Financial Stress, Monetary Policy, and Economic Activity

by Fuchun Li and Pierre St-Amant

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Acknowledgements

Abstract

This paper examines empirically the impact of financial stress on the transmission of monetary policy shocks in Canada. The model used is a threshold vector autoregression in which a regime change occurs if financial stress conditions cross a critical threshold. Using the financial stress index developed by Illing and Liu (2006) as a measure of the Canadian financial stress conditions, the authors examine questions such as: Do contractionary and expansionary monetary policy shocks have symmetric effects? Do financial stress conditions play a role as a nonlinear propagator of monetary policy shocks? Does monetary policy have the same effect on the real economy in the low financial stress regime and in the high financial stress regime? Suppose that the economy is currently in a given financial stress regime, do monetary policy shocks have a substantial effect on the transition probability of moving from the given regime to the other? The empirical findings reveal that (i) contractionary monetary shocks typically have a larger effect on output than expansionary monetary shocks; (ii) the effects of large and small shocks are approximately proportional; (iii) expansionary monetary shocks have larger effects on output in the high financial stress regime than in the low financial stress regime; (iv) large expansionary monetary shocks increase the likelihood of moving to, or remaining in, the low financial stress regime; (v) typically, high financial stress regime has been characterized by weaker output growth, higher inflation, and higher interest rates.

Résumé

Les auteurs procèdent à une étude empirique des effets des tensions financières sur la transmission des chocs de politique monétaire au Canada. Ils recourent à un modèle vectoriel autorégressif dans lequel l'atteinte d'un seuil de tension critique induit un changement de régime. Se fondant sur l'indice élaboré par Illing et Liu (2006) pour mesurer le niveau des tensions financières au Canada, ils s'efforcent de répondre à une série de questions, dont celles-ci : Les chocs de politique monétaire restrictifs et expansionnistes ont-ils une influence symétrique? La présence de tensions financières favorise-t-elle une propagation non linéaire des chocs? La politique monétaire a-t-elle la même incidence sur l'économie réelle dans un régime de faible tension financière que dans un régime de forte tension financière? Dans un régime de tension donné, les chocs monétaires influent-ils beaucoup sur la probabilité que l'économie bascule dans l'autre régime? Les auteurs constatent que : 1) les chocs monétaires restrictifs ont dans l'ensemble un retentissement plus accentué sur la production que les chocs monétaires expansionnistes; 2) les chocs de grande comme de petite ampleur ont des répercussions approximativement proportionnelles; 3) les chocs expansionnistes ont des effets plus marqués sur la production dans le régime de forte tension que dans le régime opposé;

4) les chocs expansionnistes importants augmentent la probabilité que l'économie passe ou demeure dans un régime de faible tension; 5) enfin, dans le régime de forte tension, la croissance de la production est généralement plus faible, le taux d'inflation est plus élevé et les taux d'intérêt sont plus hauts que dans l'autre régime.

Classification JEL : G01, E50, C01
Classification de la Banque : Stabilité financière; Politique monétaire et incertitude

1 Introduction

Recent years have been characterized by various episodes of significant financial stress (Asian crisis, LTCM, hightech boom and bust, the current global financial crisis, etc.). But policymakers have a very limited understanding of the impact of these episodes on economic activity and on the transmission mechanism of monetary policy. Assessing this impact is thus a very important topic.

Indeed, various papers have examined the relationship between financial sector developments, economic activity, and the transmission of monetary policy shocks (see Laidler, 2007, for an excellent survey). The recent theoretical literature has emphasized the non-linearities involved in this relationship. For example, Bernanke and Gertler (1989) construct a model in which balance-sheet conditions can amplify output fluctuations and negative shocks are likely to have a greater impact than positive shocks. Azariadis and Smith (1998) develop a model in which the economy may switch between a financially constrained regime, that has worse financial conditions such as higher interest rate, deterioration of balance sheets of firms, and weaker bank lending, and a financially unconstrained regime with reduced financial stress conditions. Interestingly, even though these theoretical models differ in various dimensions, they all imply nonlinear dynamics, such as regime switching associated with fluctuations in output, and find asymmetries in responses to shocks.

The empirical evidence of the asymmetries in the effects of monetary policy on the economy is mixed. Cover (1992) finds (using US data) that a contractionary monetary policy shock causes output to decline, whereas an expansionary monetary policy shock has no effect on output. These results are confirmed by DeLong and Summers (1988), Morgan (1993), Rhee and Rich (1995), Thoma (1994), Kandil(1995), and Karras (1996). Using threshold vector autoregression models in which the threshold variables are credit conditions, McCallum (1991) and Balke (2000) find that U.S output responds more to a tighting monetary policy in a credit-rationed regime. Balke

(2000) also finds that contractionary Fed funds shocks have a larger effect on output growth than expansionary shocks. However, Atanasova (2003) and Weise (1999) provide empirical evidence, respectively based on UK and US data, that the contractionary and expansionary monetary shocks have almost symmetric effects, while the size of monetary shocks appears to matter only when the economy's initial state is the high risk premium regime.

In this paper, we use a threshold vector autoregression model to capture asymmetries and regime switching implied by theoretical models. The econometric specification for the threshold vector autoregression model allows the economy to switch between two regimes. The economy is in the high financial stress regime if the financial stress conditions are higher than a threshold value, otherwise it is in the low financial stress regime. Regime switching can be endogenous as shocks to other variables, such as the real overnight rate, can result in regime switches. Based on the TVAR model, we can examine questions like the following: Do contractionary and expansionary monetary policy shocks have symmetric effects? Do monetary policy shocks have the same effects regardless of the current phase of economic fluctuations? If the economy is currently in a high financial stress regime, do reductions in the overnight rate increase the probability of moving from a high financial stress regime to a low financial financial stress regime? Similarly, if the economy is currently in a low financial stress regime, do rises in the overnight rate increase the probability of moving from a low financial stress regime to a high financial stress regime?

To measure financial stress, we use the financial stress index (FSI) developed for Canada by Illing and Liu (2006). This index is made of various indicators of tensions in Canadian credit markets. These indicators are weighted by the share of the underlying credit markets in total Canadian credit. Illing and Liu's FSI is currently being used at the Bank of Canada as a tool to assess financial stress conditions (see Section 2 for a more detailed discussion)[1].

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[1]Using a nonlinear approach, Misina and Tkacz (2008) find that credit and asset price variables are important

We find that contractionary monetary shocks typically have larger effects on output than expansionary monetary shocks. We also find that the effects of large and small shocks are approximately proportional and that contractionary monetary shocks have larger effects on output in the low financial stress regime than in the high financial stress regime. Moreover, we find that large contractionary monetary shocks increase the likelihood of moving to, or remaining in, the high financial stress regime. Finally we find that higher financial stress regime has typically been characterized by weaker output growth, higher inflation and higher interest rates. The remainder of this paper is organized as follows. In section 2, we present our threshold autoregression model. Section 3 estimates and tests the model. The nonlinear analysis of economic activity is presented in Section 4. Section 5 concludes, and the method for computing impulse response for the nonlinear model is in the Appendix.

2   The Model Specification

Within the class of possible nonlinear models for the transformed data, we concentrate on the threshold vector autoregressive model (hereafter TVAR). A TVAR provides a relatively simple and intuitive way to model nonlinearity such as regime switching, asymmetry, and multiple equilibria implied by the theoretical models of financial and macroeconomic activity. A TVAR model works by splitting the time series endogenously into different regimes. In this paper, the role that financial stress conditions may play as a nonlinear propagator of shocks is captured by a "structural" threshold vector autoregression model, which is specified as follows,

$$Y_t = \Psi_0^1 Y_t + \Psi_1^1(L)Y_{t-1} + (\Psi_0^2 Y_t + \Psi_1^2(L)Y_{t-1})I(c_{t-d} > \gamma) + U_t, \tag{1}$$

predictors of FSI.

where Y_t is a vector containing Canadian data for real output growth, inflation, the real overnight rate, and the financial stress index. Ψ_1^1 and Ψ_1^2 are lag polynomial matrices while U_t is structural disturbances. c_{t-d} is the threshold variable that determines which regime the system is in, and $I(c_{t-d} > \gamma)$ is an indicator function that equals 1 when $c_{t-d} > \gamma$, and 0 otherwise. Because the threshold variable, c_{t-d}, is a function of financial stress conditions, which is an element in Y_t, the TVAR describes both the evolution of Y_t and that of the financial stress regimes. This implies that shocks to output, inflation, the overnight rate, and to financial stress conditions can determine whether the economy is in a financially constrained regime.

In equation (1), in addition to the lag polynomials changing across regimes, contemporaneous relationships between variables can change as well. Ψ_0^1 and Ψ_0^2 reflect the "structural" contemporaneous relationships in the two regimes, respectively. We assume that Ψ_0^1 and Ψ_0^2 have a recursive structure with the causal ordering as follows: output growth, inflation, the real overnight rate, and the financial stress condition variable. This ordering implies that monetary policy shocks are shocks to the short-term interest rates that do not have an impact, contemporeneously, on output or inflation. This is consistent with the view that monetary policy shocks affect output and inflation only after a lag. However, monetary policy shocks can have a contemporeneous impact on the FSI. This assumption reflects the view that financial variables could respond very quickly to all types of shocks (Balke 2000 and Atanova, 2003, use similar assumptions).

We did consider alternative orderings in our testing for a threshold structure. It turns out that the choice of alternative orderings makes little difference.

The integer d is the delay lag and typically it is unknown so it must be estimated along with the other parameters in the model. Because the threshold variable is one of the variables in Y_t, this implies that shocks to any of the variables in Y_t may induce a shift to a different regime.

We measure financial stress with the index proposed by Illing and Liu (2006) for Canada. These authors' financial stress index (FSI) is a continuous variable made of a variety of measures of probable loss, risk and uncertainty. A literature review was the basis for selecting the variables to be included in this index. These variables are weighted by the relative size of the market to which they pertain in Canadian total credit. This weighting approach was found to produce an index that could fit financial stress episodes identified in a survey of Bank of Canada senior managers and economists. Illing and Liu's FSI is currently used at the Bank of Canada in monitoring financial stress(Hanschel and Monnin, 2005, have developed a similar index for the Swiss financial system).It is important to note that FSI movements could be caused by shocks originating from outside Canada. This is because foreign developments can affect Canadian variables that are captured by the FSI. This is also because the FSI includes a measure of some foreign economic variables, such as Canada/US exchange rate volatility, and U.S. 90-day treasury bill spread.

The sample period in this paper is 1981Q4 to 2006Q4. All series are quarterly. Figure 1 (P.22) plots the time series of real GDP growth rate, core inflation rate, real overnight rate, and FSI. Descriptive statistics such as the means, standard deviations, minimum, and maximum as well as stationarity test statistics of data are reported in Table 1. The results of formal augmented Dickey-Fuller non-stationary tests indicate that the null hypothesis of non-stationary is rejected at the 5% significance level. Since the test is known to have low power, which is the probability of rejecting the null hypothesis when it is not true, even a slight rejection means that stationarity of the series is very likely.

Table 1: **Summary Statistics of the Data and Stationary Test**

	Real GDP Growth Rate	Inflation Rate	Real Overnight Rate	FSI
N	101	101	101	101
Mean	0.0069	2.8011	3.9114	46.6031
Standard deviation	0.0076	2.2609	2.3285	12.7647
Test statistics	-5.5546	-3.3870	-3.8336	-3.6808
Result	Reject	Reject	Reject	Reject

Note: N is the number of observations. The stationary test is the augumented Dickey-Fuller test. The test critical value is -2.88 at 5%significant level. The augmented Dickey-Fuller test is computed as $\hat{\tau} = \hat{\alpha}_1/ase(\hat{\alpha}_1)$ in the model $\triangle y_t = \alpha_0 + \alpha_1 y_{t-1} + \sum_{j=1}^{p} \gamma_j \triangle y_{t-j} + \varepsilon_t$, where y_t is any one of the four time series. The value of p is set as the highest significant lag order from either the autocorrelation function or the partial autocorrelation function of the first difference up to a maximum lag order of $\sqrt{n}$.

3   Estimating and Testing the Threshold Vector Autoregression Model

The aim of this section is to test for asymmetry, or statistical significance of the threshold variable c_t, without specifying a priori value of the threshold. The TVAR model is estimated by least squares (LS). By definition, the LS estimators minimise jointly the sum of the squared errors S_n. γ is assumed to be restricted to a bounded set $\Gamma = [\gamma_1, \gamma_2]$, where Γ is an interval covering the sample range of the threshold variables. The computationally easiest method to obtain the LS estimates is through concentration. Conditional on γ, the estimation yields the conditional estimators. The concentrated sum of squared residuals is a function of γ and $\hat{\gamma}$ is the value that minimises $S_n(\gamma)$. Since $S_n(\gamma)$ can take on less than n (the time span of the time series) distinct values, γ can be identified uniquely as,

$$\hat{\gamma} = argmin_{\gamma \in \Gamma} S_n(\gamma). \tag{2}$$

Given that the quarterly FSI has high variability implying a frequency of regime switching that is implausible, we set the threshold variable to be a three-quarter moving average of past

FSI values. Based on the Akaike criterion, the optimal specification should be a 3-lag VAR. An important question is whether the estimated TVAR model is statistically significant relative to a linear VAR. The test procedure that we use, which explicitly accounts for the fact that the threshold parameter is not identified under the null hypothesis, is that of Hansen (1996). In order to test for threshold when γ is unknown, the threshold model is estimated by least squares for all possible threshold values. For each possible threshold value, the Wald statistic testing the hypothesis of no difference between regimes is calculated. Three separate test statistics for the threshold effect are then calculated: sup-Wald, which is the maximum Wald statistic over all possible threshold values; avg-Wald, which is the average Wald statistic over all possible threshold values; and exp-Wald, which is a function of the sum of exponential Wald statistics. The simulation method of Hansen (1996), which involves simulating an empirical distribution of sup-Wald, avg-Wald, and exp-Wald statistics, is used to conduct inference. The estimated threshold values are those that maximize the log determinant of the residuals. The p-values from the asymptotic distributions are then obtained from 500 replications of the simulation procedure.

Table 2 presents tests of a linear VAR against a threshold alternative, and the estimated threshold values. To put these into perspective, in figure 2 (P.23) we show a plot of the threshold variable and its threshold value. For reference, the economic event periods are shaded. As table 2 shows, test results provide strong evidence against linearity in the standard vector autoregression model, and in favor of the TVAR specification[2]. Table 2 also shows results obtained after replacing the FSI with a simple corporate bond spread [3]in the TVAR. The corporate bond spread is often used to measure financial conditions. Interestingly, this corporate bond spread does not capture the non-

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[2]When two-quarter moving average and four-quarter moving average are used as the threshold variables, we find that their threshold values and testing results are the same as these for the threshold variable of three-quarter moving average

[3]The difference between five year government bond rate and five year mortgage rate.

linearity that the FSI can capture. Whether this nonlinearity results in economically meaningful asymmetry in the effects of monetary policy shocks, however, must be determined by examining the dynamic effects of these shocks in the TVAR model.

Table 2: **Tests for Threshold VAR**

Threshold Variable	Threshold Value	Sup-Wald Statistic	Exp-Wald Statistic	P-Value
FSI	49.96	134.32	63.85	0.00
Corporate Bond Spread	1.50	2.8011	3.9114	0.54

Note: The delay for the threshold variable is given by $d = 1$ and the lag of the TVAR is 3. The p-values are calculated by Hansen's (1996) bootstrap method with 500 replications.

4   Analysis of Economic Activities Impulse

In this section, to gain some insight into the dynamic properties of the nonlinear model, we conduct nonlinear impulse-response analysis to examine the effects of monetary policy. Suppose that the economy is currently in a given regime, we examine the impact of various types of monetary policy shocks on the probability that the economy stays in or moves out of the given regime.

4.1   Nonlinear Impulse-Responses

We conduct impulse-response analysis to explore the asymmetric effects of monetary policy shocks along three dimensions. First, does a contractionary policy shock have different effects from an expansionary policy shock? Second, do monetary policy shocks have different effects in low and high financial stress regimes? Third, do shocks of different magnitudes have disproportionate effects.

For a nonlinear model, however, a number of complications emerge. Whereas in a linear model one set of impulse response functions is sufficient to characterize the estimated model, in the nonlinear case the impulse response functions are sensitive to initial conditions and the magnitude of

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the impulses. These issues are examined in detail by Koop, et.al (1996). By definition, the impulse response function is the change in the conditional expectation of Y_{t+k} as a result of knowing the value of an exogenous shock U_t, or

$$E[Y_{t+k}|\Sigma_{t-1},U_t] - E[Y_{t+k}|U_t], \tag{3}$$

where Σ_{t-1} is the information set at time $t-1$ and U_t is a particular realization of exogenous shocks. Typically, the effect of a single exogenous shock is examined at a time, so that the value of ith element in U_t, U_t^i, is set to a specific value. A difficulty arises because, in the TVAR, the moving-average representation is not linear in the shocks. As a result, unlike linear models, the impulse response function for the nonlinear model is conditional on the entire past history of the variables and the size and direction of the shock. Therefore, calculating a nonlinear impulse response function requires specifying the nature of shock, such as its size and sign, and initial condition, Σ_{t-1}.

First, to compute the impulse response functions, shocks for period 0 to k are drawn from the residuals of the estimated TVAR and, for given initial values of the variables, fed through the estimated model to produce a simulated data series. The result is a forecast of the variables conditional on initial values and a sequence of shocks. Second, the same procedure is undertaken (with the same initial values and residual draw), except that the given shock in period 0 is fixed at some value. The shocks are fed through the model and a forecast is produced as above. The difference between this forecast and the baseline model is the impulse response function for a particular sequence of shocks and initial values. Impulse response functions are computed in this way for 500 hundred drawn from the residuals and averaged to produce the impulse response function conditional only on initial values. These impulse response functions are averaged over initial values taken from subsamples of the data. For example, to compute the impulse response

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function for low financial stress condition regime, the impulse response functions are averaged over the initial values corresponding to all dates in which the financial stress conditions were below the estimated threshold value.

The residuals from the real overnight rate equation in (1) do not necessarily represent a pure monetary policy shock, because they may be correlated with the residuals from the other equations. Under identifying assumptions described in section 2, the Choleski orthogonalized residuals have a clear interpretation as monetary policy shocks. We use this approach to identify the monetary policy shock in this paper.

A. The Effects of Contractionary and Expansionary Monetary Policy Shocks

Figures 3 and 4 (P.24) report estimated impulse response over 12 quarters of output growth, inflation, real overnight rate, and FSI to a one-time shock to the real overnight rate in the low regime and high regime, respectively. The size of the shock is set to the standard deviation of monetary policy shocks computed in the linear model. The responses to expansionary monetary shocks, along with their 95% point-wise confidence band calculated from bootstrap method, are plotted with the sign reversed so that they could be compared with the responses to contractionary shocks. The impulse response functions from the linear model are also plotted for comparison. The responses to contractionary shocks are plotted with the sign reversed so that they can be compared with the responses to expansionary shocks.

Figures 3 and 4 provide some evidence of asymmetry in the effects of contractionary and expansionary monetary policy shocks on output growth and inflation. Regardless of the initial level of the financial stress condition, the response functions of output growth to expansionary monetary policy shocks mostly are above the 95% point-wise confidence band of the response functions to contractionary policy shocks, while the response functions of the overnight rate and FSI stay

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inside the 95% point-wise confidence band of their respective response functions to contractionary monetary shocks. This result indicates that a contractionary monetary shock has a stronger effect on output growth than an expansionary monetary policy shock, even though the real overnight rate and FSI's responses do not display significant differences. This asymmetric response of the output growth to monetary shocks is consistent with the results (obtained using different methods and data) of Cover (1992), Delong and Summer (1988), Morgan(1993), Kandil (1995), Karas (1996), and Thoma (1994)[4].

Table 3: **Mean Values of the Data in Different Regimes**

Initial State	Output Growth Rate	Inflation	Overnight Rate	FSI
Low FSI	0.735	2.652	3.150	40.152
High FSI	0.614	3.503	4.758	56.455

Note: The delay for the threshold variable is given by $d = 1$ calculated by Hansen's (1996) bootstrap method with 500 replications.

Figure 4 shows that, when the economy is in the high financial stress regime, inflation begins to fall quickly in response to a contractionary policy shock, and the negative responses are persistent for a little less than one year after the shock, after which the figure displays the positive responses. To explore the possible reasons for the positive responses, Table 3 reports the average values of the four variables in different regimes, indicating that on average, the high financial stress regime has higher inflation, FSI, real overnight rate, and lower output growth than the low financial stress regime[5]. Obviously, one of the most important features of TVAR model is that shocks can result in a switch in regimes, suggesting that the impulse response functions not only depend on the original state of the economy at the time the shock is taken, but also the current state of the economy. However, we find (next section) that when the economy begins in a high financial stress regime,

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[4]One explanation that has been proposed for this is the prices and wages are more flexible upward than downward, which means that the economy adjusts more quickly to positive than negative shocks.

[5]These are average values that do not need to repeat themselves in the future. For instance, the ongoing global financial crisis appears to be associated with disinflationary, not inflationary.

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a contractionary policy shock (an expansionary policy shock) has a higher (lower) probability of keeping the economy remain in the high regime than the absence of monetary policy shock. In addition, it is noted that output growth and inflation responses to the monetary policy shock in the TVAR model differ substantially from those for the linear model. The linear model predicts weaker output growth in the high stress regime in response to a negative monetary policy shock than does the TVAR model.

B. The Effects of Shocks in Different Regimes

Figures 5 and 6 (P.25) respectively display response functions in different regimes to one-standard deviation shock and two-standard deviation shock. As seen in Figures 5 and 6, a contractionary monetary policy shock has a larger effect on output, inflation (after two quarters) and financial stress when the economy begins in a low financial stress regime than in a high financial stress regime[6]. This contradicts McCallum's empirical finding that money-supply shocks have a larger effect on output during periods in which the economy is credit constrained[7]. An explanation for this empirical result is that a contractionary shock raises the likelihood that the economy will move to the high stress regime (Section 4.2).

C. The Effects of Large versus Small Shocks

To examine whether the output effect of monetary policy shocks may vary disproportionately with the size of the shock, especially for contractionary policy shocks, Figures 7 and 8 (P.26)report the response functions to one-standard-error and two-standard-error contractionary monetary policy shocks in, respectively, the low and the high regime. Response functions for two-standard-error

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[6]It is noted that when the shock size is increased to two-standard deviation, even though a stronger response of output growth occurs after two quarters when the economy is in the high financial stress regime the overall area under the paths for output growth (the response of output growth)is larger during high financial stress regime than during low financial stress regime.

[7]According to Blinder's model of credit rationing, a tightening of monetary policy has stronger effects on the real sector when credit is already tight but weak effects when credit is initially plentiful. Hence McCallum's empirical finding is consistent with the view of Blinder (1987).

shock are scaled down by a factor of two such that they can be directly compared with the responses to a one-standard-error shock (but unlike in Figure 3, they are not multiplied by negative one). The main conclusion is that impulse responses are not very different. The response of output may be slightly more pronounced in the short-run and a bit less pronounced after two quarters in the case of a large shock, but these differences are barely significant.

4.2 The Impacts of Monetary Policy Shocks on the Transition Probability between the Low and High Regimes

In this section, we study the impact of monetary policy shocks on the probability of a transition between the two regimes. We ask the following questions: Suppose that the economy is currently in a low financial stress regime, does a contractionary monetary policy shock increase the probability of moving from the low regime to the high regime? Similarly, does an expansionary monetary policy shock increase the probability of moving from the high regime to the low regime?

Given the information set Σ_{t-1} at time $t-1$ and a particular realization of an exogenous shock U_t at time t, the probabilities of being in the high or low financial stress regimes are respectively,

$$Pr[I(c_{t+k-1} > \gamma)|\Sigma_{t-1}, u_t], \tag{4}$$

and

$$Pr[I(c_{t+k-1} \leq \gamma)|\Sigma_{t-1}, u_t]. \tag{5}$$

The probabilities in equations (4) and (5) can be estimated respectively by:

$$\frac{1}{n}\sum_{i=1}^{n} I[c_{t+k-1}^i > \gamma|\Sigma_{t-1}, u_t], \tag{6}$$

and

$$\frac{1}{n}\sum_{i=1}^{n} I[c_{t+k-1}^i \leq \gamma|\Sigma_{t-1}, u_t], \tag{7}$$

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where c^i_{t+k-1} represents a simulated realization of the threshold variable[8] at period k for the given initial information set, Σ_{t-1}, and shock u_t. We also consider a case where the real overnight rate is increased successively over three periods.

Intuitively, the baseline simulations produce an estimated probability of moving to the high financial stress regime conditional on the economy initially being in the low financial stress regime, without the information about the occurrence of a particular shock. On the other hand, stressed simulations produce an estimated probability conditional on the occurrence of a particular shock. Hence, comparing the probability of the stressed scenario with the probability of the baseline scenario provides information on the possible impact of monetary policy shocks.

Figure 9 (P.27)plots the estimated transition probability from the low regime to the high regime. For comparison, the probability of being in the high regime in the absence of a monetary policy shock is also plotted. Figure 9 indicates that large contractionary (two-standard-deviation) monetary policy shocks can substantially increase the likelihood of switching to the high financial stress regime, while large expansionary (negative two-standard-deviation) monetary policy shocks substantially decrease the likelihood. The maximum impacts of contractionary monetary policy shocks on the transition probability occur one quarter after the shocks. The probability then begins to fall, and trails off gradually. These results suggest that monetary policy shocks have an impact on the FSI and play an important role in the evolution of financial stress regime. Figure 9 shows that successive (two-standard-deviation) increases in the interest rates are associated with a larger increase of the transition probability.

Figure 10 (P.27)shows the estimated transition probability from high regime to low regime. We observe from Figure 10 that large expansionary (negative two-standard-deviation) monetary policy

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[8]A common way of calculating probability forecasts is to assume the conditional distribution in the error term as a given conditional distribution. However, such probability forecasts may be quite misleading when the predictive conditional distribution is not the true conditional distribution.

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shocks can substantially increase the likelihood of being in the low financial stress regime. The effects of monetary policy shocks on the probability of moving from a high financial stress regime to a low financial stress regime is substantial.

5 Conclusion

Using a threshold vector autoregression to capture nonlinear relationships in the data, we find evidence that a regime change occurs if financial stress conditions cross a critical threshold. The empirical findings of this study show that regardless of the initial level of the financial stress conditions, output growth and inflation respond more strongly to contractionary monetary policy shocks than to expansionary monetary policy shocks, while the responses of the overnight rate and FSI to contractionary monetary policy shocks are not significantly different from the responses to expansionary monetary shocks.

The asymmetric response of output to monetary policy shocks is consistent with the results of Cover (1992) who found that negative monetary shocks have stronger effects than positive monetary shocks.

However, we do not find evidence that responses to large shocks are disproportionate when compared with responses to small shocks. Responses to monetary policy shocks seem proportional to the size of the shock in both high-stress and low-stress regimes.

We also find that monetary policy shocks have a larger impact on output, inflation (after 2 quarters) and financial stress when the economy begins in a low financial stress regime than in a high financial stress regime. An explanation for this is that the shock raises the likelihood that the economy will move to the high stress regime. This contradicts Blinder's (1987) conclusion that a tightening of monetary policy may have stronger effects on the real sector when credit is already

tight.

Finally, we find that large contractionary monetary policy shocks can substantially increase the likelihood of switching to the high financial stress regime, while large expansionary monetary policy shocks substantially decrease the likelihood. In particular, successive increases in the interest rates are associated with an increase of the transition probability from a low regime to a high regime. These results that monetary policy shocks have substantial effects on the transition probability from the given regime to another indicate that monetary policy shocks feed back into Canadian financial stress conditions and play an important role in the evolution of financial stress regimes. One potential concern arises from the fact that the FSI contains information related to international financial markets (Canada/US exchange rate volatility, and U.S. 90-day treasury bill spread, etc.). The TVAR methodology used here does not easily allow us include international variables as exogenous factors that might explain movements in the FSI. Thus the estimated model presented here may overstate the impact of monetary policy on the transition probability between regimes. The question of how to add international variables into the model is left for future research.

Appendix

The method for computing impulse response for the nonlinear model is similar to that described by Koop, Pesaran, and Potter (1996).

An impulse response function is defined as the effect of a one-time shock on the forecast of variables in a particular model. The response of a variable following a shock must be compared against a baseline"no shock" scenario. That is, the impulse response function can be expressed as

$$E[Y_{t+k}|\Sigma_{t-1}, U_t] - E[Y_{t+k}|U_t] \tag{A.1}$$

where k is the forecasting horizon, U_t is the shock and Σ_{t-1} are the initial values of the variables in the model, and $E[\cdot]$ is the expectations operator. The impulse response function must be computed by simulating the model. The nonlinear model generating the $m-$dimensional variable Y is assumed to be known. The shock to the $i-th$ variable of Y, occurs in period, and reswponses are computed for l periods thereafter. The shock is a one or two standard deviation shock. The following algorithm is used:

1. Pick a history U_{t-1}^r. The history is the actual value of the lagged endogenous variables at a particular date.

2. Pick a sequence of ($k-$ dimensional)shocks $u_{t+n}^b, n = 0, ..., q$. The shocks are drawn with replacement from the estimated residuals of the model. The shocks are assumed to be jointly distributed. As a result, if date $t's$ shock is drawn, all k residuals for date t are collected.

3. Using U_{t-1}^r and u_{t+k}^b, simulate the evolution of Y_{t+k} over $n+1$ periods. Denote the resulting baseline path $Y_{t+k}, k = 0, 1, ..., n$.

4. Substitute u_{i0} for the i_0 element of u_{t+k}^b and simulate the evolution of Y_{t+m} over $n+1$ periods. Denote the resulting path Y_{t+k} for $k = 0, 1, ..., n$.

5. Repeat steps 2 to 4 B times.

6. Repeat steps 1 to 5 R times and compute $Y_{t+k}(u_{i0}) = [Y_{t+n}(u_{i0}, \Sigma^r_{t-1}, u^b_{t+k}) - Y_{t+n}(\Sigma^r_{t-1}, u^b_{t+k})]/BR$

for the average impulse response function.

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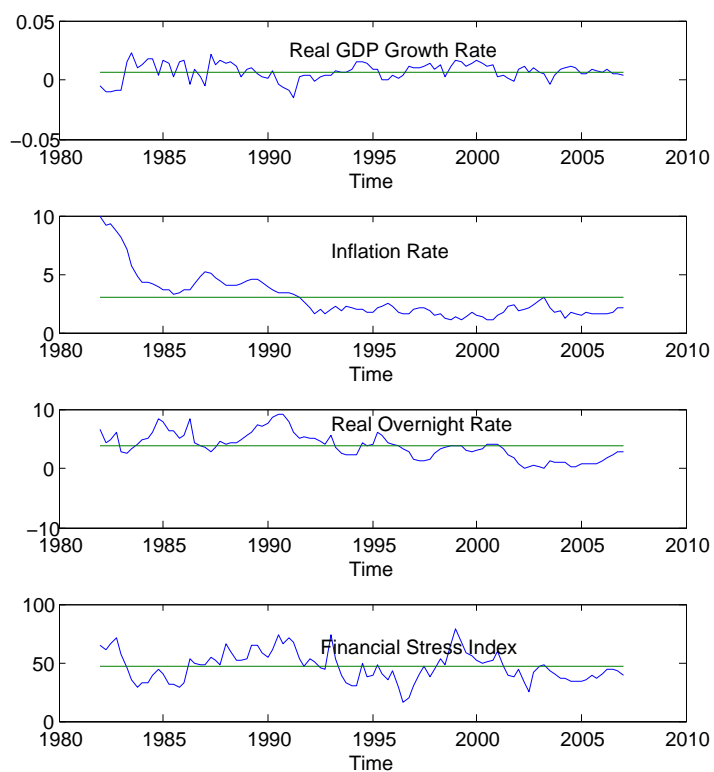
Figure 1: **Time Series 1**

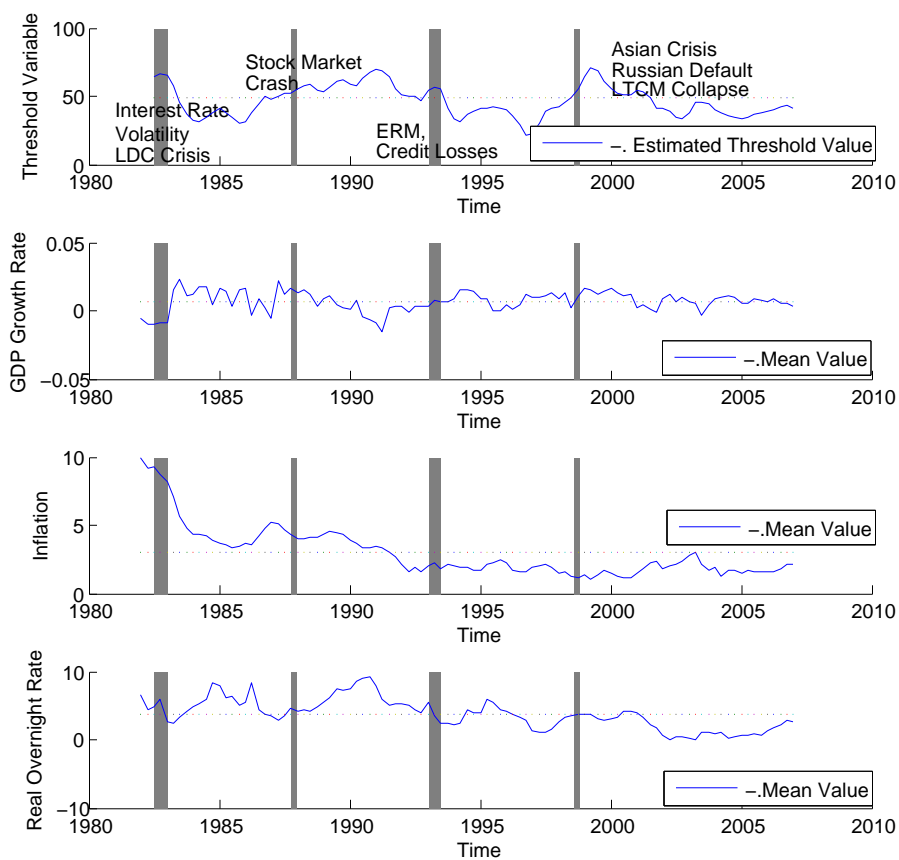Figure 2: **The Threshold Variable, Estimated Threshold Value, and Alternative Variables**

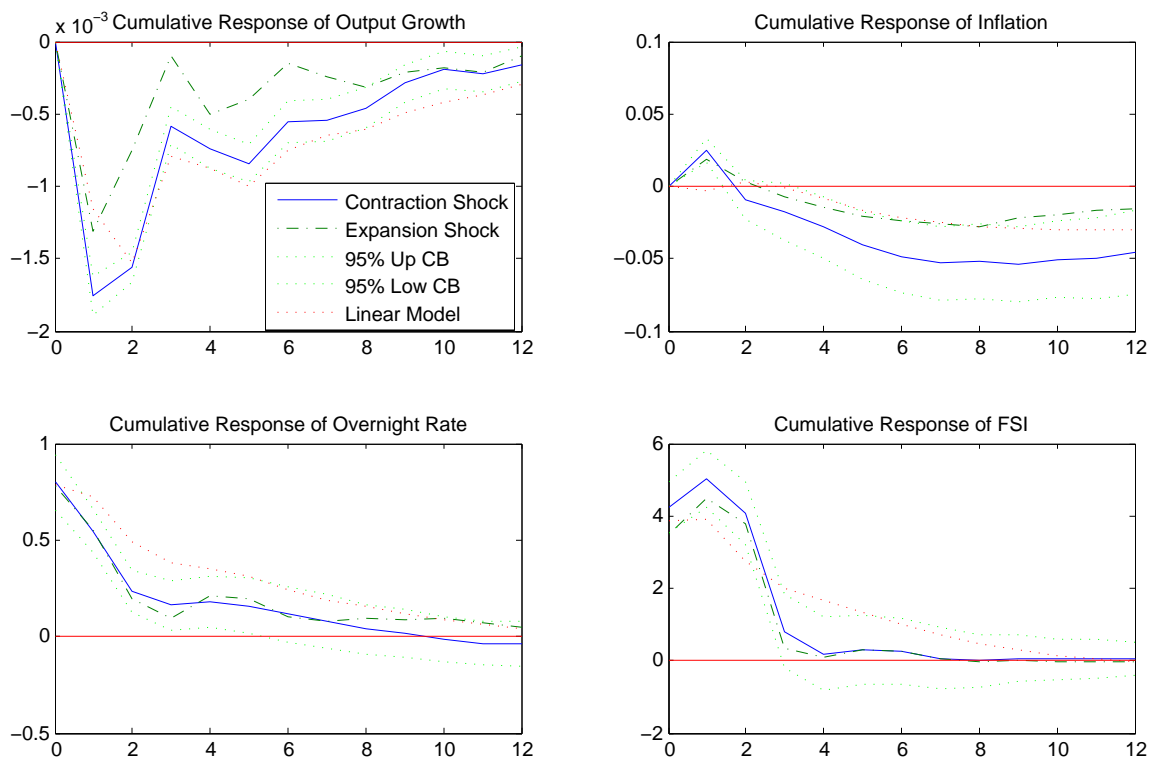Figure 3: **The Effects of Monetary Policy Shocks in the Low Regime**

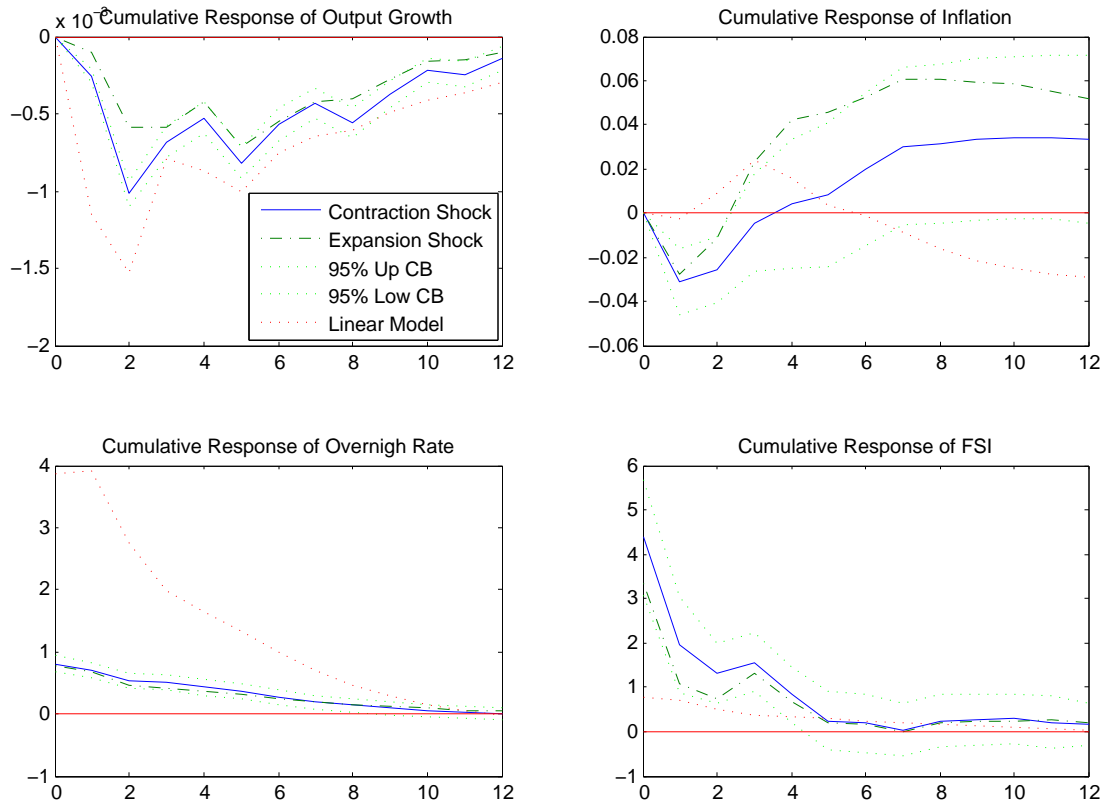Figure 4: **The Effects of Monetary Policy Shocks in the High Regime**

Figure 5: **The Effects of Contractionary Monetary Policy Shocks at Different Initial States (1SD)**
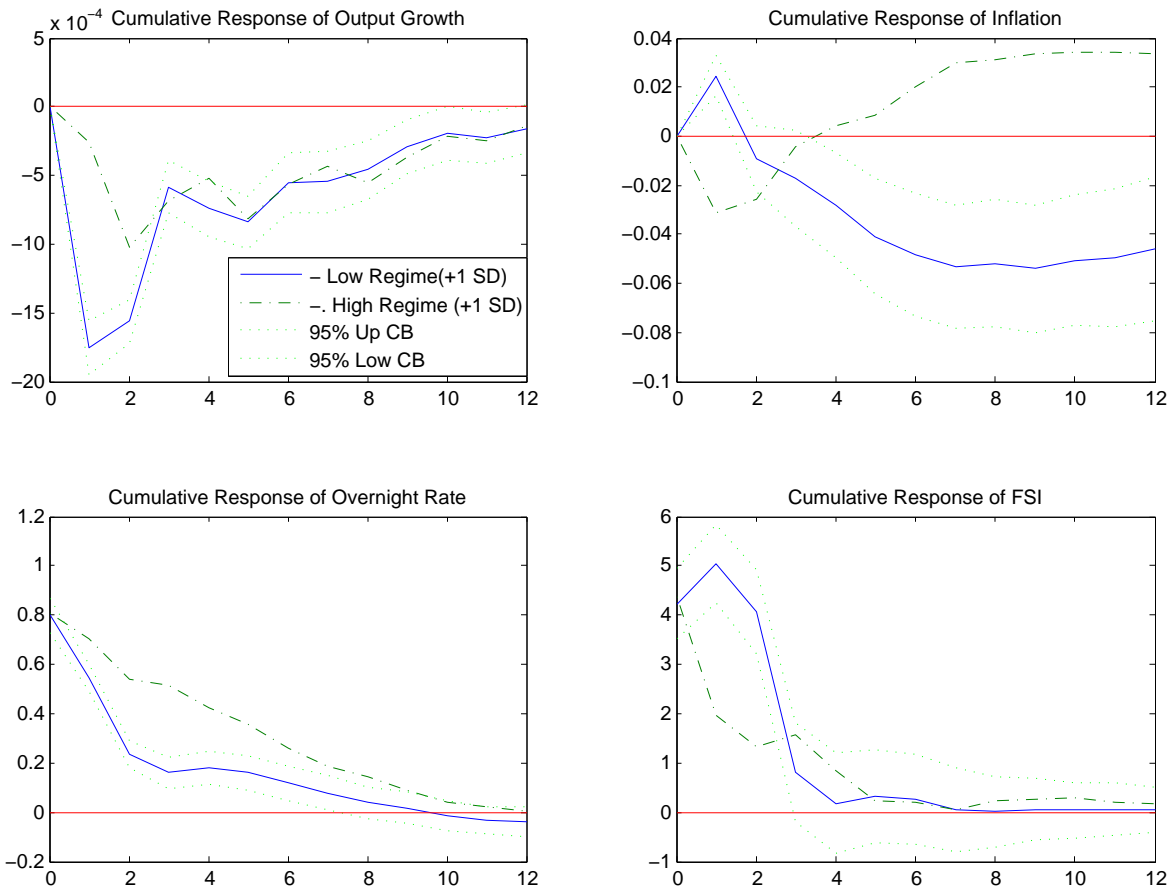
Figure 6: **The Effects of Contractionary Monetary Policy Shocks at Different Initial States(2SD)**
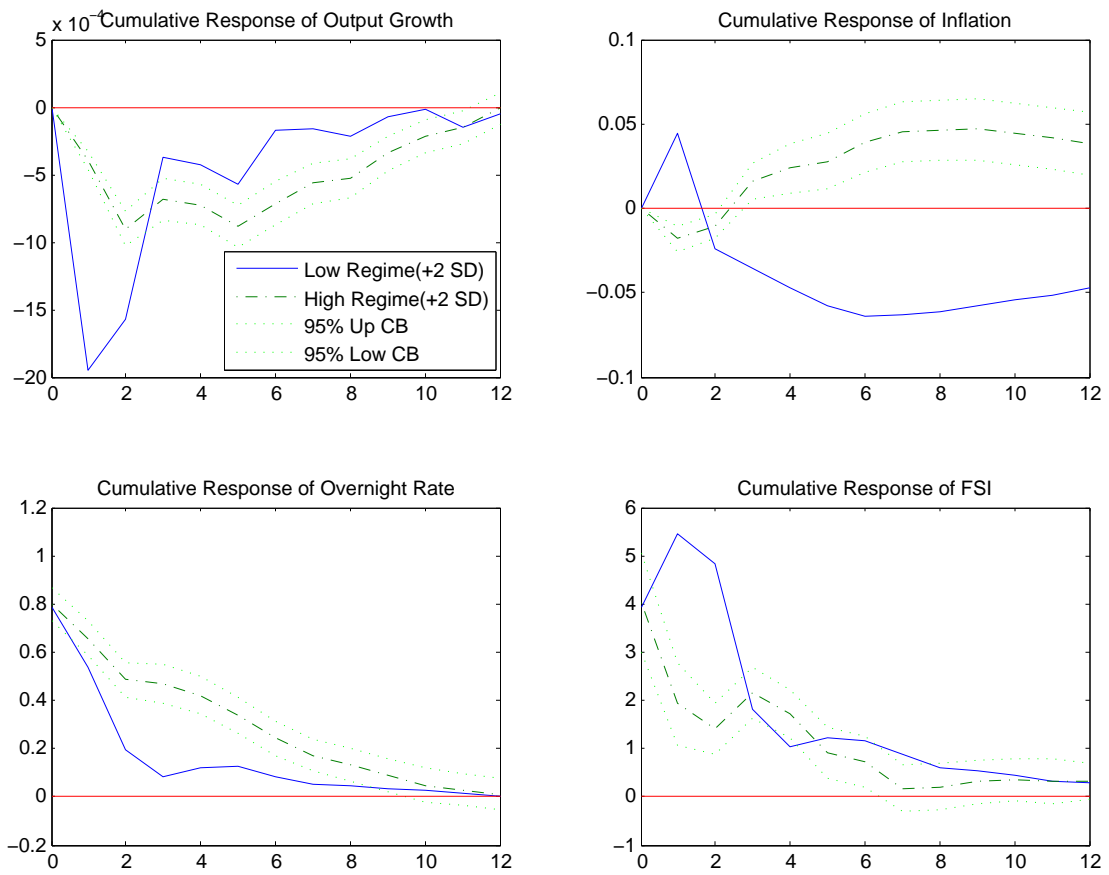
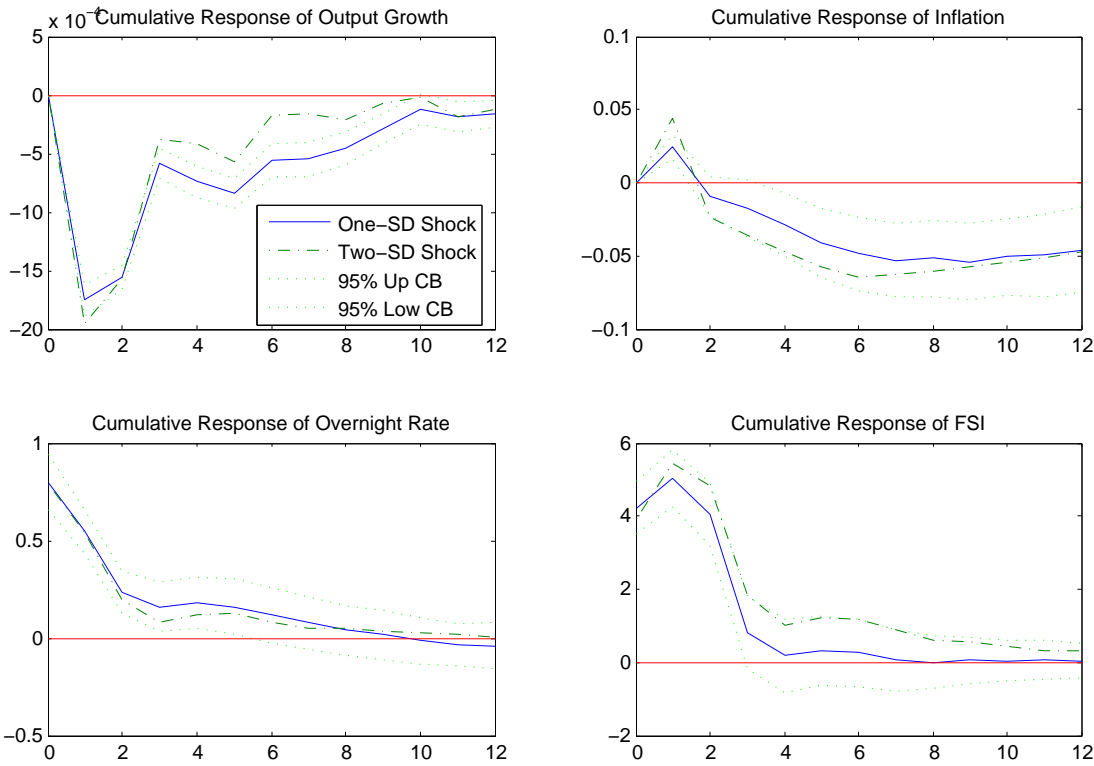Figure 7: **The Effects of Large Shock versus Small Shock in the Low Regime**

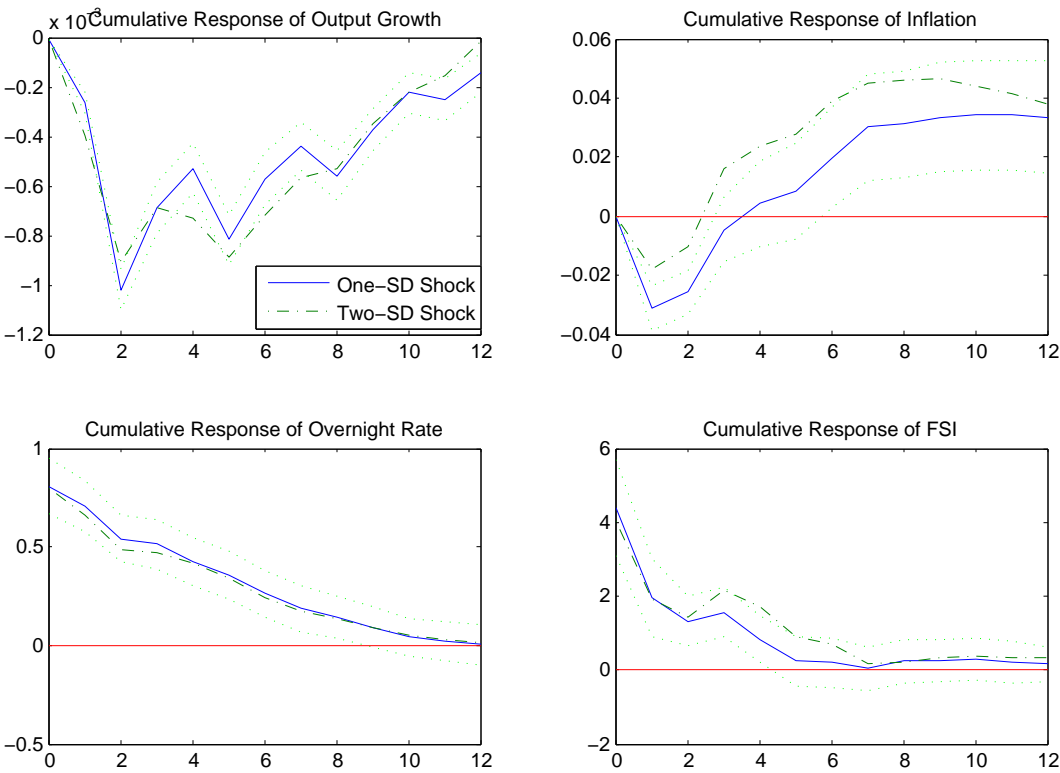Figure 8: The Effects of Large Shock versus Small Shock in the High Regime

Figure 9: **The Impacts of Monetary Policy Shocks on the Transition Probability from Low Regime to High Regime**

The Transition Probability from Low to High Regime (1)

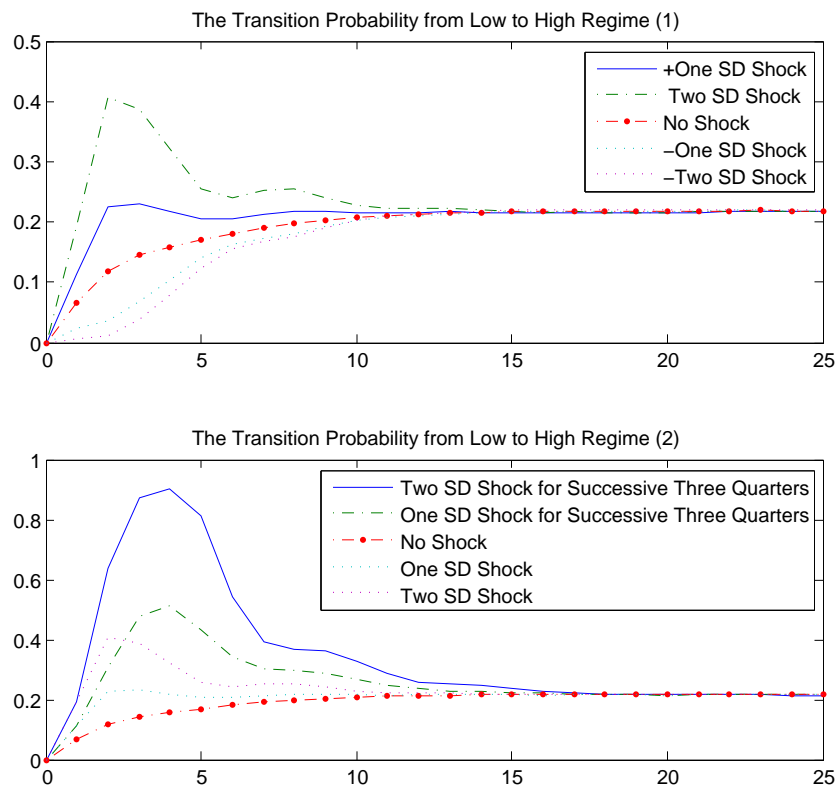The Transition Probability from Low to High Regime (2)

Figure 10: **The Impacts of Monetary Policy Shocks on the Transition Probability from High Regime to Low Regime**

The Transition Probability from High Regime to Low Regime (1)

Legend:
- +One SD Shock
- Two SD Shock
- No Shock
- −One SD Shock
- −Two SD Shock

The Transition Probability from High Regime to Low Regime (2)

Legend:
- −2 SD Shock for Successive Three Quarters
- −1 SD Shock for Successive Three Quarters
- No Shock
- −1 SD Shock
- −2 SD Shock