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Interbank rate uncertainty and bank lending

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Abstract

This paper investigates the effects of interbank rate uncertainty on lending rates to euro area firms. We introduce a novel measure of interbank rate uncertainty, computed as the cross-sectional dispersion in interbank market rates on overnight unsecured loans. Using proprietary bank-level data, we find that interbank rate uncertainty significantly raises lending rates on loans to firms, with a peak effect of around 100 basis points during the 2007-2009 global financial crisis and the 2010-2012 European sovereign crisis. This effect is attenuated for banks with lower credit risk, sounder capital positions and greater access to central bank funding.

JEL classification: E44, D80, G21.

Keywords: Interbank market, uncertainty, bank lending.

Non-technical summary

Over the last decade, a vast literature has documented the adverse effects of disruptions in the interbank market on the rest of the economy, drawing motivation from the developments during the global financial crisis of 2007-2009 and the European sovereign debt crisis of 2010-2012. This paper provides contribution to this literature by investigating empirically how interbank rate uncertainty affects bank lending rates on loans to euro area non-financial corporations, and how this is influenced by bank-specific characteristics. Understanding this connection on the disaggregated level presented here is key both for thinking about monetary policy transmission as well as bank regulation.

To that end, we introduce a novel measure of interbank rate uncertainty, computed as the cross-sectional dispersion in interest rates on overnight unsecured loans between euro area banks. Pertaining to overnight unsecured loans, our measure of interbank rate uncertainty should be relatively immune to uncertainty about the future course of (monetary policy) interest rates; instead it could be interpreted as reflecting counterparty risk and precautionary motive for hoarding liquidity in the interbank market. Using proprietary data on a large set of individual banks, we run panel regressions of bank lending rates to non-financial corporations on interbank rate uncertainty and its interactions with bank-level funding and capital positions.

We find that interbank rate uncertainty raises lending rates on loans to firms, with upward pressures peaking at around 100 basis points during the interbank market disruptions of the 2007-2009 global financial crisis and 2010-2012 European sovereign crisis. Consistent with theoretical insights, this effect of interbank rate uncertainty entails considerable time variation and bank heterogeneity. It is significantly more adverse for banks facing higher credit risk, as seen in their CDS spreads, and attenuated for banks with sounder capital positions and greater access to central bank funding. These findings lend empirical support to the bank-lending channel and suggest a possible role for monetary and macro-prudential policy to stabilise interbank rate uncertainty.

1 Introduction

During the global financial crisis of 2007-2009 and the European sovereign debt crisis of 2010-2012, central banks and researchers have argued that disruptions in the interbank market and damages to the interbank network have contributed considerably to the severity of the recessions. A substantial theoretical literature has investigated the fragility of banking networks and the possibility for ensuing systemic banking crises (for example see Acemoglu et al. 2015; Allen and Gale, 2000; Freixas et al. 2000; Brusco and Castiglionesi, 2007; Caballero and Simsek, 2013). However, it has remained a considerable challenge to shed empirical light on these issues. Some of the literature has sought to reconstruct empirical banking networks from interbank loans (Gai et al. 2011), but drawing aggregate conclusions from such measures has largely remained elusive.

In this paper, rather than assessing the details of the banking networks per se, we focus on a single characteristic of that network: the dispersion of interbank rates. Suppose a bank in need of borrowing from the bank network will know to find itself exposed to a rate drawn at random from this dispersion, now more properly interpreted as interbank rate uncertainty. In anticipation, such a bank might then decide to be more cautious in its own lending to firms, either lending less and/or charging a higher rate. Do we see this in the data? This appears to be an empirically feasible question, and it is the question that we tackle in this paper.

To that end, we introduce a novel measure of interbank rate uncertainty, computed as the cross-sectional dispersion in interbank market rates on overnight unsecured loans.[1] For the sake of a comprehensive characterisation of the overnight interbank market, we derive this measure of dispersion on the basis of a Furfine-type algorithm applied to individual transaction data extracted from the leading European payment system (TARGET2).[2] Pertaining to overnight unsecured loans, our measure of interbank rate uncertainty should be relatively immune to uncertainty about the future course of (monetary policy) interest rates; instead it could be interpreted as reflecting counterparty risk and precautionary motive for hoarding

[1] Here we follow the practice of the uncertainty literature that often uses measures of cross-sectional dispersions to proxy for uncertainty.

[2] See Arciero et al. (2016) and Frutos et al. (2016), for earlier applications of this algorithm to the euro area.

liquidity in the interbank market.[3]

Armed with our interbank rate uncertainty measure, we investigate the impact on bank-to-firm lending rates. Specifically, we employ a panel regression of bank-level lending rates to (non-financial) firms on interbank rate uncertainty as well as its interactions with three variables proxying for bank-level funding (i.e. bank CDS spreads, and banks' borrowing through ECB's refinancing operations divided by main assets) and capital positions (bank capital divided by main assets). We control for additional bank-level characteristics and macroeconomic variables. In terms of data, we match datasets on bank-level lending rates and balance-sheet characteristics with confidential data on banks' recourse to ECB's refinancing operations, and bank CDS spreads data taken from Thomson Reuters Datastream. The analysis covers monthly data starting from June 2007 for 323 individual banks, comprising 80% of the assets held by euro area Monetary Financial Institutions.

We find that interbank rate uncertainty raises lending rates on loans to firms, with upward pressures peaking at around 100 basis points during the interbank market disruptions of the 2007-2009 global financial crisis and 2010-2012 European sovereign debt crisis. The effect of interbank rate uncertainty is considerably heterogeneous across banks and periods. First, it is significantly more adverse for banks facing higher credit risk, as seen in their CDS spreads. Second, it is attenuated for banks with a sounder capital base than their peers, suggesting that macro-prudential and micro-prudential policy, via strengthening capital standards, can contribute shielding the economy from the adverse impact of interbank rate uncertainty. Third, this impact is more contained for banks with a greater access to central bank funding, pointing to some alleviating effects of monetary policy via liquidity provision.

To assess the extent to which our measure reflects a component of uncertainty that is specific to the interbank market, in our empirical application we control for two relevant measures of general economic uncertainty. The first measure is the option-implied volatility on the Standard & Poor's 500 stock market index (VIX index), which is widely used in the literature as a broad measure of uncertainty, as documented for instance in Bloom (2014). The second measure, which we define as Euribor uncertainty, is constructed as the

[3] Heider et al. (2015) for instance develop a model of interbank lending and borrowing in which liquidity hoarding and counterparty risk are intrinsically linked.

interquartile range of the option-implied probability density function of the three-month Euribor interest rate one year ahead.[4] Rather than pertaining to overnight interbank loans (and hence contrary to our measure), Euribor uncertainty refers to future interbank market rates, and so it is presumably affected by uncertainty about policy rates going forward. Our estimates hold up the inclusion of these two measures of general economic uncertainty.

Viewed from this perspective, our paper provides contribution to the literature on the economic effects of uncertainty, as extensively reviewed for instance in Bloom (2014). That literature has argued how heightened uncertainty leads to a contraction in investment and consumption, either via increasing the option value of a sit-and-wait strategy in the presence of irreversible actions ("real options" effects; see for instance Bernanke, 1983), or via raising the external finance premium in the presence of financial frictions in credit markets ("financial frictions" effects; see for instance Christiano et al., 2014). Empirically, a number of studies have provided support to these predictions using a variety of proxies and indicators for uncertainty (see for instance Bloom et al., 2007). For instance, some studies have focused on uncertainty about economic policy and the regulatory sphere. Baker et al. (2013) for example develop an index of economic policy uncertainty and investigate its effect on investment and hiring. Fernandez-Villaverde et al. (2011b) focus on the uncertainty about future fiscal policy, and its impact on aggregate economic activity. Other studies have been more agnostic on the exact source of uncertainty, focusing on a variety of uncertainty proxies and relating them to macroeconomic activity (see for instance Jurado et el., 2013). Closely connected to our paper, Buch et al. (2015), Bordo et al. (2016) and Valencia (2017) assess how alternative measures of uncertainty similarly affect the credit channel. Differently to these contributions, we are explicit on the source of uncertainty, that we identify as rooted in bank-to-bank borrowing and find statistically and economically significant for bank-to-firm lending, beyond and above proxies of general economic uncertainty. As a result, our paper fits also within the strand of literature documenting how vulnerabilities in the banking system might originate and/or amplify adverse real-financial interactions (see for instance Acharya and Skeie, 2011; Brunnermeier and Sannikov, 2014; He and Krishnamurthy, 2012;

[4] The three-month Euribor is the rate at which a selection of European banks lend one another unsecured funds denominated in euros with a maturity of three months.

Adrian and Boyarchenko, 2012). For instance, a number of studies have documented how the severe liquidity dry-ups experienced during the global financial crisis of 2007-2009 and the European sovereign debt crisis of 2010-2012 stem from distresses in interbank markets (see for instance, Allen and Carletti, 2008; Brunnermeier, 2009; Frutos et al., 2016). Afonso et al. (2011) test the importance of both liquidity hoarding and counterparty risk in the U.S. interbank market, following Lehman's bankruptcy, finding that heightened concerns about counterparty risk reduced liquidity and increased the cost of finance for weaker banks.[5] Other studies have formalised the adverse macroeconomic impact of money market freezes within dynamic general equilibrium models (see for instance Bruche and Suarez, 2010; Gertler et al., 2016; De Fiore et al., 2019). Our work provides granular evidence on a possible mechanism via which interbank market conditions interact with bank funding and capital vulnerabilities in ways that affect price conditions of bank credit to non-financial firms.

The paper is organised as follows. Section 2 describes the measure of interbank rate uncertainty and its relation with alternative measures of uncertainty, as well as the bank-level data used in the estimation. Section 3 presents the modelling framework and derives the main findings. Section 4 concludes.

2 Data and measurement of uncertainty

2.1 Bank-level data

For the empirical analysis, we combine information on bank-level variables from alternative sources. The source for the bank-level balance-sheet variables, including main assets, bank capital and interbank liquidity, is the Individual Balance Sheet Items database (IBSI) while bank lending rates (on new loans to non-financial corporations) and deposit rates are extracted from the Individual MFI Interest Rate database (IMIR).[6] These two proprietary datasets are maintained at the ECB and, for the purpose of this paper, they are matched with confidential information on banks' recourse to ECB's (standard and non-standard)

[5] A number of studies have focused on modelling frictions that limit an efficient distribution of liquidity by interbank markets (Flannery, 1996; Freixas and Holthausen, 2005; Repullo, 2005).

[6] For details on the representativeness of the dataset see Altavilla et al. (2019).

liquidity-providing operations. Finally, bank-level CDS spreads are from Thomson Reuters Datastream. Overall, the panel comprises monthly data for 323 individual banks, operating in eighteen euro area countries, covering 80% of the assets held by euro area Monetary Financial Institutions, and spanning a sample period of slightly more than ten years, i.e. from June 2007 to February 2018.

To appreciate the degree of cross-sectional and time-series variation of our sample, Figure 1 plots the time series of "lending rate spreads" (i.e. lending rates minus short-term risk-free rate) at different percentiles of the cross-sectional distribution. The global financial crisis and the European sovereign crisis, that broke out respectively in 2007 and 2010, have left a distinct footprint on lending activity, in terms of a protracted increase in median lending rate spreads. The cross-sectional dispersion in lending rate spreads also tends to widen, with a more pronounced increase of the upper tail relative to the lower tail of their distribution. Since 2012, the reabsorption of these tightening pressures is reflected in the decline in median lending rate spreads, a narrowing in their dispersion with a more pronounced drop in the upper quantiles.

Insert Figure 1

Table 1 reports mean, standard deviations, and selected percentiles of the distribution for the main variables used as regressors in the estimation, grouping them into (i) bank lending variables, (ii) bank funding and capital variables, (iii) other bank-level and aggregate macroeconomic variables.

Insert Table 1

2.2 Interbank rate uncertainty, and alternative measures of uncertainty

In this section, we introduce our novel measure of interbank rate uncertainty, computed as the cross-sectional dispersion in the interest rates at which euro area banks lend one another funds in the unsecured overnight market. Specifically, we consider the volume-weighted standard deviation of these interbank rates. The derivation of this measure rests on applying the method described in Furfine (1999) to individual transaction data extracted

from TARGET2, the leading European payment system, and firstly implemented for the euro area by Arciero et al. (2016) and Frutos et al. (2016).

Furfine's algorithm aims to retrieve the interest rate paid on loans when only data on loan flows are available, by matching reverse transactions of similar size between two banks to define a trade on the interbank market. In practice, this is achieved by assuming a round value transferred from one bank to another at a specific time and then associating that amount with a reverse transaction with the same value plus a plausible interest rate amount on the subsequent day (or at another date, for longer-term maturity loans). Once the two related transactions are identified, it is trivial to compute the interest rate applied to each specific overnight interbank loan.

In Figure 2, we plot the interbank rate uncertainty starting from June 2008, i.e. the first available month in our sample, together with vertical lines denoting the main ECB's policy measures on liquidity-providing operations. The evolution in the interbank rate uncertainty tracks well the severity of the disruption in the European money markets experienced first during the global financial crisis and then during the European sovereign debt crisis. Indeed, interbank rate uncertainty spiked up around the time of the Lehman Brothers' collapse in September 2008; it receded shortly after, at the time of the ECB's decision to carry out its liquidity operations through a fixed-rate full allotment procedure and to expand the list of eligible collateral for those operations. After having further subsided in the course of 2009, interbank rate uncertainty increased again starting from mid 2010, on the back of the sovereign debt crisis; it reached its historical peak in late 2011, as tensions in sovereign markets dramatically escalated and spilled over across financial market segments. Finally, it started to abate only after the launch by the ECB of long-term (3-year) liquidity-providing operations (VLTRO), and in general, it shows relevant declines around ECB's liquidity provision measures.

Insert Figure 2

To assess the extent to which our measure reflects a component of uncertainty that is specific to the interbank market, in our empirical analysis of Section 3 we control for two relevant measures of general economic uncertainty (see Figure 3). The first measure is the

option-implied volatility on the Standard & Poor's 500 stock market index (VIX index), which is widely used in the literature as a broad measure of uncertainty, as documented for instance in Bloom (2014). The second measure, which we call Euribor uncertainty, is constructed as the interquartile range of the option-implied probability density function of the three-month Euribor one year ahead; Euribor is the rate at which a panel of euro area banks lend unsecured funds to one another. Therefore, similar to our interbank rate uncertainty measure, Euribor uncertainty is also related to interest rates in the unsecured interbank market; contrary to our measure that refers to overnight interbank activity, Euribor uncertainty refers to three-month interbank loans taking place in one year. The main implication is that Euribor uncertainty is presumably more affected than our measure by uncertainty about (monetary policy) interest rates going forward, also as a reflection of uncertainty about future economic prospects. While a rigorous analysis of the possible links between these different measures will be undertaken in our empirical section, a cursory look at the data in Figure 3 suggests a certain degree of comovement between the three measures, albeit often with leads and lags. Not surprisingly, they all spiked up right after the Lehman's collapse in September 2008 and when the sovereign debt crisis escalated in the fall of 2011. The interbank rate uncertainty measure seems to revert back closely around the ECB's policy decisions on liquidity provision.

Insert Figure 3

3 Interbank rate uncertainty and bank lending

3.1 Regression specification

We study the impact of interbank rate uncertainty on the lending rates applied by individual banks on loans to non-financial firms. To that end, we employ a panel regression of bank-level lending rates on our measure of interbank rate uncertainty, its interactions with bank-level characteristics, and a set of additional controls. More in details, the regression specification

takes the following form:

$$Y_{i,j,t} = \alpha_i + \beta_0 \sigma_t + \beta_1 B_{i,j,t-1} \times \sigma_t + \beta_2 r_t + \beta_3 B_{i,j,t-1} + \beta_4 C_{i,j,t-1} + \beta_5 Z_{j,t} + \epsilon_{i,j,t} \quad (1)$$

The variable $Y_{i,j,t}$ denotes the lending rates applied by bank i in country j and month t on loans to non-financial corporations. Interbank rate uncertainty σ_t enters equation (1) both as an independent term and interacted with $B_{i,j,t-1}$, i.e. a vector of bank-level variables capturing funding and capital positions of euro area banks. Specifically, on the funding side, $B_{i,j,t-1}$ comprises: bank credit default swap (CDS) spreads, proxying for the credit-risk component of the cost of market-based funding for euro area banks; ECB credit (over main assets), including standard and non-standard refinancing operations, and representing an important source of funding for euro area banks especially since the outbreak of the financial crisis. On the capital side, $B_{i,j,t-1}$ comprises bank capital over main assets. The variables in $B_{i,j,t-1}$ enter also as independent terms in the regression.

Additional bank-level time-varying controls are included in the vector $C_{i,j,t-1}$. Specifically, we control for interbank market borrowing (over main assets), a traditional source of funding for euro area banks; the sharp decline in interbank borrowing throughout the various stages of the financial and European sovereign crisis is often interpreted as a manifestation of "interbank market freezing" that have driven up interbank rates. We also control for banks' deposit rates, i.e. the cost of retail funding. On the asset side, we include banks' holdings of sovereign securities (over main assets), intended to capture a possible source of vulnerability for euro area banks in face of the 2010-2012 sovereign debt crisis.[7] Finally, to appease the concerns that interbank rate uncertainty might be simply proxying for non-linear effects associated with financial distress, we include a quadratic term in bank CDS spreads, while further robustness analysis on this front is carried out in Section 3.4.

Time invariant bank-level characteristics are controlled for by including the fixed effects

[7] Altavilla et al. (2017) document for instance how in the euro area banks' sovereign exposures significantly amplifies the impact of sovereign stress on bank lending to domestic firms. Acharya et al. (2014) model an articulated bank-sovereign loop according to which a distressed financial sector induces government bailouts, whose cost leads to increased sovereign credit risk, and hence to a weaker financial sector via the erosion of the value of its bond holdings.

α_i. Macroeconomic variables comprise the three-month EONIA (OIS) spot rate r_{t-1} and the country-specific unemployment rate included in $Z_{j,t-1}$.

3.2 Regression results

Table 2 reports the estimated coefficients for four variants of equation (1). In the first two columns, interbank uncertainty enters only as an independent term, while in the two last columns it enters also in interaction with bank-level funding and capital variables. Standard errors reported in the table are clustered at the bank level.

Insert Table 2

We find that a rise in interbank rate uncertainty is associated to higher lending rates via the coefficient on the independent interbank uncertainty term, whose sign and statistical significance remain stable across the regression variants. This relationship is reinforced by the interaction terms of interbank rate uncertainty with bank-level variables $B_{i,j,t-1}$, whose estimated coefficients are statistically significant at conventional levels, have economically intuitive signs, and hold up to the inclusion of bank-level controls. Specifically, focusing on the baseline specification reported in column (4), the positive coefficient on the interaction term with CDS spreads means that, in response to a rise in uncertainty, banks with lower creditworthiness tend to charge higher lending rates on corporate loans. A possible interpretation for this finding is that banks with higher CDS spreads face higher (market-based) funding costs, that are passed on then to final borrowers. Our estimates suggests that this channel would be relevant at times of financial distress, as CDS spreads have a significant effect only when interacted with interbank rate uncertainty but not in isolation. The negative coefficient on the interaction of uncertainty with bank capital ratios indicates that the tightening pressures of uncertainty on lending rates are alleviated for banks with sounder capital positions. This is consistent with theoretical priors and empirical evidence according to which banks with high capital buffers are better insulated from the effects of adverse shocks, and/or tend to engage less in risky lending (see for instance Jiménez et al. 2017).[8]

[8] Jiménez et al. (2017) identify these credit risk-taking effects in relation to monetary policy rate changes.

Similarly to the case of CDS spreads, capital ratios enter significantly in the regression only when interacted with uncertainty, while they are not statistically significant in isolation. Finally, the negative coefficient on the interaction term of interbank rate uncertainty with ECB credit suggests that the provision of central bank funding might partly shield lending rates against heightened interbank rate uncertainty.

As documented in Section 2.2, the interbank rate uncertainty features substantial co-movement with two other relevant measures of uncertainty, and namely the VIX and Euribor uncertainty. A natural question emerges as to whether our measure captures a specific source of uncertainty stemming from the interbank market, or it is simply a reflection of general economic uncertainty. To provide indications on this front, in Table 3 we report our regression estimates once controlling for these two alternative measures of uncertainty. We find that the coefficient on the VIX is positive and statistically significant, supporting the view that increases in general economic uncertainty exert tightening pressures on the cost of bank lending faced by euro area firms. At the same time, the aspects captured by the VIX appear independent from those underpinning the interbank rate uncertainty, as the VIX inclusion does not alter the statistical and economic significance of the interbank rate uncertainty terms. Regarding Euribor uncertainty, as noticed above, its inclusion may help us to better isolate the component of interbank rate uncertainty that it is orthogonal to uncertainty about future interest rates, be the latter a reflection of future monetary policy conduct or future economic prospects. We find that the Euribor uncertainty is not statistically significant and, moreover, its inclusion does not affect the estimated coefficients on interbank rate uncertainty terms. This finding militates in favour of interpreting our interbank rate uncertainty as reflecting mostly specific aspects of the interbank market, such as counterparty risk and precautionary motive for hoarding liquidity in the interbank market.

Insert Table 3

3.3 Effect of interbank uncertainty over time and across banks

In this section, we provide assessment on the economic relevance of the effects of uncertainty on bank lending rates, as implied by our regression estimates. Specifically, in Figure 4 we plot

the in-sample contribution of interbank rate uncertainty to lending rates (blue line) together with its 95 percent confidence bands (shaded area), focusing on our baseline specification. The estimated contribution is computed by summing all the terms including interbank rate uncertainty and evaluating them for the median bank in the sample, i.e. the hypothetical bank that, at each point time, stands at the 50th percentile of the cross-sectional distribution of each bank-level variable entering the interaction terms. The upward pressure of uncertainty on lending rates is estimated at around 35 basis points, on average over the sample period. This average effect conceals substantial time variation, in ways that generally mirror the evolution of interbank rate uncertainty. Indeed, the tightening pressures on lending rates peaked immediately after the Lehman's collapse in September 2008, receded in late 2009 and beginning of 2010, to spike up again in late 2011 tracking the severity of European sovereign debt crisis and its spill-overs across financial markets. Specifically, the estimated change in lending rates stemming from the change in uncertainty observed during the fourth quarter of 2008 amounts to around 90 basis points; the impact of uncertainty on lending rates reached its peak of around 120 basis points in the fourth quarter of 2011. Since then, the impact has receded significantly, standing at around 20 basis points at the end of 2017.

Insert Figure 4

Besides varying over time, the impact of uncertainty on bank-to-firm lending rates entails also a relevant heterogeneity across banks. To illustrate the differential effects across banks in relation to their characteristics, Figure 5 depicts the in-sample contribution of uncertainty as a function of bank CDS spreads evaluated, at each point in time, at the 10th, 50th and 90th percentile of the cross-sectional distribution of CDS spreads, while the other bank-level interaction terms are evaluated at the 50th percentile of their respective distributions. Relative to their median peers, the differential response across banks is quantitatively more relevant for banks with higher CDS spreads (90th percentile) than lower CDS spreads (10th percentile). For instance, our estimates suggest that banks with CDS spreads at the 90th percentile of the distribution tightened lending rates by around 70 basis points more than the median peers in the face of the rise in uncertainty recorded at the end of 2011; instead,

the response of banks with CDS spreads at the 10th percentile of the distribution is broadly similar to their median peers.

Insert Figure 5

Cross-bank heterogeneity also emerges when considering the impact of the 2011 increase in uncertainty as a function of bank capital (see Figure 6): banks at the 10th percentile (90th percentile) of the bank capital distribution tightened lending rates by around 25 basis points more (20 basis points less) than their peers. Interestingly, the differential response across banks for alternative levels of capital tend to be relatively persistent over time.

Insert Figure 6

Figure 7 shows the extent to which higher reliance on ECB credit has shielded bank lending rates from the tightening pressures stemming from uncertainty shocks. Specifically, banks at the at the 90th percentile of the cross-sectional distribution for ECB credit tightened lending rate by around 35 basis points less than their peers, in face of the 2011 increase in interbank rate uncertainty. This relief proved also to be relatively persistent in the following years.

Insert Figure 7

3.4 Robustness

The regression specifications reported above, including our baseline specification, entail a marginal effect of interbank rate uncertainty on lending rates that is linear in the bank-level variables entering the interaction terms. This means that, for instance, in response to an uncertainty shock, the mitigating impact of an additional unit of capital on lending rates is the same for any level of capital ratio; in fact, this impact might differ depending for instance on whether banks operate at low or high capital levels. The same reasoning would apply to CDS spreads. To explore this possibility, in Table 4, we augment our baseline specification (first column) with interaction terms that are quadratic in CDS spreads (second

column) and capital ratio (third column). In doing so, we also allow for an asymmetric relationship depending on whether CDS spreads (capital ratios) are below or above their median levels. Focusing on the quadratic interaction terms, the coefficient estimates are not statistically significant for the CDS spreads, providing empirical support to our baseline specification. In fact only the quadratic term for above-median capital levels turns out to be statistically significant. To shed light further light on this aspect, Figure 8 depicts the marginal effect of uncertainty on lending rates conditional on bank capital, with and without quadratic interaction terms. The latter specification comprises also the contribution of the quadratic term for below-median capital levels, despite this term turned out to be not statistically significant, as noticed above. The range of values for bank capital spans the historical distribution; the other bank-level variables entering the interaction terms are evaluated at the 50^{th} percentile of their historical distributions. In response to an uncertainty shock, the relief of an additional unit of bank capital on lending rates (i.e. the slope of the lines in Figure 8) is estimated to be relatively high for below-median capital levels, and tends to decline for above-median levels. Only the latter effect is statistically significant, indicating that in face of an uncertainty shock, the mitigating effect of an additional unit of bank capital tends to vanish at high levels of capital buffers.

4 Conclusions

The paper investigates the effects of interbank rate uncertainty on bank lending rates charged on corporate loans. We measure interbank rate uncertainty as the cross-sectional dispersion in the interbank market rates for overnight loans among euro area banks. Pertaining to overnight unsecured loans, our measure of interbank rate uncertainty should be relatively immune to uncertainty about the future course of (monetary policy) interest rates; instead it could be interpreted as reflecting counterparty risk and precautionary motive for hoarding liquidity in the interbank market. Using bank-level balance-sheet data for the euro area, we find that heightened interbank rate uncertainty is associated with higher bank lending rates, with estimated pressures peaking at around 100 basis points during the interbank market disruptions of the 2007-2009 global financial crisis and 2010-2012 European sovereign crisis.

This effect of interbank rate uncertainty entails considerable variation across time and banks' characteristics: it is significantly more attenuated for banks with, and at times characterised by, better credit risk, sounder capital positions and greater access to central bank funding. These estimates remain robust to including uncertainty measures about future (monetary policy) interest rates, and more traditional uncertainty proxies – e.g. stock market volatility (VIX). Overall, we argue that our novel approach to assess the stress to the interbank network via our interbank rate uncertainty measure provides an empirically successful strategy to evaluate the transmission of this stress to broader financing conditions, such as the lending rates charged on corporate loans. We suggest that this parsimonious approach is a viable and practical option for monitoring interbank market developments going forward, and informing adequate policy responses.

References

[1] Acemoglu, D., Ozdaglar, A., Tahbaz-Salehi, A., (2015), "Systemic risk and stability in financial networks", American Economic Review, 105(2), 564–608.

[2] Acharya, V., Drechsler, I., Schnabel, P., (2014), "A Pyrrhic Victory? Bank Bailouts and Sovereign Credit Risk", Journal of Finance, 69(9), 2689–2739

[3] Acharya, V., Skeie, D., (2011), "A model of liquidity hoarding and term premia in inter-bank markets", Journal of Monetary Economics, 58(5), 436–447

[4] Adrian, T., Boyarchenko, N., (2012), "Intermediary Leverage Cycles and Financial Stability," Federal Reserve Bank of New York Staff Reports, No. 567.

[5] Adrian, T., Boyarchenko, N., Giannone, D., (2019), "Vulnerable Growth", American Economic Review, 109(4), 1263–89.

[6] Afonso, G., Kovner, A., and Schoar, A., (2011), "Stressed, Not Frozen: The Federal Funds Market in the Financial Crisis", Journal of Finance, 66(4), 1109–1139.

[7] Allen, F., Carletti, E., (2008), "The Role of Liquidity in Financial Crises", Jackson Hole Economic Policy Symposium on maintaining stability in a changing financial system, august 21-23, 2008.

[8] Allen, F., Gale, D., (2000), "Financial contagion", Journal of Political Economy, 108(1), 1–33.

[9] Altavilla, C., Canova, F., Ciccarelli, M., (2019), "Mending the broken link: heterogeneous bank lending and monetary policy pass-through", forthcoming in the *Journal of Monetary Economics*.

[10] Altavilla, C., Pagano, M., Simonelli, S., (2017), "Bank exposures and sovereign stress transmission", Review of Finance, 21(6), 2103–2139.

[11] Arciero L., Heijmans, R., Heuver, R., Massarenti, M., Picillo, C., Vacirca, F., (2016), "How to measure the unsecured money market? The Eurosystem's implementation and validation using TARGET2 data", International Journal of Central Banking, 12(1).

[12] Baker, S. R., Bloom, N., Davis, S. J., (2013), "Measuring Economic Policy Uncertainty", The Quarterly Journal of Economics, 131(4), 1593–1636.

[13] Bernanke, B.S., (1983), "Irreversibility, uncertainty, and cyclical investment", The Quarterly Journal of Economics, 98(1), 85–106.

[14] Bloom, N., (2009), "The impact of uncertainty shocks", Econometrica, 77(3), 623–685.

[15] Bloom, N., (2014), "Fluctuations in Uncertainty", Journal of Economic Perspectives, 28(2), 153–76.

[16] Bloom, N., Bond, S., Van Reenen, J., (2007) "Uncertainty and Investment Dynamics," Review of Economic Studies, 74, 391–415.

[17] Bordo, M., Duca, J. V., and Koch, C., (2016), "Economic policy uncertainty and the credit channel: aggregate and bank level U.S. evidence over several decades", NBER Working Papers 22021, National Bureau of Economic Research, Inc.

[18] Bruche, M., Suarez, J., (2010), "Deposit insurance and money market freezes", Journal of Monetary Economics, 57, 45–61.

[19] Brunnermeier, M., (2009), "Deciphering the 2007–08 liquidity and credit crunch" Journal of Economic Perspectives, 23, 77–100.

[20] Brunnermeier, M. K., Sannikov, Y., (2014), "A Macroeconomic Model with a Financial Sector", American Economic Review, 104, 379–421.

[21] Brusco, S., Castiglionesi, F., (2007), "Liquidity coinsurance, moral hazard, and financial contagion", The Journal of Finance, 62(5), 2275–2302.

[22] Buch, C., Buchholz, M., Tonzer, L., (2015), "Uncertainty, Bank Lending, and Bank-Level Heterogeneity", IMF Economic Review, 63(4).

[23] Caballero, R. J., Simsek, A., (2013), "Fire sales in a model of complexity", The Journal of Finance, 68(6), 2549–2587.

[24] Caldara D., Fuentes-Albero, C., Gilchrist, S., Zakrajsek, E., (2016), "The Macroeconomic Impact of Financial and Uncertainty Shocks", NBER Working Papers 22058, National Bureau of Economic Research, Inc.

[25] Carriero, A., Clark, T. E., Marcellino, M., (2019), "Measuring uncertainty and its impact on the economy", Review of Economics and Statistics, forthcoming.

[26] Christiano, L. J., Motto, R., Rostagno, M., (2014), "Risk Shocks", American Economic Review, 104(1), 27–65.

[27] De Fiore, F., Hoerova, M., Uhlig H., (2019), "Money markets, collateral and monetary policy", ECB Working Paper No. 2239.

[28] De Vincent-Humphreys, R., Puigvert Gutirrez, J., (2012), "A quantitative mirror on the euribor market using implied probability density functions", Eurasian Economic Review 2(1), 1–131.

[29] Fernández-Villaverde, J., Guerrón-Quintana, P. A., Rubio-Ramírez, J. F., Uribe, M., (2011a), "Risk Matters: The Real Effects of Volatility Shocks", American Economic Review, 101(6), 2530–61.

[30] Fernández-Villaverde, J., Guerrón-Quintana, P. A., Kuester, K., Rubio-Ramírez, J. F., (2011b), "Fiscal volatility shocks and economic activity", NBER Working Papers 17317, National Bureau of Economic Research, Inc.

[31] Flannery, M. (1996), "Financial crises, payment system problems, and discount window lending", Journal of Money Credit and Banking, 28, 804–824.

[32] Freixas, X., Holthausen, C., (2005), "Interbank market integration under asymmetric information", Review of Financial Studies, 18, 459–490.

[33] Freixas, X., Parigi, B. M., Rochet, J. C., (2000), "Systemic risk, interbank relations, and liquidity provision by the central bank", Journal of Money, Credit and Banking, 611–638.

[34] Frutos, J. C., Garcia-de-Andoain, C., Heider, F., Papsdorf P., (2016) "Stressed Interbank Markets: Evidence from the European Financial and Sovereign Debt Crisis", ECB Working Paper No. 1925.

[35] Gai, P., Haldane, A., and Kapadia, S. (2011), "Complexity, concentration and contagion", Journal of Monetary Economics, 58(5), 453–470.

[36] Gertler, M., Kiyotaki, N., Prestipino, A., (2016), "Wholesale banking and bank runs in macroeconomic modeling of financial crises", Handbook of Macroeconomics.

[37] He, Z., Krishnamurthy A., (2012), "A Model of Capital and Crises", Review of Economic Studies, 79, 735–777.

[38] Heider, F., Hoerova, M., Holthausen, C., (2015), "Liquidity hoarding and interbank market rates: The role of counterparty risk", Journal of Financial Economics, 118, 336–354.

[39] Jiménez, G., Ongena, S., Peydró, J.-L., Saurina, J., (2014), "Hazardous times for monetary policy: what do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking?", Econometrica 82 (2), 463–505.

[40] Jurado, K., Ludvigson, S., Ng, S., (2015), "Measuring Uncertainty", American Economic Review, 105, 1177–1216.

[41] Leduc S., Liu Z., (2016), "Uncertainty shocks are aggregate demand shocks", Journal of Monetary Economics, 82, 20–35.

[42] Repullo, R., (2005), "Liquidity, risk taking, and the lender of last resort", International Journal of Central Banking, 1(2), 47–80.

[43] Valencia, F., (2017), "Aggregate uncertainty and the supply of credit", Journal of Banking & Finance, 81, 150–165.

A Tables and Charts

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Percentiles				
			5th	25th	50th	75th	95th
Bank lending							
Lending rate to NFC (% per annum)	4.0	1.8	1.6	2.6	3.7	5.0	7.2
Uncertainty measure							
Interbank uncertainty (p.p.)	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Bank funding and capital							
Eurosystem Credit (in % of main asset)	2.3	6.6	0.0	0.0	0.0	2.0	12.0
Bank CDS (% per annum)	1.8	2.6	0.5	0.8	1.2	1.9	5.3
Capital ratio (in % of main asset)	8.8	17.5	1.3	4.4	7.2	10.8	20.7
Other bank-level and macro variables							
Assets (billion euro)	75.7	138.9	2.5	10.4	28.1	72.8	348.1
Deposit rate (% per annum)	1.8	1.4	0.1	0.7	1.5	2.7	4.4
Sovereign security holdings (in % of main asset)	4.2	6.4	0.0	0.0	1.8	5.9	16.3
3-month OIS (% per annum)	0.8	1.4	-0.4	0.0	0.3	0.8	4.1
Unemployment rate (%)	6.0	0.4	4.3	5.9	8.1	10.7	22.6

Notes: The table reports mean, standard deviations, and selected percentiles of the distribution for bank lending variables, bank funding indicators and capital ratio, other bank-level characteristics and macro variables.

Table 2: Fixed effects regression of lending rates on interbank rate uncertainty, its interactions and additional controls.

	(1)	(2)	(3)	(4)
3-month OIS_t	0.901***	0.787***	0.789***	0.781***
	(0.0142)	(0.041)	(0.0406)	(0.0424)
Unemployment $rate_{j,t}$	0.101***	0.101***	0.101***	0.101***
	(0.0133)	(0.0177)	(0.0171)	(0.0171)
Interbank uncertainty and interactions				
σ_t	3.392***	2.709***	3.349***	3.162***
	(0.180)	(0.271)	(0.364)	(0.394)
σ_t x ECB $credit_{i,j,t-1}$			-0.0848*	-0.0801*
			(0.043)	(0.043)
σ_t x Bank $CDS_{i,j,t-1}$			0.192***	0.195***
			(0.056)	(0.055)
σ_t x Capital $ratio_{i,j,t-1}$			-0.114**	-0.110**
			(0.0447)	(0.045)
Bank-level characteristics				
Deposit $rate_{i,j,t-1}$		0.152***	0.151***	0.149***
		(0.044)	(0.0445)	(0.0451)
ECB $Credit_{i,j,t-1}$		0.0112*	0.0233***	0.0228**
		(0.0058)	(0.0088)	(0.0088)
Bank $CDS_{i,j,t-1}$		0.0109	-0.0157	-0.006
		(0.0105)	(0.0136)	(0.025)
Capital $ratio_{i,j,t-1}$		-0.0123	0.003	0.005
		(0.0142)	(0.0162)	(0.016)
Sovereign $exposure_{i,j,t-1}$				-0.011
				(0.012)
Interbank $credit_{i,j,t-1}$				0.005
				(0.004)
$(\text{Bank CDS}_{i,j,t-1})^2$				-0.0003
				(0.0005)
Bank fixed effects	YES	YES	YES	YES
# Observations	27418	12920	12920	12850
R^2	0.769	0.788	0.789	0.79

Note: The dependent variable is the lending rates by bank i to loans on non-financial corporations in month t in country j. The sample ranges from July 2007 to February 2018. Standard errors clustered at bank level in parentheses: * p<.1, ** p<.05, *** p<.01.

Table 3: Fixed effects regression of lending rates on interbank rate uncertainty, its interactions, and additional controls including alternative uncertainty measures.

	(4)	**(5)**	**(6)**
3-month OIS_t	0.781***	0.767***	0.812***
	(0.0424)	(0.0407)	(0.0433)
Unemployment $rate_{j,t}$	0.101***	0.102***	0.100***
	(0.0171)	(0.0171)	(0.0171)
Interbank uncertainty and interactions			
σ_t	3.162***	2.825***	3.346***
	(0.394)	(0.402)	(0.416)
σ_t x ECB $credit_{i,j,t-1}$	-0.0801*	-0.0712	-0.0835*
	(0.043)	(0.0438)	(0.0435)
σ_t x Bank $CDS_{i,j,t-1}$	0.195***	0.197***	0.188***
	(0.055)	(0.0556)	(0.0541)
σ_t x Capital $ratio_{i,j,t-1}$	-0.110**	-0.100**	-0.109**
	(0.045)	(0.0457)	(0.045)
Bank-level characteristics			
Deposit $rate_{i,j,t-1}$	0.149***	0.146***	0.148***
	(0.0451)	(0.0446)	(0.0453)
ECB $credit_{i,j,t-1}$	0.0228**	0.0212**	0.0233***
	(0.0088)	(0.00891)	(0.00882)
Bank $CDS_{i,j,t-1}$	-0.006	-0.00889	-0.00746
	(0.0256)	(0.0254)	(0.0256)
Capital $ratio_{i,j,t-1}$	0.005	0.00533	0.00324
	(0.0162)	(0.0162)	(0.0157)
Sovereign $exposure_{i,j,t-1}$	-0.011	-0.0108	-0.0121
	(0.012)	(0.0121)	(0.0118)
Interbank $credit_{i,j,t-1}$	0.005	0.00538	0.00611
	(0.004)	(0.00401)	(0.00406)
$(\text{Bank } CDS_{i,j,t-1})^2$	-0.0003	-0.0003	-0.00027
	(0.0005)	(0.0005)	(0.0005)
Additional measures of uncertainty			
Vix_t		0.00660***	
		(0.00187)	
Euribor $uncertainty_t$			-0.115
			(0.0781)
Bank fixed effects	YES	YES	YES
# Observations	12850	12850	12850
R^2	0.79	0.79	0.79

Note: The dependent variable is the lending rates by bank i to loans on non-financial corporations in month t in country j. The sample ranges from July 2007 to February 2018. Standard errors clustered at bank level in parentheses: * p<.1, ** p<.05, *** p<.01.

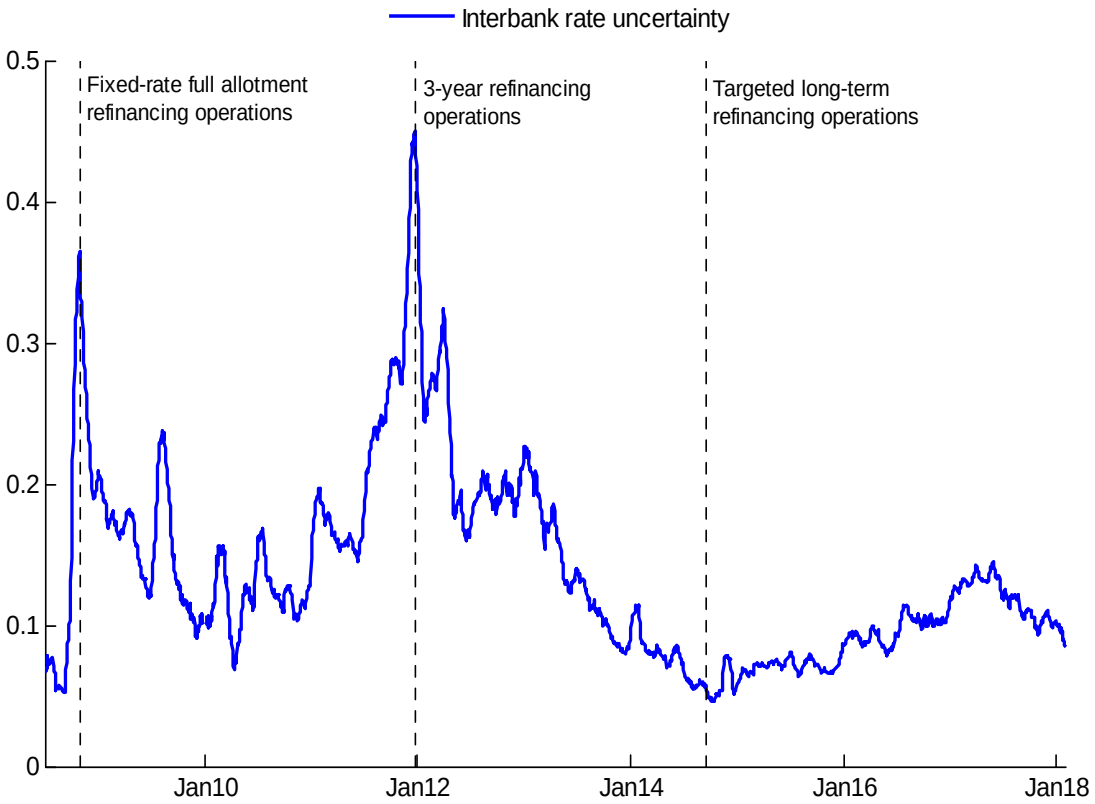
Table 4: Fixed effects regression of lending rates on interbank rate uncertainty, its interactions, and additional controls including alternative interaction terms.

	(4)	(7)	(8)
3-month OIS_t	0.781***	0.782***	0.764***
	(0.0424)	(0.0417)	(0.0416)
Unemployment $\text{rate}_{j,t}$	0.101***	0.101***	0.102***
	(0.017)	(0.017)	
Interbank uncertainty and interactions			
σ_t	3.162***	3.163***	4.501***
	(0.394)	(0.503)	(0.661)
σ_t x ECB $\text{credit}_{i,j,t-1}$	-0.0801*	-0.0880**	-0.0792*
	(0.043)	(0.043)	(0.044)
σ_t x Bank $\text{CDS}_{i,j,t-1}$	0.195***	0.255***	0.192***
	(0.055)	(0.087)	(0.056)
σ_t x Capital $\text{ratio}_{i,j,t-1}$	-0.110**	-0.112**	-0.258***
	(0.04)	(0.04)	(0.04)
Bank-level characteristics			
Deposit $\text{rate}_{i,j,t-1}$	0.149***	0.146***	0.149***
	(0.0451)	(0.044)	(0.044)
ECB $\text{credit}_{i,j,t-1}$	0.0228**	0.0237***	0.0224**
	(0.008)	(0.008)	(0.008)
Bank $\text{CDS}_{i,j,t-1}$	-0.006	-0.0129	-0.0141
	(0.0256)	(0.0146)	(0.0136)
Capital $\text{ratio}_{i,j,t-1}$	0.005	0.00587	0.00507
	(0.016)	(0.016)	(0.016)
Sovereign $\text{exposure}_{i,j,t-1}$	-0.011	-0.0111	-0.00909
	(0.012)	(0.012)	(0.012)
Interbank $\text{credit}_{i,j,t-1}$	0.005	0.00598	0.00478
	(0.004)	(0.004)	(0.004)
$(\text{Bank CDS}_{i,j,t-1})^2$	-0.0003		
	(0.0005)		
Additional squared interactions			
$\{\max[(\text{Bank CDS}_{i,j,t} - \overline{Bank\ CDS_t}), 0]\}^2$ x σ_t		-0.0045	
		(0.00507)	
$\min[(\text{Bank CDS}_{i,j,t} - \overline{Bank\ CDS_t}), 0]^2$ x σ_t		-0.0519	
		(0.0578)	
$\{\max[(\text{Capital ratio}_{i,j,t-1} - \overline{Capital\ ratio_t}), 0]\}^2$ x σ_t			0.0064***
			(0.0021)
$\{\min[(\text{Capital ratio}_{i,j,t} - \overline{Capital\ ratio_t}), 0]\}^2$ x σ_t			-0.0309
			(0.019)
Bank fixed effects	YES	YES	YES
# Observations	12850	12850	12850
R^2	0.79	0.79	0.79

Note: The dependent variable is the lending rates by bank i to loans on non-financial corporations in month t in country j. The sample ranges from July 2007 to February 2018. Standard errors clustered at bank level in parentheses: * p<.1, ** p<.05, *** p<.01.

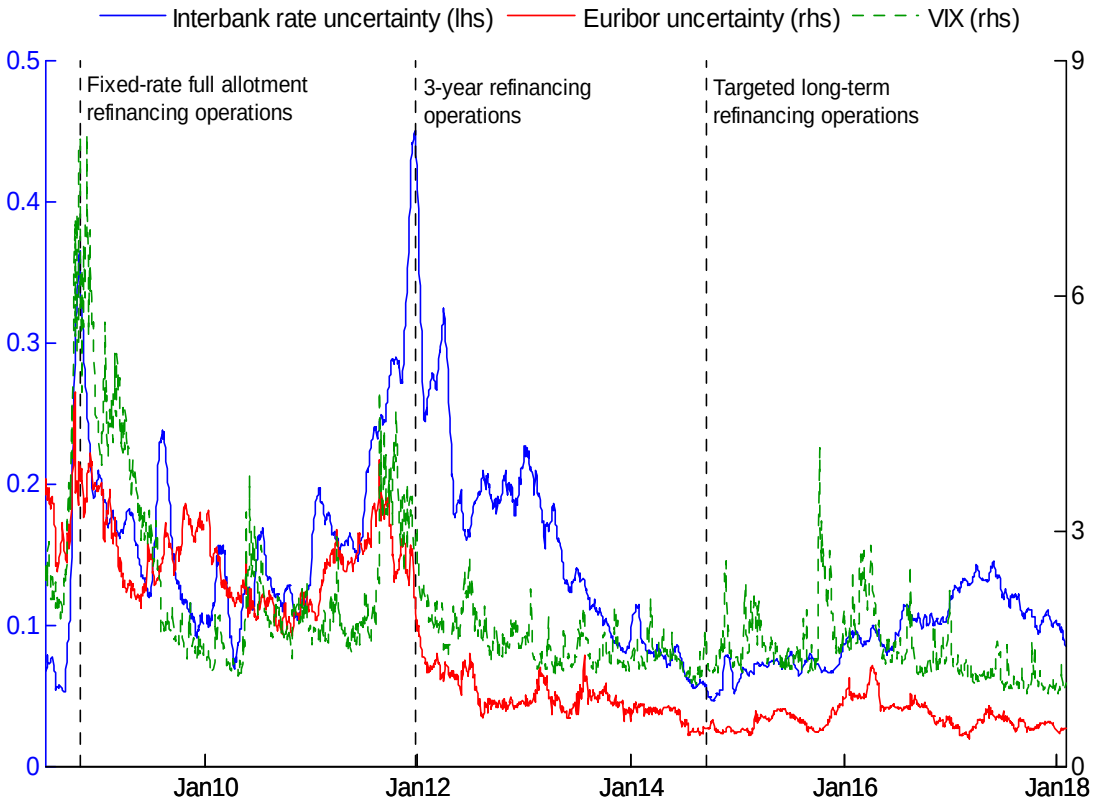
Figure 1: Time series variation of selected quantiles of the cross-sectional distribution of bank lending rate spreads (the difference between lending rates on loans to non-financial corporations and the three-month overnight index swap rate).

Figure 2: Interbank rate uncertainty.



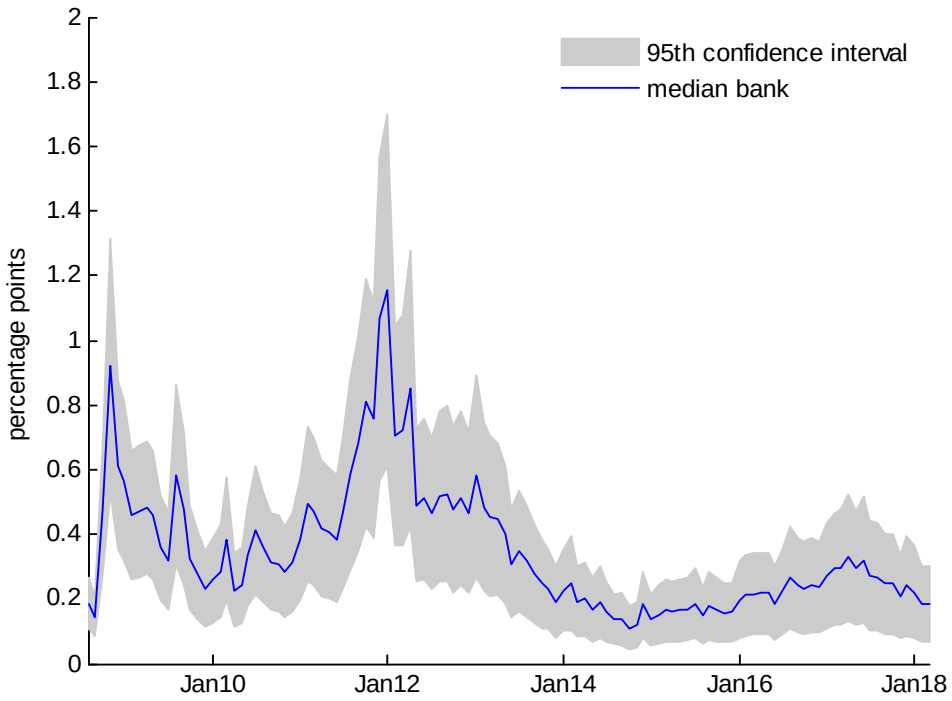
Note: The figure shows the time-serie plot of "interbank rate uncertainty" that we define as the cross-sectional dispersion in the interbank-market rates for unsecured overnight borrowing among euro area banks. The vertical lines denote main ECB's policy measures on liquidity-providing operations.

Figure 3: Interbank rate uncertainty versus alternative measures of uncertainty.



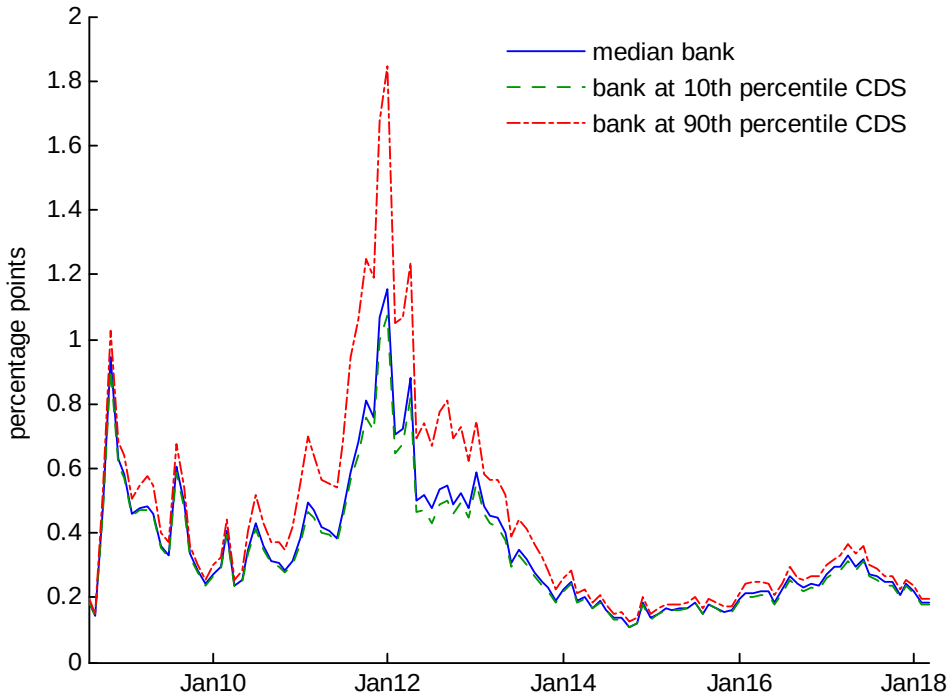
Note: The figure shows the time-serie plot of our uncertainty measure "interbank rate uncertainty" vis-á-vis alternative measures of uncertainty. We define "interbank rate uncertainty" as the cross-sectional dispersion in the interbank-market rates for unsecured overnight borrowing among euro area banks. A first alternative measure of uncertainty is the "Euribor uncertainty", computed as the difference between the 75th and the 25th percentile of the option-implied probability density functions of the future 3-month EURIBOR one-year ahead, where the EURIBOR is the (average) rate at which euro area banks lend unsecured term funds to one another. A second alterntaive measure of uncertainty is the "VIX", i.e. the option-implied volatility on the Standard & Poor's 500 stock market index; in the chart, the VIX is rescaled so to have the same standard deviation of the Euribor uncertainty. The vertical lines denote main ECB's policy measures on liquidity-providing operations.

Figure 4: Estimated historical contribution of interbank rate uncertainty on bank lending rate spreads.



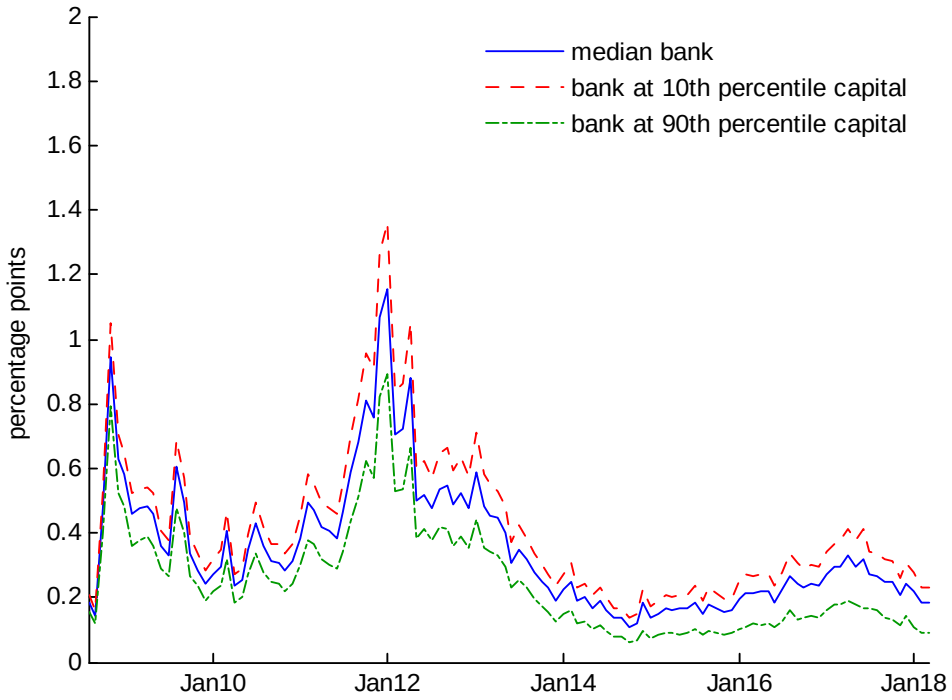
Note: The figure shows the historical contribution of interbank rate uncertainty on lending rates, based on the uninteracted and interaction terms of uncertainty and coefficient estimates of the baseline specification. The contribution "median bank" (blue line) refers to the hypothetical bank that, at each point in time, stands at the 50th percentile of the cross-sectional distribution of each bank-level variable entering the interaction terms. The shaded area denotes the 95 percent confidence bands.

Figure 5: Estimated historical contribution of interbank rate uncertainty on lending rate spreads conditional on bank CDS spreads.



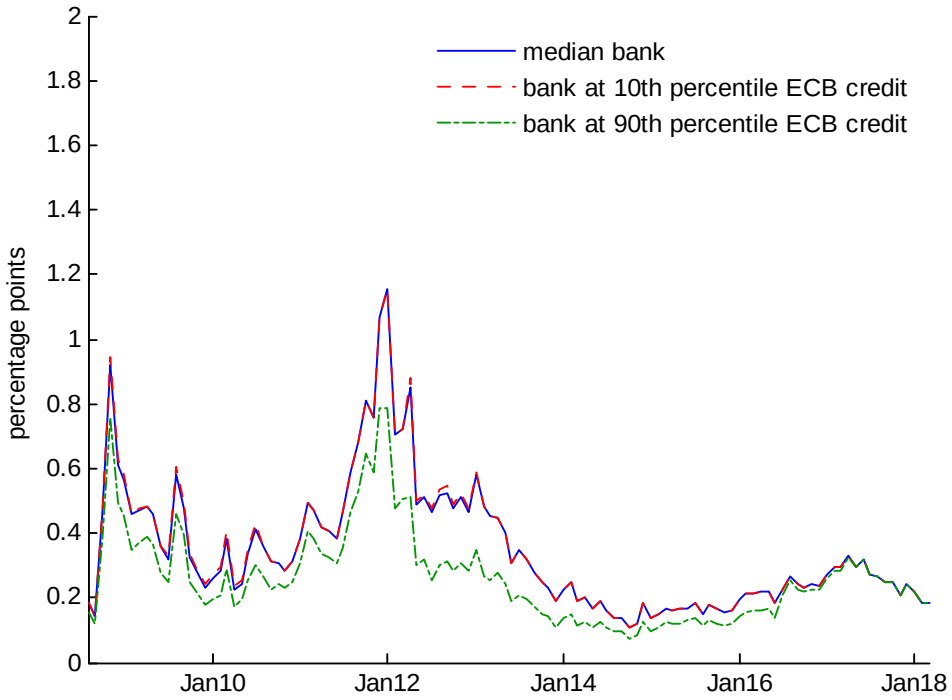
Note: The figure shows the historical contribution of interbank rate uncertainty on lending rates, based on the uninteracted and interaction terms of uncertainty and coefficient estimates of the baseline specification. The contribution "median bank" (blue line) refers to the hypothetical bank that, at each point in time, stands at the 50th percentile of the cross-sectional distribution of each bank-level variable entering the interaction terms. The green and red dashed lines refer to hypothetical banks that stand respectively at the 10th and 90th percentile of the CDS spreads cross-sectional distribution, while the other bank-level variables are evaluetd at the 50th percentile of the respective distributions.

Figure 6: Estimated historical contribution of interbank rate uncertainty on lending rate spreads conditional on bank capital ratio.



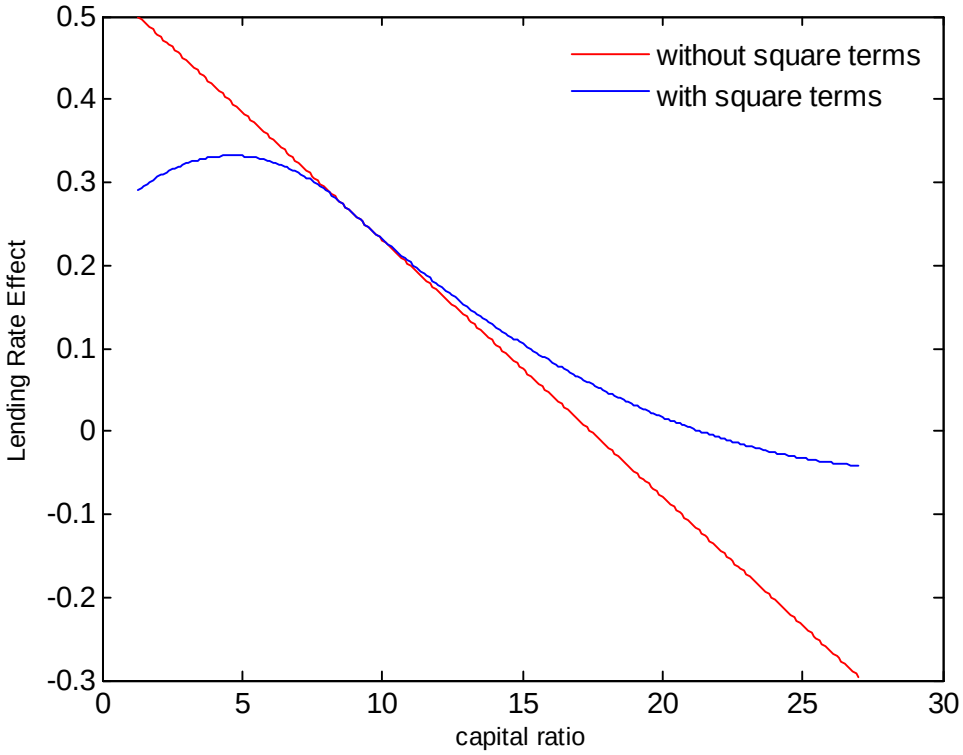
Note: The figure shows the historical contribution of interbank rate uncertainty on lending rates, based on the uninteracted and interaction terms of uncertainty and coefficient estimates of the baseline specification. The contribution "median bank" (blue line) refers to the hypothetical bank that, at each point in time, stands at the 50th percentile of the cross-sectional distribution of each bank-level variable entering the interaction terms. The red and green dashed lines refer to hypothetical banks that stand respectively at the 10th and 90th percentile of the capital (over main assets) cross-sectional distribution, while the other bank-level variables are evaluetd at the 50th percentile of the respective distributions.

Figure 7: Estimated historical contribution of interbank rate uncertainty on lending rate spreads conditional on ECB credit.



Note: The figure shows the historical contribution of interbank rate uncertainty on lending rates, based on the uninteracted and interaction terms of uncertainty and coefficient estimates of the baseline specification. The contribution "median bank" (blue line) refers to the hypothetical bank that, at each point in time, stands at the 50th percentile of the cross-sectional distribution of each bank-level variable entering the interaction terms. The red and green dashed lines refer to hypothetical banks that stand respectively at the 10th and 90th percentile of the ECB credit (over main assets) cross-sectional distribution, while the other bank-level variables are evaluetd at the 50th percentile of the respective distributions.

Figure 8: Marginal effect of interbank uncertainty on lending rates conditional on bank capital ratio - with and without square terms.



Note: The figure shows the effect of one standard deviation increase in interbank rate uncertainty on lending rates, conditional on bank capital ratio. The effect is derived considering the un-interacted of uncertainty as well as its interaction terms with banks' balance-sheets characteristics, with and without the square interaction terms. The range of values for the capital ratio spans the historical distribution; the other bank-level variables entering the interaction terms are evaluated at the 50^{th} percentile of their historical distribution.

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