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YIELD CURVE AND FINANCIAL UNCERTAINTY: EVIDENCE BASED ON US DATA

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Yield Curve and Financial Uncertainty: Evidence Based on US Data*

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Abstract

How do short and long term interest rates respond to a jump in financial uncertainty? We address this question by conducting a local projections analysis with US monthly data, period: 1962-2018. The state-of-the-art financial uncertainty measure proposed by Ludvigson, Ma, and Ng (2019) is found to predict movements in interest rates at different maturities. In particular, an increase in financial uncertainty is found to trigger a negative and significant response of both short and long term interest rates. The response of the short end of the yield curve (i.e., of short term interest rates) is found to be stronger than that of the long end (i.e., of long term ones). In other words, a financial uncertainty shock causes a temporary steepening of the yield curve. This result is consistent, among other interpretations, with medium-term expectations of a recovery in real activity after a financial uncertainty shock.

Keywords: Financial uncertainty shocks, yield curve, local projections, inflation dynamics, output growth.

JEL codes: C22, E32, E52.

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1 Introduction

How does the yield curve respond to changes in financial uncertainty? While many recent studies have quantified the effects of different types of uncertainty shocks on output, unemployment, and inflation, the impact of jumps in uncertainty on short and (above all) long term interest rates has been much less scrutinized. This is somewhat surprising, given the relevance of long term interest rates for households' consumption decisions and entrepreneurs' investment and labor demand.

This paper contributes to filling this gap by estimating the response of a battery of interest rates of US Government bonds with different maturities over the period 1962-2018. We use local projections à la Jordà (2005) to produce the impulse responses of such interest rates to a jump in the state-of-the-art financial uncertainty measure recently proposed by Ludvigson, Ma, and Ng (2019). We find financial uncertainty to negatively and significantly impact all the elements of the term structure we consider. Talking about maturities, we find a stronger response of the short end of the term structure (which relates to short term interest rates). The peak response of the 3-month interest rate is found to be close to -0.4 percentage points, while that of the 10-year yield is estimated to be about -0.2 percentage points to a jump in uncertainty (the size of the jump being one standard deviation). The positive slope of the yield curve (the sign of the slope of the yield curve being captured by the difference between long term and short term rates) conditional on a jump in uncertainty is documented to be relatively robust over the 5-year horizon we consider when we compute our impulse responses. We interpret such a slope as being consistent with expectations of future inflation and, above all, future output recovery after the shock. Interestingly, when extending our analysis to study the macroeconomic response to a financial uncertainty shock, we find a positive response of inflation in the short run, and a negative response of output growth which peaks shortly before one year, then rebounds, and temporarily becomes positive 3 years after the shock before going back to its pre-shock value.

This study relates to the burgeoning literature on the effects of uncertainty shocks that has known a renaissance for the last ten years since the paper by Bloom (2009). Surveys have been offered by Bloom (2014), Bloom (2017), Castelnuovo, Lim, and Pellegrino (2017), and Castelnuovo (2019). Different measures of uncertainty have been proposed, and there is an on-going discussion on what measure(s) one should consider to identify uncertainty shocks.¹ Our focus on financial uncertainty is justified by recent

¹Proxies for conceptually different uncertainty measures have been constructed by using, among

findings in the literature that point to this type of uncertainty as a driver of the business cycle. Differently, macroeconomic uncertainty is found to be endogenous and responsive to first moment shocks (such as, for instance, monetary policy shocks, financial shocks, fiscal shocks, technology shocks, and so on). A recent paper by Ludvigson, Ma, and Ng (2019) lends support to this view. They construct measures of financial, macroeconomic, and real uncertainty with a data-rich approach developed by Jurado, Ludvigson, and Ng (2015). They find evidence supporting the role of financial uncertainty as a driver of the business cycle, while macroeconomic uncertainty is found to act as a magnifier of the effects of other shocks. Lütkepohl and Milunovich (2016) and Casarin, Forni, Marcellino, and Ravazzolo (2018) confirm this finding. Angelini, Bacchiocchi, Caggiano, and Fanelli (2019) do not reject the hypothesis that both financial and macroeconomic uncertainty are drivers of the business cycle (for similar results, see Angelini and Fanelli (2019)).² We see the relationship between the financial side of uncertainty and the term structure of interest rates as a natural one. At the very least, the results documented in this paper can be seen as correlations that structural dynamic stochastic general equilibrium models should aim at replicating.

Our study connects with other strands of the literature. First, it relates to the papers that focus on financial uncertainty and their effects on the macroeconomic environment (Bloom (2009), Caggiano, Castelnuovo, and Groshenny (2014), Carriero, Mumtaz, Theodoridis, and Theophilopoulou (2015), Leduc and Liu (2016), Basu and Bundick (2017)). This literature has focused on (empirical and/or theoretical) frameworks where term structure data are not explicitly modeled. Differently, our paper focuses on the response of the yield curve to financial uncertainty. Second, our paper is linked to those investigating the relationship between uncertainty and monetary policy (Eickmeier, Metiu, and Prieto (2016), Aastveit, Natvik, and Sola (2017), Pellegrino (2018), Pellegrino (2019), and Castelnuovo and Pellegrino (2018)). Our findings are consistent with the "risk-management hypothesis" put forth by Greenspan (2004), i.e., the impact of (different forms of) uncertainty on the US monetary policy decision mak-

others, keywords in newspapers (Alexopoulos and Cohen (2015), Baker, Bloom, and Davis (2016)), forecast disagreement (Bachmann, Elstner, and Sims (2013), Sheen and Wang (2019)), real GDP forecast errors (Rossi and Sekhposyan (2015, 2016)), forecast errors of several macroeconomic and financial indicators (Carriero, Clark, and Marcellino (2018b)), Bloomberg forecasts (Scotti (2016)), interest rate data (Mumtaz and Zanetti (2013), Creal and Wu (2017), Istrefi and Mouabbi (2018), and Bundick, Herriford, and Smith (2017)), and Google Trends data (Castelnuovo and Tran (2017), Shields and Tran (2019)).

²This discussion is not settled yet. For instance, Carriero, Clark, and Marcellino (2018a) find macroeconomic uncertainty to be a driver of the business cycle.

ing. Taylor-rule based investigations considering proxies for risk have been proposed by Castelnovo (2003), Castelnovo (2007), Evans, Fisher, Gourio, and Krane (2015), Caggiano, Castelnovo, and Nodari (2018), Caldara and Herbst (2018), and Ponomareva, Sheen, and Wang (2019); quantile-regression frameworks linking policy rates to risk have been estimated by Giglio, Kelly, and Pruitt (2016); nonlinear VARs connecting uncertainty shocks and policy rates have been estimated by Caggiano, Castelnovo, and Nodari (2019). Our paper confirms, with a different empirical strategy such as local projections, that the response of the short end of the term structure is indeed consistent with the risk-management hypothesis postulated by Greenspan (2004). Third, the results obtained with our reduced-form empirical investigation are in line with previous findings put forth by authors working with structural nonlinear models that acknowledge a role for risk to understand the term premia (Rudebusch and Swanson (2008), Andreasen (2012), Rudebusch and Swanson (2012), Andreasen, Fernández-Villaverde, and Rubio-Ramírez (2017), Andreasen (2019), Bianchi, Kung, and Tirsikh (2019)). To some extent, it also connects with models studying the relationship between the long end of the term structure and monetary policy (Kulich (2007)). While these contributions hinge upon micro-founded theoretical frameworks, our empirical investigation employs a minimum set of assumptions and, therefore, provides a more "data-driven" answer to the question: "What happens to the yield curve when (financial) uncertainty shocks hits the economy?".

The next Section presents the data employed in this analysis and the empirical framework we use to produce our impulse responses. Section 3 documents our empirical findings. Section 4 concludes.

2 Data and empirical model

Data. We work with interest rates on Treasury Bills at different maturities, i.e., 3 and 6 months, and 1, 5, and 10-year ahead. To maximize the number of monthly observations in our sample, the first two interest rates are secondary market rates, while the other three are constant maturity rates.³ Turning to the measure of financial uncertainty, we work with the one recently proposed by Ludvigson, Ma, and Ng (2019). In short, such a measure is constructed by modeling the common volatility of the unpredictable

³Data source: Federal Reserve Bank of St. Louis' database. The 3 and 6-month constant maturity rate series are available from 1982M1. The correlation between the series we use (3 and 6-month secondary market rate) and the constant maturity rate ones is basically one.

components of 148 financial series, where the unpredictable component of each series is computed by performing a one-step ahead forecasting exercise. Finally, we also consider the year-on-year annualized growth rate of inflation and industrial production to capture the stance of the business cycle and its effects on the yield curve. All data used in this paper are downloadable from the Federal Reserve of St. Louis' website, except for the measure of financial uncertainty, which is available at Sydney Ludvigson's website <https://www.sydneyludvigson.com/> .

Figure 1 plots the time series of the interest rates and the financial volatility measure we work with. As one can see from the top panels, middle panels, and bottom/left panel, all interest rates display a clear upward trend from the early 1960s until the early 1980s. Then, a change in sign occurs, and a negative trend is followed by all rates until the end of the sample, with interest rates recording historically low values during and after the 2007-09 great recession. The low frequency component of these rates is likely to be related to the evolution of the trend inflation process estimated by many authors (Ireland (2007), Cogley and Sbordone (2008), Cogley, Primiceri, and Sargent (2010), Castelnuovo (2010b), Castelnuovo (2012a), Castelnuovo, Greco, and Raggi (2014)). The change in the slope of such process could be possibly related to the shift to a more aggressive systematic monetary policy occurred when Paul Volcker became chairman of the Federal Reserve in August 1979 (Clarida, Galí, and Gertler (2000), Lubik and Schorfheide (2004), Boivin and Giannoni (2006), Coibion and Gorodnichenko (2011), Coibion and Gorodnichenko (2012), Castelnuovo and Fanelli (2015), and Arias, Ascari, Branzoli, and Castelnuovo (2019)). Such a change is likely to have had effects also on short-run inflation expectations (Castelnuovo and Surico (2010), Castelnuovo (2010a), Castelnuovo (2012b)). In spite of this common trend, differences may be noted in the level and volatility of longer term rates (5 and 10-year) with respect to those whose maturity is 1-year or lower. In particular, the interest rates of the latter group exhibit higher volatility, lower values in a number of cases, and hit and remain at the zero lower bound in the 2008-2015 period. This difference has already been stressed by, among others, Swanson and Williams (2014), who point out that the Federal Reserve was probably not very constrained by the zero lower bound given its ability to influence longer term rates during and after the great recession (for contrasting views on this matter, see Caggiano, Castelnuovo, and Pellegrino (2017) and Swanson (2019)). Turning to financial uncertainty (Figure 1, bottom/right panel), one can clearly identify swings in this series, with the two highest peaks corresponding to the black Monday in October 1987 and the acceleration of the financial crisis triggered by the collapse of Lehman

Brothers in September 2008. Differently from the interest rates displayed in Figure 1, financial uncertainty does not appear to feature any trend.

Empirical model. For $h = 0, \dots, H$, we estimate the following framework:

$$R_{t+h}^j = c_h + \beta_h unc_t + \gamma_h z_t + \varepsilon_{t+h} \quad (1)$$

where R_{t+h}^j is the annual yield on a bond with maturity j , $j = 3$ months, 6 months, 1 year, 5 years, and 10 years; unc_t is the proxy for financial uncertainty we use, i.e., the financial uncertainty measure estimated by Ludvigson, Ma, and Ng (2019) and conditional on a forecasting horizon equal to one month; z_t is a set of controls including the contemporaneous realizations of the year-on-year growth rates of CPI inflation and industrial production, as well as the lagged values of all interest rates we work with (one lag per each interest rate).

Local projections (LP) are predictive models forecasting R_{t+h}^j directly with the covariates on the right-hand side of eq. (1). Hence, all estimated coefficients are indexed by h , which is the horizon considered when running the regression above. In particular, the coefficient β_h captures the response of R_{t+h}^j at time $t+h$ to a shock at time t . This implies that one can construct the impulse response function $\partial R_{t+h}^j / \partial unc_t$, $h = 0, \dots, H$ as a sequence of the coefficients β_h , which are estimated in a series of single regressions of interest for each horizon. Differently, VARs - often used to compute impulse responses to identified structural shocks - provide the econometrician with the parameters for $h = 0$. Then, one constructs the impulse response functions by employing the estimated VAR dynamic structure. (For a formal comparison between VAR and LP impulse responses, see Plagborg-Møller and Wolf (2018).) Before running our regressions, we standardize unc to have zero mean and variance equal to one. This enables us to interpret the percentage change response of R_{t+h}^j captured by β_h as the response to a one standard deviation jump in uncertainty.⁴ We estimate eq. (1) with ordinary least squares. One implication of Jordà's (2005) method is that the error terms ε_{t+h} are serially correlated due to the successive leading of the dependent variable. Hence, we use the Newey and West (1987) correction for our standard errors. Finally, we set $H = 60$, i.e., the maximum horizon considered for our impulse responses is 5 years.

⁴Bivariate VARs estimated with financial uncertainty and (alternatively) each one of the interest rates considered here point to evidence in favor of Granger causality going from financial uncertainty to all such rates (at least at a 10% significance level). The opposite is not true for the 3-month, 6-month, and 10-year rates, although evidence of reverse causality is found for the 1-year and 5-year rates. The main result of this paper, i.e., the steepening of the yield curve after an uncertainty shock, is robust to discarding the results related to the 1-year and 5-year rates.

3 Findings

Figure 2 plots the impulse responses to an uncertainty shock of the five interest rates we model. Financial uncertainty is found to have a negative and significant impact on the whole spectrum, with a quantitatively stronger effect on the short end of the yield curve (peak response: -0.4 percentage points) than on the long end (peak response: -0.2 percentage points). This implies that, at least in this sample, an increase in uncertainty is followed by a temporarily steeper yield curve. Interestingly, Figure 3 confirms that the steepening of the yield curve following a (mathematically) positive change in financial uncertainty occurs over most of the horizons we consider in our analysis, although - starting after about 2 years - it gets gradually less important from a quantitative standpoint for longer horizons (a sign that the effects of the shock are temporary). Importantly, the impact of uncertainty on interest rates at various maturities is present in spite of the fact that we control for the role played by inflation, output growth, and the past values of the whole battery of interest rates.⁵

Why do yields decrease? The negative response of yields can be driven by different channels. First, an increase in uncertainty reduces aggregate consumption via precautionary savings. Hence, resources switch from consumption to savings. Given the inverse relationship between bond prices and yields, the latter decrease due to an increase in the demand for bonds. Second, uncertainty shocks are typically recessionary. At least in normal times, the response by monetary policy authorities is that of slashing the policy rate. Given the connection between short and long rates via the term structure, all rates decline. Third, uncertainty surrounding the economic outlook *per se* can lead to a more cautious monetary policy if the central bank acts as a risk-manager and systematically responds to fluctuations in uncertainty.

Why does the curve get steeper? One possibility is that, after an uncertainty shock, investors decide to shorten the maturity of the financial assets they hold in their portfolio to reduce portfolio risks and avoid bearing a suboptimally high risk/yield ratio. Bianchi, Kung, and Tirsikh (2019) estimate a dynamic stochastic general equilibrium framework in which both second moment shocks to household's discount factor and second moment technology shocks can have first moment effects on the business cycle and the yield curve. In line with our findings (which are obtained with a reduced-form, "restriction-free" approach), both type of shocks lead to a temporary steepening of the

⁵The steepening of the yield curve is robust to excluding the zero lower bound period from our sample (regressions considering the 1962M1-2008M6 sample).

yield curve. Bianchi, Kung, and Tirskikh (2019) interpret such a change in the slope of the yield curve with the lower degree of insurance against the inflation risk provided by long term bonds. Other models delivering a steepening of the yield curve after an uncertainty shock for similar reasons are Andreasen (2012), Amisano and Tristani (2019), and Andreasen (2019). Another possible interpretation behind the positive slope of the yield curve after an uncertainty shock relates to the impact of inflation and output expectations formed by rational agents on long term interest rates. To the extent that a Taylor rule-type of link between the policy rate and macroeconomic indicators such as inflation and output growth exists, it may be the case that agents expect future rates to be higher than current ones because of an expected recovery of inflation and/or output growth in the medium run. We investigate this last hypothesis by extending our analysis to study the macroeconomic response to a financial uncertainty shock.

Figure 4 shows the response of inflation and output growth (proxied by the growth rate of industrial production) to an upward variation in financial uncertainty.⁶ Inflation immediately goes up after an uncertainty shock. If this response influences short run expectations more than long run ones, then expected inflation is not necessarily the explanation for the steepening of the yield curve. Differently, the response of output is negative, significant, and persistent, with a peak around 1 year. Then, output recovers, and indeed overshoots, peaking again after about 3 years before going back to its steady state. Medium-term expectations of a future recovery are possibly behind the more moderate drop of long term rates (as opposed to short term ones) after a financial uncertainty shock.

As a side note, the responses of inflation and output depicted in Figure 4 are also interesting from a macroeconomic standpoint. These responses place the financial uncertainty shock under the category "supply shocks", i.e., such a shock is found to move inflation and output in opposite directions. Interestingly, this result is not a solid one in the literature. Leduc and Liu (2016) find that both inflation and output temporarily decrease after a financial uncertainty shock, which they therefore classify as a "demand" one. Fasani and Rossi (2018) work with a slightly modified version of Leduc and Liu's (2016) model in which the policy response to an uncertainty shock is gradual due to an interest rate smoothing motive. They find that this modification of the Leduc-Liu framework changes the sign of the response of inflation and leads to classify the uncer-

⁶These responses are computed by manipulating eq. (1) to have inflation (or output growth) on the left hand side and the lag of inflation (or output growth) on the right hand side to avoid having the very same variable with the very same timing on both sides of the equation when $h = 0$.

tainty shock as a supply shock. Moreover, from a firm's standpoint, it could be optimal to increase prices in response to an increase in uncertainty when prices are sticky, because firms want to avoid signing contracts with suboptimally low prices when some possible (a priori uncertain) future realizations of technology or demand occur (realizations that, with too low prices, would lead to a loss in profits) (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015)). Obviously, understanding the nature of uncertainty shocks is relevant from a policy standpoint because of the different trade-offs implied by supply and demand shocks. Finally, focusing on the response of output in Figure 4, we note the "drop-rebound-overshoot" type of dynamics originally documented by Bloom (2009). He interprets this evidence with a model in which the reallocation of resources from low to high-productive firms after a firm-specific technology-related uncertainty shock leads to a temporary overshoot of the level of output (differently, here we have an overshoot of the growth rate).⁷ Evidence in favor of such a dynamic behavior by real activity indicators in presence of an uncertainty shock can also be found in Caggiano, Castelnuovo, and Groshenny (2014).

Before moving to our conclusions we notice what follows. While a decrease in the short term rates is a very likely event after an uncertainty shock given the monetary policy response to a fall in output, a decrease in the long term ones is far from obvious *a priori*. In fact, there are contrasting effects to consider when it comes to predicting the response of the long end of the yield curve. On the one hand, a monetary policy easing tends to push the long end of the curve downwards. On the other hand, a shortening of financial positions by investors after the shock exerts an upward pressure on long term interest rates. Hence, we see our result on the negative change of all yields (long term ones included) as an interesting stylized fact modelers should consider when constructing structural frameworks featuring uncertainty and the term structure.

4 Conclusions

This short paper has estimated the link between changes in financial uncertainty and the yield curve using US monthly data, period: 1962-2018. The main empirical findings are: i) the yield curve responds negatively and significantly to an uncertainty shock; ii) the short end of the curve (which is the end of the curve related to short term interest rates) is more responsive than the long end (which relates long term interest rates), i.e.,

⁷The persistence of the output growth rate (as well as that of the inflation rate) is in part due to the fact that we are using year-on-year rates, i.e., 12-term moving averages of monthly rates.

after an uncertainty shock, the slope of the yield curve temporarily increases; iii) such an increase is confirmed by most of the horizons considered by our predictive exercise; iv) we find evidence consistent with a possible link between the rotation of the yield curve mentioned above and the response of output growth to a financial uncertainty shock

Our analysis has just scratched the surface of the relationship between uncertainty and the term structure. First, it would be interesting to check if these results are robust to using data of other countries. For instance, Baker, Bloom, and Davis (2016) find uncertainty shocks to trigger a macroeconomic response in a variety of industrialized economies. It would be useful to understand if this is true also for the term structure of interest rates, and what the effect on the slope of the yield curve is. Given the role played by forecasts on the economic outlook for the response and the slope of the curve, one could speculate that countries with more credible central banks (perhaps thanks to the official adoption of the inflation targeting regime) could feature different responses than countries whose monetary policy is more surrounded by uncertainties. Moreover, the different business cycle effects found by some researchers to changes in the same concept of uncertainty across different countries (e.g., Castelnuovo and Tran (2017)) could also be related to different monetary policy stances (e.g., the presence of the ZLB in some countries, but not in others). Related to this issue, many researchers have recently focused on the effects of global uncertainty (for a survey and some novel empirical results based on the global financial uncertainty index developed by Caggiano and Castelnuovo (2019), see Castelnuovo (2019)). It would be interesting to understand if movements in the term structure are mostly due to domestic uncertainty or, differently, to uncertainty-triggering global events. Possibly, cross-country differences based on the different degree of trade and financial openness could emerge. Third, this piece has assumed that the transmission from financial uncertainty shocks to the term structure of interest rate in the US is linear. While being a convenient assumption, recent research has documented nonlinearities in the macroeconomic impact of exogenous changes in uncertainty due to a different stance of the business (Caggiano, Castelnuovo, and Groshenny (2014), Nodari (2014), Caggiano, Castelnuovo, and Figueres (2017), Caggiano, Castelnuovo, and Nodari (2019), Caggiano, Castelnuovo, and Figueres (2019), Pellegrino, Caggiano, and Castelnuovo (2019)) or financial (Alessandri and Mumtaz (2019)) cycle. Obviously, it would be interesting to understand if these nonlinearities play a role also for the response of the yield curve to an uncertainty shock. Finally, this study has assumed that changes in financial uncertainty are exogenous to movements in the term structure

of interest rates. Developing instruments to minimize the risk of getting spurious results from endogeneity-prone regressions is clearly an important avenue for future research. For a first attempt in this sense, see Piffer and Podstawski (2018).

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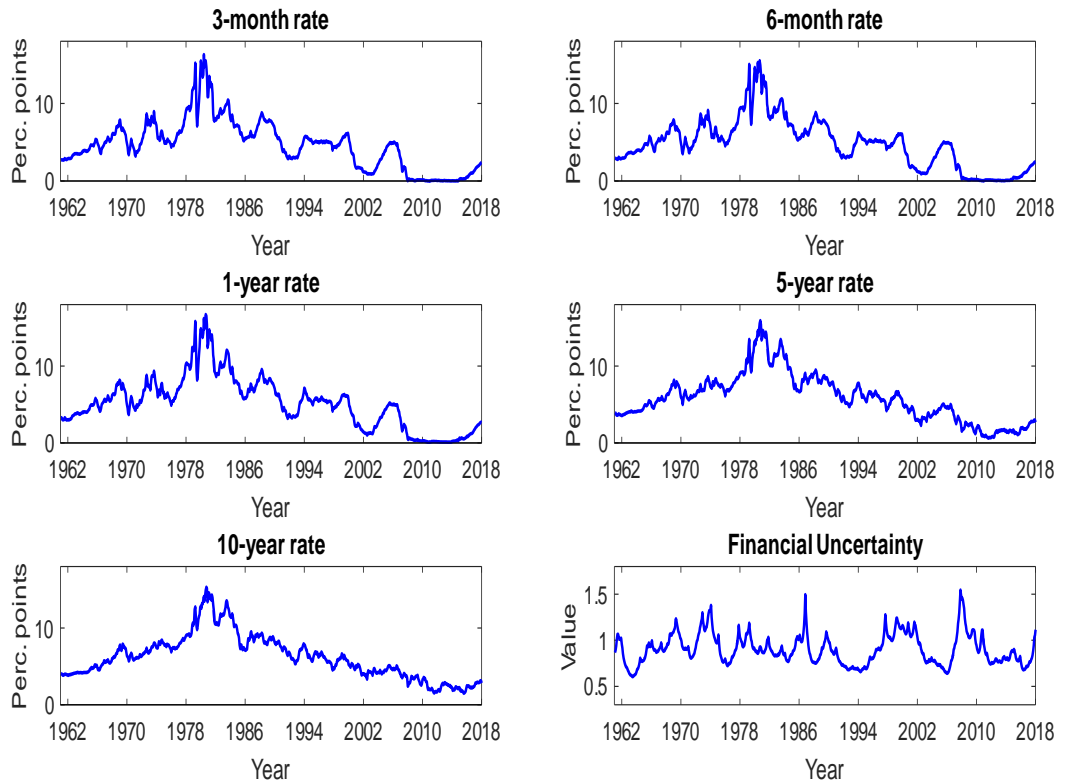


Figure 1: **Interest rates and financial volatility.** Top panels, middle panels and bottom panel/left column: Interest rates related to Treasury Bills at different maturity. Bottom panel/right column: Measure of financial volatility by Ludvigston, Ma, and Ng (2019) (conditional on a forecasting horizon = 1 month).

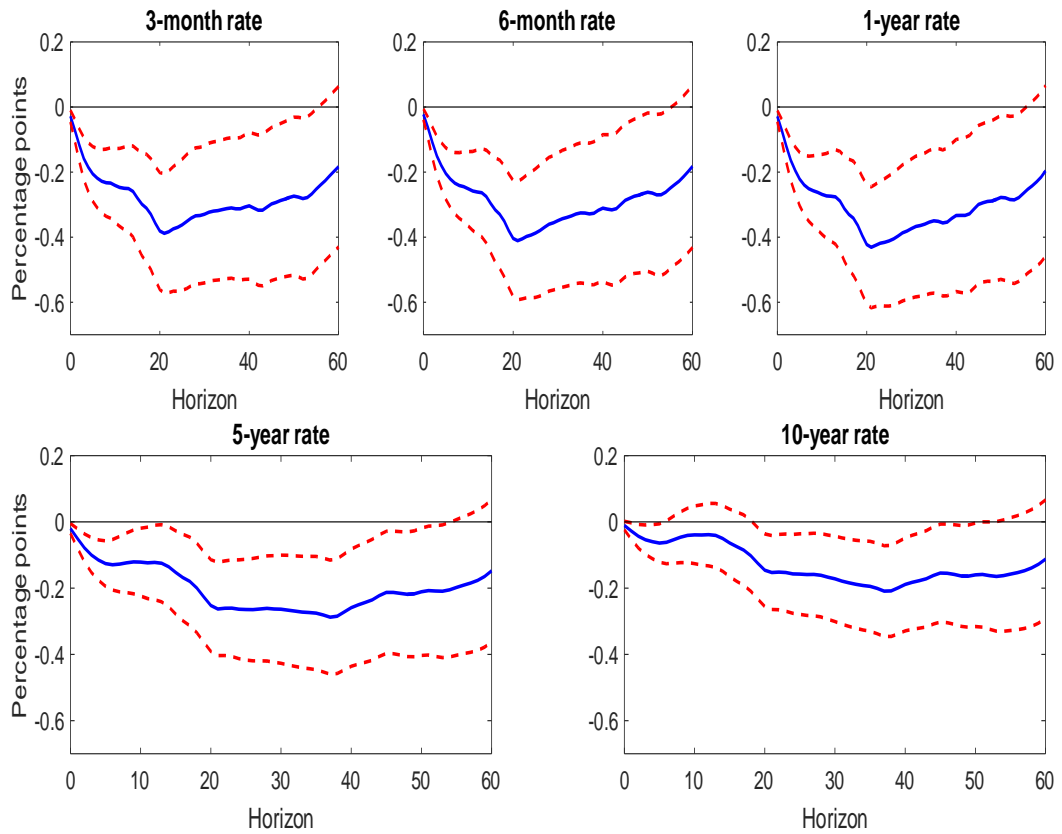


Figure 2: **Response of interest rates to a financial uncertainty shock.** Measure of financial uncertainty by Ludvigson, Ma, and Ng (2019) standardized to have zero mean and standard deviation equal to one to interpret the responses above as responses to one-standard deviation shock. Point estimates (68% confidence bands) identified by solid blue (dashed red) lines.

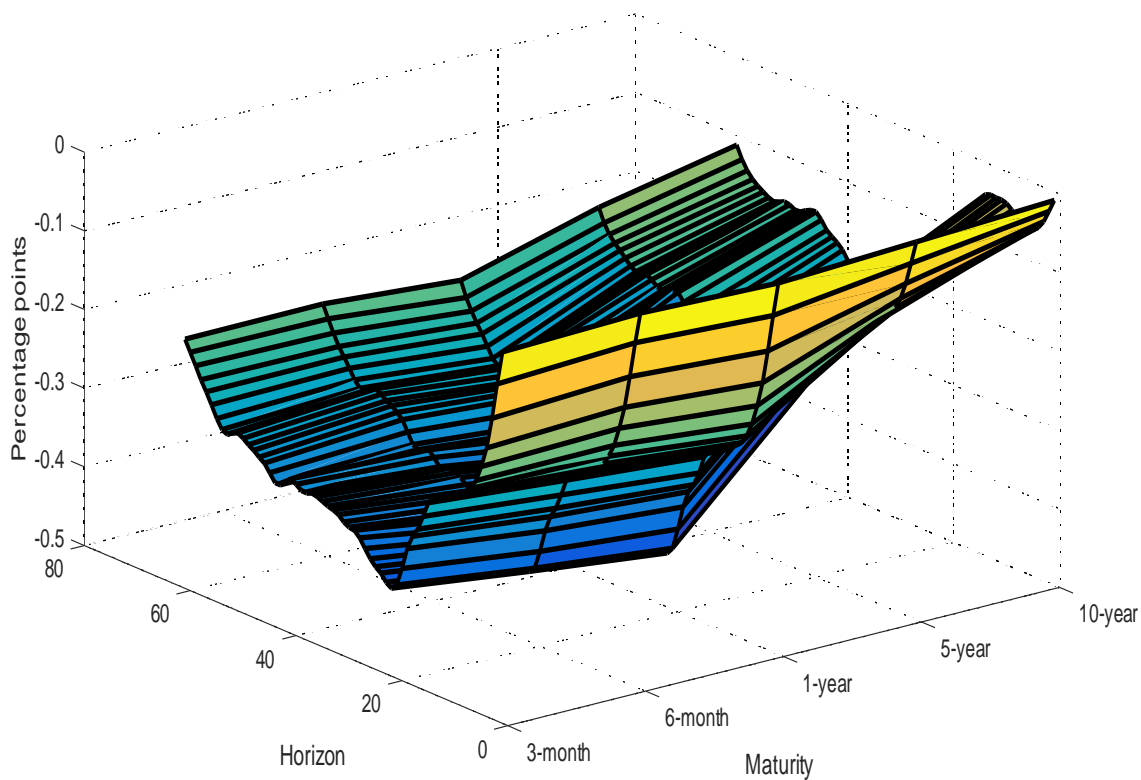


Figure 3: **Evolution of the yield curve over different horizons in response to a financial uncertainty shock.** Figure constructed by relying on the point estimates presented in Figure 2. Measure of financial uncertainty by Ludvigson, Ma, and Ng (2019) standardized to have zero mean and standard deviation equal to one to interpret the responses above as responses to one-standard deviation shock.

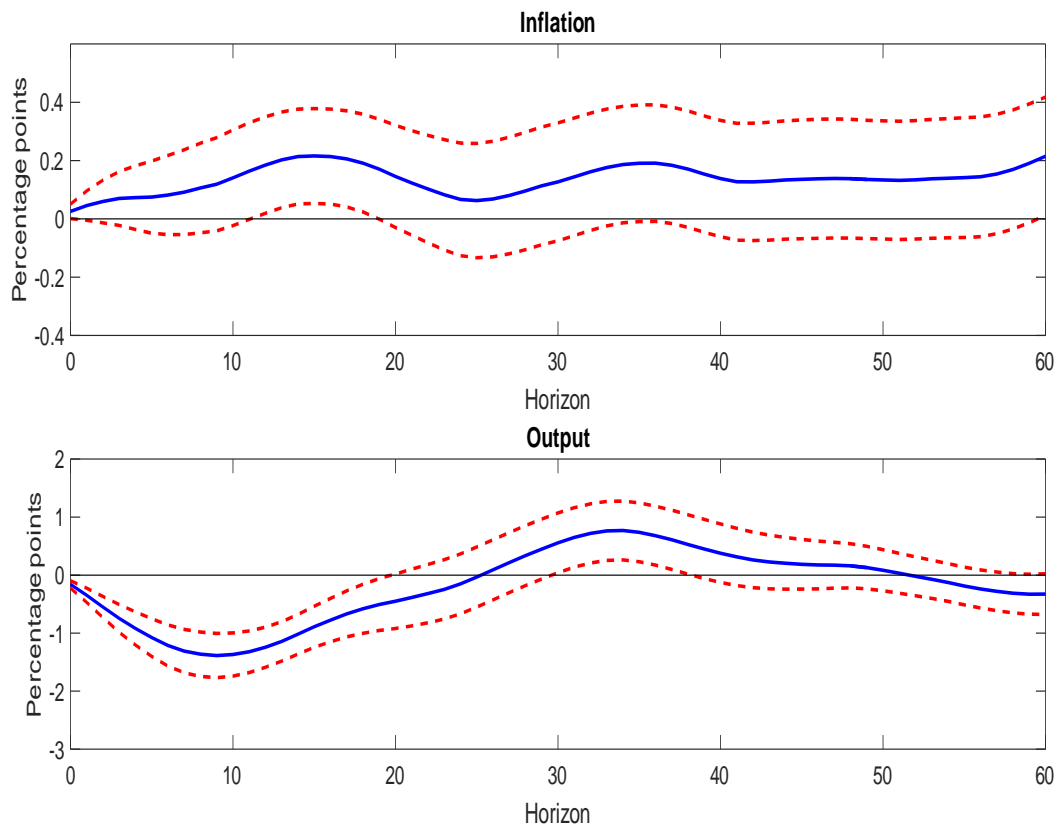


Figure 4: **Response of inflation and output to a financial uncertainty shock.** Measure of financial uncertainty by Ludvigson, Ma, and Ng (2019) standardized to have zero mean and standard deviation equal to one to interpret the responses above as responses to one-standard deviation shock. Inflation (output) computed as the percentualized yearly growth rate of the consumer price (industrial production) index. Point estimates (68% confidence bands) identified by solid blue (dashed red) lines.