DEUTSCHE BUNDESBANK
EUROSYSTEM

Discussion Paper

Deutsche Bundesbank
No 26/2012

Determinants of the interest rate pass-through of banks – evidence from German loan products

Tobias Schlüter
(University of Cologne)

Thomas Hartmann-Wendels
(University of Cologne)

Ramona Busch
(Deutsche Bundesbank)

Sönke Sievers
(University of Cologne)

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0
Telex within Germany 41227, telex from abroad 414431

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

Internet http://www.bundesbank.de

ISBN 978–3–86558–851–7 (Printversion)
ISBN 978–3–86558–852–4 (Internetversion)

Abstract

This article examines the loan rate-setting behavior of German banks for a large variety of retail and corporate loan products. We find that a bank's operational efficiency is priced in bank loan rates and alters interest-setting behavior. Specifically, we establish that a higher degree of operational efficiency leads to lower loan markups, which involve more competitive prices, and smoothed interest rate-setting. This study contributes to prior literature that has been suggesting this relationship but has produced mixed findings. For the German market this relationship is unexplored. By employing stochastic frontier analysis to comprehensively capture cost efficiency, we take the bank customers' perspective and demonstrate the extent to which borrowers benefit from cost efficient banking.

Keywords: interest rate pass-through models, error correction models, bank efficiency, cost efficiency, stochastic frontier analysis

JEL classification: G21, G28

Non-technical summary

In bank based economies, such as Germany, households as well as corporations are financed to a large extent by bank debt. Consequently, economic agents are notably reliant on the conditions on which banks price their offered credit products. Banks typically adjust their interest rates with regard to general market developments but research has found that this interest rate pass-through from market interest rates to bank lending rates is sticky and price rigidities prevail. In addition, significant heterogeneities among the individual credit institutions' product pricing persist. Attributes such as market power or funding structure have been found to be important determinants explaining how banks set their lending rates and how they react to changes in market interest rates. Prior international studies have also suggested a bank's operating efficiency to affect credit pricing since efficiency gains could be used to set more competitive prices in the spirit of gaining market share or binding existing borrowers. However, although suggested and emphasized by theoretical models this link is so far untested for the German market. Furthermore, international studies have only provided weak and even mixed results relying on financial accounting ratios to capture a bank's efficiency. Thus, we turn our attention to the question, whether banks that operate their business more cost efficiently than their competitors, provide more competitive prices to borrowers. In particular, we ask the following research question: Do efficient banks charge lower markups above the market interest level and do they set loan rates more smoothly? The results suggest that retail and corporate borrowers benefit in two ways when banks operate more cost efficiently than their competitors: a) loan rate markups decrease and b) loan rate offers will be less volatile.

Nichttechnische Zusammenfassung

In bankbasierten Volkswirtschaften wie der deutschen finanzieren sich Haushalte und Unternehmen vorrangig über Bankkredite. Somit sind die einzelnen Wirtschaftssubjekte besonders auf die Kreditkonditionen der Banken angewiesen. Typischerweise passen Banken ihre Kreditkonditionen an die allgemeine Marktentwicklung an, wobei empirische Studien zeigen, dass Marktzinsänderungen nur unvollständig und langsam an die Produktkonditionen einzelner Banken weitergegeben werden. Zudem ist das Preissetzungsverhalten der Institute durch eine breite Heterogenität charakterisiert, die zum Teil durch Eigenschaften wie Marktmacht oder die Refinanzierungsstruktur der Banken erklärt werden kann. Darüber hinaus besteht in der wissenschaftlichen Literatur die Vermutung, dass die operationelle Effizienz einer Bank eine entscheidende Rolle bei der Preissetzung spielt. Dabei könnten Effizienzvorteile bei der Produkterstellung auf der einen Seite genutzt werden, um für die Eigentümer der Bank eine höhere Rendite zu erwirtschaften. Auf der anderen Seite könnten diese Vorteile verwendet werden, um kompetitivere Preise zur Marktanteilsgewinnung bzw. -verteidigung zu setzen. Dies würde sich dann in besseren Produktkonditionen für die Kunden widerspiegeln. Obwohl gerade der letztgenannte Zusammenhang von mehreren Studien und theoretischen Modellen vermutet wird, ist er für den deutschen Bankensektor noch nicht untersucht worden. Darüber hinaus haben internationale Studien, welche meist traditionelle Finanzkennzahlen zur Effizienzmessung heranziehen, bis heute nur schwache und sich teils widersprechende Evidenz zu diesem Sachverhalt gefunden. Der Fokus dieser Studie wird daher auf die Frage gelegt, ob Banken, die kosteneffizienter als ihre Mitbewerber arbeiten, Effizienzvorteile an ihre Kreditnehmer weitergeben. Konkret wird untersucht, ob kosteneffizientere Banken Kredite mit einem geringeren Aufschlag auf das Marktzinsniveau preisen und Zinsanpassungen für die Kunden glätten. Unsere Resultate zeigen, dass Kreditnehmer in zweifacher Hinsicht von Kosteneffizienz profitieren: a) Preisaufschläge auf das Marktzinsniveau fallen geringer aus und b) Kreditkonditionen sind weniger volatil.

Contents

Appendix

Determinants of the interest rate pass-through of banks − Evidence from German loan products[1]

1. Introduction

In the German bank-based economy the loan rate-setting behavior of banks is highly relevant for businesses and individuals. Consequently, a substantial body of research focuses on the estimation and description of the behavior of banks that pass-through changes in official and market-wide interest rates to their borrowers (ECB, 2009; De Bondt, 2005; Weth, 2002). Analyzing the process of financial intermediation between general market conditions and final customer prices is of key interest for monetary policy and bank regulators. The broad evidence suggests that the pass-through of market interest rates to the prices of bank products is incomplete and price rigidities prevail. Based on this knowledge recent research examines the determinants of the interest rate-setting behavior of banks (i.e., in terms of bank characteristics, such as regulatory capital ratios, liquidity, bank risk and funding structure, or market power). One key suggestion is that the degree to which a bank operates its business in a cost efficiently manner should affect its loan rate-setting behavior. However, this cost efficiency channel is currently untested with regard to the loan pricing behavior of German banks. In addition, although suggested by prior international research, the influence of cost efficient banking on interest-setting behavior should be more thoroughly examined because evidence

[1] Tobias Schlüter (corresponding author), University of Cologne, Department of Banking, Albertus Magnus Platz, 50923 Cologne, Germany, e-mail: schlueter@wiso.uni-koeln.de, tel.: +49 221 470 1670; fax: +49 221 470 2305. Ramona Busch (ramona.busch@bundesbank.de) is with the Deutsche Bundesbank, Financial Stability Department. Thomas Hartmann-Wendels (hartmann-wendels@wiso.uni-koeln.de) is with the University of Cologne, Department of Banking. Sönke Sievers (sievers@wiso.uni-koeln.de) is with the University of Cologne, Accounting Area.

This paper has benefited from the comments of research seminars at the Deutsche Bundesbank and at the University of Cologne. We would like to thank Thomas Kick and Christoph Memmel for helpful comments. The authors gratefully acknowledge funding from the Deutsche Bundesbank and the Department of Banking, University of Cologne. This paper represents the authors' personal opinions and not necessarily those of the Deutsche Bundesbank.

on this topic is weak.[2] Consequently, this study tries to fill this gap by examining the loan rate-setting behavior of German banks for a large variety of retail and corporate loan products.[3] Being precise, we address the question of whether a bank's degree of operational efficiency alters its interest-setting behavior and find that this effect is clearly verifiable if we rely on state-of-the-art stochastic frontier models to capture cost efficiency (instead of traditional accounting ratios). Charged loan markups are reduced if a bank efficiently operates its business, and the interest rate adjustment speed is affected towards bank customers' benefit, (i.e., the bank loan rates are set more smoothly, and borrowers are protected from upward changes in market interest rates for a longer time period).

These findings are established by estimating interest rate-setting behavior consistent with a large body of research that analyzes the pass-through of market rates to bank loan rates. Specifically, we employ error-correction interest rate pass-through (IPT) models that result in bank-specific pricing characteristics which describe how a bank passes market movements on to product prices. IPT model characteristics include the markup of loan rates above a market rate, which can best be understood as the margin that a bank locks in between the charged loan rate and the marginal cost of funding. Furthermore, the adjustment speed of product rates as well as the short- and long-term pass-through of market movements are IPT characteristics. Error correction models are commonly used to describe an IPT process and provide the advantages of a possible disentanglement of short- and long-run dynamics as well as the contemporaneous identification of equilibrium interest rate markups.

---

2 See section 2.

3 Our investigation is related to the area of literature concerning the explanation of a bank's net interest margin (NIM; i.e., interest income minus interest expenses over total assets). This part of the literature provides theoretical models and empirical findings that the NIM is related to factors that capture the operational costs of a bank; thus, banks with more cost efficient operations typically have smaller NIMs (e.g., Maudos and De Guevara, 2004; Maudos and Solis, 2009). A downsizing of NIM of a bank is likely to result in lower loan rates and/or higher deposit rates for bank customers (Clayes and Vander Vennet, 2008). However, these studies employ ex-post accounting interest margins at the bank level and cannot observe whether the reduction of the NIM is caused by a change in the pricing of assets, such as loans, or liabilities, such as deposits. Finally, a detailed presentation of different products or product and customer classes is not possible for those studies.

While the IPT parameters provide the key dependent variables in our later econometric analysis, we extend the literature by employing stochastic frontier analysis (SFA) for measuring cost efficiency to establish that interest rates are more beneficial for borrowers of cost efficient banks (cost efficiency pass-through effect). While one could expect this to be an obvious first-order effect prior studies had difficulties to establish this finding by relying on traditional accounting ratio-based efficiency measures, such as the 'cost-income ratio' or the 'costs to total assets ratio'. In contrast, the concept of SFA cost efficiency is to evaluate each bank's operational efficiency compared to its market competitors by asking the following question: can the bank more advantageously allocate its resources to produce its output portfolio relative to other banks? Exemplary a bank could possess a superior degree of operational efficiency (e.g., low screening and monitoring costs, or it is able to obtain funding at a lower rate than other banks). Then, the bank is said to operate its business more cost efficiently than its competitors and could pass on at least part of its efficiency gains to set more competitive prices.[4] In recent years, the SFA-based cost efficiency measurement has become the standard to assess a financial institution's operating efficiency (Banker et al., 2010; Berger and Mester, 1997).[5]

Thus, our research question combines the two streams of literature regarding interest rate pass-through and bank efficiency measurement via stochastic frontier analysis. Put differently, prior studies that concentrate on bank efficiency measurement primarily analyze how efficient banks are, how to optimally measure cost efficiency or the extent to which efficiency differs among institutions. To the best of our knowledge, thus far, a SFA-based efficiency estimate has not been employed to capture variations in interest rate pass-through behavior. We find that this approach is much more appropriate than the previously used financial ratios.

4 See section 3.
5 See sections 2 and 5 for details.

This paper proceeds as follows: the next section broadly integrates this study into the existing literature. Section 3 develops testable hypotheses. Section 4 describes the employed data sample, and section 5 describes how interest rate pass-through and cost efficiency are estimated. Section 6 presents the main results, which are validated in the following robustness section. The final section concludes the paper.

2. Related Literature

The estimation of interest rate pass-through models has been extensively discussed in prior literature (e.g., Kashyap and Stein, 2000; Mojon, 2000; De Bondt, 2005). The purpose of estimating how bank prices react to changes in official or market interest rates is motivated by the aim of analyzing how well banks perform as financial intermediaries between general market conditions and final customer prices (e.g., Hofman and Mizen, 2004; Kleimeier and Sander, 2006). Furthermore, the speed and extent to which changes in funding costs are passed on to bank customers should be known by banking regulation authorities (Wang and Lee, 2009; Sander and Kleimeier, 2004). Thus, many studies focus on the estimation of certain pass-through parameters that describe the interest-setting behavior of banks (i.e., the final results of pass-through models, such as interest rate markups, long-term pass-through coefficients or the speed of interest rate adjustment) (De Bondt, 2005; ECB, 2009; Kwapil and Scharler, 2010; Liu et al., 2008; Rosen, 2002; Sander and Kleimeier, 2004). Consistent with international research, studies of the German context document price rigidities and incomplete pass-through behavior, such that market interest rate changes are not directly reflected in adjusted bank rates (e.g., Von Borstel, 2008; Nehls, 2006; Weth, 2002; Mueller-Spahn, 2008).

Due to commonly observed price stickiness, it is essential to analyze which bank characteristics alter or hinder a complete and rapid product price adjustment following a market interest rate change (e.g., De Greave et al., 2007; Ehrmann et al., 2003; Fuertes et al., 2010). Attributes, such as excess regulatory capital or a bank's liquidity position, are found to hinder a perfect market-to-customer interest rate pass-through. In the case of Germany, the studies of Weth (2002) and Mueller-Spahn (2008) group banks successively according to their liquidity, size, funding and asset diversification and then compare the estimated pass-through parameters. In other words, these studies highlight that, for example, banks with a high fraction of deposit funding exhibit a slower adjustment speed than their capital market-financed competitors. Furthermore, prior research argues that a bank's (in-)efficiency should be another key factor impeding direct and complete pass-through (De Greave et al., 2007; Fuertes et al., 2010, Gambacorta, 2008). For example, these researchers argue that cost efficiency gains could be used to charge lower lending rates to gain market share. To control for efficiency effects, studies rely on financial accounting ratios, such as the cost-income ratio (e.g., De Greave et al., 2007; Focarelli and Panetta, 2003) or the costs-to-total assets ratio (e.g., Gambacorta, 2008). However, although this approach is theoretically appealing, the research does not report significant relationships (Fuertes and Heffernan, 2009; De Greave et al., 2007; Berger and Hannan, 1997) or just 'marginally significant relationships (Fuertes et al., 2010; Gambacorta, 2008). To the best of our knowledge, no study has analyzed the effects of efficiency on pass-through behavior for Germany.

In addition, accounting-based financial ratios insufficiently capture the economic construct of efficient banking (Banker et al., 2010; Berger and Humphrey, 1997; Goddard et al., 2007). Research regarding the strand of literature concerning the measurement of bank efficiency indicates that concepts, such as stochastic frontier models, are much more appropriate for assessing cost or operational efficiency (e.g., Aigner et al., 1977; Fiorentino et al., 2006, Fiordelisi et al., 2011; Altunbas et al., 2001). The degree of cost efficiency is referred to as a relative valuation of a bank compared to the best-practice credit institution in terms of a comparable input and output portfolio and the lowest operating and financial costs (Fiorentino and Herrmann, 2009).

Thus, the effects of bank efficiency on price setting have not been thoroughly explored for German banks. Motivated by rather weak international evidence, we focus on obtaining an appropriate measurement of bank efficiency and its implications on loan rate setting and on the pass-through behavior of banks.

3. Research Question

The relative SFA cost efficiency measure directly relates to the ability of a bank to operate its business more cost efficiently than its market competitors. The natural question pertains to whether bank borrowers benefit from the ability of a bank to operate cost efficiently. The literature concerning the interest rate-setting behavior of banks assumes that at least a portion of cost efficiency gains or other cost advantages will be used for the benefit of the customers and thus for the provision of more competitive loan prices (see, e.g., De Greave et al., 2007; Fuertes et al., 2010). However, empirical evidence of the possible effects of efficiency is either insignificant or weak. In the case of Germany, it is unexplored.

These rather weak findings can naturally be explained by the assumption that all banks maximize their profits. For banks with more cost efficient operations, it could be beneficial under certain circumstances to retain efficiency gains to benefit the shareholders of such banks. This perception would clearly explain why evidence of a possible cost efficiency pass-through to more favorable customer loan rates is weak or cannot be detected. Contrary, because the German banking market is saturated and mature, the organic growth of banks is quiet low. Thus, under the common assumption that banks intend to maintain or even increase their market share, they might find it appealing to set loan prices below those of their competitors. Therefore, banks working cost efficiently might pass on their efficiency gains while still considering their long-run business continuance (i.e., they do not set such low loan rates that would not cover the costs over a long time period).

However, a large body of supportive evidence for the latter consideration relates to the area of research that is focused on identifying the determinants of the net interest margins (NIM) of banks: theoretical models indicate the importance of operational and overhead costs and their influence on NIMs. Specifically, Maudos and De Guevara (2004) introduce a model that explains a NIM that increases as a result of higher operational costs and these authors refer to the negligence of controlling for operational efficiency as a potential omitted variable bias of all prior studies explaining the NIM. Broad empirical evidence indicates that NIMs decline (rise) as operational costs decrease (increase) (Entrop et al., 2012; Maudos and Solis, 2009; Clayes and Vander Vennet, 2008; Carbo and Fernandez, 2007). This strand of the literature is highly supportive of our hypothesis, as a change in NIM is likely to cause higher interest paid on liabilities and/or lower credit rates charged. However, the extent to which the pricing of liabilities or assets is affected cannot be observed by those studies given an interest margin that is calculated using ex-post accounting income and expense figures at the bank level (for this specific topic, see Clayes and Vander Vennet, 2008). Only the recent study by Entrop et al. (2012) examines the interest income and expense margins separately. However, the degree to which new business interest rates, the loan rates that are charged to certain customer and product groups, or even individual loan products are affected by operational efficiency remains unclear in the NIM studies.

To provide insight into this theoretical association between efficiency and interest rate-setting behavior, we conduct an empirical examination of the effects of cost efficiency on the loan rate-setting behavior of German banks. Following the previously suggested relationships between loan rates and the degree of operational efficiency of a bank, we would expect that an increase in efficiency could lead to benefits for bank borrowers. As noted in the introduction, a bank is considered to operate beneficially for its customers when it charges lower interest rate markups and provides more stable interest rate offers compared with its competitors (i.e., the bank adjusts its loan rates more slowly). While the benefits of lower markups are obvious, the literature argues that a delayed, slow pass-through of market movements to loan rates is beneficial for bank borrowers. Banks shield their customers from sudden market movements and provide smooth interest rate adjustments (Fuertes and Heffernan, 2009; Von Borstel, 2008; Mueller-Spahn, 2008). Especially in the environment of increasing market interest rates between the fall of 2005 and the fall of 2008, interest rate smoothing will have been valued by bank borrowers.

In addition, we analyze whether SFA-based cost efficiency is more appropriate than the previously suggested traditional accounting ratios. Lastly, we turn our attention to the question whether for some loan products the efficiency effects are more pronounced than for others. The next section describes the data and presents evidence regarding their representativeness.

4. Data

4.1. Sample description

Our dataset is obtained from the German central bank ('Deutsche Bundesbank'). The main sample consists of the regulatory information pertaining to 150 banks that have all of necessary interest rate, balance sheet and profit and loss (P&L) account data for the period from January 2003 to September 2008.[6] For information on interest rates, we employ the monthly MFI interest rate (MIR) statistics ('EWU Zinsstatistik'). We augment the sample with publicly available market interest rates, which we obtain from Deutsche Bundesbank.[7] Additionally, we obtain balance sheet statistics ('BISTA') and information on P&L from the schedule pursuant to the auditor reports ('Sonderdatenkatalog'). For interest rates, the monthly MIR statistics present interest rates and new business volumes for 11 standardized retail loan products and 7 corporate loan products collected for approximately 200 German banks.[8] However, we request observations with consecutive, non-missing interest rate data for each bank and product such that we are able to analyze 150 banks, resulting in a total of 127,891 bank-product-month observations for the pass-through estimation.[9] Table 1 presents summary statistics for the employed interest rates.

---

6 We focus our main analysis on the time period January 2003 to September 2008 for two reasons. First, the employed interest rate statistics were introduced in January 2003 and second we want exclude any effects attributable to the Lehman collapse and the following financial crisis. However, in the robustness section we include the time span after the Lehman collapse until September 2011 and our findings remain valid.

7 We use EURIBOR and government bond rates with varying maturities.

8 See Table 1 for a list of products. For more details, see the Deutsche Bundesbank monthly report for January 2004, which is available at http://www.bundesbank.de/download/volkswirtschaft/monatsberichte/2004/200401mb_e.pdf.

9 This requirement is the major condition that reduces the possible sample size. For more details, see the next section regarding the estimation of the interest rate pass-through models. Panel A Table 3 of presents the distribution of available time-series data for the examined loan products.

Table 1: MIR statistics – surveyed products and interest rates summary statistics

		average interest rates	
Panel A: retail loans	product number	all banks (N = 150)	
		mean	s.d.
overdrafts	12	10.84	2.39
consumer credit with			
floating rate or initial rate fixation of up to 1 year	13	6.53	1.76
initial rate fixation of over 1 and up to 5 years	14	6.69	1.45
initial rate fixation of over 5 years	15	6.93	1.61
housing loans with			
floating rate or initial rate fixation of up to 1 year	16	5.09	0.89
initial rate fixation of over 1 and up to 5 years	17	4.68	0.59
initial rate fixation of over 5 and up to 10 years	18	4.97	0.45
initial rate fixation of over 10 years	19	4.70	0.57
other loans with			
floating rate or initial rate fixation of up to 1 year	20	5.26	1.21
initial rate fixation of over 1 and up to 5 years	21	5.36	0.88
initial rate fixation of over 5 years	22	5.12	0.76
Panel B: non-financial corporate loans			
overdrafts	23	7.76	2.08
loans up to euro 1 million with			
floating rate or initial rate fixation of up to 1 year	24	5.16	1.15
initial rate fixation over 1 and up to 5 years	25	5.27	0.83
initial rate fixation over 5 years	26	5.06	0.75
loans over euro 1 million with			
floating rate or initial rate fixation of up to 1 year	27	4.41	1.15
initial rate fixation over 1 and up to 5 years	28	4.59	0.96
initial rate fixation over 5 years	29	4.82	0.74

Notes:

The MFI interest rate (MIR) statistics requires about 200 German banks to report monthly on the above stated interest rates. Each product is identified with a ‘product number’ ranging from 12 to 29. See the Deutsche Bundesbank monthly report of January 2004 for details.

In addition, this table presents loan product summary statistics of MFI interest rates from January 2003 until September 2008. We present mean interest rates and its standard deviation for the 150 banks.

Our final sample consists of 24 commercial banks (Comms), of which 4 banks are the major German Comms (large banks). Furthermore, we are able to analyze 82 savings banks (Savs), of which 11 banks supra-regional central banks for local Savs (‘Landesbanken’). Finally, our sample contains information on 44 cooperative banks (Coops), of which 2 banks are central banks for the other cooperative banks. Panel A of Table 2 presents summary statistics regarding the compiled balance sheet, P&L and risk relevant data. Panel B presents the covariates motivated by prior literature employed and discussed in the later regression analysis. Finally, Panel C includes summary statistics on key variables to capture the representativeness of our sample, which is elaborated in detail below.[10]

Table 2: Summary statistics of sample banks

Panel A: assets and liabilities, profit and loss information and risk relevant data (mio. €)

	mean	s.d.		mean	s.d.
cash	53	123	interest income	1,310	3,544
lending to banks	7,530	24,300	interest expenses	983	2,826
lending to non-banks	13,100	37,000	net interest income	328	785
bonds and other interest bearing sec.	5,920	15,700	non-interest income	150	566
stocks and other non-interest bearing sec.	1,150	5,520	non-interest expenses	37	132
total assets	29,000	86,300	net non-interest income	112	447
deposits of banks	9,600	31,000	trading results	27	175
deposits of non-banks	11,800	34,100	tier 1 capital	965	2,179
saving deposits	1,830	3,640	tier 2 capital	586	1,389
equity	942	2,220	risk weighted assets	11,500	25,630

Panel B: covariates of regression

	mean	s.d.
'excess capital'	5.37	3.25
'liquidity'	31.97	16.56
'deposit funding'	60.39	17.80
'market share'	1.12	0.40
'credit risk'	2.66	1.88
'size'	22.78	1.36

Panel C: sample representativeness
(relative to German banking system)

	average	year					
		2003	2004	2005	2006	2007	2008
total assets#	0.62	0.62	0.65	0.73	0.74	0.74	0.49
lending to banks (MFIs)	0.66	0.66	0.70	0.81	0.80	0.76	0.50
lending to non-banks (non-MFIs)	0.59	0.59	0.61	0.68	0.70	0.71	0.48
saving deposits	0.41	0.38	0.39	0.44	0.45	0.45	0.38
securitized liabilities	0.68	0.64	0.67	0.81	0.83	0.84	0.54

Notes:
This table presents summary statistics of the MIR statistics reporting banks. We report mean values and the standard deviation of the employed variables. Panel A presents balance sheet summaries and profit and loss account information and summaries statistics of bank capital and risk weighted assets. Panel B presents summaries on the independent variables used for the main regressions. Last, Panel C presents sample representativeness: For five balance sheet figures we present the sum of all 150 MIR statistics reporting banks relative to all German banks (i.e., in 2007 the sample of 150 banks accounts for 74% of total assets in the German banking market and on average for 62% during the sample period).

[10] Our sample is adjusted for mergers; thus, we treat a merged bank as two separate banks before the merger and as one new bank after the merger.

4.2. Sample representativeness

Because the complete German banking market consists of approximately 2,000 credit institutions[11], we have to address the question of whether the analyzed 150 banks are a representative sample. Because our study is limited to MIR reporting banks, we must acknowledge the nature of the MIR statistics. In the selection of banks for the reports, the Deutsche Bundesbank mirrors the German banking market (i.e., banks are selected such that all German bank groups all over the country are represented).[12] Thus, Deutsche Bundesbank indicates that the sample of MIR reporting banks is a representative profile of the German banking market.

Furthermore, when we compare our sample to all BISTA reporting banks (i.e., more than 2,000 banks), we show that our sample represents a large portion of the German banking business. Panel C of Table 2 presents comparisons of the 150 banks analyzed to the complete market. Regardless of whether total assets, lending to banks or non-banks, or debt are considered, the 150 banks are largely representative of the market (e.g., our sample banks account for approximately 62% of the total assets of all banks and are responsible for 66% of all non-bank lending). Furthermore, the total assets of all German banks account for approximately 25% of the total assets of all European banks at the end of 2008.[13] Thus, we note that our sample is representative for Germany and even accounts for large parts of the European banking market.

The next section describes how we estimate the characteristics of the interest rate-setting behavior, primarily the markup of loan rates above a market rate and the adjustment speed with which market movements are passed through to bank customers. Then, the following section describes how to properly measure bank efficiency.

[11] See http://www.bundesbank.de/Redaktion/DE/Downloads/Statistiken/Banken_Und_Andere_Finanzielle_Institute/Banken/Banken_In_Deutschland/S131ATB10607.pdf?__blob=publicationFile

[12] See the Bundesbank monthly report of January 2004 for details. Within one geographical region, the largest credit institutions of each bank group are selected.

[13] We obtain data pertaining to the total assets of all European banks from www.ecb.int.

5. Estimation Procedure and Econometric Considerations

5.1. Loan pricing behavior

This section describes the estimation of the interest rate pass-through (IPT) parameters that will be explained by bank factors in the subsequent analysis. The results of IPT models will be bank- and product-specific loan markups (i.e., the spread above the market interest rate), the speed of interest rate adjustment (i.e., the length of time that is required to pass on a market interest rate change) and the short- and long-run adjustment coefficients that capture whether a pass-through is one for one. To determine which market interest rates are chosen, we follow the 'cost of funds' approach that is used in many prior studies and that considers market rates to be a representation of a bank's marginal funding costs (e.g., Sander and Kleimeier, 2004). The selection is based on the identification of market interest rates whose evolution exhibits the highest correlation with the development of new-business bank interest rates (e.g., De Bondt, 2005; Sander and Kleimeier, 2004). Additionally, we require the market rate to have a similar maturity as the bank product; for example, if a loan has a maturity range of one to three years, then the same range must be applied to the market rate (De Greave et al., 2007; Mueller-Spahn, 2008; Sørensen and Werner, 2006). For short maturities, we employ public money market rates, and we rely on German government bond rates for maturities of more than one year.[14] Panel B of Table 3 presents the results of the correlation analysis that is performed.

The standard approach of estimating the pass-through of market interest rates to bank lending rates is to represent a bank's interest rate at time t as a function of its own lagged values and of the corresponding market interest rate at time t and its lagged values (Sander and

[14] Some studies highlight the advantages of bank bond rates compared with government bond rates. Von Borstel (2008) argues that bank bonds better reflect the actual marginal cost of funding for longer maturities. Nevertheless, the study finds that the results of pass-through parameters do not differ significantly, regardless of whether government or bank bond rates are employed.

Kleimeier, 2004, Sander and Kleimeier, 2006; Weth, 2002; Kremers et al., 1992; Pesaran and Shin, 1999; Cottarelli and Kourelis, 1994). Because interest rate time series often exhibit an $I(1)$ property (i.e., integrated of order one), the estimation of bank interest rates in first differences (VAR) is necessary to avoid spurious results (Granger and Newbold, 1974; Philipps, 1986).[15] However, the estimation of differences does not prevent the absolute levels of loan and market rates from departing from one another to a great extent (i.e., possible long-run relationships between both time series could be ignored). Further, in the case of cointegration between the market and bank interest rate time series (i.e., when a stationary equilibrium exists), the VAR process can be augmented by the inclusion of an error correction term (ECT) (e.g., Engle and Granger, 1987; Kleimeier and Sander, 2006; Sander and Kleimeier, 2004; Burgstaller, 2005). To verify the existence of a cointegration relationship between the bank interest rate and the chosen market rate, we perform two different tests: the first test is a two-step residual-based test and involves the tests for cointegration that are proposed by Engle and Granger (1987), whereas the second test is based on Johansen's (1995, 1991) maximum likelihood estimator (Kwapil and Scharler, 2010).

15 The augmented Dickey-Fuller test indicates that nearly all time series are of order one.

Table 3: Interest rate pass-through models – preliminary analysis

Panel A: number of observations per product

	retail loan rates										
product number	12	13	14	15	16	17	18	19	20	21	22
statistic											
mean	64.23	64.70	64.75	64.70	64.04	63.99	64.08	64.23	64.06	64.05	64.15
median	69	69	69	69	69	69	69	69	69	69	69
p25	69	69	69	69	69	69	69	69	69	69	69

	corporate loan rates						
product number	23	24	25	26	27	28	29
statistic							
mean	54.94	54.96	54.99	55.00	55.23	54.47	55.39
median	58	58	58	58	58	58	58
p25	58	58	58	58	58	58	58

Panel B: correlation analysis for relevant market interest rates

	retail loan rates										
product number	12	13	14	15	16	17	18	19	20	21	22
maturity	(-)	<1y	1-5y	>5y	<1y	1-5y	5-10 y	>10y	<1y	1-5y	>5y
market rate	EB	EON	GB	GB	EB	EB	GB	GB	EB	EB	GB
maturity	3m	(-)	5y	10y	1w	1y	8y	14y	1w	3m	10y
correlation	0.71	0.66	0.47	0.77	0.63	0.76	0.76	0.71	0.57	0.56	0.52

	corporate loan rates						
product number	23	24	25	26	27	28	29
maturity	(-)	< 1y	1-5y	>5y	<1y	1-5y	>5y
market rate	EB	EB	GB	GB	EB	EB	GB
maturity	1w	3m	2y	10y	1m	12m	12y
correlation	0.56	0.73	0.64	0.50	0.84	0.63	0.56

Panel C: lag selection results

	retail loan rates										
product number	12	13	14	15	16	17	18	19	20	21	22
mean	1.05	1.07	1.05	1.05	1.08	1.06	1.17	1.06	1.10	1.06	1.10
min	1	0	0	1	0	1	1	1	0	0	0
max	3	3	6	3	4	3	4	3	4	3	6

	corporate loan rates						
product number	23	24	25	26	27	28	29
mean	1.08	1.08	1.08	1.03	1.11	1.00	1.07
min	1	1	1	1	1	1	1
max	4	4	5	2	5	1	4

Panel D: distribution of non-cointegrated time series

	retail loan rates										
product	12	13	14	15	16	17	18	19	20	21	22
#	39	16	27	25	12	14	2	2	3	1	4

	corporate loan rates						
product	23	24	25	26	27	28	29
#	44	2	4	1	4	0	0

Notes:
This table presents initial summary statistics and necessary tests before the interest rate pass-through model can be estimated. Panel A presents statistics on interest data availability. Reported statistics are mean and quantiles of 'number of months of observations' for the banks per product. Panel B shows the results of the performed correlation analysis. For each loan product its maturity is shown. Below we present the market interest rate with highest correlation to the bank product. 'EON' refers to the EONIA rate, 'EB' to EURIBOR and 'GB' to German government bonds. The respective maturity of market interest rates is presented below. 'w' is 'week', 'm' equals 'month' and last 'y' is the abbreviation for 'year'.
Panel C shows the summary statistics of the lag selection statistics by following Engle and Granger (1987) for the banks and each banking product using minimization of the Schwarz Bayesian information criterion ('SBIC'). The maximum lag is set to six months (e.g., De Greave et al., 2007). Results remain qualitatively unchanged if maximum lag is varied. Last, Panel D presents the frequencies of non-cointegrated time series per product. The total number of interest time series is 2,146.

Panel C of Table 3 presents summary statistics for the two-step test that is performed.[16] We perform the tests for each bank and each loan product, respectively, and thus account for pricing heterogeneities across the credit institutions and their products. Further analysis is based on only bank and market interest rate time series that are cointegrated, whereas cointegration applies to more than 90% of all available time series.[17] Panel D of Table 3 presents the distribution of the non-cointegrated time series. Most of these cases appear to occur with overdraft products for retail and corporate customers. This result is expected because the pricing of those products is the most rigid and is not driven by minor market movements. Panel A of Figure 1 provides hypothetical examples of co-integrated time series while Panel B provides two generalized examples of time series of loan rates and market rates that lack cointegration.[18] The estimation of error-correction pass-through models would be disputable for such time series.

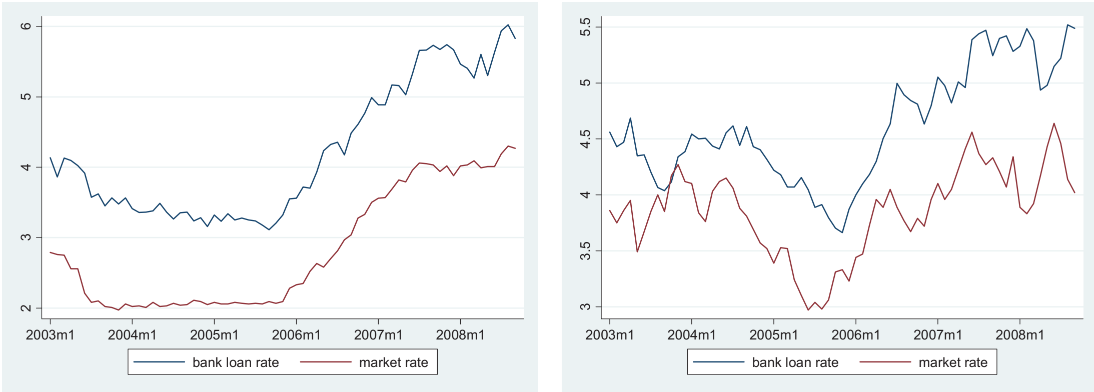
Because our main sample consists only of time series that are cointegrated, the error correction representation (ECM) is the standard approach to estimate the reaction of bank interest rates to changes in market interest rates (Fuertes and Heffernan, 2009; Liu et al., 2008; Mojon, 2000; Weth, 2002). Our study employs two different methods of estimating the interest rate pass-through process suggested by the literature.[19] First, we use two-step estimation models to determine pass-through (e.g., De Greave et al., 2007; Engle and Granger, 1987). Second, we run simultaneous error correction estimation advocated by more recent research (Liu et al., 2008; Hofman and Mizen, 2004; Johansen, 1995). In the following sections, we present the results for both methodologies (i.e., the simultaneous maximum likelihood error correction estimations and the two-step Engle and Granger (1987) method).

---

[16] The results for the test proposed by Johansen (1995, 1991) differ only to a minor extent.
[17] That is, the null hypothesis of an existing cointegration relationship cannot be rejected at the 10% level.
[18] We do not present interest rate time series of individual banks but present generalized time series being averaged data of several banks.
[19] This choice was motivated by Lozano-Vivas and Pasiouras (2010), who claim that few studies compare different methodologies.

Figure 1: Examples of bank product time series

Panel A: examples of cointegrated times series



Panel B: examples of non-cointegrated times series

Notes:

Panels A and B present generalized, hypothetical examples of retail consumer loans with a maturity of one to three years during January 2003 and September 2008. Being precise, we do not present interest rate time series of individual banks but present time series being averaged data of several banks due to confidentiality. The red colored time series present the market rate which would be used for the error correction framework. Panel A shows examples that are cointegrated with the market rate and thus used for the estimation of an interest rate pass-through models. Panel B presents examples of time series that are non-cointegrated. These are excluded from the analysis (blue colored). Estimating an ECM would be misleading because the loan rates are obviously not set according to the market rate development.

The maximum likelihood model estimates the pass-through of market interest rates to bank rates using the following representation for each loan product:

$$\Delta br_{i,j,t} = \alpha_{i,j} \cdot \left(br_{i,j,t-1} - \beta_{i,j} \cdot mr_{j,t-1} - \mu_{i,j}\right) + \sum_{k=1}^{p^*} \Lambda_{i,j,k} \cdot \Delta mr_{j,t-k} + \sum_{l=1}^{q^*} \Gamma_{i,j,l} \cdot \Delta br_{i,j,t-l} + \varepsilon_{i,j,t}$$

where $br_{i,j,t}$ is the observed bank interest rate at time t (i.e., the bank loan rate for each of the 18 loan products); $i = 1, \dots, 150$ indexes the banks; $j = 1, \dots, 18$ indexes the loan products; and $mr_{j,t}$ is the market interest rate. Δ accounts for the difference operator, and $\alpha_{i,j}$ is the equilibrium restoring condition that captures the error correction adjustment speed when bank rates depart from their equilibrium relationship with market rates. For ease of interpretation, we refer to $1/\alpha_{i,j}$ as the adjustment duration with that market interest rate changes are passed through to bank rates.[20] $\mu_{i,j}$ is the bank- and product-specific markup above the corresponding market interest rate. The bank and loan product-specific long-term pass-through coefficient is measured by $\beta_{i,j}$, which measures whether a market interest change is completely passed on to bank rates in the long run. $\Lambda_{i,j,1}$ describes the short-run pass-through (i.e., the extent to which changed market conditions alter loan rates within a one-month period). $\varepsilon_{i,j,t}$ is the error term, and p^* and q^* are the optimal lag lengths, which are chosen by the minimization of the Schwarz Bayesian information criterion (see Panel C of Table 3 for summary statistics on the results of the lag selection). The parameters are obtained simultaneously by applying maximum likelihood optimization.

In contrast to the simultaneous maximum likelihood estimates the two-step Engle and Granger model estimates two separate ordinary least squares regressions (OLS): First, the error correction term '$br_{i,j,t} = \mu_{i,j} + \beta_{i,j} \cdot mr_{j,t-1} + u_{i,j,t}$' is estimated, and the obtained

[20] Some studies (e.g., De Greave et al., 2007) define the adjustment duration as $\left(\beta_{i,j} - \Lambda_{i,j,1}\right)/\alpha_{i,j}$. If this definition were employed, our estimation results would resemble those for the adjustment duration as defined above. However, note that the definition proposed by De Greave et al. (2007) relies on the individual long- and short-term pass-through behavior of a bank; thus, the comparability across institutions will suffer.

residuals are included with one lag in the error correction representation. Table 4 presents the results of the Engle and Granger two-step estimation and the results for the simultaneous error correction framework. Clearly, the results do not differ greatly. Thus, the considerations by Liu et al. (2008), who criticize the OLS two-step estimation of pass-through parameters, may be attenuated in our setting.

Table 4: Estimation results of the interest rate pass-through models

Panel A: retail loan rates			markup		adj. duration		adj. coef.		LTPT	
product group	IPT model		mean	median*	mean	median*	mean	median*	mean	median*
loans - overall	EG	coef	3.61	3.17	2.09	1.53	-65.63	-65.35	66.24	63.50
		pval	0.05	0.00	0.01	0.00	0.01	0.00	0.04	0.00
	SEC	coef	3.42	3.09	2.52	1.64	-61.39	-60.67	72.90	68.27
		pval	0.10	0.00	0.02	0.00	0.02	0.00	0.05	0.00
overdraft	EG	coef	7.94	9.19	3.35	2.96	-39.26	-33.82	69.15	69.13
		pval	0.02	0.00	0.03	0.00	0.03	0.00	0.02	0.00
	SEC	coef	7.85	9.12	4.52	3.20	-35.48	-31.20	76.15	74.06
		pval	0.03	0.00	0.07	0.00	0.07	0.00	0.06	0.00
consumer credits	EG	coef	4.42	4.46	2.65	1.80	-56.96	-55.47	64.48	59.96
		pval	0.08	0.00	0.03	0.00	0.03	0.00	0.11	0.00
	SEC	coef	4.23	4.34	3.21	1.93	-54.24	-51.80	70.85	62.80
		pval	0.12	0.00	0.03	0.00	0.03	0.00	0.15	0.01
housing loans	EG	coef	2.33	2.41	1.89	1.56	-64.82	-64.21	66.83	66.69
		pval	0.05	0.00	0.01	0.00	0.01	0.00	0.01	0.00
	SEC	coef	2.04	2.15	2.22	1.70	-59.70	-58.75	75.61	74.01
		pval	0.10	0.00	0.02	0.00	0.02	0.00	0.02	0.00
other loans	EG	coef	2.93	3.09	1.34	1.15	-85.48	-87.08	65.97	61.41
		pval	0.05	0.00	0.00	0.00	0.00	0.00	0.03	0.00
	SEC	coef	2.85	3.03	1.51	1.22	-80.84	-81.93	69.78	65.73
		pval	0.09	0.00	0.01	0.00	0.01	0.00	0.04	0.00
Panel B: non-financial corporate loan rates										
loans - overall	EG	coef	2.97	2.75	1.48	1.18	-82.58	-84.19	70.43	69.95
		pval	0.05	0.00	0.01	0.00	0.01	0.00	0.03	0.00
	SEC	coef	2.81	2.63	1.98	1.27	-75.10	-78.33	76.65	74.44
		pval	0.08	0.00	0.02	0.00	0.02	0.00	0.04	0.00
overdraft	EG	coef	5.19	5.46	2.57	2.62	-45.81	-38.22	63.86	60.19
		pval	0.02	0.00	0.03	0.00	0.03	0.00	0.07	0.00
	SEC	coef	4.86	5.45	3.86	3.15	-36.29	-31.75	74.23	66.60
		pval	0.06	0.00	0.07	0.00	0.07	0.00	0.10	0.00
loans up to € 1 million	EG	coef	2.77	2.84	1.21	1.09	-92.21	-92.06	67.22	62.60
		pval	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00
	SEC	coef	2.64	2.72	1.43	1.15	-86.20	-87.31	71.64	68.40
		pval	0.08	0.00	0.01	0.00	0.01	0.00	0.04	0.00
loans over € 1 million	EG	coef	1.85	1.57	1.23	1.12	-90.25	-89.57	80.80	85.01
		pval	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00
	SEC	coef	1.70	1.50	1.71	1.18	-81.48	-84.91	87.46	90.07
		pval	0.09	0.00	0.02	0.00	0.02	0.00	0.03	0.00

Notes:
This table presents the coefficients of the 2-step Engle and Granger (EG) estimation of interest rate pass-through as well as the results for the simultaneous error correction (SEC) estimation as discussed in section 5. Panel A shows the results for retail loan rates, while Panel B reports the findings for corporate loan rates. The first column presents the product group. The second column states the estimation procedure. We present average as well as median* values for the markup, the adjustment duration, the adjustment coefficient and the long term pass-through (LTPT). We report coefficients and below p-values. '*' Due to confidentiality the reported medians are average values of three banks.

Table 5 presents the results of a correlation analysis of all Engle and Granger and simultaneous error correction (SEC) model parameters. Specifically, each Engle and Granger parameter and its SEC counterparts exhibit a high correlation (e.g., for the markup, the correlations are 94% for retail loans and 92% for corporate loans). This result again emphasizes that OLS-based two-step models do not differ greatly from the simultaneous single-equation models that employ maximum likelihood procedures.

Table 5: Correlations of interest rate pass-through parameters

Panel A: retail loan rates

			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			correlation of EG parameters									
Engle / Granger	(1)	markup	1									
	(2)	STPT	-0.07	1								
	(3)	LTPT	-0.61	0.20	1							
	(4)	adj. coef.	0.14	-0.09	0.10	1						
	(5)	adj. duration	0.13	-0.05	0.16	0.84	1					
			correlation of EG- and SEC parameters					correlation of SEC parameters				
SEC	(6)	markup	**0.94**	-0.03	-0.60	0.10	0.12	1				
	(7)	STPT	-0.19	**0.79**	0.12	-0.21	-0.21	-0.22	1			
	(8)	LTPT	-0.56	0.09	**0.86**	0.13	0.12	-0.70	0.18	1		
	(9)	adj. coef.	0.14	-0.04	0.06	**0.91**	0.72	0.11	-0.24	0.11	1	
	(10)	adj. duration	0.13	0.05	0.06	0.61	**0.69**	0.13	-0.28	0.07	0.74	1

Panel B: non-financial corporate loan rates

			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			correlation of EG parameters									
Engle / Granger	(1)	markup	1									
	(2)	STPT	-0.32	1								
	(3)	LTPT	-0.76	0.37	1							
	(4)	adj. coef.	0.27	-0.06	-0.06	1						
	(5)	adj. duration	0.31	-0.07	-0.05	0.91	1					
			correlation of EG- and SEC parameters					correlation of SEC parameters				
SEC	(6)	markup	**0.92**	-0.30	-0.73	0.25	0.28	1				
	(7)	STPT	-0.03	**0.77**	0.00	-0.23	-0.20	0.00	1			
	(8)	LTPT	-0.66	0.27	**0.87**	-0.04	-0.04	-0.79	0.04	1		
	(9)	adj. coef.	0.25	-0.02	-0.06	**0.89**	0.82	0.18	-0.27	0.04	1	
	(10)	adj. duration	0.21	0.07	-0.03	0.62	**0.69**	0.09	-0.30	0.08	0.81	1

Notes:
This table presents correlations of the parameters estimated by the interest rates pass-through models. Panel A presents correlations for interest rate pass-through parameters for retail loan rates, Panel B presents correlations for corporate loan rates. The bold printed diagonals exhibit strong correlation of the Engle and Granger (EG) parameters and those estimated by a simultaneous error correction (SEC) model.

In the following sections, we base our main results on the Engle and Granger two-step estimates, whereas the robustness section presents the results for the simultaneous model.

5.2. Cost efficiency measurement

This study estimates cost efficiency, i.e., input-, price- and output-factor combinations of individual banks are observed and benchmarked against those of market competitors (Fiorentino et al., 2006). We utilize the stochastic frontier analysis (SFA) that was introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977). Because this method allows for random error capturing stochastic effects and measurement errors, SFA is the appropriate method to evaluate the relative market position of banks (e.g., Berger and Humphrey, 1997).

Our estimation procedure resembles the current approach of Lozano-Vivas and Pasiouras (2010). As recommended by their study, we estimate a variety of different efficiency classes, as presented in greater detail below. Given that the aim of our study is to analyze the standardized loan products that are offered by most German banks, our main bank efficiency measures are based on a common global frontier for all 150 banks that report the MIR statistics and have sufficient data.[21] Thus, each bank can be compared to a common benchmark, as recommended by Lozano-Vivas and Pasiouras (2010). This procedure is especially suitable in our study because each possible bank customer who requests, for example, a mortgage will compare the loan rates that are offered by banks belonging to different bank groups. Our approach relies on the intermediation approach, in which banks use deposits as inputs to transform them into loans and other outputs (Berger and Humphrey, 1997; Sealy and Lindley, 1977).

As usual, we assume that banks have three traditional outputs:[22] interbank loans (y_1), non-bank loans (y_2) and securities (y_3). Because this output portfolio choice will worsen cost efficiency estimates, especially for banks that are engaged in off-balance sheet (obs) businesses

[21] For the main analysis we do not estimate separate frontiers for each bank group. The results of such local frontiers (i.e., cost efficiency estimations that are performed separately for each bank group) are presented in the robustness section.

[22] See Panel A of Table 6 for definitions and details regarding the variables that are used in the estimation of cost efficiency measures.

(Lozano-Vivas and Pasiouras, 2010), we additionally use a fourth output factor that controls for obs activities: consistent with Tortosa-Ausina (2003) and Bos and Schmiedel (2007), our main cost efficiency measure incorporates the inclusion of obs items (y_{4a}). As suggested by Tortosa-Ausina (2003), we hereafter replace obs items with fee income (y_{4b}), which serves as another proxy for obs activities, and estimate a third efficiency measure. The dependent variable of the stochastic frontier function is the total operating costs, including the financial costs (TOC) of the bank at time t. Finally, we assume that banks have three different inputs with corresponding input prices (e.g., Altunbas et al., 2002; Burgstaller and Cocca, 2011):[23] write downs on fixed assets and intangibles divided by the amount of fixed assets and intangibles (w_1); the price of borrowed funds, which is defined as interest expenses divided by total debt (w_2); and the price of labor, which is calculated as personnel expenses divided by the number of full-time employees (w_3).

Motivated by Tortosa-Ausina (2003), Panel B of Table 6 presents summary statistics regarding the employed variables as well as the outputs and inputs as a percentage of total assets.[24] Each of the three cost efficiency specifications employs bank group indicator variables.

---

[23] As noted by Bos et al. (2005), the underlying assumption is perfect competition in debt markets, such that input prices will be exogenously caused and accepted by banks.

[24] The summary statistics are based on the 150 analyzed banks. The banks that report MIR statistics tend to be larger on average if compared with all German banks. However, when we construct summary statistics for the SFA parameters on the sample of all German banks, these summaries closely resemble those of Fiorentino et al. (2006) and Koetter (2006).

Table 6: Summary statistics of variables for the stochastic frontier estimation

Panel A: variable description

variable	label	description
total operating costs	TOC	= general administrative expenses + write downs on intangibles and fixed assets + interest expenses
inputs	x1	fixed assets plus intangibles
	x2	borrowed funds
		= non-bank deposits + bank deposits + debt securities and money market paper outstanding + subordinated debt
	x3	number of full time employees (or full time equivalents)
input prices	w1	price of fixed assets (%)
		= write downs on fixed assets and intangibles and general administrative expenses (except personal expenses) by the amount of fixed assets and intangibles
	w2	price of borrowed funds (%)
		= total interest expenses divided by total debt
	w3	price of labor (€ per employee)
		= total personnel expenses divided by number of full time employees
outputs	y1	interbank loans
	y2	commercial loans
	y3	securities
	y4a	off balance sheet items (obs-items)
	y4b	fee income
accounting for heterogeneity	group	bank group indicator variables
	z	book value of equity

Panel B: summary statistics

			mean	s.d.	x/a.t.
total operating costs	TOC	mio.€	1,470	4,490	(-)
inputs	x1	mio.€	97.9	185	(0.01)
	x2	mio.€	31,100	98,000	(0.92)
	x3	#	1,842	3,675	(0.01)
input prices	w1	%	15.15	14.51	(-)
	w2	%	13.58	17.07	(-)
	w3*	mio.€	0.07	0.03	(-)
outputs	y1	mio.€	8,670	27,700	(0.15)
	y2	mio.€	13,800	42,700	(0.54)
	y3	mio.€	8,910	29,100	(0.25)
	y4a	mio.€	4,940	17,700	(0.07)
	y4b	mio.€	156	584	(0.01)
heterogeneity	z	mio.€	1,470	4,490	(-)

Notes:
Panel A shows definitions of the variables used for stochastic frontier estimation. Panel B presents summary statistics of the variables used to estimate the stochastic frontier function. We show average values of each variable, it's standard deviation and if suitable its value relative to total assets of the bank ('x/a.t.'). '*' Labor expenses.

Consistent with Fiordilisi et al. (2011), Bos et al. (2005) and Koetter (2006), we include the value of equity to account for an alternative capital source financing outputs and to avoid scale bias. We include a time trend in each of the three specifications that controls for technological changes to represent possible changes in the cost function over time (Ariss, 2010).[25]

[25] Additionally, we re-estimate all specifications without a time trend because the estimation period covers only six years. Thus, these newly obtained additional efficiency estimates assume a constant technological level and serve as auxiliary efficiency specifications, as motivated by Lozano-Vivas and Pasiouras (2010).

According to Lang and Welzel (1997) and Lozano-Vivas and Pasiouras (2010), we divide TOC, w_1 and w_2 by w_3 to impose linear homogeneity restrictions.[26]

In the following section, we motivate the general concept of SFA efficiency measurement: banks are assumed to minimize their costs by choosing optimal input portfolios to produce their output composition. In general, a functional representation of bank i's costs is as follows:

$$TOC_i = f(\boldsymbol{y}_i, \mathbf{w}_i, z_i)$$

where $\boldsymbol{y}_i$ and $\boldsymbol{w}_i$ are the output and price vectors, and z_i accounts for equity. The solution with minimum total operating costs, $TOC^* = f(\boldsymbol{y}^*, \boldsymbol{w}^*, z^*)$, serves as a benchmark against which all other banks are compared. The SFA efficiency concept measures the distance of each bank to the best-practice competitor. Typically, the stochastic cost frontier is estimated in logarithms and incorporates an error term ε_i (e.g., Ariss, 2010; Fiordilisi et al., 2011):

$$ln(TOC_i) = f(\ln(\boldsymbol{y}_i), \ln(\boldsymbol{w}_i), \ln(z_i)) + \varepsilon_i$$

The error term, ε_i, can be additively separated into v_i and u_i. Random errors are captured by v_i, and one commonly assumes that v_i are iid $N(0, \sigma_v^2)$ for every bank i and independent of all other model variables (e.g., Stevenson, 1980). Inefficiency, which increases the total costs of bank i beyond the optimal amount, is captured by u_i, which is assumed to be independent of v_i and iid $N^+(\mu, \sigma_u^2)$ (i.e., truncated-normally distributed, see Fiordilisi et al., 2011). Inefficiency leads to higher than optimal costs for a given output portfolio and refers to a suboptimal combination of different inputs. Specifying the multi-product translog function, con-

[26] The inclusion of loan loss provisions in the stochastic frontier function to account for bank risk and output quality (see also Sun and Chang (2011) on this issue) yields correlations of 98% in efficiencies such that all results remain unchanged.

sistent with Bos et al. (2005) and Fiorentino et al. (2006), our main stochastic frontier is estimated as follows:[27]

$$ln\left(\frac{TOC_{it}}{w_{3it}}\right) = \beta_0 + \sum_l \beta_l \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) + \sum_l \beta_l \cdot \frac{1}{2}\left(ln\left(\frac{w_{lit}}{w_{3it}}\right)\right)^2 + \beta_l \cdot ln\left(\frac{w_{1it}}{w_{3it}}\right) \cdot ln\left(\frac{w_{2it}}{w_{3it}}\right)$$

$$+\sum_l \beta_l \cdot ln(y_{lit}) + \sum_l \beta_l \cdot \frac{1}{2}\left(ln(y_{lit})\right)^2$$

$$+\sum_{\substack{m,n \\ m<n}} \beta_{mn} \cdot ln(y_{mit}) \cdot ln(y_{nit}) + \sum_j \sum_m \beta_{im} \cdot ln(y_{jit}) \cdot ln\left(\frac{w_{mit}}{w_{3it}}\right)$$

$$+\beta_l \cdot ln(z_{ti}) + \beta_l \cdot \frac{1}{2}\left(ln(z_{it})\right)^2 + \sum_l \beta_l \cdot ln(z_{it}) \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right)$$

$$+\sum_l \beta_l \cdot ln(y_{lit}) \cdot ln(z_{it}) + \beta_l \cdot T + \beta_l \cdot T^2 + \sum_l \beta_l \cdot T \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right)$$

$$+\sum_l \beta_l \cdot T \cdot ln(y_{lit}) + \beta_l \cdot T \cdot ln(z_{it}) + \sum_{k=1}^{2} \beta_k \cdot group_k + \underbrace{\varepsilon_{it}}_{:=v_{it}+u_i}$$

Because bank-specific efficiency scores are unobservable, they must be estimated. To perform these estimations, we use the time-invariant cost frontier model for panel data, which assumes that the inefficiency term is constant over time. Following Battese and Coelli (1988), we calculate the conditional expectation of u_i given an observed ε_i, (i.e., $\mathbf{E}[exp(-u_i|\varepsilon_i)]$).[28] Cost efficiency is bounded between 0 and 1, where the latter indicates a best-practice or a completely efficient bank. The estimation results for the main efficiency measure are presented in Table 7, and Panels A and B of Table 8 present the summary statistics for the efficiency measures that were obtained by different specifications. The estimated efficiencies are individually employed as the major independent variables of our models to explain the loan rate-setting behavior of banks. Panel C of Table 8 presents the correlations among the efficiency measures.

[27] Brueckner (2007) advises against the inclusion of equity in the translog function as an independent variable but recommends the division of total costs and outputs by the amount of equity. In a robustness check, we verify that our results are not distorted by this procedure.

[28] We estimate a time-invariant model that assumes that u_i does not change over time. Given an estimation period of six years, this assumption is not strict. This assumption is underlined because time-varying decay models assuming that a bank's efficiency improves during time only differ to a minor extent.

Table 7: Estimation results of the stochastic frontier function

	coef	st.error	p-val		coef	st.error	p-val
ln(w1*)	-0.58	0.20	0.01	ln(z)	0.78	0.24	0.00
ln(w2*)	-1.29	0.16	0.00	0.5 ln(z) ln(z)	-0.01	0.01	0.22
0.5 ln(w1*) ln(w1*)	0.03	0.02	0.06	ln(w1) ln(z)	-0.02	0.01	0.00
0.5 ln(w2*) ln(w2*)	0.03	0.03	0.24	ln(w2) ln(z)	0.07	0.01	0.00
ln(w1*) ln(w2*)	-0.11	0.02	0.00	ln(y1) ln(z)	0.00	0.00	0.33
ln(y1)	-0.16	0.13	0.24	ln(y2) ln(z)	-0.01	0.01	0.41
ln(y2)	0.80	0.28	0.01	ln(y3) ln(z)	-0.01	0.01	0.26
ln(y3)	0.32	0.13	0.02	ln(y4) ln(z)	0.01	0.01	0.08
ln(y4)	-0.63	0.18	0.00	t	0.01	0.06	0.93
0.5 ln(y1) ln(y1)	0.05	0.00	0.00	t^2	0.00	0.00	0.02
0.5 ln(y2) ln(y2)	0.09	0.03	0.01	ln(w1) t	0.00	0.00	0.36
0.5 ln(y3) ln(y3)	0.07	0.01	0.00	ln(w2) t	0.01	0.01	0.26
0.5 ln(y1) ln(y4)	0.01	0.01	0.50	ln(z) t	0.00	0.00	0.10
ln(y1) ln(y2)	-0.04	0.01	0.00	ln(y1) t	0.00	0.00	0.48
ln(y1) ln(y3)	-0.01	0.00	0.00	ln(y2) t	-0.01	0.00	0.04
ln(y1) ln(y4)	0.00	0.00	0.35	ln(y3) t	0.00	0.00	0.42
ln(y2) ln(y3)	-0.04	0.01	0.00	ln(y4) t	0.00	0.00	0.06
ln(y2) ln(y4)	0.07	0.01	0.00	comm indicator	0.06	0.03	0.04
ln(y3) ln(y4)	0.00	0.01	0.61	coop indicator	-0.01	0.03	0.75
ln(y1) ln(w1*)	0.01	0.01	0.30	constant	-25.58	2.60	0.00
ln(y1) ln(w2*)	-0.03	0.01	0.00				
ln(y2) ln(w1*)	0.06	0.01	0.00	additional information			
ln(y2) ln(w2*)	-0.04	0.02	0.05	μ	0.38	0.04	0.00
ln(y3) ln(w1*)	0.01	0.01	0.14	$ln(\sigma_S^2)$	-3.53	-0.13	0.00
ln(y3) ln(w2*)	0.00	0.01	0.70	$ln^{-1}(\gamma)$	2.68	0.16	0.00
ln(y4) ln(w1*)	-0.01	0.01	0.22	σ_S^2	0.03	0.00	(-)
ln(y4) ln(w2*)	-0.01	0.01	0.46	γ	0.94	0.01	(-)
				σ_u^2	0.03	0.00	(-)
N - obs	801						
N - id	150						

Notes:
This table presents the regression results for the main bank efficiency measure (i.e., estimation on a common frontier of 150 banks, with obs-items and with time trend).
The variables are coded as presented in section 5. The dependent variable of the model is log of total operating costs normalized by w_3. We report coefficient estimates, standard errors as well as p-values. ‘N - obs’ refers to the number of bank-year observations, ‘N - id’ to the number of individual banks. ‘w_1^*’ equals w_1/w_3, ‘w_2^*’ equals w_2/w_3.

Table 8: Summary statistics and correlations of SFA efficiencies

Panel A: overall summary statistics

		mean	p50	s.d.	min	max
with time trend	without obs	71.77	71.19	9.73	43.74	98.28
	obs-items 73.	**12**	**72.64**	**9.50**	**47.06**	**99.37**
	fee income	89.80	90.94	7.62	67.31	99.98
without time trend	without obs	78.07	80.02	11.33	44.02	99.84
	obs-items	76.63	77.99	11.27	43.02	99.68
	fee income	87.65	88.85	8.49	64.68	99.98

Panel B: pair wise correlations of estimated efficiency measures and traditional ratios

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) without time trend	without obs	1										
(2)	obs-items	0.99	1									
(3)	fee income	0.82	0.80	1								
(4) with time trend	without obs	0.87	0.89	0.71	1							
(5)	obs-items	0.86	0.89	0.71	0.98	1						
(6)	fee income	0.64	0.64	0.89	0.64	0.65	1					
(7) ROE		0.14	0.12	0.13	0.03	0.02	0.05	1				
(8) ROA		0.08	0.04	0.15	-0.07	0.08	0.14	0.77	1			
(9) TCTA		-0.23	-0.26	-0.05	-0.31	-0.34	-0.10	-0.17	0.00	1		
(10) TCTR		-0.30	-0.27	-0.28	-0.14	-0.15	-0.27	-0.59	-0.70	0.30	1	
(11) CIR		-0.27	-0.32	-0.16	-0.50	-0.49	-0.22	0.08	0.38	0.38	-0.20	1

Panel C: pair wise correlations of SFA efficiencies estimated by global frontiers and local frontiers

global frontier on 150 MIR banks	local frontiers of each bank group	global frontier based on all BISTA reporting banks
with time trend and with obs-items	66%	63%
without time trend and with obs-items	75%	55%

Notes:

This table presents summary statistics on estimated efficiency measures. Panel A shows average summaries for the sample banks We report the average efficiency, the median, standard deviation as well as minimum and maximum. We report summaries on efficiencies estimated with time trend and without time trend. For each category we estimate efficiencies without incorporation of off-balance sheet items, with obs-items (i.e., off-balance sheet items) or with fee income as obs-activities proxy. The bold printed summaries highlight our main efficiency measure being used for estimation of the main results in the other tables.

Panel B presents correlations of efficiency measures based on the global frontier of 150 MIR statistics reporting banks. Additionally, we present correlations with return on equity (ROE), return on assets (ROA), total costs to total assets (TCTA), total costs to total revenues (TCTR) and the cost income ratio (CIR) as suggested by Fiorentino et al. (2006).

Panel C presents correlations of efficiency measures for two alternative SFA methods: Lozano-Vivas and Pasiouras (2010) suggest estimating local frontiers (i.e., a SFA estimation on each bank group, respectively), which is labeled 'local frontiers of each bank group'. Further, Fiorentino et al. (2006) and Koetter (2006) estimate cost efficiency using all BISTA reporting German banks (more than 2,000). We re-estimate correlations on local frontiers and a global frontier for all German banks. For clearness only the correlations of our main efficiency measure as well as for the measure without time trend with those estimated on local frontiers or with all German banks are presented. Thus, evidence is provided that our chosen global estimation based on 150 banks is highly correlated with the other two estimation methods.

Consistent with prior literature, the correlations are high and range from 64% to 99%. Additionally, consistent with Fiorentino et al. (2006), we present correlations of SFA efficiencies and traditional financial ratio-based cost measures, such as the ratios of total costs to total assets (TCTA) and total costs to total revenues (TCTR) and the cost-income ratio (CIR), as well as performance measures, such as the return on equity (ROE) and return on assets (ROA).

The correlations are in the expected direction but weak. This result emphasizes that traditional financial ratios do not capture cost efficiency and are instead driven by price differences and other exogenous factors as argued by Bauer et al. (1998). Panel C of Table 8 presents the correlations of the efficiency measures for two alternative SFA methods: individual SFA estimation for each bank group (local frontiers) and the estimation of cost efficiency based on all German banks (global frontiers). The correlations are sufficiently high such that the estimation of a common frontier on 150 banks will not attenuate our findings.

5.3. Further bank characteristics

In addition to a bank's degree of operational efficiency that could influence its loan rate pass-through behavior, other bank determinants have been proposed by prior research: We begin with the introduction of two well-established factors and, consistent with Ehrmann et al. (2003), calculate '**excess capital**' as the average Tier 1 plus Tier 2 capital less than risk weighted assets times 8%.[29] The bank's '**liquidity**' will be the average sum of cash, securities and the net interbank position divided by total assets (see also Mueller-Spahn, 2008).[30] Capitalization and liquidity reflect a bank's financial structure and are assumed to serve as buffers against market interest rate shocks. Highly liquid and well-capitalized banks could insulate bank customers from market interest rate shocks (i.e., such banks could smooth loan rate adjustment). In addition, Gambacorta (2008) and De Greave et al. (2007) find that well-capitalized banks charge higher loan rates and markups, respectively. The costs of holding more capital than necessary could lead to less favorable bank prices. Next, consistent with De Greave et al. (2007) and Gambacorta (2008), we include the ratio of '**deposit funding**' as the

[29] An alternative is the equity to total assets, as suggested by Fuertes et al. (2010). The robustness check includes this variation.

[30] To account for the initial lack of confidence in interbank markets in 2008, we re-estimate liquidity without the net interbank position in the robustness section.

amount of non-bank deposits divided by total assets. The reasoning is that banks with a high fraction of costly deposit funding (compared with, for example, less expensive capital market funding) could be enforced to charge higher loan rate markups.[31] However, deposit interest rates have been found to be rather sticky, such that banks that rely heavily on deposit funding and less on capital market financing could smooth their loan rate adjustments following a market interest rate change to a greater extent because their funding costs increase at a ratio of less than one-to-one with the market.

The market power of a bank is proxied by '**market share**', which we calculate as the average amount of non-bank loans relative to the sum of all non-bank loans within the sample. Banks with a large market share that are able to exert market power could establish prices less competitively and thus result in higher loan markups. Additionally, less stable price offers could be observed because the market interest rates increased during the estimation period (i.e., banks with market power could adjust their loan rates upward more rapidly). We recognize that the measurement of market power is of particular interest and that it deviates throughout the literature. In addition, accounting for market power appears to be highly relevant for the pricing of bank loans. Under the assumption of pure competition, profit-maximizing banks could not pass on efficiency in terms of lower loan rates and retain their gains to increase profits. In contrast, if banks dispose of a certain type of market power, then the adjustment of loan rates to higher efficiency could be advantageous to maximize profits because market share could be increased. Thus, our analysis includes different proxies for market power as well as competition and concentration in markets.[32] This enhances the meaning of cost efficient banking relative to the exertion of market power. Specifically, we successively replace market share as defined above with the **market share as measured in terms of new business**

[31] The costs may arise either directly because of the deposit interest expenses or indirectly because of the costs of a decentralized sales organization. Especially, Weth (2002) finds funding structure to be an important determinant of a bank's IPT.

[32] See section 7 for details.

volumes per bank divided by the sum of all new business volumes obtained from the MIR statistics (see, e.g., De Greave et al., 2007). However, because this proxy is likely to suffer from endogeneity concerns, we then use a **Lerner index** for each bank to indicate the extent to which the bank is able to establish prices that are above marginal costs.[33] To account for market concentration we alternatively use **Herfindahl indices**, which measure the concentration of total assets first based on the individual 16 German federal states and then based on the finer German postal codes.

To account for a possible '**risk**' effect on loan rate-setting behavior, we include the ratio of bad loans to total loans in our analysis.[34] If a bank issues riskier loans, then these loans will be priced with a higher loan markup.

According to Gambacorta (2008), Ehrmann et al. (2003) and Weth (2002), we include the logarithm of total assets as a possible '**size**' effect. Thus, we are able to account for the size imbalances among the banks. Panel B of Table 2 provides summary statistics for the control variables of the models, which are comparable to the statistics of De Greave et al. (2007) and Clayes and Vander Vennet (2008). Finally, we include indicators for bank groups and products to control for different group-product-specific levels of markups and adjustment speeds (e.g., De Greave et al., 2007).

---

33 See Appendix 1 for details on the Lerner estimation.
34 Specifically, we use the ratio of loan charge-offs to total loans. Alternatively, we add a loan loss provision to the numerator.

6. Econometric Analysis and Main Results

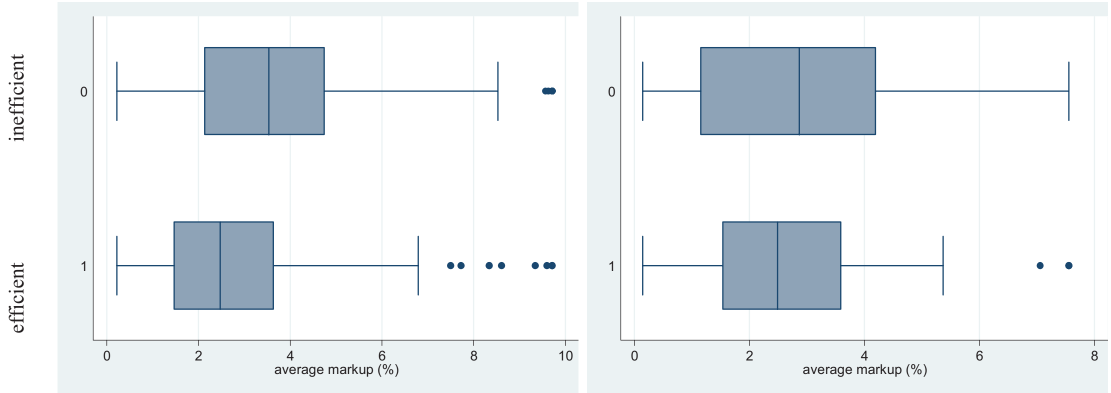
This section presents our main results of the analysis of which bank characteristics assist in explaining bank-specific interest rate pass-through behavior. Specifically regarding our research hypothesis, we examine whether and to what extent cost efficiency affects the interest rate-setting behavior of banks. To obtain an initial indication of this effect, we examine the absolute values of banks' loan markups and adjustment durations: Figure 2 presents box plots indicating that cost efficient banks charge smaller loan markups and employ smoother interest rate-setting behavior than their inefficient market competitors (i.e., an initial indicator that cost efficiency could be beneficial for bank customers).

Because the graphical representation averages different loan products, Table 9 presents a more detailed overview of possible cost efficiency effects.

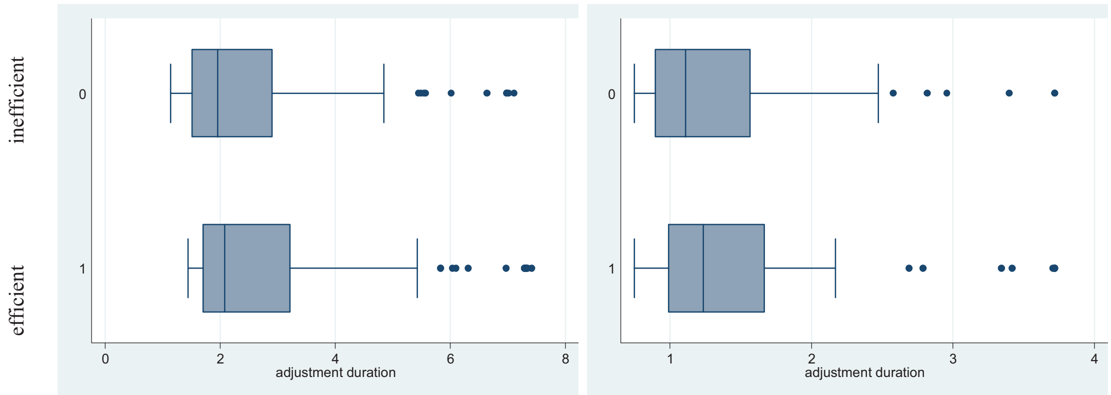
Figure 2: Markups and adjustment durations of efficient and inefficient banks

retail loan products	**corporate loan products**

Panel A: loan markups



Panel B: adjustment durations



Notes:
This figure presents the univariate results that cost efficient banks request lower loan markups. The left column presents box plot of average retail- and corporate loan markups whereas the right column presents average adjustment durations. In this setting we refer to a bank as being cost efficient if it belongs to the top 25% of the most efficient banks and as inefficient if it belongs to the lowest 25% of efficient banks. Grouping is done according to our main efficiency measure (i.e., estimated with a common frontier, with obs-items and a time trend).
The boxes cover all IPT figures between the 25% and 75% percentile. The vertical line within a box presents the average markup or adjustment duration. Both vertical line left and right of the box show the 1% and 99% quantile of interest rates. The dots represent outliers.
Our classification of being efficient and inefficient is naturally arbitrary ('25% quantile'). However, the same picture emerges, if we take advantage of other quantiles, such as comparing the most efficient 5%, 10%, 30% or 40% banks.

Table 9: Changes of markups and adjustment durations with increasing efficiency

Panel A: retail loans	product no.	eff. vs. ineff. banks Δ markup percentage points	Δ duration	correlation of efficiency and i) markup	ii) duration
average of all retail loans	(-)	-0.96	0.13		
overdrafts	12	-1.15	0.30	-0.06	0.15
consumer credit with					
floating rate or initial rate fixation of up to 1 year	13	0.94	0.31	0.06	0.08
initial rate fixation of over 1 and up to 5 years	14	-0.70	0.41	-0.09	0.14
initial rate fixation of over 5 years	15	-2.26	1.05	-0.26	0.10
housing loans with					
floating rate or initial rate fixation of up to 1 year	16	-1.13	0.58	-0.17	0.15
initial rate fixation of over 1 and up to 5 years	17	-0.56	0.14	-0.16	0.10
initial rate fixation of over 5 and up to 10 years	18	-0.39	0.13	-0.20	0.16
initial rate fixation of over 10 years	19	-0.64	0.05	-0.19	0.02
other loans with					
floating rate or initial rate fixation of up to 1 year	20	-0.40	0.03	-0.14	0.08
initial rate fixation of over 1 and up to 5 years	21	-1.01	0.29	-0.17	0.23
initial rate fixation of over 5 years	22	-1.73	0.10	-0.27	0.03
Panel B: non-financial corporate loans					
average of all corporate loans	(-)	-0.20	0.30		
overdrafts	23	-0.55	0.67	-0.06	0.30
loans up to euro 1 million with					
floating rate or initial rate fixation of up to 1 year	24	-0.35	-0.11	-0.06	0.13
initial rate fixation over 1 and up to 5 years	25	-1.29	-0.12	-0.18	0.10
initial rate fixation over 5 years	26	0.01	-0.07	-0.10	0.11
loans over euro 1 million with					
floating rate or initial rate fixation of up to 1 year	27	-0.43	0.21	-0.03	0.10
initial rate fixation over 1 and up to 5 years	28	0.95	0.01	0.27	0.22
initial rate fixation over 5 years	29	1.05	0.11	0.13	0.22

Notes:
This table presents summary statistics on analyzed IPT characteristics depending on whether the bank operates cost efficiently (eff) or not (ineff). We classify a bank as cost efficient if it belongs to the upper 25% of efficient banks and as inefficient if it belongs to the 25% of banks with lowest efficiency (see for a similar procedure Weth, 2002).
Panel A presents summary statistics for all retail loans whereas Panel B refers to corporate loans. The first column presents the interest rate product, the second column shows its MIR statistics' number. 'Δ' accounts for the difference operator. If cost efficient banks set loan markups below their inefficient competitors, the difference for markups is negative. If efficient banks smooth their loan rate offers, the difference for the adjustment duration is positive. Our classification of being efficient and inefficient is freely chosen ('lower 25% vs. upper 75% quantile'). However, the same picture emerges, if we take advantage of other quantiles, such as comparing the most efficient 5%, 10%, 30% or 40% banks.
In addition we present the correlation of our SFA-based efficiency measure and the loan markups and the adjustments durations. For markups a negative correlation is expected while the opposite hold true for the adjustment duration. Correlations exceeding the absolute value of 0.08 are significant at the 10% level.

As indicated, banks that operate in a cost efficient manner establish lower loan markups in the majority of offered products and less volatile loan rate setting.

In a shift of focus from the univariate assessment of possible efficiency effects to the multivariate verification, the dependent variables of our main OLS models examine two major facets of pass-through parameters: the loan markup above the market interest rate level and the duration in which a bank passes-through a market interest rate change to its loan rates (i.e., the speed with which loan rates are adjusted). The former can be referred to as the equilibrium margin between loan rates and the marginal cost of funds, whereas the latter reflects whether a bank prices its products closely to the evolution of the market or whether loan rates are smoothed.

In addition to our main cost efficiency measure (i.e., based on the estimation of a common frontier on all sample banks with obs items and a time trend), the models of Table 10 include the bank factors excess capital, liquidity, the ratio of deposit funding as measure for funding diversification, market share accounting for market power, credit risk and bank size in our regressions.[35] Additionally, each model includes indicator variables for the three major bank groups.[36]

Table 10: Determinants of loan markups and adjustment duration

	loan markup		**adjustment duration**	
	(1)	(2)	(3)	(4)
cost efficiency	**-0.017****	**(-)**	**0.013*****	**(-)**
excess capital	0.011	0.018	-0.004	-0.009
liquidity	-0.011**	-0.011**	-0.004*	-0.004*
deposit funding	0.013*	0.017***	0.009***	0.005*
market share	0.194	0.261	-0.149	-0.201
size	-0.071	-0.026	0.151***	0.116**
credit risk	0.017	0.039	-0.012	-0.030*
comm indicator	-0.344	-0.347	0.281**	0.283**
coop indicator	0.106	0.054	0.015	0.056
product indicator	(yes)	(yes)	(yes)	(yes)
cons	4.807	2.219	-2.943**	-0.933
Adj. R^2	0.50	0.48	0.27	0.26
R^2	0.51	0.50	0.28	0.28
N	1951	1951	1951	1951
Wald test: model (1) compared to model (2), (3) compared to (4), respectively:				
(p-val)	(0.02)		(0.00)	

Notes:
This table presents OLS estimates of the determinants of the loan interest rate markup and the adjustment speed. The dependent variable of models (1)-(2) is the loan markup. The dependent variable of models (3)-(4) is each loan rate's adjustment duration after a market interest rate's change (both pass-through parameters are estimated by Engle and Granger's procedure). The cost efficiency measure is based on estimation of a common frontier, with time trend and with obs-items.
The main models are (1) and (3). Furthermore, we estimate restricted models (2) and (4), which suppress the variable 'cost efficiency'. We report Adjusted-R^2 ('Adj.-R^2') and R^2. 'N' is the number of observations. Standard errors are clustered at the bank level. '***' denotes the significance at the 1% level, '**' refers to the significance at the 5% level and '*' to the 10% level significance.

35 See section 5 for definitions.
36 Consistent with De Greave et al. (2007), the models include product indicator variables that account for structural differences among the analyzed products. Coefficient estimates are not tabulated.

Regarding our first hypothesis (i.e., cost efficient banks charge lower loan rates), the OLS results of model (1) show a significant negative relationship of higher cost efficiency on loan markups. An increase in cost efficiency by one standard deviation leads to a loan markup reduction of approximately 0.5 percentage points (i.e., a reduction of an average markup of 3% to 2.5% above the market level). Thus, this finding supports our first hypothesis regarding the loan rate level. Regarding our control variables that present other relevant bank factors, we find that these variables behave as expected and are consistent with the findings of prior literature: for example, high liquidity reduces loan rate markups. As argued by De Greave et al. (2007), excess capital exhibits a positive effect on loan markups (although it is marginally insignificant in our setting). The positive coefficient of market share indicates that banks exert market power to a certain degree (i.e., a higher market share enables a bank to price loans less competitively).[37] Credit risk is insignificant but in the expected direction (i.e., banks with higher credit risk charge higher loan rates). The model fit is satisfactory with an adjusted R^2 value of 0.50. For the sake of completeness, we also estimate a restricted model that suppresses cost efficiency (see model (2)). A Wald test emphasizes that the inclusion of cost efficiency significantly increases the model fit (i.e., the inclusion of cost efficiency improves the explanatory power).

With regard to the second dimension of interest pass-through behavior, regulators and monetary policy are concerned with how rapidly banks adjust their prices following a market interest change. From the perspective of bank customers, the steadiness of bank prices is valued: i.e., does a bank frequently change its charged loan rates when minor market movements occur, or does it provide stable price offers? If the latter is the case, then a greater duration of the process of loan rate adjustment is beneficial for borrowers. Thus, one encounters the question

[37] Concerning market power, we perform several robustness checks using the Herfindahl and Lerner indices or market share based on new business volumes. Cost efficiency consistently remains significant and some other market power proxies exhibit a significant effect. See section 7 for details.

of whether banks that operate more cost efficiently than their competitors use their advantage to stabilize their offered loan rates and thus provide benefits to their customers. Cost efficiency provides a significant, positive effect on the duration of loan rate adjustment; thus, more cost efficient banks offer more stable loan rates. However, one standard deviation increase in cost efficiency leads to a change in adjustment duration of approximately 0.25 months (i.e., the pass-through is delayed by more than one week).

Again, the covariates are those suggested by prior literature: banks that rely heavily on deposit funding tend to charge higher loan markups but offer more stable prices, as indicated by the greater duration of the loan rate adjustment (point estimate of 0.013). High market power is associated a more rapid loan rate adjustment and pricing that is similar to market interest developments (point estimate of -0.149). Banks that confront higher credit risks do not insulate their customers from market interest rate shocks. Again, this effect is only observed in the expected direction.

We conclude that customers generally benefit from cost efficient banking (i.e., more cost efficient banks are associated with smaller loan markup above the market interest rate and smoother loan rate adjustment after a market rate change). Thus, we find evidence to support our research hypothesis that operational efficiency alters the interest rate-setting behavior of German banks.

We now examine the question of whether traditional ratio-based measures of operational efficiency would have been sufficient proxies for explaining variations in interest rate pass-through behavior (see, e.g., De Greave et al., 2007)

Table 11: Traditional accounting ratios and SFA cost efficiency

Panel A: traditional, financial ratios based efficiency measures

	loan markup				
	ROE	ROA	CIR	TCTR	TCTA
	(1)	(2)	(3)	(4)	(5)
trad. (in-)efficiency	**0.01**	**0.367**	**-0.007**	**-0.01**	**0.067**
excess capital	0.019	0.01	0.017	0.013	0.021
liquidity	-0.011**	-0.009*	-0.012**	-0.010*	-0.011**
deposit funding	0.016***	0.015**	0.018***	0.015**	0.017***
market share	0.306	0.306	0.259	0.287	0.245
size	-0.031	-0.02	-0.013	-0.012	-0.024
credit risk	0.04	0.036	0.045	0.038	0.037
comm indicator	-0.371	-0.375	-0.246	-0.275	-0.386*
coop indicator	0.068	0.085	0.094	0.107	0.044
product indicator	(yes)	(yes)	(yes)	(yes)	(yes)
cons	2.222	2.005	7.72***	2.943	1.856
Adj. R^2	0.48	0.48	0.50	0.48	0.48
R^2	0.49	0.49	0.51	0.49	0.49
N	1951	1951	1951	1951	1951

	adjustment duration				
	ROE	ROA	CIR	TCTR	TCTA
	(6)	(7)	(8)	(9)	(10)
trad. (in-)efficiency	**0.002**	**0.002**	**-0.0028**	**-0.009*****	**-0.107****
excess capital	-0.009	-0.009	-0.009	-0.014	-0.013
liquidity	-0.004*	-0.004	-0.0036*	-0.002	-0.004**
deposit funding	0.005*	0.005*	0.0056**	0.003	0.006**
market share	-0.193	-0.201	-0.201	-0.178	-0.176
size	0.115**	0.116**	0.121**	0.129***	0.112**
credit risk	-0.030*	-0.030*	-0.027*	-0.031**	-0.026*
comm indicator	0.279**	0.283**	0.325**	0.348***	0.346***
coop indicator	0.058	0.056	0.072	0.103	0.072
product indicator	(yes)	(yes)	(yes)	(yes)	(yes)
cons	-0.933	-0.934	0.456	-0.29	-0.351
Adj. R^2	0.27	0.27	0.25	0.28	0.27
R^2	0.28	0.28	0.27	0.28	0.28
N	1951	1951	1951	1951	1951

Panel B: traditional accounting ratios and SFA cost efficiency

	loan markup		**adj. duration**	
	EG	SEC	EG	SEC
	(1)	(2)	(3)	(4)
cost efficiency	**-0.018** -**	**0.018***	**0.013*****	**0.005***
ROE	-0.021	-0.01	0.012	0.009
ROA	0.581	0.117	-0.304	-0.172
CIR	-0.004	-0.016	-0.002	-0.001
TCTA	0.02	0.076	0.01	-0.091
TCTR	-0.013**	-0.012	-0.008***	-0.001
(all other covariates as before)	(yes)	(yes)	(yes)	(yes)
Adj. R^2	0.50	0.42	0.28	0.16
R^2	0.51	0.43	0.29	0.17
N	1951	1951	1951	1951

Notes:

This table presents OLS regression estimates of the determinants of loan interest rate markup and adjustment speed. Panel A shows that the results for traditional, financial ratios are not suitable to explain variations in interest rate pass-through behavior: The dependent variable of models (1)-(5) is the loan markup. The dependent variable of models (6)-(10) is each loan rate's adjustment duration after a market interest rate's change (both pass-through parameters are estimated by Engle and Granger's procedure). 'ROE' is 'return on equity', 'ROA' is 'return on assets', 'CIR' is 'cost income ratio', 'TCTA' is 'total costs to total assets' and 'TCTR' is 'total costs to total revenues'. All models incorporate traditional financial ratios as a proxy for 'bank efficiency' (see e.g., De Greave et al., 2007; Gambacorta, 2008).

Panel B employs SFA cost. Because Panel A presents significant results for at least TCTA and TCTR the question is whether SFA cost efficiency estimates outperform the traditional financial ratios as competing proxies for 'bank efficiency'. The dependent variable of models (1)-(2) is each loan product's markup. The dependent variable of models (3)-(4) is each loan rate's adjustment duration after a market interest rate's change. Models (1) and (3) use pass-through parameters obtained from Engle and Granger's two step procedure. Models (2) and (4) use parameters obtained from the simultaneous error correction equation. All models include product indicator variables for each loan product. Standard errors are clustered at the bank level. '***', '**', '*' denote the significance at the 1%, 5% and 10% level.

Panel A of Table 11 relies on cost measures that include the ratio of 'total costs to total assets', 'total costs to total revenues' or the 'cost-income ratio'. Additionally, we include models that capture bank performance using 'return on equity' or 'return on assets', as motivated by Fiorentino et al. (2006).

The results indicate that those traditional models are not suitable for depicting differences in loan rate setting. However, both total cost measures perform as expected in explaining the adjustment duration of interest rates. Higher inefficiency (i.e., higher costs) leads to more rapid interest rate adjustment.

The ad hoc question is whether SFA-based cost efficiency is more appropriate than these traditional measures; thus, Panel B of Table 11 estimates models that capture SFA-based cost efficiency in addition to traditional ratios. The results show that cost efficiency still significantly explains both markup and adjustment duration.

Finally, we address the question of whether there are differences among the separate borrower groups (i.e., retail and corporate customers) or even differences among the product classes (e.g., housing loans or consumer loans).

Table 12: Differentiation between customer groups and loan products

		markup	**duration**
		coef.	coef.
Panel A: customer groups - overall			
retail loans	cost efficiency (all else as Table 10)	-0.022***	0.014***
non-financial corporate loans	cost efficiency (all else as Table 10)	-0.008*	0.011***
Panel B: retail loan product classes			
overdrafts	cost efficiency (all else as Table 10)	0.0001	0.022*
consumer loans	cost efficiency (all else as Table 10)	-0.037**	0.021**
housing loans	cost efficiency (all else as Table 10)	-0.028***	0.011***
other loans	cost efficiency (all else as Table 10)	-0.021**	0.010**
Panel C: non-financial corporate loan product classes			
overdrafts	cost efficiency (all else as Table 10)	-0.046*	0.019*
loans up to euro 1 million	cost efficiency (all else as Table 10)	-0.015*	0.008***
loans over euro 1 million	cost efficiency (all else as Table 10)	0.011	0.009***

Notes:
This table re-estimates the main models of Table 10 on individual customer and products groups. All prior covariates are included as in the main models though their coefficient estimates are suppressed.
Panel A presents estimates on the customer groups (i.e., the retail as well as the corporate loans products). Panels B and C re-estimate the main models on more detailed product groups (e.g., only housing loans).

Panel A of Table 12 provides evidence that in general retail as well as corporate borrowers benefit from cost efficient banking. Now, we seek to explore the different loan products in more detail. First of all, Panel B of Table 12 exhibits no significant relationship of cost efficiency on markups for retail overdrafts. This result is in line with the recent study of Dick et al. (2012) who analyze the overdraft pricing behavior of German banks and find that these loan rates will only be adjusted to a minor extent, when the bank's refinancing costs decrease. Because overdrafts are used occasionally or may be taken unconsciously by the borrower (i.e., being a credit line for short term financing) banks might find it inappropriate to pass on cost efficiency gains to set more attractive prices for this particular loan product.

However, turning the attention to all other retail loans the cost efficiency effect is clearly pronounced. A possible explanation for this result could be that borrowers compare loan rate offers when they consciously plan to invest (e.g., buying a house or a car) such that banks set prices more competitively for the corresponding loan products (i.e., housing loans and consumer loans). In contrast, corporate overdraft pricing is affected towards the borrowers benefit, if the bank is able to operate more efficiently. The prior results cannot be verified for corporate loans with volume exceeding 1 million €. Bearing in mind that for high volume loans the individual banks may not be on their own responsible for pricing (i.e., issues of syndication turn important or the cooperation of local savings and cooperative banks with their group central banks), the observed loan rates may be too noisy to detect the efficiency pass-through. In sum, for almost all individual product groups the efficiency effect on loan rate markups and adjustment speeds can be established. The next section presents the robustness of our main results.

7. Further Empirical Analysis and Robustness

7.1. Measurement alternatives for various control variables

This section discusses the robustness of our main results that are presented in Table 10. Prior research has suggested different **alternative explanatory variables** to explain IPT behavior (e.g., the ratio of total loans to total assets as a variable that captures possible credit risk or the Herfindahl index to capture market concentration and competition). Therefore, we re-estimate our main models and repeatedly replace the independent variables.

Table 13: Robustness – alternative covariates

	new covariate	**markup durat**	**ion**	**alt. covariate**
		coef.	coef.	mean (s.d.) [%]
cost efficiency alt. capital (1) (all else as Table 10)	equity / total assets	**-0.016** 0.** 0.047	**013***** -0.028*	4 (1.2)
cost efficiency alt. capital (2) (all else as Table 10)	RWA / total assets	**-0.017** 0.** 0.40	**013***** -0.013	55 (12)
cost efficiency alt. liquidity (all else as Table 10)	(cash+securities) / total assets	**-0.017** 0.** -0.006*	**013***** -0.004*	24 (11)
cost efficiency alt. market share (1) (all else as Table 10)	HHI - federal states	**-0.017** 0.** 0.037	**013***** -0.043*	17 (9)
cost efficiency alt. market share (2) (all else as Table 10)	HHI - postal codes	**-0.015** 0.** 0.065**	**013**** -0.086	50 (21)
cost efficiency alt. market share (3) (all else as Table 10)	Lerner	**-0.017** 0.** 0.03*	**013***** 0.014**	28 (5)
cost efficiency alt. market share (4) (all else as Table 10)	new business market share	**-0.017** 0.** -0.007	**014***** 0.08***	0.69 (1.55)
cost efficiency alt. credit risk (all else as Table 10)	loans / total assets	**-0.017** 0.** -0.003	**014***** 0.001	69 (11)

Notes:
This table presents robustness for the main results of Table 10. We re-estimate the main models but replace the individual covariates with alternatively (alt) suggested IPT determinants. 'RWA' accounts for 'risk weighted assets', 'HHI' is the Herfindahl/Hirschman index calculated as the sum of squared market shares. We base the calculation on each Federal state and then on the finer composed German postal codes. Thus, we account especially for concentration within local markets operating Savs and Coops. The 'Lerner' is calculated as described in Appendix 1. For each new covariate its mean and standard deviation are reported. All other independent variables are included in the models but coefficient estimates are suppressed. Cost efficiency is our main measure as suggested in Table 10.

The results show that the alternative measures always have the same directional effect on loan markup and adjustment duration as their equivalents in the main models. Cost efficiency consistently performs well.

7.2. Measurement alternatives for the main independent variable

We emphasize that our results are not driven by any particular estimation procedure of cost efficiency. Our results are robust to the replacement of the cost efficiency estimates. Specifically, we present estimations that are based on the following **modifications of our main efficiency measure**:[38]

Efficiency measurement	frontier function	obs activities proxy	see Table 14
(i)	common frontier	**fee income**	(i)
(ii)	common frontier	**no obs activities**	(ii)
(iii)	**local bank group frontiers**	obs items	(iii)
(iv)	**global frontier on all German banks**	obs items	(iv)

[38] Recall that the main frontier function is a common frontier on all 150 banks with obs items and a time trend.

Table 14: Robustness – various cost efficiency measures

	(i) fee income				(ii) without obs activities			
	loan markup		**adj. duration**		**loan markup**		**adj. duration**	
	OLS	IV - 2SLS	OLS	IV - 2SLS	OLS	IV - 2SLS	OLS	IV - 2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
cost efficiency	**-0.011 -**	**0.042****	**0.017*****	**0.035*****	**-0.016****	**-0.020*****	**0.013*****	**0.014*****
excess capital	0.019	0.020	-0.010	-0.010	0.013	0.011	-0.004	-0.004
liquidity	-0.012**	-0.014***	-0.002	-0.001	-0.012**	-0.012***	-0.003**	-0.003**
deposit funding	0.015**	0.010*	0.008***	0.011***	0.013*	0.012**	0.009***	0.009***
market share	0.377	0.692***	-0.375**	-0.563***	0.159	0.136	-0.120	-0.116
size	-0.077	-0.214*	0.192***	0.273***	-0.064	-0.073	0.146***	0.148***
credit risk	0.032	0.012	-0.019	-0.007	0.017	0.012	-0.012	-0.011
comm indicator	-0.381	-0.474***	0.334***	0.390***	-0.316	-0.309**	0.258***	0.257***
coop indicator	0.048	0.031	0.065	0.075	0.109	0.121	0.012	0.010
product indicator	(yes)	(yes)	(yes)	(yes)	(yes)	(yes)	(yes)	(yes)
cons	4.520	10.78**	-4.374***	-8.10***	4.624	5.158**	-2.850**	-2.947***
Adj. R^2 / Gen. adj. R^2	0.50	0.50	0.28	0.27	0.50	0.50	0.28	0.27
R^2 / Gen. R^2	0.51	0.51	0.28	0.28	0.51	0.51	0.28	0.28
N	1,951	1,951	1,951	1,951	1951	1951	1951	1951
Instrument diagnostics								
Excl. instruments, stat (p-val)		4.55 (0.00)		4.55 (0.00)		41.42 (0.00)		31.37 (0.00)
Under-ident., stat. (p-val)		13.60 (0.00)		13.60 (0.00)		71.74 (0.00)		33.41 (0.00)
Weak- ident.; stat.		4.55		4.55		41.41		41.41
Over-ident., stat. (p-val)		2.62 (0.27)		0.78 (0.67)		2.29 (0.31)		2.06 (0.36)

	(iii) local frontiers				(iv) global frontier on all 2,000 BISTA-banks			
	loan markup		**adj. duration**		**loan markup**		**adj. duration**	
	OLS	IV - 2SLS	OLS	IV - 2SLS	OLS	IV - 2SLS	OLS	IV - 2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
cost efficiency	**-0.002 -**	**0.028****	**0.009****	**0.023*****	**-0.018*****	**-0.037*****	**0.008*****	**0.024*****
excess capital	0.018	0.018	-0.009	-0.009	0.025	0.033**	-0.012	-0.019**
liquidity	-0.011**	-0.012***	-0.003*	-0.003**	-0.016***	-0.020***	-0.002	0.002
deposit funding	0.018**	0.011*	0.007**	0.011***	0.015**	0.012**	0.006**	0.009***
market share	0.270	0.093	-0.148	-0.065	0.228	0.193	-0.187	-0.156
size	-0.024	-0.069	0.130***	0.150***	-0.018	-0.010	0.112**	0.105***
credit risk	0.040	0.031	-0.027*	-0.023**	0.028	0.015	-0.025	-0.014
comm indicator	-0.330	-0.648***	0.379***	0.528***	-1.003***	-1.698***	0.579***	1.185***
coop indicator	0.049	0.146	0.027	-0.019	0.127	0.204*	0.023	-0.044
product indicator	(yes)	(yes)	(yes)	(yes)	(yes)	(yes)	(yes)	(yes)
cons	2.002	6.038**	-2.148	-4.045***	3.674	5.215**	-1.590	-2.933**
Adj. R^2 / Gen. adj. R^2	0.49	0.49	0.27	0.27	0.50	0.49	0.27	0.27
R^2 / Gen. R^2	0.50	0.50	0.28	0.28	0.51	0.51	0.28	0.28
N	1951	1951	1951	1951	1951	1951	1951	1951
Instrument diagnostics								
Excl. instruments, stat (p-val)		20.73 (0.00)		20.73 (0.00)		6.28 (0.00)		6.28 (0.00)
Under-ident., stat. (p-val)		46.97 (0.00)		46.97 (0.00)		18.15 (0.00)		18.15 (0.00)
Weak- ident.; stat.		20.73		20.73		6.28		6.28
Over-ident., stat. (p-val)		1.57 (0.46)		2.86 (0.24)		2.76 (0.25)		2.32 (0.31)

Notes:
This estimation differs from Table 10 in the use of the cost efficiency estimate:

(i) Here cost efficiency is estimated using a common frontier on 150 banks, a time trend is included and obs activities are proxied by **fee-income**.

(ii) Cost efficiency is based on a common frontier of 150 banks, a time trend is included. **Neither obs-items nor fee income** is used to account for obs activities of a bank.

(iii) Employs cost efficiency estimated on **local bank group frontiers**, obs-items and a time trend are included.

(iv) Employs cost efficiency estimated on **a global frontier of all BISTA reporting banks,** obs-items and a time trend are included.

To account for a possible measurement error of cost efficiency, we re-estimate the models using 2-stage least squares instrumental variables. We report Adjusted-R^2 ('Adj.-R^2') and R^2 for OLS models as well as Pesaran and Smith's (1994) generalized R^2 and Pesaran and Pesaran's (2009) generalized adjusted R^2 for IV estimations. 'N' is the number of observations.

We present instrument diagnostics for the instrumented cost efficiency variable: We report the F-Test of excluded instruments and its p-value in parentheses. We report the Kleibergen Paap rk LM statistic as a test for under-identification and the Kleibergen-Paap Wald F-statistic for weak instrument identification. Further, we report the Hansen J statistic and the corresponding p-value as a test for over-identification. The Under-identification test is rejected in each of the models and the over-identification test (H_0: Instruments are valid and the excluded instruments are correctly excluded from the estimated equation) is not rejected, indicating a well specified equation.

7.3. Addressing the errors-in-variables problem

Next to modifications of cost efficiency estimates, we analyze the generated regressor problem. Put differently, because bank efficiency is first estimated in regressions and then used as an independent variable in the main analysis, the results may be biased downward because of efficiency measurement error (i.e., the coefficient of efficiency may be skewed toward zero). The instrumental variable approach is the most appropriate for overcoming these issues regarding estimated independent variables (Hausman, 2001; Griliches, 1986).

Using **two-stage least squares (2sls),** we address this issue and provide thorough instrument tests and diagnostics regarding the validity of the instruments (Baum et al., 2007; Murray, 2006; Andrews and Stock, 2005; Hahn and Hausman, 2003; Stock et al., 2002; Hahn and Hausman, 2002). Because the concept of cost efficiency evaluates whether a bank allocates its inputs optimally to transform them into its output portfolio, variables that mirror a bank's cost situation together with its profitability are likely to constitute a good and valid set of instruments; we take advantage of interest expenses divided by total assets and the return on assets.

As noted and requested by Hausman (2001), the IV estimation yields an increase in the absolute amounts of the cost efficiency coefficient (see models (2), (4), (6) and (8) of Table 14). The IV results emphasize the OLS findings and highlight a significant, negative effect of cost efficiency on loan markups and a positive effect on adjustment duration.[39] The instrument diagnostics show that our IV models do not suffer from under-, weak- or over-identification issues: the under-identification test refers to the question of whether the instruments are sufficiently correlated with the cost efficiency estimate (Kleibergen and Paap, 2006; Kleibergen, 2007). The null hypothesis is that the system is under-identified such that the aim is to reject the test; this under-identification causes no problems in our case (p-value equals 0.00). In in-

[39] With regard to the use of IV estimations, the results of our main models in Table 10 are underlined.

stances of weak identification, we may encounter concerns that result from the weak correlation of the instruments with the cost efficiency estimate. The outcomes of weak identification could be distorted estimations or problematic inferences (Stock et al., 2002; Stock et al., 2005; Hausman et al., 2005). Observing high test statistics, we encounter no concerns regarding weak identification (Stock et al., 2005). Finally, over-identification tests analyze the null hypothesis that the instruments are valid (Hansen, 1982; Sargan, 1958). Thus, the rejection of the null hypothesis would indicate problems with the chosen instruments. In our case, we obtain a p-value exceeding 0.25 and thus conclude that our instruments are valid and relevant for capturing the underlying principle of cost efficiency measurement. In summary, we find supporting evidence for our research hypothesis regarding the benefits for borrowers.

7.4. Further specifications: re-estimation on the individual product level

Our cross-sectional regression approach closely resembles that of De Greave et al. (2007). These authors also include product indicator variables in their regressions (see De Greave et al., 2007, p. 273, fn. 15). However, we re-estimate all models on the **individual product level** and find strong evidence of the effect of cost efficiency on markups and adjustment duration.

Furthermore, all previously presented results regarding markup and duration are based on separate regressions. Because both analyzed dependent variables are estimated using the same pass-through model, one could argue that a **multiple-equation model** should be used to account for possible dependencies between the error terms. Robustness tests for this specification emphasize our main findings. However, to ensure the simplicity of the analysis, we rely on single-equation regressions.

7.5. Extending the time span and excluding group central banks and large banks

Ultimately, we include a **longer time period** for estimation. Because the MIR statistics are unavailable prior to January 2003, we extend the time series to September 2011 to include the financial crises beginning in September 2008. The results of the markup and adjustment duration regressions are confirmed. However, our results after the sharp decrease in market interest rates following the Lehman Brothers collapse must be interpreted with caution.

Finally, we acknowledge that the **Landesbanken** and the **cooperative central banks** as well as **the four German large banks** are special and not easily comparable to common savings and cooperative banks. Exemplary, Bos et al. (2005) argue to only use banks for the SFA estimation with similar business models. Thus, we re-estimate all model variables based on remaining 138 banks that do not belong to the above mentioned special credit institutions and verify that our results are not impaired in any way. Table 15 presents the results for the subpopulation of sample banks.

Table 15: Robustness – subpopulation of sample banks

	loan markup		**adjustment duration**	
	(1)	(2)	(3)	(4)
cost efficiency	**-0.02** -**	**0.02***	**0.015*****	**0.011****
excess capital	0.025	0.035	-0.011	0.008
liquidity	-0.013**	-0.015**	-0.003	-0.002
deposit funding	0.012*	0.015*	0.009**	0.011**
market share	0.213	0.066	-0.033	-0.16
size	-0.08	-0.081	0.140***	0.304***
credit risk	0.009	-0.001	-0.009	-0.002
comm indicator	-0.34	-0.20	0.243*	0.156
coop indicator	0.15	0.19	-0.029	0.188*
product indicator	(yes)	(yes)	(yes)	(yes)
cons	5.12	4.85	-2.83*	-6.72**
Adj. R^2	0.51	0.42	0.27	0.17
R^2	0.52	0.44	0.28	0.18
N	1783	1783	1783	1783

Notes:
This table presents robustness for the main results of Table 10. We re-estimate the main models but exclude the central banks of the savings banks (Landesbanken), the cooperative central banks as well as the German large banks. Models (1) and (3) use pass-through parameters obtained from Engle and Granger's two step procedure. Models (2) and (4) use parameters obtained from the simultaneous error correction equation.

The results actually underline our previously reported findings.

8. Conclusion and Discussion

This study examines the credit-pricing behavior of German banks for retail and corporate loan products. The pass-through of market interest rates to product rates is estimated using error correction models and consistent with international research, German banks exhibit sluggish and sticky pricing behavior. Given the importance for monetary policy makers and banking regulation authorities to assess how well the process of financial intermediation works and to what extent individual bank characteristics influence or hinder a perfect adjustment of product rates based on changed market conditions, this study explores the main bank determinants that alter and affect pass-through behavior.

Conducting the first study in this setting by applying the well-established stochastic frontier analysis method to explain interest rate pass-through behavior, we focus on the operational efficiency of banks and identify the degree to which changed funding conditions, superior operational and capital allocation skills lead to benefits for bank borrowers. The results indicate that cost efficient banks charge lower loan markups and provide more stable loan rate offers, which both will be valued by their borrowers.

This study combines two streams of literature: the measurement of how banks establish interest rates and pass-through changed market conditions to their customers as well as the thorough measurement of the cost efficiency of banks, which is typically performed using a stochastic frontier analysis based on the assumption that this methodology is superior to traditional financial ratios. Thus, the study provides important insights into how changing funding costs are transferred to credit prices via the operating efficiency channel.

9. References

Aigner, D., C.A. Knox Lovell and P. Schmidt (1977), 'Formulation and Estimation of Stochastic Frontier Production Models', *Journal of Econometrics*, Vol. 6, No. 1 (July), pp. 21-37.

Altunbas, Y., L. Evans and P. Molyneux (2001), 'Bank Ownership and Efficiency', *Journal of Money, Credit and Banking*, Vol. 33, No. 4 (November), pp. 926-54.

Altunbas, Y., O. Fazylow and P. Molyneux (2002), 'Evidence on the bank lending channel in Europe', *Journal of Banking & Finance*, Vol. 26, No. 11 (November), pp. 2093-2110.

Andrews, D.W.K. and B. Lu (2001), 'Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models', *Journal of Econometrics*, Vol. 101, No.1 (March), pp. 123-64.

Andrews, D.W.K. and Stock J.H. (2005), 'Inference with Weak Instruments', *NBER Technical Working Papers* 0313 (National Bureau of Economic Research, Inc.).

Ariss, R.T. (2010), On the implications of market power in banking: Evidence from developing countries', *Journal of Banking & Finance*, Vol. 34, No. 4 (April), pp. 765-75.

Banker, R.D., J.D. Cummins and P.J.B. Klumpes (2010), 'Editorial - Performance measurement in the financial services sector: Frontier efficiency methodologies and other innovative techniques', *Journal of Banking & Finance*, Vol. 34, No. 7 (July), pp. 1413-16.

Battese, G.E. and T.J. Coelli (1988), 'Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data', *Journal of Econometrics*, Vol. 38, No. 3 (July), pp. 387-99.

Battese, G.E. and T.J. Coelli (1992), 'Frontier Production Functions, Technical Efficiency and Panel Data: With application to Paddy Farmers in India', *Journal of Productivity Analysis*, Vol. 3, pp. 153-69.

Bauer, P.W., A.N. Berger, G.D. Ferrier and D.B. Humphrey (1998), 'Consistency Conditions for Regulatory Analysis of Financial Institutions: A Comparison of Frontier Efficiency Methods', *Journal of Economics and Business*, Vol. 50, No. 2 (March-April), pp. 85-114.

Baum, C.F., M.E. Schaffer and S. Stillman (2007), 'Enhanced routines for instrumental variables/GMM estimation and testing', *Boston College Working Papers in Economics 66*7 (Boston College Department of Economics, revised 05 Sep 2007).

Berger, A.N. and D.B. Humphrey (1997), 'Efficiency of financial institutions: International survey and directions for future research', *European Journal of Operational Research*, Vol. 98, No. 2 (April), pp. 175-212.

Berger, A.N. and L.J. Mester (1997), 'Inside the black box: What explains differences in the efficiencies of financial institutions?', *Journal of Banking & Finance*, Vol. 21, No. 7 (July), pp. 895-947.

Berger, A.N. and T.H. Hannan (1997), 'Using Efficiency Measures to Distinguish Among Alternative Explanations of the Structure-Performance Relationship in Banking', *Managerial Finance*, Vol. 23, No.1 (January), pp. 6-31.

Bos, J.W.B. and H. Schmiedel (2007), 'Is there a single frontier in a single European banking market?', *Journal of Banking & Finance*, Vol. 31, No. 7 (July), pp. 2081-2102.

Bos, J.W.B., F. Heid, M. Koetter, J.W. Kolari and C.J.M. Kool (2005), 'Inefficient or just different? Effects of heterogeneity on bank efficiency scores', *Bundesbank Discussion Paper*, Series 2: Banking and Financial Studies, No 15/2005.

Brueckner, Y. (2007), 'Der deutsche Universalbankensektor: Funktion, Effizienz und Perspektiven', *Dissertation*, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Dissertation [only available in German].

Burgstaller, J. and T.D. Cocca (2011), 'Efficiency in private banking: Evidence from Switzerland and Liechtenstein', *Financial Markets and Portfolio Management*, Vol. 25, No. 1, pp. 75-93.

Burgstaller, J. (2005), 'Interest rate pass-through estimates from vector autoregressive models', Working Paper No. 0510 (December), available at: http://www.econ.jku.at/papers/2005/wp0510.pdf.

Carbo, S.V. and F.R. Fernandez (2007), 'The determinants of bank margins in European banking', *Journal of Banking & Finance*, Vol. 31, No 7 (July), pp. 2043-63.

Clayes, S. and R. Vander Vennet (2008), 'Determinants of bank interest margins in Central and Eastern Europe: A comparison with the West', *Economic Systems*, Vol. 32, No. 2 (June), pp. 197-216.

Cotarelli, C. and A. Kourelis (1994), 'Financial structure, bank lending rates and financial structure in Italy', *IMF Staff Papers*, Vol 41, No. 4 (December), pp. 587-623.

De Bondt, G.J. (2005), 'Interest rate pass-through: Empirical result for the Euro area', *German Economic Review*, Vol. 6, No. 1 (February), pp. 37-78.

De Graeve, F., O. De Jonghe and R.V. Vennet (2007), 'Competition, transmission and bank pricing policies: Evidence from Belgian loan and deposit markets', *Journal of Banking & Finance*, Vol. 31, No. 1 (January), pp. 259-78.

Dick, C., M. Knobloch, K.S. Al-Ulmaray, L. Jaroszek, M. Schröder and A. Tiffe (2012), 'Studie zu Dispozinsen / Ratenkrediten', Joint study of the "Institut für Finanzdienstleistungen e.V." and the "Centre for European Economic Research" on behalf of the German *"Federal Ministry of Food, Agriculture and Consumer Protection"*, (July), available at: http://www.bmelv.de/SharedDocs/Downloads/Verbraucherschutz/FinanzenVersicherungen/Studie-DispoZinsRatenKredit.pdf?__blob=publicationFile, [only available in German].

ECB (2009), 'Recent Development in the Retail Bank Interest Rate Pass-Through in the Euro Area', *ECB Monthly Bulletin* (August), pp. 93-105.

Ehrmann, M., L. Gambacorta, J. Martinez-Pages, P. Sevestre and A. Worms (2003), 'Financial Systems and the Role of Banks on Monetary Policy Transmission in the Euro Area', in: *Monetary Policy Transmission in the Euro Area*, Cambridge University Press, pp. 235-69.

Engle R.F. and C.W.J. Granger (1987), 'Co-integration and Error Correction: Representation, Estimation and Testing', *Econometrica*, Vol. 55, No 2 (March), pp. 251-76.

Entrop, O., C. Memmel, B. Ruprecht and M. Wilkens (2012), 'Determinants of bank interest margins: impact of maturity transformation', *Bundesbank Discussion Paper*, Series 2: Banking and Financial Studies, No. 17/2012.

Fiordelisi, F., D. Marques-Ibanez and P. Molyneux (2011), 'Efficiency and risk in European banking', *Journal of Banking & Finance*, Vol. 35, No. 5 (May), pp. 1315-26.

Fiorentino, E., A. Karmann and M. Koetter (2006), 'The cost efficiency of German banks: a comparison of SFA and DEA', *Bundesbank Discussion Paper*, Series 2: Banking and Financial Studies, No. 10/2006.

Fiorentino, E. and H. Herrmann (2009), 'Effizienz und Wettbewerb im deutschen Bankensektor', *Vierteljahrshefte zur Wirtschaftsforschung*, Vol. 78, No. 1, pp. 114-26 [Only available in German].

Focarelli, D. and F. Panetta (2003), 'Are Mergers Beneficial to Consumers? Evidence from the Market for Bank Deposits', *The American Economic Review*, Vol. 93, No. 4 (September), pp. 1152-72.

Fuertes, A.M., S. Heffernan (2009), 'Interest Rate Transmission in the UK: A Comparative Analysis across Financial Firms and Products', *International Journal of Finance & Economics*, Vol. 14, No. 1 (January), pp. 45-63.

Fuertes, A.M., S. Heffernan and E. Kalotychou (2010), 'How do UK Banks react to changing Central Bank Rates?', *Journal of Financial Services Research*, Vol. 37, No. 2-3 (June), pp. 99-130.

Gambacorta, L. (2008), 'How do banks set interest rates?', *European Economic Review*, Vol. 52, No. 5, (July), pp. 792-819.

Goddard, J., P. Molyneux, J.O.S. Wilson and M. Tavakoli (2007), 'European banking: An overview', *Journal of Banking & Finance*, Vol. 31, No. 7 (July), pp. 1911-35.

Granger, C.W.J. and P. Newbold (1974), 'Spurious Regressions in Econometrics', *Journal of Econometrics,* Vol. 2, No. 2 (July), pp. 111-20.

Griliches, Z. (1986), 'Economic data issues', in: Griliches Z. and M.D. Intriligator (ed.), *Handbook of Econometrics*, Edition 1, Vol. 3, Chapter 25, pp. 1465-1514.

Hahn, J. and J. Hausman (2002), 'A New Specification Test for the Validity of Instrumental Variables', *Econometrica*, Vol. 70, No. 1 (January), pp. 163-89.

Hahn, J. and J. Hausman (2003), 'Weak Instruments: Diagnosis and Cures in Empirical Econometrics', *American Economic Review*, Vol. 93, No. 2 (May), pp. 118-25.

Hansen, L.P. (1982), 'Large Sample Properties of Generalized Method of Moments Estimators', *Econometrica*, Vol. 50, No. 4 (July), pp. 1029-54.

Hausman, J. (2001), 'Mismeasured Variables in Econometric Analysis: Problems from the Right and Problems from the Left', *Journal of Economic Perspectives*, Vol. 15, No. 4 (Fall), pp. 57-67.

Hausman, J., J.H. Stock and M. Yogo (2005), 'Asymptotic properties of the Hahn–Hausman test for weak-instruments', *Economics Letters*, Vol. 89, No. 3 (December), pp. 333-42.

Hofmann, B. and P. Mizen (2004), 'Interest Rate Pass-Through and Monetary Transmission: Evidence from Individual Financial Institutions' Retail Rates', *Economica*, New Series, Vol. 71, No. 281 (February), pp. 99-123.

Hughes J. and L.J. Mester (1993), 'A quality and risk adjusted cost function for banks: evidence on the Too-Big-to-Fail-Doctrine', *Journal of Productivity Analysis*, Vol. 4, No. 3 (September), pp. 292-315.

Johansen, S. (1991), 'Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models', *Econometrica*, Vol. 59, No. 6 (November), pp. 1551-80.

Johansen, S. (1995), 'Likelihood-Based Inference in Cointegrated Vector Autoregressive Models', *Oxford University Press* (Oxford).

Kashyap, A.K. and J.C. Stein (2000), 'What do a Million Observations on Banks Say about the Transmission of Monetary Policy?', *The American Economic Review*, Vol. 90, No. 3 (June), pp. 407-28.

Kleibergen, F. and R. Paap (2006), 'Generalized reduced rank tests using the singular value decomposition', *Journal of Econometrics*, Vol. 133, No. 1 (July), pp. 97-126.

Kleibergen, F. (2007), 'Generalizing weak instrument robust IV statistics towards multiple parameters, unrestricted covariance matrices and identification statistics', *Journal of Econometrics*, Vol. 139, No. 1 (July), pp. 181-216.

Kleimeier, S. and H. Sander (2006), 'Expected versus unexpected monetary policy impulses and interest rate pass-through in euro-zone retail banking markets', *Journal of Banking & Finance*, Vol. 30, No. 7 (July), pp. 1839-70.

Koetter, M. (2006), 'Measurement Matters - Alternative Input Price Proxies for Bank Efficiency Analyses', *Journal of Financial Services Research*, Vol. 30, No. 2 (October), pp. 199-227.

Kremers, J.J.M., N.R. Ericsson and J. Dolado (1992). 'The power of co-integration tests', *Oxford Bulletin of Economics and Statistics*, Vol. 54, No. 3 (August), pp. 325-348.

Kwapil, C. and J. Scharler (2010), 'Interest rate pass-through, monetary policy rules and macroeconomic stability', *Journal of International Money and Finance*, Vol. 29, No. 2 (March), pp. 236-51.

Lang, G. and P. Welzel (1997), 'Größe und Kosteneffizienz im deutschen Bankensektor', *Zeitschrift für Betriebswirtschaft*, Vol. 67, No. 3, pp. 269-83 [only available in German].

Liu, M.H., D. Margaritis and A. Tourani-Rad (2008), 'Monetary policy transparency and pass-through of retail interest rates', *Journal of Banking & Finance*, Vol. 32, No. 4 (April), pp. 501-11.

Lozano-Vivas, A. and F. Pasiouras (2010), 'The impact of non-traditional activities on the estimation of bank efficiency: International evidence', *Journal of Banking & Finance*, Vol. 34, No. 7 (July), pp. 1436-49.

Maudos, J. and J.F. De Guevara (2004), 'Factors explaining the interest margin in the banking sectors of the European Union', *Journal of Banking & Finance*, Vol. 28, No. 9 (September), pp. 2259-81.

Maudos, J. and L. Solis (2009), 'The determinants of net interest income in the Mexican banking system: An integrated model', *Journal of Banking & Finance*, Vol. 33, No. 10 (October), pp. 1920-33.

Meeusen, W. and J. van den Broeck (1977), 'Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error', *International Economic Review*, Vol. 18, No. 2 (June), pp. 435-44.

Mojon, B. (2000), 'Financial Structure and the Interest Rate Channel of ECB Monetary Policy', *ECB Working Paper Series*, No. 40 (November).

Mueller-Spahn, S. (2008), 'The Pass-Through From Market Interest Rates to Retail Bank Rates in Germany', Working Paper 08/05, available at: http://nottingham.ac.uk/cfcm/documents/papers/08-05.pdf.

Murray, M.P. (2006), ‘Avoiding Invalid Instruments and Coping with Weak Instruments’, *Journal of Economic Perspectives,* Vol. 20, No. 4 (Fall), pp. 111-32.

Nehls, H. (2006), ‘The Interest Rate Pass-Through in German banking groups’, *Jahrbücher für Nationalökonomie und Statistik*, Vol. 226, No. 4, pp. 463-79.

Pesaran, M.H. and Shin, Y. (1999), ‘An autoregressive distributed lag modeling approach to cointegration analysis', in Strom, S. (ed.), *Econometrics and economic theory in the 20th century*, Cambridge: Cambridge University Press.

Pesaran, B. and M.H. Pesaran (2009), ‘Microfit 5.0’, *Oxford University Press*.

Pesaran, M.H. and R.J. Smith (1994), ‘A Generalized R2 Criterion for Regression Models Estimated by the Instrumental Variables Method’, *Econometrica*, Vol. 62, No. 3 (May), pp. 705-10.

Phillips, P.C.B. (1986), ‘Understanding spurious regressions in econometrics’, *Journal of Econometrics*, Vol. 33, No. 3 (December), pp. 311-40.

Rosen, R.J. (2002), ‘What goes up must come down? Asymmetries and Persistence in Bank Deposit Rates’, *Journal of Financial Services Research*, Vol. 21, No. 3 (June), pp. 173-93.

Sander, H. and S. Kleimeier (2004), ‘Convergence in euro-zone retail banking? What interest rate pass-through tells us about monetary policy transmission, competition and integration‘, *Journal of International Money and Finance*, Vol. 23, No. 3 (April), pp. 461-92.

Sander, H. and S. Kleimeier (2006), ‘Convergence of interest rate pass-through in a wider euro zone?‘, *Economic Systems*, Vol. 30, No. 4 (December), pp. 405-23.

Sargan, J.D. (1958), ‘The Estimation of Economic Relationships using Instrumental Variables’, *Econometrica*, Vol. 26, No. 3 (July), pp. 393-415.

Schaeck K. and M. Čihák (2008), ‘How does competition affect efficiency and soundness in banking? New empirical evidence’, *ECB Working Paper Series*, No. 932 (September).

Sealey, C.W. and J.T. Lindley (1977), ‘Inputs, Outputs, and a Theory of Production and Cost and Depository Financial Institutions’, *Journal of Finance*, Vol. 32, No. 4 (September), pp. 1251-65.

Sørensen, C.K. and T. Werner (2006), ‘Bank interest rate pass-through in the Euro area: A cross country comparison’, *ECB Working Paper Series*, No. 580 (January).

Stevenson, R.E. (1980), ‘Likelihood functions for generalized stochastic frontier estimation’, *Journal of Econometrics*, Vol. 13, No. 1 (May), pp. 57-66.

Stock, J.H., J.H. Wright and M. Yogo (2002), ‘A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments’, *Journal of Business & Economic Statistics*, Vol. 20, No. 4 (October), pp. 518-29.

Stock, J.H., J.H. Wright and M. Yogo (2005), ‘Testing for weak instruments in linear IV regression’, Ch. 5 in J.H. Stock and D.W.K. Andrews (eds), *Identification and Inference for Econometric Models: Essays in Honor of Thomas J. Rothenberg*, Cambridge University Press.

Sun, L. and T.P. Chang (2011), ‘A comprehensive analysis of the effects of risk measures on bank efficiency: Evidence from emerging Asian countries’, *Journal of Banking & Finance*, Vol. 35, No. 7 (July), pp. 1727-35.

Tortosa-Ausina, E. (2003), ‘Nontraditional activities and bank efficiency revisited: A distributional analysis for Spanish financial institutions’, *Journal of Economics and Business*, Vol. 55, No. 4 (July), pp. 371-95.

Von Borstel, J. (2008), ‘Interest Rate Pass-Through in Germany and the Euro Area’, *ROME Discussion Paper Series*, No. 08-05 (July).

Weth, M.A. (2002), ‘The pass-through from market interest rates to bank lending rates in Germany’, *Bundesbank Discussion Paper*, Economic Research Centre of the Deutsche Bundesbank (March).

Wang, K.M. and Y.M. Lee (2009), ‘Market volatility and retail interest rate pass-through’, *Economic Modelling*, Vol. 26, No. 6 (November), pp. 1270-82.

Appendix 1

Lerner Index

The Lerner index is a competition measure that indicates to which extend a firm is able to set its prices above its marginal costs. It is calculated as follows

$$Lerner = (price - marginal\ costs)/price$$

Consistent with previous studies (e.g. Schaeck and Čihák, 2008; Maudos and De Guevara, 2004), we determine the price of total assets as total income (interest and non-interest) divided by total assets. To calculate marginal costs we first estimate a translog cost function with one output (total assets) and three inputs (capital, labor and deposits and borrowed funds).[40] TOC and y denote total operating costs and total assets. As in section 5, $\boldsymbol{w}$ is a vector of input prices, z accounts for equity and $group$ is a dummy which indicates to which banking group a bank belongs. We divide TOC, w_1 and w_2 by w_3 to impose linear homogeneity restrictions.

$$\ln\left(\frac{TOC_{it}}{w_{3it}}\right) = \beta_0 + \sum_{l=1}^{2} \beta_l \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) + \sum_{l=1}^{2} \gamma_l \cdot \frac{1}{2} \cdot \left(ln\left(\frac{w_{lit}}{w_{3it}}\right)\right)^2 + \delta_1 \cdot \ln(y_{it})$$

$$+\delta_2 \cdot \frac{1}{2} \cdot (\ln(y_{it}))^2 + \sum_{l=1}^{2} \varepsilon_l \cdot \ln(y_{it}) \cdot \ln\left(\frac{w_{lit}}{w_{3it}}\right) + \epsilon_1 \cdot \ln(z_{it})$$

$$+\epsilon_2 \cdot \frac{1}{2} (\ln(z_{it}))^2 + \sum_{l=1}^{2} \rho_l \cdot \ln\left(\frac{w_{lit}}{w_{3it}}\right) \cdot \ln(z_{it}) + \varphi_1 \cdot \ln(y_{it}) \cdot \ln(z_{it})$$

$$+\varphi_2 \cdot T + \varphi_3 \cdot T^2 + \varphi_4 \cdot T \cdot \ln(y_{it}) + \varphi_4 \cdot T \cdot \ln(z_{it})$$

$$+ \sum_{l=1}^{2} \tau_l \cdot T \cdot \ln\left(\frac{w_{lit}}{w_{3it}}\right) + \sum_{l=1}^{2} \omega_l \cdot group_i + \varepsilon_{it}$$

[40] In line with other studies, for example Schaeck and Čihák (2008), Maudos and De Guevara (2004) and Maudos and Solis (2009), we consider only one output.

As in section 5 the error term ε_{it} consists of two parts: a random error component which is assumed to be normally distributed and a time invariant inefficiency term which is assumed to be truncated-normal distributed.[41]

Marginal costs (mc_{it}) are calculated by differentiating the equation above with respect to the output y:

$$mc_{it} = \frac{\partial TOC}{\partial y} = \frac{TOC_{it}}{y_{it}}\left[\delta_1 + \delta_2 \cdot ln(y_{it}) + \sum_{l=1}^{2} \varepsilon_l \cdot \ln\left(\frac{w_{lit}}{w_{3it}}\right) + \varphi_1 \cdot \ln(z_{it}) + \varphi_3 \cdot T\right]$$

41 Similar results are obtained by calculating a time-varying decay model as suggested by Battese and Coelli (1992).

The following Discussion Papers have been published since 2012:

01	2012	A user cost approach to capital measurement in aggregate production functions	Thomas A. Knetsch
02	2012	Assessing macro-financial linkages: a model comparison exercise	Gerke, Jonsson, Kliem Kolasa, Lafourcade, Locarno Makarski, McAdam
03	2012	Executive board composition and bank risk taking	A. N. Berger T. Kick, K. Schaeck
04	2012	Stress testing German banks against a global cost-of-capital shock	Klaus Duellmann Thomas Kick
05	2012	Regulation, credit risk transfer with CDS, and bank lending	Thilo Pausch Peter Welzel
06	2012	Maturity shortening and market failure	Felix Thierfelder
07	2012	Towards an explanation of cross-country asymmetries in monetary transmission	Georgios Georgiadis
08	2012	Does Wagner's law ruin the sustainability of German public finances?	Christoph Priesmeier Gerrit B. Koester
09	2012	Bank regulation and stability: an examination of the Basel market risk framework	Gordon J. Alexander Alexandre M. Baptista Shu Yan
10	2012	Capital regulation, liquidity requirements and taxation in a dynamic model of banking	Gianni De Nicolò Andrea Gamba Marcella Lucchetta
11	2012	Credit portfolio modelling and its effect on capital requirements	Dilek Bülbül Claudia Lambert

12	2012	Trend growth expectations and U.S. house prices before and after the crisis	Mathias Hoffmann Michael U. Krause Thomas Laubach
13	2012	The PHF: a comprehensive panel survey on household finances and wealth in Germany	Ulf von Kalckreuth Martin Eisele, Julia Le Blanc Tobias Schmidt, Junyi Zhu
14	2012	The effectiveness of monetary policy in steering money market rates during the financial crisis	Puriya Abbassi Tobias Linzert
15	2012	Cyclical adjustment in fiscal rules: some evidence on real-time bias for EU-15 countries	Gerhard Kempkes
16	2012	Credit risk connectivity in the financial industry and stabilization effects of government bailouts	Jakob Bosma Micheal Koetter Michael Wedow
17	2012	Determinants of bank interest margins: impact of maturity transformation	O. Entrop, C. Memmel B. Ruprecht, M. Wilkens
18	2012	Tax incentives and capital structure choice: evidence from Germany	Thomas Hartmann-Wendels Ingrid Stein, Alwin Stöter
19	2012	Competition for internal funds within multinational banks: foreign affiliate lending in the crisis	Cornelia Düwel Rainer Frey
20	2012	Fiscal deficits, financial fragility, and the effectiveness of government policies	Markus Kirchner Sweder van Wijnbergen
21	2012	Saving and learning: theory and evidence from saving for child's college	Junyi Zhu

22	2012	Relationship lending in the interbank market and the price of liquidity	Falk Bräuning Falko Fecht
23	2012	Estimating dynamic tax revenue elasticities for Germany	Gerrit B. Koester Christoph Priesmeier
24	2012	Identifying time variability in stock and interest rate dependence	Michael Stein, Mevlud Islami Jens Lindemann
25	2012	An affine multifactor model with macro factors for the German term structure: changing results during the recent crises	Arne Halberstadt Jelena Stapf
26	2012	Determinants of the interest rate pass-through of banks − evidence from German loan products	Tobias Schlüter, Ramona Busch Thomas Hartmann-Wendels Sönke Sievers

The following Discussion Papers have been published since 2011:

Series 1: Economic Studies

01	2011	Long-run growth expectations and “global imbalances”	M. Hoffmann M. Krause, T. Laubach
02	2011	Robust monetary policy in a New Keynesian model with imperfect interest rate pass-through	Rafael Gerke Felix Hammermann
03	2011	The impact of fiscal policy on economic activity over the business cycle – evidence from a threshold VAR analysis	Anja Baum Gerrit B. Koester
04	2011	Classical time-varying FAVAR models – estimation, forecasting and structural analysis	S. Eickmeier W. Lemke, M. Marcellino

05	2011	The changing international transmission of financial shocks: evidence from a classical time-varying FAVAR	Sandra Eickmeier Wolfgang Lemke Massimiliano Marcellino
06	2011	FiMod – a DSGE model for fiscal policy simulations	Nikolai Stähler Carlos Thomas
07	2011	Portfolio holdings in the euro area – home bias and the role of international, domestic and sector-specific factors	Axel Jochem Ute Volz
08	2011	Seasonality in house prices	F. Kajuth, T. Schmidt
09	2011	The third pillar in Europe: institutional factors and individual decisions	Julia Le Blanc
10	2011	In search for yield? Survey-based evidence on bank risk taking	C. M. Buch S. Eickmeier, E. Prieto
11	2011	Fatigue in payment diaries – empirical evidence from Germany	Tobias Schmidt
12	2011	Currency blocs in the 21st century	Christoph Fischer
13	2011	How informative are central bank assessments of macroeconomic risks?	Malte Knüppel Guido Schultefrankenfeld
14	2011	Evaluating macroeconomic risk forecasts	Malte Knüppel Guido Schultefrankenfeld
15	2011	Crises, rescues, and policy transmission through international banks	Claudia M. Buch Cathérine Tahmee Koch Michael Koetter
16	2011	Substitution between net and gross settlement systems – A concern for financial stability?	Ben Craig Falko Fecht

17	2011	Recent developments in quantitative models of sovereign default	Nikolai Stähler
18	2011	Exchange rate dynamics, expectations, and monetary policy	Qianying Chen
19	2011	An information economics perspective on main bank relationships and firm R&D	D. Hoewer T. Schmidt, W. Sofka
20	2011	Foreign demand for euro banknotes issued in Germany: estimation using direct approaches	Nikolaus Bartzsch Gerhard Rösl Franz Seitz
21	2011	Foreign demand for euro banknotes issued in Germany: estimation using indirect approaches	Nikolaus Bartzsch Gerhard Rösl Franz Seitz
22	2011	Using cash to monitor liquidity – implications for payments, currency demand and withdrawal behavior	Ulf von Kalckreuth Tobias Schmidt Helmut Stix
23	2011	Home-field advantage or a matter of ambiguity aversion? Local bias among German individual investors	Markus Baltzer Oscar Stolper Andreas Walter
24	2011	Monetary transmission right from the start: on the information content of the eurosystem's main refinancing operations	Puriya Abbassi Dieter Nautz
25	2011	Output sensitivity of inflation in the euro area: indirect evidence from disaggregated consumer prices	Annette Fröhling Kirsten Lommatzsch
26	2011	Detecting multiple breaks in long memory: the case of U.S. inflation	Uwe Hassler Barbara Meller

27	2011	How do credit supply shocks propagate internationally? A GVAR approach	Sandra Eickmeier Tim Ng
28	2011	Reforming the labor market and improving competitiveness: an analysis for Spain using FiMod	Tim Schwarzmüller Nikolai Stähler
29	2011	Cross-border bank lending, risk aversion and the financial crisis	Cornelia Düwel, Rainer Frey Alexander Lipponer
30	2011	The use of tax havens in exemption regimes	Anna Gumpert James R. Hines, Jr. Monika Schnitzer
31	2011	Bank-related loan supply factors during the crisis: an analysis based on the German bank lending survey	Barno Blaes
32	2011	Evaluating the calibration of multi-step-ahead density forecasts using raw moments	Malte Knüppel
33	2011	Optimal savings for retirement: the role of individual accounts and disaster expectations	Julia Le Blanc Almuth Scholl
34	2011	Transitions in the German labor market: structure and crisis	Michael U. Krause Harald Uhlig
35	2011	U-MIDAS: MIDAS regressions with unrestricted lag polynomials	C. Foroni M. Marcellino, C. Schumacher

Series 2: Banking and Financial Studies

01	2011	Contingent capital to strengthen the private safety net for financial institutions: Cocos to the rescue?	George M. von Furstenberg
02	2011	Gauging the impact of a low-interest rate environment on German life insurers	Anke Kablau Michael Wedow
03	2011	Do capital buffers mitigate volatility of bank lending? A simulation study	Frank Heid Ulrich Krüger
04	2011	The price impact of lending relationships	Ingrid Stein
05	2011	Does modeling framework matter? A comparative study of structural and reduced-form models	Yalin Gündüz Marliese Uhrig-Homburg
06	2011	Contagion at the interbank market with stochastic LGD	Christoph Memmel Angelika Sachs, Ingrid Stein
07	2011	The two-sided effect of financial globalization on output volatility	Barbara Meller
08	2011	Systemic risk contributions: a credit portfolio approach	Klaus Düllmann Natalia Puzanova
09	2011	The importance of qualitative risk assessment in banking supervision before and during the crisis	Thomas Kick Andreas Pfingsten
10	2011	Bank bailouts, interventions, and moral hazard	Lammertjan Dam Michael Koetter
11	2011	Improvements in rating models for the German corporate sector	Till Förstemann

12	2011	The effect of the interbank network structure on contagion and common shocks	Co-Pierre Georg
13	2011	Banks' management of the net interest margin: evidence from Germany	Christoph Memmel Andrea Schertler
14	2011	A hierarchical Archimedean copula for portfolio credit risk modelling	Natalia Puzanova
15	2011	Credit contagion between financial systems	Natalia Podlich Michael Wedow
16	2011	A hierarchical model of tail dependent asset returns for assessing portfolio credit risk	Natalia Puzanova
17	2011	Contagion in the interbank market and its determinants	Christoph Memmel Angelika Sachs
18	2011	Does it pay to have friends? Social ties and executive appointments in banking	A. N. Berger, T. Kick M. Koetter, K. Schaeck

Visiting researcher at the Deutsche Bundesbank

The Deutsche Bundesbank in Frankfurt is looking for a visiting researcher. Among others under certain conditions visiting researchers have access to a wide range of data in the Bundesbank. They include micro data on firms and banks not available in the public. Visitors should prepare a research project during their stay at the Bundesbank. Candidates must hold a PhD and be engaged in the field of either macroeconomics and monetary economics, financial markets or international economics. Proposed research projects should be from these fields. The visiting term will be from 3 to 6 months. Salary is commensurate with experience.

Applicants are requested to send a CV, copies of recent papers, letters of reference and a proposal for a research project to:

Deutsche Bundesbank
Personalabteilung
Wilhelm-Epstein-Str. 14

60431 Frankfurt
GERMANY