ARTICLE IN PRESS

Journal of Financial Markets xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Financial Markets

journal homepage: www.elsevier.com/locate/finmar

Sidedness in the interbank market

Celso Brunetti [a,1], Jeffrey H. Harris [b,1], Shawn Mankad [c,*,1]

[a] Federal Reserve Board, USA
[b] American University, USA
[c] Cornell University, 366 Sage Hall Ithaca, NY, 14853, USA

A R T I C L E I N F O

JEL classification:
G21
C10
G10

Keywords:
Sidedness
Liquidity
Credit default swaps

A B S T R A C T

We study the motivations of traders in the interbank market around the 2007–2009 subprime crisis. We extend the market sidedness of Sarkar and Schwartz (2009) to a panel setting to study the dispersion of beliefs for banks domiciled in different European countries. We find that country-level sidedness reveals information from the interbank market: sidedness leads sovereign credit default swap (CDS) spreads and reacts to central bank interventions introduced during the crisis. Our results map the linkages between the interbank market and sovereigns, as well as provide insight on the channels that give rise to the sovereign-bank nexus.

1. Introduction

Financial markets reflect forward-looking investor views about security-specific and general market conditions. Sarkar and Schwartz (2009), for instance, examine market sidedness, where one-sided markets reflect high information asymmetry and two-sided markets reflect heterogeneous beliefs. In this paper, we build on and extend their sidedness measure to explore market conditions in the European interbank market, computing sidedness by country (based on the primary country of domicile for each bank) to examine whether information asymmetries or heterogeneous beliefs across countries are informative about sovereign health and/or systemic risk.

Indeed, highly urgent banks trading on one side of the market using aggressive market orders to access overnight funds may reveal underlying financial problems that could become systemic if magnified or accelerated. By examining country-specific sidedness, our work expands on how interbank markets might translate these financial problems through the "sovereign-bank nexus," which is the set of connections linking sovereigns and the banking sector as a conduit for transmitting distress between the two.[2]

Interbank markets connect banks with excess reserves to banks with reserve deficits and thus reflect information about bank-specific liquidity needs. A well-functioning interbank market plays a critical role in mitigating systemic risk by effectively and efficiently channeling liquidity from institutions with surplus funds to those in need. For this reason, central banks actively monitor interbank markets and may intervene to facilitate more efficient financial intermediation.[3]

The goal of the interbank market is to help banks manage their transitory surpluses and deficits. But a distressed bank with access to this market can easily create or exacerbate systematic risk. For that reason, we are interested in understanding the motives for

* Corresponding author.
E-mail addresses: celso.brunetti@frb.gov (C. Brunetti), jharris@american.edu (J.H. Harris), spm263@cornell.edu (S. Mankad).
[1] All authors contributed equally and are listed in alphabetical order.
[2] See Dell'Ariccia et al. (2018) for a comprehensive discussion of the sovereign-bank nexus. Our related results are included in Section 5.
[3] See Gertler and Kiyotaki (2010).

https://doi.org/10.1016/j.finmar.2021.100663
Received 30 May 2020; Received in revised form 11 August 2021; Accepted 12 August 2021
Available online 25 August 2021
1386-4181/

borrowing in the interbank market. As a laboratory, we study the motivation of overnight borrowers and lenders to trade in the European e-MID interbank market around the 2007–2009 subprime crisis (hereafter, the crisis).[4] We examine sidedness for each bank in the market and aggregate within and across countries to characterize information asymmetry and heterogeneous beliefs both within and across borders. While sidedness has been previously utilized to understand the stock market around news, corporate events, and market efficiency,[5] we are the first to study sidedness in the interbank market where the desire to trade more likely results from liquidity demands generated by regulatory capital and reserve requirements rather than exogenous information events.[6] In this light, sidedness reflects information about a particular bank's motivation for trading in the interbank market.

We compute sidedness using e-MID data. As a quote disseminating market, e-MID is structured like the original Nasdaq (OTC) market, with banks posting publicly visible quotes. Trades are consummated on e-MID when an initiating bank contacts a quoting bank to negotiate trade terms. Our data thus include the identity of both the aggressive trade-initiating bank and the passive quote-posting bank, as well as the agreed-upon price and quantity.

Using sidedness, we document that banks from Greece, Ireland, Portugal, Spain, the United Kingdom, and the Netherlands borrowed very aggressively at different points during the crisis—banks domiciled in these countries traded on the same side of the market at various times. We hypothesize that country-specific information transmitted by the sidedness metric also drives sovereign CDS spreads via the sovereign-bank nexus. Alternatively, if sidedness reflects more random (but concurrent) liquidity needs, we would expect no systematic link to sovereign CDS spreads.

While ample evidence documents how sovereign distress affects bank health and may result in banking crises, support for the reverse channel is less clear. Grouping banks by country, we find that sidedness leads (Granger causes) sovereign CDS spreads in several countries where individual banks are domiciled. These results provide strong evidence of the reverse channel where the trading behavior of banks domiciled in distressed countries presages sovereign CDS spreads and conveys information about the health of the sovereign entity.

We also explore the role banks play in transmitting monetary policy (another important aspect of the sovereign-bank nexus) by examining how central bank interventions affect sidedness. We find that main ECB refinancing operations are largely associated with reduced asymmetric information in the interbank market, a result that supports the notion that main refinancing operations not only provide liquidity, but serve to balance supply and demand for interbank funds. Indeed, we find that main refinancing operations helped to reduce asymmetric information in the interbank market for banks domiciled in Belgium, the Netherlands, Portugal, and the United Kingdom.

However, we find that non-standard European Central Bank (ECB) operations are not uniformly successful in reducing asymmetric information in the interbank market. Indeed, sidedness metrics reveal that these non-conventional operations are more reflective of asymmetric information.[7] While sidedness among German and Italian banks increases (these banks trade significantly on both sides of the market), sidedness decreases for banks in the Netherlands, the U.K., Ireland, and Belgium, reflecting asymmetric information among banks in these countries.

The rest of the paper is organized as follows. Section 2 contains background information on the e-MID and the European interbank market, Section 3 presents details on sidedness and our extension to the dynamic panel data setting, and Section 4 contains estimation results. In Section 5, we analyze how each measure relates to CDS spreads, ECB interventions, and market variables. We conclude in Section 6.

2. e-MID and the European interbank market

Established in 1990 as a Bank of Italy initiative, e-MID manages the only interbank unsecured deposit market on an electronic platform for the euro system. Prior to the 2007, e-MID held an estimated 17%–22% market share in all euro interbank transactions (with this share plausibly falling during the crisis). More than 200 commercial banks in 29 countries utilize e-MID, posting public quotes (i.e., bids, offers, or both) and executing trades primarily for overnight interbank deposits, helping banks to meet regulatory capital, liquidity, and daily reserve requirements.

The e-MID market operates similar to the original Nasdaq OTC model where banks can observe each other's quotes, including top of book (highest bid and lowest offer) and others displayed by descending price terms. The trading mechanism stems from the quote-driven display, similar to a limit order book in a stock market (but without consolidation). Banks can contact any counterparty displayed in the book to initiate a trade via brokers, phone, or the e-MID platform. Trades are not automated, but when a bank hits a displayed quote, the system allows both banks to negotiate quantity and interest rate terms. Consummated trades are processed and automatically settled through the TARGET2 system when an aggressor bank actively chooses a quoted order. The platform also allows

[4] e-MID, the only electronic market for interbank deposits in the euro region, includes the most complete data containing information about which counterparty initiated the interbank trade.

[5] Sarkar and Schwartz (2009) analyze sidedness in TAQ NYSE data around news events, Chordia et al. (2016) relate sidedness to short- and long-run returns, Baruch et al. (2017) examine sidedness around corporate events, and Xu et al. (2019) show sidedness in ETF markets affects market efficiency in ETF component securities.

[6] Private information may arise from observed order flows in foreign exchanges (Evans and Lyons, 2002) and Treasury futures markets (Menkveld et al., 2012).

[7] Brunetti et al. (2011) demonstrate ECB interventions during the crisis failed to improve interbank market liquidity and argue that counterparty risk (perhaps reflecting asymmetric information) posed systemic risk.

credit line checking and mandates trade confirmation by both counterparties.[8]

Importantly, European banks can also trade overnight funds bilaterally (within or outside the e-MID platform) or through the central bank without reporting trades via e-MID. To counter against potential sample selection issues that this raises, we are careful to apply Heckman (1976, 1977) corrections in our analyses.

3. Methodology: sidedness

In this section, we provide important background information on the sidedness measure and demonstrate that it has an equivalent formulation using linear regression. We then formulate country-specific sidedness metrics and discuss their estimation. To facilitate the following discussion, let v_{Buy} and v_{Sell} be the volume (or count) of initiated buys and sells within some interval.

3.1. Extending sidedness to the interbank market

The sidedness measure of Sarkar and Schwartz (2009) is based upon repeated observations of v_{Buy} and v_{Sell}, and is calculated as follows. First, the volume (or count) of initiated buys and sells are typically observed in high-frequency data (as in TAQ data) over short time intervals (e.g., 5 min around an event). This yields a sample of observations for each variable that can be standardized to have zero mean and unit variance and that we denote with a tilde ($\sim$) on top of the variable. Sidedness is then defined as the correlation between each standardized count of initiated trades:

$$\text{Sidedness} = Cor\left(\widetilde{v}_{Buy}, \widetilde{v}_{Sell}\right). \tag{1}$$

Sidedness is summarized relative to a benchmark level (e.g., during a high-news period to a low-news period) so that values closer to negative one generally indicate a "one-sided" market where asymmetric information drives trading, and values closer to positive one indicate the market is "two-sided" where trading is caused by more heterogeneous beliefs. In our setting, for example, one-sided markets could result from banks using aggressive market orders to access overnight funds, which would create negatively correlated $\widetilde{v}_{Buy}$ and $\widetilde{v}_{Sell}$.

Differences in our empirical setting motivate our extensions of sidedness. Firstly, we compute sidedness in the interbank overnight lending market, where daily capital, liquidity, and reserve requirements suggest a daily resolution as a natural choice. Secondly, our data contain 212 unique banks domiciled in different European countries, which allows us to test several hypotheses about the trading behavior of banks from different countries. In fact, we compute sidedness for each country at the daily frequency using a 30-day rolling window (i.e., forming a panel).

While sidedness has been developed for the stock market, we apply it here to the interbank market. In the stock market, an impatient trader demands immediacy and certainty of execution, perhaps due to a short-lived information advantage. In the interbank market, an impatient bank may also need funds to comply with regulatory requirements. In both cases, the sidedness measure can be used to assess the motives of trade initiation.

Extending sidedness to be defined within a regression setting has statistical and econometric advantages over directly utilizing the correlation coefficient in equation (1). While the correlation is straightforward to calculate, we find this estimator can be problematic due to the lack of initiated trading in the interbank trading data.[9] We address this critical issue by utilizing a regression-based formulation of sidedness, which facilitates use of related econometric and statistical techniques.

To extend sidedness, we consider the following cross-sectional equation:

$$\widetilde{v}_{Buy} = \alpha + \beta\widetilde{v}_{Sell} + u, \tag{2}$$

where u is Gaussian noise. We note that the choice of which initiated trading variable is the dependent or independent variable is arbitrary, as both are co-determined (we explore writing sidedness using a system of equations in Appendix A). In fact, the estimate for the slope parameter remains unchanged even if the independent and dependent variables are reversed in equation (2) due to there being only one independent variable and both the initiated buy and sell variables are standardized. As we elaborate in Appendix A, under ordinary least squares (OLS) estimation of equation (2), this regression-based formulation is equivalent to the correlation-based sidedness of Sarkar and Schwartz (2009) in equation (1).

To define sidedness by country, we aggregate trades for banks domiciled within the same country so that $\widetilde{v}_{Buy,c}$ and $\widetilde{v}_{Sell,c}$ are the standardized buy and sell volumes for country c. We can then define country-specific sidedness with the following system of equations:

$$\widetilde{v}_{Buy,c} = \alpha_c + \beta_c\widetilde{v}_{Sell,c} + u_c \tag{3}$$

where u_c is Gaussian noise. Again, the equation is estimated using OLS, and similar arguments prove that the estimates of β_c is identical

[8] Further details on the e-MID market can be found in Brunetti et al. (2011).

[9] For example, suppose that some banks from a given country only trade passively over the sample period, then sidedness for those banks is undefined. Zero volume observations can also be caused by banks from a given country choosing not to trade via e-MID and instead trade bilaterally or through the central bank, so the observed sample will not represent the population of interest and sidedness will be biased—a preponderance of zeroes can indicate sample selection bias.

and equal to the Pearson correlation between initiated buys and sells for each country. We estimate equation (3) within 30 days and utilize a rolling window so that the country-specific sidedness is updated daily. Next, we demonstrate that this regression formulation accommodates Heckman corrections for potential sample selection bias.

3.2. Heckman corrections

The e-MID electronic platform represents just one avenue for banks to access overnight funds, raising questions about the representativeness of our e-MID data. Alternatively, euro area banks can trade funds through bilateral negotiations, via phone brokers, or directly with the ECB. In this light, e-MID trades may be censored by the rates bid (or offered) on these various other options for trading. If so, the sidedness metric will suffer from sampling bias as the desire to borrow may increase rates and push banks away from using e-MID.

Other evidence suggests that a sampling bias may be material, particularly for the interbank market. For example, Heider et al. (2015) show that during the crisis, urgent banks were charged higher rates potentially because they were viewed as riskier counterparties. Consequently, we are less likely to observe e-MID bank activity as the desire to borrow increases. If so, the observed sample will no longer fully represent the population of interest and sidedness estimates will be biased.[10] We address this issue by employing Heckman's (1976, 1977) two-step correction, which mitigates potential sample selection bias.

Because our Heckman correction utilizes lagged variables, we introduce an additional subscript t to index time. Suppose we only observe a bank's activity when its available rates for either borrowing or lending are above/below their reservation price in the appropriate direction. In other words, the different types of trading volumes are censored according to the following probit-type selection equation:

$$WillingnessToTrade_{c,t} = \gamma_0 + \gamma_1\left(Lending\ Rate_{c,t-1} - \overline{Lending\ Rate}_{t-1}\right) + \gamma_2\left(Borrowing\ Rate_{c,t-1} - \overline{Borrowing\ Rate}_{t-1}\right) + \varepsilon_{c,t}, \tag{7}$$

where non-zero volumes for country c on day t when the $WillingnessToTrade_{c,t} > \lambda$ for some unknown λ. The variables $Lending\ Rate_{c,t-1}$ and $Borrowing\ Rate_{c,t-1}$ denote the observed rate for lending (sell) and borrowing (buy) averaged over all trades in the previous time period for banks originating from country c. A bar above any term, $\bar{\cdot}$, denotes the average for the entire market. We proxy for the rate differential of trading via the e-MID and brokered trade or directly with the central bank by using the difference between the observed e-MID rate averaged over all trades in the previous time period for banks originating from country c and the average e-MID rate for the entire market.[11] Additionally, driven by the economic argument of how information asymmetry and banks' desire to trade can influence participation in the e-MID market, we assume that the Gaussian error terms are correlated $\begin{bmatrix} u_{c,t} \\ \varepsilon_{c,t} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \widetilde{\sigma}_{11} & \widetilde{\sigma}_{12} \\ \widetilde{\sigma}_{21} & \widetilde{\sigma}_{22} \end{bmatrix}\right)$.

Then under the sampling mechanism described above, a derivation similar to the original Heckman (1976, 1977) correction shows that a two-stage correction procedure yields accurate and consistent estimates of sidedness (see Appendix B for details). In the first stage, we estimate the inverse Mills ratio[12] with a probit model, where the response variable is a dummy variable indicating whether banks from a given country participated in e-MID during the 30 day rolling window. We then include the estimated inverse Mills ratio as an additional variable in the second stage estimation of equation (3) to obtain consistent estimates for countries that did have banks participating in the e-MID interbank market.[13]

4. Empirical analysis

We begin by discussing our data and describing the time series of market statistics (e.g., volume, interest rate, effective spread) reflected in our e-MID data. We then present country-level time series estimates for sidedness.

4.1. Data on interbank lending

The e-MID platform, the only electronic market for interbank deposits in the euro region, offers interbank loans ranging from overnight (one day) to two years in duration.[14] The e-MID market is open to all banks admitted to operate in the European interbank

[10] A similar argument can also be made for sampling bias on lenders.

[11] This censoring captures the fact that unobservable rates from these other trading options may influence the choice of using e-MID. In economic terms, rates might differ among alternatives if adverse selection, counterparty risks, or liquidity hoarding differ among options. Brunetti et al. (2011), for example, demonstrate that ECB open market operations draw volume away from e-MID as, at times, banks are more confident trading with the central bank than with other banks.

[12] The inverse Mills ratio plays a crucial role in Heckman-type correction procedures, appearing in the moments of a random variable following a truncated normal distribution (Maddala, 1986).

[13] When including the inverse Mills ratio for sidedness, we estimate the system of equations given in Appendix A since the estimated slope coefficients will in general not be identical. We then average the estimates for β_1 and β_2 together to measure sidedness for each country.

[14] See Brunetti et al. (2011). Brunetti et al. (2019) use e-MID data to examine interbank networks.

market and non-European banks can access the market through their European branches.[15] Our trading data spans from January 2006 through December 2012 and includes 212 unique banks and 464,772 trades, with overnight contracts representing about 90% of total volume. Each e-MID transaction includes the time (to the second), lender, borrower, interest rate, quantity, and an indication of which party is executing the trade.

Fig. 1 shows several market statistics at the daily level for e-MID. We see that interest rates fell starting with the onset of the crisis. Rates started to recover as the crisis abated, but in 2012 fell again to crisis levels as Europe experienced a weak recovery. Effective spreads remain relatively stable across our sample period, suggesting that interbank market liquidity did not suffer appreciably during the crisis. On the other hand, there is a clear negative trend in both the number of active banks trading and daily volume. Signed volume is also negative throughout our sample period with a clear increasing trend toward zero. These patterns indicate that banks actively used the e-MID platform for selling funds, though activity levels diminished by the end of our sample period. Trade imbalance (scaled by volume) shows a greater proportion of aggressive lending during the crisis. Throughout the weak recovery in Europe, trade imbalances even became positive for a handful of days indicating that many banks were aggressively borrowing. Lastly, likely driven by the reduction in active banks, the Herfindahl index rises consistently over our sample period, reflecting greater concentration among banks using e-MID.

4.2. *Country-level sidedness*

We utilize the trading data from the e-MID platform to calculate the daily sidedness over a 30-day rolling window with the Heckman correction by country (i.e., for banks domiciled in the same country).[16] Fig. 2 shows excess sidedness with respect to each country's average pre-crisis (prior to August 7, 2007 when the ECB noted worldwide liquidity shortages) level for the ten European countries in our data. Sidedness differs significantly by country over time and by comparing the country values against each other we can characterize countries as more or less "sided" relative to each other. During the crisis, Sidedness in French, Greek, Italian, Dutch, and British banks was largely negative, reflecting more asymmetric information-driven trading. In contrast, sidedness among German banks was more commonly positive, which suggests more heterogeneous belief-driven trading by German banks. For other countries, sidedness is less stable, suggesting periods where trade motivations differ relative to each other. Importantly, Fig. 2 indicates that banks from different countries utilized e-MID for different purposes.

5. The sovereign-bank nexus

The patterns of changes in country-specific sidedness surrounding the crisis suggests that this metric reflects differential changes in information asymmetry, belief heterogeneity, and the desire to trade across banks. In this section, we study how the information content of our two metrics relates to the sovereign-bank nexus by testing for linkages among interbank market sidedness, sovereign CDS spreads, and central bank interventions.

The sovereign-bank nexus stems from a complex set of connections linking sovereigns and the banking sector together. Dell'Ariccia et al. (2018) identify three main channels: (i) the sovereign exposure channel—banks hold large amounts of sovereign debt; (ii) the safety net channel—central banks and sovereigns both provide safety net arrangements and backstops to distressed banks and/or the distressed banking sector; and (iii) the macroeconomic channel—sovereign crises driven by slow economic activity also negatively impact the banking sector.

For all three channels, contagion effects run in both directions, from sovereigns to the banking sector and vice versa. While the former seems more obvious, the latter is also possible. Through the sovereign exposure channel, for example, if banks hold large amounts of sovereign debt [as established in Hristov et al. (2020)], bank distress may affect liquidity conditions in the sovereign bond market. Similarly, with the macroeconomic channel, banks reduce the supply of credit if they incur unexpected losses, depressing investment, economic growth, the tax base, and ultimately increasing sovereign risk. Though these effects are difficult to document since central banks often intervene to mitigate the transmission of bank distress on sovereigns, recent work demonstrates the importance of financial sector risk on sovereign risk.[17]

We test formally for connections between country-specific interbank market activity and sovereign credit risk, hypothesizing that Sidedness reveals private information from the interbank market that subsequently affects sovereign CDS spreads.

5.1. *Linking sidedness with sovereign CDS spreads*

The crisis hit Europe with some delay relative to the U.S. but persisted longer, with many peripheral countries experiencing the so-called sovereign debt crisis (see Kräussl et al., 2016). CDS spreads capture the riskiness of a country and during the crisis Euro-area sovereign CDS spreads rose significantly. Following Alter and Beyer (2014) (who document links between sovereign CDS spreads and the banking sector), we explore links among CDS spreads and Sidedness.

During the crisis, the banking system's exposure to domestic sovereign debt increased substantially, especially in countries where

[15] See Finger et al. (2013) for further e-MID details.

[16] Results at the highest level of granularity (bank-level) are theoretically possible, but data confidentiality restrictions prohibit such analysis.

[17] Böhm and Eichler (2020) causally identify and measure the strength of the linkage in both directions using CDS and equities data (see also Dieckmann and Plank, 2012; Mody and Sandri, 2012; Kallestrup et al., 2016; Fratzscher and Rieth, 2019).

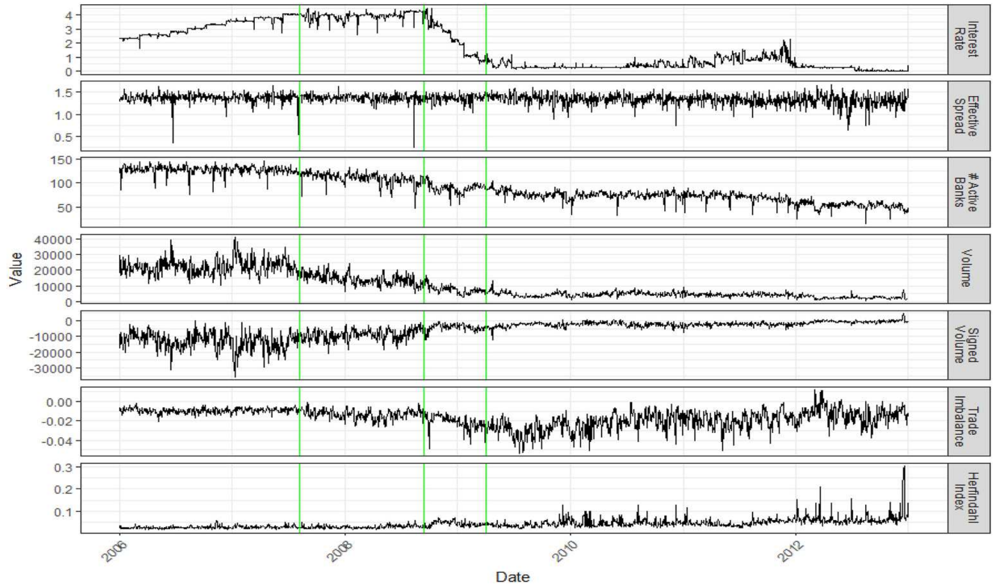

Fig. 1. Financial statistics at the daily resolution from the e-MID interbank market. The three vertical lines correspond to August 7, 2007 (when the ECB noted worldwide liquidity shortages), September 12, 2008 (Lehman), and April 1, 2009 (when the ECB announced the end of the recession).

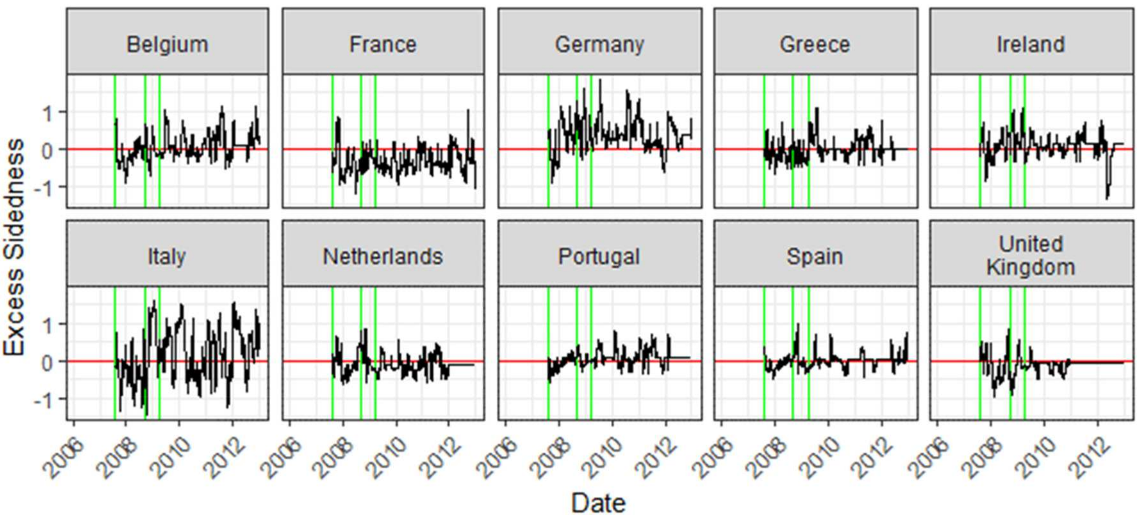

Fig. 2. The time-series of Excess Sidedness (30-day rolling window) by country. Excess sidedness for each country is equal to sidedness minus its pre-crisis mean level. The three vertical lines correspond to August 7, 2007 (when the ECB noted worldwide liquidity shortages), September 12, 2008 (Lehman), and April 1, 2009 (when the ECB announced the end of the recession). Values closer to negative one generally indicate a "one-sided" market where asymmetric information drives trading, and values closer to positive one indicate the market is "two-sided" where trading is caused by more heterogeneous beliefs.

public debt was perceived as risky (see Broner et al., 2014). In this environment, we expect that domestic sovereign CDS spreads would affect the interbank trading behavior of domestic banks through the macroeconomic and sovereign exposure channels. More generally, we expect a strong directional connection from sovereign risk to the interbank market. Whether the interbank market feeds back into sovereign risk during these crises remains an open empirical question.

Following Billio et al. (2012), we formally test the linkages between country-specific sidedness, and the corresponding sovereign

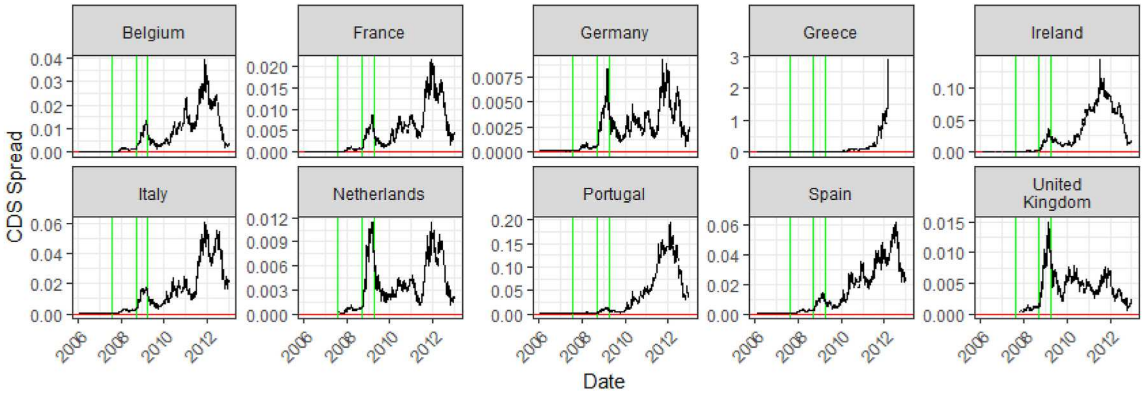

Fig. 3. Time-series of 5-year sovereign CDS spreads. The three vertical lines correspond to August 7, 2007 (when the ECB noted worldwide liquidity shortages), September 12, 2008 (Lehman), and April 1, 2009 (when the ECB announced the end of the recession).

CDS spreads using Granger causality within a bivariate vector autoregressive (VAR) framework. Fig. 3 displays the time series of 5-year CDS spreads for ten countries operating in e-MID over our sample period. While every country experienced a sudden increase in CDS spreads in 2009, Greece, Ireland, Italy, Portugal, and Spain experienced larger, more persistent changes.[18]

Fig. 4 shows the results for Granger causality tests between sidedness and CDS spreads estimated using the full data sample. An arrow in the direction of a country node indicates that sidedness or CDS spreads of that country Granger-causes another country's sidedness or CDS spreads. The figure shows several lead-lag relations between sidedness and sovereign CDS spreads. We see that the trading activity of non-domiciled banks tends to lead the CDS spreads of other countries. For example, the sidedness of German, Italian, Portuguese, and Spanish banks Granger-cause Dutch CDS spreads, often without feedback.

These results complement the findings in Brutti and Sauré (2015), who document that the bank holdings of foreign sovereign debt represent an important transmission channel in the sovereign-bank nexus. They show that euro area sovereign premiums widened in response to negative news coming out of Greece. Interestingly, they do not find evidence of cross-border transmission through interbank exposures, which is exactly what our granular data allow us to capture through sidedness.

5.2. *Transmitting monetary policy: sidedness and ECB operations*

During the crisis, the ECB intervened with open market operations that affected the interbank market that we study (see Brunetti et al., 2011). In this sub-section, we explore how sidedness is impacted by ECB interventions, which plausibly change interbank market dynamics.[19] We distinguish among long-term refinancing operations (LTRO), main refinancing operations (MRO), and other types (OT) of ECB operations when estimating the following model:

$$y_{it} = \alpha + \alpha_{Year} + \alpha_{Month} + \beta_1 LTRO_t + \beta_2 MRO_t + \beta_3 OT_t + \eta_{it} \tag{10}$$

where y_{it} is sidedness for country i, α_{Year} and α_{Month} are year and monthly dummies, and $LTRO_t$, MRO_t, and OT_t are intervention dummies equal to one on the day of the intervention t to day $t+2$ and zero otherwise.[20]

Estimation results for sidedness are in Table 1, where negative (positive) coefficients indicate increasing (decreasing) asymmetric information. Interestingly, other types of ECB operations and MROs are most significant. MROs serve to steer short-term (usually a week) interest rates, to manage the liquidity situation, and to signal the monetary policy stance in the euro area, while LTROs provide additional, longer-term (three-month) refinancing to the financial sector. However, during the crisis, the ECB introduced more operations, such as programs of outright asset purchases (APP), long-term (up to 3-year) refinancing operations in euros and in dollars, as well as fine-tuning operations. While MROs and LTROs represent the Eurosystem's regular open market operations, OTs are non-conventional and may convey more information to the market.

The OT coefficients for Germany and Italy are positive, indicating that German and Italian banks trade on both sides of the market. However, the OT coefficients are negative for the Netherlands, the U.K., Ireland, and Belgium—banks from these countries tend to trade on one side of the market during other types of operations. These results reveal that OTs are not uniformly successful in reducing asymmetric information across countries in the interbank market. Indeed, sidedness metrics reveal that these non-conventional operations are more reflective of increased asymmetric information among many countries' banks, but heterogeneous beliefs among

[18] When testing the null hypothesis of Granger-non-causality, we use the levels for sidedness, as well as the first difference of all CDS variables since its levels are non-stationary. We test for stationarity by the GLS-DF and the ADF unit root tests. The number of lags in the bivariate VARs is chosen using the Akaike information criterion (AIC).

[19] ECB intervention data are available from the ECB website.

[20] The data reflect yearly trends and monthly seasonality but no consistent day-of-the-week effects. Dummy variables are, by definition, weakly exogenous. Hence, our analysis does not suffer from any endogeneity issue.

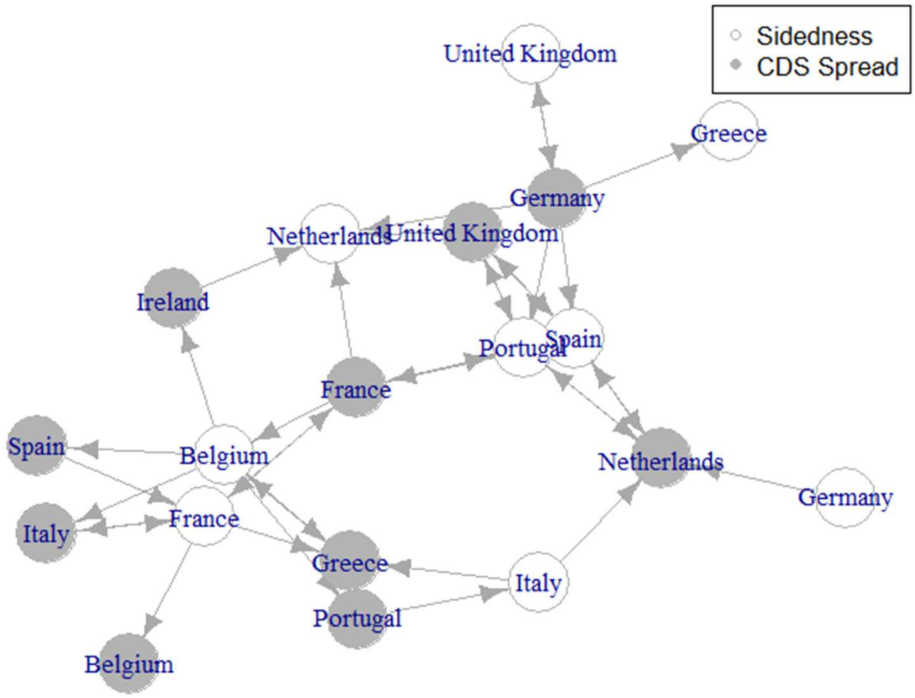

Fig. 4. Granger causality between sidedness and sovereign CDS spreads, by country. A→B indicates that variable A Granger-causes variable B at the 5% significance level. Results are based on the full data sample.

German and Italian banks.

On the other hand, the coefficients for the MROs are significantly positive for Belgium, the Netherlands, Portugal, and the U.K., signifying that these operations helped to reduce asymmetric information among banks across many countries. These operations appear to benefit the market overall, with no countries exhibiting increased asymmetric information.

As might be expected, LTROs, which provide three-month refinancing to the financial sector, have a more muted effect on sidedness at the daily level. Sidedness among banks from very few countries appears to change with these LTROs. Only German banks reflect significant one-sided trading and only Belgian banks reflect significant two-sided trading during LTROs.

6. Conclusion

We build on and extend Sarkar and Schwartz's (2009) market sidedness measure, creating a time series of sidedness and country-specific sidedness metrics. We then examine sidedness in the European interbank market for overnight funds during the periods surrounding the subprime mortgage crisis. We show that country-specific sidedness helps to describe how interbank market trades feed into the sovereign-bank nexus. For example, the sidedness of German, Italian, and Spanish banks lead changes in the sovereign CDS spreads of other countries, suggesting that bank activity in the interbank market conveys early information about country-specific risks.

In addition, we also show that sidedness responds to ECB interventions during the crisis—evidence that central bank policies also attenuate vulnerabilities through the sovereign-bank nexus. Country-specific market sidedness metrics reflect the fact that main refinancing operations, in particular, serve to effectively reduce information asymmetries among banks in most countries. Conversely, however, non-standard ECB operations more commonly reflect increased asymmetric information within countries, as more countries experience banks trading on the same side of the market during these events (perhaps reflecting extraordinary circumstances or fund imbalances that prompt these operations in the first place).

These findings demonstrate that institutions and scholars can utilize sidedness in a variety of settings and in combination with econometric tools (such as the Heckman correction) to better understand activity in financial markets. From a policy perspective, our results suggest that regulators can utilize metrics like sidedness (perhaps as a flag or early warning metric) for monitoring country-specific information that emerges from trading in the interbank market.

Declaration of competing interest

This material is based upon work supported by the National Science Foundation under Grant No. 1633158 (Mankad).

The views in this paper should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System. All errors and omissions, if any, are the authors' sole responsibility.

Table 1
Assessing the impact of ECB operations on sidedness.

	Portugal	Netherlands	Italy	Ireland	Greece	United Kingdom	France	Spain	Germany	Belgium
OT	−0.053***	−0.042***	0.037***	−0.040***	0.017	−0.053***	−0.015	−0.035**	0.026**	−0.105***
	(0.008)	(0.008)	(0.010)	(0.011)	(0.011)	(0.008)	(0.011)	(0.014)	(0.011)	(0.011)
MRO	0.041***	0.027**	−0.021	0.021	−0.013	0.035***	0.009	0.020	−0.012	0.074***
	(0.011)	(0.011)	(0.014)	(0.015)	(0.015)	(0.012)	(0.015)	(0.020)	(0.016)	(0.016)
LTRO	0.0004	0.016	0.010	−0.0005	0.004	0.019*	−0.011	−0.004	−0.048***	0.041***
	(0.010)	(0.011)	(0.014)	(0.014)	(0.014)	(0.011)	(0.014)	(0.019)	(0.015)	(0.015)
Year Fixed Effect	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Month Fixed Effect	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Adjusted R^2	0.347	0.222	0.381	0.319	0.314	0.536	0.444	0.257	0.281	0.254
F Statistic	48.0***	26.3***	55.5***	42.5***	41.6***	103.3***	71.8***	31.6***	35.6***	31.1***
Observations	1771	1771	1771	1771	1771	1771	1771	1771	1771	1771

Note: $^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Appendix A. Regression framework for sidedness

Here we show how sidedness can be equivalently expressed using simple linear regression. First, note that by construction, $\widetilde{v}_j$, where $j \in \{Buy, Sell\}$, have standard deviation equal to one. By expanding the definition of correlation, we have:

$$Sidedness = Cor\left(\widetilde{v}_{Buy}, \widetilde{v}_{Sell}\right)$$

$$= \frac{Cov\left(\widetilde{v}_{Buy}, \widetilde{v}_{Sell}\right)}{SD\left(\widetilde{v}_{Buy}\right)SD\left(\widetilde{v}_{Sell}\right)} = Cov\left(\widetilde{v}_{Buy}, \widetilde{v}_{Sell}\right) \tag{A1}$$

Then recall that in the simple linear regression:

$$\widetilde{v}_{Buy} = \alpha + \beta\widetilde{v}_{Sell} + u \tag{A2}$$

And the slope coefficient is:

$$\beta = \frac{Cov\left(\widetilde{v}_{Buy}, \widetilde{v}_{Sell}\right)}{SD\left(\widetilde{v}_{Sell}\right)^2} = Cov\left(\widetilde{v}_{Buy}, \widetilde{v}_{Sell}\right). \tag{A3}$$

Therefore, the slope coefficient (equation (A3)) from regressing initiated buys on initiated sells is exactly equal to Sidedness (equation (A1)) of Sarkar and Schwartz (2009). Since the result would still hold even if one regressed initiated sells on initiated buys and initiated buys and sells are codetermined, we can also represent sidedness using the following cross-sectional system of equations:

$$\widetilde{v}_{Buy} = \alpha_1 + \beta_1\widetilde{v}_{Sell} + u_1 \tag{A4}$$

$$\widetilde{v}_{Sell} = \alpha_2 + \beta_2\widetilde{v}_{Buy} + u_2, \tag{A5}$$

where u_1 and u_2 are Gaussian noise. When each equation is estimated separately using OLS, then the arguments above establishes that $\widehat{\beta}_1 = \widehat{\beta}_2 =$ Sidedness. Thus, even though OLS estimation of the system is subject to simultaneity bias (Woolridge, 2009), this regression-based formulation and estimation strategy is unbiased with respect to the sidedness of Sarkar and Schwartz (2009).

Appendix B. Heckman corrections

To review our notation, let c index country and t index time. Under the sampling mechanism described in Subsection 3.2, the OLS estimates of sidedness are unbiased if $\mathrm{E}(u_{c,t}|WillingnessToTrade_{c,t} > \lambda) = 0$. Expanding the expectation yields:

$$\mathrm{E}\left(u_{c,t}\middle|WillingnessToTrade_{c,t} > \lambda\right) = E\left(u_{c,t}\middle|\varepsilon_{c,t} > \lambda + f\left(Lending\ Rate_{c,t-1}, Borrowing\ Rate_{c,t-1}\right)\right) \tag{C1}$$

However, due to the correlation between $u_{c,t}$ and $\varepsilon_{c,t}$, the expectation is non-zero and can be written in closed form as a function of the inverse Mills ratio (Maddala, 1986).

$$\mathrm{E}\left(u_{c,t}\middle|WillingnessToTrade_{c,t} > \lambda\right) = \frac{\sigma_{12}}{\sigma_{22}}\mathrm{IMR}\left(Lending\ Rate_{c,t-1}, Borrowing\ Rate_{c,t-1}, \sigma_{22}\right). \tag{C2}$$

This key result from Heckman (1976, 1977) allows the sampling bias to be represented as an omitted variable. Consequently, we use a two-stage correction procedure to obtain accurate and consistent estimates of sidedness. First, we estimate the inverse Mills ratio with a probit model, where the response variable is a dummy variable indicating whether banks from a given country participated in the e-MID in the time interval of interest. We then include the estimated inverse Mills ratio as an additional variable in the second stage estimation of equation (3) to obtain consistent estimates for countries that did have banks participating in the e-MID interbank market.

In Table B1, we report the average sidedness over the entire data span with and without the Heckman correction. The table shows that estimates with the Heckman correction tend to become more extreme, indicating OLS estimates that are biased towards zero.

On the issue of whether the OLS or Heckman results should be utilized, from a statistical point of view, a major consideration beyond bias reduction is that the Heckman procedure can result in inflated standard errors that greatly reduce statistical power. However, the standard errors around the estimates are controlled and within reasonable limits. Therefore, the Heckman correction is advantageous because it does not add much noise relative to the benefits of reducing the bias.

Table B1
The average sidedness over the entire data span with and without the Heckman correction

	Sidedness	
Country	Regression	with Heckman Correction
Portugal	−0.230 (0.014)	−0.239 (0.018)
Netherlands	−0.023 (0.010)	−0.145 (0.013)
Italy	0.043 (0.008)	0.088 (0.008)
Ireland	−0.092 (0.013)	−0.139 (0.018)
Greece	−0.053 (0.011)	−0.278 (0.014)
United Kingdom	−0.191 (0.012)	−0.213 (0.013)
France	−0.115 (0.009)	−0.186 (0.012)
Spain	−0.266 (0.014)	−0.424 (0.018)
Germany	−0.102 (0.009)	−0.021 (0.0010)
Belgium	−0.155 (0.011)	−0.086 (0.013)

References

Alter, A., Beyer, A., 2014. The dynamics of spillover effects during the European sovereign debt turmoil. J. Bank. Finance 42, 134–153.
Baruch, S., Panayides, M., Venkataraman, K., 2017. Informed trading and price discovery before corporate events. J. Financ. Econ. 125, 561–588.
Billio, M., Getmansky, M., Lo, A., Pelizzon, A., 2012. Econometric measures of connectedness and systemic risk in the finance and insurance sectors. J. Financ. Econ. 104, 535–559.
Böhm, H., Eichler, S., 2020. Avoiding the fall into the loop: isolating the transmission of bank-to-Sovereign distress in the euro area. J. Financ. Stabil. 100763.
Broner, F., Erce, A., Martin, A., Ventura, J., 2014. Sovereign debt markets in turbulent times: creditor discrimination and crowding-out effects. J. Monetary Econ. 61, 114–142.
Brunetti, C., di Filippo, M., Harris, J.H., 2011. Effects of central bank intervention on the interbank market during the subprime crisis. Rev. Financ. Stud. 24, 2053–2083.
Brunetti, C., Harris, J.H., Mankad, S., Michailidis, G., 2019. Interconnectedness in the interbank market. J. Financ. Econ. 133, 520–538.
Brutti, F., Sauré, P., 2015. Transmission of sovereign risk in the Euro crisis. J. Int. Econ. 97, 231–248.
Chordia, T., Goyal, A., Jegadeesh, N., 2016. Buyers versus sellers: who initiates trades, and when? J. Financ. Quant. Anal. 51, 1467–1490.
Dell'Ariccia, G., Ferreira, C., Jenkinson, N., Laeven, L., Martin, A., Minoiu, C., Popov, A., 2018. Managing the sovereign-bank nexus. IMF Departmental Paper No. 18/16.
Dieckmann, S., Plank, T., 2012. Default risk of advanced economies: an empirical analysis of credit default swaps during the financial crisis. Rev. Finance 16, 903–934.
Evans, M.D., Lyons, R.K., 2002. Order flow and exchange rate dynamics. J. Polit. Econ. 110, 170–180.
Finger, K., Fricke, D., Lux, T., 2013. Network analysis of the e-MID overnight money market: the informational value of different aggregation levels for intrinsic dynamic processes. Comput. Manag. Sci. 10, 187–211.
Fratzscher, M., Rieth, M., 2019. Monetary policy, bank bailouts and the sovereign-bank risk nexus in the euro area. Rev. Finance 23, 745–775.
Gertler, M., Kiyotaki, N., 2010. Financial intermediation and credit policy in business cycle analysis. Handb. Monetary Econ. 3, 547–599.
Heckman, J.J., 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economic and Social Measurement*, NBER 5, 475–492.
Heckman, J.J., 1977. Sample Selection Bias as a Specification Error (With an Application to the Estimation of Labor Supply Functions). NBER Working Paper, p. w0172.
Heider, F., Hoerova, M., Holthausen, C., 2015. Liquidity hoarding and interbank market spreads: the role of counterparty risk. J. Financ. Econ. 118, 336–354.
Hristov, N., Hülsewig, O., Scharler, J., 2020. Unconventional Monetary Policy Shocks in the Euro Area and the Sovereign-Bank Nexus. Discussion Papers 19/2020. Deutsche Bundesbank.
Kallestrup, R., Lando, D., Murgoci, A., 2016. Financial sector linkages and the dynamics of bank and sovereign credit spreads. J. Empir. Finance 38, 374–393.
Kräussl, R., Lehnert, T., Denitsa, S., 2016. The European sovereign debt crisis: what have we learned? J. Empir. Finance 38, 363–373.
Maddala, G.S., 1986. Limited-dependent and Qualitative Variables in Econometrics. Cambridge University Press, Chicago IL.
Menkveld, A.J., Sarkar, A., van der Wel, M., 2012. Customer order flow, intermediaries, and discovery of the equilibrium risk-free rate. J. Financ. Quant. Anal. 47, 821–849.
Mody, A., Sandri, D., 2012. The eurozone crisis: how banks and sovereigns came to be joined at the hip. Econ. Pol. 27, 199–230.
Sarkar, A., Schwartz, R.A., 2009. Market sidedness: insights into motives for trade initiation. J. Finance 64, 375–423.
Woolridge, J., 2009. Econometric Analysis of Cross Section and Panel Data. The MIT Press, Cambridge, Massachusetts; London, England.
Xu, L., Yin, X., Zhao, J., 2019. The sidedness and informativeness of ETF trading and the market efficiency of their underlying indexes. Pac. Basin Finance J. 58, 1–19.