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Explaining the Czech Interbank Market Risk Premium

Adam Geršl and Jitka Lešanovská*

Abstract

This paper focuses on the development of the interbank market risk premium in the Czech Republic during the global financial crisis. We explain the significant departure of interbank interest rates from the key monetary policy rate by a combination of different factors, including liquidity risk, counterparty risk, foreign influence, interbank relations, and strategic behavior. The results suggest a relevant role of market factors, and some importance of counterparty risk.

JEL Codes: G19, G21.

Keywords: Counterparty risk, interbank market, liquidity risk, risk premium.

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Nontechnical Summary

The paper focuses on identifying individual components of the risk premium in the Czech interbank market which is defined as the departure of 3M PRIBOR rates from the monetary policy 2W repo rate. This spread increased at the beginning of the global crisis, first only a little and then rather abruptly after September 2008. Such an increase in the risk premium negatively influences the transmission of monetary policy to the real economy. Given the foreign ownership of Czech banks and the resulting close links with European banks that were hit by the sub-prime crisis, the uncertainty observed in the international financial markets and the unexpected difficulties of large banks abroad could also have been transmitted to their Czech subsidiaries' and branches' behavior.

We consider counterparty risk and liquidity risk as potentially significant determinants of the interbank risk premium in the Czech Republic. However, we also examine other factors that might significantly influence interbank lending conditions in the Czech Republic, such as market conditions in relevant domestic as well as international markets, interbank lending relations of banks, and possible strategic behavior. Following a review of the literature on interbank markets, an analysis of the specific features of the Czech interbank market, and a description of interviews conducted with reference banks' representatives, we define five hypotheses relating to the individual components of the risk premium and test them using the Bayesian Model Averaging (BMA) method.

Daily data on reference banks' quotes for PRIBOR fixing as well as other daily and monthly data on market developments and banks' balance-sheet positions are used. We aim at explaining the banks' behavior when providing quotes for 3M PRIBOR fixing and define the interbank risk premium as the departure of 3M PRIBOR rates from the monetary policy repo rate. The explanatory variables include liquidity and solvency indicators of quoting (reference) banks; the averages and standard deviations of these variables across potential interbank counterparties to capture counterparty risk; market variables such as bond market liquidity, the euro interbank risk premium, and credit default swap spreads; indicators capturing the interbank lending relations of reference banks; and specifically constructed variables to capture possible strategic behavior, for example the ratio of loans linked to PRIBOR to total assets and the sensitivity of the interest rate derivatives portfolio to PRIBOR changes. We perform our analysis both for the whole period 2007–2012 and separately for the crisis period (2008–2009) and the recession period (2009–2012).

The results using daily data show significant persistence of the risk premium and a relevant role of market variables such as bond market liquidity and the euro area interbank risk premium. We find some role of counterparty risk, as measured by the average ratio of non-performing loans to total client loans of potential interbank counterparties and the dispersion of the credit default swap spreads of parent companies of potential interbank counterparties. The latter variable indicates possible cross-border contagion effects via foreign ownership on the Czech interbank market risk premium. We do not find robust evidence for strategic behavior of banks when quoting PRIBOR rates.

1. Introduction

The interbank markets play an important role in many aspects in almost all economies. They serve as a source of funding and a venue for liquidity management of banks. Moreover, interbank markets play a key role in the monetary policy transmission mechanism and represent one of the main channels through which the official interest rates set by central banks are transmitted further to commercial bank rates and to the real economy. Finally, interbank market rates reflect the actual situation of the demand for and supply of liquid funds in the market and play an important role as reference rates for a number of financial products – be they selected derivatives, bank loans or deposits.

During the global financial crisis which started in the US sub-prime mortgage segment in 2007, interbank markets worldwide experienced an increase in volatility and decrease in liquidity. While interbank market rates usually closely mirror the monetary policy rate in normal times, a quite strong departure of interbank rates from the key central bank rate has been observed since the onset of the global financial crisis. This increase in risk premium and a parallel significant decrease in interbank market liquidity also happened in the Czech interbank market despite the fact that Czech banks were not directly hit by losses from subprime-related structured products.

The objective of this paper is to identify individual components of the interbank risk premium in the Czech interbank market during the global financial crisis period. We consider credit and liquidity risk as potentially significant determinants of the interbank risk premium in the Czech Republic. However, we also examine other factors that might significantly influence interbank lending conditions in the Czech Republic. Specifically, we examine the role of other bank-specific characteristics (e.g., market share, interbank lending relations, portfolio composition of the bank) and the situation in the relevant domestic as well as international markets.

The paper is structured as follows. The following section 2 is devoted to a review of relevant literature, while section 3 describes the Czech interbank market. Section 4 introduces the hypotheses that are tested. Section 5 describes the data used for the analysis and explains the methodology. Section 6 discusses the results and section 7 concludes.

2. Literature Review

A number of theoretical and empirical papers examine interbank markets and try to explain the interbank market freeze during the global financial crisis. Heider et al. (2009) show that the unsecured interbank market freeze stems mainly from counterparty risk and the asymmetric information problem, where an interbank market breakdown occurs when average counterparty risk and the dispersion of counterparty riskiness are high. Similarly, Freixas and Jorge (2008) find that asymmetric information might lead to credit rationing in the interbank market.[1]

[1] Credit rationing is the situation where demand for credit exceeds supply and borrowers do not receive the full amount of credit they require or some of the borrowers are completely turned down (Afonso and Aubyn, 1998).

According to Gai et al. (2011) an interbank market freeze can occur not only due to the counterparty credit risk, but also due to liquidity hoarding, possibly with the precautionary motive.[2] The precautionary motive becomes more important as the funding risk of the "creditor" bank increases. In their model, hoarding behavior by one bank leads to liquidity hoarding by other banks, where the probability and scope of such a domino effect is dependent on the interbank market structure. Although precautionary hoarding can introduce reputational costs for the hoarding bank, the authors assume such costs to be lower than the costs resulting from fire sales of banking assets.

Caballero and Simsek (2009) emphasize the role of the complexity of the interbank market structure and the cost of information gathering in a potential interbank market freeze. In normal times, it might be sufficient for a bank to assess the riskiness of its direct counterparties only. However, when financial distress occurs, the bank should become better informed not only about its direct trading partners, but also about the trading partners of its trading partners, and so on. Information gathering becomes impossible during the crisis due to the complex interbank structure, so the bank decides to withdraw its loan commitments from its counterparties and starts hoarding liquidity. This can lead to a credit crunch.

Moreover, Acharya et al. (2010a) show that if market power is concentrated in highly liquid banks, borrowing becomes too costly for banks that need liquidity even when there is no shortage of liquidity on the aggregate level. Weaker banks are then left with the option of either using expensive interbank borrowing or selling their assets. Banks with a liquidity surplus will then be able to purchase those assets at a price well below their fundamental value (predatory behavior). Acharya et al. (2010a) provide a rationale for the role of a central bank as a lender of last resort, enabling small banks to borrow from the central bank and to avoid being under pressure from banks with predatory intentions.

Similarly to the theoretical literature, empirical papers on the interbank market assume credit and liquidity risk factors to be the main drivers of the interbank risk premium during the global financial crisis. The pioneering testing of this hypothesis was undertaken by Taylor and Williams (2008) and Michaud and Upper (2008). Both studies use the London Interbank Offer Rate (LIBOR) over the overnight indexed swap[3] (OIS) spread.[4] However, the results of these studies differ. Michaud and Upper (2008) suggest that the increase in the interbank premium was driven mainly by liquidity factors, specifically by concerns about the banks' own funding liquidity position, and that the credit

[2] Since the functioning of the interbank market might be disrupted in the crisis, banks might be uncertain about whether they will be able to obtain sufficient liquidity in the market in future if they are hit by a liquidity shock (i.e., significant withdrawals by depositors). Hence, banks might become reluctant to lend to other banks and instead keep sufficient liquidity in their balance sheets. Moreover, such behavior might be more apparent among banks with weaker balance sheets, since these banks might be facing even higher funding risk. Acharya and Merrouche (2010) found that banks with higher losses were more prone to liquidity hoarding during the crisis.

[3] An overnight indexed swap is an interest rate swap where the floating leg of the contract is linked to a particular index of overnight interest rates (for example EONIA in the euro area or CZEONIA in the Czech Republic). Given its construction – the counterparties exchange only the difference between the fixed and floating rate times the nominal value of the contract – it should be (almost) free of counterparty credit risk and liquidity risk premium and capture expectations of future short-term interest rates well.

[4] The spread between LIBOR and OIS should capture only the risk premium in the interbank market, as both the LIBOR rate and the OIS rate incorporate expectations of future short-term interest rates, which are mainly determined by central bank monetary policy. Monetary policy expectations are therefore cancelled out by deducting the OIS rate from the LIBOR rate.

risk measured by credit default swap (CDS) spreads[5] is transmitted to LIBOR rates over a longer period of time. Taylor and Williams (2008), on the other hand, focus solely on the US interbank market and find a strongly significant effect of counterparty credit risk on the interbank premium, but a low impact of liquidity risk. Liquidity risk seemed to be of minor importance, since the impact of the Term Auction Facility of the Federal Reserve System on the interbank premium turned out to be insignificant.

Nobili (2009) and Kamps (2009) examine the risk premium in the European interbank market (EURIBOR-OIS spreads) during the global financial crisis. They find that both credit risk and liquidity risk were sources of the excessive EURIBOR-OIS spreads, and Nobili (2009) shows that their relative importance varied over time. Liquidity risk was more apparent at the beginning of the crisis and its weight significantly weakened in the last quarter of 2008. This decrease in liquidity risk is attributed to the effectiveness of the ECB's unconventional monetary policy.

Angelini et al. (2009) focus on interbank market rates of longer maturities (beyond one week) before and during the global crisis. Unlike the previous studies, which looked at aggregate reference rates, their analysis is conducted using micro data on real euro-denominated transactions executed by Italian and other European banks further merged with bank-specific characteristics. Their results show that in the pre-crisis period, borrowers' capital and liquidity position played no significant role, while lenders' capital and liquidity position mattered, i.e., more liquid and less risky lenders provided their funds at lower rates. Lenders' behavior has changed since the onset of the crisis, with highly liquid banks charging higher interest rates. They conclude that this might be in line with the predatory behavior suggested by Acharya et al. (2010a) or it may reflect idiosyncratic risk aversion of liquidity-rich banks. Moreover, the effect of borrower capitalization became significant during the crisis.

Acharya and Merrouche (2010), analyzing the sterling secured and unsecured interbank markets, find precautionary hoarding due to increased funding liquidity risk to be the main factor contributing to the elevated interbank market spreads in the UK, in line with the theoretical explanation by Gai et al. (2011). However, their analysis only includes the crisis period between the start of the crisis in August 2007 and June 2008, whereas the role of counterparty credit risk might have become more crucial in the post-Lehman period. Moreover, the stress on the secured market might also have been influenced by a decrease in the debt capacity of assets[6] used in repo transactions. Acharya et al. (2010b) show that the debt capacity of an asset can decrease quickly when the rollover frequency of debt is sufficiently high, even though the quality of the asset is respectable.

3. The Czech Interbank Market and the Role of PRIBOR

3.1 Characteristics of the Czech Interbank Market

The interbank market is used by commercial banks to exchange short-term liquid funds among themselves at a pre-specified price. In a wider sense, the interbank market also includes the transactions of commercial banks with the central bank. The interbank market is of key relevance for

[5] A credit default swap (CDS) is a financial derivative that allows the security holder to insure against debtor default. The CDS price paid by the buyer of the insurance, called the CDS spread, should therefore be a good indicator of counterparty credit risk.

[6] The debt capacity of an asset represents the size of borrowing that can be obtained using the asset as collateral.

the monetary transmission mechanism, since monetary policy rates are expected to be transmitted to interbank market rates and on to the real economy (the interest rate channel), possibly also influencing the amount of credit to the private sector due to balance-sheet effects (the credit channel). Moreover, interbank rates – especially "reference" rates such as LIBOR, EURIBOR, and (in the Czech Republic) PRIBOR – often serve as base rates for pricing different financial products, both retail (client loans and deposits) and wholesale (derivatives such as interest rate swaps). While the interbank market serves as an important source of funding for banks in a number of countries (e.g., the UK, Italy, and Sweden) banks in the Czech Republic use interbank lending rather to balance their short-term liquidity needs.

The size of the Czech banking sector has risen significantly over the last decade. The total assets of Czech banks have doubled since 2000 and currently amount to roughly 120% of GDP, while the number of banks has increased only marginally (from 40 in 2000 to 44 in 2012). The Czech banking sector consisted of 18 banks, 21 foreign bank branches and 5 special-purpose building societies in 2012. The development of the Czech banking sector has been influenced by large-scale privatizations of large, previously state-owned banks in the early 2000s as well as by subsequent mergers and acquisitions.[7] A distinct feature of the Czech banking sector is that the majority of banks are foreign owned.[8]

The Czech banking system exhibits favorable values of key indicators such as profitability and solvency (capital adequacy exceeding 15%), a relatively low level of non-performing loans, and, unlike Hungary or Poland, no household FX loans. Moreover, there is an overhang of deposits over loans, leading to a structural excess of liquidity in the sector. This contributes to a favorable liquidity position of most banks and no dependence on foreign funding (CNB, 2012). This holds not only for the pre-crisis period, which was marked by respectable credit growth, but also for the peak of the 2008–2009 crisis. Due to the strong position of the banking sector there have been no bank failures or bank runs since the global financial crisis started and thus there has been no need for public intervention (Frait et al., 2011).

The structural excess of liquidity in the domestic banking sector is regularly absorbed by the CNB via its repo operations, unlike in the euro area, where the ECB injects liquidity into the banking sector.[9] In October 2008, following a liquidity crisis in the Czech government bond market, the CNB launched a temporary liquidity-providing facility with 2W and 3M maturities, in which Czech government bonds can be used as collateral.[10] This facility proved to be of great importance, since around 15% of banking assets consist of government bonds (CNB, 2012). It helped to calm the government bond market (as holders were reassured that they could always exchange it for liquidity using the CNB facility). Given the continuing stress in the international financial markets in the period 2008–2012, it is still in place for prudential reasons, although only for 2W maturity. Nevertheless, there is very often no interest in the auctions; the facility is used rather sporadically.

[7] The development of the Czech banking sector is discussed, for example, in Bárta and Singer (2006).

[8] Almost 97% of the banking sector's balance-sheet assets are controlled (directly or indirectly) by foreign owners (CNB, 2012).

[9] In total, roughly 10% of aggregated banking sector assets are deposited with the CNB as a result of these repo operations.

[10] See Geršl and Komárková (2009).

An important feature of the Czech interbank market is its relatively low market liquidity not only in the crisis period, but also in the pre-crisis period. Average trading volumes of unsecured Czech koruna deposits amount to around CZK 60 billion (more than half of which conducted with non-resident banks) and are heavily concentrated at the shorter end of the maturity curve (O/N trading usually represents around 80% of daily trading volumes).[11] Interbank trading on a secured basis has increased since the onset of the global financial crisis, but there is still much less activity in comparison to unsecured lending. Finally, Czech banks are quite active in trading interest rate derivatives linked to interbank market rates, especially forward rate agreements (FRA) and interest rate swaps (IRS).

3.2 Specifics of PRIBOR

Unlike in the case of EURIBOR and LIBOR, reference interbank market rates are quoted for both the bid (PRIBID, Prague Interbank Bid Rate) and offer (PRIBOR, Prague Interbank Offered Rate) sides of the contract in the Czech Republic. The benchmark PRIBOR and PRIBID are calculated from individual quotes submitted by so-called reference banks. Reference banks are supposed to be significant participants in the interbank market for deposits and products derived from interest rates, even under rapidly changing market conditions (CNB, 2006).

The official definition of PRIBOR differs from the definition of EURIBOR and LIBOR. PRIBOR is defined as the reference interest rate on the interbank deposit market calculated (fixed) by the calculation agent for the Czech Forex Club from the quotations of reference banks for the sale of deposits (CNB, 2006).[12] The "quotation" is the price at which a reference bank is willing to sell an interbank deposit to another reference bank (CNB, 2006). EURIBOR is the rate at which euro interbank term deposits are offered by one prime bank to another prime bank within the EMU zone, and is published at 11.00 a.m. (CET) for spot value (T+2) (European Banking Federation). In contrast, LIBOR is the rate at which an individual contributor panel bank could borrow funds, were it to do so by asking for and then accepting interbank offers in reasonable market size, just prior to 11.00 a.m. London time (British Bankers' Association).

Since the definitions of LIBOR, EURIBOR, and PRIBOR differ, they might not be fully comparable and might be associated with different difficulties. Quotes for the benchmark LIBOR might be biased downwards, since LIBOR banks should indicate via their quotes how costly it would be to secure funding for themselves. By providing lower quotes, LIBOR banks might prevent negative signaling about their possibly tight funding risk position (Kamps, 2009). The EURIBOR rate might be influenced by the unclear definition of the term "prime bank," as the notion of prime bank might differ across the banks providing quotes for EURIBOR and also across time (Taboga, 2013). In the case of PRIBOR, both the lender and the borrower (counterparty bank) are exactly defined, as both of them are reference banks. However, the Czech banking sector is rather small by international comparison and the dozen or so reference banks providing quotes for PRIBOR differ significantly from each other in various respects, such as the size of the bank, its legal form (subsidiaries versus branches of foreign banks), and riskiness. Hence, it might be challenging for a representative of a

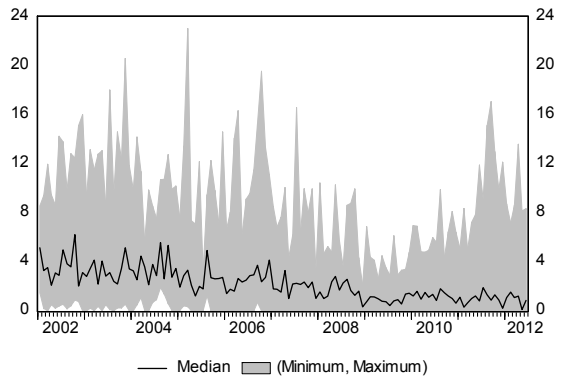
[11] See the results of the regular money market turnover survey on the CNB website: http://www.cnb.cz/en/financial_markets/money_market/mm_turnover/.

[12] The reference bank submits data for the calculation of the PRIBID and PRIBOR reference rates every business day between 10.30 a.m. and 10.45 a.m. local time. The calculation of PRIBID and PRIBOR takes place at 11.00 a.m. local time and the PRIBOR and PRIBID rates are published immediately after the calculation is completed.

reference bank to provide an appropriate quote for such a heterogeneous group of potential counterparties.[13]

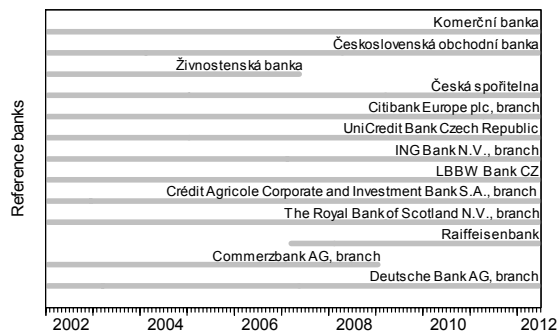
PRIBOR and PRIBID reference rates are calculated as the mathematical arithmetic mean rounded to two decimal places for overnight (O/N) maturity and for maturities of 1 and 2 weeks and 1, 2, 3, 6, 9, and 12 months. Since there are 11 reference banks in the PRIBOR and PRIBID panel as of June 2012, the two highest and two lowest quotes are removed from the calculations in order to prevent deliberate manipulation of the PRIBOR index.[14] The resulting PRIBOR and PRIBID rates are not binding, i.e., banks only indicate what would be the approximate price for lending to or depositing the money of other reference banks. The real price might differ from the quoted price in PRIBOR and PRIBID.[15]

Figure 1: Share of Interbank Exposures in Balance Sheet of Reference Banks (%)



Note: Exposures to resident banks in CZK.
Source: CNB

Figure 2: Number of Reference Banks Over Time



Note: The bank names are as of June 2012. Živnostenská banka stopped being a reference bank due to M&A (see footnote 16).
Source: CNB, Thomson Reuters

The 11 reference banks account for 69% of the total assets of the Czech banking sector and for 51% of total domestic interbank lending in CZK as of June 2012. On average, however, the interbank exposures of the reference banks as a proportion of their assets are rather small (Figure 1). The panel of reference banks comprises all four large banks, five branches of foreign banks, and two small and medium-sized banks. All reference banks are under foreign control.

However, the number of reference banks has varied between 11 and 13 over the last decade (Figure 2). Moreover, there have been some mergers and acquisitions (M&As) during the period, influencing not only the size and market shares of the banks concerned, but also their ownership structure and

[13] There are other additional differences between LIBOR, EURIBOR, and PRIBOR fixing, e.g. differences in the number of panel banks or the number of quotes that are excluded from the calculation of the benchmark rates.

[14] When 11 or more banks provide quotes, the two highest and two lowest quotes are removed from the calculations. When the number of quotes is between 6 and 10, the highest quote and the lowest quote are excluded. When the number of quotes is 4 or 5, all the quotes are included in the calculation sample. When the number of quotes is less than 4, the interest rate for the relevant maturity is not fixed.

[15] Unfortunately, data on whether the interest rate on real transactions is close to the quoted PRIBOR rates are not available.

related corporate governance structure (domestically owned bank vs. subsidiary of foreign bank vs. branch of foreign bank).[16]

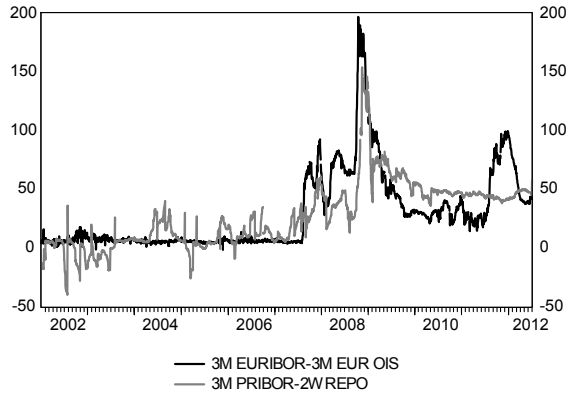
Out of the nine maturity buckets for both PRIBOR and PRIBID (O/N, 1W, 2W, 1M, 2M, 3M, 6M, 9M, and 12M), the 1M, 3M, and 6M PRIBORs are the most followed reference interbank rates, since they represent the base rate for pricing financial products such as interest rate derivatives and certain deposits and loans, mainly to non-financial corporations. In comparative analyses and models, the 3M PRIBOR plays an important benchmark role. Also, the official forecasting model of the CNB (the DSGE-type "g3" model) includes the 3M PRIBOR as a market proxy for the monetary policy. In this paper, we focus mainly on the 3M PRIBOR, acknowledging the fact that the other PRIBORs are correlated with the 3M rate to a large extent.

3.3 Development of the Risk Premium in the Czech Interbank Market

Prior to the global crisis, the situation in the domestic interbank market was stable and the 3M PRIBOR closely mirrored the key monetary policy rate (the CNB's 2-week repo rate), resulting in a very tight spread between these two rates, with its occasional variation mainly reflecting short-term (3-month) expectations of changes in the monetary policy rate (Figure 3). However, the 3M PRIBOR–2W repo spread increased at the beginning of the global crisis, first only a little and then rather abruptly after September 2008. Given the foreign ownership of Czech banks and the resulting close links with European banks that were hit by the sub-prime crisis, the uncertainty observed in the international financial markets and the unexpected difficulties of large banks abroad could also have been transmitted to their Czech subsidiaries' and branches' behavior.

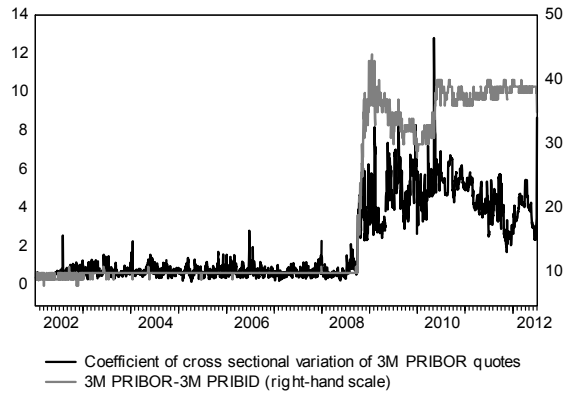
[16] First, BAWAG Bank CZ merged with BAWAG International Bank CZ (previously Dresdner Bank) on March 31, 2005. BAWAG Bank CZ became a reference bank instead of BAWAG International Bank CZ. Moreover, the change of ownership of BAWAG Bank CZ on September 1, 2008 was also connected with the rebranding of the bank to LBBW Bank CZ. LBBW Bank CZ continued to serve as a reference bank. Second, the merger of HVB Bank Czech Republic and Živnostenská banka reduced the number of reference banks from 13 to 12, since both of them had been providing quotes in PRIBOR/PRIBID fixing until then. The result of the merger on November 5, 2007 was UniCredit Bank Czech Republic, the fourth biggest bank in the Czech banking sector, which continued to be a reference bank in PRIBOR/PRIBID fixing. Third, Raiffeisenbank started providing quotes for PRIBOR/PRIBID fixing at the beginning of March 2007. This temporarily increased the number of reference banks to 13. On July 7, 2008, Raiffeisenbank and eBanka completed their merger and Raiffeisenbank continued providing quotes in PRIBOR/PRIBID fixing. Fourth, Crédit Agricole (in that time CALYON BANK, previously Crédit Lyonnais) and Citibank Europe changed their governance structures from a subsidiary to a branch of a foreign bank at the end of 2005 and 2007/2008, respectively. Both remained reference banks. Fifthly, ABN AMRO Bank N.V. changed its name to The Royal Bank of Scotland N.V. in 2010.

Figure 3: Risk Premium in Czech and Euro Interbank Markets (bp)



Source: CNB, Thomson Reuters Datastream

Figure 4: Coefficient of Cross-sectional Variation of 3M PRIBOR Quotes and Bid-ask Spread (%, bp)



Source: CNB, Thomson Reuters, authors' calculation

In parallel to the increase in the 3M PRIBOR−2W repo spread there was a significant rise in the bid-ask spread in the interbank market, connected with higher cross-sectional variation of the individual quotes from the end of September 2008 onwards as measured by the standard deviation of the individual quotes divided by the mean (Figure 4). Until then, the market practice had been to keep the spread between the quotes submitted for PRIBOR and PRIBID at 10 bp, limiting arbitrage opportunities in the interbank market. This practice, however, stopped in September 2008, as some reference banks – reflecting the conditions then prevailing in international financial markets – increased the quoted PRIBOR independently of their quoted PRIBID. As a result, the PRIBOR-PRIBID spread increased to around 40 bp, which also contributed to higher dispersion of PRIBOR and PRIBID quotes.

In order to gain more information on the market practice as regards PRIBOR quoting, we conducted several interviews with reference bank representatives. The main messages can be summarized as follows. First, there was a clear structural change in PRIBOR quoting in September/October 2008, when banks stopped quoting a PRIBOR-PRIBID spread of 10 bp and started to take more account of various risks related to interbank market lending (counterparty, liquidity, etc.) as well the general uncertainty in markets and the economy. The preceding period (say 2002–early 2007) had been rather exceptional from today's perspective, as there had been a high persistence in quoting, the main driver had been monetary policy expectations, and the role of counterparty and other risks had been limited. Second, the liquidity in the Czech money market has always been and remains rather low (with the exception of the O/N segment), so the quotes should be understood only as reference or benchmark rates. Actual interest rates in trading with other banks could differ from the reference rate. Third, charging different rates for different counterparties – although also used to some degree – was not the main strategy. Rather, banks increased or reduced their credit lines/limits for particular counterparties and/or the maturity of interbank loans to reflect counterparty risk. In addition, the risk management strategy was often influenced or even set by the parent bank. Moreover, when assessing counterparty risk, banks looked at the situation of parent banks of possible domestic counterparties, including their CDS spreads. Finally, when providing quotes to PRIBOR, banks took significant account of market developments such as euro area spreads and other market variables.

4. Hypotheses

The literature overview provides a number of potential hypotheses that could be tested in the Czech context. Generally, the increase in the interbank risk premium is seen as a consequence of liquidity hoarding by banks reluctant to lend in the interbank market during the global crisis. However, there are various possible sources of such hoarding behavior. Heider et al. (2009), Freixas and Jorge (2008), and Taylor and Williams (2008) suggest that the source of liquidity hoarding is counterparty credit risk, while Gai et al. (2011), Acharya and Merrouche (2010), and Michaud and Upper (2008) explain liquidity hoarding behavior by concerns about the banks' own liquidity position.

Precautionary hoarding due to liquidity effects is influenced not only by the current liquidity position of a bank, but also by expectations about the future development of the market situation and banks' solvency position. For example, expectations of increasing credit risk losses on the loan portfolio might reduce liquidity inflows (interest income) and increase liquidity risk in terms of a possible bank run should the bank come closer to insolvency.

Further, the complex and highly interconnected structure of the interbank market might influence banks' behavior in the interbank market. The complexity of interbank relationships might increase the interbank risk premium in crisis times (Caballero and Simsek, 2009). However, the market complexity hypothesis is difficult to test, since banks' representatives quoting PRIBOR do not directly observe the complexity of the market over time. On the other hand, long-term lending relationships between banks (relationship lending) and high connectivity of the reference banks with other reference banks (reference banks are very well known counterparties) might decrease the interbank risk premium.

Besides the above-mentioned factors discussed in the theoretical and empirical literature, specific features of the Czech banking sector are also taken into account. First, conditions abroad might be relevant for PRIBOR quoting by domestic reference banks due to their foreign ownership and specific corporate governance structure. A worsening of the liquidity and solvency position of a parent bank could be transmitted to increased PRIBOR quotes provided by its Czech subsidiary, since the parent bank usually needs to satisfy some liquidity and solvency standards on the consolidated banking group level, so the parent bank might aim to influence the behavior of its subsidiary on the Czech interbank market.[17] Moreover, the counterparty risk of domestic banks might not be viewed by the quoting reference bank as completely separated from the riskiness of the counterparty's parent bank. Second, given the high exposure of domestic banks to Czech government bonds, which account for an important part of their liquid assets, market conditions in this particular asset market are covered by our data, as they directly influence banks' balance-sheet positions. Finally, we also reflect individual banks' business models in the data construction.

More recently, the LIBOR manipulation scandal revealed that the quoting behavior of individual reference banks might be driven by strategic considerations and attempts to manipulate the final

[17] Eventually, the risk of subsidiaries could also be transmitted to parent banks, influencing the riskiness of the whole banking group. However, the Czech subsidiaries of Western European banks did not increase the risk of the group compared to the losses of the parent bank or other subsidiaries. On the contrary, even in the crisis period the highly profitable Czech banks helped stabilize the overall banking group position.

benchmark rate.[18] In the Czech context, such strategic behavior could emerge if there were benefits in doing so in terms of profitability considerations. Banks in the Czech interbank market could have had an incentive to report higher rates in order to increase profits on financial products held in their balance sheets and linked to PRIBOR, such as PRIBOR-linked loans to non-financial corporations or interest rate derivatives such as FRA and IRS.[19] However, while the potential incentive to manipulate PRIBOR upwards to generate income on PRIBOR-linked loans exists across all banks, the direction of potential manipulation of PRIBOR to influence the value of derivatives held and linked to PRIBOR can differ across banks, as net exposures and their sensitivity to changes in PRIBOR also differ. Moreover, predatory behavior could also have played a role given the good liquidity position of some reference banks and the strong concentration of the Czech banking sector, in which the four biggest banks have dominant positions.

In the empirical investigation, we test the following hypotheses:

H1: Higher funding liquidity risk of the reference banks, as measured by liquidity and – due to their impact on possible funding liquidity risk – solvency risk indicators, including indicators of the foreign parent bank, increases the risk premium in the domestic interbank market.

H2: Counterparty risk, as measured by indicators of potential counterparties and – allowing for contagious effects – of their foreign parent banks, increases the risk premium in the domestic interbank market.

H3: Market variables, especially higher uncertainty, lower liquidity, and higher volatility in other domestic and foreign markets, contribute to the risk premium in the domestic interbank market.

H4: Higher connectivity of reference banks among themselves, together with long-term interbank lending relationships (relationship lending), increases the knowledge of reference banks about each other, leading to a decrease in the interbank risk premium.

H5: Some strategic behavior by domestic reference banks emerged during the crisis period.

[18] See UK Treasury Wheatley Review of LIBOR: Initial Discussion Paper, available at http://www.hm-treasury.gov.uk/d/condoc_wheatley_review.pdf.

[19] Mortgages and consumer loans are traditionally provided with longer interest rate fixations (3–5 years being the most common period over which the interest rate is fixed in the case of mortgages).

5. Empirical Approach

5.1 Data

Data for the empirical analysis were taken from various sources. Firstly, a full dataset comprising PRIBOR and PRIBID quotes by individual reference banks was obtained from Thomson Reuters. Secondly, reference banks' bank-level data were extracted from CNB supervisory reporting and the CNB's credit register. Thirdly, market data were obtained from Bloomberg and Thomson Reuters Datastream. The bond market liquidity index is internally calculated by the CNB using the methodology described in Geršl and Komárková (2009).

All variables used in the empirical analysis are summarized in Appendix A in the structure defined by the hypotheses. We construct a number of ratios and indicators following the related literature as well as our judgment as to what could best capture the determinants of the quoting behavior of reference banks. The reference-bank-specific data, originally at monthly and quarterly frequency, were linearly interpolated in order to obtain a daily data set, in contrast to the counterparty banks' characteristics, where constant observation was applied, reflecting the information available to the representatives of the reference banks at the time of PRIBOR quoting. Alternatively, to obtain the monthly dataset used for the robustness check of the results based on daily frequency, monthly averages of the daily variables were created.

The interbank risk premium in the Czech interbank market is represented by the 3M PRIBOR less the 2W repo. We use this spread to capture the domestic interbank risk premium – despite the fact that it includes a term premium and expectations about the monetary policy rate over the next 3 months – for three main reasons. Firstly, the alternatives (such as the PRIBOR–OIS spread[20]) are not reliable due to the low liquidity of the CZK OIS market. Secondly, the 3M PRIBOR–2W repo spread is often publicly discussed, since monetary policy analysts compare the repo rate and the benchmark 3M PRIBOR rate. Thirdly, the official CNB "g3" forecasting model includes this premium, so the results of this analysis can help complement the forecasts based on the g3 model. Moreover, we control for expected monetary policy changes using the 1x4 FRA rate, which captures expectations about future monetary policy in the immediate future. We also include dummies for individual banks to capture bank-specific effects.

The first group of explanatory variables comprises funding liquidity and solvency indicators which indirectly influence *funding liquidity risk*, such as bank run risk if a bank's solvency position deteriorates, to test the H1. Liquidity indicators are represented by traditionally used indicators such as the ratio of liquid assets[21] to total assets and the loan-to-deposit ratio. We cannot use the traditional solvency indicators, such as the regulatory capital adequacy ratio or the capital to assets ratio, as a number of reference banks are foreign bank branches without regulatory capital. Thus, we use variables that are related to or influence solvency, i.e., credit risk indicators of banks' portfolios (the

[20] The difference between the interbank market rate (e.g., EURIBOR) and the OIS of the corresponding maturity and currency is commonly used in the literature as an approximation of the interbank risk premium. This expression of the interbank risk premium has the advantage that expectations about monetary policy are effectively removed from the spread. However, the OIS in CZK is illiquid and thus cannot be used as a good proxy for expectations of future policy rates anyway.

[21] Liquid assets are defined by the CNB and comprise cash, claims on the CNB, government bonds, and short-term interbank claims.

ratio of non-performing loans, the loan loss provisions ratio, and the 3M default rate on corporate loans) and one profitability indicator (return on assets, ROA). Finally, this group includes the CDS spreads of the parent banks of reference banks quoting PRIBOR as a variable capturing group-wide pressure related to the group-wide liquidity or solvency position, to reflect possible contagion effects from the parent bank to the domestic reference bank.

The second group of variables serves to test H2 on *counterparty risk*. While it is easy for a bank to judge its own liquidity and solvency position, given that all the necessary data are available internally in the bank, it is much more difficult to get information about potential counterparties for interbank transactions. As a proxy for counterparty solvency, the CDS spreads of the counterparty bank are usually used in the literature. However, the CDS of Czech banks are not traded. Instead, the average counterparty's ratio of non-performing loans (NPL) and the average counterparty's return on assets (ROA) are used, since we believe there is close link between a potential counterparty's level of bad loans and profitability on the one hand and its solvency on the other hand. The NPL ratio is published monthly by the CNB as an aggregate for the banking sector, so each reference bank can roughly estimate the average for the rest of the banking sector using its knowledge of its own NPL ratio and the aggregate NPL ratio. Moreover, NPL data for banking groups (such as large, medium-sized, and small banks and foreign bank branches) are available on a quarterly basis. ROA is publicly available on the CNB website at quarterly frequency for the aggregated banking sector and for some large banks also on an individual basis and is usually closely monitored by banking sector analysts. Ideally, one would also like to include some measure of the dispersion of these variables among potential counterparties, but individual data for all reference banks are not publicly available, hence banks would not be able to calculate it.

This group of variables also includes indicators related to the parent banks of potential counterparties. We construct average CDS spreads across all parent banks of potential counterparties as well as the dispersion of CDS spreads, since individual data are publicly available for this variable to capture the source of potential counterparty risk premium that is due to the contagion effect of parent (foreign) banks.[22]

The third group includes variables to test H3 on the effect of domestic and foreign *financial markets*. For domestic markets, we use indicators of bond market liquidity constructed by the CNB, long-term (5Y) government bond spreads vis-à-vis 5Y IRS, and exchange rate volatility. For foreign markets, we use the risk premium in the euro interbank market, constructed as the difference between the 3M EURIBOR and the 3M EUR OIS.

The fourth group of variables captures *interbank market activity* to test H4 and includes the ratio of net interbank market exposure to total assets, the connectivity of the reference bank with other reference banks, and the durability of interbank exposures.

The final group of variables allows for testing various aspects of possible *strategic behavior* (H5). Firstly, we include the share of corporate loans linked to PRIBOR in total assets to see whether banks with a higher share of these loans strategically push PRIBOR up. Secondly, to test whether banks take into account the sensitivity of their derivatives exposures to changes in PRIBOR when submitting quotes (i.e., if a bank would earn when PRIBOR goes up, it could strategically push PRIBOR

[22] Interviews with reference bank representatives confirmed that when judging counterparty risk, a bank takes into account the CDS of parent banks.

upwards), a good variable to capture this sensitivity is needed. Unfortunately, the CNB reports on interest rate derivatives only at monthly frequency and only includes their real and nominal values and not such a sensitivity parameter. Thus, we constructed an indicator of sensitivity ourselves in a simplified manner – we divided the monthly changes in the real value of the interest rate derivatives by the monthly changes in the 3M PRIBOR. Positive figures of this measure would indicate that the derivatives portfolio increases with the 3M PRIBOR. A significant and positive coefficient of this measure would be indicative of possible strategic behavior to push up PRIBOR in order to earn. If banks were passive holders of such derivatives, this would capture the sensitivity relatively well. Clearly, however, banks use these derivatives in an active manner and thus the indicator of sensitivity (which is, moreover, only at monthly frequency) is probably a very weak proxy, so the results must be interpreted with caution.

5.2 Methodology

With respect to the time and cross-sectional dimension of the data set, our preferred approach to exploring the relevant determinants of the interbank market spread is the panel estimation method. We opt for the fixed-effects model, allowing for unobserved effects specific to the individual reference banks. The reduced-form equation in matrix notation can be expressed as:

$$spread = c_\gamma + X_\gamma \beta_\gamma + \varepsilon \qquad \varepsilon \sim (0, \sigma^2 I) \ ,$$

where $spread$ is the vector of the dependent variable, the 3M PRIBOR–2W repo spread, X represents the matrix of explanatory variables (see Appendix A), β_γ is the vector of the coefficient to be estimated, and ε denotes the vector of disturbances. Lower-index γ represents a particular model which includes a particular subset of potentially relevant explanatory variables.

The common approach to removing fixed effects from the data is to use a within transformation. Alternatively, one may include dummy variables for individual reference banks in order to capture bank-specific effects. Since we have up to 13 cross sections (banks) and the number of time periods is high in our sample, we are able to use the dummy variable approach without losing a significant number of degrees of freedom. The estimated equation can be rewritten into:

$$spread = c_\gamma + X_\gamma \beta_\gamma + D_\gamma \eta_\gamma + \varepsilon \, ,$$

where matrix D represents dummies for individual cross sections (banks). Although the fixed-effect technique seems to be appropriate for addressing our task, we still face high uncertainty about the "true" model which reflects the decision-making process of reference banks when quoting PRIBOR and hence influencing the interbank market spread. We identify 23 potentially relevant explanatory variables (excluding dummies). To examine all the potential models, we would have to run 2^{23} regressions, which would be computationally demanding.

Therefore, we take advantage of the Bayesian Model Averaging (BMA) method in combination with the Markov Chain Monte Carlo Model Composition (MC^3) algorithm, which can effectively tackle the issue of a large number of potential explanatory variables.[23] This method is becoming popular also in the finance literature for dealing with the problem of model uncertainty (Sousa and Sousa,

[23] For more details on MC^3 see Madigan and York (1995). The computations of BMA in combination with MC^3 were done using the BMS package by Feldkircher and Zeugner (2009).

2011; Crespo-Cuaresma et al., 2010). The crucial outputs of BMA are the posterior model probability (PMP), the posterior inclusion probability (PIP) of each variable, and the posterior mean (PM) of the coefficients. Posterior model probabilities denote the probability that a particular model is the "true" model. Given the prior model probability $p(M_\gamma)$, the PMP can be calculated using Bayes' Rule:

$$p(M_\gamma \mid y, X) = \frac{p(y \mid M_\gamma, X)\, p(M_\gamma)}{\sum_{s=1}^{2^K} p(y \mid M_s, X)\, p(M_s)},$$

where $p(y \mid M_\gamma, X)$ is the marginal likelihood of the model and $p(M_\gamma)$ is the prior model probability reflecting our prior beliefs about the model space. We use the binomial-beta model prior as suggested by Ley and Steel (2009). The denominator (integrated likelihood), given by the sum of the marginal likelihoods of all individual models weighted by the prior model probability, is constant over all models. The marginal likelihood can in theory be calculated in the following way:

$$p(y \mid M_\gamma, X) = \int p(y \mid \theta^\gamma, M_\gamma)\, p(\theta^\gamma \mid M_\gamma)\, d\theta^\gamma,$$

where $p(y \mid \theta^\gamma, M_\gamma)$ is the likelihood and $p(\theta^\gamma \mid M_\gamma)$ represents the prior density of the parameter vector θ^γ under model M_γ. Setting prior densities is of crucial importance. To reflect the lack of knowledge, we set a non-informative prior on the intercept and error variance, thus $p(c_\gamma) \propto 1$ and $p(\sigma) \propto \sigma^{-1}$. Further, we employ Zellner's g-prior (Zellner, 1986) for parameters β_γ with a benchmark hyper-prior on g according to Fernández et al. (2001) in the form of $g = \max(N, K^2)$, where N is the number of observations and K is the total number of covariates.

PIP determines the robustness of a variable with respect to the dependent variable and is calculated as the sum of the PMPs of models where the variable was included, formally:

$$PIP = p(\beta_\gamma \neq 0 \mid y, X) = \sum_{\beta_\gamma \neq 0} p(M_\gamma \mid y, X)$$

The PM of a coefficient β is calculated as the weighted average, with the weights being the PMPs, formally:

$$PM = E(\beta \mid y, X) = \sum_{\gamma=1}^{2^K} E(\beta_\gamma \mid y, X, M_\gamma)\, p(M_\gamma \mid y, X)$$

Additionally, we report the standardized version of the posterior mean (SPM) of the coefficients, which might provide more helpful information on the importance of the explanatory variable with respect to the dependent variable.[24] Finally, we also report the posterior standard deviation of the coefficients and their conditional posterior sign.

A special approach is applied to address the uncertainty about the appropriate number of lags of market-based variables included in the BMA estimation.[25] In principle, it would be possible to

[24] Standardized coefficients arise if both the dependent variable and the explanatory variables are normalized (zero mean and variance of one), hence effectively bringing the data down to the same order of magnitude.

[25] For other variables, expert-based judgment is used to determine the optimal number of lags.

include, say, up to five lags of all market-based variables. However, this would substantially increase the number of models and possibly introduce multicollinearity into the models, to which BMA is not robust. Hence, we employ the panel VAR (PVAR[26]) approach, similarly to Babecký et al. (2011), which allows for heterogeneity among individual cross sections. The PVAR approach should suggest how fast a change on a given market is reflected in the domestic interbank risk premium. The estimated bivariate PVAR with 5 lags is of the form:

$$spread\_d_{it} = c_1 + \alpha_{1,1} spread\_d_{it-1} + \ldots + \alpha_{1,5} spread\_d_{it-5} + \beta_{1,1} market\_d_{it-1} + \ldots + \beta_{1,5} market\_d_{it-5} + \varepsilon_{1,it}$$
$$market\_d_{it} = c_2 + \alpha_{2,1} spread\_d_{it-1} + \ldots + \alpha_{2,5} spread\_d_{it-5} + \beta_{2,1} market\_d_{it-1} + \ldots + \beta_{2,5} market\_d_{it-5} + \varepsilon_{2,it}$$

where $spread\_d_{it}$ stands for the change in the risk premium for bank i at time t and $market\_d_{it}$ is the change in the respective market variable. The optimal lag of the market-based variables is set based on the response of the dependent variable in terms of magnitude and the sign to the shock to the respective market variable. The results of the PVAR analysis are provided in Appendix A (column "Lag(method)") and Appendix B (impulse-response functions).

6. Results

We run the BMA on the period 2007–2012 using daily data, given that the quoting behavior is a process that happens daily, with banks judging daily market developments as well as less frequent balance-sheet information. Each model includes dummy variables representing reference-bank-specific effects which were not subjected to the BMA selection procedure.[27] The results indicate strong persistence of the risk premium, as evidenced by the large standardized posterior mean (SPM) of the lagged risk premium. The control variable for expectations of future monetary policy has large posterior inclusion probability (PIP) and the expected sign.

As to the individual hypotheses, the results can be summarized as follows (see Figure 5; a table with detailed underlying BMA results, including PIP, PM, and SPM, can be found in Appendix C): First, we do not find strong support for the funding liquidity risk hypothesis H1. The only variable from this group of explanatory variables that has large PIP is the provisions ratio (*provisionsratio*), with the correct sign, indicating some role of indirect funding liquidity risk through decreased solvency.

Second, two variables on counterparty risk, namely, the average NPL ratio of potential counterparties (*nplratioavg_l*) and the dispersion of the CDS spreads of foreign parent banks of potential counterparties (*cdsstd_l*), have high PIP and the correct signs. This can be considered supportive of H2 on the role of counterparty risk. The latter variable is also indicative of possible cross-border contagion effects via foreign ownership links, causing the Czech interbank market risk premium to increase if the dispersion of the CDS spreads of foreign parent banks increases. This is in line with Heider et al. (2009), who suggest that the dispersion of riskiness among potential counterparties is crucial during turbulent times. The average of the CDS spreads of foreign parent banks of potential

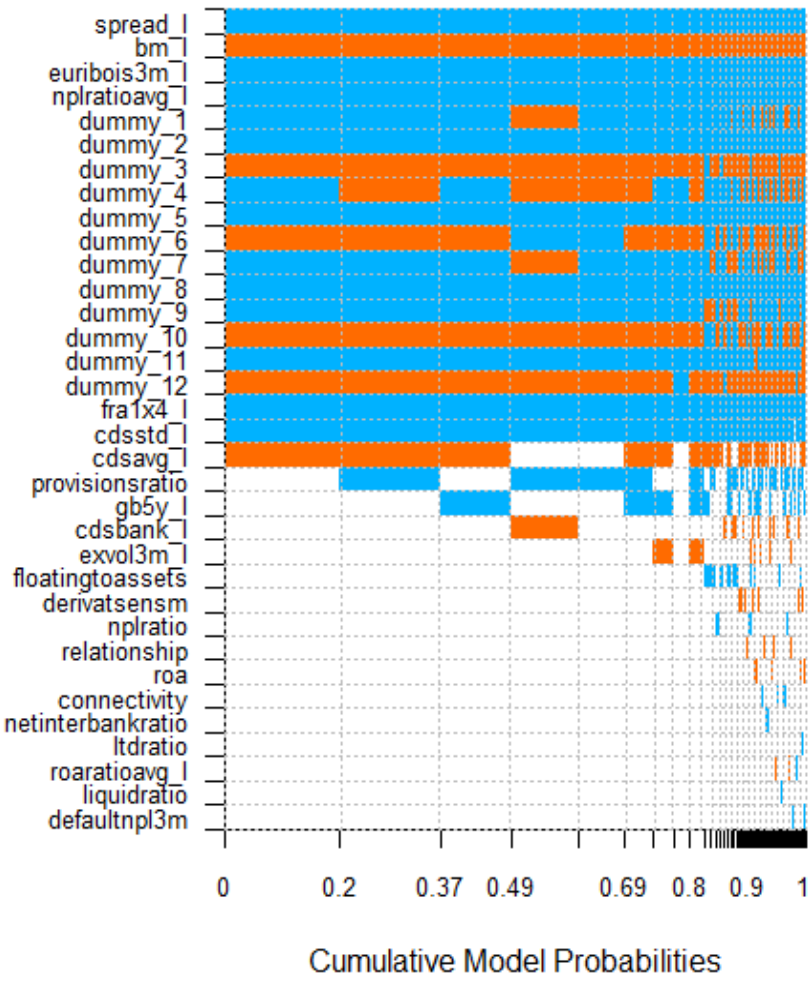
[26] The program for PVAR was written and first used by Love and Zicchino (2006).

[27] The number of dummy variables representing reference-bank-specific effects corresponds to the number of reference banks operating within a given period minus one in order to avoid perfect multicollinearity, since each model also includes an intercept. In this case, the intercept represents a benchmark bank to which other reference-bank-specific effects are compared.

counterparties (*cdsavg_l*) has large PIP, too, but the incorrect sign. Michaud and Upper (2008) suggest that it takes longer for the information in CDS spreads to feed into the interbank risk premium. Moreover, our results indicate that the dispersion of counterparty riskiness might be more relevant for the interbank risk premium than the average counterparty riskiness within a short period of time, as supported by the higher PIP of *cdsstd_l* compared to *cdsavg_l*. This result is rather intuitive, since in the Czech case the counterparty bank might be any of the reference banks, which are quite heterogeneous in their characteristics (see section 3.2).

Third, market variables – in particular domestic bond market liquidity (*bm_l*) and the euro area money market risk premium (*euribois3m_l*) – are relevant for the determination of the domestic interbank risk premium (hypothesis H3). Fourth, the connectivity indicators (*connectivity* and *relationship*) have low PIP, thus not supporting H4. Finally, we do not find any strong evidence of strategic behavior in the BMA analysis (hypothesis H5).

Figure 5: Results of BMA Based on Daily Data (1/1/2007−6/30/2012)

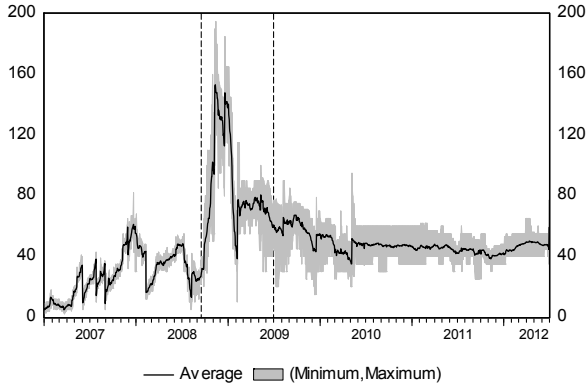


Note: This figure shows the 1000 best models indicated by the BMA procedure resulting from 2 million iterations after 1 million burn-ins. The order of the variables is set according to their PIP. The colors in the figure represent the sign of the coefficient, i.e., blue (+), red (-). The dummy variables representing reference-bank-specific effects are included in each model by default, i.e., they are not subjected to the selection procedure.

Source: Authors' calculation

We look additionally at two sub-periods of our sample. Since the pre-crisis period 2007–September 2008 is characterized by low cross-sectional volatility of individual PRIBOR quotes supported by the convention of a 10 bp bid-ask spread, we run the BMA only for the sub-periods after September 2008, namely, September 15, 2008–June 2009 (the crisis period) and July 2009–June 2012 (the recession period) – see Figure 6 and Table 1. The crisis period is the turbulent period following the collapse of Lehman Brothers, characterized by significant uncertainty. The recession period mainly covers the low interest rate environment and economic recession in the Czech Republic and abroad, but with a high level of uncertainty about future economic developments. The results for the two sub-samples can be found in Appendix D.

Figure 6: Individual Quotes of Reference Banks for 3M PRIBOR Less 2W Repo (bp)



Source: Thomson Reuters, authors' calculation

Table 1: Estimation Details

Dependent variable (pp)	3M PRIBOR quote - 2W repo
Period	1/1/2007–6/30/2012
Number of cross sections (reference banks)	13
Number of time periods (daily/monthly)	1435/66
Number of explanatory variables	22*
Crisis subperiod	9/15/2008–6/30/2009
Recession subperiod	7/1/2009–6/30/2012

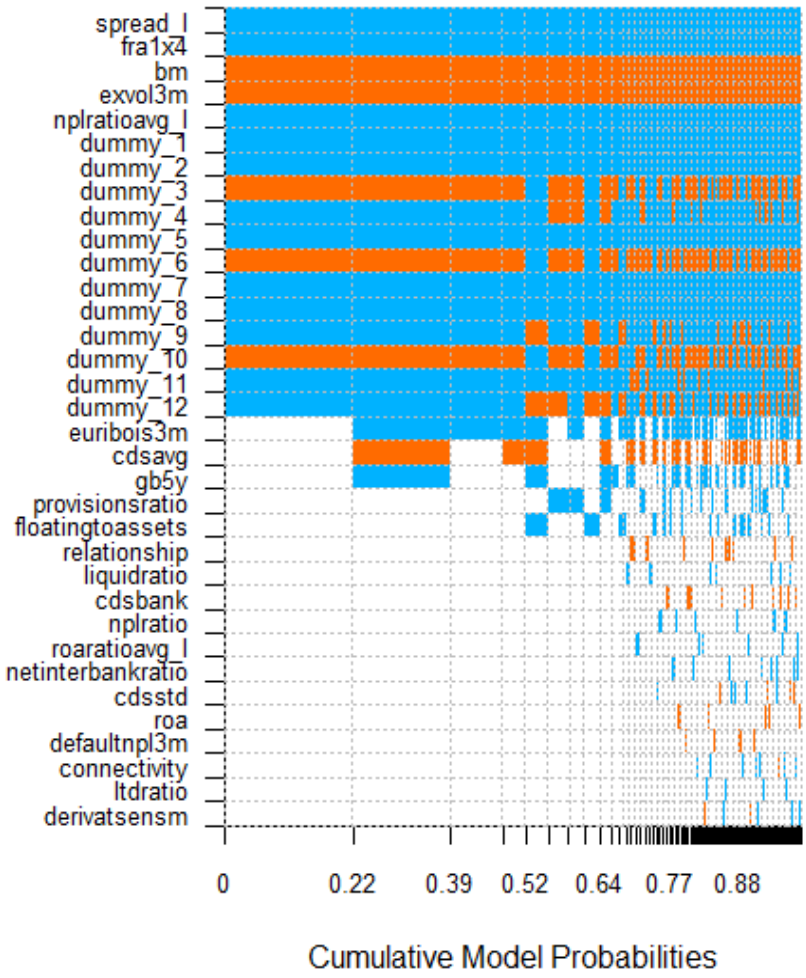
Note: *Due to its relatively low variation and hence relatively high correlation with reference banks' dummy variables, market share has been excluded from the initial set of variables examined by BMA.

In the *crisis period*, the most important explanatory variable (next to the lagged risk premium and FRA to control for expectations about monetary policy) is bond market liquidity, confirming the impact of the bond market crisis in October 2008 on banks' behavior. In the *recession period*, the counterparty credit risk variables – mainly the dispersion of the CDS spreads of parent banks of potential counterparties and the average ROA of potential counterparties – take over. This is in line with the characteristics of this sub-period. The euro area interbank market risk premium has large PIP, too, but the incorrect sign. The main reason could be that the stress in the euro area banking system reflecting the government debt crisis in 2010–2011 did not affect the Czech banking sector which experienced even slight decrease in the interbank risk premium in that time (see Figure 3).

As a robustness check, we performed the BMA analysis for the whole period on monthly data (see Figure 7; a table with detailed underlying BMA results, including PIP, PM, and SPM, can be found in Appendix C). The main reason for running monthly estimations is to exclude the possibility that the various balance-sheet indicators which are originally at monthly frequency have lower variability vis-à-vis daily market variables and thus could end up as unimportant in the daily estimations. The monthly results broadly confirm the main results of the analysis performed on daily data, especially for H2 on counterparty risk and H3 on market variables. The negative sign for the coefficient for

exchange rate volatility, which was also observed in the daily estimations but with much lower PIP, might reflect a preference for domestic interbank lending relative to interbank lending abroad in an environment of increased exchange rate uncertainty.

Figure 7: Results of BMA Based on Monthly Data (January 2007−June 2012)



Note: This figure shows the 1000 best models indicated by the BMA procedure resulting from 2 million iterations after 1 million burn-ins. The order of the variables is set according to their PIP. The colors in the figure represent the sign of the coefficient, i.e., blue (+), red (-). The dummy variables representing reference-bank-specific effects are included in each model by default, i.e., they are not subjected to the selection procedure.

Source: Authors' calculation

To fully exclude the possibility of strategic behavior we also examine the cross-sectional variability rather than the within-variation, because part of the cross-sectional variability causing strategic behavior might be hidden in the fixed effects. Therefore, we employ analysis based on the estimated fixed effects (dummies for individual reference banks, *dummy_1–dummy_12*). We divide reference banks into two groups depending on whether their bank-specific intercept (i.e., the sum of the common intercept and the bank-specific dummy) is above or below the average of the bank-specific intercepts.[28] For these two groups, we report separately the average ratio of liquid assets to total assets

[28] The former group of banks includes banks with an above-average intercept identified in both the daily and monthly estimations.

and the average market share to test for possible predatory behavior, and the average ratio of PRIBOR-linked corporate loans to total assets to test for strategic behavior aiming at increasing revenues from PRIBOR-linked loans.[29] Table 2 shows that banks with above-average bank-specific intercepts have on average better liquidity ratios and large market shares, suggesting the possibility of predatory behavior (larger and more liquid banks quoting higher PRIBOR and earning more on lending interbank funds). The average results also indicate that there might have been some strategic behavior in terms of quoting higher PRIBOR rates to increase interest income from PRIBOR-linked loans in loan portfolios.

Table 2: Analysis Based on the Estimated Fixed Effects

	Averages over 1/1/2007–6/30/2012		
	Predatory behavior		Intentions to increase profits
	Ratio of liquid assets to total assets (%)	Market share (%)	Ratio of PRIBOR-linked corporate loans to total assets (%)
Banks with above-average intercept	24.2	7.7	21.3
Banks with below-average intercept	21.4	4.1	17.4

Source: CNB, authors' calculation

Nevertheless, the results of the analysis based on the bank-specific intercepts must be interpreted with caution. First, the differences among bank-specific intercepts are very low, so that the economic significance of the potential strategic behavior is also very low. Second, a detailed look at the bank-specific intercepts suggests that there is quite some heterogeneity in banks' characteristics within the two groups. Thus, while on average the banks with above-average intercepts have higher liquidity, there are also banks in this group with relatively low liquidity, and the other way round. This also holds for market share and PRIBOR-linked loans, so that these factors are not necessarily the only ones to contribute to above-average intercepts. There might also be other factors playing a role in the cross-sectional variability, often working against strategic behavior, for example possible higher risk aversion of larger and more liquid banks. Thus, our findings provide relatively weak support for strategic behavior. Finally, if only a small number of banks give above-average quotes, the effect on the final PRIBOR would be reduced by dropping the two highest quotes (CNB, 2006), effectively preventing the manipulation of PRIBOR.

7. Conclusion

The global financial crisis has featured an increase in risk premium in interbank markets worldwide. This paper focuses on explaining the risk premium – defined as the departure of the reference 3M PRIBOR from the monetary policy 2W repo rate – in the Czech interbank market. Given the structural features of the Czech banking sector (a comfortable solvency and liquidity situation of banks and foreign ownership as a potential channel for contagion), we tested a number of specific hypotheses on banks' behavior in terms of their quoting contributing rates for PRIBOR, using bank-level, sector-level, and market data. Our results, based on the Bayesian Model Averaging method, can be summarized as follows:

[29] The averages are constructed first as averages across time and then as averages across banks with 1) an above-average intercept and 2) a below-average intercept.

First, funding liquidity risk measured by various liquidity and solvency indicators based on balance-sheet ratios is not found to influence the interbank risk premium significantly. Although some liquidity tensions might have been felt by the banks, the results could reflect the fact that domestic banks have long had comfortable liquidity positions and thus liquidity risk did not increase sufficiently in the crisis and recession period to be fully reflected in the interbank market risk premium.

Second, the explanatory variables used to capture counterparty risk proved to be important, especially in the period after 2009. Some of these variables are based on the characteristics of foreign parent banks of Czech banks, indicating possible cross-border contagion effects influencing the Czech interbank market premium. Third, market variables reflecting risks abroad and risks in the domestic bond market played an important role in the quoting behavior of reference banks. Fourth, the results do not suggest any high relevance of reference banks' interbank lending relations. Finally, we do not find robust evidence for strategic behavior of banks when quoting PRIBOR rates.

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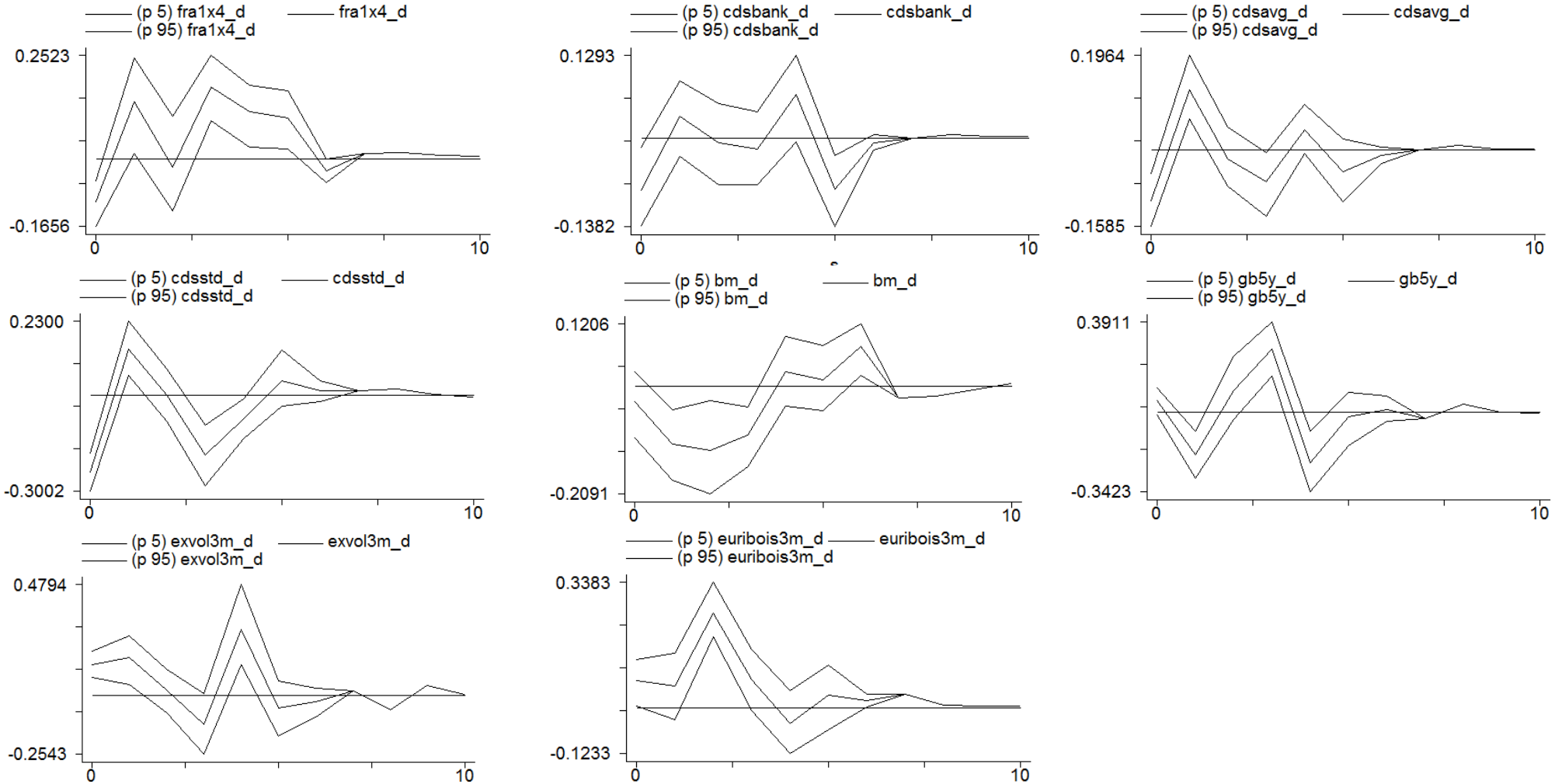
Appendix A: List of Explanatory Variables

Category	Shortcut	Variable	Description	Expected Sign	Lag (method)	Linearly interpolated	Original frequency
Dependent	spread	3M PRIBOR quote less 2W REPO (bp)					daily
Lag of dependent variable and control of monetary policy expectations	spread_l	One-day lag of 3M PRIBOR quote less 2W REPO (bp)					daily
	fra1v4	Forward rate agreement (FRA 1x4, %)			3 days (VAR)		daily
(1) Funding liquidity risk	liquidratio	Ratio of liquid assets to total assets (%)	Liquidity risk of a reference bank	-		LI	monthly
	ltdratio	Loan-to-deposit ratio (%)		+		LI	monthly
	roa	Return on assets (%)	Credit risk of a reference bank	-		LI	monthly
	npl	Ratio of NPLs to total client loans (%)		+		LI	monthly
	provisionsratio	Ratio of loan loss provisions to total client loans (%)		+		LI	monthly
	defaultnpl3m	3M default rate of corporate loans (%)		+		LI	monthly
	cdsbank_l	5Y CDS of parent bank (bp)		+	4 days (VAR)		daily
(2) Counterparty risk	roaratioavg_l	Average return on assets across counterparty reference banks (%)	Credit risk of "average" counterparty reference bank	-	1 month (expert-based)		quarterly
	nplratioavg_l	Average ratio of NPLs to total client loans across counterparty reference banks (%)		+	1 month (expert-based)		monthly
	cdsavg_l	Average 5Y CDS spreads across parent banks of counterparty reference banks (bp)		+	1 day (VAR)		daily
	cdsstd_l	Standard deviation of 5Y CDS spreads across parent banks of counterparty reference banks divided by mean (%)		+	1 day (VAR)		daily
(3) Financial markets	bm_l	Bond market liquidity index	Domestic markets	-	2 days (VAR)		daily
	gb5y_l	Risk premium on 5Y bonds (5Ygovernment bond yield less 5Y IRS, bp)		+	3 days (VAR)		daily
	exvol3m_l	3M implied exchange rate volatility CZK/EUR (%)		+	4 days (VAR)		daily
	euribois3m_l	Risk premium on euro interbank market (3M EURIBOR less 3M EUR OIS, bp)	Foreign market	+	2 days (VAR)		daily
(4) Interbank market activity	netinterbankratio	Net interbank exposure to total assets (%)		-		LI	monthly
	connectivity*	Connectivity of a reference bank with other reference banks (%)		-		LI	quarterly
	relationship+	One-year persistence of lending relationship of a reference bank with other reference banks (%)		-		LI	quarterly
(5) Strategic behavior	floatingtoassets	Ratio of PRIBOR-linked corporate loans to total assets (%)		+		LI	monthly
	derivatsensm	Sensitivity of derivatives to change in PRIBOR index (thousands of CZK)		+		LI	monthly
	marketshare	Market share of a bank according to assets (%)		+		LI	monthly
Bank dummies	dummy_x	Dummies for individual reference banks	Bank-specific effects				daily

Note: This table is related to the analysis based on daily data. For the analysis based on monthly data, monthly averages of daily variables were calculated without assuming any lag of these variables except for a one-month lag of the dependent variable.

- The bond market liquidity index is normalized (i.e., expressed in standard deviations from the historical mean) and moves roughly between 2.5 and -2.5 with zero mean and a standard deviation of one.
- The variables expressed in percent are to be understood in units of percent (for example, a value of 26.2 for 26.2%).
- *Connectivity is calculated as the ratio of the number of lending relations with other reference banks to the maximum number of relations which can potentially be created with other reference banks. +Relationship lending is defined as the ratio of lending relations with other reference banks lasting for one year to total lending relations with other reference banks existing in a given period.

Appendix B: Results of PVAR Used for the Determination of the Optimal Lag of Market-based Variables



Note: Each figure represents the impulse response functions of the dependent variable (spread_d) resulting from the PVAR with five lags to a shock to a particular market variable (the market variables are mentioned at the top of each figure). The impulse response functions of the market variables to spread_d are not reported in order to limit the number of output figures.

Appendix C: Underlying Results of BMA

Results of BMA based on daily data (1/1/2007−6/30/2012)

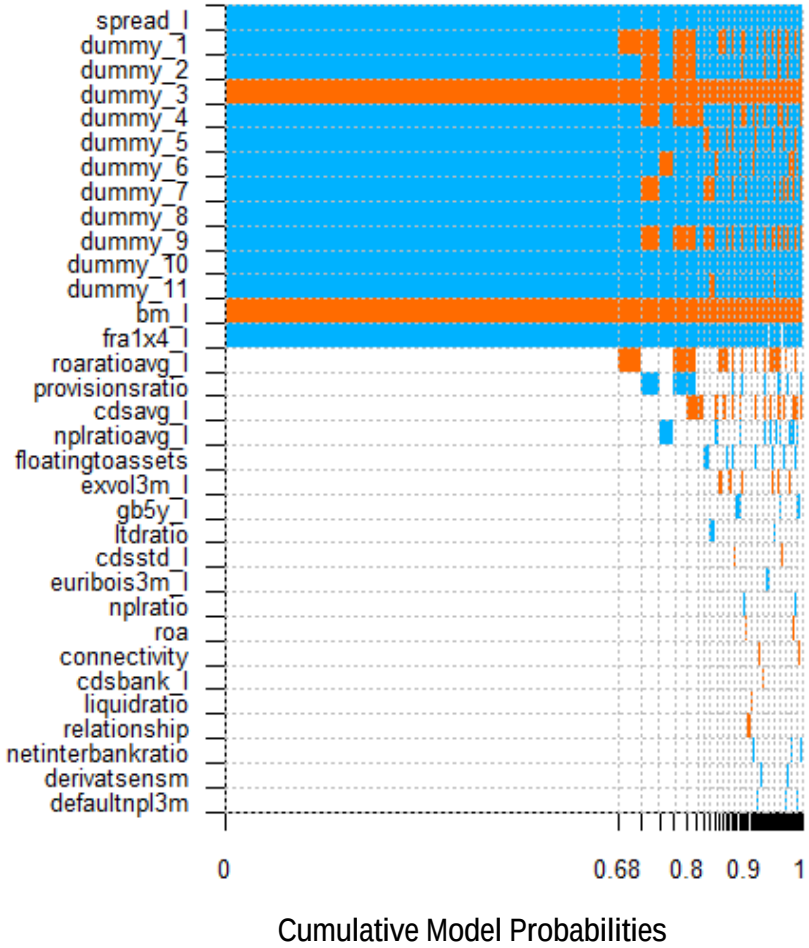
	PIP	Posterior mean	Posterior standard deviation	Posterior mean (standardized)	Conditional posterior sign
spread_l	1.00	0.9360	0.0026	0.9369	1.00
bm_l	1.00	-1.0804	0.1095	-0.0281	0.00
euribois3m_l	1.00	0.0171	0.0028	0.0248	1.00
nplratioavg_l	1.00	0.7565	0.0796	0.0438	1.00
dummy_1	1.00	0.1173	0.2116	0.0013	0.86
dummy_2	1.00	0.2850	0.2281	0.0033	1.00
dummy_3	1.00	-0.1692	0.1966	-0.0019	0.02
dummy_4	1.00	0.0391	0.2159	0.0004	0.50
dummy_5	1.00	0.3411	0.1787	0.0039	1.00
dummy_6	1.00	-0.0935	0.2486	-0.0011	0.27
dummy_7	1.00	0.1533	0.2574	0.0018	0.82
dummy_8	1.00	0.3428	0.1875	0.0039	1.00
dummy_9	1.00	0.1678	0.2126	0.0019	0.95
dummy_10	1.00	-0.0037	0.2244	0.0000	0.07
dummy_11	1.00	0.1028	0.2450	0.0007	0.99
dummy_12	1.00	-0.0768	0.4821	-0.0002	0.04
fra1x4_l	1.00	0.7165	0.1525	0.0328	1.00
cdsstd_l	1.00	0.0210	0.0044	0.0109	1.00
cdsavg_l	0.73	-0.0027	0.0019	-0.0092	0.00
provisionsratio	0.53	0.0773	0.0792	0.0053	1.00
gb5y_l	0.30	0.0023	0.0038	0.0032	1.00
cdsbank_l	0.16	-0.0003	0.0007	-0.0012	0.00
exvol3m_l	0.08	-0.0059	0.0212	-0.0008	0.00
floatingtoassets	0.05	0.0016	0.0074	0.0006	1.00
derivatsensm	0.02	0.0000	0.0000	-0.0001	0.00
nplratio	0.02	0.0007	0.0054	0.0001	1.00
relationship	0.01	0.0000	0.0004	0.0000	0.00
roa	0.01	-0.0010	0.0129	0.0000	0.00
connectivity	0.01	0.0000	0.0003	0.0000	0.92
netinterbankratio	0.01	0.0001	0.0013	0.0000	1.00
ltdratio	0.01	0.0000	0.0002	0.0000	0.98
roaratioavg_l	0.01	-0.0006	0.0429	0.0000	0.40
liquidratio	0.01	0.0000	0.0004	0.0000	0.77
defaultnpl3m	0.00	0.0000	0.0026	0.0000	0.85
intercept	1.00	-3.2084		-0.1305	

Results of BMA based on monthly data (January 2007−June 2012)

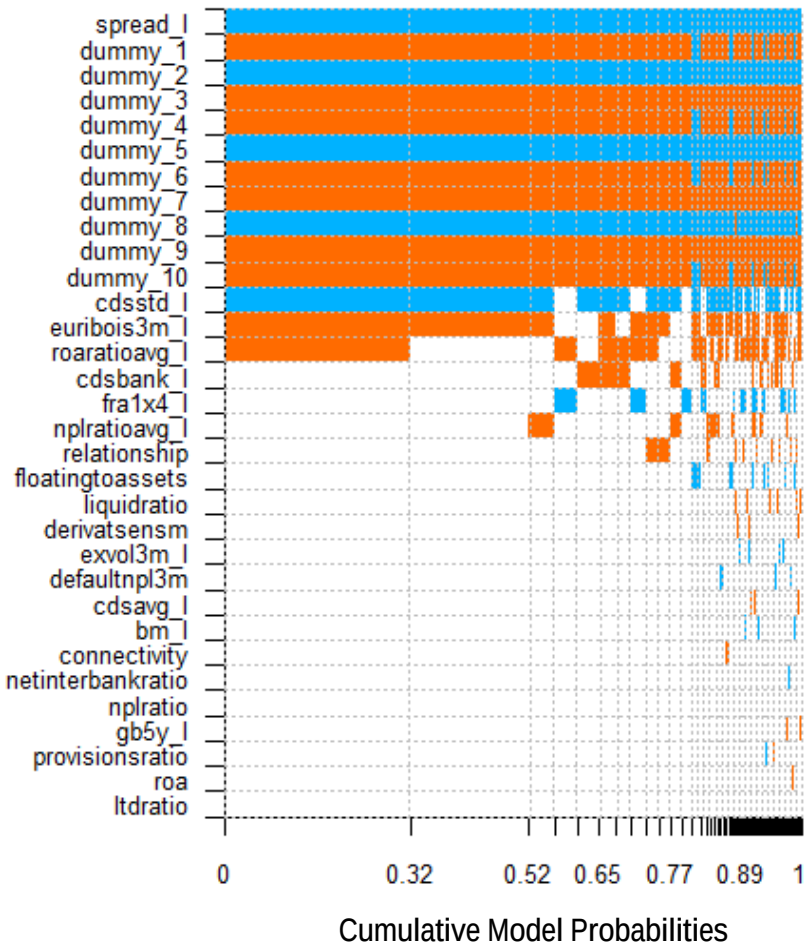
	PIP	Posterior mean	Posterior standard deviation	Posterior mean (standardized)	Conditional posterior sign
spread_l	1.00	0.6093	0.0192	0.6232	1.00
fra1x4	1.00	7.4256	1.7795	0.3581	1.00
bm	1.00	-23.6528	1.8384	-0.5945	0.00
exvol3m	1.00	-2.1421	0.2800	-0.2962	0.00
nplratioavg_l	1.00	5.7582	0.7261	0.3522	1.00
dummy_1	1.00	1.6234	1.5283	0.0197	1.00
dummy_2	1.00	2.9081	1.8160	0.0353	1.00
dummy_3	1.00	-0.1462	1.5255	-0.0018	0.20
dummy_4	1.00	0.9235	1.5874	0.0112	0.87
dummy_5	1.00	2.1935	1.4417	0.0267	1.00
dummy_6	1.00	-1.2200	2.0670	-0.0148	0.14
dummy_7	1.00	2.3072	1.6445	0.0280	1.00
dummy_8	1.00	2.0711	1.6116	0.0252	1.00
dummy_9	1.00	1.4049	1.7973	0.0167	0.86
dummy_10	1.00	0.4339	2.2181	0.0053	0.22
dummy_11	1.00	0.3243	1.9655	0.0025	0.94
dummy_12	1.00	0.3007	3.8516	0.0010	0.76
euribois3m	0.61	0.0456	0.0429	0.0688	1.00
cdsavg	0.42	-0.0137	0.0176	-0.0485	0.00
gb5y	0.38	0.0305	0.0429	0.0432	1.00
provisionsratio	0.16	0.1200	0.3047	0.0088	1.00
floatingtoassets	0.14	0.0333	0.0905	0.0125	1.00
relationship	0.05	-0.0011	0.0061	-0.0012	0.00
liquidratio	0.04	0.0021	0.0133	0.0010	1.00
cdsbank	0.03	-0.0002	0.0016	-0.0009	0.01
nplratio	0.03	0.0044	0.0355	0.0006	0.96
roaratioavg_l	0.03	0.1082	1.0128	0.0005	0.90
netinterbankratio	0.02	0.0019	0.0177	0.0004	1.00
cdsstd	0.02	0.0008	0.0085	0.0004	0.83
roa	0.02	-0.0076	0.1001	-0.0002	0.01
defaultnpl3m	0.02	-0.0030	0.0439	-0.0002	0.00
connectivity	0.02	0.0002	0.0032	0.0002	0.89
ltdratio	0.02	0.0000	0.0022	0.0000	0.74
derivatsensm	0.02	0.0000	0.0000	0.0000	0.54
intercept	1.00	-11.7948		-0.5064	

Appendix D: Results of BMA for the Crisis and Recession Periods (Daily Data)

Results of BMA for the crisis period (9/15/2008−6/30/2009)



Results of BMA for the recession period (7/1/2009−6/30/2012)



Note: This figure shows the 1000 best models indicated by the BMA procedure resulting from 2 million iterations after 1 million burn-ins. The order of the variables is set according to their PIP. The colors in the figure represent the sign of the coefficient, i.e., blue (+), red (-). The dummy variables representing reference-bank-specific effects are included in each model by default, i.e., they are not subjected to the selection procedure.

Source: Authors' calculation

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