LUND UNIVERSITY

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Nonlinearities in the Transmission Between Financial Stress, Monetary Policy and the Business Cycle – a Threshold VAR Approach

Master Thesis I, May 2017

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Abstract

This paper investigates nonlinear transmissions between financial stress, monetary policy and the business cycle. Using a threshold VAR model on Swedish quarterly data the presence of nonlinearities in aforementioned transmission is corroborated by the nonlinearity-test suggested by Hansen (1996). Further, a nonlinear impulse-response analysis reveals several results worthwhile mentioning; (i) shocks occurring in a financially stressful regime on average seem to have a greater impact on GDP growth; (ii) monetary policy shocks during financially stressful times seem to have a greater and more immediate but less persistent effect on output growth; (iii) financial shocks occurring in times already characterized by high financial stress create larger contractions in output growth compared to those occurring under low financial stress and (iv); positive GDP growth shocks starting in periods characterized by high financial stress seem to worsen the level of financial stress.

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1. Introduction

This paper seeks to enhance the understanding of nonlinear transmissions between financial stress, monetary policy and the business cycle. Historically, there have been various periods which have been characterized with particularly high financial stress (e.g., the great depression in the 1930s, the Swedish financial crisis in the early 1990s and the dot-com bubble burst in early 2000s). The recent subprime financial crisis is a showcase on how tightly the financial sector is tied to the real economy, forcing policy makers to lower policy rates to historical lows and in some cases to negative figures in order to relieve the effects of the excessive financial stress. Thus, the recent financial crisis has propagated an interest in the study of the transmission between monetary policy, the real economy and the financial sector, often referred to as the transmission mechanism.

Economic dynamics during periods characterized by high financial stress are potentially different from periods characterized by low financial stress. This raises the question if unexpected shocks (e.g. monetary policy shocks) during particularly financial stressful times have a different impact on the economy than those equivalent shocks occurring during non-stressful times. In an attempt to answer this question, this study adapts a regime-switching threshold VAR (TVAR) model on Swedish quarterly data in spirit of Balke (2000). Using a model inhibiting regime-switching capabilities equips us with a perfect toolbox to study potential nonlinearity between monetary policy, the real economy and financial stress as it allows us to divide our data into a financial stressful regime and a financial non-stressful ditto.

The study reveals several results worthwhile mentioning: *(i)* the use of a nonlinear two regime TVAR model with financial stress as the threshold variable over a linear ordinary structural VAR model is validated by nonlinearity tests; *(ii)* shocks occurring in the financially stressful regime on average seem to have a greater impact on GDP growth; *(iii)* monetary policy shocks during financially stressful times seem to have a greater and more immediate but less persistent effect on output growth; *(iv)* financial shocks occurring in times already characterized by high financial stress create larger contractions in output growth compared to those occurring under low financial stress; *(v)* positive output growth shocks starting in the high financial stress regime seem to worsen the level of financial stress.

The linkage between the financial and the real sector has been recognized by economists as diverse as Knut Wicksell, Irving Fischer and Freidrich Von Hayek.[1] However, even though more recent empirical development in the area is rich and includes a wide variety of authors, much of the research designated towards describing the connection between the real economy, fiscal developments and financial stress in Sweden originates from the linear point of view.

For example, Shahnazarian & Bjellerup (2015) develop a structural VAR-model on Swedish data trying to capture four channels of the monetary transmission mechanism. To achieve this, they construct summary indices containing a wide variety of variables in their analysis. In this fashion they are able to capture the characteristics of the economy and the monetary transmission mechanism at the same time as they preserve model parsimony. Among other findings, the authors find that the financial system is important for the real economy and are able to quantify the effect for each of the identified transmission channels. However, the authors raise the possibility of these economic relationships may work differently during an economic crisis, i.e. they raise the possibility of nonlinearity within the parameters of the model, which this paper is designated to address.

Not much has been done when it comes to accounting for nonlinearities in the transmission between the financial markets, monetary policy and the business cycle in Sweden, but there are some studies originating from outside Sweden. Recent research includes Hubrich & Tetlow (2014) who build a richly parameterized Markov Switching VAR-model estimated using Bayesian methods on American data. Using a financial stress index as a threshold variable, they find that a shift to a stress event is highly harmful for the outlook of the economy. Furthermore, they conclude that the effect of monetary policy is relatively weak during such periods.

Afónso, Baxa & Slavik (2011) use a TVAR model to study the possibility of a nonlinear propagation of fiscal policy under different regimes of financial stress on US, UK, German and Italian data. Using a financial stress index as a threshold variable, the authors find support for a nonlinear model with regime switches over a linear alternative. Furthermore, amongst other findings, the authors find that financial stress has a negative effect on output

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[1] See Leidler (2007) for a historical overview.

growth and that the nonlinearity in the response of output growth to a shock to financial stress is charactarized by the behaviour under different financially stressful regimes.

Chiu & Hacioglu (2016) estimate two types of regime switching models using Bayesian methods on UK data: A TVAR model and a Markov-switching VAR. The paper concludes that the two models provide similar empirical results and the authors present three main findings: *(i)* financial shocks hitting during recessionary times create disproportionally more severe contractions in output; *(ii)* output growth shocks hitting during periods characterized by high financial stress result in disproportionally further financial stress; *(iii)* monetary policy shocks hitting in recessionary times create more severe contractions in output.

The empirical exercise in this paper follows the paper written by Balke (2000). Using US data, Balke applies a TVAR-model from a frequentist point of view to examine whether or not credit plays a role as a nonlinear propagator of shocks. Balke finds strong evidence for the existence of different regimes related to monetary conditions. He also finds that on average a monetary policy shock stemming from a tightening policy have greater effect than an easing policy. Furthermore, the findings of Balke indicate that shocks have a higher impact on output during tight credit regimes than during normal times.

As pointed out by Li (2010), one has to keep in mind that the paper by Balke target the commercial paper market and thus neglect stress in other markets. In order to overcome this constraint, this paper will adapt a financial stress index in order to reflect stress on a variety of Swedish credit markets.

The remainder of this paper is structured as follows; in section 2, the methodology including the TVAR model and nonlinear impulse response functions are explained. In section 3, the empirical analysis including data, model specification, model output and nonlinear impulse response analysis are presented. Section 4 concludes.

2. Methodology

2.1 The TVAR model

In order to investigate the potential of financial stress being a propagator of nonlinear shocks the following two-regime 'structural' TVAR proposed by Balke (2000) is estimated:

$$Y_t = u^1 + A^1 Y_t + B^1(L)Y_{t-1} + (u^2 + A^2 Y_t + B^2(L)Y_{t-1})I(c_{t-d} > \gamma) + \varepsilon_t \qquad (1)$$

where Y_t is a $n \times 1$ vector of the endogenous variables GDP, inflation, the one week average interbank lending rate and a financial stress index[2], $B^1(L)$ and $B^2(L)$ are lag polynomial matrices, ε_t are structural disturbances and *I* is an indicator variable which takes the value 1 if the d-lagged value of the threshold variable c_{t-d} (the financial stress index in our case) is higher than the threshold critical value γ and 0 otherwise. Thus, the indicator variable effectively separates the two regimes and allows regimes to switch endogenously. A^1 and A^2 reflect the 'structural' contemporaneous relationship in the financially stressful regime and the non-stressful regime respectively. Balke uses a recursive identification scheme in his paper, hence why he calls it a structural threshold VAR.[3] The recursive identification ordering used in this paper is as following: GDP growth, inflation, one week interbank lending rate and the financial stress index following e.g. Bernanke, Gertler & Gilchrist (1996) and Leeper (1996) who uses a similar recursive ordering. In the choice of recursive ordering, we implicitly choose which variables that are allowed to contemporaneously affect each other in the system. By choosing the financial stress index as the last variable in the recursive structure, we allow all macroeconomic variables to have a contemporaneous effect on the financial market within the same quarter whereas GDP only is affected by the other variables after 1-2 lags (Afónso et al., 2011).

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[2] A description of the financial stress index used in this paper can be found under section 3.2.

[3] However, one should keep in mind that even though recursive VARs are often referred to as structural VARs in the literature, i.e. Balke (2000), a recursive VAR is not exactly a structural VAR. Stock & Watson (2001) provides an excellent discussion of the differences between the structures of the two models. For an overall discussion of VAR identification, please see Christiano, Eichenbaum & Evans (1998).

The model under the regime characterized by $I(c_{t-d} > \gamma) = 0$ comprises the parameters u^1, A^1 and $B^1(L)$, whereas in the regime characterized by $I(c_{t-d} > \gamma) = 1$ the parameters of the TVAR becomes $u^1 + u^2$, $A^1 + A^2$ and $B^1(L) + B^2(L)$. If γ was known on beforehand, we could easily test for threshold effects with an ordinary F-test and the hypothesis H_0: $u^2 = A^2 = B^2(L) = 0$.

In our case, however, as the threshold value is not known it has to be endogenously estimated and since γ is not identified under the null of no threshold, the test procedure involves non-standard inference (Afónso et al., 2011). Firstly, the TVAR model is estimated using OLS for *all* possible values of γ.[4] For each possible threshold value, the Wald statistic testing the hypothesis of no threshold effects are calculated and saved. Three test statistics are then calculated: one with the maximum value of the Wald-statistic (sup-Wald), one with the average of the Wald-statistic (avg-Wald) and one with the sum of the exponential Wald-statistic (exp-Wald) (see e.g. Hansen, 1996 & 1999; Galbraith, 1996 and Balke, 2000). In order to make inference, these test statistics are then compared to the simulated empirical distribution suggested by Hansen (1996). The estimated threshold value is the value that maximizes the log-determinant of the structural residuals e_t.[5]

2.2 Nonlinear Impulse Responses

If the alternative of a TVAR model is accepted, it is possible to evaluate whether or not the economic dynamics differ across regimes. By applying impulse-response functions (IRF's), we can analyze whether or not the size, sign and persistence of a shock is substantially different in one regime compared to another. One way assess these asymmetries is to calculate ordinary linear IRF's conditional on each regime. This way one would be able to compare shocks in financially stressful times compared to non-stressful dittos. However, as the IRF is calculated conditioned on the current regime, it is implicitly assumed that we will stay in the same regime during the whole horizon of our IRF. In such case, both the sign and size of the response of a structural shock is symmetric and constant over time due to the fact that the covariance structure does not change (Afónso et al., 2011). In our case however, the financial stress index in the TVAR is allowed to be contemporaneously affected by all other variables in the system, i.e. a shock to any variable may induce a shift in the threshold

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[4] Following Balke (2000), in order to avoid overfitting of the model, the possible threshold values are restricted such that at least 15% of the observations and all parameters are in each regime.

[5] The result of the nonlinearity test and the estimated threshold-value is presented under the *results* section of this paper.

variable, causing the model to shift from one regime to another. The threshold variable may therefore potentially cause the model to switch repeatedly between regimes over the horizon of the impulse-response. Thus, a nonlinear IRF where we allow for endogenous regime-shifts may be more appealing (Calza & Sousa, 2005). Whilst calculation of the IRF's in the linear case is relatively simple; calculation of the nonlinear IRF's (NIRF) is more complex.[6] The NIRF is given by:

$$NIRF = E[Y_{t+k}|\Omega_{t-1}, \varepsilon_t] - E[Y_{t+k}|\Omega_{t-1}] \quad (2)$$

where Ω_{t-1} denotes the information set available at time *t – 1* and ε_t is an exogenous shock. This formulation implies that we have to condition on the nature of the shock (i.e the sign and size) as well as the entire past history of the variables (Balke, 2000). Henceforth, the conditional expectations $E[Y_{t+k}|\Omega_{t-1}, \varepsilon_t]$ and $E[Y_{t+k}|\Omega_{t-1}]$ has to be estimated by simulating the model. The estimation procedure follows Balke (2000): In step one, in order to produce a simulated forecast series, shocks from period 0 to q are drawn from the residuals of the estimated TVAR model and then for each initial value, that is for each point of our sample, is fed through the model. The resulting forecast series is then conditional on the particular sequence of the shocks and the initial values of the variables. The simulation in step one thus returns *one* estimate of $E[Y_{t+k}|\Omega_{t-1}]$. In step two, step one is repeated for the same initial values and residuals, with the modification that we let the shock to the variable of interest being fixed to +/- 2 standard errors or +/- 1 standard error at time $t = 0$. The simulation in step two therefore returns *one* estimate of $E[Y_{t+k}|\Omega_{t-1}, \varepsilon_t]$. By taking the difference of the estimates given in step one and step two above, we can produce one simulated value for NIRF in (2). In order to erase asymmetries originating from sampling variation in the draws of the period 0 to q shocks, this procedure is replicated 500 times. The average of these 500 simulated NIRF's is then our estimated NIRF. (See e.g. Balke, 2000; Afónso et al., 2011 and Atanasova, 2003).

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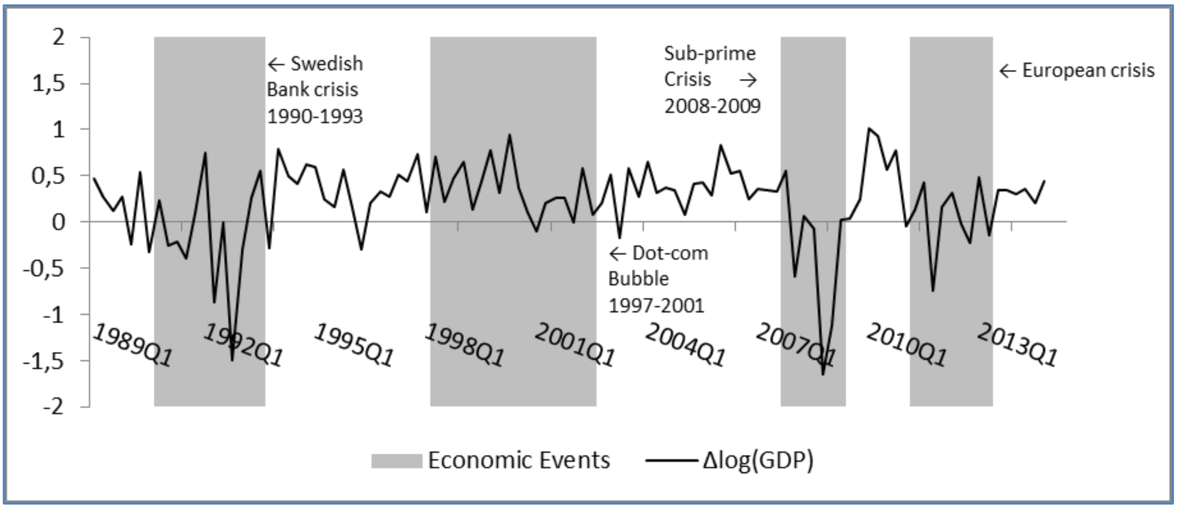
[6] For a general discussion of nonlinear impulse-responses and dynamics, see: Koop, Pesaran & Potter (1996), Potter (2000) and Gallant, Rossi & Tauchen (1993).

3. Empirical Analysis

3.1 Data and Model Selection

Appropriate variables for the empirical research are chosen following the litterature on fiscaly related VAR models (see e.g. Balke, 2000; Atanasova, 2003; Afónso et al., 2011; Calza & Sousa, 2005 and Li, 2010). In spirit of e.g. Afónso et al. (2011) and Hubrich & Tetlow (2014) a financial stress index is used as the summary variable of the financial market conditions. Further, the TVAR includes GDP (GDP_t), core inflation (π_t), the one week interbank lending rate ($STIBOR_t$) and the financial stress index (SI_t).[7] After testing for unit roots in levels[8], GDP_t, π_t and $STIBOR_t$ are transformed into log differences. The data runs from 1989Q1 to 2014Q4 and comprise 104 observations. The reason to why the analysis does not include the latest data is that the stress index was only available up to this point.[9] The source of the original data series includes SCB Sweden, OECD, The Swedish Riksbank and Shahnazarian & Bjellerup (2015) for GDP, CPI, STIBOR and SI respectively. The transformed data is presented in figures 1 to 4, shaded areas represent important economic events during the timespan as a reference.

Figure 1: GDP transformed as Δlog(GDP)



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[7] The variables output, inflation and the short term interest rate followed by financial variables seem rather standard in most of the VAR-literature regarding transmission mechanism dynamics.

[8] Not reported for the sake of brevity.

[9] I would like to thank Mr. Hovick Sahnazarian for providing me with the stress index used in Shanazarian & Bjellerup (2015).

Figure 2: Inflation transformed as $\Delta log(\pi_t)$

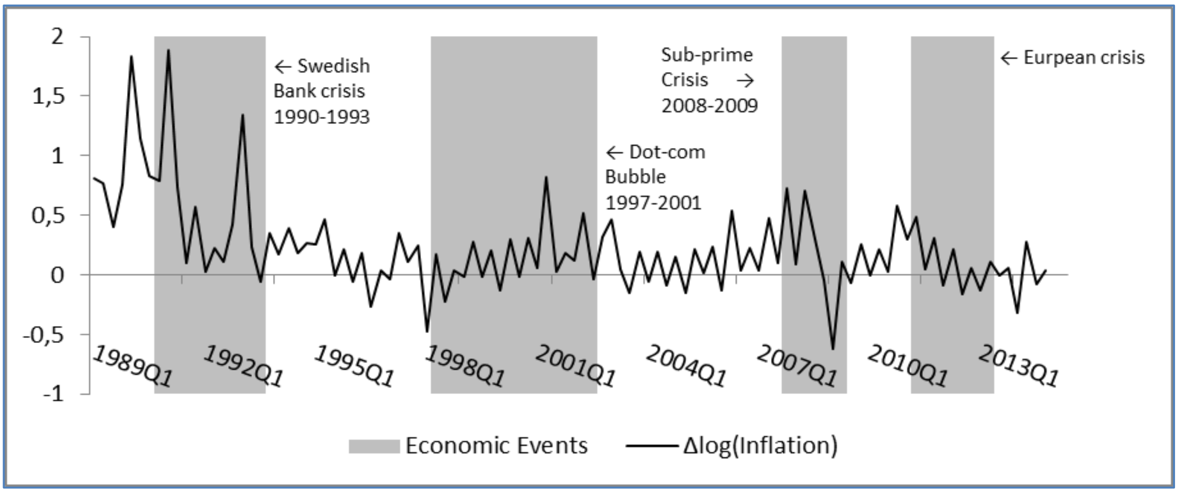


Figure 3: One week interbank lending rate averaged over each quarter. Transformed as $\Delta log(STIBOR_t)$

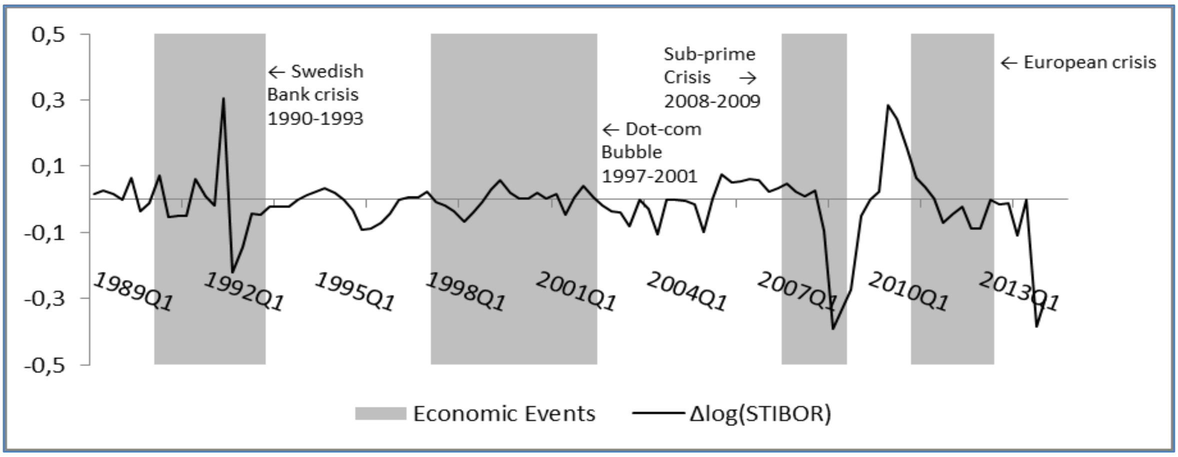
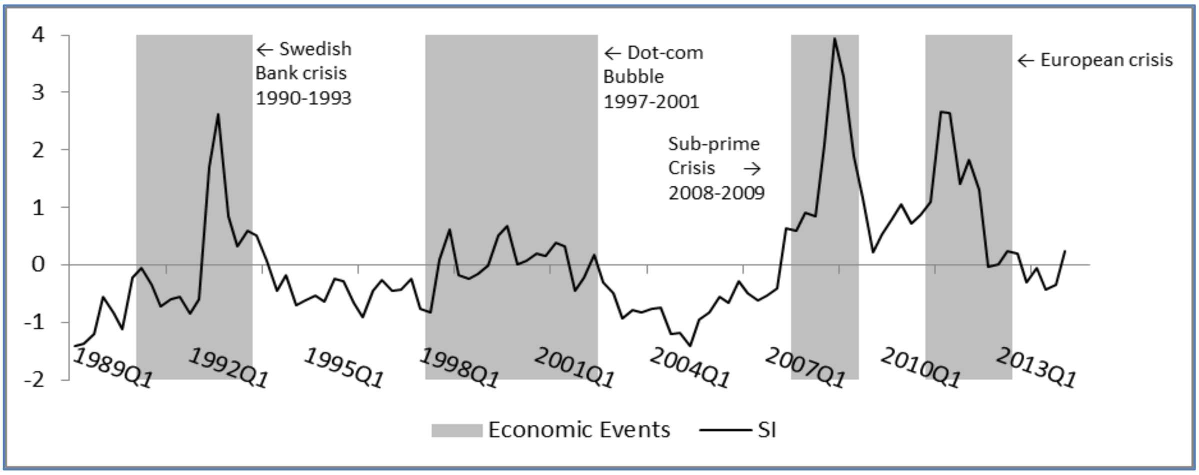


Figure 4: Stress index



The 4×1 vector Y_t in the TVAR model is then given by:

$$Y_t = [\Delta log(GDP_t), \Delta log(\pi_t), \Delta log(STIBOR_t), SI_t]$$

The delay parameter of the threshold variable, d, is set to 1 following Balke (2000). Given the smallness of the sample, only one or two lags are considered for the TVAR since more than two lags would make no sense in a four-variable VAR with only ~ 25-35 observations in the high stress regime. As supported by the Akaike information criteria (AIC)[10], the lag order of the TVAR is set to two.

3.2 Financial Stress Index

The financial stress index consists of four summary indicators of the financial market conditions: *(i)* Uncertainty in the stock market measured as the standard deviation of OMX index for the previous 30 days; *(ii)* uncertainty in the currency market measured as the standard deviation of the SEK exchange rate against the euro for the past 30 days; *(iii)* uncertainty on the money market measured as the difference between the interbank lending rate and the interest on a treasury bill with corresponding maturity, the so called TED spread and *(iv)* uncertainty in the bond market which is measured as the spread between the interest rates on mortgages and government bonds. These four indicative variables are then weighted equally into a summary index which is standardized, i.e. the financial stress index is transformed to have a mean 0 and a standard deviation of 1 (Shahnazarian & Bjellerup, 2015). This means that when the series takes the value 0, the series will equal its historical mean and therefore can be considered as the normal level of stress. Following the same reasoning, when the index takes the value 1, the level of financial stress is equal to one standard deviation above the normal level (Shahnazarian & Bjellerup, 2015). Figure 1 shows the stress index alongside GDP growth over our sample. It is evident that the two has a high rate of covariation, i.e. in periods of low output growth the stress index tends to be high and in periods of high and stable output growth the financial stress index tend to be low.

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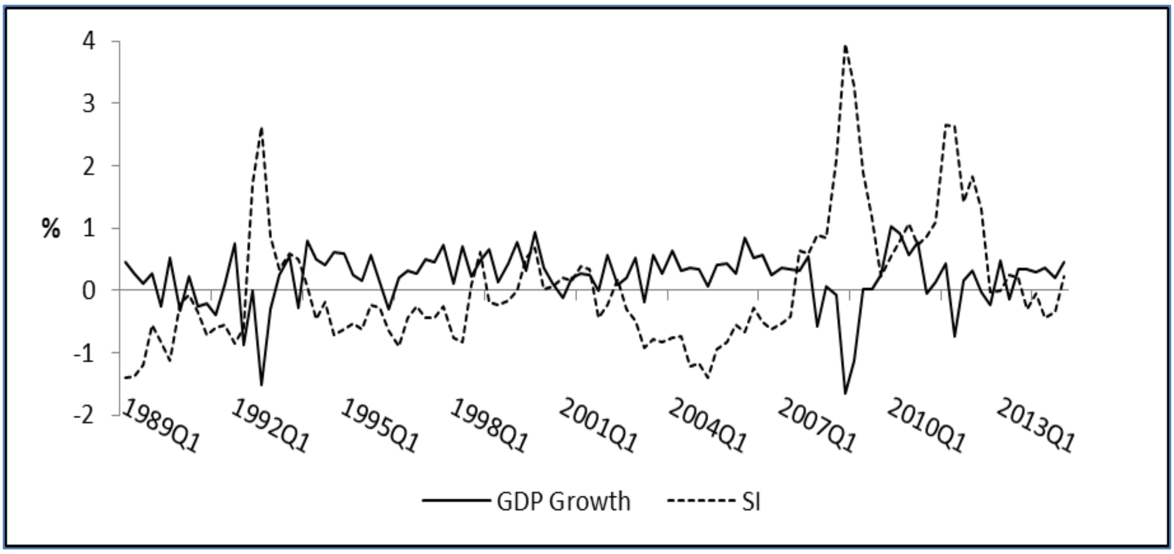
[10] Not reported for the sake of brevity.

Figure 5: GDP growth and financial stress index over the sample 1989Q1-2014Q4



3.3 Estimated threshold value and nonlinearity test

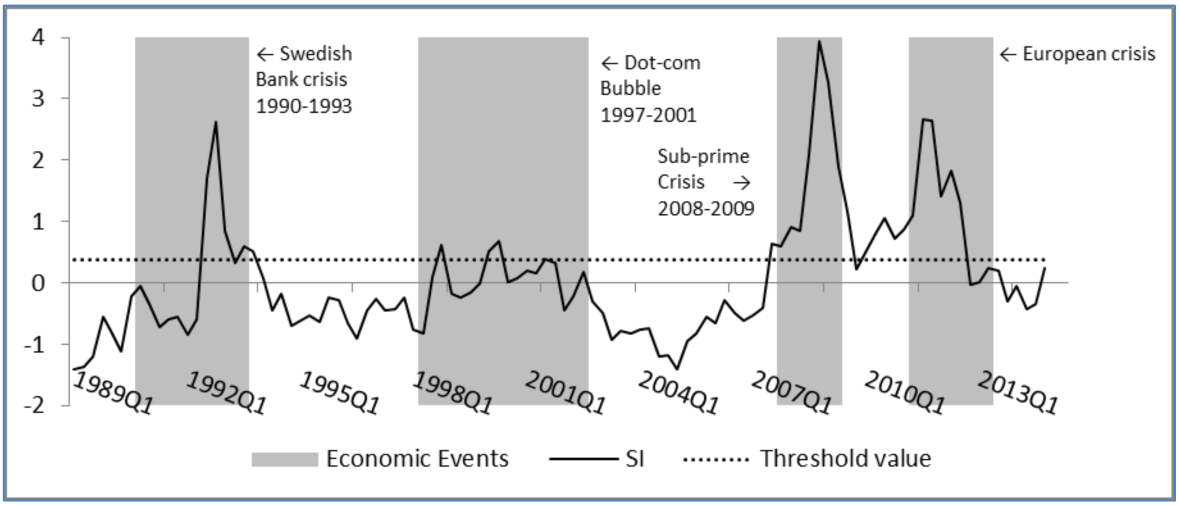
Table 1 presents the estimated threshold value as well as the test results of a linear VAR-model against the alternative of the TVAR model. The test results, with p-values of 0.00 for all three of the calculated test statistics show strong support of the TVAR model and reject linearity. How these nonlinearities affect the economic dynamics will be presented later in this paper under the section of the impulse-response analysis.

Threshold Variable	Estimated Threshold	Sup-Wald Statistic	Avg-Wald	Exp-Wald Statistic	# observations in high regime	# observations in low regime
SI	$\hat{\gamma}$=0.377	125.30 (0.00)	95.70 (0.00)	58.82 (0.00)	28	74

Table 1: Test of a linear VAR against a two regime TVAR. *P*-values (in brackets) are calculated using Hansen (1996) method. Note: the delay parameter is set to 1 following Balke (2000) and each regime is restricted to contain at least 15% of the total observations.

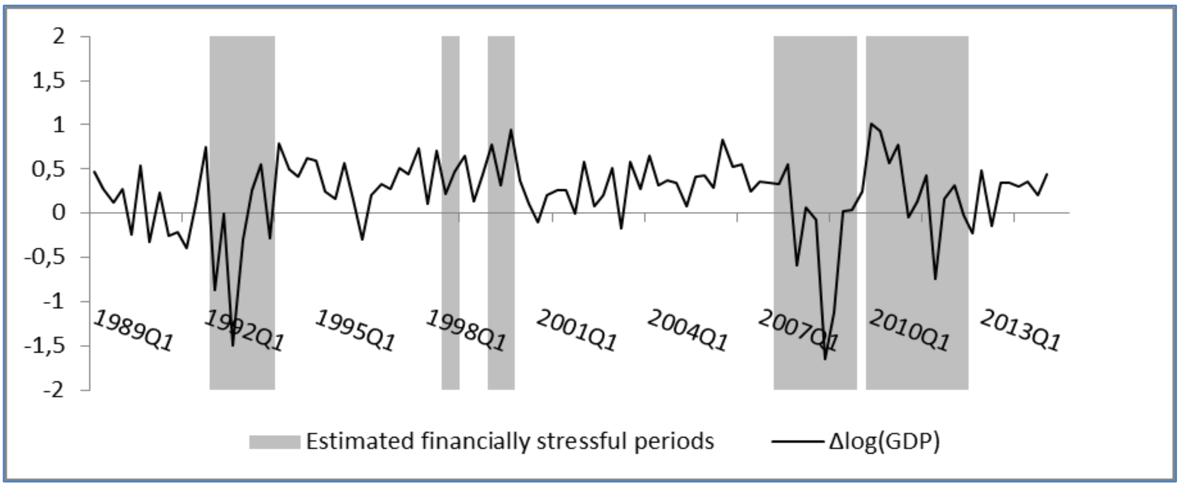
The threshold value of the financial stress indicator is estimated to 0.377, which means that we are in a high-stress regime if the financial stress index is 0.377 standard deviations higher than normal. This effectively splits up the data, resulting in 28 observations in the high financial stress regime and 74 observations in the low financial stress regime. Figure 2 plots the financial stress index together with the estimated threshold value. As a reference, the shaded areas represent important economic events that may have induced a high or low regime historically.

Figure 6: Stress index. The dashed line represents the estimated threshold value and the shaded areas are economic events during the time-span as a reference



As seen in figure 6, the estimated threshold value does a fairly good job in tracking events historically characterized with high financial stress, capturing the majority of the Swedish bank crisis during the early 1990s, the sub-prime crisis and the Euro-zone crisis. However, it only catches a glimpse of the dot-com bubble which is expected since the stress index does not recognize the dot-com bubble as an event characterized by particularly high financial stress.

Figure 7: $\Delta log(GDP_t)$



As a comparison, figure 7 shows GDP growth where the shaded areas represent periods which the estimated threshold variable identifies as particularly stressful. As observed, the estimated threshold variable does a good job in identifying periods characterized by both low GDP growth and high financial stress as expected from figure 5.

Figure 8: $\Delta log(\pi_t)$

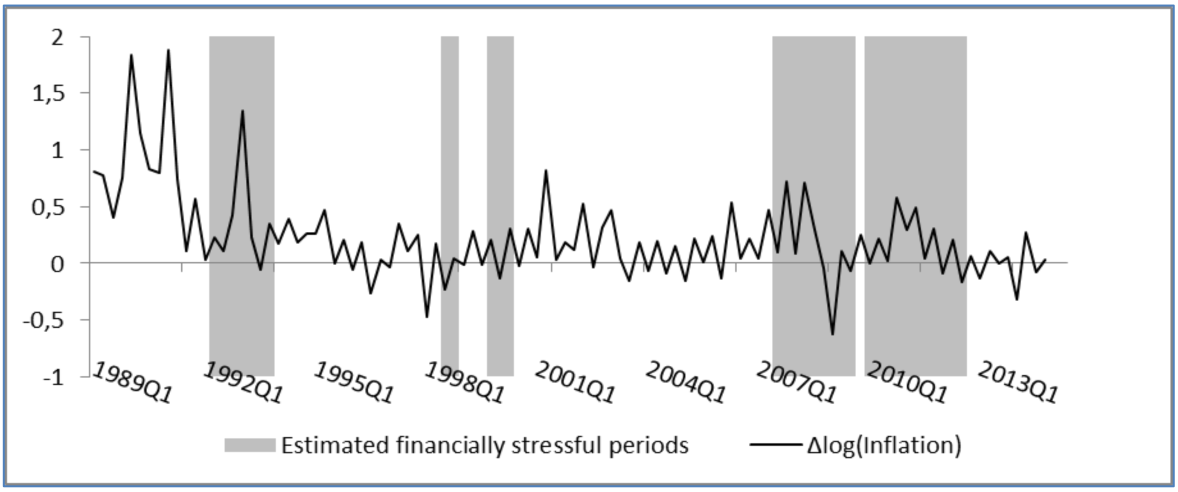


Figure 9: $\Delta log(STIBOR_t)$

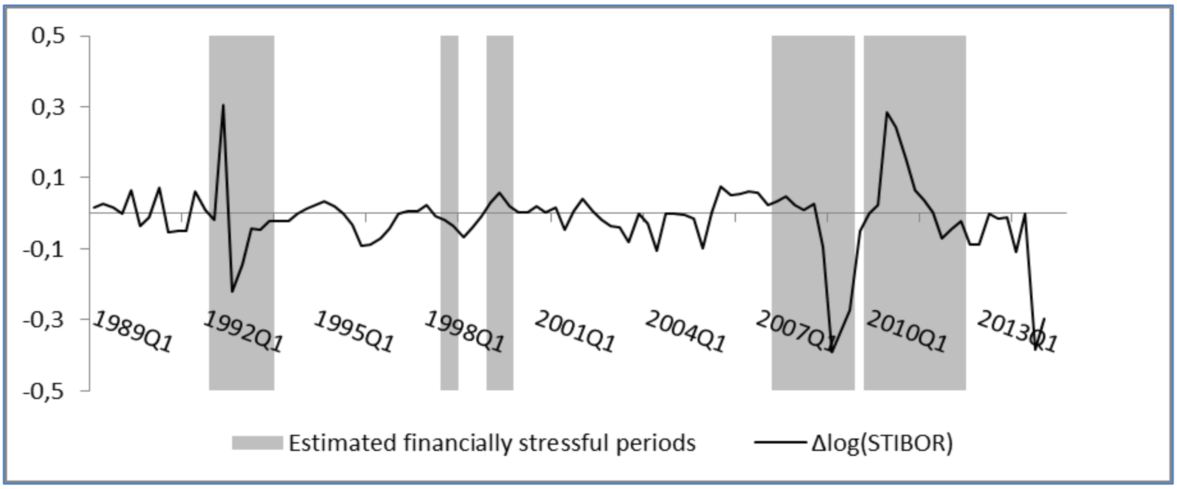


Figure 10: SI_t

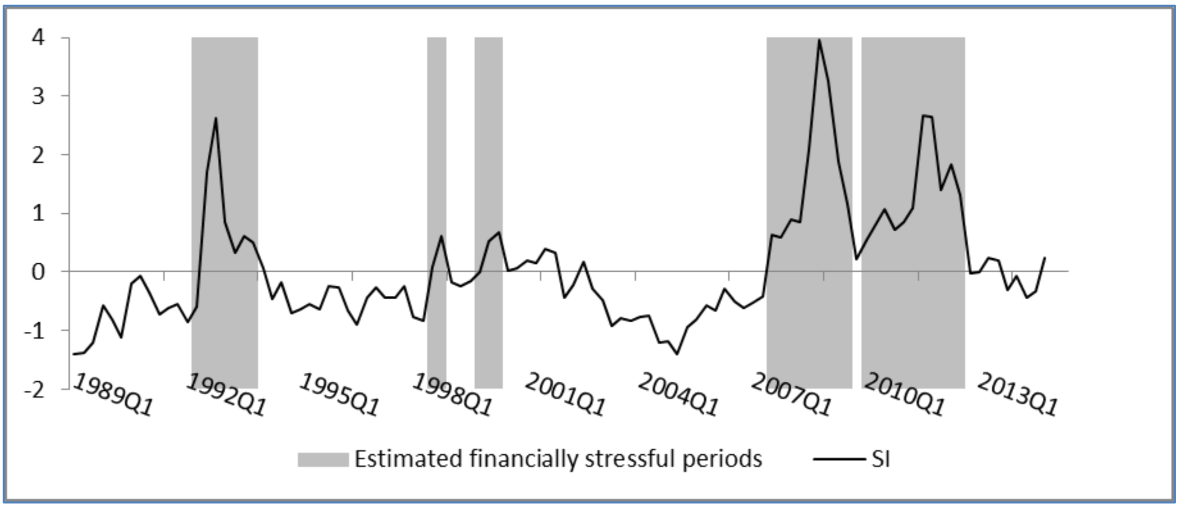


Figure 8-10 represent CPI, STIBOR and SI respectively where the shaded areas are the same as in figure 7. Notably, periods which the TVAR characterizes as stressful often coincides with particularly high or low interest rates and to some extent with high or low rate of inflation. Furthermore, the estimated threshold value clearly catches the peaks of the stress index which can be seen as a sign of a correctly specified model.

3.4 Model Output

Table 2 and 3 present the model output for the low and high stress regime respectively. As a reference, table 4 presents the model output of a linear VAR. The coefficients in the low stress regime are generally more consistent in both sign and size with the output of the linear VAR compared to the coefficients attained in the high stress regime. This may not be a surprise since the majority of the sample is in the low stress regime. There are several cases where the coefficients between the high stress and low stress regime differ considerably in size, sign or both which may be seen as supporting evidence for the existence of different economic dynamics under different financially stressful regimes. Interestingly, GDP reacts positively to financial stress in $t-1$ whereas it reacts negatively in both the linear model and in the stressful regime. On the other hand, GDP reacts negatively to financial stress in $t-2$ in the high stress regime whereas it reacts positively in both the linear model and the low stress regime. Except for $t-1$ in the high stress regime, all three models seem to suffer from the prize puzzle, i.e. an increased interest rate seems to lead to increased inflation. The prize puzzle is common in the fiscally related VAR literature and in a model not incorporating exogenous variables the prize puzzle is not always easily resolved.[11]A reason to this other than the prize puzzle may be that the model includes too few lags in order for the inflation to react adequately to changes in the interest rate.

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[11] For further reading on the prize puzzle in the fiscal VAR literature, please see Sims (1992), Eichenbaum (1992) and Castelnuovo & Surico (2010).

Table 2: TVAR model output for the low stress regime

Low Stress Regime
TVAR Estimates
Standard errors in ( ) & t-statistic in [ ]
Included observations: 74

	$\Delta\log(GDP_t)$	$\Delta\log(CPI_t)$	$\Delta\log(STIBOR_t)$	SI_t
$\Delta\log(GDP_{t-1})$	-0.009208	-0.068764	-0.056839	-0.356107
	(0.122173)	(0.140919)	(0.029538)	(0.180510)
	[-0.075365]	[-0.487970]	[-1.924261]	[-1.972788]
$\Delta\log(GDP_{t-2})$	0.235377	-0.172256	0.020032	0.014550
	(0.123704)	(0.142685)	(0.029909)	(0.182773)
	[1.902736]	[-1.207243]	[0.669763]	[0.079610]
$\Delta\log(CPI_{t-1})$	-0.099352	0.175356	-0.025680	-0.202932
	(0.101500)	(0.117073)	(0.024540)	(0.149965)
	[-0.978836]	[1.497828]	[-1.046472]	[-1.353191]
$\Delta\log(CPI_{t-2})$	-0.160687	0.381712	0.007232	-0.032218
	(0.101321)	(0.116868)	(0.024497)	(0.149702)
	[-1.585917]	[3.266193]	[0.295205]	[-0.215217]
$\Delta\log(STIBOR_{t-1})$	0.920321	0.980437	0.546921	-0.209975
	(0.584898)	(0.674643)	(0.141413)	(0.864184)
	[1.573472]	[1.453268]	[3.867537]	[-0.242975]
$\Delta\log(STIBOR_{t-2})$	-1.751081	0.560018	0.276031	2.071609
	(0.899440)	(1.037448)	(0.217461)	(1.328918)
	[-1.946856]	[0.539803]	[1.269334]	[1.558869]
SI_{t-1}	0.085457	0.181951	0.026026	0.740229
	(0.104120)	(0.120096)	(0.025173)	(0.153836)
	[0.820752]	[1.515050]	[1.033876]	[4.811790]
Si_{t-2}	-0.065648	-0.135097	-0.039858	-0.112602
	(0.099254)	(0.114483)	(0.023997)	(0.146647)
	[-0.661420]	[-1.180065]	[-1.660973]	[-0.767847]
Intercept	0.284364	0.206618	0.007532	0.077374
	(0.090591)	(0.104491)	(0.021902)	(0.133847)
	[3.139001]	[1.977379]	[0.343889]	[0.578078]

Table 3: TVAR model output for the high stress regime

High Stress Regime
TVAR Estimates
Standard errors in ( ) & t-statistic in [ ]
Included observations: 28

	$\Delta\log(GDP_t)$	**$\Delta\log(CPI_t)$**	**$\Delta\log(STIBOR_t)$**	**SI_t**
$\Delta\log(GDP_{t-1})$	-0.009338	-0.097199	0.105154	0.319664
	(0.219989)	(0.159853)	(0.032110)	(0.316728)
	[-0.042447]	[-0.608055]	[3.274837]	[1.009269]
$\Delta\log(GDP_{t-2})$	0.322766	-0.092353	0.105108	-0.556247
	(0.195028)	(0.141715)	(0.028466)	(0.280790)
	[1.654974]	[-0.651682]	[3.692365]	[-1.981011]
$\Delta\log(CPI_{t-1})$	-0.238886	-0.039714	0.079299	0.198334
	(0.305835)	(0.222231)	(0.044640)	(0.440322)
	[-0.781097]	[-0.178707]	[1.776421]	[0.450428]
$\Delta\log(CPI_{t-2})$	-0.090620	0.015884	0.042341	0.449712
	(0.287073)	(0.208599)	(0.041901)	(0.413311)
	[-0.315667]	[0.076147]	[1.010507]	[1.088073]
$\Delta\log(STIBOR_{t-1})$	-0.306402	-0.515605	0.111863	1.312925
	(1.058185)	(0.768919)	(0.154452)	(1.523511)
	[-0.289555]	[-0.670559]	[0.724257]	[0.861775]
$\Delta\log(STIBOR_{t-2})$	0.078584	1.196818	0.133359	0.172873
	(0.835023)	(0.606760)	(0.121880)	(1.202216)
	[0.094110]	[1.972473]	[1.094183]	[0.143795]
SI_{t-1}	-0.599423	-0.107235	-0.040402	1.000881
	(0.154433)	(0.112217)	(0.022541)	(0.222343)
	[-3.881444]	[-0.955606]	[-1.792395]	[4.501513]
Si_{t-2}	0.411695	-0.084335	0.052581	-0.354310
	(0.166454)	(0.120952)	(0.024296)	(0.239650)
	[2.473330]	[-0.697264]	[2.164228]	[-1.478446]
Intercept	0.347788	0.445997	-0.075994	0.244660
	(0.302463)	(0.219782)	(0.044147)	(0.435469)
	[1.149851]	[2.029272]	[-1.721377]	[0.561832]

Table 2: Linear VAR model output

Linear VAR Estimates
Standard errors in ( ) & t-statistic in [ ]
Included observations: 102 After Adjustments

	$\Delta\log(GDP_t)$	**$\Delta\log(CPI_t)$**	**$\Delta\log(STIBOR_t)$**	**SI_t**
$\Delta\log(GDP_{t-1})$	0.016826	-0.048674	0.034232	0.033434
	(0.10222)	(0.09439)	(0.002216)	(0.15086)
	[0.15460]	[-0.51568]	[1.54467]	[0.22163]
$\Delta\log(GDP_{t-2})$	0.303946	-0.101184	0.074757	-0.224042
	(0.10277)	(0.09490)	(0.02228)	(0.15167)
	[2.95740]	[-1.06626]	[3.35526]	[-1.47718]
$\Delta\log(CPI_{t-1})$	-0.097640	0.184776	0.022257	-0.080422
	(0.10821)	(0.09992)	(0.02346)	(0.15969)
	[-0.90231]	[1.84932]	[0.94876]	[-0.50361]
$\Delta\log(CPI_{t-2})$	-0.188893	0.297117	0.017003	0.1115600
	(0.10558)	(0.09748)	(0.02289)	(0.15581)
	[-1.78913]	[3.04783]	[0.74287]	[0.74195]
$\Delta\log(STIBOR_{t-1})$	0.113519	0.095812	0.365705	1.543116
	(0.50168)	(0.46322)	(0.10876)	(0.74034)
	[-1.78913]	[0.200684]	[3.36254]	[2.08433]
$\Delta\log(STIBOR_{t-2})$	-0.692805	0.779797	0.022673	0.056784
	(0.50168)	(0.46732)	(0.10972)	(0.74690)
	[-1.36886]	[1.66865]	[0.20664]	[0.07603]
SI_{t-1}	-0.353529	0.004428	-0.031453	0.959956
	(0.07666)	(0.07079)	(0.01662)	(0.11314)
	[-4.61141]	[0.06256]	[-1.89249]	[8.48495]
Si_{t-2}	0.258672	-0.042259	0.028599	-0.175761
	(0.07576)	(0.06996)	(0.01642)	(0.11181)
	[3.41418]	[-0.60408]	[1.74120]	[-1.57199]
Intercept	0.214963	0.152123	-0.044246	0.084405
	(0.06737	(0.06221)	(0.01461)	(0.09942)
	[3.19067]	[2.44538]	[-3.02934]	[0.84894]

3.5 Nonlinear Impulse-response Analysis

Having rejected the linear VAR model, we can now proceed to examine the economic dynamics of each regime separately, but before starting the analysis, one should keep in mind the recursive ordering of the TVAR model;

$$\Delta log(GDP_t) \rightarrow \Delta log(\pi_t) \rightarrow \Delta log(STIBOR_t) \rightarrow SI_t$$

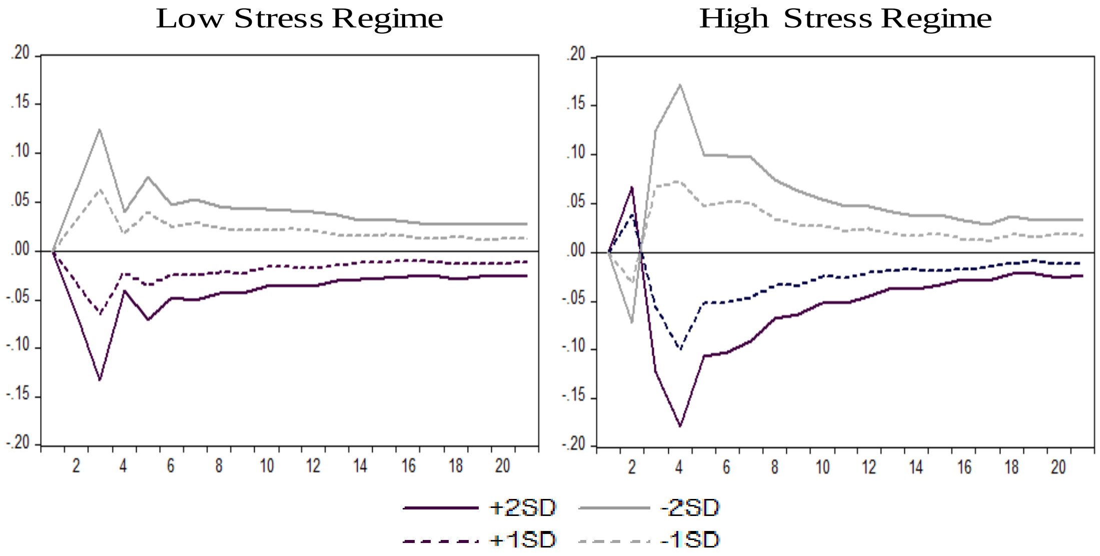
This specific ordering of the variables means that all other variables in the system reacts contemporaneously to shocks to GDP growth whereas GDP growth only reacts to shocks of the other variables in the system after one or two quarters. STIBOR reacts contemporaneously to changes in GDP growth and inflation whereas inflation and GDP growth only reacts to changes in STIBOR after one or two quarters. Shocks to the stress index are only transmitted to the other variables after one or two quarters, but shocks to any of the other variables will have a contemporaneous effect on the stress index.

3.5.1 Response of GDP

Figure 11 to 13 shows the response of GDP growth to shocks of the other endogenous variables in the TVAR. Notably, GDP growth reacts more to both positive and negative shocks when the economy is initially in the high stress regime than in the low stress regime. This may not be a surprise but acknowledges the presence of asymmetries.

Figure 11

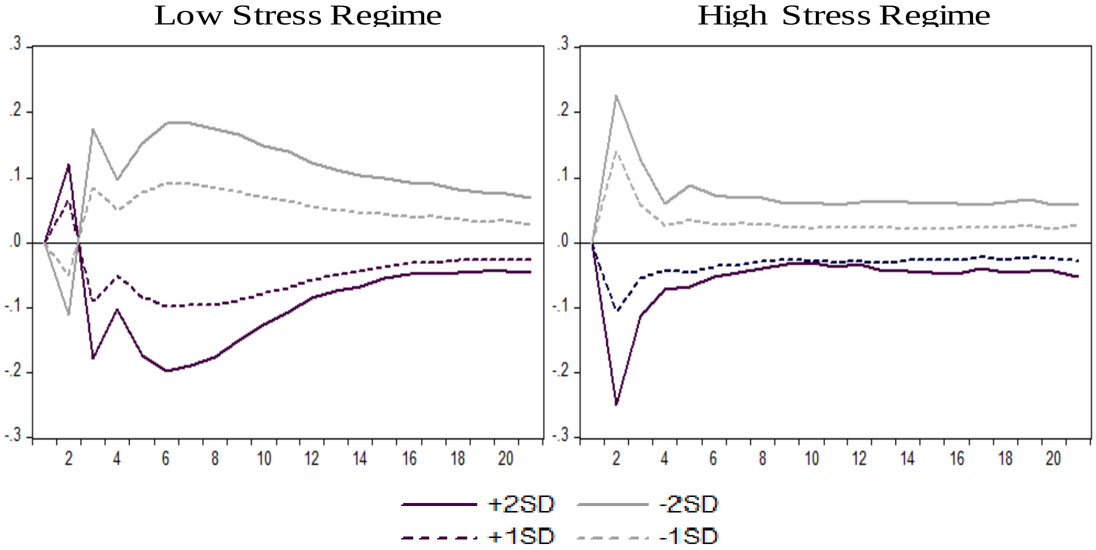
Response Variable: Δlog(GDP$_t$)
Shock Variable: Δlog(π_t)



As seen in figure 11, the response of GDP growth to inflationary shocks seems to be fairly symmetrical in both the high stress regime as well as in the low stress regime, i.e. positive and negative shocks seem to have roughly the same impact in both regimes. On average, GDP growth reacts more to inflationary shocks starting in the high stress regime. Whereas GDP growth immediately reacts negatively to an increase in the inflation rate in the low stress regime, it seem to first react negatively in the high stress regime before taking negative figures below the ones attained in the low stress regime. The reason for such tendencies may be due to endogenous regime switches during the horizon of the impulse-response.

Figure 12

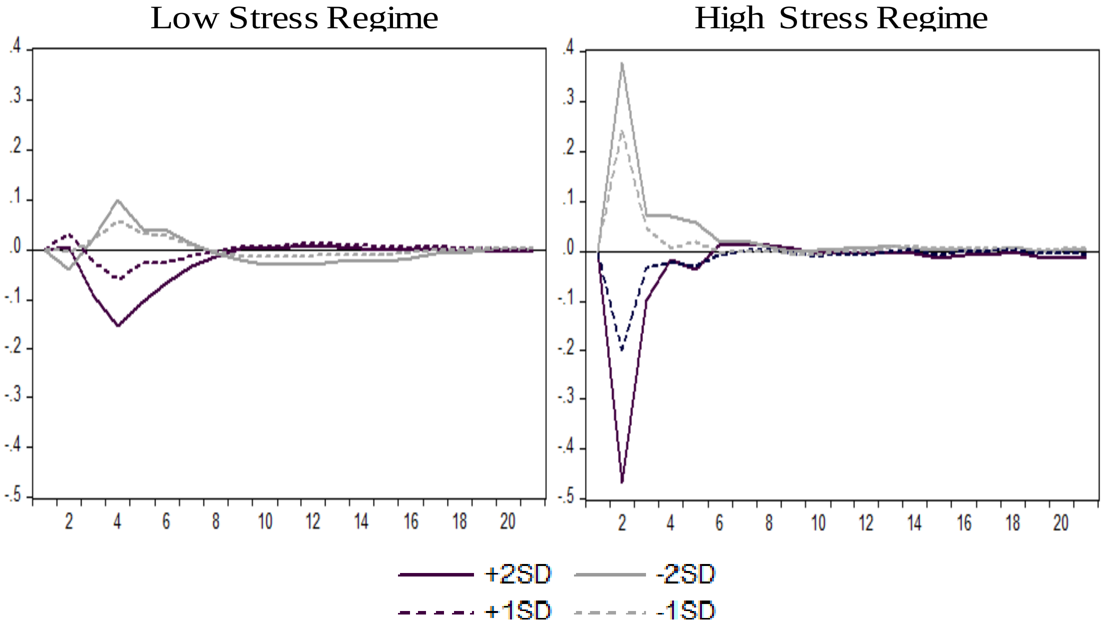
Response Variable: $\Delta\log(GDP_t)$
Shock Variable: $\Delta\log(STIBOR_t)$



These tendencies can also be found for the interest rate in figure 12; a positive shock to STIBOR in the low stress regime initially induces positive values of GDP growth before turning negative. On average however, a positive shock to STIBOR leads to decreasing GDP growth in both regimes, confirming macroeconomic theory. More interestingly is the fact that the response of GDP growth to shocks of STIBOR is greater for both negative and positive shocks when we start in the high stress regime compared to the low stress regime. This may be a sign that the economy is more sensitive to monetary policy during financially stressful times than it is during normal times, to some extent contradicting the finding of Shahnazarian and Bjellerup (2015) stating that monetary policy is less effective under periods of high financial stress. On the other hand, if we play with the thought that financially stressful times coincide with recessionary times, this observation goes hand in hand with the findings of Chiu & Hacioglu (2016) who finds that monetary policy shocks occuring in financially stressful times create dispropportionally larger contractions in output. Furthermore, monetary policy does seem to have greater persistence, i.e. higher effects under longer horizon, when starting in the low stress regime. This in turn may potentially be due to the fact that monetary policy is conducted in order to achieve long run stability when we are in a period of low financial stress and as a mean to resolve crisis in the case of when there is high financial stress present.

Figure 13

Response Variable: $\Delta\log(GDP_t)$
Shock Variable: $\Delta\log(SI_t)$

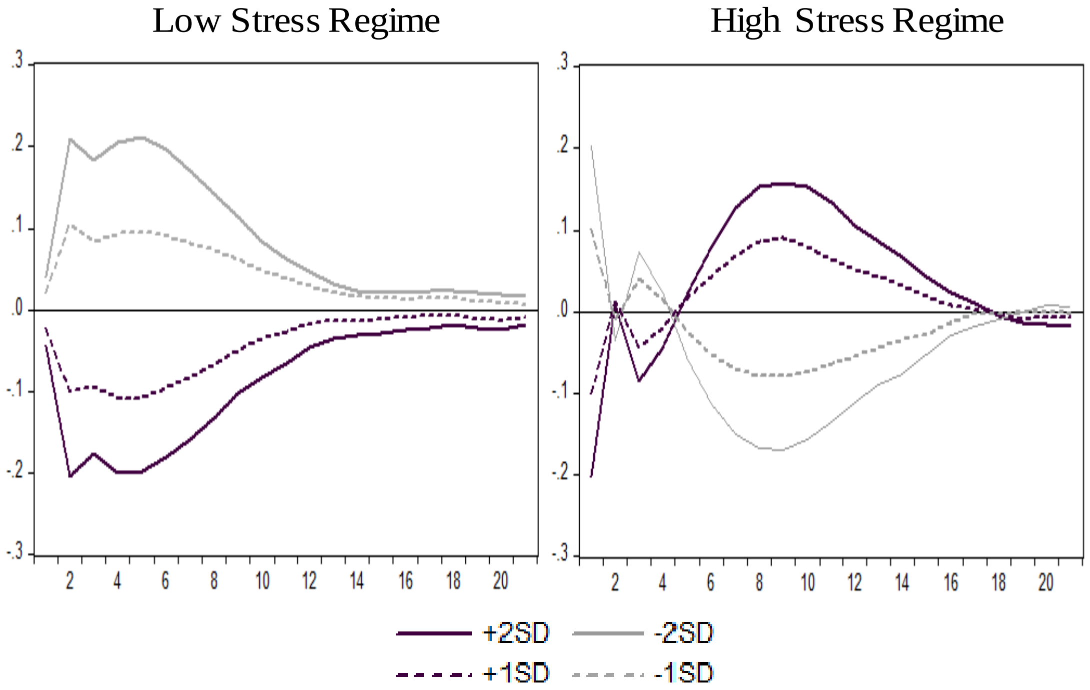


As expected, higher financial stress seems to cause a decrease in GDP growth and on average a positive shock to the financial stress index will have a greater impact on GDP growth than a negative shock, acknowledging nonlinearities within each regime separately. There also seem to be substantial differences if the shock occurs when the economy is in low stress or in high financial stress. In line with the findings of Afónso et al. (2011), starting in the high financial stress regime, financial stress shocks have a greater impact on GDP growth than when starting in the low stress regime, i.e. when the economy is under high financial stress, shocks of the same sign and size have a considerably greater impact compared to when the shock occurs in the low stress regime. Therefore, the response of GDP growth to financial stress shocks seems to be subject to nonlinearities across regimes.

3.5.2 The impact on financial stress

Figure 14

Response Variable: SI_t
Shock Variable: $\Delta\log(GDP_t)$



Given by figure 14, the response of financial stress to shocks to GDP growth is symmetric in the low stress regime. Starting in the low stress regime, a decrease in GDP growth leads to a positive response of the stress index, i.e. lower GDP growth leads to higher financial stress which seems reasonable. Starting in the high stress regime, however, the response of SI is very volatile for the first 5-6 quarters before a pronounced positive relationship can be seen, i.e. on average a positive shock to GDP growth in the high stress regime leads to an increased level of financial stress. The results attained in the high stress regime is in line with Chiu & Hacioglu (2016) who finds that GDP growth shocks occurring in periods already characterized by high financial stress create further financial stress.

Figure 15

Response Variable: SI_t
Shock Variable: $\Delta\log(STIBOR_t)$

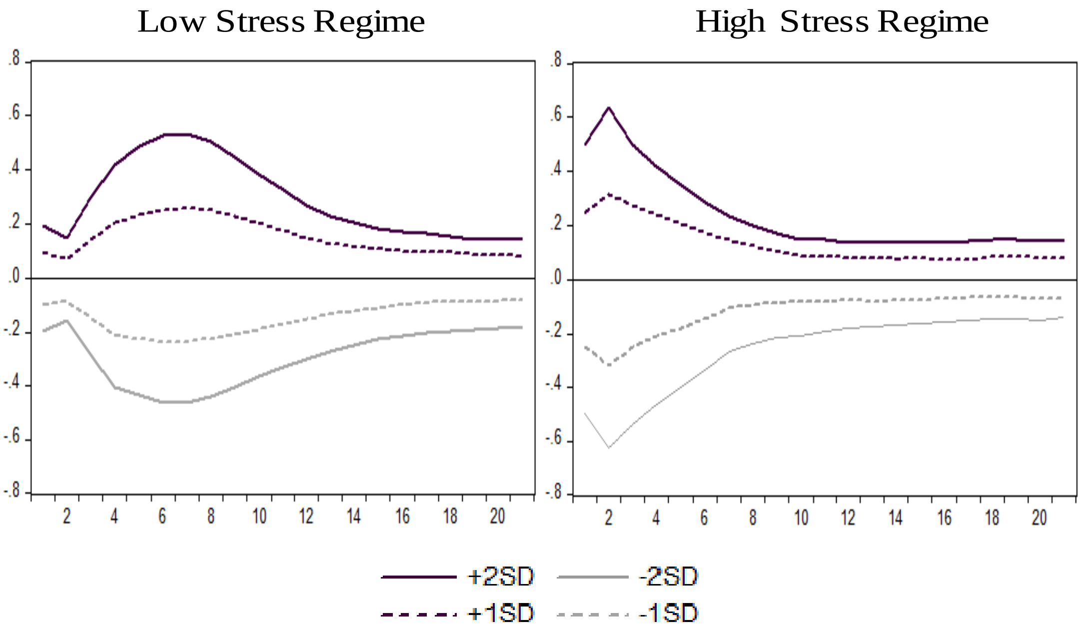


Figure 15 presents the response of SI to shocks to STIBOR. In both regimes, a higher rate of interest will lead to increased financial stress which may be expected. Monetary policy shocks seem to have a greater, more immediate effect on financial stress in the high stress regime whereas financial stress reacts slower in the low stress regime, although the difference is not very pronounced. In the low stress regime however, the effect of shocks to STIBOR seem to have somewhat greater persistence.

4. Conclusion

Literature on the area of fiscally related VAR models has emphasized the role of financial conditions as a possible propagator of asymmetries in the transmission between monetary policy, the business cycle and the financial sector. Using Swedish data, the test proposed by Hansen (1996) is applied to test a linear VAR against a two-regime TVAR alternative. Generally consistent with the related TVAR literature, the test show supporting evidence for nonlinearities. As of such, this paper acknowledges the existence of asymmetries in the transmission between the financial sector, monetary policy and the real economy.

By applying a nonlinear impulse-response analysis the paper further concludes that shocks to any of the endogenous variables in the TVAR model occurring in a period of high financial stress have higher effect on GDP growth than those similar shocks occurring in periods of low financial stress. As a result, monetary policy shocks occurring when the economy is in a state of high financial stress create higher fluctuations in output than when the economy is in a state of low financial stress, supporting the findings of Balke (2000), Chiu & Hacioglu (2016) amongst others. On the other hand, monetary policy seems to have greater persistence when conducted in times of low financial stress.

Supporting the findings of Afónso et al. (2011), financial shocks starting in times which already is characterized by particularly high financial stress create disproportionally larger fluctuations in output growth compared to shocks of the same sign and size occurring in times of low financial stress. Furthermore, the results indicate that output growth shocks occurring in times characterized by high financial stress lead to further financial stress.

The empirical exercise in this paper points towards the need for policy makers to acknowledge these aforementioned asymmetries in the transmission mechanism between the financial sector, monetary policy and the business cycle. Even though the TVAR model applied in this paper does not use the same set of variables as those of Sahnazarian & Bjellerup (2015), the results show support of their issue regarding nonlinearities within the parameters of their model. Testing a similar model of Sahnazarian & Bjellerup in order to capture the entire transmission mechanism but allowing for endogenous regime-shifts using for example a TVAR model would therefore be of interest for future research.

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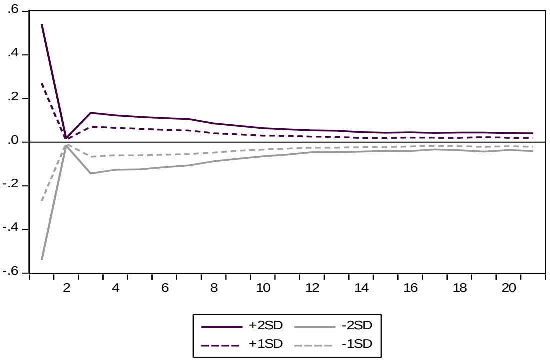
Appendix

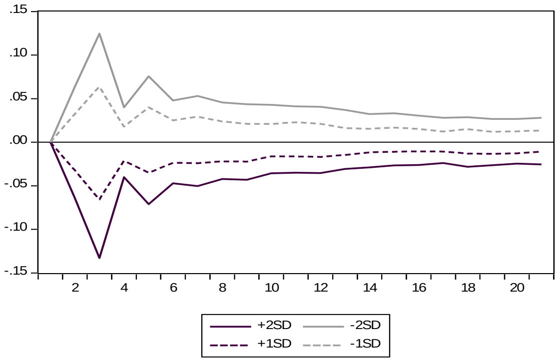
A. Impulse response summary

Low Stress Regime:

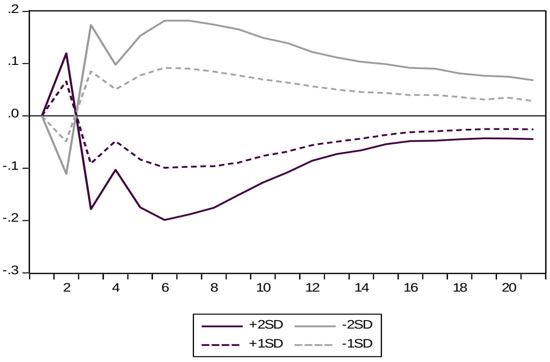
Response of GDP_GROWTH to shock to GDP_GROWTH



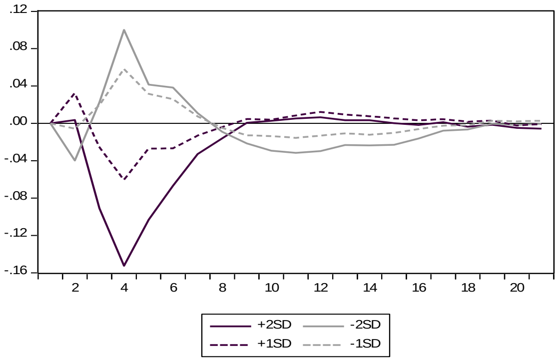
Response of GDP_GROWTH to shock to CPI



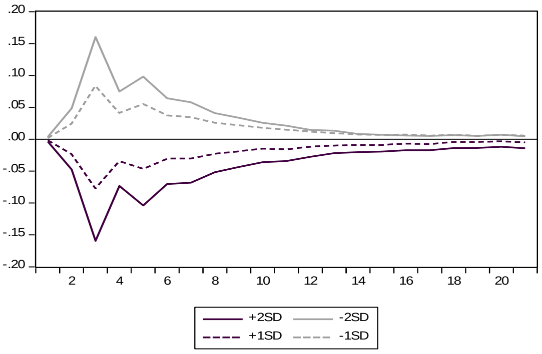
Response of GDP_GROWTH to shock to DLOGSTIBOR



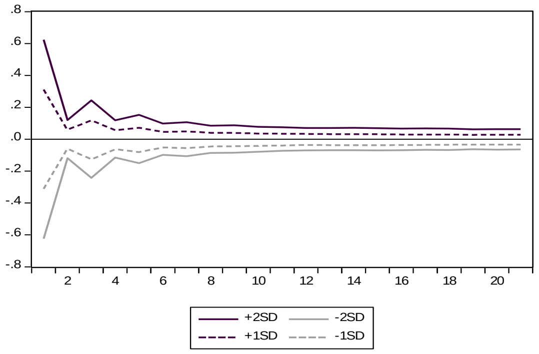
Response of GDP_GROWTH to shock to SI



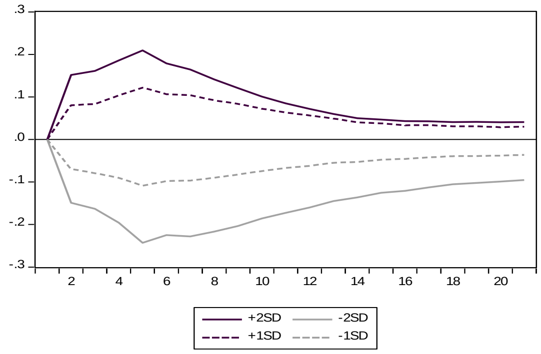
Response of CPI to shock to GDP_GROWTH



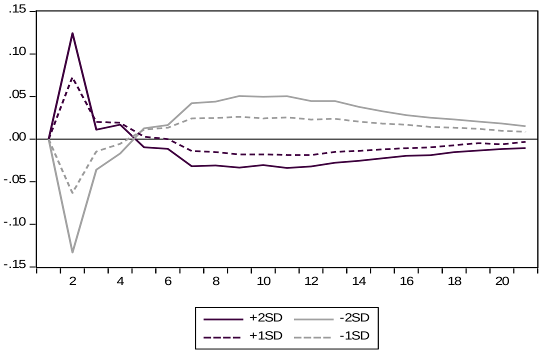
Response of CPI to shock to CPI



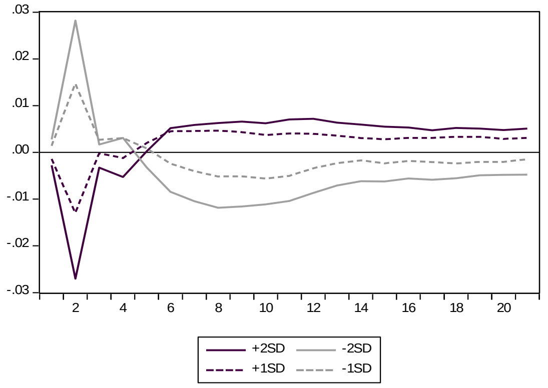
Response of CPI to shock to DLOGSTIBOR



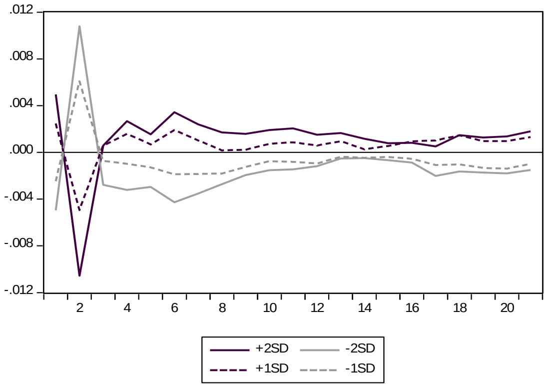
Response of CPI to shock to SI



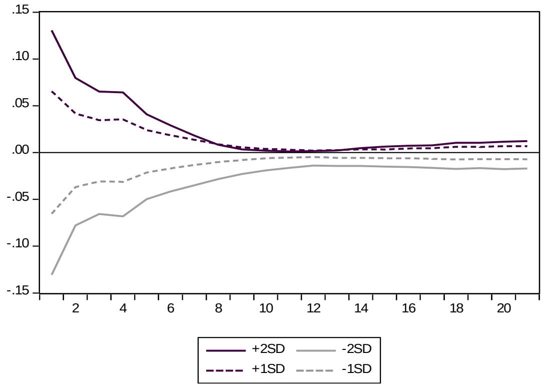
Response of DLOGSTIBOR to shock to GDP_GROWTH



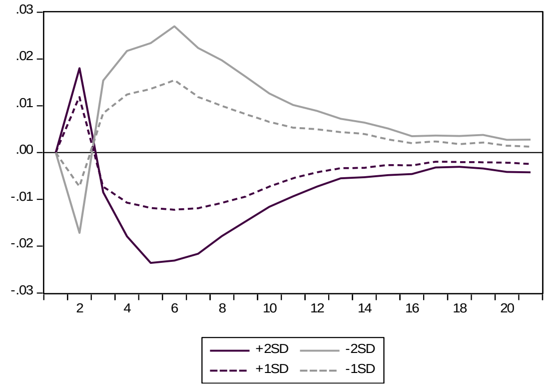
Response of DLOGSTIBOR to shock to CPI



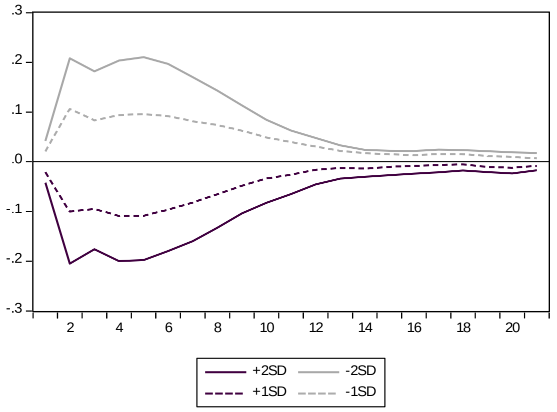
Response of DLOGSTIBOR to shock to DLOGSTIBOR



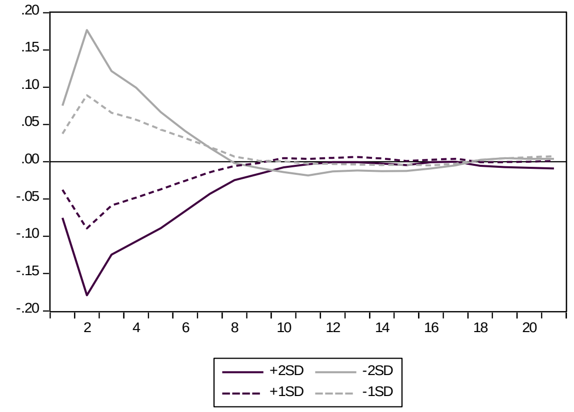
Response of DLOGSTIBOR to shock to SI



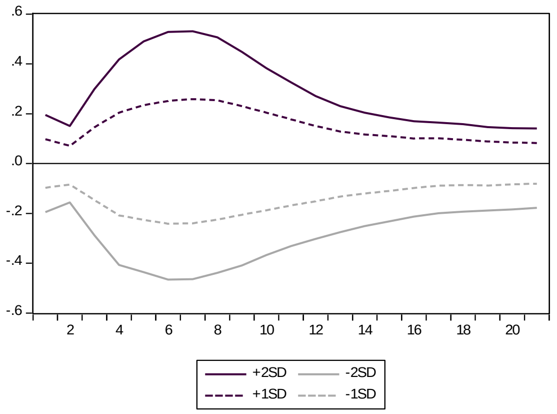
Response of SI to shock to GDP_GROWTH



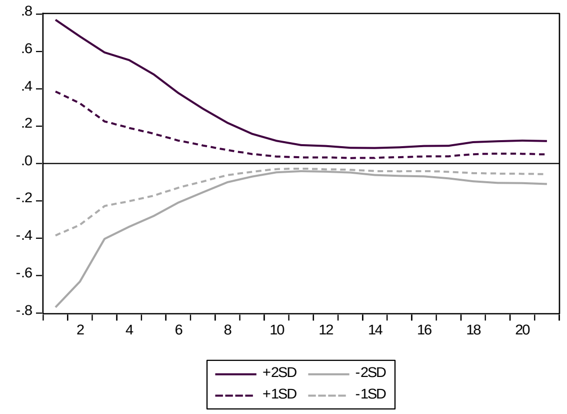
Response of SI to shock to CPI



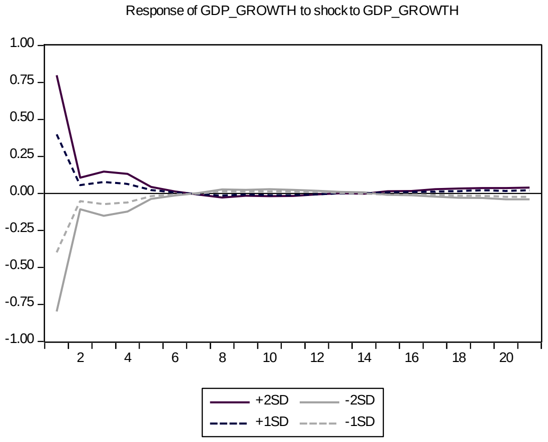
Response of SI to shock to DLOGSTIBOR

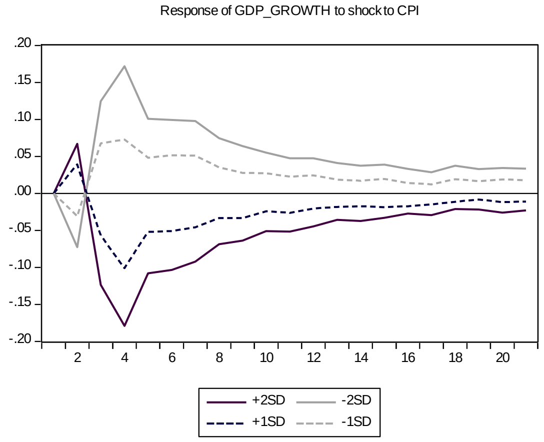


Response of SI to shock to SI



High Stress Regime:


Response of GDP_GROWTH to shock to GDP_GROWTH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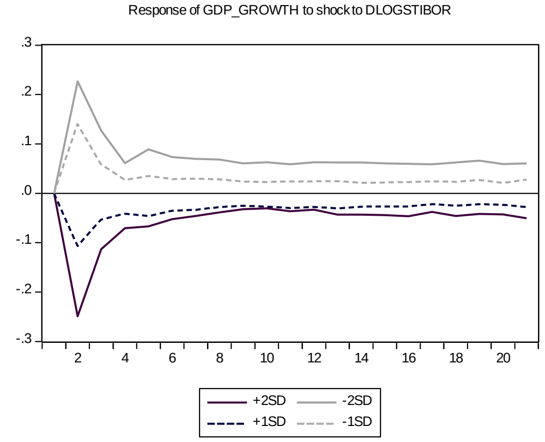
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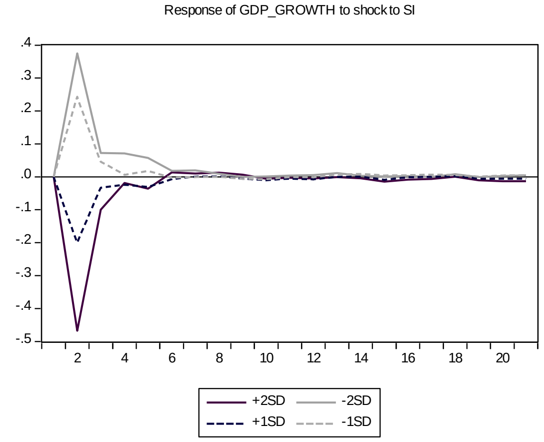
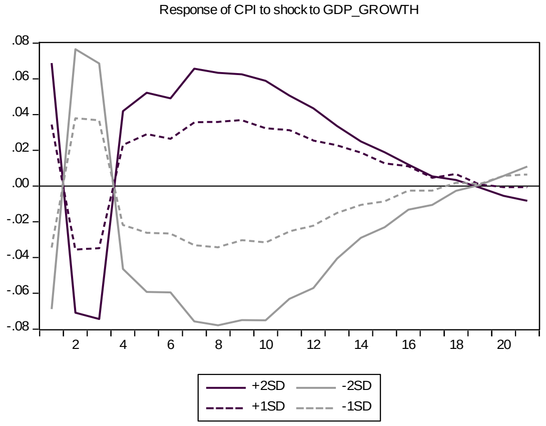
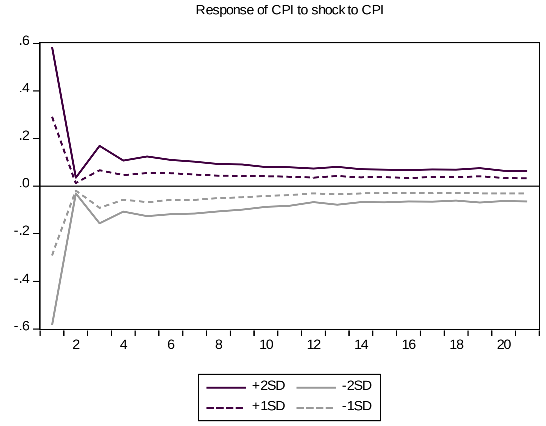
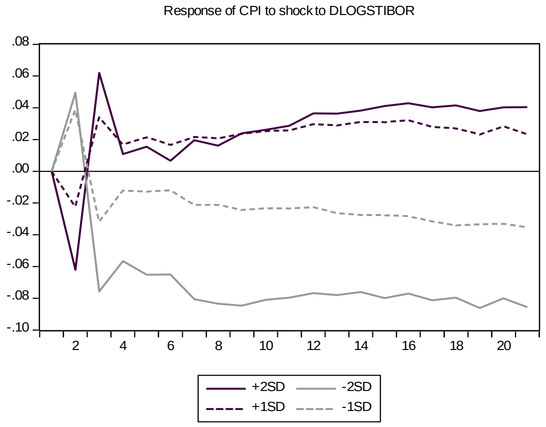
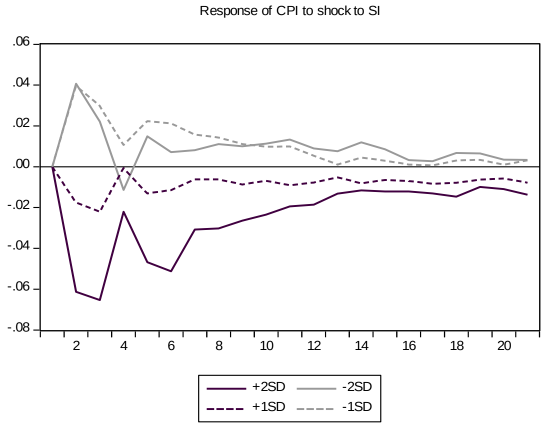
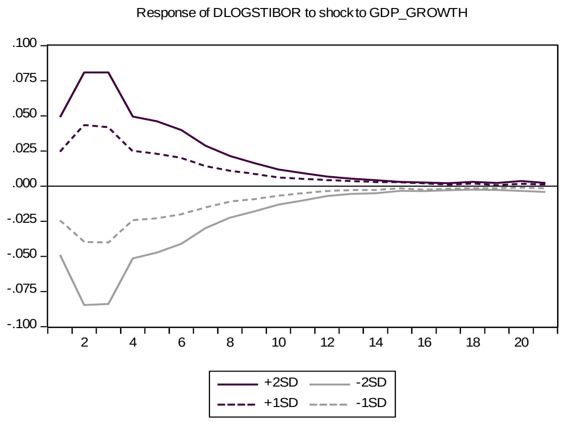

Response of GDP_GROWTH to shock to SI

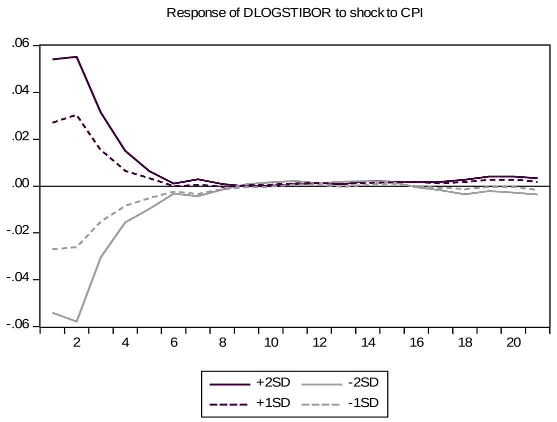

Response of CPI to shock to GDP_GROWTH

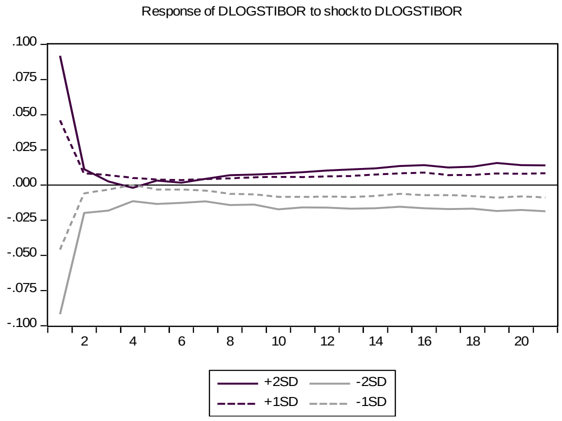

Response of CPI to shock to CPI

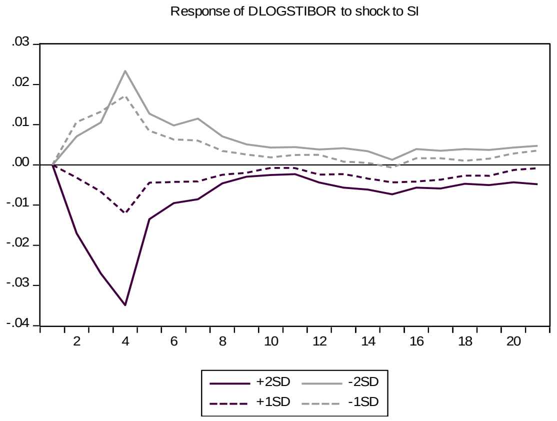

Response of CPI to shock to DLOGSTIBOR


Response of CPI to shock to SI


Response of DLOGSTIBOR to shock to GDP_GROWTH


Response of DLOGSTIBOR to shock to CPI


Response of DLOGSTIBOR to shock to DLOGSTIBOR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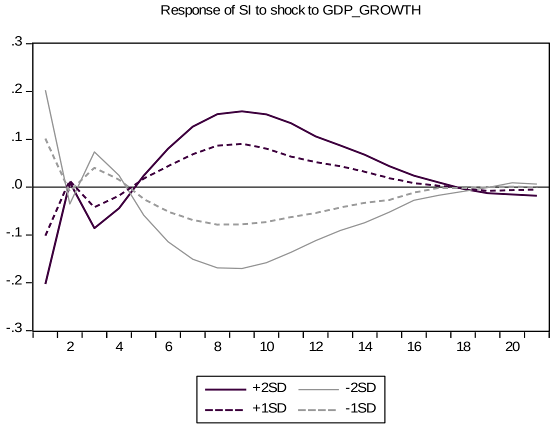
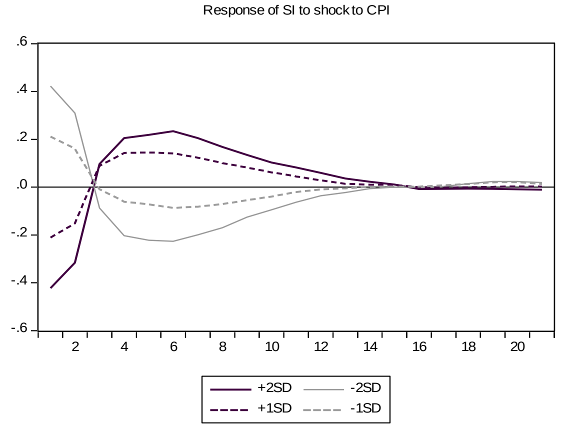
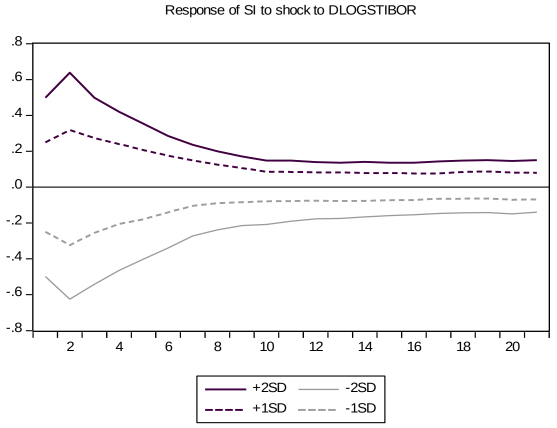
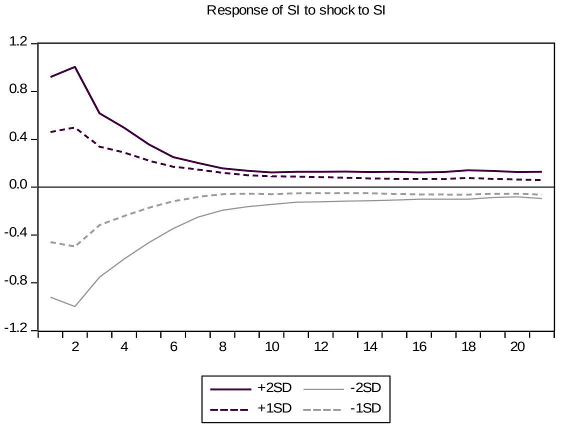

Response of SI to shock to GDP_GROWTH


Response of SI to shock to CPI


Response of SI to shock to DLOGSTIBOR


Response of SI to shock to SI