

# **Risk, Uncertainty, and Leverage\***

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## **Abstract**

Using mostly theoretical models and traditional risk/uncertainty measures (VIX index, panic, precaution, scary bad news, etc.), the current literature tries to clarify the risk/uncertainty-deleveraging pattern. The findings are not sufficient to explain the dynamic empirical relationship between modern risk/uncertainty indicators and leverage. We fill this gap in the literature by using US quarterly data, from 1985:1 to 2018:4, Granger causality tests, and a structural vector autoregression model. We find that commercial bank leverage rises when geopolitical risk and macroeconomic, policy, and equity uncertainty increase. Client-based business relationships of banks and high government borrowing from banks during crises periods are responsible for this relationship. We find that the leverage of broker-dealers and shadow banks declines when Chicago risk and macroeconomic, policy, financial, and equity uncertainty increase. We argue that the vulnerability of broker-dealers and shadow banks to the risk/uncertainty of the entire market system is responsible for this relationship.

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## 1. Introduction

The global financial crisis of 2007-2009 pushed the United States, as well as other advanced and emerging market economies, at the bottom of the leverage cycle, with the leverage of some financial institutions declining significantly compared to the pre-crisis period. The deleveraging during and after the financial crisis was not an isolated incident. In fact, the procyclical nature of leverage of some financial institutions renders leverage endogenous or dependent on other economic and financial variables. The current literature suggests that some warning signals, like ‘uncertainty’, ‘panic’, ‘precaution’, and ‘scary bad news’, among others, are the primary cause of deleveraging. Most of these warning signals are traditional and qualitative, and it is difficult to calculate their effects on the leverage decisions of financial firms. This backdrop provides an interesting research question: Does risk/uncertainty explain deleveraging by financial firms? We attempt to answer this question by investigating the effects of different modern quantitative risk and uncertainty measures on the leverage decisions of commercial banks, broker-dealers, and shadow banks.

Leverage allows economic agents to acquire assets in excess of net worth, and as Geanakoplos (2010, p. 102) puts it, “sometimes, especially in times of crisis, collateral rates (equivalently, margins or leverage) are far more important than interest rates.” In fact, the leverage of commercial banks is pretty constant, but that of broker-dealers and shadow banks shows procyclical patterns. See, for example, Adrian and Shin (2010, 2014), Serletis *et al.* (2013), Adrian *et al.* (2014), Istiak and Serletis (2016, 2017), and Nitoi *et al.* (2019). Moreover, risk and uncertainty can affect the leverage cycle. Knight (1921) defines risk as the known probability distribution for a set of known outcomes. On the other hand, Bloom (2014) mentions that uncertainty is subject to other less understood, but important factors, such as unquantifiable outcomes, asymmetric information, liquidity, and subjective behavioral biases. He also argues that a single concept of uncertainty is a mixture of risk and uncertainty. As Turlakov (2017) argues, uncertainty and risk constrain leverage. He also opines that the link between leverage and uncertainty is important both on the micro-level and on the macro-systemic level.

In this paper, we argue that the connection between risk/uncertainty and the leverage cycle works through the “risk and uncertainty-real GDP-leverage” channel. We use six risk and uncertainty indices --- geopolitical risk, Chicago risk, macroeconomic uncertainty, financial

uncertainty, economic policy uncertainty, and equity uncertainty --- and three of the most important financial intermediaries --- commercial banks, broker-dealers, and shadow banks --- to investigate the relationship between risk/uncertainty and leverage. We present a comprehensive analysis within three classes of empirical models --- a forecasting model, Toda-Yamamoto (1995) Granger causality tests, and a structural VAR model --- to examine the relationship in a dynamic macroeconomic framework.

By using the forecasting model, we find that higher risk and uncertainty reduces real GDP by influencing consumption, investment, export, and import. The Toda-Yamamoto (1995) Granger causality tests indicate that the risk indicators do not Granger-cause leverage, but most uncertainty measures Granger-cause the leverage of financial institutions. Finally, the structural VAR model shows that the risk and uncertainty indicators do not have a significant negative impact on the leverage of commercial banks. On the other hand, except for geopolitical risk, all other risk and uncertainty measures can explain the deleveraging of broker-dealers and shadow banks. So, mostly the uncertainty indicators work as a warning signal for deleveraging in the leverage cycle. Our results are not sensitive to the financial crisis period, as they remain valid for the full sample period and also for the pre-financial crisis period.

The rest of the paper is organized as follows. Section 2 provides the theoretical foundations regarding the relationship between risk/uncertainty and leverage. Section 3 describes the data. Section 4, 5, and 6 present the empirical results in the context of a forecasting model, Granger causality tests, and a structural VAR model, respectively. Section 7 examines the robustness of the results. Section 8 discusses the economic and policy implications of the empirical findings, and the final section briefly concludes.

## **2. Motivation and Literature Review**

There is some theoretical literature that is related to our paper. Geanakoplos (2003) argues that bad news, especially “scary bad news”, is responsible for big crises and deleveraging. He claims that scary bad news raises tail volatility (for example, the VIX index) and ultimately leads to a decline in leverage. This mechanism is also supported by Fostel and Geanakoplos (2008), Brunnermeier and Pedersen (2009), Geanakoplos (2009, 2011), Fostel and Geanakoplos (2012, 2014), and Simsek (2013), among others. Brunnermeier (2009), Gorton and Metrick

(2010, 2012), and Krishnamurthy *et al.* (2014) show that uncertainty regarding the value of collateral in repo transactions may force the shadow banking system to deleverage. Turlakov (2017) finds that uncertainty and risk constrain leverage, although the model is not applied to any particular financial institution. Tian (2017) argues that when asset return uncertainty increases, it becomes costlier for shadow banks to roll over their debt, forcing them to deleverage. Finally, Tella (2017) finds that aggregate uncertainty shocks (defined by idiosyncratic risk in the economy) can create balance sheet recessions.

Most of the literature explores the relationship between risk/uncertainty and leverage in a theoretical framework, and there are few empirical studies in this field. Our research fills this gap in the literature. To explore the relationship between risk/uncertainty and leverage, the existing few empirical studies deal with only one or two uncertainty indices, as in Baum *et al.* (2009), Tian (2017), and Tella (2017), and with mostly one institution, nonfinancial firms by Baum *et al.* (2009), Krishnamurthy *et al.* (2014), and shadow banks by Tian (2017). Without a comprehensive framework that explains how different risk and uncertainty indices affect the leverage of different financial intermediaries, we are only half-way in explaining the risk and uncertainty-deleveraging pattern observed in the leverage cycle.

The main contribution of our paper is to shed more light on this missing link. Thus, we extend the literature discussing the dynamic relationship of risk and uncertainty with leverage and other important macroeconomic variables of the economy. As noted in the Introduction, to empirically investigate the relationship between risk/uncertainty and leverage, we use two proxies for risk --- geopolitical risk and the Chicago financial conditions risk --- and four proxies for uncertainty --- macro uncertainty, financial uncertainty, economic policy uncertainty, and equity market uncertainty --- to explore their relationship with the leverage of commercial banks, broker-dealers, and shadow banks.

We argue that the relationship between risk/uncertainty and leverage works through the “risk and uncertainty-real GDP-leverage” channel. The first part of the relationship (risk and uncertainty lead to a lower level of economic activity) is widely discussed in the literature. For example, Cover (2011) finds that higher risk causes a statistically significant and economically important decline in output. Bekaert *et al.* (2013) show that the uncertainty component of the VIX index has a statistically strong effect on the business cycle. Bordo *et al.* (2016) show that

policy uncertainty curbed the bank credit channel of monetary policy transmission, and thus delayed the recovery of the U.S. economy from the recent financial crisis. Caggiano *et al.* (2017) and Bloom *et al.* (2018) also opine that uncertainty was one of the principal factors for the recent Great Recession.

High risk and uncertainty lead to lower real GDP by depressing durable consumption and investment. Giavazzi and McMahon (2012) argue that higher uncertainty is associated with lower consumer spending. Knotek and Khan (2011) also argue that when policy uncertainty rises, consumers follow a “wait-and-see” mode that dampens their spending. A large number of authors argue that uncertainty decreases irreversible types of investment, which is consistent with the “option value of waiting under uncertainty” --- see Dixit and Pindyck (1994), Bloom (2014), and Bonaime *et al.* (2018), among others. In this regard, Caggiano *et al.* (2017) argue that the real option effect makes firms more careful about hiring and investing, and consumers more cautious about spending, which ultimately leads to a lower real GDP. This “real options” channel is also consistent with Belke *et al.* (2018) who show that when uncertainty increases, firms follow a “wait-and-see attitude” towards investment-type decisions. Thus, higher risk and uncertainty are responsible for the decline in consumption, investment, productivity, and economic activity.

We argued in this section that risk and uncertainty affect leverage through the “risk and uncertainty-real GDP-leverage” channel. The second part of the channel that real GDP can influence leverage is based on the standard economic theory. Lower GDP or income decreases the demand for assets. So, asset prices decline when the economy is bad. A large number of authors report that when security prices go down in bad times, financial institutions contract their balance sheets by selling their securities. This procyclical nature of leverage is widely discussed in Adrian and Shin (2010, 2014) and Adrian *et al.* (2014), among others. So, both economic theory and existing literature suggest that risk and uncertainty affect leverage through the “risk and uncertainty-real GDP-leverage” channel.

### **3. The Data**

The quarterly aggregate leverage series for commercial banks, broker-dealers, and shadow banks are from the Board of Governors of the Federal Reserve System, over the period

from 1985:1 to 2018:4. We follow Adrian and Shin (2011) and define shadow banks as the combination of asset-backed securities issuers, finance companies, and funding corporations.

Following Adrian *et al.* (2014) and Istiak (2019a) we define leverage as

$$\frac{\text{Total financial assets}}{\text{Total financial assets} - \text{Total liabilities}}$$

Adrian *et al.* (2014) argue that this book value measure of leverage works well for both time series and cross-section analyses. To avoid extremely high leverage in some quarters, we follow Serletis and Istiak (2017) and do not include unidentified miscellaneous liabilities to get total liabilities of finance companies. Similarly, to avoid negative leverage in some quarters, we do not include total miscellaneous liabilities to get total liabilities of commercial banks.

Over the same period, we use data for two proxies of risk --- geopolitical risk and Chicago Fed national financial conditions risk --- and four proxies for uncertainty --- macro uncertainty, financial uncertainty, economic policy uncertainty, and equity market related economic uncertainty. We obtain the geopolitical risk index from the website of Matteo Iacoviello. This index reflects automated text-search results of the electronic archives of 11 US and international newspapers. Caldara and Iacoviello (2018) calculate the geopolitical risk index by counting the number of articles related to geopolitical risk in each newspaper as a share of the total number of news articles for each month --- see Caldara and Iacoviello (2018) for a detailed discussion of this index.

We obtain the Chicago Fed national financial conditions risk index from the Federal Reserve Economic Database (FRED) maintained by the Federal Reserve Bank of St. Louis. This index provides a comprehensive update of the financial conditions in debt and equity markets, money markets, and the traditional as well as shadow banking systems of the United States. Positive values of this index indicate that financial conditions are tighter than average whereas negative values indicate that financial conditions are looser than average. We scale up the index by 1 point to get rid of the negative values, so that we can take its logarithmic value and calculate its growth rate.

We obtain the macro uncertainty and financial uncertainty indices from the website of Sydney C. Ludvigson. The construction of these two indices is different from that of other

traditional uncertainty indices. In this respect, Jurado *et al.* (2015) argue that economic decision making is not dependent on whether particular economic indicators have become more or less variable or disperse, rather it depends on whether the economy has become less or more uncertain. The authors construct uncertainty indices for  $h$ -month ahead uncertainty, for  $h = 1, 3$ , and 12. As financial variables, such as leverage, respond very quickly to market events, we only use the values for 1-month ahead uncertainty indices in our paper.

It is to be noted that in constructing the macro uncertainty indices, Jurado *et al.* (2015) use 132 indicators. These include real output and income, employment and hours, manufacturing and trade sales, consumer spending, inventories and inventory sales ratios, housing starts, orders and unfilled orders, compensation and labor costs, capacity utilization measures, bond and stock market indices, price indices, and foreign exchange measures. They also use 148 financial series including valuation ratios, such as the earnings-price ratio and dividend-price ratio, growth rates of aggregate dividends and prices, yields on corporate bonds of different ratings grades, default and term spreads, yields on treasuries, and a broad cross-section of industry equity returns. See the appendix on the website of Sydney C. Ludvigson for a detailed discussion regarding the construction of these indices.

We obtain the economic policy uncertainty series, developed by Baker *et al.* (2016), from the website at <http://www.policyuncertainty.com/>. Baker *et al.* (2016) construct the economic policy uncertainty indices from three components. The first component considers newspaper coverage of policy-related economic uncertainty from major national U.S. newspapers. The second component reflects the number of federal tax code provisions expiring in the next ten years. This reflects the uncertainty about the path the federal tax code will follow in the future. The third component of the index uses divergence among economic forecasters as a proxy for uncertainty. See Baker *et al.* (2016) for a detailed discussion of the U.S. economic policy uncertainty index.

The equity market related economic uncertainty index is obtained from FRED. The index is produced through an analysis of newspaper articles related to the terms uncertainty, the economy, and the stock market. The newspapers from the Access World News of *NewsBank* (<https://www.newsbank.com>) are used to construct the index.

In Online Appendix Figure A1, we plot the leverage series for all three types of financial intermediaries. Online Appendix Figure A2 plots the geopolitical risk index (shaded areas represent NBER recessions). As can be seen in the figure, the geopolitical risk was the highest during the Iraq invasion in September of 2002 and was low during the global financial crisis. The Chicago risk index is shown in Online Appendix Figure A3. The Chicago risk was the highest during the global financial crisis of 2007-2009 and was the lowest during 1992-1993. Online Appendix Figures A4 and A5 plot the macro and financial uncertainty indices, respectively. As can be seen, macroeconomic uncertainty and financial uncertainty were the highest during the global financial crisis. Online Appendix Figure A6 shows the economic policy uncertainty index. Economic policy uncertainty was the highest during the debt ceiling crisis and the corresponding stock market crash in 2011. Equity uncertainty is shown in Online Appendix Figure A7, which indicates that equity uncertainty was the highest during the stock market crash followed by the Black Monday of 1987.

We also obtain quarterly data on real GDP, the GDP deflator, the S&P 500 index, and the federal funds rate from FRED, over the same period, from 1985:1 to 2018:4. We conduct unit root (Augmented Dickey-Fuller (ADF)) test and stationarity (Kwiatkowski–Phillips–Schmidt–Shin (KPSS)) test for all the variables used in this paper, both in logged levels and first logged differences. We conclude that the variables in log levels are all nonstationary. However, when they are first differenced, we find that the variables are all stationary. Online Appendix Table A1 presents the summary statistics of all the leverage and risk/uncertainty indicators.

#### 4. The Forecasting Model

We start by exploring the roles of risk and uncertainty indicators as potential predictors of each of the components of real GDP. We use the model of Caldara *et al.* (2016) and estimate the following forecasting regression

$$\Delta_h Y_{t+h} = \rho + \beta_1 \sigma_t + \beta_2 SPREAD_t + \sum_{i=1}^h \psi_i \Delta Y_{t-i} + u_{t+h} \quad (1)$$

where  $Y_t$  denotes a GDP component,  $\Delta_h Y_{t+h} = \frac{400}{h+1} \ln \left( \frac{Y_{t+h}}{Y_{t-1}} \right)$ ,  $h \geq 0$  is the forecast horizon,  $\sigma$  represents a risk and uncertainty indicator,  $SPREAD$  is the difference between the 10-year-treasury-rate and the 3-month-treasury-rate (this spread is a widely used indicator to study the yield curve), and  $u$  is the forecast error. The  $SPREAD$  variable is used as a control variable to

examine the marginal contribution of risk and uncertainty indicators to predict each of the components of real GDP. We obtain the risk and uncertainty variables from the sources mentioned in the Data section, and the rest of the series are from the FRED website.

We estimate the forecasting model (1) using the OLS method. The results, for forecast horizons of 1 quarter ( $h=1$ ) and 2 quarters ( $h=2$ ), are shown in Tables 1-4. Table 1 shows that all of the risk and uncertainty indicators, except for equity uncertainty, significantly reduce the consumption of durable goods and services. We see that geopolitical risk, Chicago risk, and equity uncertainty do not significantly reduce the consumption of nondurable goods and services. Table 2 shows that all the risk and uncertainty indicators, except for equity uncertainty, significantly reduce business fixed investment and inventories. We also find that all of the risk and uncertainty indicators, except for economic policy uncertainty and equity uncertainty, have a significantly negative impact on private residential fixed investment. In Table 3 we find that except for economic policy uncertainty, all other risk and uncertainty indicators do not have any significant negative impact on federal expenditures. We also find that none of the risk and uncertainty indicators have any significant negative impact on state & local expenditures. Finally, as can be seen in Table 4, all of the risk and uncertainty indicators, except for Chicago risk and equity uncertainty, have significant negative effects on exports. Moreover, we find that all risk and uncertainty indicators, except for equity uncertainty, have significant negative effects on imports. In general, our results indicate that consumption of durable goods and services, business fixed investment and inventories, private residential fixed investment, and exports and imports are highly reactive to risk and uncertainty.

Next, we investigate which of these risk/uncertainty indicators is the most influential. Tables 1, 2, and 4 indicate that macroeconomic uncertainty, financial uncertainty, and economic policy uncertainty have a significant negative impact on the consumption of durable and nondurable goods and services, business fixed investment and inventories, and net exports. In this regard, consumption of durable and nondurable goods and services, business fixed investment and inventories, and net exports accounted for 68%, 17.7%, and -3.3% of real GDP, respectively, in the fourth quarter of 2018. This suggests that macroeconomic uncertainty, financial uncertainty, and economic policy uncertainty, as a whole, have the largest impact on

the United States. Table 3 also shows that among these three uncertainty indicators, only economic policy uncertainty has a significant negative impact on federal expenditures.

## 5. Granger Causality Tests

Next, we use the Toda and Yamamoto (1995) Granger causality test to investigate the causal relationship between each of the risk and uncertainty measures and the leverage of each of the three financial intermediaries --- commercial banks, broker-dealers, and shadow banks. Toda and Yamamoto (1995) propose an augmented version of the Granger (1969) causality test that includes extra lags of the dependent variables. Although the Granger-causality test is a standard test for causality between variables, the results from this test may suffer from specification bias and spurious regression. Toda and Yamamoto's causality test is superior and less restrictive than the Granger causality test, because it can be applied to a group of variables with different orders of integration. See Asai and Shiba (1995) for a detailed discussion about the Toda and Yamamoto (1995) Granger causality test.

We carry out Toda and Yamamoto causality tests, with the variables in levels, in the context of the following regression equation

$$X_t = B_0 + \sum_{j=1}^m B_j X_{t-j} + \sum_{n=m+1}^{m+d_{max}} C_n X_{t-n} + e_t \quad (2)$$

where  $X_t = (\ln y_t, \ln p_t, \ln u_t, \ln l_t, \ln s_t, i_t)'$ , including the log of real GDP, log of GDP deflator, log of the respective risk/uncertainty index, log of the respective financial intermediary leverage, log of S&P 500 index, and the level of the federal funds rate, respectively.

We use the Schwarz information criterion (SIC) to determine the lag length  $m$ . The  $C$  matrix is associated with  $n$  extra lags of the variables. The parameter  $d_{max}$  indicates the maximum order of integration of the variables (here  $d_{max} = 1$ ) used in the model. The Toda and Yamamoto test essentially tests the null hypothesis of non-causality between the variables. To investigate the robustness of the results, we also use a bivariate model that includes leverage and risk/uncertainty indicators only; that is,  $X_t = (\ln u_t, \ln l_t)'$ . The causality test results, for both the six- and two-variable models, are shown in Tables 5-7.

In Table 5, we test for causality between each of the risk/uncertainty measures and commercial bank leverage. As can be seen, there is evidence of causality from financial uncertainty, economic policy uncertainty, and equity market uncertainty to commercial bank leverage with both the six- and two-variable models. We also find causality from the Chicago risk index to commercial bank leverage for the six-variable model. Finally, there is evidence of unidirectional causality from commercial bank leverage to macroeconomic uncertainty for the six-variable model.

Table 6 indicates evidence of unidirectional causality from macro uncertainty and financial uncertainty to broker-dealer leverage with both models. The table also shows unidirectional causality from economic policy uncertainty to broker-dealer leverage for the two-variable model. There is no evidence of causality from broker-dealer leverage to any of the risk and uncertainty measures.

Finally, in Table 7 we find bidirectional causality between financial uncertainty and shadow bank leverage as well as unidirectional causality from equity market uncertainty to shadow bank leverage (with the bivariate model only).

In general, we find that mostly the uncertainty indicators Granger-cause leverage, but not the other way around.

## 6. The Structural VAR Model

In choosing the variables in the VAR, we consider a set of variables for the U.S. economy with the specific ordering shown by the  $6 \times 1$  vector  $z_t = (u_t, y_t, \pi_t, l_t, s_t, i_t)'$ . In particular,  $u_t$  is the quarterly change in the log of the respective risk and uncertainty index,  $y_t$  is the quarterly change in the log of real GDP,  $\pi_t$  is the annual change in the log of the GDP deflator,  $l_t$  is the quarterly change in the log of the respective leverage series,  $s_t$  is the quarterly change in the log of the S&P 500 index, and  $i_t$  is the level of the federal funds rate.

The “risk and uncertainty-real GDP-leverage” channel discussed in section 2 is used to determine the ordering of the variables in  $z_t$  vector in the VAR model. The channel indicates that fluctuations in risk and uncertainty indicators are originated from forces that are external to the economy. So, the risk and uncertainty variables are positioned in the first place of  $z_t$  in the VAR

model. This ordering is consistent with Baker *et al.* (2016), Caggiano *et al.* (2017), Istiak and Alam (2020), and Alam and Istiak (2020), who place the risk and uncertainty variables at the first place of the ordering in the VAR. After placing risk/uncertainty as the first variable, the rest of the variables of  $z_t$  are ordered according to the data-generating process found in Bjørnland and Leitmo (2009) and Istiak and Serletis (2017). The orderings of variables in the “risk and uncertainty-real GDP-leverage” channel and those in the  $z_t$  vector of the VAR model are consistent, because in both cases risk/uncertainty is followed by real GDP, which is again followed by leverage.

We use six variables in the model, because as Kilian (2013) argues, with a typical sample size, standard VAR models cannot deal with more than six variables. He also argues that adding more variables creates overfitting problems and thus weakens the credibility of the VAR model.

The Akaike information criterion (AIC) suggests two lags in the VAR model. Moreover, the Lagrange multiplier test for autocorrelation shows that the VAR is free from serial correlation. The VAR also satisfies the stability condition.

The VAR model is as follows

$$Bz_t = \Gamma_0 + \sum_{j=1}^2 \Gamma_j z_{t-j} + \varepsilon_t \quad (3)$$

where  $B$  is the contemporaneous coefficient matrix,  $\Gamma_j$ ,  $j = 1, 2$ , are  $6 \times 6$  parameter matrices,  $\Gamma_0$  is a  $6 \times 1$  parameter vector, and  $\varepsilon_t$  is a  $6 \times 1$  vector of mean zero serially uncorrelated innovations (or shocks),  $\varepsilon_t = (\varepsilon_t^\mu, \varepsilon_t^\nu, \varepsilon_t^\pi, \varepsilon_t^l, \varepsilon_t^s, \varepsilon_t^i)'$ .

For the structural identification of the VAR, we assume that the conditional covariance matrix  $\Sigma_\varepsilon$  is diagonal. We assume that the diagonal elements of  $B^{-1}$  are equal to 1, and also use the recursive identification method in the structural VAR model. We also investigate robustness to alternative orderings of the variables in the VAR model. The results remain robust with other orderings and are available on request. With all these restrictions, the  $B^{-1}$  matrix can be written as

$$B^{-1} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & 1 \end{pmatrix}$$

The zero restrictions in the first row of the  $\mathbf{B}^{-1}$  matrix imply that risk/uncertainty is the most exogenous variable in the structural VAR indicating that real output, inflation, leverage, stock prices, and the federal funds rate do not have contemporaneous effects on risk/uncertainty, but only affect it with a lag. The zero restrictions from the second row to the last row on  $\mathbf{B}^{-1}$  follow the standard monetary VAR literature indicating that macroeconomic variables do not simultaneously react to policy variables, but policy variables simultaneously react to the macroeconomic environment. See Christiano *et al.* (1999, 2005), Bjørnland and Leitemo (2009), and Istiak and Serletis (2017). The zero restrictions in the second row indicate that real GDP simultaneously reacts to risk/uncertainty only. The nonzero elements of the third row of the matrix imply that risk/uncertainty and real GDP have a contemporaneous effect on inflation, but leverage, stock prices, and the interest rate have a lagged effect on these indices. The zero elements of the fourth row indicate that only the S&P 500 index and the interest rate have a lagged effect on leverage. The zero element of the fifth row indicates that only the interest rate has a lagged effect on the stock market. All the nonzero elements of the sixth row imply that all variables have a simultaneous effect on the interest rate. With the imposition of these zero identifying restrictions, there is exact identification in the VAR.

We use six variables in our structural VAR, which is consistent with other influential papers in the VAR literature dealing with uncertainty --- see, for example, Nodari (2014). We do not add more variables in the VAR model to avoid the degree of freedom problems. A VAR includes any missing effect of the missing variables (if any) through the lags of the dependent variables. As we have included sufficient variables (with two lags) to examine the impact of risk and uncertainty on leverage, we posit that our SVAR is not suffering from any potential bias. Moreover, the structure of the SVAR model makes the risk and uncertainty shocks purely orthogonal and structural. So, the impact of the risk and uncertainty shocks on leverage is different from the impact due to other financial market synchronization.

We estimate the model 18 times, one for each combination of risk/uncertainty measures and financial intermediary leverage. Figures 1-18 show the impulse responses of real GDP, inflation, leverage, the S&P 500 index, and the interest rate to the different risk and uncertainty shocks. In particular, Figures 1-6 investigate the relationship with commercial bank leverage, Figures 7-12 that with broker-dealer leverage, and Figures 13-18 the relation with shadow bank

leverage. The shocks are normalized in the first quarter and the responses are graphed with probability bands represented as 0.16 and 0.84 fractiles (equivalent to a 90% confidence interval). The probability bands are computed using the Monte Carlo method described in Doan (2004).

Figure 1 shows that an unexpected increase in geopolitical risk has a significant positive impact on the commercial bank leverage and a significant negative impact on the interest rate and real GDP. Figures 2-6 show that an unexpected increase in all risk and uncertainty measures has a statistically significant and negative impact on all the variables except for the leverage of commercial banks. The leverage of commercial banks rises when geopolitical risk, macroeconomic uncertainty, economic policy uncertainty, and equity uncertainty increase. Commercial bank leverage does not respond to Chicago risk and financial uncertainty shocks.

Figure 7 shows that an unexpected increase in geopolitical risk does not have a significant impact on all the variables except for the interest rate and real GDP. In general, Figures 8-12 show that an unexpected increase in all risk and uncertainty measures has a significantly negative impact on all the variables including the leverage of broker-dealers. Our result is consistent with Mallick *et al.* (2017) who find that a positive shock in the VIX index, or an increase in global risk aversion, has a sizeable negative effect on broker-dealer leverage.

Figure 13 shows that an unexpected increase in geopolitical risk does not have a significant impact on the variables except for the interest rate and real GDP. In general, Figures 14-18 show that an unexpected increase in all risk and uncertainty measures has a significantly negative impact on all the variables including the leverage of shadow banks.

It can be noted that the results from the Granger causality tests (as found in section 5) and those from the impulse response analysis from the VAR model are not always similar. For example, Tables 6 and 7 show that Chicago risk does not Granger cause broker-dealer and shadow bank leverage, respectively. However, Figures 8 and 14 show that Chicago risk has a significant negative effect on broker-dealer and shadow bank leverage, respectively. In fact, Granger causality does not indicate actual economic causality, rather it indicates predictability. Granger causality analyzes only the flow of information between two-time series. The Granger causal relationships do not depend on structural economic relations. The Granger causality based

outcomes do not depend on the order of the variables of the structural VAR. On the other hand, in a structural VAR, we impose a particular causal chain rather than learning about causal relationships from the data --- see Kilian (2013). The causal chain among the variables of the structural VAR model is not based on Granger causality, rather it is based on institutional knowledge and economic theory with minimum assumptions. Though the Granger causality based causal relationships from risk/uncertainty to leverage are interesting to consider, the impulse responses from the structural VAR model represent the actual responses of leverage resulting from an unexpected change in risk and uncertainty.

In addition to the impulse responses, we also use a variance-decomposition analysis to quantify the ability of the key variables in explaining the variation of leverage over time. To save space, we only show the results for financial uncertainty and broker-dealer leverage. We select the model with financial uncertainty and broker-dealer leverage, because the relation between financial market activities and broker-dealer leverage has attracted a great deal of attention in the recent literature --- see, for example, Adrian *et al.* (2014), Istiak and Serletis (2017), and Serletis and Istiak (2018), among others.

The results are shown in Table 8. The table shows that after the first quarter, 0.96% and 0.006% variation in broker-dealer leverage can be explained by financial uncertainty and real GDP, respectively. However, the contribution of financial uncertainty and real GDP increases overtime to explain the variation of broker-dealer leverage. After the tenth quarter, 9.4% and 6.14% variation in broker-dealer leverage can be explained by financial uncertainty and real GDP, respectively. So, uncertainty is an important factor in our model in explaining the variation of leverage. The results for other measures of risk/uncertainty and leverage can be interpreted similarly. The results are not reported here, but are available on request.

## **7. Robustness**

The global financial crisis officially ended in June 2009, but it has reshaped the attitudes of financial institutions to risk and uncertainty. The leverage and other financial decisions nowadays are far more sensitive to risk and uncertainty compared to the pre-crisis period. This is

evident from the Taper Tantrum in 2013 when the financial market reacted massively responding to the Fed's announcement of future tapering of its policy of quantitative easing.

To check whether the deleveraging of highly sensitive financial institutions during the post-financial crisis period affects the results of the VAR model, we re-run the model with the data over the pre-financial crisis period. Qualitatively, we obtain similar impulse responses as those in Figures 1-18. This indicates that our findings in the previous section remain valid also for the pre-financial crisis period, suggesting that our evidence is robust across sample periods. The impulse responses of the VAR model over the pre-financial crisis period are not presented here for brevity, but are available upon request.

## **8. Analysis and Policy Implications**

The impulse responses from the VAR model indicate that the risk and uncertainty measures have mixed effects on the leverage decisions of commercial banks; either commercial bank leverage rises or does not respond following risk and uncertainty shocks. There are three reasons why commercial bank leverage rises when geopolitical risk, macroeconomic uncertainty, economic policy uncertainty, and equity uncertainty increase.

First, higher risk/uncertainty is associated with higher unemployment --- see, for example, Caggiano *et al.* (2017). In this regard, when the risk/uncertainty is high, tax revenue usually declines. In order to continue the ongoing federal, state, and local government projects (the government usually uses expansionary fiscal policy by increasing federal and state spending when the risk/uncertainty is high), the government borrows from commercial banks and other organizations by issuing treasury securities. Higher risk/uncertainty reduces bank borrowing via a reduction in consumption and investment, but this effect may be offset by higher federal and state borrowing under risk/uncertainty. Thus, on the whole, the leverage and assets of commercial banks may rise when geopolitical risk, macroeconomic uncertainty, economic policy uncertainty, and equity uncertainty rise.

Second, the impulse response functions show that when geopolitical risk, macroeconomic uncertainty, economic policy uncertainty, and equity uncertainty rise, the federal funds rate declines, suggesting that borrowing from commercial banks becomes cheaper. The cheaper loans

lead to an increase in assets and leverage when geopolitical risk, macroeconomic uncertainty, economic policy uncertainty, and equity uncertainty rise. Our argument is consistent with Froyen and Guender (2019) who argue that under an easy monetary policy, banks make more loans and increase leverage.

Third, commercial banks follow a client-based business and their activities are less vulnerable to risk and uncertainty. When a commercial bank makes a loan contract, the bank continues channeling the loan to the clients irrespective of economic conditions (Istiak and Serletis, 2016). Because of such contracts, if banks make new loans during the crisis periods, their assets and leverage may go up during a bad time (for example, when geopolitical risk, macroeconomic uncertainty, economic policy uncertainty, and equity uncertainty rise). If banks just serve previous contracts, but do not make new loan contracts, their assets and leverage may remain unchanged during a bad time (as, for example, when Chicago risk and financial uncertainty rise).

Unlike traditional banks, broker-dealers and shadow banks are not constrained by relationship-based lending. They collect funds from the money market and provide loans to borrowers. Their balance sheets are fully marked to market and recent research shows that the leverage of broker-dealers and shadow banks is procyclical --- see, for example, Adrian and Shin (2010, 2011, 2014), Adrian *et al.* (2014), Serletis *et al.* (2013), Istiak and Serletis (2017), and Istiak (2019b), among others. Their risky asset portfolios expand during good times and contract during recessions, suggesting that the leverage of broker-dealers and shadow banks can better reflect the financial conditions and health of the economy.

The impulse responses from the VAR model indicate that, except for geopolitical risk, other risk and uncertainty measures have a significant negative impact on the leverage of broker-dealers and shadow banks and most other variables. When risk and uncertainty increase, aggregate demand declines, leading to a fall in real GDP and inflation. The decline in the level of economic activity leads to a decline in stock prices, and inflation-targeting central banks reduce policy rates to stimulate the economy. Broker-dealers and shadow banks fund their assets with collateralized debt with a very short maturity. When risk/uncertainty increases, the prices of their assets (which act as collateral) decline. Because of a shortage of collateral, broker-dealers and shadow banks cannot roll over their lending and start to deleverage.

In general, we find that the uncertainty indicators can better explain the leverage cycle than the risk indicators. This result is consistent with Bloom (2014), who argues that uncertainty is a mixture of risk and uncertainty, making uncertainty a comparatively stronger factor to affect financial decisions, such as leverage. Our result is also consistent with Turlakov (2017), who finds that uncertainty determines absolute leverage and risk determines relative leverage, with absolute leverage depending on the investor's available capital and relative leverage depending on the relative allocation between different assets (or trading strategies) within the investor's portfolio. Our results also support Osband (2011) who argues that uncertainty plays a central role in finance and markets.

Our results have important policy suggestions for the stakeholders. First, the Toda-Yamamoto causality test and the impulse response functions show that geopolitical risk has no impact on the leverage of broker-dealers and shadow banks. Caldara and Iacoviello (2018, p. 2) define geopolitical risk “as the risk associated with wars, terrorist acts, and tensions between states that affect the normal and peaceful course of international relations.” As the index is influenced by mostly social and international factors compared to domestic economic factors, the geopolitical risk does not affect leverage of market-based financial institutions, inflation, and the S&P 500 in our VAR model. Thus, our results suggest that geopolitical risk may not be a major factor in understanding the deleveraging of financial institutions in the United States.

Second, the impulse response functions show that higher uncertainty leads to lower stock prices (thus supporting Zhang *et al.*, 2019; and Li and Peng, 2017) and lower leverage of broker-dealers and shadow banks. Given that there exists a feedback effect on asset prices from the leverage of financial intermediaries [see Fostel and Geanakoplos (2014), Adrian and Shin (2010), and Serletis and Istiak (2017), among others], lower leverage may lead to a further fall in the stock market. Our findings support Brunnermeier and Pedersen (2009) who argue that the subprime losses in 2007-2008 were several hundred billion dollars, which was only about 5% of overall stock market capitalization. As highly leveraged financial institutions owned these assets, spiral effects multiplied the losses and made the crisis worse. As a consequence, the overall stock market losses amounted to more than 8 trillion dollars by 2009. This suggests that policymakers should be adopting macroprudential policies during high risk and uncertainty periods to smooth the leverage cycle before the burden of deleveraging gets unbearable.

Third, the impulse responses from the VAR model indicate that the Fed adopts an easy monetary policy by lowering interest rates in the wake of high risk and uncertainty. Traditional monetary economic theory indicates that lower interest rates should boost up asset prices and also the leverage of market-based financial intermediaries (as leverage is procyclical for those institutions). But, in contrast with the theory, the impulse responses of our VAR model show that the leverage of broker-dealers and shadow banks and interest rates decline when uncertainty rises in the economy. Our result is consistent with Nelson *et al.* (2018), who find that easy monetary policy contributed little to the balance sheet expansion of U.S. financial intermediaries since 2001. The authors mention that because of the complex financial innovations of the modern era, financial institutions cannot always take advantage of easy monetary policy. In this regard, Bernanke (2009) argues that increased complexity in subprime mortgage loans, credit default swaps, and structured investment vehicles have made it difficult to expand loans even under a low-interest-rate environment. We propose that financial innovations should be sufficiently transparent and understandable during periods of high risk and uncertainty. This will reduce the chance of financial intermediary deleveraging.

Finally, we propose that the Fed should continue with its forward guidance as part of its unconventional monetary policy tools in the near future. Recent risky and uncertain events (for example- the trade war with China, uncertainty regarding the workings of USMCA agreement, the current impasse of Brexit, slow progress of the EU countries, political conflict between the United States and North Korea, Iran, and Venezuela, and the recent COVID-19 pandemic) may lead to slower growth of the American (and world) economy. We suggest that maintaining a low-interest-rate environment may not be enough to protect the economy. The Fed's forward guidance policy will help anchor inflationary expectations and thus ensure lower longer-term yields, but unconventional policies are needed to ease financial conditions and prevent deleveraging during periods of high-risk and uncertainty.

## **9. Conclusion**

Most of the literature follows a theoretical framework to explore the relationship between risk/uncertainty and leverage. There are few empirical studies in this field, using only one or two risk/uncertainty indicators to explore the risk/uncertainty-leverage relationship. We fill the gap in

the literature by using a structural VAR model to investigate the relationship. We explore how different risk and uncertainty indices (geopolitical risk, Chicago risk, macroeconomic uncertainty, financial uncertainty, economic policy uncertainty, and equity uncertainty) affect the leverage decisions of financial intermediaries (commercial banks, broker-dealers, and shadow banks). To the best of our knowledge, this is one of the few empirical studies that explores this issue in a comprehensive framework.

We follow a step-by-step approach to investigate the relationship of risk and uncertainty with leverage. We postulate that the connection of risk and uncertainty with leverage works through the “risk and uncertainty-real GDP-leverage” channel.

Using a forecasting model, we find that higher risk and uncertainty reduces real GDP by influencing consumption, investment, export, and import. Granger causality tests indicate that the risk indicators do not Granger-cause the leverage of financial intermediaries, but almost all the uncertainty measures do. Thus, uncertainty indicators can be used to predict financial intermediary leverage. The impulse responses of the structural VAR model show that positive shocks in all of the risk and uncertainty indicators depress real GDP, inflation, and the stock market. As real GDP and asset prices decline, the total assets of broker-dealers and shadow banks fall and these market-based intermediaries reduce their leverage. We find that, except for geopolitical risk, all the risk and uncertainty measures can explain the dynamic behavior of the leverage of broker-dealers and shadow banks. As commercial banks maintain a relationship-based business, their activities are not fully dependent on market conditions, and their leverage either rises or does not respond to risk and uncertainty measures.

As geopolitical risks do not influence leverage, we conclude that domestic economic and financial factors are more responsible compared to international factors (such as, for example, wars, terrorist attacks, and migration issues in other countries) in the leverage decisions of U.S. financial institutions. Given the systemic nature of financial markets, deleveraging may easily create panic in other sectors. We advocate for macroprudential policies, transparent financial innovations, and forward guidance to prevent massive deleveraging during times of high risk and uncertainty.

The current paper contributes to the literature by empirically investigating the relationship of different risk and uncertainty indicators with the leverage decisions of commercial banks, broker-dealers, and shadow banks in a dynamic macroeconomic framework. Exploring for spillovers and interactions among the uncertainty indicators and their impact on leverage is an area for productive future research.

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Table 1. Coefficient estimates of risk and uncertainty in forecasting different components of consumption expenditure

| Coefficient                                                                   | Geopolitical | Chicago  | Macro     | Financial | Economic policy | Equity |
|-------------------------------------------------------------------------------|--------------|----------|-----------|-----------|-----------------|--------|
| <i>Consumption of durable goods &amp; services with 1-quarter horizon</i>     |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                                 | -0.013*      | -2.384** | -26.383** | -4.482*   | -0.024*         | 0.003  |
| Adj. $R^2$                                                                    | 0.421        | 0.443    | 0.494     | 0.422     | 0.419           | 0.409  |
| $\sigma_t$ when $\beta_2 \neq 0$                                              | -0.014*      | -2.445** | -26.614** | -4.689*   | -0.033**        | 0.003  |
| Adj. $R^2$                                                                    | 0.433        | 0.446    | 0.493     | 0.420     | 0.423           | 0.406  |
| <i>Consumption of durable goods &amp; services with 2-quarters horizon</i>    |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                                 | -0.014**     | -1.191   | -20.546** | -2.185    | -0.016          | 0.007* |
| Adj. $R^2$                                                                    | 0.594        | 0.587    | 0.635     | 0.573     | 0.586           | 0.589  |
| $\sigma_t$ when $\beta_2 \neq 0$                                              | -0.015**     | -1.209*  | -20.571** | -2.286    | -0.022*         | 0.007* |
| Adj. $R^2$                                                                    | 0.593        | 0.575    | 0.633     | 0.571     | 0.578           | 0.589  |
| <i>Consumption of nondurable goods &amp; services with 1-quarter horizon</i>  |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                                 | -0.006       | -0.756   | -11.333** | -2.957**  | -0.028**        | -0.001 |
| Adj. $R^2$                                                                    | 0.494        | 0.495    | 0.541     | 0.505     | 0.533           | 0.487  |
| $\sigma_t$ when $\beta_2 \neq 0$                                              | -0.005       | -0.716   | -11.186** | -2.797**  | -0.028**        | 0.001  |
| Adj. $R^2$                                                                    | 0.497        | 0.499    | 0.544     | 0.507     | 0.529           | 0.491  |
| <i>Consumption of nondurable goods &amp; services with 2-quarters horizon</i> |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                                 | -0.006*      | -0.277   | -8.817**  | -1.933*   | -0.023**        | 0.002  |
| Adj. $R^2$                                                                    | 0.570        | 0.559    | 0.605     | 0.569     | 0.604           | 0.560  |
| $\sigma_t$ when $\beta_2 \neq 0$                                              | -0.005       | -0.235   | -8.640**  | -1.731*   | -0.021**        | 0.002  |
| Adj. $R^2$                                                                    | 0.579        | 0.572    | 0.616     | 0.579     | 0.603           | 0.574  |

Notes: \*\* and \* indicate significance at the 5% and 10% level, respectively. The model is  $\Delta_h Y_{t+h} = \rho + \beta_1 \sigma_t + \beta_2 SPREAD_t + \sum_{i=1}^h \psi_i \Delta Y_{t-i} + u_{t+h}$ .

$\beta_2 = 0$  indicates the reduced model:  $\Delta_h Y_{t+h} = \rho + \beta_1 \sigma_t + \sum_{i=1}^h \psi_i \Delta Y_{t-i} + u_{t+h}$ .  $\sigma_t$  stands for the risk and uncertainty indicators.

Table 2. Coefficient estimates of risk and uncertainty in forecasting different components of investment expenditure

| Coefficient                                                                | Geopolitical | Chicago  | Macro     | Financial | Economic policy | Equity |
|----------------------------------------------------------------------------|--------------|----------|-----------|-----------|-----------------|--------|
| <i>Business fixed investment &amp; inventories with 1-quarter horizon</i>  |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                              | -0.029**     | -3.755** | -40.033** | -10.557** | -0.056**        | -0.001 |
| Adj. $R^2$                                                                 | 0.614        | 0.617    | 0.662     | 0.619     | 0.615           | 0.593  |
| $\sigma_t$ when $\beta_2 \neq 0$                                           | -0.031**     | -3.819** | -40.065** | -10.916** | -0.077**        | -0.001 |
| Adj. $R^2$                                                                 | 0.617        | 0.618    | 0.663     | 0.621     | 0.629           | 0.594  |
| <i>Business fixed investment &amp; inventories with 2-quarters horizon</i> |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                              | -0.024**     | -2.162** | -30.374** | -7.466**  | -0.045**        | 0.002  |
| Adj. $R^2$                                                                 | 0.749        | 0.740    | 0.780     | 0.747     | 0.749           | 0.730  |
| $\sigma_t$ when $\beta_2 \neq 0$                                           | -0.025**     | -2.183** | -30.185** | -7.673**  | -0.062**        | 0.001  |
| Adj. $R^2$                                                                 | 0.753        | 0.742    | 0.781     | 0.749     | 0.761           | 0.731  |
| <i>Private residential fixed investment with 1-quarter horizon</i>         |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                              | -0.021**     | -4.573** | -35.245** | -7.593**  | -0.009          | 0.002  |
| Adj. $R^2$                                                                 | 0.786        | 0.800    | 0.813     | 0.788     | 0.779           | 0.778  |
| $\sigma_t$ when $\beta_2 \neq 0$                                           | -0.023**     | -5.094** | -37.673** | -8.490**  | -0.024          | 0.001  |
| Adj. $R^2$                                                                 | 0.789        | 0.805    | 0.819     | 0.792     | 0.782           | 0.780  |
| <i>Private residential fixed investment with 2-quarters horizon</i>        |              |          |           |           |                 |        |
| $\sigma_t$ when $\beta_2 = 0$                                              | -0.020**     | -3.360** | -29.883** | -5.574**  | -0.005          | 0.003  |
| Adj. $R^2$                                                                 | 0.845        | 0.849    | 0.863     | 0.842     | 0.837           | 0.837  |
| $\sigma_t$ when $\beta_2 \neq 0$                                           | -0.022**     | -3.710** | -31.528** | -6.211**  | -0.017          | 0.002  |
| Adj. $R^2$                                                                 | 0.847        | 0.852    | 0.867     | 0.844     | 0.839           | 0.838  |

Note: See Notes to Table 1.

Table 3. Coefficient estimates of risk and uncertainty in forecasting different components of government expenditure

| Coefficient                                                             | Geopolitical | Chicago | Macro | Financial | Economic policy | Equity  |
|-------------------------------------------------------------------------|--------------|---------|-------|-----------|-----------------|---------|
| <i>Federal government expenditure with 1-quarter horizon</i>            |              |         |       |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                           | -0.003       | 0.885   | 4.086 | 0.470     | -0.019*         | 0.005   |
| Adj. $R^2$                                                              | 0.366        | 0.373   | 0.369 | 0.364     | 0.381           | 0.370   |
| $\sigma_t$ when $\beta_2 \neq 0$                                        | -0.004       | 0.869   | 4.024 | 0.401     | -0.026**        | 0.004   |
| Adj. $R^2$                                                              | 0.363        | 0.369   | 0.365 | 0.360     | 0.385           | 0.366   |
| <i>Federal government expenditure with 2-quarters horizon</i>           |              |         |       |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                           | -0.003       | 0.862*  | 4.327 | 0.712     | -0.015**        | 0.006** |
| Adj. $R^2$                                                              | 0.424        | 0.435   | 0.429 | 0.421     | 0.438           | 0.440   |
| $\sigma_t$ when $\beta_2 \neq 0$                                        | -0.004       | 0.850*  | 4.299 | 0.658     | -0.020**        | 0.006** |
| Adj. $R^2$                                                              | 0.421        | 0.431   | 0.426 | 0.417     | 0.443           | 0.435   |
| <i>State &amp; local government expenditure with 1-quarter horizon</i>  |              |         |       |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                           | -0.001       | 1.319   | 6.202 | 0.564     | -0.018          | 0.008   |
| Adj. $R^2$                                                              | 0.083        | 0.092   | 0.089 | 0.083     | 0.090           | 0.092   |
| $\sigma_t$ when $\beta_2 \neq 0$                                        | 0.001        | 1.418   | 6.593 | 0.891     | -0.014          | 0.009   |
| Adj. $R^2$                                                              | 0.082        | 0.093   | 0.088 | 0.082     | 0.085           | 0.093   |
| <i>State &amp; local government expenditure with 2-quarters horizon</i> |              |         |       |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                           | -0.005       | 1.334*  | 1.584 | 0.472     | -0.018          | 0.010*  |
| Adj. $R^2$                                                              | 0.370        | 0.380   | 0.367 | 0.367     | 0.375           | 0.384   |
| $\sigma_t$ when $\beta_2 \neq 0$                                        | -0.005       | 1.388*  | 1.776 | 0.645     | -0.017          | 0.011*  |
| Adj. $R^2$                                                              | 0.366        | 0.378   | 0.365 | 0.364     | 0.371           | 0.383   |

Note: See Notes to Table 1.

Table 4. Coefficient estimates of risk and uncertainty in forecasting exports and imports

| Coefficient                                                   | Geopolitical | Chicago  | Macro     | Financial | Economic policy | Equity  |
|---------------------------------------------------------------|--------------|----------|-----------|-----------|-----------------|---------|
| <i>Export of goods &amp; services with 1-quarter horizon</i>  |              |          |           |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                 | -0.027**     | 0.324    | -25.777** | -6.766**  | -0.060**        | 0.007   |
| Adj. $R^2$                                                    | 0.610        | 0.586    | 0.628     | 0.600     | 0.620           | 0.588   |
| $\sigma_t$ when $\beta_2 \neq 0$                              | -0.027**     | 0.330    | -25.799** | -6.809**  | -0.072**        | 0.007   |
| Adj. $R^2$                                                    | 0.607        | 0.583    | 0.626     | 0.597     | 0.623           | 0.585   |
| <i>Export of goods &amp; services with 2-quarters horizon</i> |              |          |           |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                 | -0.025**     | 1.194    | -21.321** | -5.502**  | -0.050**        | 0.015** |
| Adj. $R^2$                                                    | 0.671        | 0.647    | 0.681     | 0.655     | 0.672           | 0.659   |
| $\sigma_t$ when $\beta_2 \neq 0$                              | -0.025**     | 1.243    | -21.215** | -5.409**  | -0.056**        | 0.016** |
| Adj. $R^2$                                                    | 0.669        | 0.646    | 0.678     | 0.653     | 0.672           | 0.659   |
| <i>Import of goods &amp; services with 1-quarter horizon</i>  |              |          |           |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                 | -0.022**     | -2.309** | -32.955** | -6.196**  | -0.062**        | 0.001   |
| Adj. $R^2$                                                    | 0.712        | 0.709    | 0.750     | 0.709     | 0.726           | 0.700   |
| $\sigma_t$ when $\beta_2 \neq 0$                              | -0.023**     | -2.387** | -33.239** | -6.524**  | -0.082**        | 0.000   |
| Adj. $R^2$                                                    | 0.712        | 0.709    | 0.751     | 0.709     | 0.738           | 0.699   |
| <i>Import of goods &amp; services with 2-quarters horizon</i> |              |          |           |           |                 |         |
| $\sigma_t$ when $\beta_2 = 0$                                 | -0.021**     | -1.040   | -26.250** | -3.879*   | -0.050**        | 0.008   |
| Adj. $R^2$                                                    | 0.784        | 0.772    | 0.812     | 0.775     | 0.793           | 0.774   |
| $\sigma_t$ when $\beta_2 \neq 0$                              | -0.021**     | -1.048   | -26.316** | -3.937*   | -0.061**        | 0.008   |
| Adj. $R^2$                                                    | 0.783        | 0.771    | 0.811     | 0.773     | 0.796           | 0.772   |

Note: See Notes to Table 1.

Table 5. *p*-values of causality tests for risk/uncertainty measures and commercial bank leverage

| <i>Null hypothesis</i>                            | <i>Six-variable model</i> | <i>Bivariate model</i> | <i>Finding</i>                                                          |
|---------------------------------------------------|---------------------------|------------------------|-------------------------------------------------------------------------|
| Geopolitical risk $\nRightarrow$ Leverage         | 0.951                     | 0.752                  | Geopolitical risk does not Granger cause leverage                       |
| Chicago risk index $\nRightarrow$ Leverage        | 0.056*                    | 0.870                  | <b>Chicago risk index Granger causes leverage in six-variable model</b> |
| Macro uncertainty $\nRightarrow$ Leverage         | 0.349                     | 0.473                  | Macro uncertainty does not Granger cause leverage                       |
| Financial uncertainty $\nRightarrow$ Leverage     | 0.010*                    | 0.006*                 | <b>Financial uncertainty Granger causes leverage in both models</b>     |
| Econ policy uncertainty $\nRightarrow$ Leverage   | 0.001*                    | 0.002*                 | <b>Econ policy uncertainty Granger causes leverage in both models</b>   |
| Equity market uncertainty $\nRightarrow$ Leverage | 0.000*                    | 0.002*                 | <b>Equity market uncertainty Granger causes leverage in both models</b> |
|                                                   |                           |                        |                                                                         |
| Leverage $\nRightarrow$ Geopolitical risk         | 0.531                     | 0.461                  | Leverage does not Granger cause geopolitical risk                       |
| Leverage $\nRightarrow$ Chicago risk index        | 0.183                     | 0.101                  | Leverage does not Granger cause Chicago risk index                      |
| Leverage $\nRightarrow$ Macro uncertainty         | 0.038*                    | 0.235                  | <b>Leverage Granger causes macro uncertainty in six-variable model</b>  |
| Leverage $\nRightarrow$ Financial uncertainty     | 0.888                     | 0.621                  | Leverage does not Granger cause financial uncertainty                   |
| Leverage $\nRightarrow$ Econ policy uncertainty   | 0.516                     | 0.326                  | Leverage does not Granger cause econ policy uncertainty                 |
| Leverage $\nRightarrow$ Equity market uncertainty | 0.514                     | 0.886                  | Leverage does not Granger cause equity uncertainty                      |

Note: \* indicates that the null hypothesis of no causality is rejected at 6% level

Table 6. *p*-values of causality tests for risk/uncertainty measures and broker-dealer leverage

| <i>Null hypothesis</i>                            | <i>Six-variable model</i> | <i>Bivariate model</i> | <i>Finding</i>                                                            |
|---------------------------------------------------|---------------------------|------------------------|---------------------------------------------------------------------------|
| Geopolitical risk $\nRightarrow$ Leverage         | 0.764                     | 0.156                  | Geopolitical risk does not Granger cause leverage                         |
| Chicago risk index $\nRightarrow$ Leverage        | 0.494                     | 0.840                  | Chicago risk index does not Granger cause leverage                        |
| Macro uncertainty $\nRightarrow$ Leverage         | 0.005*                    | 0.005*                 | <b>Macro uncertainty Granger causes leverage in both models</b>           |
| Financial uncertainty $\nRightarrow$ Leverage     | 0.002*                    | 0.001*                 | <b>Financial uncertainty Granger causes leverage in both models</b>       |
| Econ policy uncertainty $\nRightarrow$ Leverage   | 0.678                     | 0.008*                 | <b>Econ policy uncertainty Granger causes leverage in bivariate model</b> |
| Equity market uncertainty $\nRightarrow$ Leverage | 0.448                     | 0.079                  | Equity uncertainty does not Granger cause leverage                        |
|                                                   |                           |                        |                                                                           |
| Leverage $\nRightarrow$ Geopolitical risk         | 0.697                     | 0.808                  | Leverage does not Granger cause geopolitical risk                         |
| Leverage $\nRightarrow$ Chicago risk index        | 0.756                     | 0.101                  | Leverage does not Granger cause Chicago risk index                        |
| Leverage $\nRightarrow$ Macro uncertainty         | 0.704                     | 0.125                  | Leverage does not Granger cause macro uncertainty                         |
| Leverage $\nRightarrow$ Financial uncertainty     | 0.751                     | 0.908                  | Leverage does not Granger cause financial uncertainty                     |
| Leverage $\nRightarrow$ Econ policy uncertainty   | 0.421                     | 0.550                  | Leverage does not Granger cause econ policy uncertainty                   |
| Leverage $\nRightarrow$ Equity market uncertainty | 0.414                     | 0.179                  | Leverage does not Granger cause equity uncertainty                        |

*Note: \* indicates that the null hypothesis of no causality is rejected at 6% level*

Table 7. *p*-values of causality tests for risk/uncertainty measures and shadow bank leverage

| <i>Null hypothesis</i>                            | <i>Six-variable model</i> | <i>Bivariate model</i> | <i>Finding</i>                                                          |
|---------------------------------------------------|---------------------------|------------------------|-------------------------------------------------------------------------|
| Geopolitical risk $\nRightarrow$ Leverage         | 0.566                     | 0.530                  | Geopolitical risk does not Granger cause leverage                       |
| Chicago risk index $\nRightarrow$ Leverage        | 0.444                     | 0.287                  | Chicago risk index does not Granger cause leverage                      |
| Macro uncertainty $\nRightarrow$ Leverage         | 0.208                     | 0.274                  | Macro uncertainty does not Granger cause leverage                       |
| Financial uncertainty $\nRightarrow$ Leverage     | 0.021*                    | 0.008*                 | <b>Financial uncertainty Granger causes leverage in both models</b>     |
| Econ policy uncertainty $\nRightarrow$ Leverage   | 0.299                     | 0.777                  | Econ policy uncertainty does not Granger cause leverage                 |
| Equity market uncertainty $\nRightarrow$ Leverage | 0.176                     | 0.050*                 | <b>Equity uncertainty Granger causes leverage in bivariate model</b>    |
|                                                   |                           |                        |                                                                         |
| Leverage $\nRightarrow$ Geopolitical risk         | 0.724                     | 0.580                  | Leverage does not Granger cause geopolitical risk                       |
| Leverage $\nRightarrow$ Chicago risk index        | 0.218                     | 0.597                  | Leverage does not Granger cause Chicago risk index                      |
| Leverage $\nRightarrow$ Macro uncertainty         | 0.242                     | 0.398                  | Leverage does not Granger cause macro uncertainty                       |
| Leverage $\nRightarrow$ Financial uncertainty     | 0.096                     | 0.013*                 | <b>Leverage Granger causes financial uncertainty in bivariate model</b> |
| Leverage $\nRightarrow$ Econ policy uncertainty   | 0.177                     | 0.626                  | Leverage does not Granger cause econ policy uncertainty                 |
| Leverage $\nRightarrow$ Equity market uncertainty | 0.097                     | 0.353                  | Leverage does not Granger cause equity uncertainty                      |

Note: \* indicates that the null hypothesis of no causality is rejected at 6% level

Figure 1. Responses to a geopolitical risk shock in a VAR with commercial bank leverage, 1985Q1-2018Q4

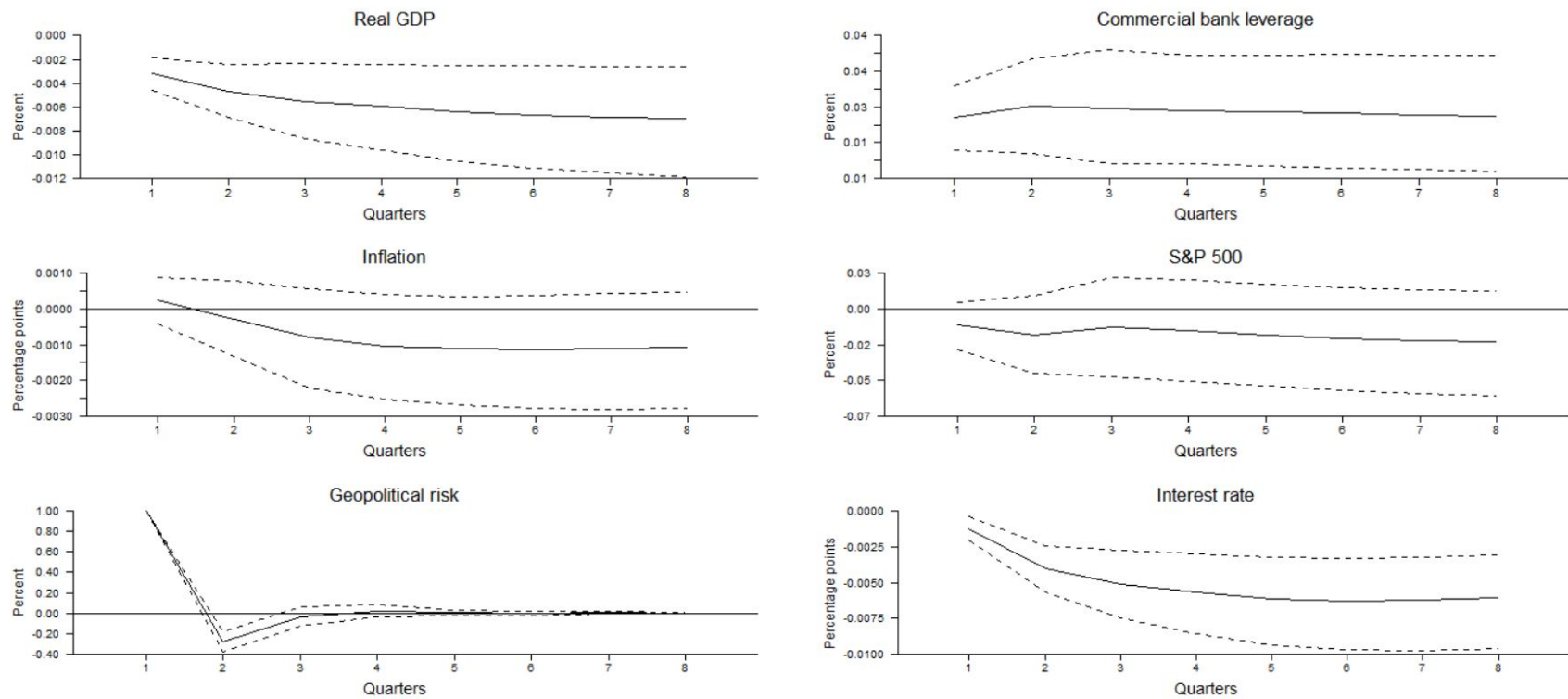


Figure 2. Responses to a Chicago risk shock in a VAR with commercial bank leverage, 1985Q1-2018Q4

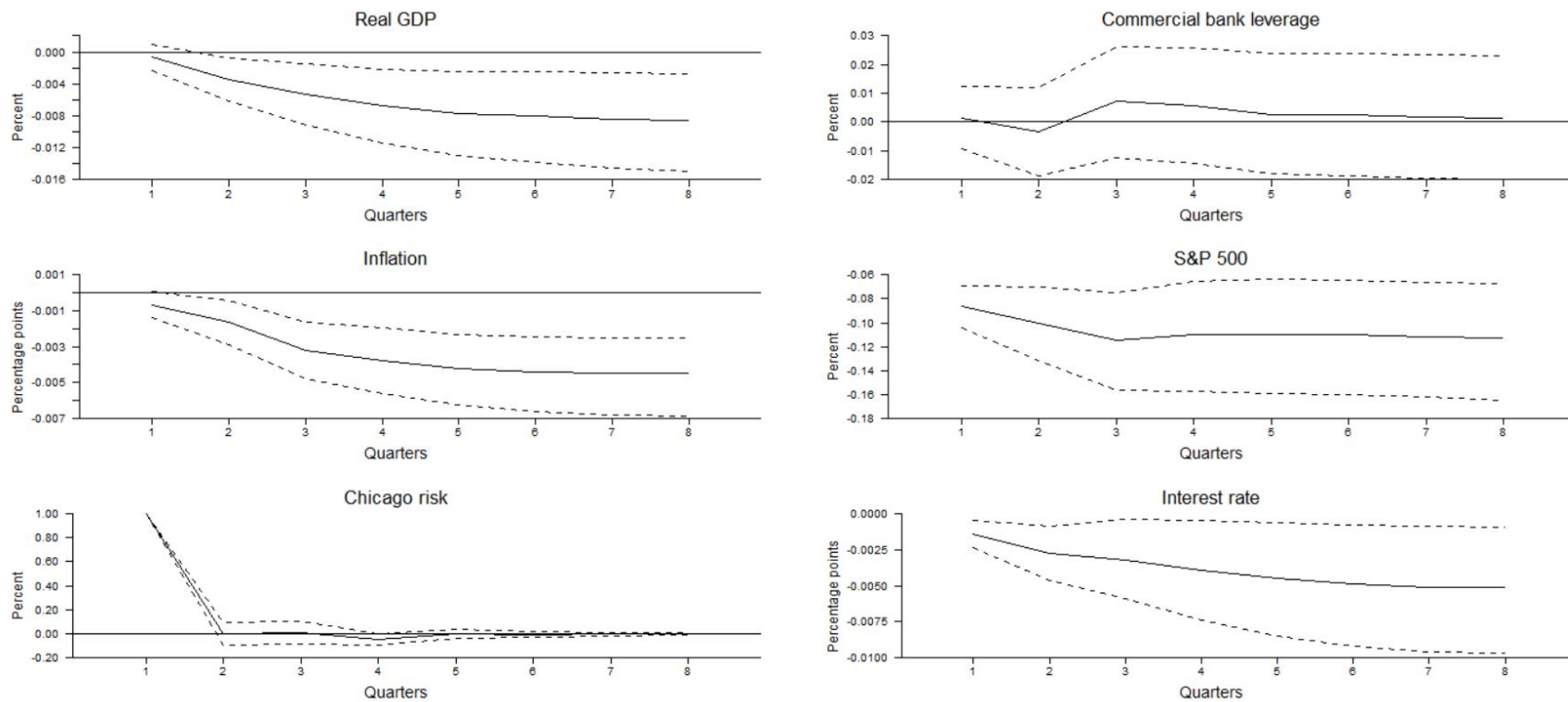


Figure 3. Responses to a macroeconomic uncertainty shock in a VAR with commercial bank leverage, 1985Q1-2018Q4

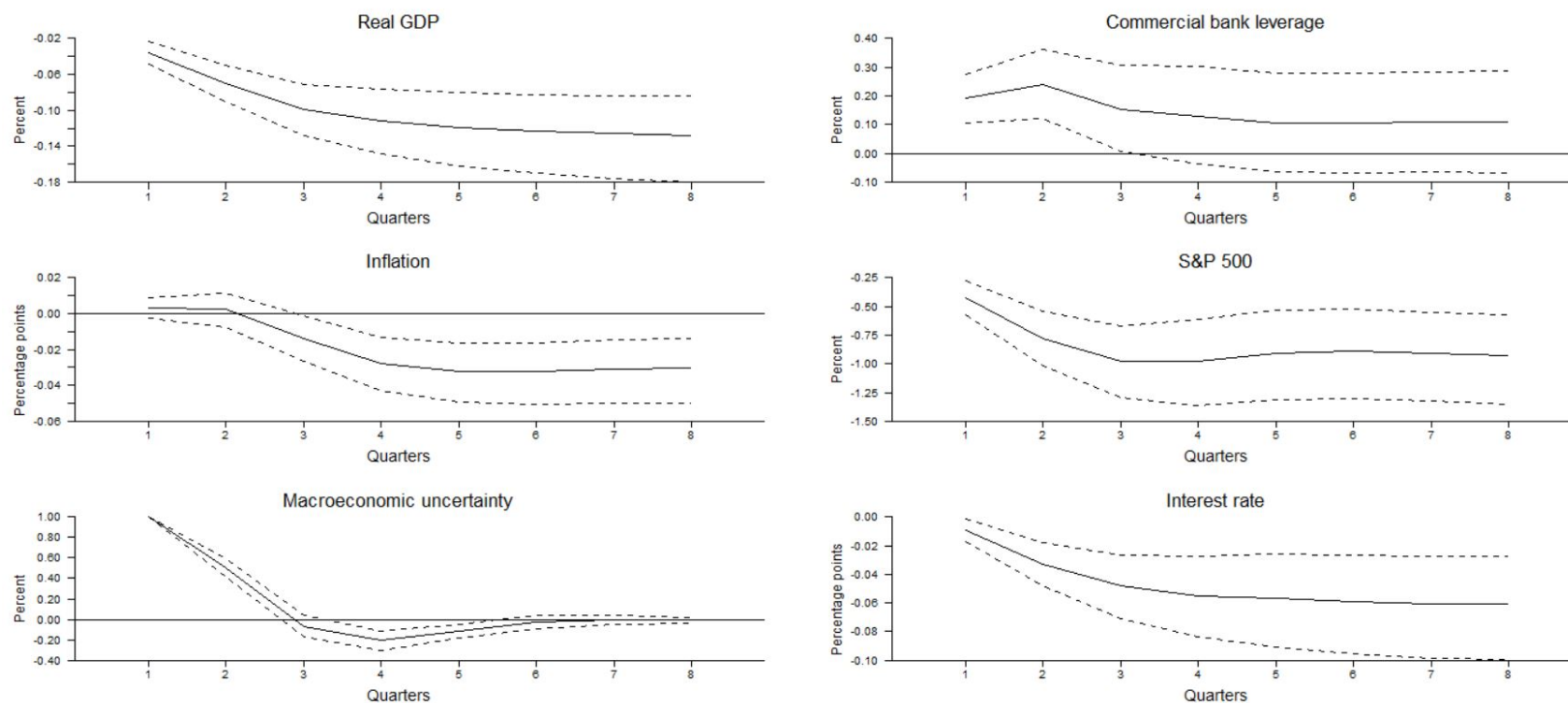


Figure 4. Responses to a financial uncertainty shock in a VAR with commercial bank leverage, 1985Q1-2018Q4

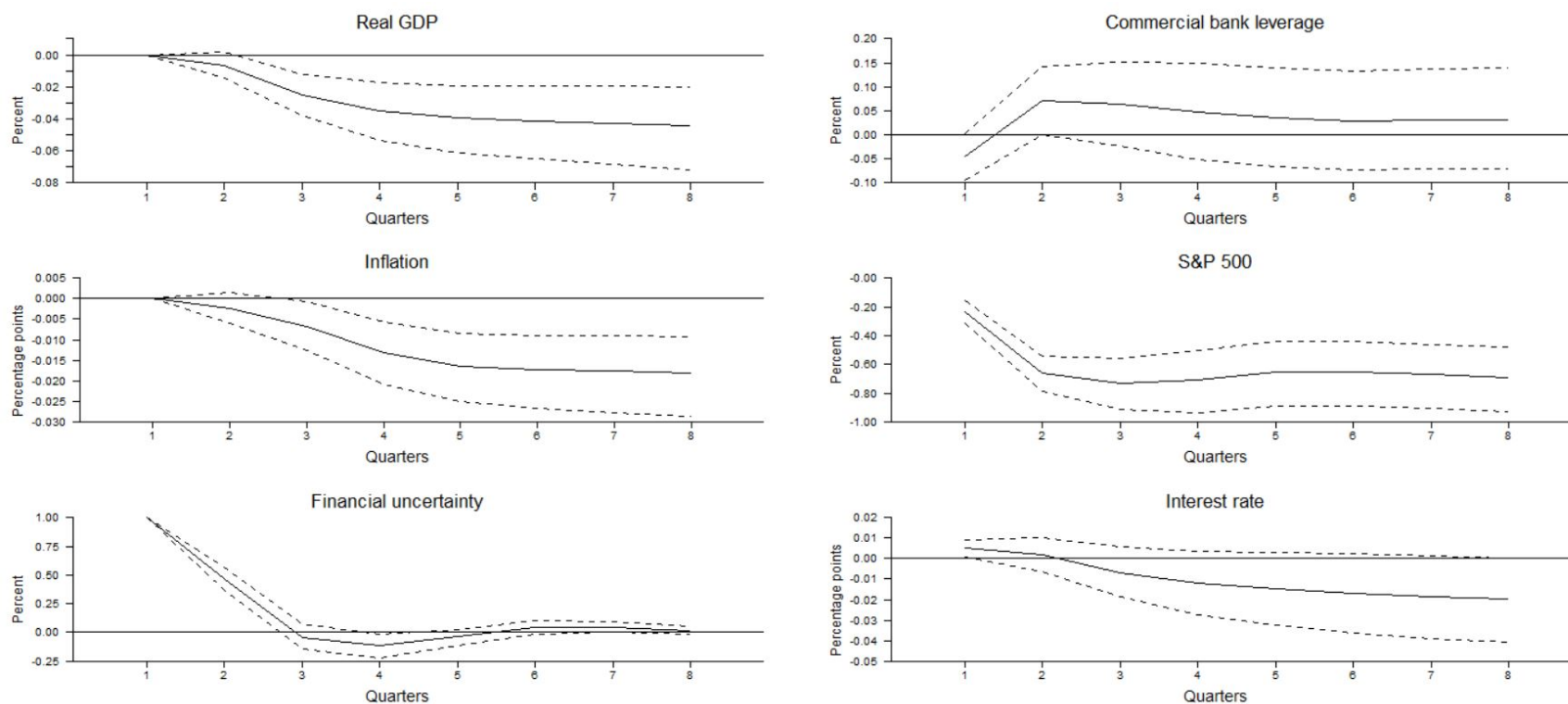


Figure 5. Responses to an economic policy uncertainty shock in a VAR with commercial bank leverage, 1985Q1-2018Q4

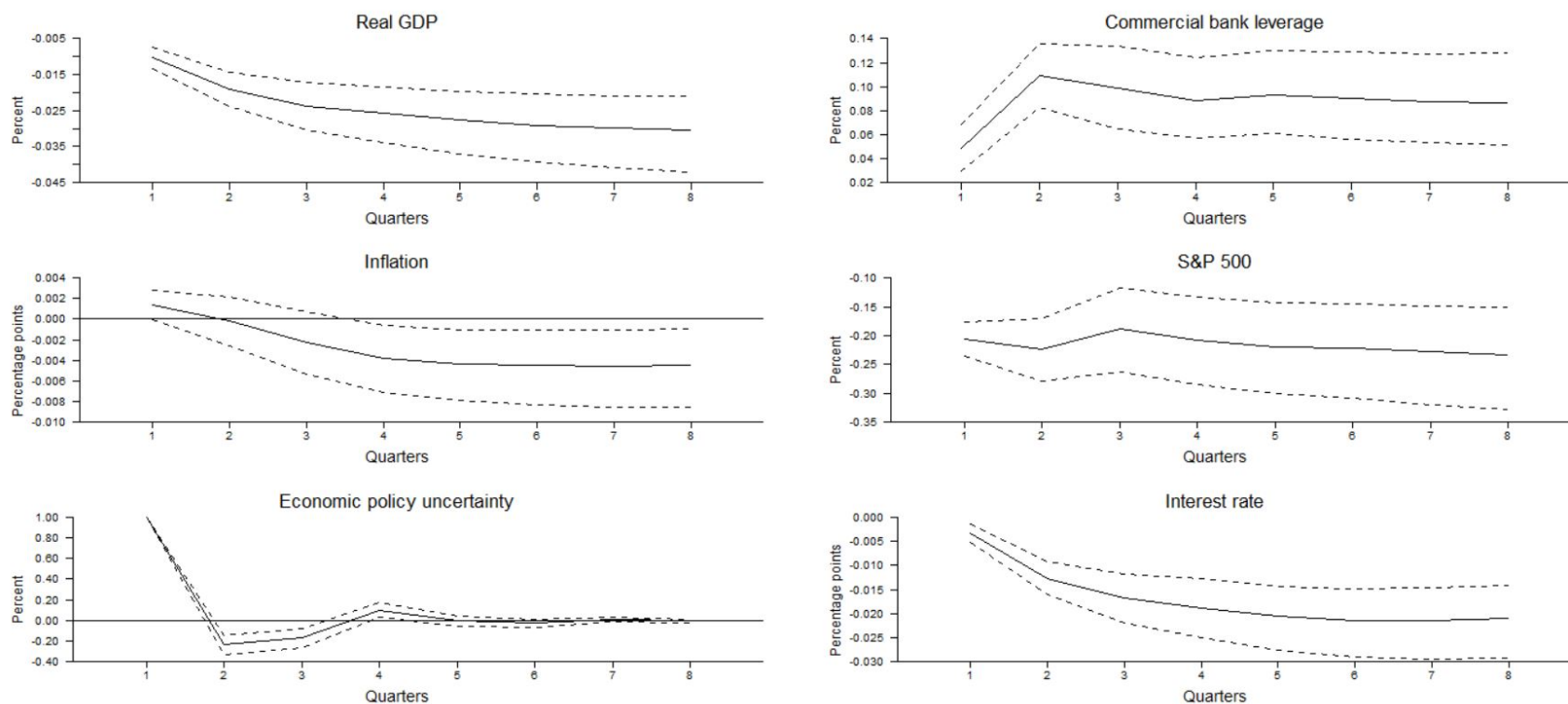


Figure 6. Responses to an equity uncertainty shock in a VAR with commercial bank leverage, 1985Q1-2018Q4

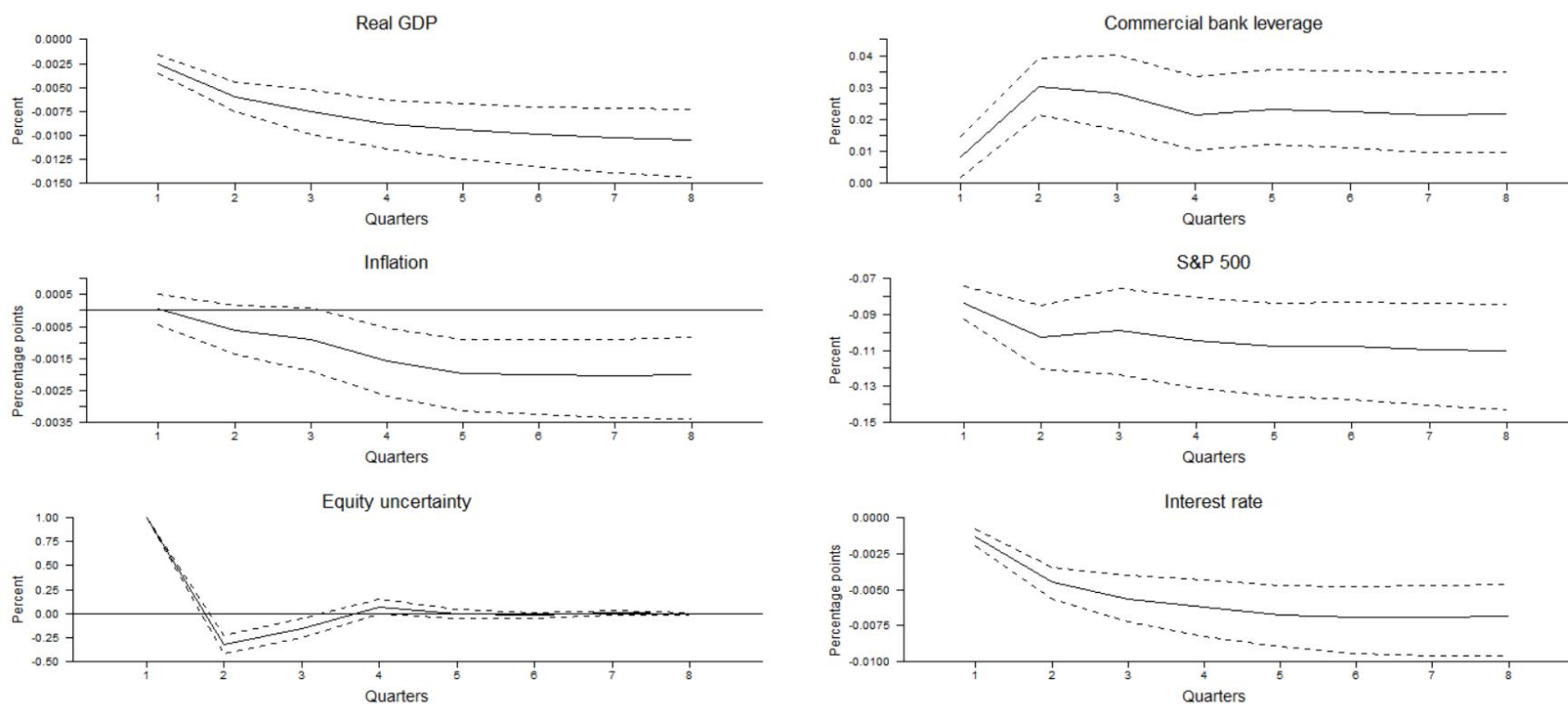


Figure 7. Responses to a geopolitical risk shock in a VAR with broker-dealer leverage, 1985Q1-2018Q4

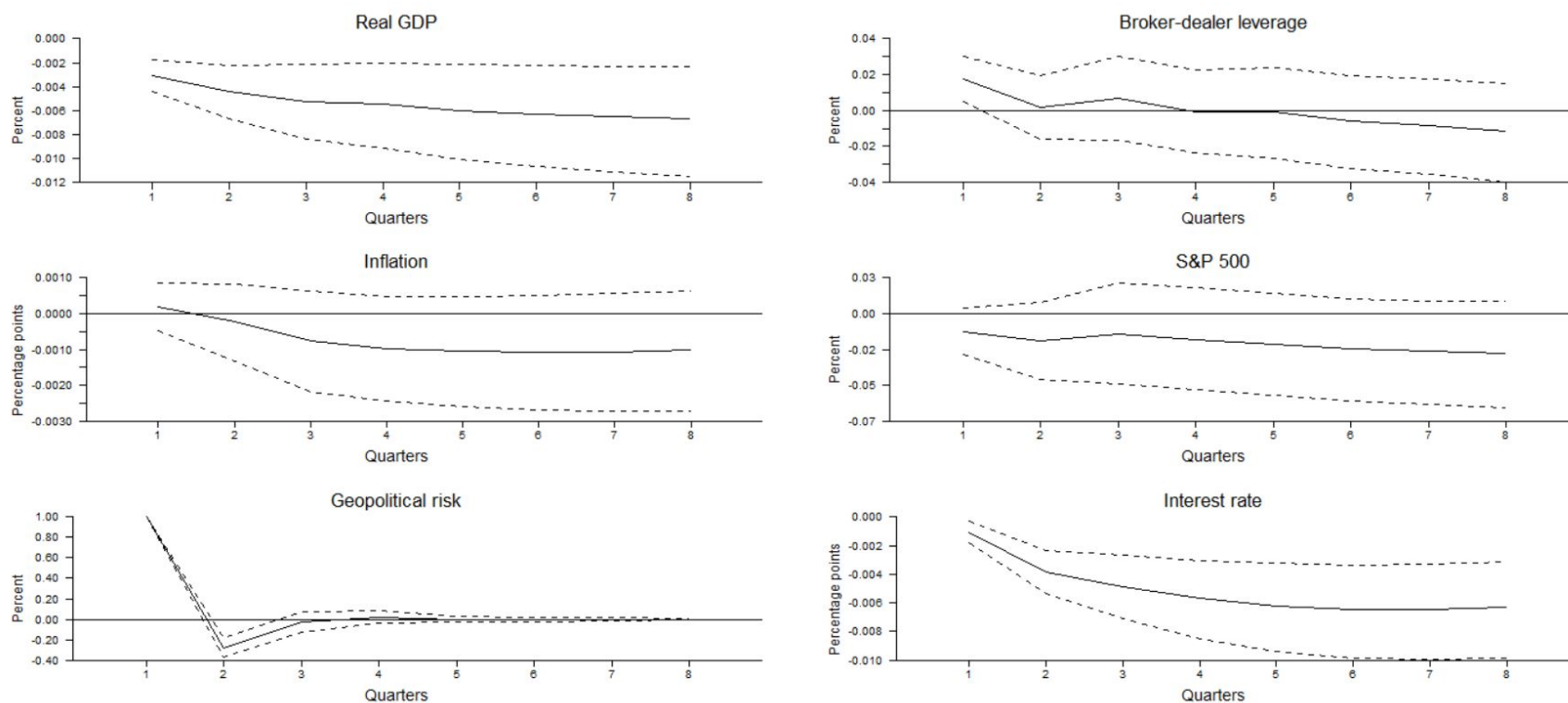


Figure 8. Responses to a Chicago financial conditions risk shock in a VAR with broker-dealer leverage, 1985Q1-2018Q4

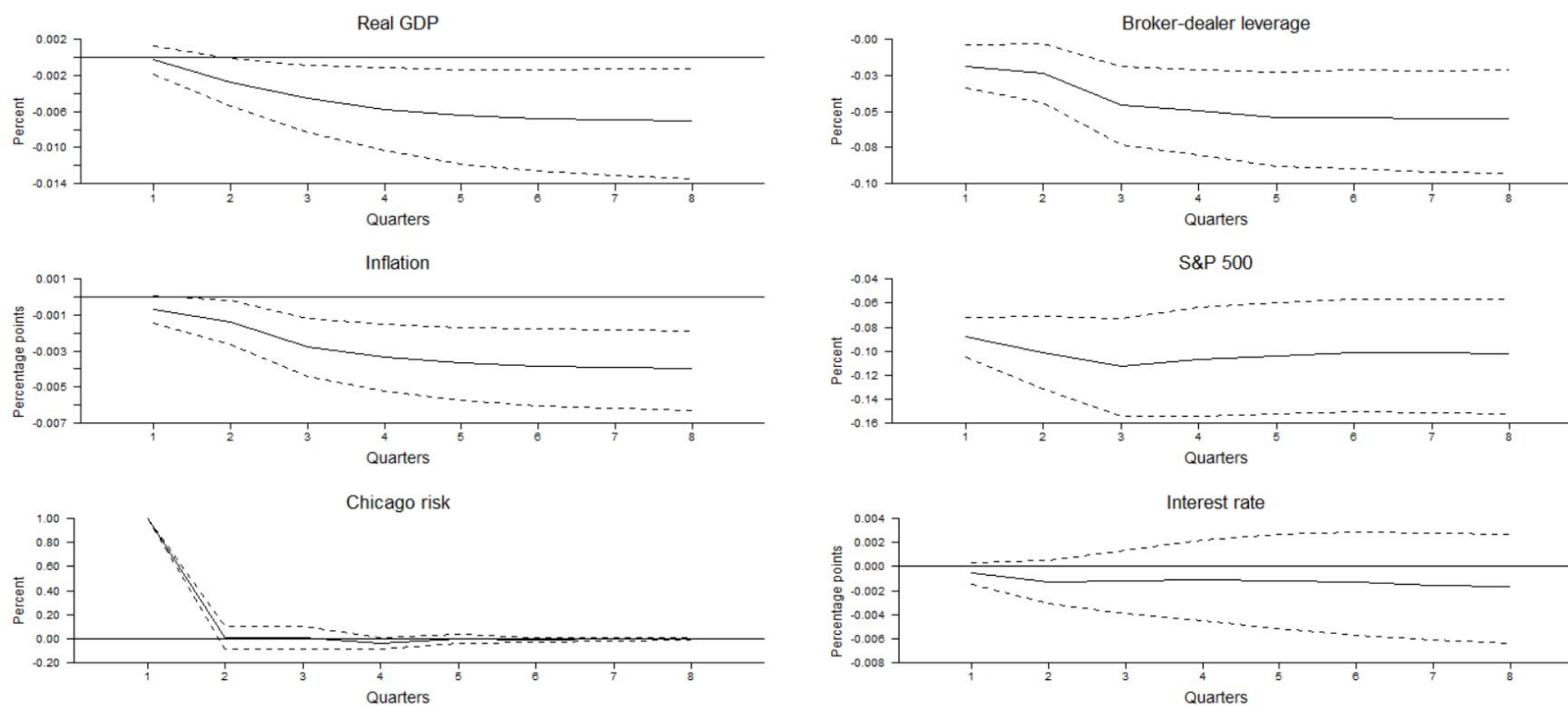


Figure 9. Responses to a macroeconomic uncertainty shock in a VAR with broker-dealer leverage, 1985Q1-2018Q4

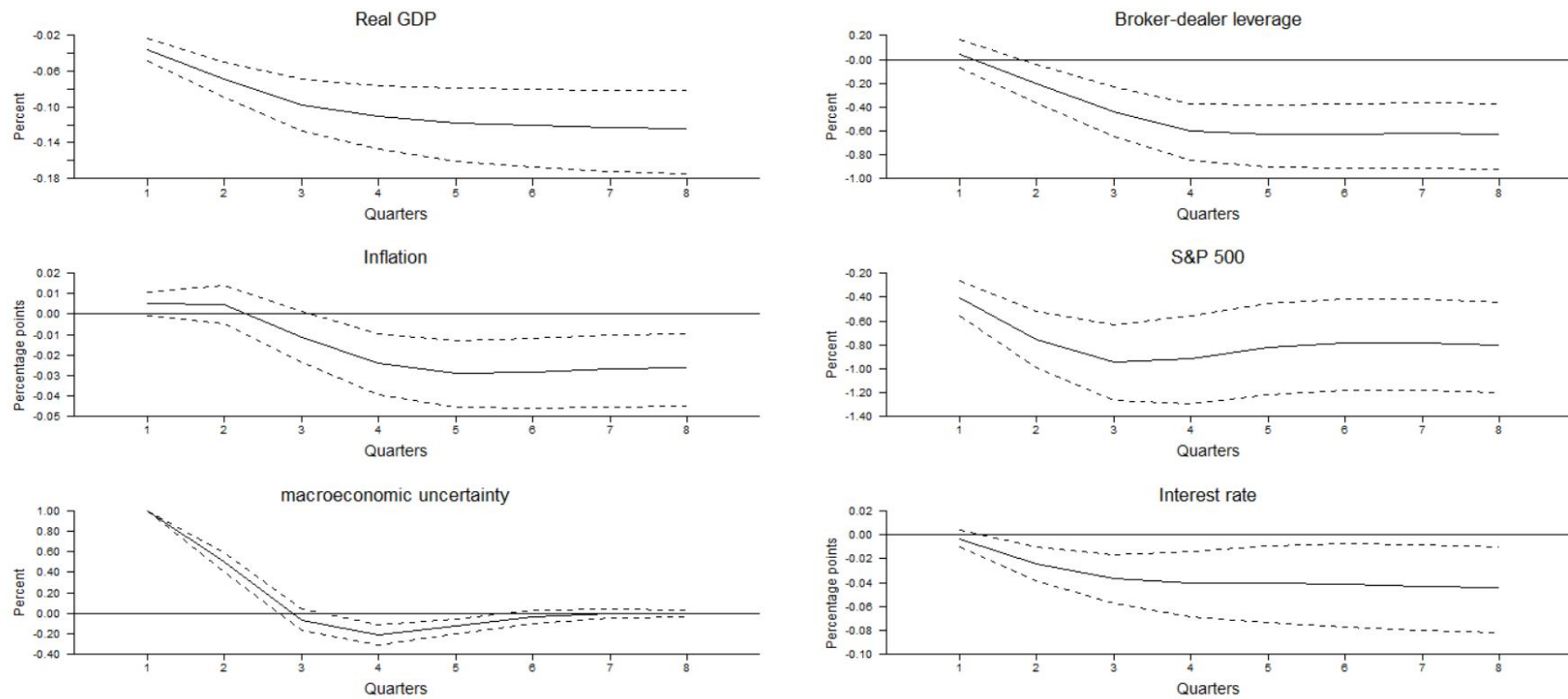


Figure 10. Responses to a financial uncertainty shock in a VAR with broker-dealer leverage, 1985Q1-2018Q4

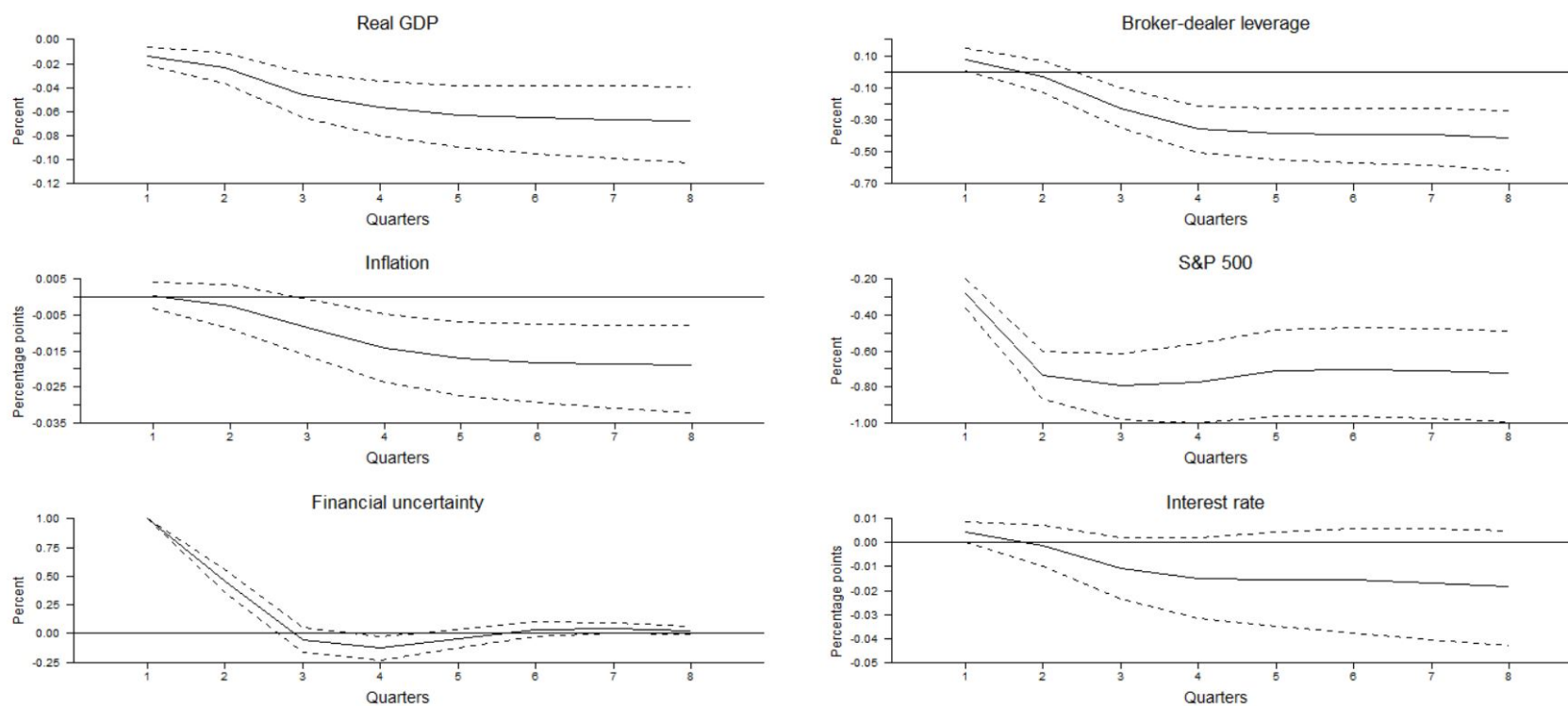


Figure 11. Responses to an economic policy uncertainty shock in a VAR with broker-dealer leverage, 1985Q1-2018Q4

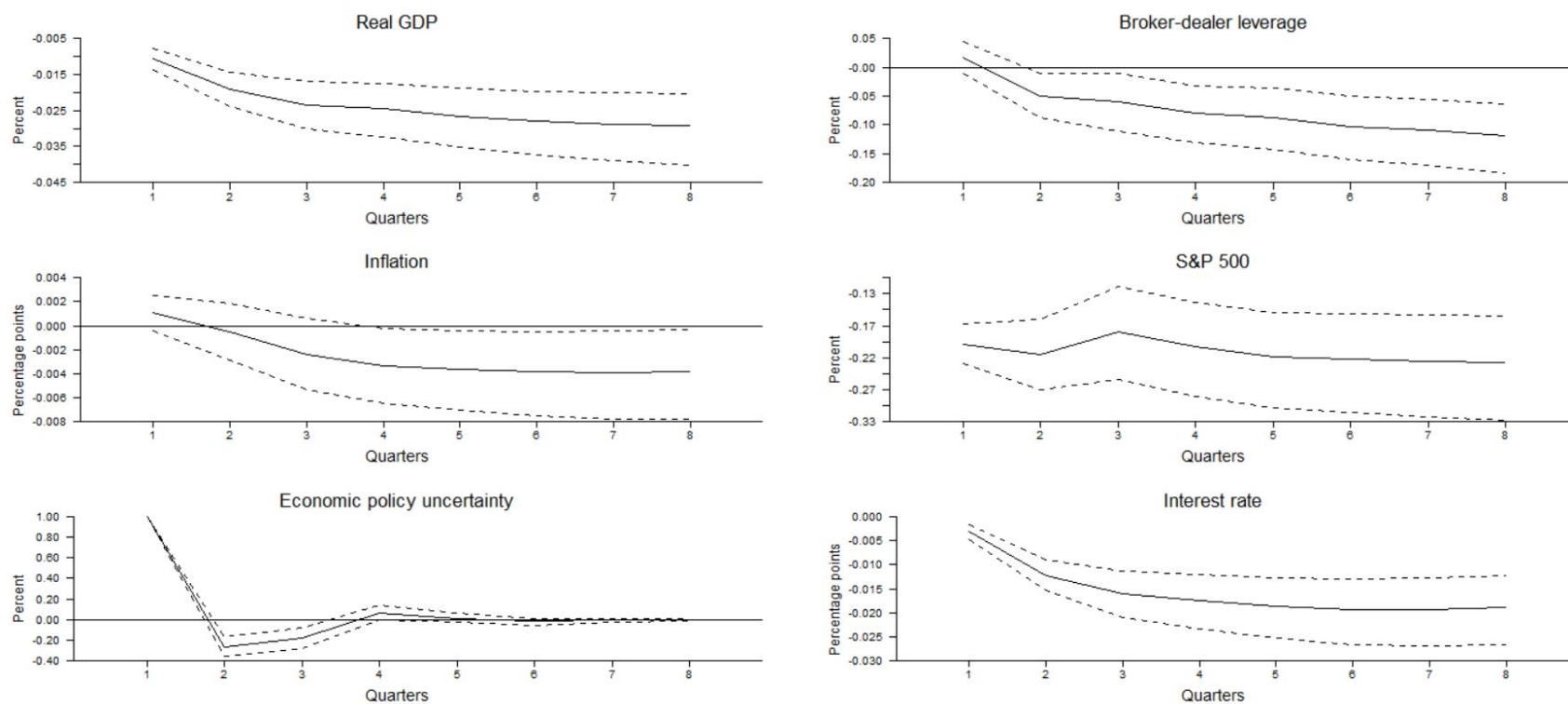


Figure 12. Responses to an equity uncertainty shock in a VAR with broker-dealer leverage, 1985Q1-2018Q4

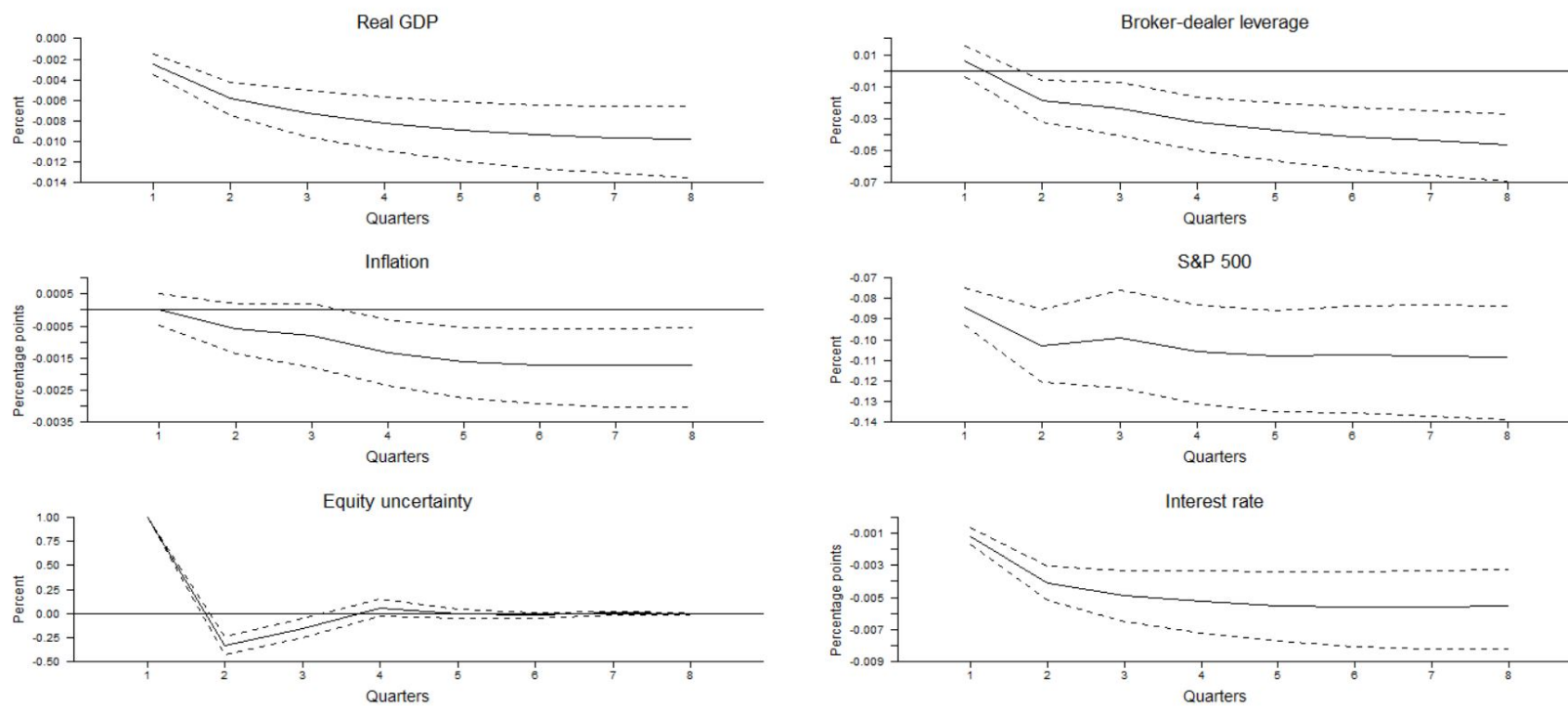


Figure 13. Responses to a geopolitical risk shock in a VAR with shadow bank leverage, 1985Q1-2018Q4

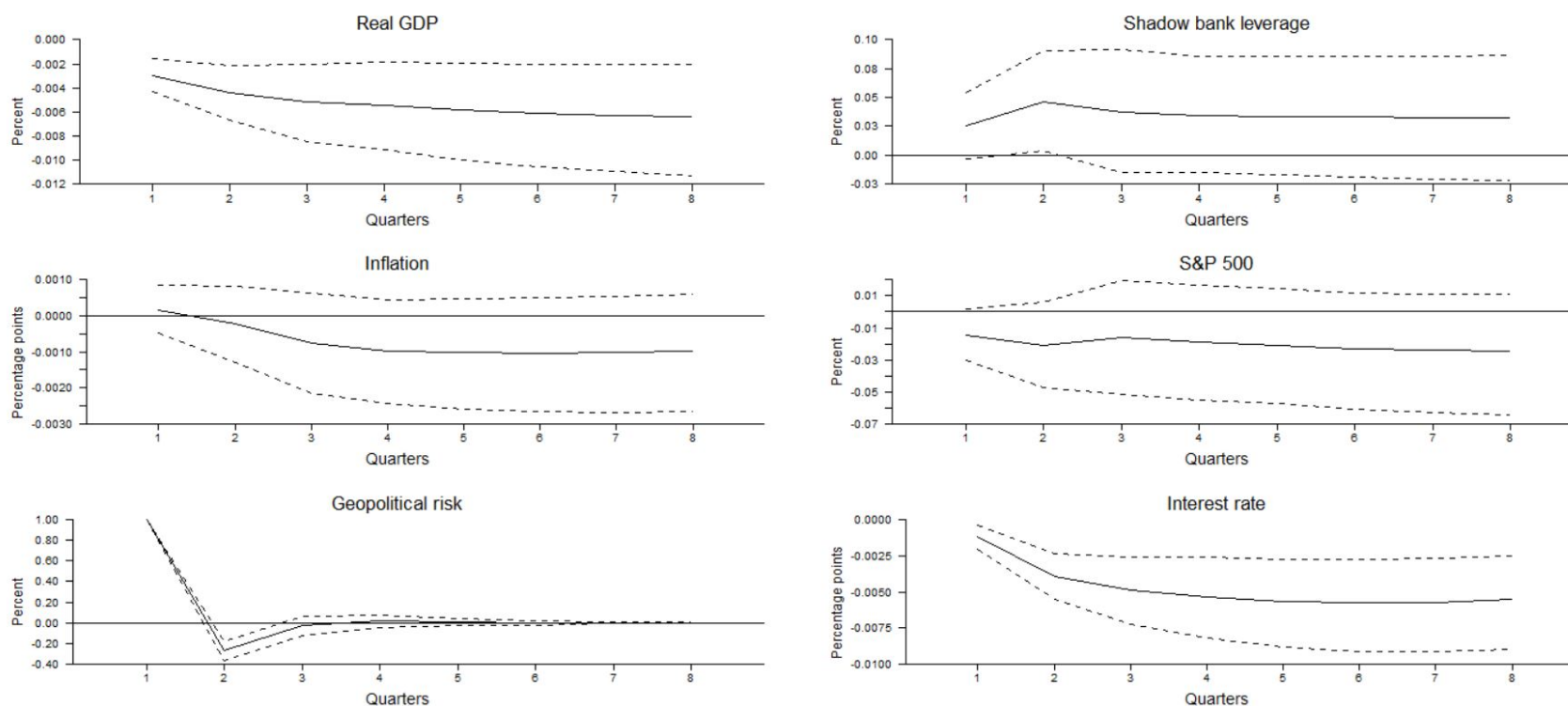


Figure 14. Responses to a Chicago financial conditions risk shock in a VAR with shadow bank leverage, 1985Q1-2018Q4

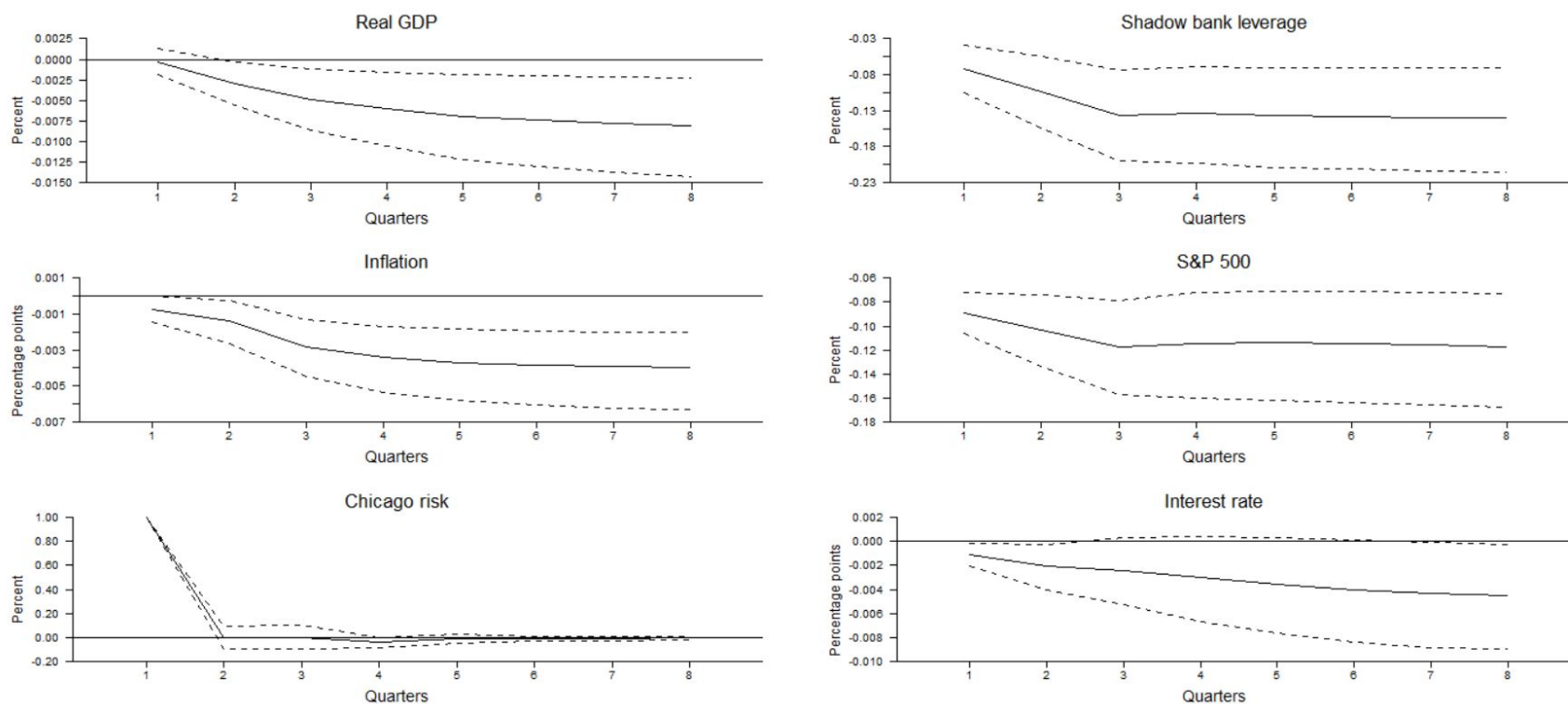


Figure 15. Responses to a macroeconomic uncertainty shock in a VAR with shadow bank leverage, 1985Q1-2018Q4

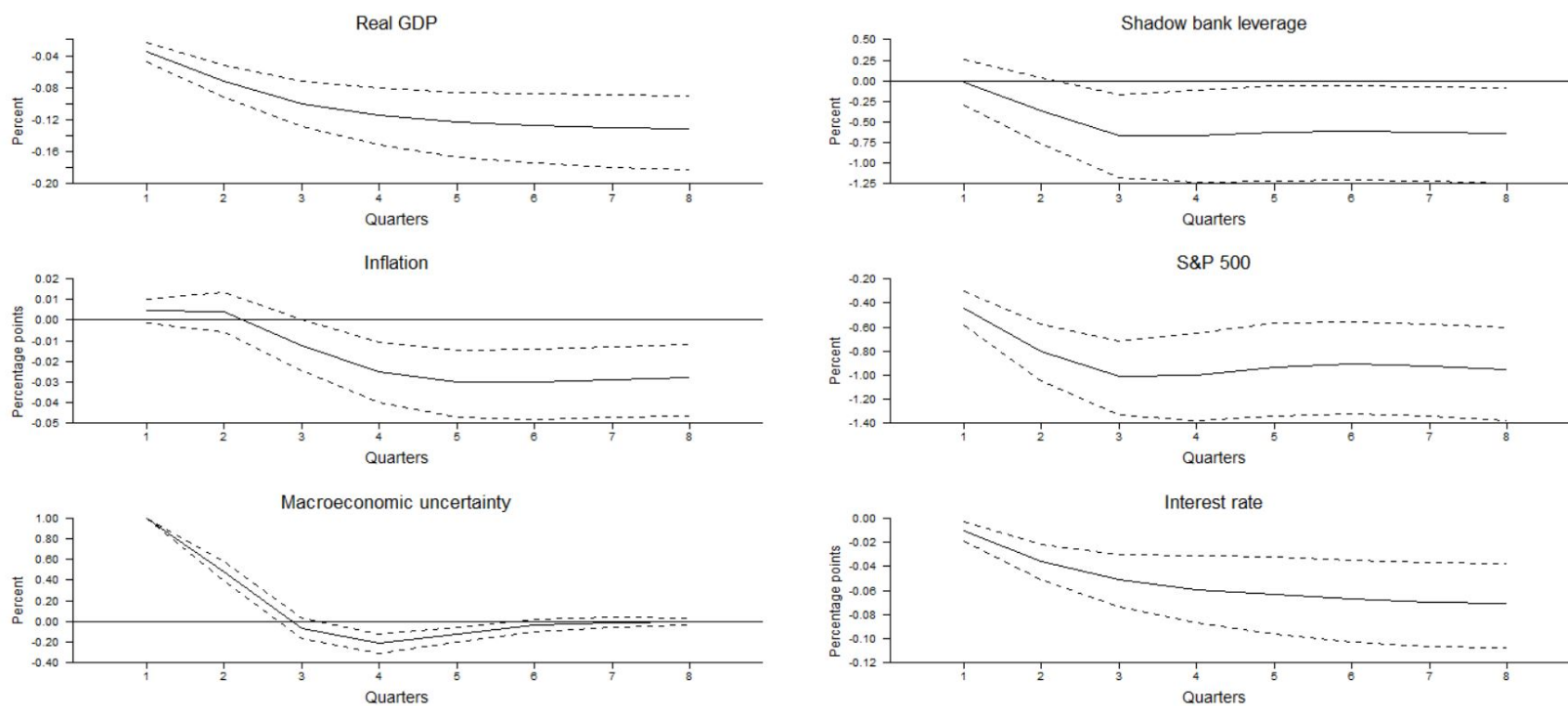


Figure 16. Responses to a financial uncertainty shock in a VAR with shadow bank leverage, 1985Q1-2018Q4

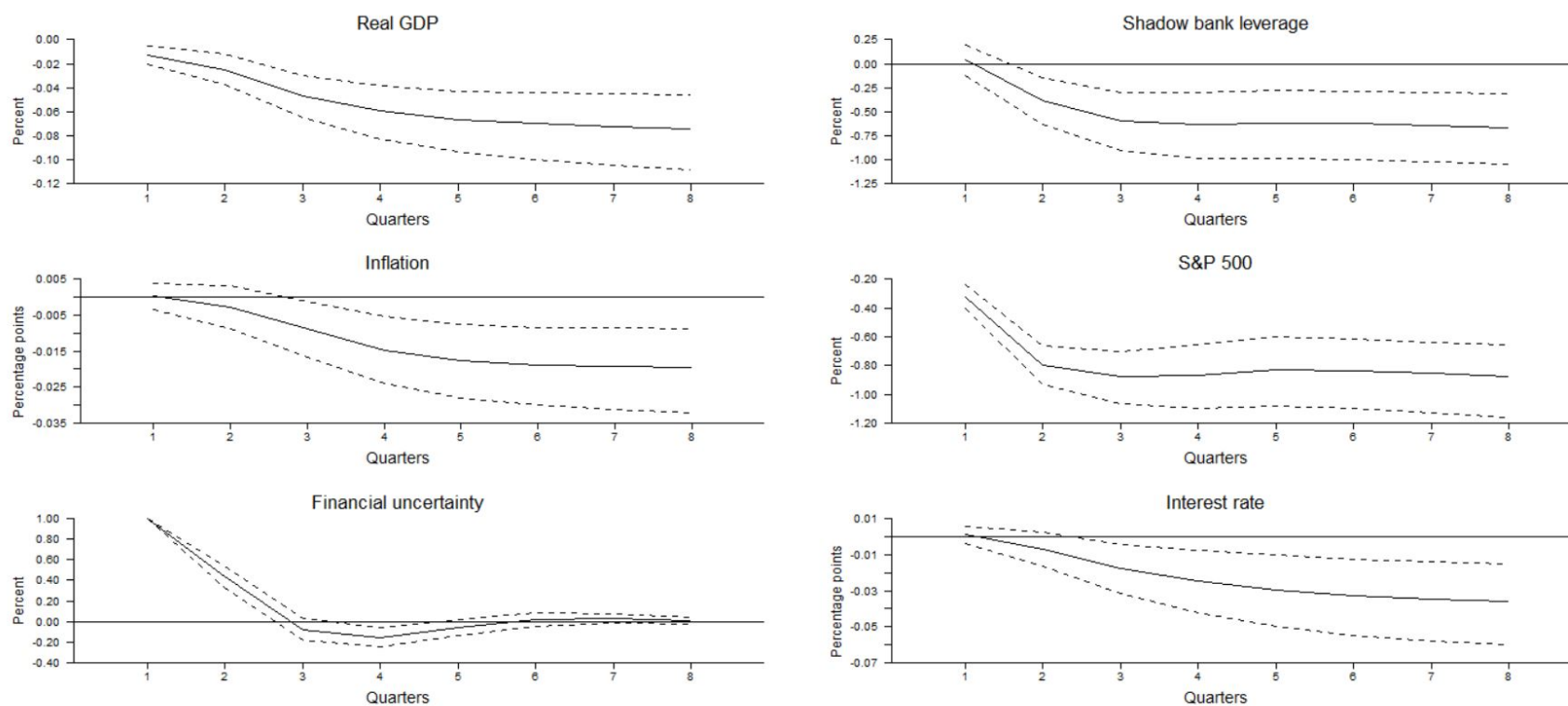


Figure 17. Responses to an economic policy uncertainty shock in a VAR with shadow bank leverage, 1985Q1-2018Q4

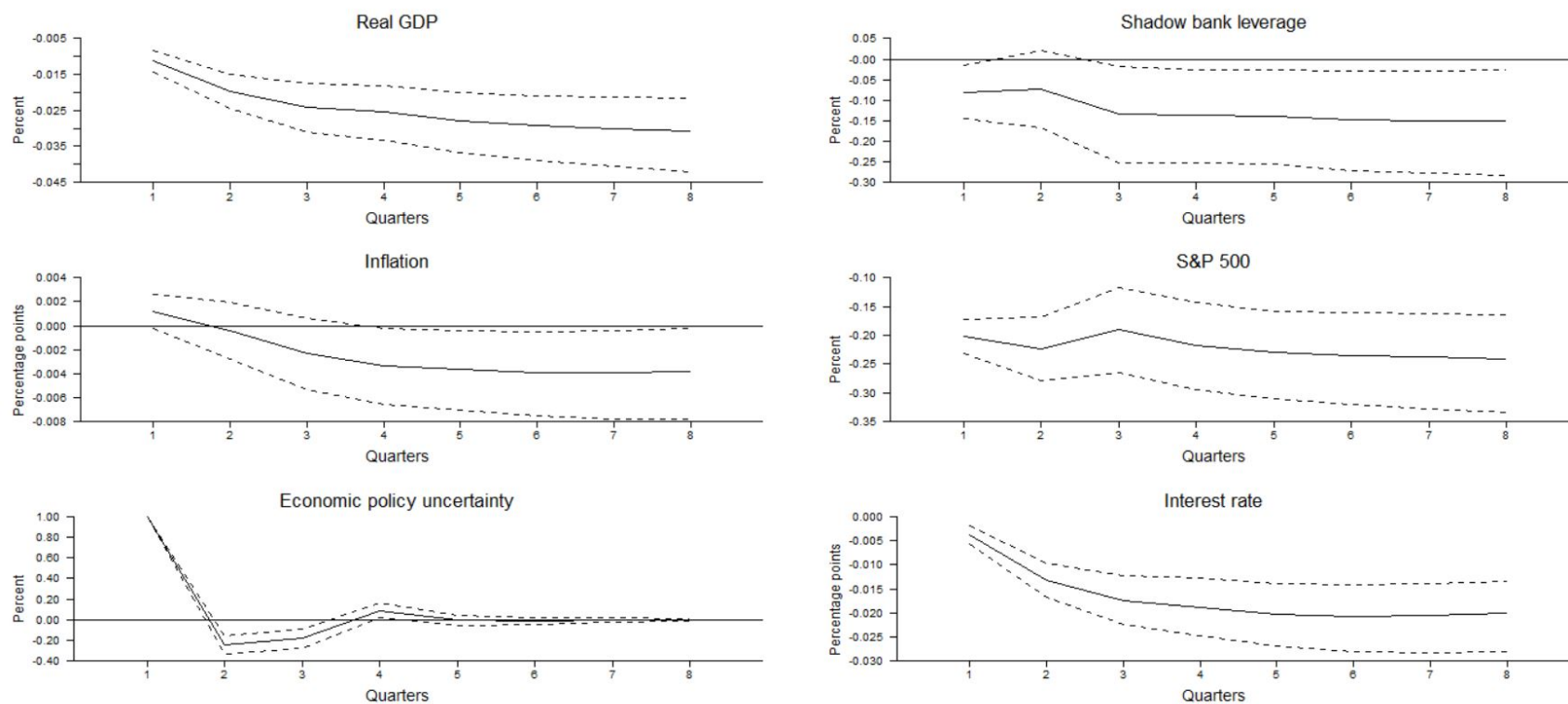


Figure 18. Responses to an equity uncertainty shock in a VAR with shadow bank leverage, 1985Q1-2018Q4

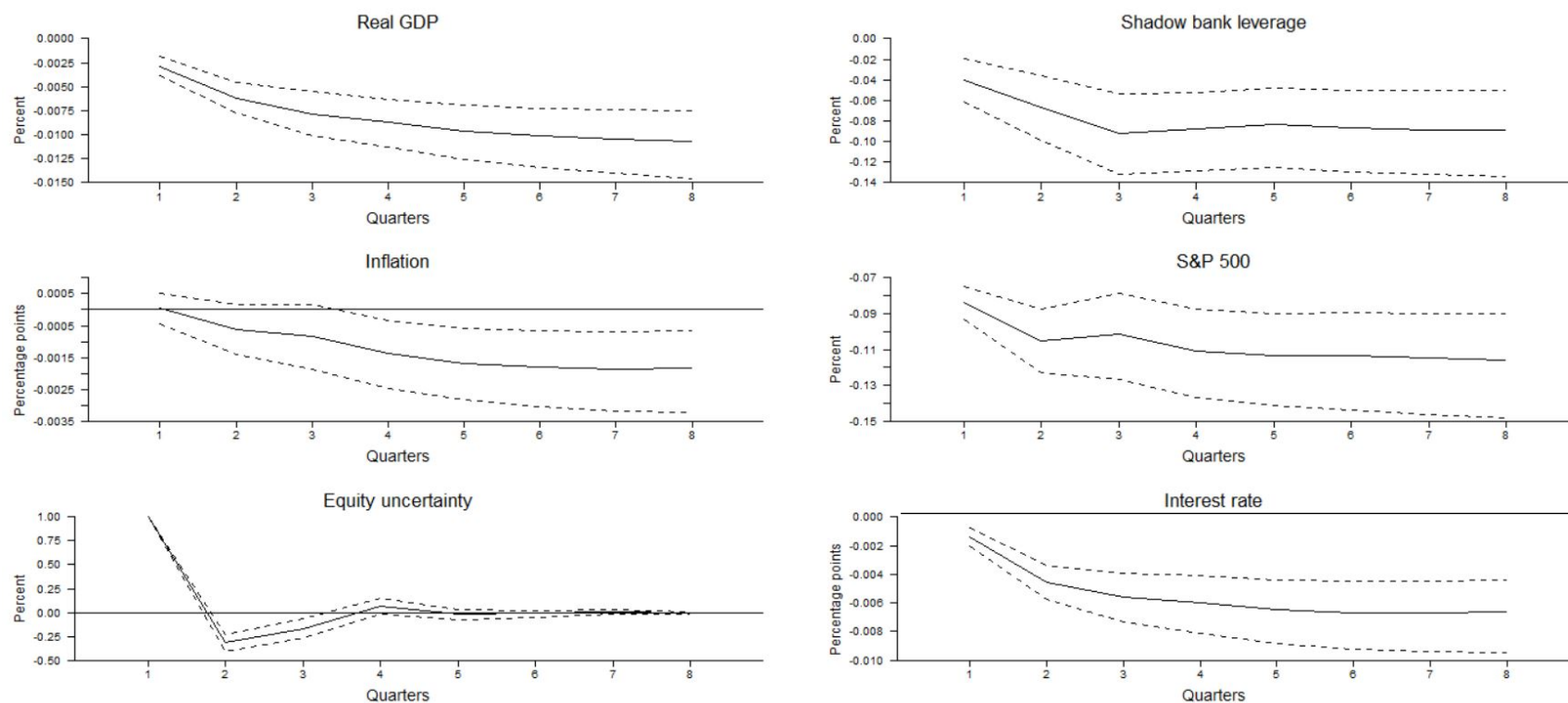


Table 8: Variance decomposition from the structural VAR

| Step                                    | Financial uncertainty | Real GDP | Inflation | Broker-dealer leverage | S&P 500 | Interest rate |
|-----------------------------------------|-----------------------|----------|-----------|------------------------|---------|---------------|
| Decomposition of financial uncertainty  |                       |          |           |                        |         |               |
| 1                                       | 100.000               | 0.000    | 0.000     | 0.000                  | 0.000   | 0.000         |
| 2                                       | 89.416                | 0.005    | 0.193     | 0.166                  | 10.043  | 0.176         |
| 5                                       | 77.910                | 0.332    | 3.783     | 0.355                  | 16.573  | 1.047         |
| 10                                      | 76.830                | 0.535    | 3.906     | 0.479                  | 16.395  | 1.854         |
| Decomposition of real GDP               |                       |          |           |                        |         |               |
| 1                                       | 2.589                 | 97.411   | 0.000     | 0.000                  | 0.000   | 0.000         |
| 2                                       | 3.398                 | 91.651   | 0.866     | 0.027                  | 4.044   | 0.013         |
| 5                                       | 9.726                 | 84.624   | 1.309     | 0.198                  | 3.858   | 0.285         |
| 10                                      | 9.734                 | 84.169   | 1.622     | 0.309                  | 3.843   | 0.322         |
| Decomposition of inflation              |                       |          |           |                        |         |               |
| 1                                       | 0.021                 | 0.265    | 99.714    | 0.000                  | 0.000   | 0.000         |
| 2                                       | 0.590                 | 3.031    | 96.102    | 0.132                  | 0.110   | 0.036         |
| 5                                       | 4.432                 | 6.870    | 88.075    | 0.256                  | 0.325   | 0.043         |
| 10                                      | 4.496                 | 6.973    | 87.420    | 0.289                  | 0.365   | 0.457         |
| Decomposition of broker-dealer leverage |                       |          |           |                        |         |               |
| 1                                       | 0.962                 | 0.006    | 0.238     | 98.793                 | 0.000   | 0.000         |
| 2                                       | 2.660                 | 4.169    | 0.809     | 92.042                 | 0.188   | 0.132         |
| 5                                       | 9.603                 | 4.928    | 1.174     | 82.115                 | 1.235   | 0.945         |
| 10                                      | 9.400                 | 6.139    | 1.999     | 79.695                 | 1.624   | 1.144         |
| Decomposition of S&P 500                |                       |          |           |                        |         |               |
| 1                                       | 9.285                 | 9.190    | 0.498     | 0.321                  | 80.706  | 0.000         |
| 2                                       | 24.874                | 9.062    | 2.760     | 0.248                  | 61.239  | 1.818         |
| 5                                       | 24.254                | 8.710    | 3.787     | 0.605                  | 58.747  | 3.897         |
| 10                                      | 24.116                | 8.967    | 3.923     | 0.748                  | 58.350  | 3.896         |
| Decomposition of interest rate          |                       |          |           |                        |         |               |
| 1                                       | 0.828                 | 13.897   | 4.527     | 4.617                  | 0.009   | 76.121        |
| 2                                       | 0.231                 | 25.261   | 4.978     | 1.701                  | 0.028   | 67.802        |
| 5                                       | 1.306                 | 33.556   | 8.150     | 4.452                  | 0.926   | 51.610        |
| 10                                      | 1.893                 | 39.723   | 11.120    | 6.943                  | 1.658   | 38.664        |

Notes: The variance decomposition indicates the contribution of a variable in explaining the variation of the VAR variables. The table indicates that financial uncertainty plays an important role in explaining the variation of the variables in the VAR model.

# **Risk, Uncertainty, and Leverage**

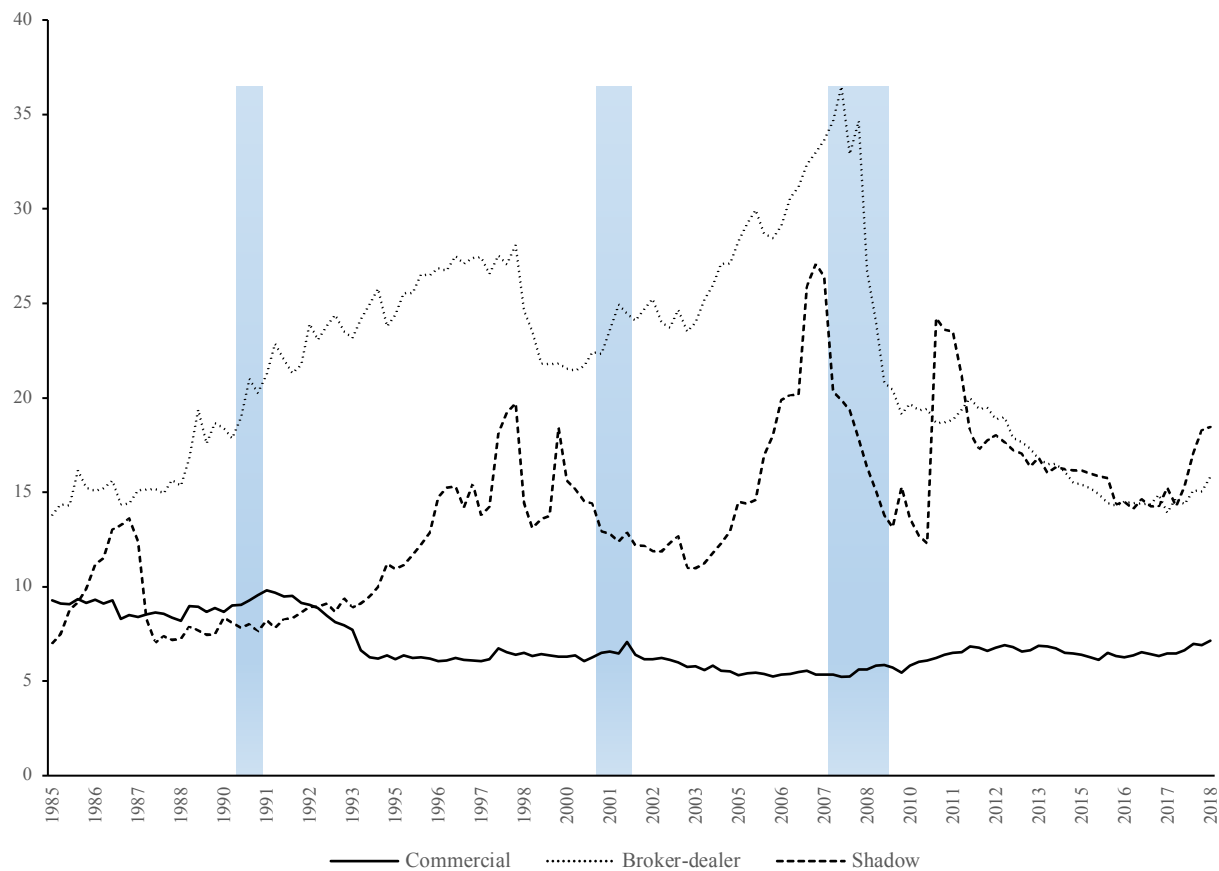
## **Online Appendix**

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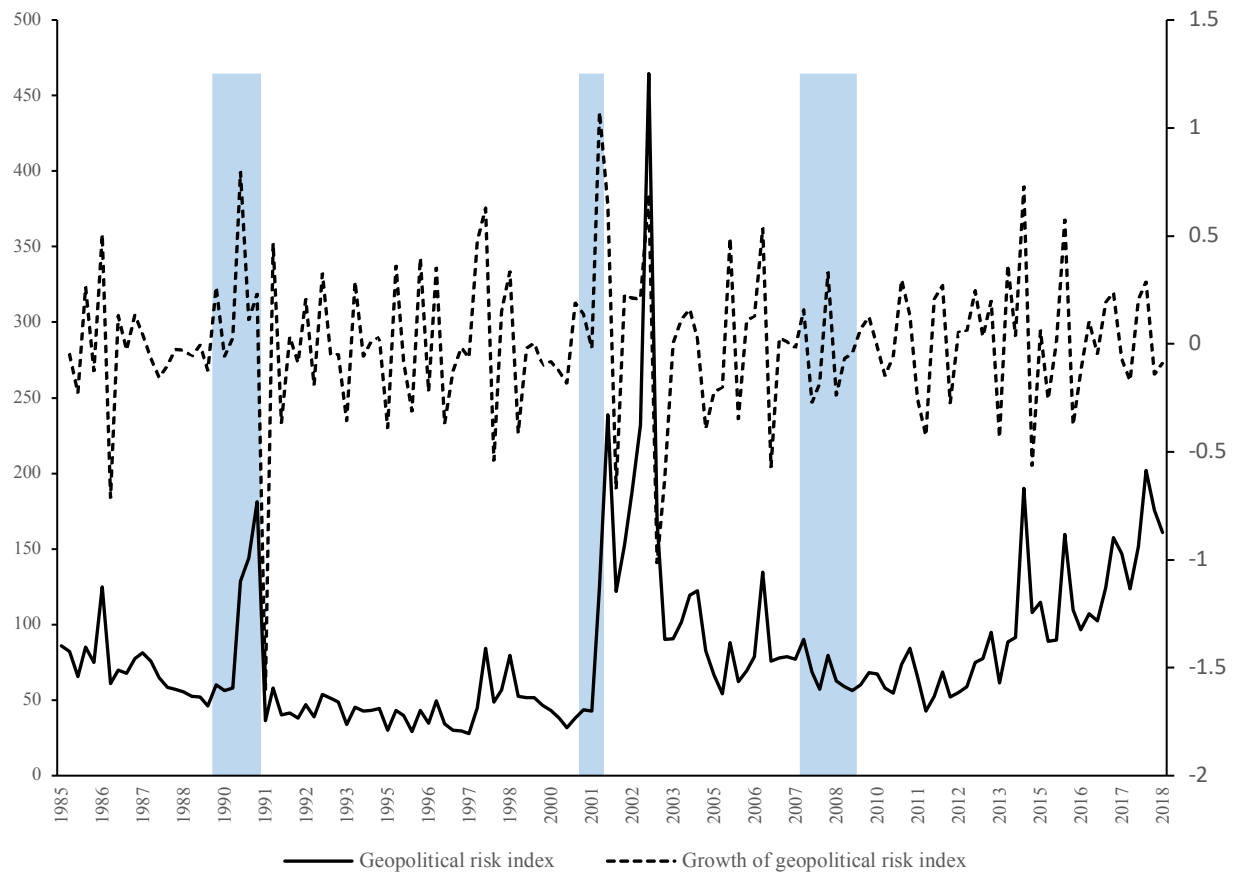
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E-mail: [Serletis@ucalgary.ca](mailto:Serletis@ucalgary.ca)

Appendix Figure A1. Leverage of commercial banks, broker-dealers, and shadow banks

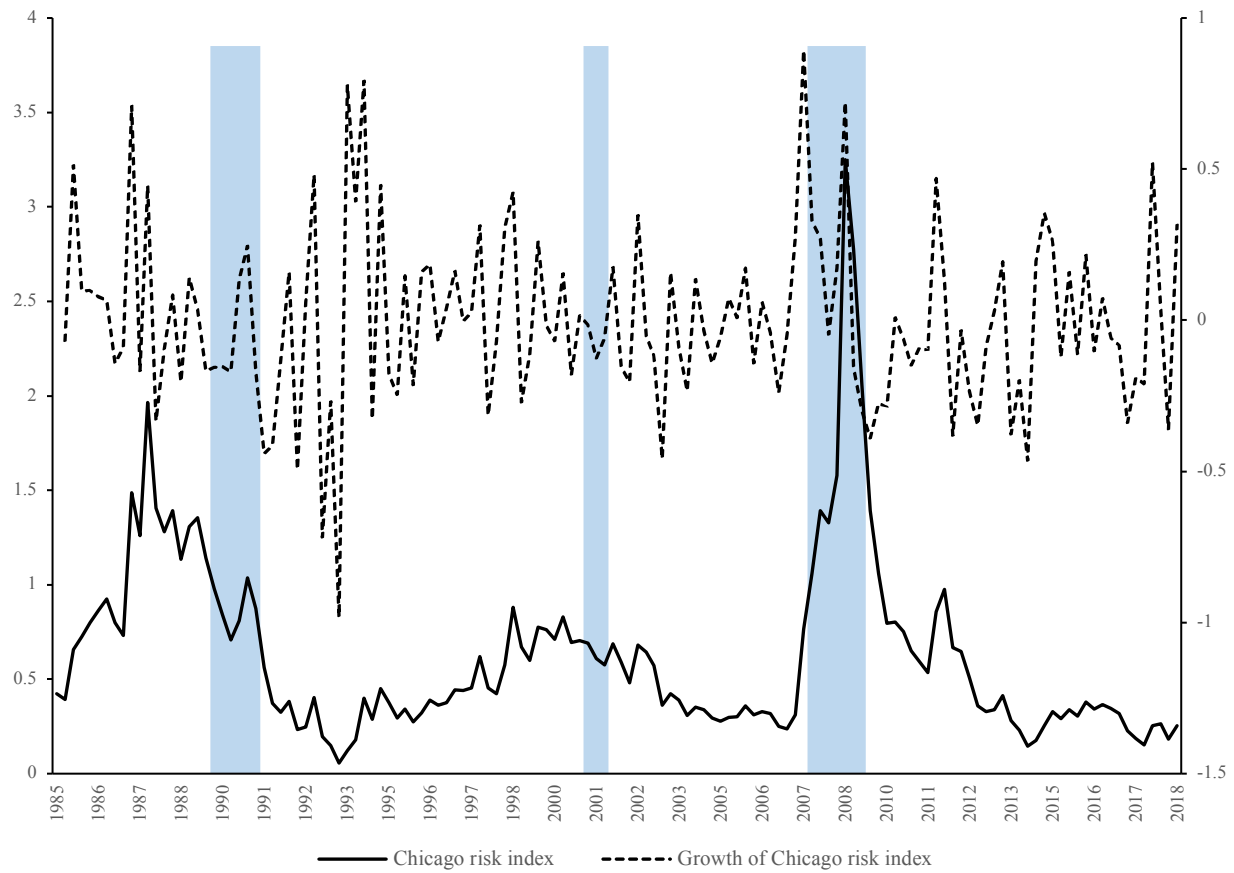


*Note:* The shaded areas indicate NBER recessionary periods.

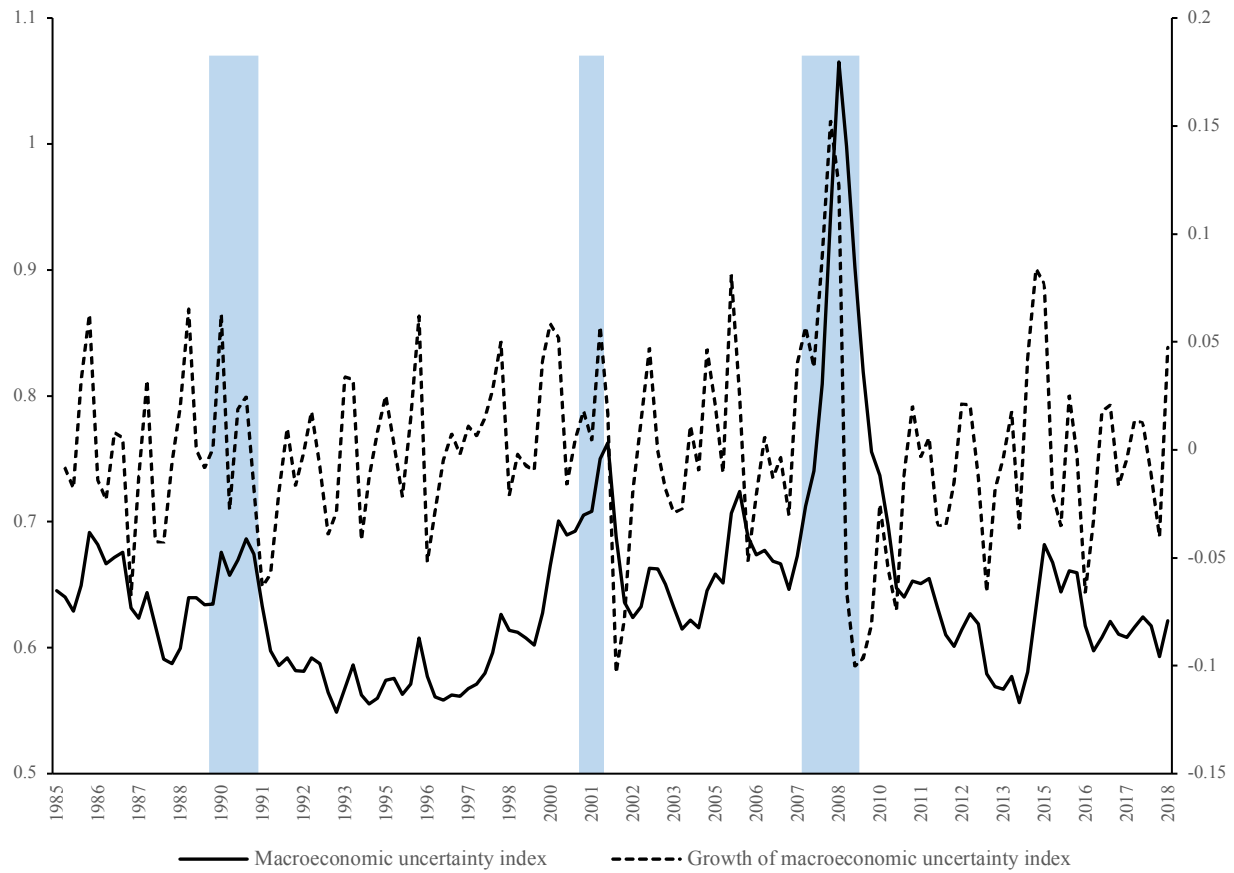
Appendix Figure A2. Geopolitical risk index and its growth rate



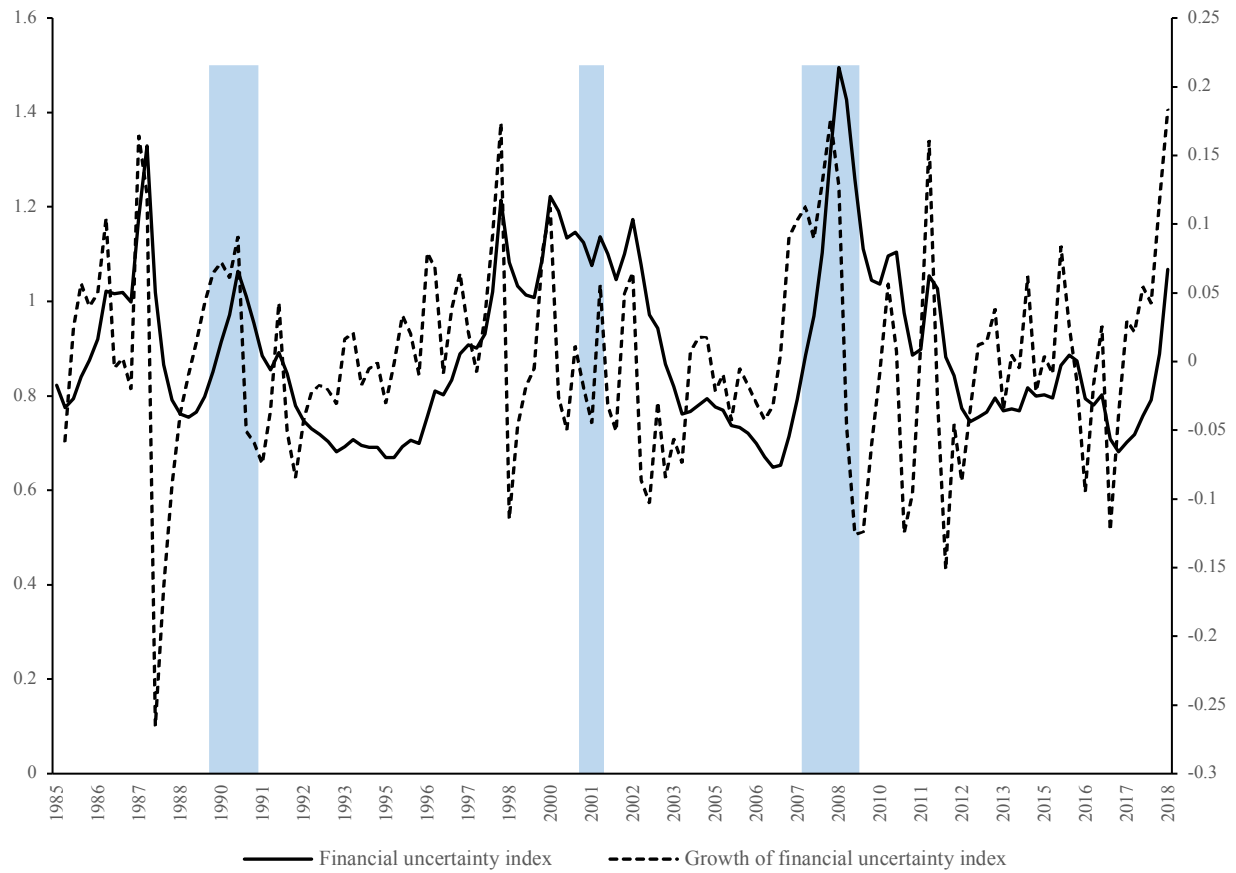
Appendix Figure A3. Chicago risk index and its growth rate



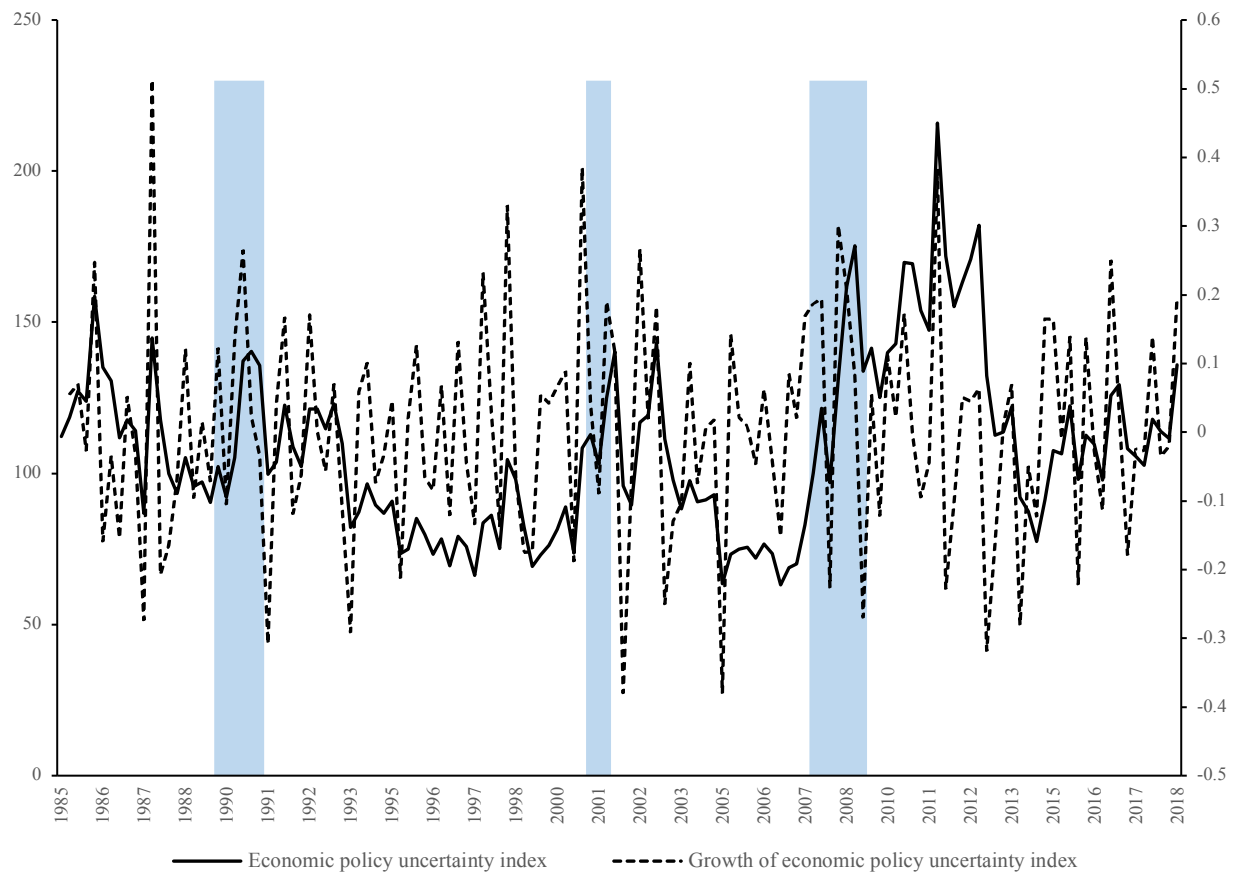
Appendix Figure A4. Macroeconomic uncertainty and its growth rate



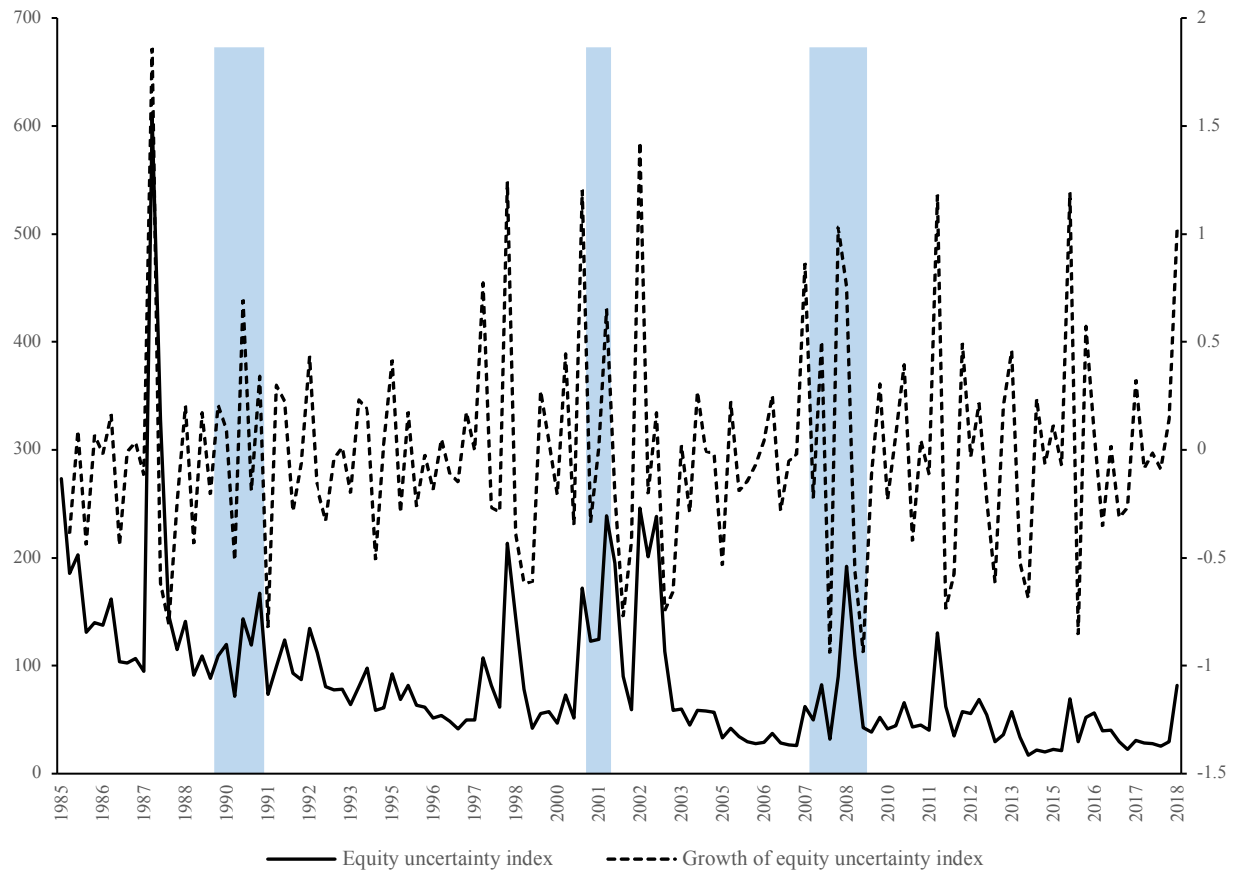
Appendix Figure A5. Financial uncertainty and its growth rate



Appendix Figure A6. Economic policy uncertainty and its growth rate



Appendix Figure A7. Equity uncertainty and its growth rate



Appendix Table A1. Summary statistics of all the leverage, risk, and uncertainty indicators

| Series                                 | Mean   | Variance | Skewness | ADF test  | KPSS test |
|----------------------------------------|--------|----------|----------|-----------|-----------|
| <i>Log levels</i>                      |        |          |          |           |           |
| Commercial banks                       | 1.915  | 0.031    | 0.664    | -0.974    | 0.519**   |
| Broker-dealers                         | 3.041  | 0.064    | 0.014    | -1.596    | 0.558**   |
| Shadow banks                           | 2.573  | 0.104    | -0.182   | -2.934    | 0.191*    |
| Geopolitical risk                      | 4.262  | 0.261    | 0.661    | -4.521**  | 0.155*    |
| Chicago risk                           | -0.697 | 0.443    | 0.108    | -2.711    | 0.140     |
| Macroeconomic uncertainty              | -0.446 | 0.011    | 1.868    | -3.294    | 0.188*    |
| Financial uncertainty                  | -0.131 | 0.034    | 0.535    | -3.612*   | 0.107     |
| Economic policy uncertainty            | 4.651  | 0.065    | 0.221    | -3.766*   | 0.238**   |
| Equity uncertainty                     | 4.223  | 0.443    | 0.358    | -6.452**  | 0.061     |
| <i>First differences of log levels</i> |        |          |          |           |           |
| Commercial banks                       | -0.194 | 11.602   | -0.482   | -11.995** | 0.059     |
| Broker-dealers                         | 0.101  | 25.603   | -1.151   | -6.445**  | 0.051     |
| Shadow banks                           | 0.718  | 113.79   | 1.384    | -10.351** | 0.119     |
| Geopolitical risk                      | 0.463  | 1173.8   | -0.612   | -14.727** | 0.029     |
| Chicago risk                           | -0.381 | 851.11   | 0.383    | -11.327** | 0.041     |
| Macroeconomic uncertainty              | -0.028 | 17.359   | 0.341    | -8.341**  | 0.034     |
| Financial uncertainty                  | 0.193  | 52.487   | -0.061   | -7.421**  | 0.038     |
| Economic policy uncertainty            | 0.142  | 252.13   | 0.159    | -11.182** | 0.032     |
| Equity uncertainty                     | -0.891 | 2384.8   | 0.941    | -9.714**  | 0.028     |

*Notes: The ADF test is associated with the null hypothesis of the existence of a unit root. The KPSS test is associated with the null hypothesis of the existence of trend-stationarity. \*\* and \* indicate that the test rejects the null hypothesis at the 1% and 5% significance level, respectively. We conclude that the first differences of the logged series do not contain a unit root and they are trend stationary.*