate the interaction between financial institutions which can amplify the individual risks.

Second the CLIFS indices include housing stress, along with equity, government bonds, foreign exchange and banking stress. Indeed, while there exists a growing number of financial stress indices, a major shortcoming with these other indices is that they fail to directly incorporate stress emanating from the housing sector – a contributing factor to the 2008 financial crisis and a huge concern for the Canadian economy as house prices have grown at alarming rates throughout 2016.

Third, the CLIFS database of Duprey and Klaus (2017) includes 46 countries and ensures cross-country comparability, which is important here as we want to include both the US and Canadian financial stress indices to look at financial stress spillovers. Otherwise different construction methods would be used to compute the US versus the Canadian financial stress index, introducing a bias in the way we investigate financial stress spillover from the US. The CLIFS indices are available for the US and Canada starting in 1981, allowing us to encompass more stressful episodes than most other available indices.

The CLIFS indices for the US and Canada are plotted in Figure 1 along with significant financial market stress events since the beginning of the indices. It is of interest to note that Hubrich and Tetlow (2014) make clear within their research, that not all financial stress events which produce headlines come through as relatively stressful periods for the US economy (S&L crisis, 1987 crash, Peso crisis, Asia crisis). Furthermore, although not plotted here and as outlined in Duprey et al (2017) for EU countries, not all financial stress events are associated with recession, or all recessions associated with financial stress events.

3.1 Macroeconomic Data

We use monthly Canadian and US data from 1981M1 to 2016M1. To model the effect of US stress on the Canadian economy. To measure stress, we use the previously discussed Country-level Index of Financial Stress for Canada and the United States. The model also includes monthly Canadian inflation, the overnight interest rate and the growth rate of the industrial production index.[2] We opt for the monthly growth in industrial production as opposed to the quarterly growth in real gross domestic product in order to improve the size of our sample. Later on, we will consider the growth in real gross domestic product and alternative measures of financial stress, more specifically banking stress, in order to examine the robustness of results. The time series of the CLIFS Canada and US are plotted above in Figure 1, while the time series of the growth of industrial production, the overnight rate and inflation are plotted in Figure 2. Comparing our plot of the growth in industrial production to financial stress we observe that sharp decreases in industrial production tend to roughly line up with sharp increases in financial stress but follow no discernible pattern during average financial stress periods. The plot of Canadian inflation is fairly stable with only one large spike around the time which the Bank of Canada announced inflation targeting. The overnight rate has gradually fallen, with the highest rates through the early 1980s. Since the 2008 financial crisis, rates have remained relatively low.

The time series plots all appear to be stationary which we confirm using the augmented Dicky-Fuller test. We reject the null hypothesis of non-stationarity at the 5% significance level for all of the above variables. Table 1 presents the results as well as some summary statistics of the data.

[2] All three variables are detrended until 2001. Results of sequential Bai-Perron breakpoint test inform us that there exists a break in the trend occurring in 1996/2001. Results are robust to using either break point in the trend.

Table 1: Summary Statistics and Stationarity Test

	Growth in IPI	Overnight Rate	Inflation Rate	CLIFS US	CLIFS Canada
N	421	421	421	421	421
Mean	0.007	2.680	0.064	0.129	0.108
Standard Deviation	0.008	1.980	0.190	0.129	0.089
Min	-0.034	-1.051	-0.652	0.010	0.009
Max	0.035	10.926	2.033	0.793	0.549
Test statistic	-5.531	-4.828	-4.733	-4.161	-4.315
Result	Reject	Reject	Reject	Reject	Reject

Through Figure 1 and the summary statistics it can be seen that CLIFS US has historically experienced not only higher levels of financial stress than that of Canada, but also more volatile periods of financial stress. Over the 2008 financial crisis the CLIFS US peaked at 0.793 while Canada fared much better, peaking at 0.549. Canada's performance throughout the financial crisis can be attributed to solid risk management practices within the Canadian banking system leading into the crisis (Arjani and Paulin, 2013).

4 Model Specification

In order to analyze the nonlinear relationship between monetary policy, financial stress, and the real economy we will estimate both a benchmark Vector Autoregressive model (VAR) as well as a Threshold Vector Autoregressive model (TVAR). The TVAR model has several benefits over the benchmark and other nonlinear models. The TVAR model provides us with a relatively simple and intuitive way to model nonlinearities, asymmetric reactions to shocks, and the existence of multiple equilibria. The TVAR model works by splitting the time series into two separate regimes, in our case, high US financial stress and low US financial stress. The standard VAR model can be written as,

$$Y_t = c + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \varepsilon_t, \tag{1}$$

while we will estimate a 'structural' TVAR model of the form,

$$Y_t = \beta_0^1 + \beta_1^1(L)Y_{t-1} + (\beta_0^2 + \beta_1^2(L)Y_{t-1})I(c_{t-d} > \gamma) + \varepsilon_t, \tag{2}$$

where Y_t is a vector of endogenous variables containing US financial stress, the growth of industrial production, the inflation rate, the overnight rate, and Canadian financial stress. The parameter β_0^1 is a constant term, β_1^1 is a lagged polynomial matrices and ε_t the structural disturbances. $I(c_{t-d} > \gamma)$ is an indicator function which equals one when the threshold variable (c_{t-d}) is greater than some threshold (γ), and zero otherwise. The TVAR model allows a time delay (d) to be set on the threshold variable which we choose by minimizing the information criteria.

The TVAR model follows a recursive structure, the variables are ordered as: US financial stress, growth in industrial production, the inflation rate, the overnight rate, and lastly Canadian financial stress. The ordering, which follows closely to the work of Li and St-Amant (2012) is based off the assumption that the short-term interest rate does not have a contemporaneous impact on output growth or the inflation rate but can have an immediate impact on Canadian financial stress. We add to their model US financial stress, which we argue, due to the relative sizes of the two economies and importance of the United States to the Canadian economic activity, shocks to the US financial system are more likely to have a contemporaneous effect on the Canadian economy than the Canadian economy on to the US. While we do consider moving CLIFS US down, there is a trade off in that under our recursive structure, shocks to Canadian variables would affect the CLIFS US. We believe it is more likely that US financial shocks contemporaneously effect the Canadian economy than the other way around. However, we do consider moving CLIFS US to the fourth position in our model (so that US financial stress cannot contemporaneously affect the Canadian real economy but can effect Canadian financial stress), and our results remains robust to these changes. As an additional restriction, we set the coefficients of the Canadian variables in the CLIFS US equation to zero so that our Canadian variables do not affect the level of financial stress within the US. We would not expect for developments within the Canadian economy to significantly impact the United States financial system.

4.1 Model Estimation and Significance Testing

The TVAR model is estimated using log likelihood.[3] In order to estimate our TVAR model we must first determine the optimal lag length, time delay and threshold value. We choose our optimal lag length and time delay by minimizing the Akaike information criteria while limiting the maximum number of lags to 6 months. This gives us an optimal lag length of 3 months and time delay of 1 month. The threshold value, γ, is determined by maximizing the log-likelihood within each regime. The threshold should reflect relatively rare, stressful events while maintaining a sufficient number of observations in order to estimate our model. Similar to other research in the field, we set the trim (the minimum percentage of observations within each regime) to 15%. This results in a threshold value of 0.231 which leaves around 17% of the total observations within the high stress regime. While we experimented with raising the trim to 20-25% there were no

[3] The model is estimated using the TVAR toolbox developed by Gabriel Bruneau (https://sites.google.com/site/bruneaugabriel/my-matlab-toolboxes)

significant changes with the results; as such, we use the 15% trim, similar to previous research. Figure 3 plots the US CLIFS as well as the optimal threshold value.

Looking at Figure 3, we can see that our high stress regime captures several different financial crises. The sample begins with the spike in interest rates and Mexican debt crisis around 1981-1983, the threshold picks up developments around the time of the Long-term Capital Management crisis, Russian default and Dot-com bubble, and ends with the 2008 financial crisis.

To check for the statistical significance of our threshold model over the linear VAR model we use a multivariate extension of the linearity against threshold test from Hansen (1999). We reject the null hypothesis of the linear VAR model in favour of the nonlinear threshold model at a 1% significance level, Table 2 presents the results from these tests.

Table 2: Tests for Threshold VAR

Threshold Variable	Threshold Value	Test Statistic	P-Value
CLIFS US	0.231	171.134	0.00

Note: Delay (d) = 1 with 1 lag. The p-values are calculated from Hansen (1999) bootstrap method with 1000 replications.

Now that we have proven the significance of our TVAR model it is of interest to examine the differing dynamics between regime, Table 3 presents the average value of each of our variables within both regimes. As to be suspected, the high stress regime is not only associated with lower growth in industrial production than the low stress regime but negative growth. These values are consistent with those predicted by models like the financial accelerator and real options framework; when financial stress is high, output growth slows. We find that periods of high financial stress have typically been associated with higher inflation and interest rates than low stress periods. As noted by Li and St-Amant (2012), although the recent 2008 financial crisis has been associated with low interest rates and deflationary pressures, these are average values which do not need to be repeated within the future. Lastly, high financial stress within the US is associated with high financial stress in Canada. This is not surprising, due not only to the size and importance of the US financial system, but to the Canadian economies proximity and reliance with that of the US; as such our economy and financial system should be expected to be integrated and dependent on the US system.

Table 3: Regime Dependent Mean Values

Regime	CLIFS US	IPI Growth	Inflation	Overnight Rate	CLIFS Canada
Low Stress	0.083	0.003	0.056	2.524	0.086
High Stress	0.364	-0.001	0.169	3.661	0.214

Note: Regimes based off of TVAR(3) model, 1 month delay, 15% trim.

5 Analysis of Impulse Response Functions

In order to examine the differing dynamics between high and low US financial stress we will conduct an analysis of the linear impulse response functions. The linear impulse response functions work by assuming that the model is already within either the high or the low regime and subsequently shocking the variable of choice. This analysis will focus on two types of shocks; firstly, how do shocks to the US financial system differ in their impact on the Canadian economy under high and low US financial stress conditions. And secondly, how do US financial conditions affect the ability for expansionary monetary policy to stimulating the Canadian economy.

5.1 Shocks to US Financial Stress

Figure 4 presents the impulse response functions following a one standard deviation increase in the CLIFS US for all regimes. The impulse response functions plot the 12 months following the initial shock for the low stress regime, high stress regime, the linear VAR model, and their 80 percent confidence bands. Confidence bands are calculated using bootstrap methods and corrected for small-sample bias using methods outlined in Killian (1998).

Following our shock to the US financial system, in the high stress regime, Canada experiences a much sharper drop in the growth of industrial production; significantly more impactful than the drop predicted by the linear VAR model. The effect within the high stress regime remains statistically significant for the full 12-month period. By the end of the simulation, industrial production falls by around 3% as opposed to the 1.6% decline predicted by the linear VAR model. Within the low stress regime, industrial production rises slightly but this effect quickly becomes statistically insignificant.

Tracing the shock through the model, inflation reacts similarly to how we would expect; falling with the drop in output. Given a one standard deviation shock to US financial stress we find that within all regimes inflations initially falls. Within the low stress and linear model this effect dies down by the second period and inflation rises slightly for the remainder of the simulation. Within the high stress regime, we observe something much more like what we experienced during the 2008 financial crisis. The shock to US financial stress leads to a drop in inflation which remains significant for four months. The overnight rate does not react significantly in any of the regimes.

Lastly, we find that regardless of which regime we are in, Canadian financial stress rises, although not one for one with US financial stress. Within the low stress regime, around 50% of the US shock spreads into the Canadian financial system and remains significant for a close to the full 12-month period. The CLIFS Canada responds only slightly to the US financial shock within the high stress regime, rising by about 20% of the US shock. This response within the high stress regime quickly becomes insignificant and continues to fall. These results may seem counterintuitive at first but it is important to keep in mind that within the impulse response functions, the model is already assumed to be within a certain regime. As noted in Table 3, when the US is in the high financial stress regime, on average, Canada is also experiencing above average stress. Given that our impulse response function starts within the high stress regime, it may be assumed that Canada is already experiencing high levels of financial stress so that additional shocks from the US may be less impactful. This failure to differentiate between high stress in the US and high stress in Canada may be a shortcoming to the TVAR model and, given the availability of more data, a Markov-switching VAR model may better estimate this relationship.

The results in Figure 4 coincide with those of the related literature and what is to be expected from theory. The nonlinearities between the high and low stress regime were the most apparent when examining the real impact on the Canadian economy where, within the high stress regime industrial production fell significantly more than both the linear VAR model and the low stress simulation. This may be for several reasons, high stress in the US not only affects financial stress within Canada which lowers domestic activity, as shown in Table 3, but also impacts the real economy within the US, Canada's largest trading partner. So, the effect is most likely two-fold; first, US financial stress slows investment within the US as explained through either the real options framework or financial accelerator model which then lowers foreign demand for Canadian goods, and second, the increase in US and Canadian stress slows investment and demand domestically in Canada.

Canada's relationship with the US is vital to the health of the economy. As global markets continue to become more connected, it is increasingly more important to understand how this impacts not only the Canadian economy but policy makers within Canada.

5.2 Monetary Policy under Financial Stress

While it is clear that there exists a contagion of stress from the US financial system to the Canadian economy, what is less clear is how this contagion of stress affects policy actions within Canada. Figure 5 plots the impulse response functions following a -100 basis point shock (bps) to the overnight rate. As before, Figure 5 plots the response of variables for the 12-month period following the initial shock, as well as the 80 percent confidence bands.[4]

Within both the low stress regime and linear VAR model, we find that expansionary monetary policy is effective in raising the growth rate of industrial production. Consistent with the idea that monetary policy takes time to work its way through the economy, the effect becomes significant within the fourth period and continues to grow. This shock helps to raise industrial production by approximately 1.6% in the low stress regime by the end of the 12-month period. Within the high stress regime, we find that the response of industrial production is weakened. By the end of the 12-month simulation, industrial production rises by around 0.9%. However, we find the effect of monetary policy to be statistically insignificant in the high stress regime; although, this may be explained by our small sample size. The weakness in monetary policy may be explained by several factors. Industrial production as a proxy for real economic activity has certain caveats; while we improve our sample size there is a trade-off in using industrial production over gross domestic product. Industrial production fails to pick up consumption by Canadians, only capturing production within the industrial sector (mining, manufacturing, public utilities). These sectors of the economy rely heavily on exports, a majority of which are to the United States. Therefore, given that high financial stress is emanating from the US economy, although

[4] We do not plot the CLIFS US as, by our restrictions, there is no response.

expansionary monetary policy may make Canadian products more attractive through the exchange rate channel, it may not be enough to help significantly stimulate investment and activity within the United States. We will show later that by substituting the growth in real gross domestic product for industrial production we find that monetary policy becomes slightly more effective in stimulating the economy.

Although we would expect for our expansionary policy to increase inflation we find no long lasting significant effects on inflation. Moving to Canadian financial stress we again find weak results. Within the low stress regime, we find that by lowering our policy rate by 100bps we experience brief periods of relieved stress but this effect is economically insignificant. Within the high stress regime, we find financial stress to fall slightly but the effects of monetary policy are statistically insignificant. However, this statistical insignificance may again explained by the small sample size within the high stress regime.

While we find that monetary policy may be effective in stimulating the real economy under low stress financial stress conditions, under high US financial stress policy loses the ability to stimulate production. Contrasted with the results of Li and St-Amant (2012) who found that monetary policy was more effective in stimulating the Canadian economy within the high stress regime, it seems that in our model monetary policy becomes less effective in stimulating real activity. This difference in the effectiveness of monetary policy may be explained by two factors. Firstly, our choice of industrial production over gross domestic product captures less domestic activity. And secondly, Li and St-Amant (2012) only estimate their model using data from 1981Q4 to 2006Q4, failing to capture the 2008 financial crisis; a very important event in recent financial history. Opposed to the IMF (2017) findings that on average, countries still maintained control over domestic financial conditions; under our framework we find that given high stress spreading from the US, we find evidence that the effectiveness of monetary policy is weakened. These differences in results may be explained by two separate reasons; (1) as stated before, the relative importance of the US economy for Canadian economic activity and, (2) the use of a nonlinear TVAR model over the linear VAR model used by the IMF. Despite these results, the CLIFS is not the only measure for financial stress or industrial production the perfect proxy for real activity.

5.3 Robustness of Results

Within this section we will attempt to answer two questions; do alternative measures for financial stress uncover different dynamics of crises and, does the inclusion of gross domestic product capture more information regarding real economic activity than that of industrial production. To begin our analysis, we will examine how our model reacts when replacing the broad CLIFS US for the Marginal Expected Shortfall (MES) of US financial institutions.

Marginal Expected Shortfall is a market-based indicator for the stress of financial institutions developed by Acharya et al (2009, 2012) which captures the systemic risk associated with the solvency of financial institutions. Market-based indicators have several advantages over the broad financial stress indices; data is available in near real time and at high frequencies due to it being market-based. As well, market-based indicators provide us with a relatively easy way to narrow down our definition of financial stress; by using marginal expected shortfall we are able to focus more specifically on the effects that banking stress has on our economy.[5] Macdonald and van Oordt (2017) define the marginal expected shortfall as the expected loss of an institution given that the financial system suffers an adverse shock. The higher the marginal expected shortfall, the larger the expected losses of financial institutions in the presence of a large negative financial

[5] See MacDonald and van Oordt (2017) for good overview of market-based measures for financial stress.

shock. We calculate the MES for the US using the top 50 financial institutions, ranked by asset size. The individual MES is the expected drop in an institutions equity return conditional on the S&P 500 falling by more than 2% in a single day. The US MES is then calculated by taking the monthly average of the daily MES for each institution, weighting them by their market capitalizations.

We estimate our TVAR model for the period of 1981M1 to 2016M1. We follow the same model specifications as the CLIFS US variation which includes a three-month lag, one period time delay and a 15% trim. This results in a threshold value of 3.2897, leaving around 16% of all observations within the high stress regime. Figure 6 plots the threshold for the MES model as well as the CLIFS US model for comparison. The MES threshold picks up similar events as the CLIFS US. The MES does not capture the interest rate spikes and Mexican debt crisis during the early 1980s. However, the threshold captures more of the LTCM crisis, Russian default, Dot-com bubble and 2008 financial crisis. Additionally, the model now picks up some of the S&L crisis and 1987 market crash.

Figure 7 plots the impulse response functions for the 12-month period given a one standard deviation shock to the US MES. We focus our analysis on the impact of US banking stress on the real economy (captured by growth in industrial production) and on Canadian financial stress (captured by the CLIFS Canada). As before we find that within the low stress regime, shocks to US MES have insignificant effects on the growth in industrial production. While in the high stress regime shocks to financial stress have significant and large negative effects on the growth in industrial production. Shocks in the high stress regime correspond to a roughly 2.3% drop in industrial production by the end of the 12-month period compared to the 3% drop predicted within the CLIFS US model. As a result, we find that shocks to banking stress in the US fairly similar effects to that of broad US financial shocks. The explanation for both remain the same, higher stress restricts credit growth and as a result lowers investment, leading to a slow down in real economic activity.

Looking at the response of Canadian financial stress to shocks to US banking stress we find that in the low stress regime stress rises slightly and, in the high stress regime stress falls. While statistically significant these results are economically insignificant only corresponding to a 0.004 drop in Canadian financial stress in the high stress regime and an increase of 0.002 in the low stress regime. Unlike with the CLIFS model where we found that financial stress spread to the Canadian system within the low stress regime, shocks to banking stress do not have a significant impact. We offer two possible explanations for this, in the low stress regime, given the resilience and strength of the Canadian banking system (see; Arjani N., and G. Paulin (2013)), shocks to US financial institutions may not significantly effect the Canadian system. As before, in the high stress regime Canada is most likely already experiencing high levels of financial stress so, additional shocks may be insignificant.[6]

Moving forward to the effects of monetary policy under US banking stress, Figure 8 plots the 12-month response of industrial production and the CLIFS Canada following a -100bps shock to the overnight rate. Looking at the response of industrial production we find almost an identical response compared to the CLIFS US model. In the low stress regime industrial production grows slowly, becoming significant within the 6th period and continuing to grow. The total response to our monetary policy shock is a 1.3% increase in industrial production, compared to the 1.6% predicted within the CLIFS US model. Under high US stress we do not observe any significant

[6] We confirm this by looking again at the high regime average values for MES US (4.9480) and CLIFS Canada (0.1801)

impact on the growth of industrial production, again, this may be explained in part by the importance of US exports for industrial production.

While we still find weakness in policy in stimulating the real economy under high stress we find slightly different results for Canadian financial stress. In the low stress regime, monetary policy lowers financial stress for just over 6 months, although only slightly. The response of Canadian stress in high stress is volatile, initially lowering stress, then jumping up in the second period, and falling in the third until the effect becomes insignificant. This volatility induced by monetary policy may be explained by the markets reaction to observing policy within the high stress scenario. This response is similar to Hubrich and Tetlow (2014) who find that shocking the federal funds rate in the high stress regime significantly raises US financial stress, concluding that: "… in high-stress situations, agents regard conventional policy actions that would normally be beneficial as confirmation of incipient financial difficulties.". In our high stress regime, shocks to the overnight rate may signal to market participants that the future economic outlook is bleak, raising uncertainty and as a result increasing volatility within markets.

Switching out the CLIFS US for the US MES did not change our results dramatically. We still find that in the high stress regime, monetary policy is less effective in stimulating both the real economy and financial system. However, as stated earlier, this may stem from our choice in using industrial production over the gross domestic product. By using the gross domestic product instead of industrial production, we should be able to better capture developments within the Canadian real economy.

We estimate our GDP model using quarterly data from 1981Q1 to 2016Q1. We keep the same ordering of variables as our original model but replace industrial production with the growth in real gross domestic product. Under this frequency it is more likely that developments within the US financial system may contemporaneously effect the Canadian economy. We follow the same procedure as above in specifying our model. Minimizing the Akaike information criteria we find that the optimal lag length and time delay is one quarter. Using a 15% trim we find our optimal threshold to be 0.2292, capturing 18% of all observations in the high stress regime.

Figure 9 plots the impulse response functions for our GDP model for the 8 quarters following a one standard deviation shock to the CLIFS US. For shocks to CLIFS US the overall response remains consistent with our previous impulse response functions. By the end of our 8 quarter simulation, real GDP shrinks by close to 3% given a one standard deviation shock to US financial stress. While in the low stress regime real GDP grows slightly in the beginning, before becoming insignificant by the fourth quarter. Canadian financial stress reacts in much of the same way as it did within our original model. In the low stress regime, Canadian financial stress rises by roughly $3/7^{th}$ the original shock and slowly fades away. In the high stress regime, we still see no long lasting significant effect of US financial stress on Canadian stress.

These results help to increase our confidence in previous variations of our model. Switching from industrial production to gross domestic product does not significantly impact our results for shocks to the US financial system. However, what is more interesting is whether or not the inclusion of GDP can better capture the effects of monetary policy under financial stress.

Figure 10 plots the impulse response functions for the GDP model following a -100bps shock to the overnight rate. In the low stress regime, monetary policy remains an effective tool for stimulating the growth in real GDP, raising output by 0.65% by the end of the 8-quarter period. Different from previous models we find that monetary policy has regained some of it’s ability to stimulate the growth in output in the high stress regime. We find that output growth responds quicker within the high stress regime, becoming significant within the second quarter and raising output by around 0.4% by the third quarter. By the end the simulation real output rises by 0.75%, marginally better than the low stress regime. However, this effect becomes statistically insignificant by the fourth quarter and remains so for the rest of the simulation. With the inclusion of real GDP growth in our model, monetary policy has gained some control. Looking at Canadian financial stress, under the high stress regime we find that monetary policy gains some ability in lowering Canadian stress levels. Monetary policy seems to have little effect within the low stress regime but manages to lower Canadian financial stress by around 0.02 for up to four quarters.

While the effects of monetary policy remain low, these results help to support our initial model. Between broad financial stress and banking stress we find similar effects regarding the transmission of stress from the US to the Canadian economy. By substituting gross domestic product in for industrial production we find that policy makers were able to gain some control over their domestic conditions. However, despite this substitution we still find that in the high US financial stress regime, the effect of Canadian monetary policy is statistically insignificant. This may still be explained by the heavy reliance of the Canadian economy on exports to the US. Although we may be able to stimulate some consumption within the Canadian economy (as seen in Figure 10), ultimately, the real effects on output coming from the US outweigh the increases in production. While impulse response functions are useful tools to examine the differing dynamics within regimes, we fail to learn from them how our model responds to changes in regimes.

6 The Importance of Switching Regimes: 2008 Counterfactual

To finish our analysis of the US financial stress and its effects on the Canadian economy, we look at the relative importance of the size and sequence of shocks coming from the US versus the change in dynamic from when the United States moves from the low stress regime to the high stress regime. To do this we will compare the historical paths for our variables to two sets of two counterfactuals. One set of counterfactuals will simulate how interest rates develop, while the other set will follow the historical path of interest rates. For each set we will simulate how the Canadian economy would have developed under the two different scenarios. We will start by forcing shocks to follow their historical path but we will not allow the model to switch to the high stress regime in order to examine the importance of switching dynamics. The only difference between this first counterfactual and the historic path of variables will be the switch from low stress to the high stress regime. In our second counterfactual we will cut off shocks to the CLIFS US before the crisis starts. These counterfactuals should give us a few insights. Firstly, the effect/importance of monetary policy in stimulating the Canadian economy through the financial crisis. And secondly, the importance of regime switching as opposed to the actual financial shocks coming from the US financial system during the 2008 financial crisis.

To estimate our counterfactuals we perform two nonlinear simulations; our nonlinear simulations differ from the linear impulse response functions in that now, both the starting point for variables, as well as the size of the shocks effect the simulated path of the variables.[7] We start our simulation just before the start of the financial crisis. Figure 11 plots the two sets of counterfactuals from 2007M1 to 2011M12. All simulations follow the historic path until 2007M8,

[7] Within linear impulse response functions, the size of shocks simply rescales the response while in nonlinear simulations the size of the shock may have nonlinear effects on the response.

right before entering the high stress regime, and then are allowed to deviate from the historical experience.

Starting out we find that within both sets of counterfactuals that by forcing the CLIFS US into the low stress regime, shocks to the CLIFS US lead to lower levels of US financial stress than what was experienced historically. These results match those found by Hubrich and Tetlow (2014). When stress is low, market participants tend to react less to additional financial shocks than within the high stress regime. By the peak of the crisis we find that a little more than $3/4^{th}$ of the US financial stress was caused by large shocks while the additional $1/4^{th}$ can be explained by the switch in regime. This may be explained by the financial accelerator model; when the economy is within the high stress regime, additional shocks to the economy are amplified due to credit conditions.

As a result, substantial monetary policy action throughout the crisis is no longer necessary. Looking at the response of the overnight rate we see that by removing financial shocks in the US and forcing the simulation into the low stress regime we require close to no policy response throughout the crisis. By keeping US financial shocks and forcing the simulation into the low stress regime we see Canada raising rates throughout the crisis. This may be explained by the fact that within low stress periods, financial shocks are not necessarily seen as negative events, but financial shocks are part of a growing economy. By forcing the economy into the low stress regime we find that we are able to maintain sufficient room for policy action throughout the crisis which we use to help stimulate the economy post-crisis.

Moving to the simulations of industrial production, by forcing the simulation into the low stress regime the Canadian experience is significantly different than the historic path. Keeping US shocks and allowing the overnight rate to deviate from the historic path results in the Canadian economy almost completely ignore the crisis, leading to a roughly 8% increase in industrial production by the end of the 5-year simulation (compared to the historic drop of 5% in industrial production). By shutting off shocks to the US financial system Canada performs even better through the financial crisis, growing industrial production by around 16% by the end of the simulation. When monetary policy follows the historic path we find an even greater increase in industrial production, rising close to 25% by the end of our simulation.

By essentially removing the US financial crisis from our simulation we were able to increase industrial production by about 20 percentage points. Around 67% of this increase is attributed to forcing the simulation into the low stress regime (the move from the historic path to the low stress simulation with shocks). The other 33% may be explained by the size of shocks coming from the US financial system (the change in industrial production by removing shocks completely). When forcing the monetary policy rate to follow the historic path, almost all of the increases in industrial production may be explained by the change from the low stress to the high stress regime.

Looking at the simulation of Canadian financial stress we see that monetary policy has little effect on the level of financial stress within the Canadian economy (comparing the simulation which follows the historic monetary policy path to the path which simulates interest rates). By the peak of the crisis in 2009, forcing the simulation into the low stress regime manages to lower Canadian financial stress by 67% within both sets of simulations. By shutting off US financial shocks the Canadian financial experience is little changed. Through these simulations we find that during low stress periods, financial shocks emanating from the US have little effect on the Canadian financial system. The change in dynamics when moving from the low stress regime to the high stress regime largely accounts for the rise in Canadian financial stress throughout the crisis.

These simulations stress the importance of the nonlinearities between periods of low stress and periods of high stress. When the economy is forced into the low stress regime Canada reacts much less to negative shocks spilling over from the US. These findings conform to the results predicted by the financial accelerator framework; when the US economy moves into the high stress regime, shocks to financial stress are greatly amplified and spillovers into the Canadian economy are much more severe.

7 Conclusion and Future Research

Volatile periods of financial stress within the last two decades have demonstrated the existence of two separate regimes within our economy; a low stress regime where we spend most of our time as well as a high stress regime in which shocks to both the financial system and real economy are greatly amplified. The 2008 financial crisis has provided us insight into how crucial it is to not only understand these two states of the economy but to also understand the transmission of financial crises across borders.

Through our TVAR model we were able to empirically estimate this relationship between US financial stress and the Canadian economy. Compared to the low stress regime, we find that shocks to US financial stress in the high stress regime have a significantly more negative impact on real economic activity within Canada. Not only did the high stress regime lead to large declines in economic activity but a weakening of monetary policy. In the high stress regime, we find that the ability for monetary policy to help stimulate the real economy or Canadian financial system is greatly weakened. The goal of our paper does not aim to prescribe policy implications but simply to help support the research into the relationship between the transmission of financial crises and monetary policy.

By running counterfactual experiments throughout the 2008 financial crisis we find that much of the Canadian experience over this period can be attributed to the switch in regime. Without switching from the low stress to high stress regime, Canada not only would have gained flexibility in monetary policy by not dropping to the zero lower bound but avoided much of the decline in industrial production. While the Canadian financial system fared relatively well throughout the financial crisis, we find that without switching regimes Canadian financial stress would have remained significantly lower.

While these results help to improve our understanding of both the transmission of financial stress from the US to Canada and the effect on policy makers within Canada we consider this a starting point for future research into the issue. By separating between Canadian financial stress and US financial stress with the use of a Markov-Switching VAR we may be able to gain a better understand the transmission of crises and resulting impact on policy makers within Canada.

Appendix

Figure 1: CLIFS Canada and CLIFS US, 1981M1-2016M1

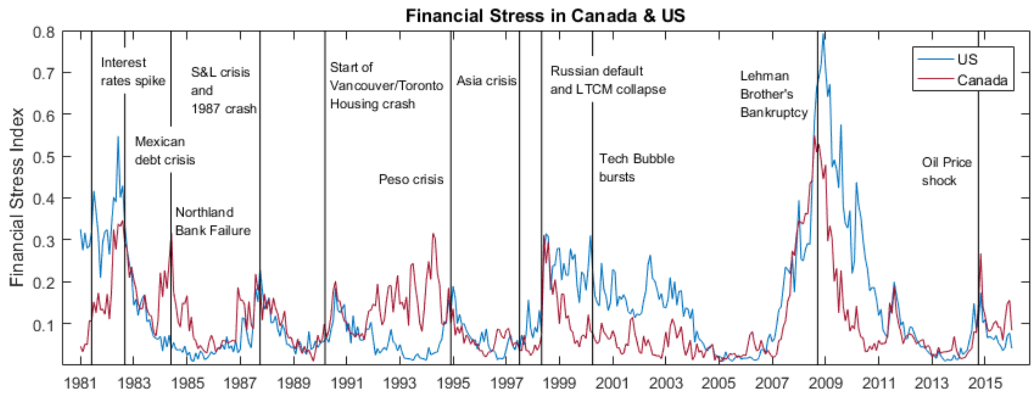


Figure 2: Time series plots of detrended growth in IPI, inflation, and the overnight rate

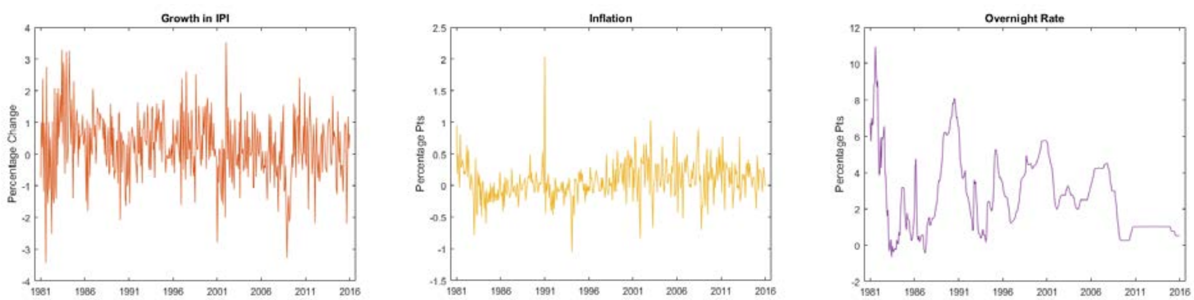


Figure 3: CLIFS US and TAR(3) Threshold value

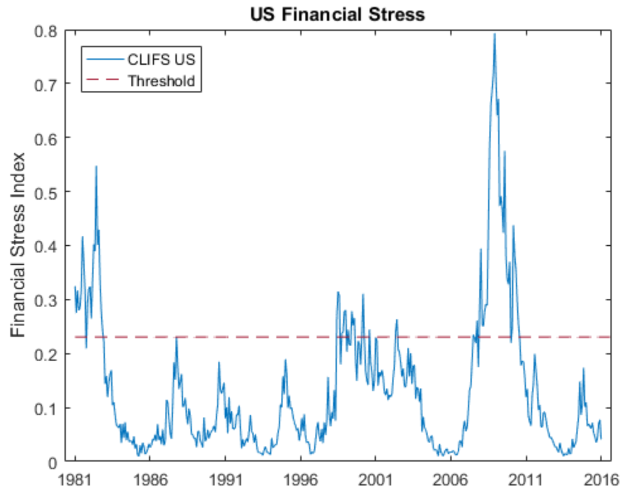


Figure 4: Impulse response functions for one standard deviation shock to CLIFS US

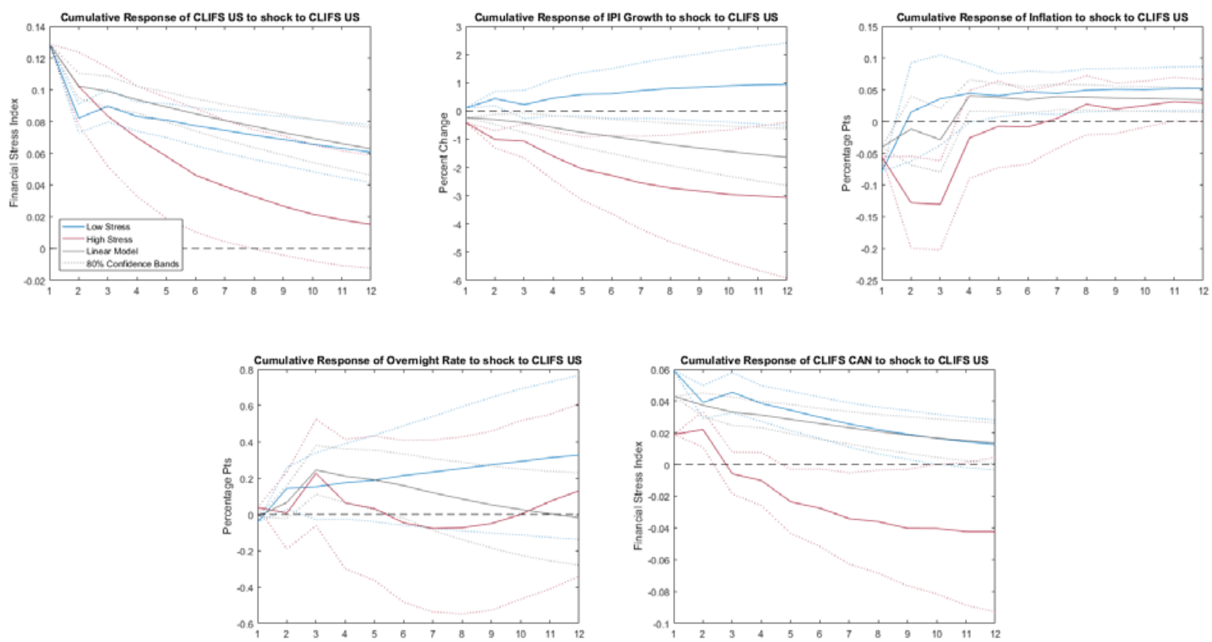


Figure 5: Impulse response functions for expansionary (-100bps) to the overnight rate

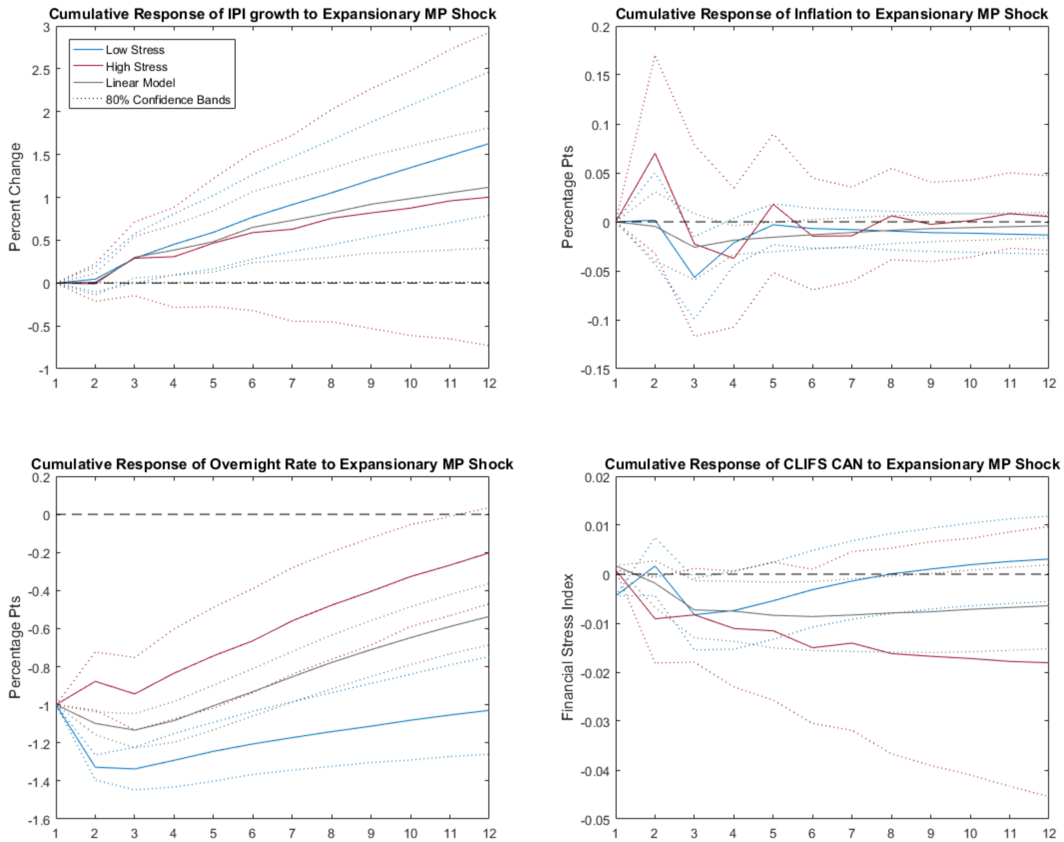


Figure 6: MES US and MES TVAR(3) Threshold value with CLIFS US model for comparison

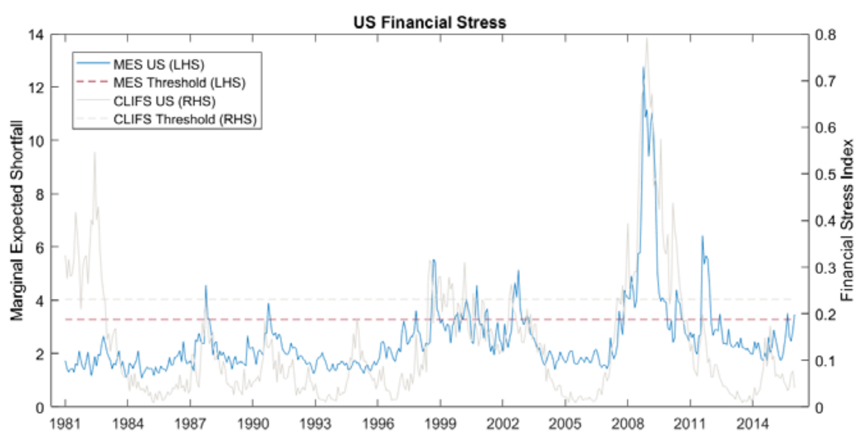


Figure 7: Impulse response function for one standard deviation shock to the MES US

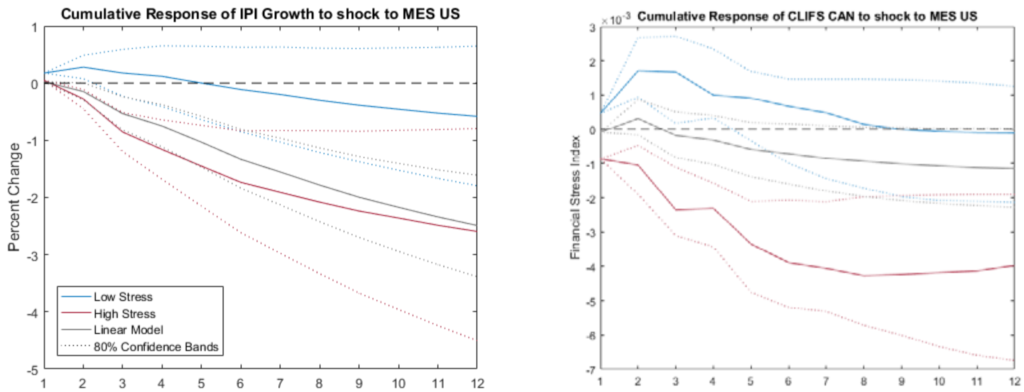


Figure 8: Impulse response function for expansionary (-100bps) shock to overnight rate (MES Model)

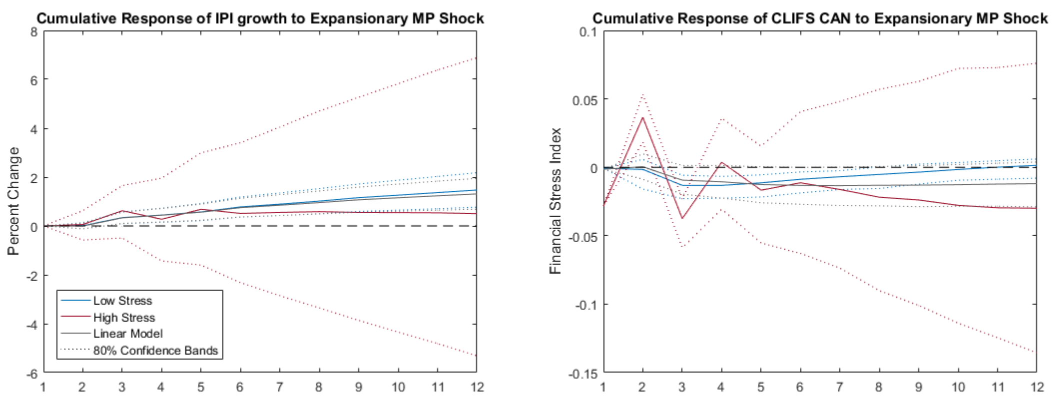


Figure 9: Impulse response functions for one standard deviation shock to CLIFS US (GDP Model)

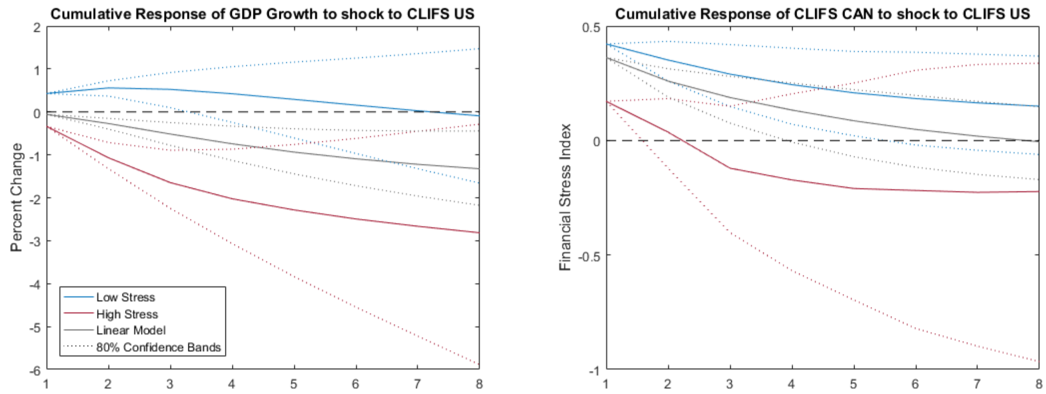


Figure 10: Impulse response functions for expansionary (-100 bps) shock to the overnight rate (GDP Model)

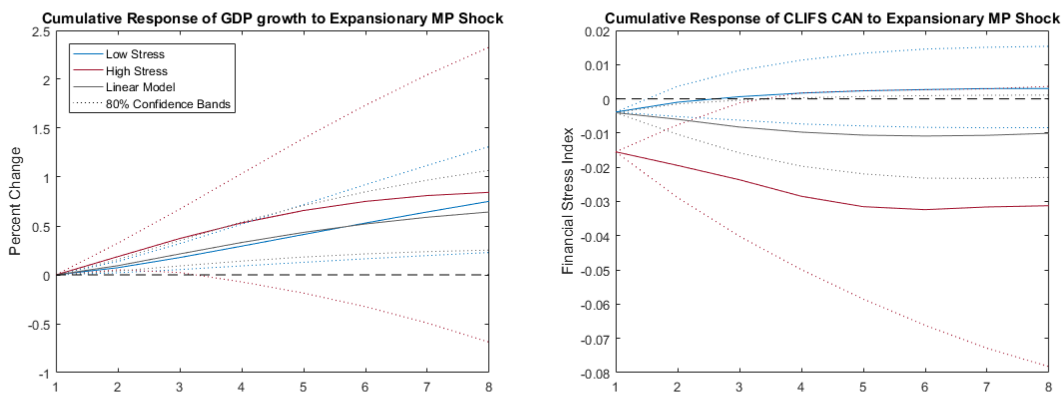
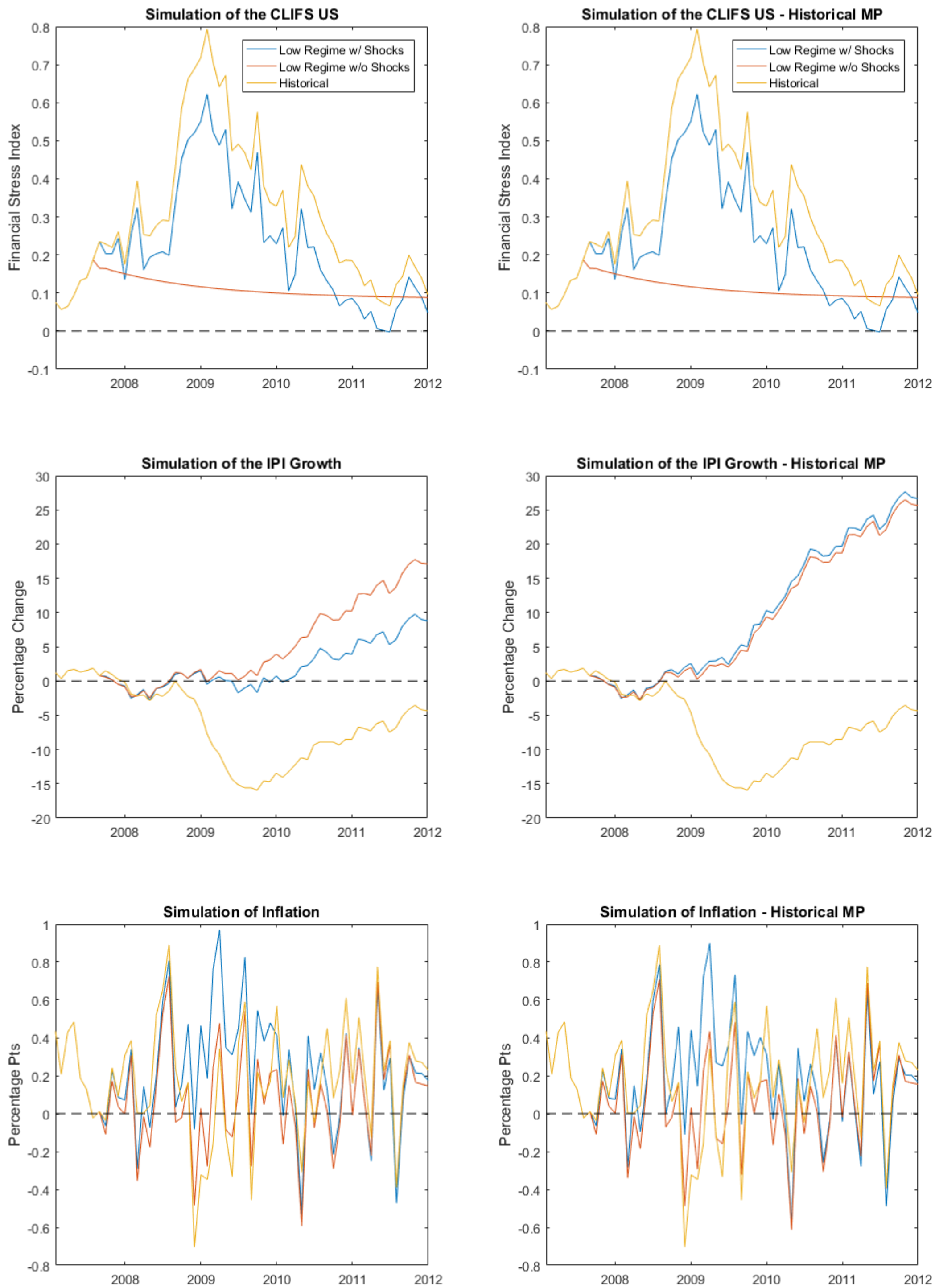
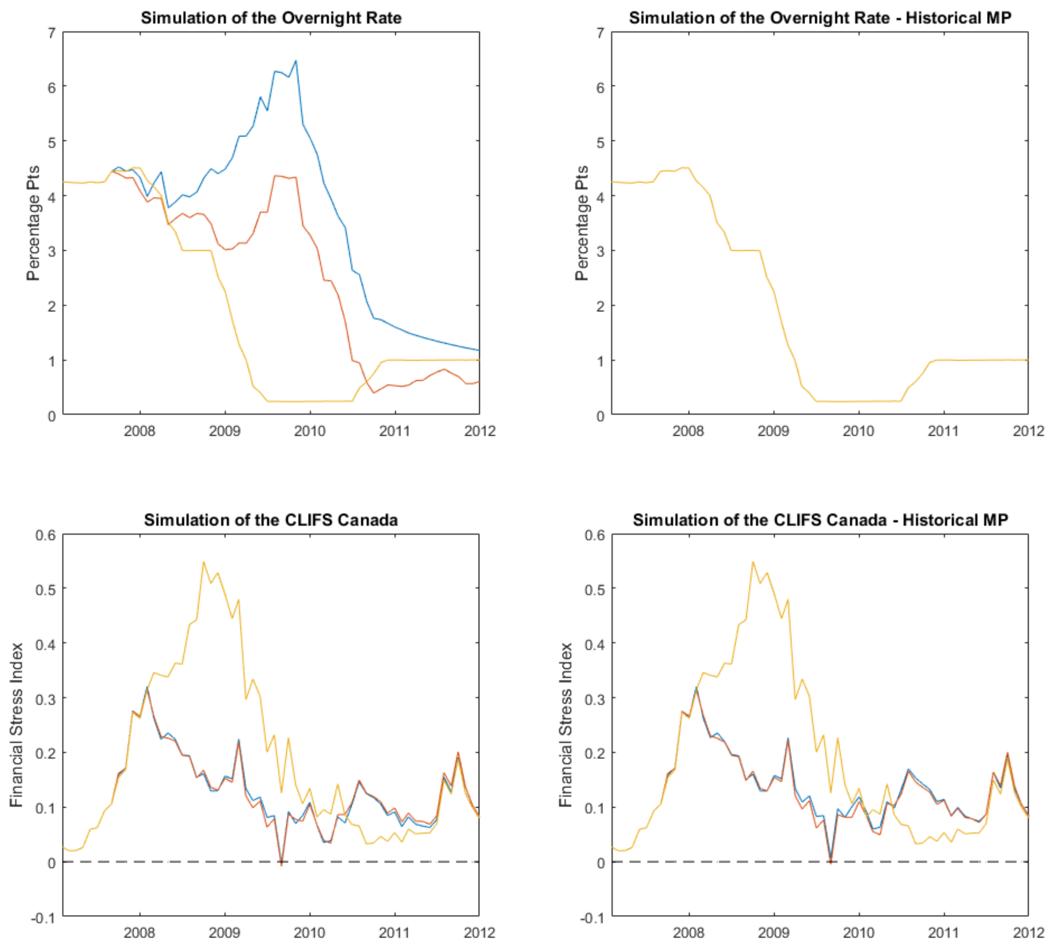


Figure 11: 2008 counterfactual simulations





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