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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.

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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 scrutinised. This is somewhat surprising, given the relevance of long-term interest rates for households' consumption decisions and entrepreneurs' investment and labour 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

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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 three 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 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 et al. (2018) confirm this finding. Angelini et al. (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 et al. 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 modelled. 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 et al. 2017; Pellegrino 2018; Pellegrino 2019; Castelnuovo and Pellegrino 2018). Our findings are consistent with the 'risk-management hypothesis' put forth by Greenspan (2004), that is, the impact of (different forms of) uncertainty on US monetary policy decision making. Taylor-rule based investigations considering proxies for risk have been proposed by Castelnuovo (2003), Castelnuovo (2007), Evans et al. (2015), Caggiano, Castelnuovo 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, Castelnuovo 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;

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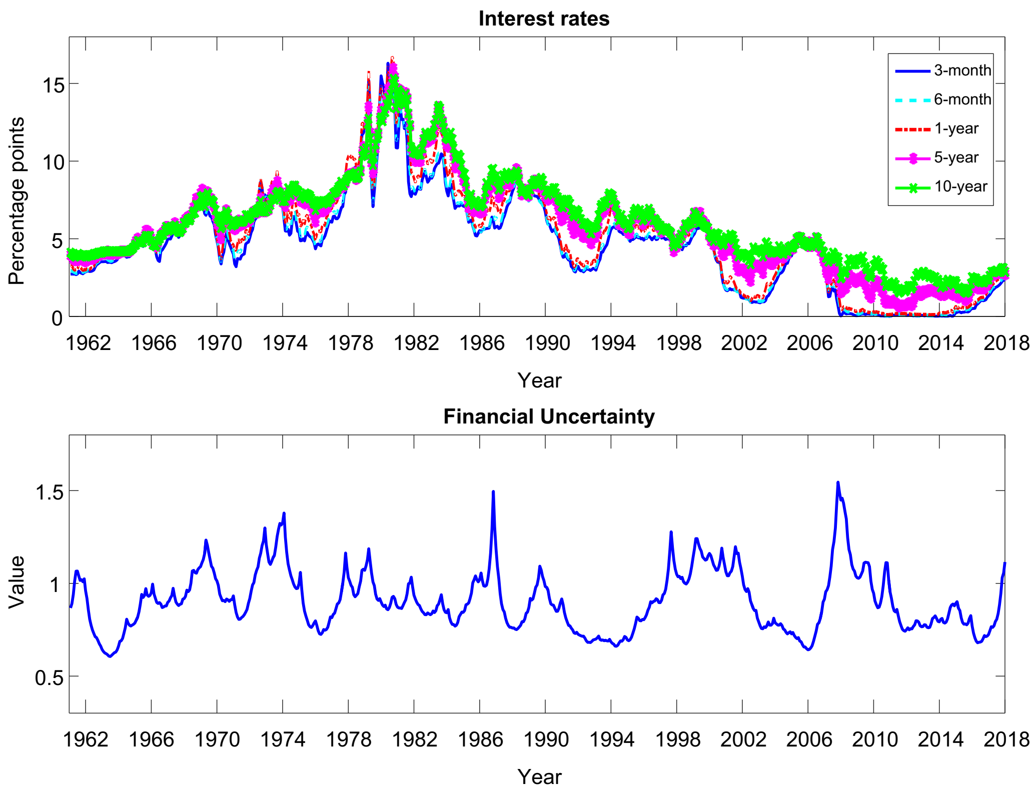
Andreasen 2012; Rudebusch and Swanson 2012; Andreasen, Fernández-Villaverde and Rubio-Ramírez 2017; Andreasen 2019; Bianchi, Kung and Tirskikh 2019). To some extent, it also connects with models studying the relationship between the long end of the term structure and monetary policy (Kulish 2007). While 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, that is, 3 and 6 months, and 1, 5 and 10-year ahead. To maximise 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 modelling the common volatility of the unpredictable 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 annualised growth rate of inflation and industrial production to

Figure 1 Interest Rates and Financial Volatility



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

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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 2007–2009 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; Arias et al. 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; 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 $h = 0,...,H$, we estimate the following framework:

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

where R^j_{t+h} 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, that is, 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 realisations 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^j_{t+h} directly with the covariates on the right-hand side of equation (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^j_{t+h} at time $t + h$ to a shock at time t. This implies that one can construct the impulse response function $\partial R^j_{t+h} / \partial unc_t$, $h = 0,..,H$ 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

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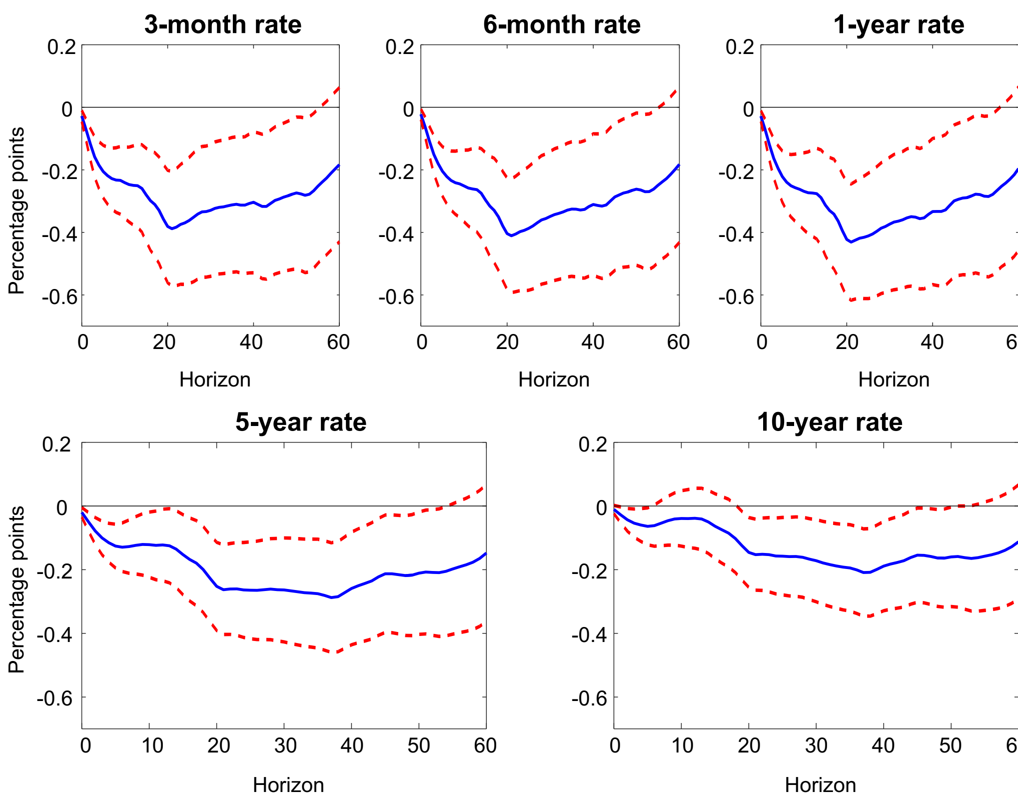
response functions by employing the estimated VAR dynamic structure. (For a formal comparison between VAR and LP impulse responses, see Plagborg-Møller and Wolf 2018). Before running our regressions, we standardise *unc* to have zero mean and variance equal to one. This enables us to interpret the percentage change response of R^j_{t+h} captured by β_h as the response to a one standard deviation jump in uncertainty.[4] We estimate equation (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 $H = 60$, that is, the maximum horizon considered for our impulse responses is 5 years.

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

Figure 2 Response of Interest Rates to a Financial Uncertainty Shock



Notes: Measure of financial uncertainty by Ludvigson, Ma and Ng (2019) standardised 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% condence bands) identified by solid blue (dashed red) lines.

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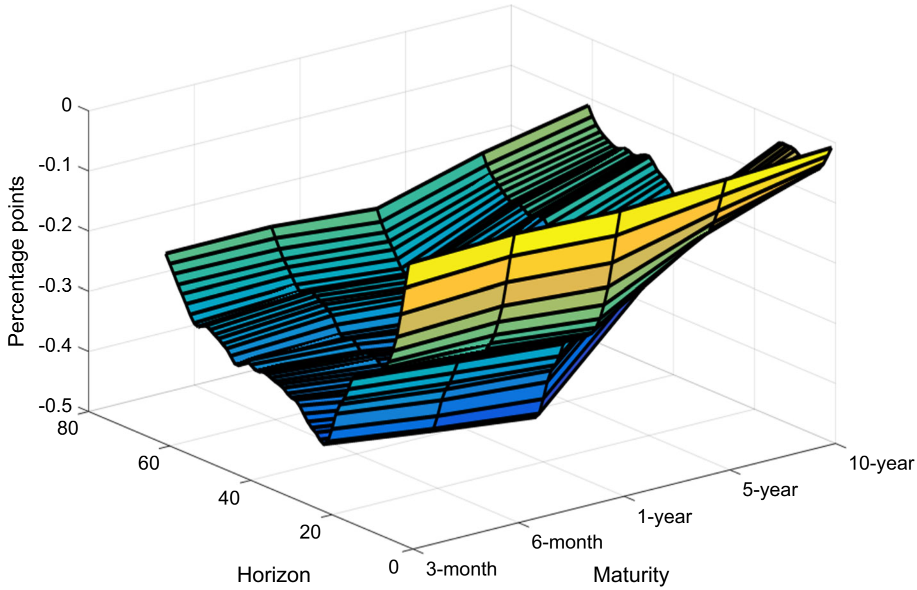
Figure 3 Evolution of the Yield Curve over Different Horizons in Response to a Financial Uncertainty Shock



Notes: Figure constructed by relying on the point estimates presented in Figure 2. Measure of financial uncertainty by Ludvigson, Ma and Ng (2019) standardised to have zero mean and standard deviation equal to one to interpret the responses above as responses to one-standard deviation shock.

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 cautions 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 Tirskikh (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 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),

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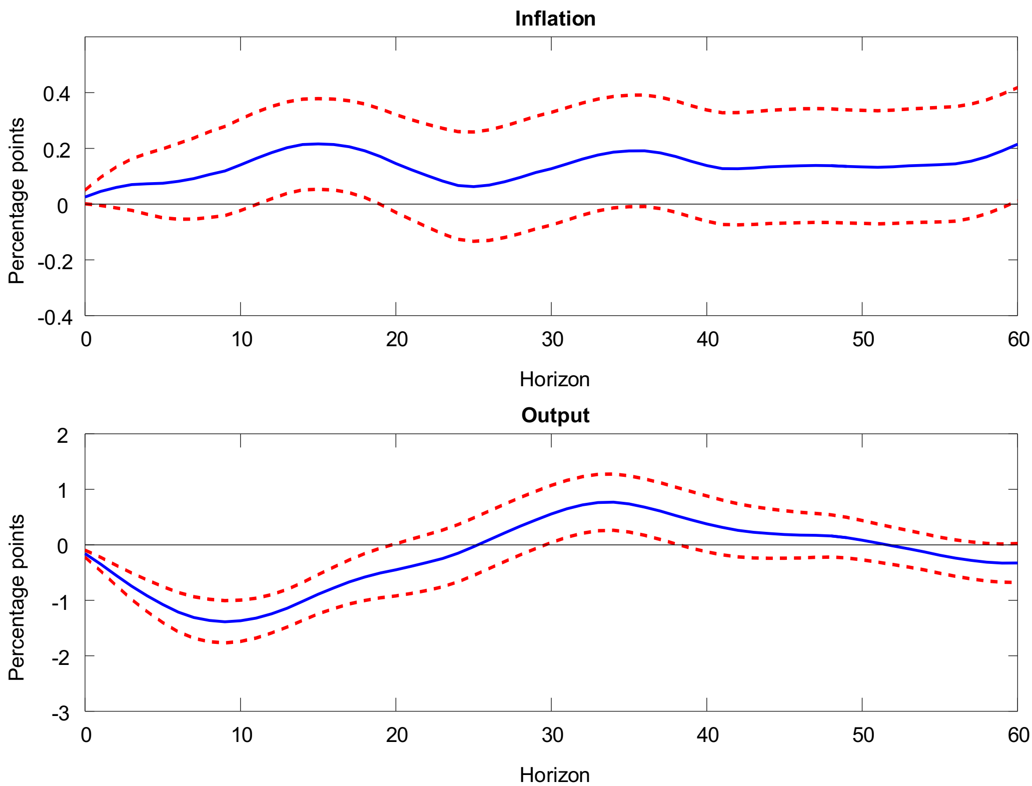
Amisano and Tristani (2019), and Andreasen (2019). Another possible interpretation behind the positive slope of the yield curve after an uncertainty shock relates to the impact of inflation and output expectations formed by rational agents on long-term interest rates. To the extent that a Taylor rule-type 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', that is, such

Figure 4 Response of Inflation and Output to a Financial Uncertainty Shock



Notes: Measure of financial uncertainty by Ludvigson, Ma and Ng (2019) standardised 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 percentualised yearly growth rate of the consumer price (industrial production) index. Point estimates (68% condence bands) identified by solid blue (dashed red) lines.

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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 uncertainty 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 realisations of technology or demand occur (realisations that, with too low prices, would lead to a loss in profits) (Fernández-Villaverde et al. 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 favour of such a dynamic behaviour 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 stylised 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), that is, 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 industrialised 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 where monetary policy is more surrounded by

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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 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 United States 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 minimise 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).

Endnotes

1. Proxies for conceptually different uncertainty measures have been constructed by using, among 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 2018), Bloomberg forecasts (Scotti 2016), interest rate data (Mumtaz and Zanetti 2013; Creal and Wu 2017; Istrefi and Mouabbi 2018; Bundick, Herriford and Smith 2017), and Google Trends data (Castelnuovo and Tran 2017; Shields and Tran 2019).

2. This discussion is not settled yet. For instance, Carriero, Clark and Marcellino (2019) find macroeconomic uncertainty to be a driver of the business cycle.

3. Data 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.

4. Bivariate VARs estimated with financial uncertainty and (alternatively) each one of the interest rates considered here point to evidence in favour 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, that is, 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.

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

6. These responses are computed by manipulating equation (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 $h = 0$.

7. The 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, that is, 12-term moving averages of monthly rates.

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