EUROPEAN CENTRAL BANK
EUROSYSTEM

Working Paper Series

Gonzalo Camba-Mendez,
Francesco Paolo Mongelli

Risk aversion and bank loan pricing

No 2514 / January 2021

Abstract

How much of the heterogeneity in bank loan pricing is explained by disparities in banks' attitude towards risk? The answer to this question is not simple because there are only very weak proxies for gauging the degree of a bank's risk aversion. We handle this constraint by means of a novel econometric approach that allows us to disentangle the amount of risk faced by banks and the price they charge for holding that risk. Some of our results are aligned with previous studies and confirm that disparities in market power, banks' funding costs, and banks' funding risks are reflected in bank lending rates. However, our new modelling framework reveals that the heterogeneity in bank lending rates is also a reflection of the non-negligible disparities in banks' risk aversion.

JEL classification: C23, E58, G21
Keywords: Bank loan pricing, risk aversion.

EXECUTIVE SUMMARY

Risk aversion should play a critical role in loan pricing. However, to our knowledge, little empirical analysis of this issue has been conducted. This is most likely a reflection of the fact that bringing risk aversion into empirical analyses is challenging because there are only very weak proxies to account for it. In this paper, we handle this challenge by treating bank risk aversion as an unobservable random effect. This econometric modelling strategy enables us to disentangle the amount of risk faced by banks from the price which banks charge for holding that risk. This is a convenient modelling assumption which resembles the hierarchical models, also sometimes referred to as multilevel models, commonly employed in empirical research. We illustrate this approach with a study on bank loan pricing in the euro area between October 2008 and October 2013, the height of the recent Global Financial Crisis.

Our results show that a large degree of heterogeneity across bank lending rates is not exclusively justified by simple disparities in heterogeneity in risk exposures to both credit and financing risks. The heterogeneity in bank lending rates is also a reflection of the non-negligible disparities in banks' risk aversion.

1 Introduction

Some recent studies have concluded that in view of the large dispersion of banks' stock market returns, it is likely there is a large degree of heterogeneity in risk aversion across euro area banks, see Altunbas et al. (2017). This view is aligned with the usual treatment of banks in the economics literature as risk averse agents operating in an uncertain environment, see e.g. (Sealey, 1980; Ratti, 1980; Ho and Saunders, 1981; Koppenhaver, 1985; Angbazo, 1997). Risk aversion should thus play a critical role in loan pricing. However, to our knowledge, little empirical analysis of this issue has been conducted. This is most likely a reflection of the fact that bringing risk aversion into empirical analyses is challenging because there are only very weak proxies to account for it. In this paper, we handle this challenge by treating bank risk aversion as an unobservable random effect. This econometric modelling strategy enables us to disentangle the amount of risk faced by banks from the price which banks charge for holding that risk. This is a convenient modelling assumption which resembles the hierarchical models, also sometimes referred to as multilevel models, commonly employed in empirical research. We illustrate this approach with a study on bank loan pricing in the euro area between October 2008 and October 2013, the height of the recent Global Financial Crisis.

The paper is organised as follows. Section 2 presents our econometric strategy. Section 3 provides the empirical results. Finally, section 4 provides some concluding remarks.

2 Risk aversion as a random coefficient

2.1 An econometric model for the bank lending rate

We adopt the theoretical framework employed in Camba-Mendez et al. (2016), which in effect extends the framework of Ho and Saunders (1981) and Angbazo (1997) to account for the main financing challenges faced by euro area banks during the Global Financial Crisis. Under this extended setting, banks finance themselves via: deposits, the interbank market, the central bank, and debt issuance. Banks' access to interbank market financing is subject to uncertainty, i.e. there is a probability that they will not be able to draw liquidity from it. However, banks have unlimited access to central bank financing.[1] The bank sets the lending rate, r_L, with a view to maximize the expected value of its wealth. It follows from

[1] The policies introduced by the ECB during the Global Financial Crisis allowed banks to build up precautionary liquidity reserves. This resulted in an environment of protracted excess liquidity in interbank markets which exerted downward pressure on the overnight interbank market rates. This meant that the cost of financing via the interbank market was at a discount with respect to the financing via the ECB.

Camba-Mendez et al. (2016) that this should be set according to:[2]

$$r_L = r + \delta\lambda_\delta + \frac{1}{2}\frac{\alpha}{\beta} + \frac{1}{4}\tilde{\rho}(1-2\alpha)\sigma_r^2 + \frac{1}{4}\tilde{\rho}\sigma_L^2 + \frac{1}{1-\beta\tilde{\rho}\sigma_r^2}\left[\frac{s}{2} + \frac{1}{8}\beta\tilde{\rho}^2\sigma_L^2\sigma_r^2\right] \tag{1}$$

where r is the reference short-term rate set by the central bank; δ is the discount (a negative value) at which the interbank market rate trades with respect to the central bank short-term rate; λ_δ is the probability that the bank has access to interbank market financing; ρ is the coefficient of relative risk aversion; $\frac{\alpha}{\beta}$ reflects the bank's market power for setting rates; $s = (r_B - r - \delta)$ is the bank's bond yield financing spread; and finally σ_r^2 and σ_L^2 are respectively the volatility of interbank market shocks and the volatility associated with the return from the loan and thus relate respectively to the refinancing risks and the default risks encountered by the bank. The bank lending rate therefore reflects the expected rate of short-term financing (dependent on access to the interbank market), market power, compensation for interbank market risk, credit risk, and debt market financing costs. The later compensation is dependent on the degree of risk aversion of the bank.

We choose to handle the nonlinearities of the model by means of interaction terms. We thus adopt the following econometric specification for our regression analysis:

$$\begin{aligned} r_{L,it} - r_t = \gamma_0 + \gamma_1\bar{\delta}_{it} + \gamma_2 C_{it} + \gamma_3 HFI_{ct} + \rho_i\sigma_{r,t}^2 + \\ \beta_1\rho_i\sigma_{L,ct}^2 + \beta_2\rho_i s_{it} + \beta_3\rho_i\sigma_{r,t}^2\sigma_{L,ct}^2 + \beta_4\rho_i\sigma_{r,t}^2 s_{it} + \mu_i + \varepsilon_{it} \end{aligned} \tag{2}$$

where we define $\bar{\delta}_{it} = \delta_t\lambda_{\delta it}$; where C_{it} is the ratio of operational costs to total assets, to account for the fact, as in Maudos and Fernandez de Guevara (2004), that loans are processed at a cost; and HFI relate to the Herfindahl indexes to measure market power. Finally, the bank-specific random effect, μ_i, accounts for other bank specific features potentially left out from our formulation. We now turn to our approach for dealing with risk aversion, ρ_i.

2.2 Estimation

An alternative formulation for equation (2), and where we use the standard notation y_{it} to refer to the dependent variable, is as follows:

$$y_{it} = \boldsymbol{\gamma}'\boldsymbol{p}_{it} + \rho_i x_{it} + \rho_i\boldsymbol{\beta}'\boldsymbol{z}_{it} + \mu_i + \varepsilon_{it} \tag{3}$$

where $\boldsymbol{\gamma}$; $\boldsymbol{\beta}$ are parameters to be estimated; and where $\boldsymbol{p}_{it}$, x_{it} and $\boldsymbol{z}_{it}$ are respectively a $p \times 1$ vector, a scalar and a $k \times 1$ vector of regressors.[3] We then choose to treat risk aversion,

[2]The appendix provides precise details on the derivation of this equation.

[3]For our empirical model in equation (2) the parameter vectors and regressors are defined as follows: $\boldsymbol{\gamma} = (\gamma_0, \ldots, \gamma_3)$; $\boldsymbol{\beta} = (\beta_1, \ldots, \beta_4)$; $\boldsymbol{p}_{it} = \left(1, \bar{\delta}_{it}, C_{it}, HFI_{ct}\right)$, $x_{it} = \sigma_{r,t}^2$ and $\boldsymbol{z}_{it} = \left(\sigma_{L,ct}^2, s_{it}, \sigma_{r,t}^2\sigma_{L,ct}^2, \sigma_{r,t}^2 s_{it}\right)$.

ρ_i as a random parameter, which we model as:

$$\rho_i = \rho + \nu_i$$

with ν_i a bank specific random effect, and ρ a constant parameter.[4] For simplicity, we define the vector of random effects $\boldsymbol{b}_i = (\mu_i, \nu_i)'$. The statistical model is completed by adopting multivariate normal distributional assumptions for the random terms, namely $\varepsilon_{it} \sim N(0, \sigma^2)$ and $\boldsymbol{b}_i \sim N_2(0, \boldsymbol{D})$, and further assuming that $E\{\boldsymbol{b}_i \varepsilon_{it}\} = \mathbf{0}$ for all t.

The model is non-linear on the fixed parameters to be estimated, $\boldsymbol{\gamma}, \rho, \boldsymbol{\beta}, \boldsymbol{D}$ and σ^2. We then proceed to derive the i-th likelihood for the n_i observations across each bank for the estimation of the vector of fixed effect parameters $\boldsymbol{\theta} = (\boldsymbol{\gamma}', \rho, \boldsymbol{\beta}')'$. Prior to that we adopt the following definitions, $\boldsymbol{y}_i = (y_{i1}, \ldots, y_{in_i})'$, and $\boldsymbol{x}_i = (x_{i1}, \ldots, x_{in_i})'$ are both $n_i \times 1$ vectors defined for each bank i; $\boldsymbol{Z}_i$ is a $n_i \times k$ matrix where each row contains the elements of $\boldsymbol{z}_{it}$; and $\boldsymbol{P}_i$ is a $n_i \times p$ matrix where each row contains the elements of $\boldsymbol{p}_{it}$. It then follows that the likelihood for each i is:

$$L_i(\boldsymbol{y}_i, \boldsymbol{b}_i | \boldsymbol{\theta}) = \phi_{n_i}\left(\boldsymbol{q}_i - \boldsymbol{Q}_i \boldsymbol{b}_i, \sigma^2 \boldsymbol{I}_{n_i}\right) \phi_2(\boldsymbol{b}_i, \boldsymbol{D}) \tag{4}$$

with:

$$\begin{aligned}
\boldsymbol{q}_i &= \boldsymbol{y}_i - \boldsymbol{P}_i \boldsymbol{\gamma} - \rho \boldsymbol{\varphi}_i \\
\boldsymbol{\varphi}_i &= \boldsymbol{x}_i + \boldsymbol{Z}_i \boldsymbol{\beta} \\
\boldsymbol{Q}_i &= \left[\begin{array}{cc} \boldsymbol{\imath} & \boldsymbol{\varphi}_i \end{array}\right]
\end{aligned}$$

where $\phi_k(\boldsymbol{z}, \boldsymbol{\Sigma})$ denotes the density of a k-dimensional multivariate normal distribution with zero mean and covariance matrix $\boldsymbol{\Sigma}$, evaluated at point $\boldsymbol{z}$; and $\boldsymbol{\imath}$ a $n_i \times 1$ vector of ones. It follows that:

$$\begin{aligned}
L_i(\boldsymbol{y}_i, \boldsymbol{b}_i | \boldsymbol{\theta}) &= \left[\frac{1}{\sigma\sqrt{2\pi}}\right]^{n_i} \exp\left\{-\frac{1}{2}\left[\tilde{q}_i^2 - 2\tilde{n}_i' \boldsymbol{b}_i + \boldsymbol{b}_i' \tilde{\boldsymbol{Q}}_i \boldsymbol{b}_i\right]\right\} \phi_2(\boldsymbol{b}_i, \boldsymbol{D}) \\
&= \left[\frac{1}{\sigma\sqrt{2\pi}}\right]^{n_i} \frac{1}{|\boldsymbol{D}|^{\frac{1}{2}} 2\pi} \exp\left\{-\frac{1}{2}\left[\tilde{q}_i^2 - 2\tilde{\boldsymbol{n}}_i' \boldsymbol{b}_i + \boldsymbol{b}_i' \boldsymbol{S}_i \boldsymbol{b}_i\right]\right\} \\
&= \left[\frac{1}{\sigma\sqrt{2\pi}}\right]^{n_i} \frac{1}{|\boldsymbol{D}|^{\frac{1}{2}} 2\pi} \exp\left\{-\frac{1}{2}\left[(\boldsymbol{b}_i - \mathbf{b}_{0i})' \boldsymbol{S}_i (\boldsymbol{b}_i - \mathbf{b}_{0i}) + \tilde{q}_i^2 - \tilde{\boldsymbol{n}}_i \boldsymbol{S}_i^{-1} \tilde{\boldsymbol{n}}_i'\right]\right\}
\end{aligned} \tag{5}$$

[4]Strictly speaking, our econometric strategy does not identify risk aversion at the bank level because ρ_i represents $\frac{1}{4}\tilde{\rho}(1 - 2\alpha)$ in equation (1). That is ρ_i also contains the 'standard' compensation for bearing refinancing risks. However, the variation in ν_i reflects the variation in risk aversion across banks.

where we have defined along the way:

$$
\begin{aligned}
\tilde{q}_i^2 &= \frac{1}{\sigma^2}\boldsymbol{q}_i'\boldsymbol{q}_i \\
\tilde{\boldsymbol{n}}_i &= \frac{1}{\sigma^2}\boldsymbol{q}_i'\boldsymbol{Q}_i \\
\tilde{\boldsymbol{Q}}_i &= \frac{1}{\sigma^2}\boldsymbol{Q}_i'\boldsymbol{Q}_i \\
\boldsymbol{S}_i &= \tilde{\boldsymbol{Q}}_i + \boldsymbol{D}^{-1} \\
\boldsymbol{b}_{0i} &= \boldsymbol{S}_i^{-1}\tilde{\boldsymbol{n}}_i'
\end{aligned}
\tag{6}
$$

From equation (5) the marginal likelihood of L_i can be easily worked out as follows:

$$
L_i\left(\boldsymbol{y}_i\,|\boldsymbol{\theta}\,\right) = \int L_i\left(\boldsymbol{y}_i, \boldsymbol{b}_i\,|\boldsymbol{\theta}\,\right) d\boldsymbol{b}_i = \left[\frac{1}{\sigma\sqrt{2\pi}}\right]^{n_i} \frac{1}{|\boldsymbol{D}|^{\frac{1}{2}}\,|\boldsymbol{S}_i|^{\frac{1}{2}}} \exp\left\{-\frac{1}{2}\left[\tilde{q}_i^2 - \tilde{\boldsymbol{n}}_i\boldsymbol{S}_i^{-1}\tilde{\boldsymbol{n}}_i'\right]\right\}
$$

The sample likelihood is then computed as:

$$
L = \prod_{i=1,\ldots,K} L_i
$$

The $\boldsymbol{b}_{0i}$ defined in equation (6) provides an estimator for the random effects. This is equivalent to the standard best linear unbiased estimator, see e.g. Robinson (1991). It should be noted that this econometric model is more restrictive than a pure 'heterogeneous' panel regression model where all elasticities are different across individual banks. In particular, in our model, ρ_i (risk aversion) has a proportional impact on the price elasticities (or prices of risk).

3 Empirical results

For our empirical analysis we employ the data used in Camba-Mendez et al. (2016). These data contain monthly observations for a sample of large euro area banks, covering the period from October-2008 to October 2014.[5] For our analysis we distinguish between bank lending rates offered to *small and medium-sized enterprises* (SME) and to *large non-financial corporations* (large NFC). The regression model does not contain explanatory variables which are liable to induce endogeneity problems, e.g. Maudos and Fernandez de Guevara (2004), and Santos (2011). A possible exception relates to operational costs, but to mitigate this shortcoming, we have included this variable with a lag.

Results shown in Table 1 suggest that several theoretical implications of the model are broadly validated. First, those banks with access to interbank markets, and thus banks that

[5]The appendix provides more precise details on the data.

relied less on ECB financing, offered lower bank lending rates to their customers. Interestingly, and as revealed by the magnitude of the coefficient γ_1 in the table, the additional cost of financing via the ECB, for those banks with reduced access to interbank market financing, is passed almost in full to SME loans, whereas only around half of that additional cost ends up being reflected in the pricing of loans to large NFC. Second, market power, HFI, is both significant and positive, as expected, particularly for SME loans compared to other large NFC loans. This suggests indeed that large corporations, may have more negotiating power with various banks. Third, banks with access to cheaper financing via debt also offer lower lending rates, as shown by the positive sign of the average marginal effect associated with s_{it} reported in Table 2. This result is thus aligned with empirical studies documenting a positive link between bank lending rates and debt-financing costs, Gambacorta (2008) and Holton and d'Acri (2015). Finally, higher risk aversion translates into higher bank lending rates, as shown by the positive estimated average marginal effect reported in Table 2.

Other modelling results, however, are not fully aligned with theoretical expectations. For example, the coefficient associated with operational costs, γ_2 is not significant. Furthermore, risks associated with the volatility of interbank market rate, σ_r^2, turned out to be negative for SME loans, as shown by the marginal effects reported in Table 2. Of course, in our model, access to interbank market is already accounting for a large part of the uncertainties associated with short-term financing. It appears that risks associated with the volatility of the Euribor are of a second order of importance for pricing loans during the period under study. In the same vein, the estimation results show that the average marginal effect associated with credit risk is not significant. Here, it cannot be excluded that our proxy for credit risk fails to fully account for the true risk in the loan portfolio of the banks. The loan portfolio of the banks was shrinking for most of our sample period, this was both a result of the strong decline in demand, but also on account of the deleveraging process which unfolded. The non-significance of the average marginal effect associated with credit risk may thus reflect that new loans were being granted to the most solvent, less highly leveraged firms which had more power to embark on expansionary investments than weaker firms.

Despite its relative parsimony, our econometric model can explain a large part of the variation in bank lending rates, as indicated by the large R^2 coefficients. Nevertheless, a non-negligible part of the variation is explained by our two random effects, μ_i and ν_i; which as indicated above may serve as a proxy for disparities in operating costs and market power, the former, as well as disparities in risk aversion (illustrated by the magnitude of σ_ν in Table 1), the latter. The reported average marginal effects in Table 2, does not reflect the heterogeneity of marginal effects across banks.

Equally large heterogeneity in the impact from changes to risk aversion across loan types is revealed by the estimated ranges reported in Figure 1. The reported heterogeneity of the marginal effect of a change in risk aversion also illustrates the disparity of risk exposures across banks. Figure 1 reveals that loans are responsive to changes in risk aversion. This figure equally shows that for loans to large NFCs, at the time when risk exposures were high during the period from early 2010 to mid 2012, the marginal effect of an increase in risk aversion was also at its highest.

4 Conclusions

We have presented a novel econometric approach to gauge the impact of bank risk aversion in bank loan pricing. Our method is illustrated with a brief study on bank loan pricing in the euro area from October 2008 to October 2014 during the Global Financial Crisis when most banks had difficulties refinancing their short-term liabilities, and the ECB intervened with policies that led to an environment of ample central bank liquidity provision. Our results show that a large degree of heterogeneity across bank lending rates is not exclusively justified by simple disparities in heterogeneity in risk exposures to both credit and financing risks. The heterogeneity in bank lending rates is also a reflection of the non-negligible disparities in banks' risk aversion.

References

Altunbas, Y., S. Manganelli and D. Marques-Ibanez (2017): "Realized Bank Risk during the Great Recession," *Journal of Financial Intermediation*, 32, pp. 29–44.

Angbazo, L. (1997): "Comercial bank net interest margins, default risk, interest-rate risk and off-balance sheet banking," *Journal of Banking and Finance*, 21, pp. 55–87.

Camba-Mendez, G., A. Durre and F. P. Mongelli (2016): "Bank interest rate setting in the euro area during the Great Recession," ECB Working Paper Series, No 1965, September 2016.

Gambacorta, L. (2008): "How do banks set interest rates?" *European Economic Review*, 52, pp. 792–819.

Ho, T. and A. Saunders (1981): "The determinants of bank interest rate margins: Theory and empirical evidence," *Journal of Financial and Quantitative Analysis*, 16(4), pp. 581–600.

Holton, S. and C. R. d'Acri (2015): "Jagged cliffs and stumbling blocks: interest rate pass-through fragmentation during the euro area crisis," ECB Working Paper, No 1850.

Koppenhaver, G. D. (1985): "Bank Funding Risks, Risk Aversion, and the Choice of Futures Hedging Instrument," *Journal of Finance*, 40(1), pp. 241–255.

Maudos, J. and J. Fernandez de Guevara (2004): "Factors explaining the interest rate margin in the banking sectors of the European Union," *Journal of Banking and Finance*, 28, pp. 2259–2281.

Ratti, R. A. (1980): "Bank Attitude toward Risk, Implicit Rates of Interest, and the Behavior of an Index of Risk Aversion for Commercial Banks," *Quarterly Journal of Economics*, 95(2), pp. 309–331.

Robinson, G. K. (1991): "That BLUP is a good thing: The estimation of random effects," *Statistical Science*, 6(1), pp. 15–32.

Santos, J. A. C. (2011): "Bank Corporate Loan Pricing Following the Subprime Crisis," *Review of Financial Studies*, 24(6), pp. 1916–1943.

Sealey, C. W. (1980): "Deposit Rate-Setting, Risk Aversion, and the Theory of Depository Financial Intermediaries," *Journal of Finance*, 35(5), pp. 1139–1154.

Table 1: Bank loan pricing estimation results I: parameter estimates

	γ_0	γ_1	γ_2	γ_3	ρ	β_1	β_2	β_3	β_4	R^2	obs.	N	σ_μ	σ_ν	σ_ε
SME	3.35^{**}	0.67^{**}	0.02	1.52^{**}	0.93^{**}	-0.06	0.30^{**}	0.38	-1.16^{**}	0.64	2303	41	1.08	0.72	0.93
	(0.22)	(0.11)	(0.07)	(0.18)	(0.34)	(0.06)	(0.09)	(0.40)	(0.30)						
large NFC	3.08^{**}	0.43^{**}	-0.09	0.51^{**}	0.09	1.52	0.31	-2.73	-0.55^{*}	0.39	2369	41	0.94	0.68	0.92
	(0.18)	(0.11)	(0.07)	(0.14)	(0.11)	(1.23)	(0.23)	(2.48)	(0.31)						

Note: Table 1 shows the estimation results of the regression model in equation (2). Standard deviations of estimated coefficients are reported in between brackets. obs is used to denote available observations, N gives the number of banks in the sample. The reported R^2 is computed using the unbiased estimators for the random effects described in the main text. Significance levels higher than 5% and 10% are denoted with ** and *, respectively.

Table 2: Bank loan pricing estimation results II: average marginal effects

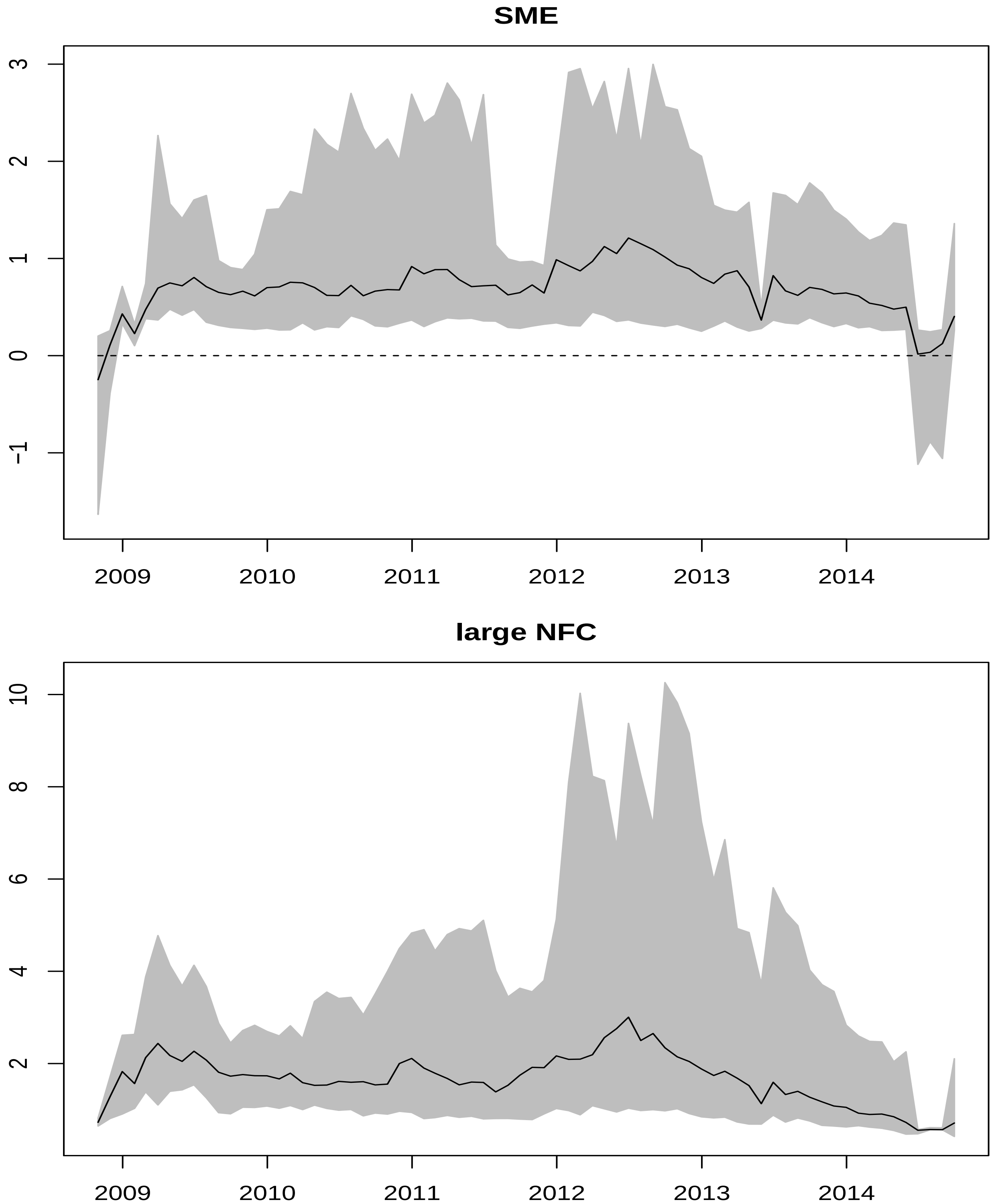
	$\sigma^2_{r,t}$	$\sigma^2_{L,ct}$	s_{it}	ρ_i
SME	-2.03^{**}	-0.02	0.16^{**}	0.72^{**}
	(0.51)	(0.05)	(0.04)	(0.22)
large NFC	0.06	0.04	0.01	1.85
	(0.38)	(0.17)	(0.04)	(1.39)

Note: Table 2 reports average marginal effects for the estimated regression model in equation (2). Standard deviations of estimated average marginal effects are reported in between brackets. The average marginal effects are computed as $T^{-1}K^{-1}\sum_i\sum_t \widehat{ME}_{it}(\cdot)$, with $\widehat{ME}_{it}(\cdot)$ defined as follows:

$$\widehat{ME}_{it}\left(\sigma^2_r\right) = \hat{\rho}_i + \hat{\beta}_3\hat{\rho}_i\sigma^2_{L,ct} + \hat{\beta}_4\hat{\rho}_i s_{it}$$
$$\widehat{ME}_{it}\left(\sigma^2_L\right) = \hat{\beta}_1\hat{\rho}_i + \hat{\beta}_3\hat{\rho}_i\sigma^2_{r,t}$$
$$\widehat{ME}_{it}(s) = \hat{\beta}_2\hat{\rho}_i + \hat{\beta}_4\hat{\rho}_i\sigma^2_{r,t}$$
$$\widehat{ME}_{it}(\rho) = \sigma^2_{r,t} + \hat{\beta}_1\sigma^2_{L,ct} + \hat{\beta}_2 s_{it} + \hat{\beta}_3\sigma^2_{r,t}\sigma^2_{L,ct} + \hat{\beta}_4\sigma^2_{r,t}s_{it}$$

The standard errors of these marginal effects are computed by means of Monte Carlo simulations. Significance levels higher than 5% and 10% are denoted with ** and *, respectively.

Figure 1: Range of the marginal effect of risk aversion on the bank lending rate



NOTE: The figure shows the range of the simulated medians for each bank i, of the marginal effect $\widehat{ME}_{it}(\rho)$ at every t. See the notes in Table 2 for details on the computation of $\widehat{ME}_{it}(\rho)$.

Appendix

A The bank loan pricing model

The model is a one-period decision model where a representative bank maximizes the expected utility of its wealth. Banks can finance themselves via: the interbank market, the central bank, deposits, and/or debt issuance. Bank's access to interbank market financing is subject to uncertainty. In contrast, all banks have unlimited access to central bank financing because the central bank operates in an environment of extended liquidity. The cost of financing in the interbank market is discounted with respect to the cost of financing via the central bank.

A.1 Financing costs

The cost of financing via either the central bank or the interbank market is not fully known a priori, and is defined as follows:

$$r + \delta R_\delta + Z_r$$

where r is the reference short-term rate set by the central bank. δ is the discount at which the interbank market rate trades with respect to the central bank short-term rate, and in an environment of extended central bank liquidity will be negative. Banks' access to the interbank market is incorporated into our model by means of R_δ, which is an independent Bernoulli random variable with probability λ_δ; this probability is in effect the probability that the bank has access to interbank market financing when it needs to.[6] Finally, Z_r is a normally distributed random shock with mean zero and variance σ_r^2. The random shock Z_r reflects the uncertainty concerning the short-term rate set by the central bank. Note that from this perspective, the expected cost of financing from either the interbank market, if the bank happens to have access, or the central bank, is equal to $r + \delta\lambda_\delta$. Throughout the text we will use the notation $\bar{\delta} = \delta\lambda_\delta$, to denote the *expected interbank market discount*. For those banks with zero probability of having access to the interbank market, the expected interbank market discount will of course be zero.

The bank sets the value for the deposit rate, r_D. The amount of funding that the bank will raise via deposits will depend on this deposit rate. For simplicity, we assume that the bank deposit rate is set with reference to the expected rate of short-term financing. For placing a deposit in the interbank market there are no access restrictions, and thus the expected

[6] A Bernoulli random variable takes the value of 1 with a probability λ and a value of zero with a probability $1 - \lambda$.

return of placing a deposit in the interbank market would be $r + \delta$. That is:

$$r_D = r + \delta + a \tag{A-1}$$

where a is a margin to be set by the bank.

Financing via debt issuance is the most expensive form of financing; however, the bank can borrow the amount it chooses, which we denote as B, at a cost rate r_B which is known a priori. The deposits and lending opportunities may arrive at different periods of time. Were a new loan request to arrive that was not matched by the arrival of new deposits or by funds available in the form of cash raised via debt issuance, then the bank would have to finance the new loan by either borrowing funds in the interbank market or accessing the liquidity lines of the central bank. From this perspective, debt issuance allows the bank to hedge the refinancing risks of having to raise money from the interbank market or the central bank in the future.

A.2 Deposit arrivals and demand for loans

It is further assumed that the bank also sets its lending rate with reference to the expected rate of short-term financing, and namely:[7]

$$r_L = r + \delta\lambda_\delta + b \tag{A-2}$$

where b is a margin set by the bank. By manipulating the margins a and b, banks understand how they can influence the arrival of deposits and the demand for loans, i.e. they hold a certain monopolistic power that they can exploit. This is modelled, for simplicity and as in Ho and Saunders (1981), by assuming that the probability of granting a new loan (λ_L) and the probability of obtaining a new deposit (λ_D) are symmetric and linear functions of the margin applied by the bank, i.e.

$$\lambda_D = \alpha + \beta a$$

$$\lambda_L = \alpha - \beta b$$

The arrival of a new deposit and the request for a new loan will thus be modelled as two independent Bernoulli random variables R_D and R_L with respective probabilities λ_D and λ_L. In line with Ho and Saunders (1981), and without loss of generality, it is assumed that at most one loan and/or deposit may arrive, and that these are of equal size defined as Q.

[7] These definitions of r_D and r_L could equally be read as a convenient modelling representation for these rates.

A.3 Bank's expected utility

At time 0, the wealth of the bank, W_0, is measured as the value of loan assets, minus deposit liabilities, plus net cash holdings. For simplicity, we assume that the initial wealth of banks is zero, $W_0 = 0$. The initial loan and deposit portfolios are also assumed to be zero. The return on the loan granted by the bank is subject to uncertainties, it is assumed that the bank will receive in return from a loan $(1 + r_L + Z_L)$, where Z_L is a normal random shock with mean zero and variance σ_L^2. It is further assumed that the random shocks, Z_r and Z_L as well as the random events of the arrival of a new deposit, R_D, and the request for a new loan, R_L, are all independent.

The bank needs to make a decision on the margins, a and b, and on the amount of borrowing in debt instruments, B.[8] The increase in wealth is defined as follows:

$$W - W_0 = \Delta W_B + R_D \Delta W_D + R_L \Delta W_L$$

where ΔW_B is the increase in net wealth not resulting from the arrival of a new deposit or loan, ΔW_D is the net increase in wealth resulting from the arrival of a new deposit, and ΔW_L is the net increase in wealth resulting from granting a new loan. The evolution of bank's wealth is given by:

$$\begin{aligned}\Delta W_B &= B(1 + r_B) - B(1 + r + \delta + Z_r) \\ &= B(s - Z_r)\end{aligned}$$

$$\begin{aligned}\Delta W_D &= -Q(1 + r_D) + Q(1 + r + \delta + Z_r) \\ &= Q(-a + Z_r)\end{aligned}$$

$$\begin{aligned}\Delta W_L &= -Q(1 + r + \delta R_\delta + Z_r) + Q(1 + r_L + Z_L) \\ &= Q(b - \delta(R_\delta - \lambda_\delta) - Z_r + Z_L)\end{aligned}$$

and where we have used $s = (r_B - r - \delta)$ to denote the bond yield spread. ΔW_B suggests that the amount borrowed in B could be placed in the interbank market to help servicing part of the interest on the debt in the event of no arrival of a new loan request. In a similar vein, the equation for ΔW_D suggests, were a new deposit to arrive, that amount could be placed in the interbank market to pay back part of the cost associated with remunerating the deposit. Finally, and in relation with ΔW_L, if a request for a new loan arrives, the financing

[8] It is implicitly assumed that loans are expected to be more profitable than investing in either money or the return in debt instruments.

could either go via deposits, if any, or borrowed debt, if any. The reminder financing need would need to be financed through either the interbank market or the central bank.

Bank's expected utility function is then approximated using a Taylor expansion around wealth at time 0, namely:

$$U^e(W) = U(W_0) + U'(W_0)E(W - W_0) + \frac{1}{2}U''(W_0)E(W - W_0)^2$$

The expression for the expected increase in wealth, $E(W - W_0)$, can be derived from the independence assumptions on the random shocks and noting that for the Bernoulli random variables $E(R_D) = \lambda_D$ and $E(R_D^2) = E(R_D) = \lambda_D$. Using these results, it follows that:

$$\begin{aligned} E(W - W_0) &= E\left[Bs - BZ_r + (-a + Z_r) QR_D + (-Z_r + b + Z_L - \delta (R_\delta - \lambda_\delta)) QR_L\right] \\ &= Bs - \lambda_D Qa + \lambda_L Qb \end{aligned}$$

For the derivation of $E(W - W_0)^2$, following Ho and Saunders (1981), it is further assumed that the terms involving the square terms of the loan and deposit margins, a and b, are negligible and can be safely ignored. We follow this same rationale with the cross product between the loan and deposit margin with the spreads s and δ.

$$\begin{aligned} E(W - W_0)^2 &= E\left[Bs + Z_r(-B + R_D Q - R_L Q) + Z_L Q R_L - R_D Q a + R_L Q b - (R_\delta - \lambda_\delta) Q\delta\right]^2 \\ &\approx E\left[Z_r(-B + R_D Q - R_L Q)\right]^2 + E\left[Z_L Q R_L\right]^2 \\ &\approx \sigma_r^2\left[B^2 + \lambda_D Q^2 + \lambda_L Q^2 + 2BQ(\lambda_L - \lambda_D) - 2Q^2\lambda_D\lambda_L\right] + \sigma_L^2 Q^2 \lambda_L \\ &\approx \sigma_r^2\left[B^2 + \lambda_D Q^2 + \lambda_L Q^2 + 2BQ(\lambda_L - \lambda_D) - 2Q^2\alpha\beta(a - b)\right] + \sigma_L^2 Q^2 \lambda_L \end{aligned}$$

A.4 The bank lending rate

The objective of the bank is to maximize its expected utility of wealth, $U^e(W)$. Tedious but simple algebra gives us the following three first order conditions:

$$\begin{aligned} a &= -\frac{1}{2}\frac{\alpha}{\beta} - \frac{1}{4}\rho Q(1 - 2\alpha)\sigma_r^2 + \frac{1}{2}\rho B\sigma_r^2 \\ b &= \frac{1}{2}\frac{\alpha}{\beta} + \frac{1}{4}\rho Q(1 - 2\alpha)\sigma_r^2 + \frac{1}{4}\rho Q\sigma_L^2 + \frac{1}{2}\rho B\sigma_r^2 \qquad \text{(A-3)} \\ B &= \frac{s}{\rho\sigma_r^2} - Q(\lambda_L - \lambda_D) \end{aligned}$$

where we have used the definition of the coefficient of relative risk aversion, ρ, as:

$$\rho = -\frac{U''(W_0)}{U'(W_0)}$$

In this setting, we once again reach some familiar results. Namely that the spread between the deposit and loan lending rates and the interbank market rate (a and b respectively in the equations above) reflect a certain market power for setting bank rates (α/β), and compensation for funding risks (σ_r^2) and credit risk (σ_L^2). The price for such compensation is in turn also related to the risk aversion coefficient (ρ). However, the current setting provides some new insights. In particular, the impact of debt issuance on bank rate settings now becomes apparent. If the bank borrows in the form of debt issuance, it will be less inclined to compete for deposits, and should thus offer lower deposit rates ($\rho B \sigma_r^2$). On the lending rate there is also an impact, reflecting the fact that debt offers an insurance against uncertain financing in the interbank market, allowing to lower the spread to be charged when granting loans. Decisions on debt issuance, are dependent on the spread s. Also, the higher the probability of a loan arrival (λ_L) and the lower the probability of a deposit arrival (λ_D), the more inclined the bank will be to issue debt.

The first order conditions can be solved for a and b. It follows from the first two of the first order conditions in (A-3) that:

$$a + b = \frac{1}{4}\rho Q \sigma_L^2 + \rho Q \sigma_r^2 B \tag{A-4}$$

Furthermore, the third first order condition in (A-3) can equally be written as:

$$B = \frac{s}{\rho \sigma_r^2} + \beta Q \left(b + a\right)$$

Using (A-4) into the equation for B, and solving for B, results into:

$$B = \frac{1}{1 - \rho \beta Q \sigma_r^2} \left[\frac{s}{\rho \sigma_r^2} + \frac{1}{4} \rho \beta Q^2 \sigma_L^2 \right]$$

Finally, using this solution for B into the second of the first order conditions in (A-3), and then after solving for b would give us:

$$b = \frac{1}{2}\frac{\alpha}{\beta} + \frac{1}{4}\rho Q(1 - 2\alpha)\sigma_r^2 + \frac{1}{4}\rho Q \sigma_L^2 + \frac{1}{1 - \rho \beta Q \sigma_r^2} \left[\frac{s}{2} + \frac{1}{8} \rho^2 \beta Q^2 \sigma_L^2 \sigma_r^2 \right]$$

Placing this solution for b into equation (A-2), provides us with the bank lending rate:

$$r_L = r + \delta \lambda_\delta + \frac{1}{2}\frac{\alpha}{\beta} + \frac{1}{4}\tilde{\rho}(1 - 2\alpha)\sigma_r^2 + \frac{1}{4}\tilde{\rho}\sigma_L^2 + \frac{1}{1 - \beta \tilde{\rho} \sigma_r^2} \left[\frac{s}{2} + \frac{1}{8} \beta \tilde{\rho}^2 \sigma_L^2 \sigma_r^2 \right] \tag{A-5}$$

where we use $\tilde{\rho} = \rho Q$.

B The data

Our database contains monthly data for a sample of large euro area banks selected from across eleven euro area countries: Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, the Netherlands, and Portugal. We focus our analyses on the sample period October-2008 to October 2014. This sample period is representative of the environment characterised by fragmented markets and extended liquidity provision by the ECB. In what follows, we adopt the convention of using the subindex t to denote time, i to denote banks, and c to denote countries.

Bank lending rates ($r_{L,it}$). We study bank loan pricing for loans to non-financial corporations. We take these data from the 'Individual MFI Interest Rate Statistics' (IMIR) collected by the ECB that is not released to the public. We further distinguish between two different lending rates charged for loans to non-financial corporations. In particular, the ECB's IMIR Statistics distinguish between lending rates charged to non-financial corporations for small loans, granted for amounts smaller than one million euro, and large loans, of amounts larger than one million euro. We assume that the former is most representative for the type of loans granted to small and medium sized enterprises (SME), while the latter is more representative of loans granted to large corporation (large NFC). Bank lending rates relate to rates charged for the 'new' loans granted on a given month.

Short-term rate set by the central bank (r_t). This is the interest rate of the main refinancing operations of the ECB.

Expected interbank market discount ($\bar{\delta}_{it} = \delta_t \lambda_{\delta,it}$). To compute this discount rate we proceed as follows. First, δ_t is the difference between the EONIA rate and the rate of the ECB main refinancing operations. Second, the probability of having access to interbank markets, $\lambda_{\delta,it}$ is computed using ECB internal data. In particular, for every bank in our sample, we check how often in the previous six months, the bank was reliant on ECB financing. To compute the probability of having access to interbank markets we take the difference between 1 and the ratio between the number of months in which the bank was making use of ECB financing and six. For the early period of the sample, the type of ECB financing available to banks were loans with a maturity of at most 6 months. After June 2009 and December 2011, ECB financing for one and three-year horizons also were made available to banks. It may be argued that the role of this type of long-term financing does not exclusively cover short-term liquidity shocks in the spirit of our model, but also may serve other balance sheet purposes, such as countering fragmentation and securing bank access to sufficient funding.

However, we have chosen to include this type of ECB financing in our computation, as this long term financing equally alleviated short-term liquidity pressures.

Operational Costs, C_{it}. This is measured as the ratio of non-interest rate expenditures over total assets, and we collect these data from Bankscope.

Market Power, HFI_{ct}. Here we employ the Herfindahl indexes for the banking sector of the country of domicile of the bank. We divide the data by the mean to scale the data, and we also center the series at zero for easing the interpretation of the estimated coefficients. In particular, we use the indexes published as part of the monetary and financial statistics of the ECB. These HFI indexes are obtained by summing the squares of the market shares of all the credit institutions in the banking sector of a given country.

Funding risks in interbank markets, ($\sigma^2_{r,t}$). This is measured by the implied volatility of the three-month Euribor options with a time to maturity of three months. The source for these data is Bloomberg.

Credit risk on bank loans ($\sigma^2_{L,ct}$). We use the expected default frequency of non-financial corporations in a given country, to measure the exposure of a resident bank to the risk of default on loans in its balance sheet. These series are taken from Moody's KFW. It would have been preferable to include bank-specific credit risk indicators, however, these data are not available to us.

Corporate bond yield spread (s_{it}). For the computation of banks' bond yields (and compute the spreads) we proceed as follows. First, we identify from Dealogic the ISIN codes of high yield or investment grade senior bonds of series with face value larger than 100 million. This is in order to guarantee a certain liquidity and thus availability of frequent Bloomberg quotes. Quotes for those ISIN codes are then retrieved from Bloomberg. Furthermore, in order to capture the cost of debt financing at the five-year maturity, we choose from the available ISIN quotes for a bank, the one closest to the five year maturity. We then compute the spread between that quoted yield, and the Euribor swap rate of similar maturity. The corporate bond yield is then computed as the sum of that spread (between the Bloomberg quote and the Euribor swap rate of corresponding maturity) and the five-year Euribor swap rate. Finally, the corporate bond yield spread is the difference between the corporate bond yield and the EONIA rate.

Acknowledgements

The views in this paper do not necessarily reflect those of the European Central Bank

Gonzalo Camba-Mendez (corresponding author)
European Central Bank, Frankfurt am Main, Germany; email: gonzalo.camba-mendez@ecb.europa.eu

Francesco Paolo Mongelli
European Central Bank, Frankfurt am Main, Germany; Frankfurt Goethe University; email: francesco.mongelli@ecb.europa.eu

PDF ISBN 978-92-899-4514-1 ISSN 1725-2806 doi:10.2866/99163 QB-AR-21-005-EN-N