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Abhandlungen

Loan Pricing: Do Borrowers Benefit from Cost-Efficient Banking?*

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Abstract

This study examines the loan-pricing 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 makes prices more competitive and smoothes the setting of interest rates. By employing state-of-the-art stochastic frontier efficiency measures to capture a bank's operational efficiency, we take a look at the bank customers' perspective and demonstrate the extent to which borrowers benefit from cost-efficient banking.

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Kreditkonditionierung: Haben Kreditnehmer kosteneffizienter Banken Vorteile?

Zusammenfassung

Diese Studie untersucht den Einfluss der Kosteneffizienz bei der Preisbestimmung von Krediten auf Basis einer großen Vielfalt von Kreditprodukten deutscher Banken. Obwohl theoretische Studien die Weitergabe von Kostenvorteilen an Kunden (zumindest teilweise) vermuten, ist die internationale empirische Evidenz hierzu nicht einheitlich. Unsere Resultate zeigen, dass unter Anwendung von modernen Verfahren zur Effizienzmessung von Banken Kreditnehmer in zweifacher Hinsicht von Kosteneffizienz profitieren: a) Preisaufschläge bzw. Margen auf das Marktzinsniveau fallen geringer aus und b) Kreditkonditionen sind weniger volatil.

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

JEL Classification: G21, G28

I. Introduction

The loan pricing behavior of banks in the German, bank-based economy is highly relevant for businesses and individuals. Consequently, a substantial body of research focuses on the levels and dynamics of banks' interest rates and the pass-through behavior of market-wide and official interest rates to their borrowers (ECB, 2009; *De Bondt*, 2005; *Weth*, 2002). The broad evidence regarding these two dimensions (levels and dynamics of banks' interest rates) suggests that the pass-through of market interest rates to the prices of bank products is often incomplete, i.e. bank customers do not benefit one-to-one from a reduction of market-wide interest rate levels. Furthermore, even when banks adjust interest rates on their credit products downward, the speed of this downward adjustment differs significantly among banks.

Based on this knowledge, recent research examines the determinants of banks' interest-rate-setting behavior (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-efficient manner could affect its loan-rate-setting behavior. Although prior research theoretically argues that an efficiency effect should be observable, the influence of cost-efficient banking on interest-setting behavior should be more thoroughly examined because empirical evidence on this topic is weak or even mixed. The realm of loan pricing behavior of German banks remains unexplored.

Consequently, our 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. To be 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. Charged loan markups are reduced if a bank operates its business efficiently and the interest rate adjustment speed is affected to the benefit of bank customers (i.e. bank loan rates are set more smoothly and borrowers are protected from upward changes in market interest rates for a longer period of time).

These findings are established by estimating interest-rate-setting behavior which is 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 (i.e. mark-up or spreads above the marginal cost of funding and the adjustment duration) which describe how a bank passes on market movements to product prices.

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 to 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 in establishing this finding by relying on traditional accounting ratio-based efficiency measures.

Our research question combines the two streams of literature regarding interest rate pass-through and bank efficiency measurement on the basis of SFA. To the best of our knowledge, thus far, an SFA-based efficiency estimate has not been employed to capture variations in interest rate pass-through behavior. We find that this approach is far more appropriate than previous financial ratios.

This paper proceeds as follows: the next section broadly integrates this study into the existing literature. Section III. develops testable hypotheses. Section IV. describes the employed data sample, and section V. describes how interest rate pass-through and cost efficiency are estimated. Section VI. presents the main results, which are validated in the subsequent robustness section (section VII.). The final section, section VIII., outlines the conclusion of this paper.

II. Related Literature

The estimation of interest rate pass-through models has been extensively discussed in previous literature (e.g. *Kashyap/Stein*, 2000; *De Bondt*, 2005). The purpose of estimating how bank prices react to changes in 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 (see *Hofman/Mizen*, 2004; *Kleimeier/Sander*, 2006). Furthermore, banking regulators should be aware of the speed and extent to which changes in funding costs are passed on to bank customers (*Wang/Lee*, 2009). 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/Scharler*, 2010; *Liu* et al., 2008; *Rosen*, 2002). 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. *De Haan/Sterken*, 2010; *Von Borstel*, 2008; *Weth*, 2002; *Mueller-Spahn*, 2008; *Craig/Dinger*, 2009). However, the statistical and economic impact of cost efficiency using state-of-the-art stochastic frontier efficiency measures remains unexplored.

In addition, 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 operating costs of a bank; hence, banks with more cost-efficient operations typically have smaller NIMs (e.g. *Maudos/De Guevara*, 2004; *Maudos/Solis*, 2009). In this context, *Busch* and *Memmel* (2014) show that on average 47 % of net interest margin is needed to cover operating costs for providing liquidity and payment services. A downsizing of a bank's NIM is likely to result in lower loan rates and/or higher deposit rates for bank customers (*Claeys/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 (e.g. loans) or liabilities (e.g. deposits). Finally, a detailed presentation of different products or classes of products and customers is not possible for those studies.

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, e.g. banks with a high share of deposit funding exhibit a slower adjustment speed than their capital-market-financed competitors. However, prior research argues that a bank's (in-)efficiency should be another key factor impeding a 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/Panetta*, 2003) or the costs-to-total-assets ratio (e.g. *Gambacorta*, 2008). While this approach is theoretically appealing, the research does not report significant relationships (*Fuertes/Heffernan*, 2009; *De Greave* et al., 2007; *Berger/Hannan*, 1997) or just marginally significant relationships (*Fuertes* et al., 2010; *Gambacorta*, 2008). To the best of our knowledge, there has been no study analyzing 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/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 far 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; *DeYoung*, 1998). 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 similar input and output portfolio and the lowest operating and financial costs (*Fiorentino/Herrmann*, 2009).

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

III. Research Question

Assuming that competition in the German banking market is not perfect, banks have a certain pricing margin. Hence, it could be beneficial for a bank whose goal is to maximize profits to pass through increased efficiency by lowering prices in order to increase its market share. The natural question pertains to whether bank borrowers benefit from a bank's ability to operate cost efficiently. The literature concerning the interest-rate-setting behavior of banks assumes that at least some of the cost efficiency gains or other cost advantages will be used to benefit the customers in the form of more competitive loan prices (see, e.g. *De Graeve* et al., 2007; *Fuertes* et al., 2010).

The empirical and theoretical literature on the determinants of interest margins also provides hints regarding this consideration. Specifically, *Maudos* and *De Guevara* (2004) introduce a model that explains a NIM which increases as a result of higher operating costs and refer to the negligence of controlling for operational efficiency as a potentially omitted variable bias of all prior studies explaining the NIM. Empirical evidence indicates that NIMs decline (rise) as operating costs decrease (increase) (*Entrop* et al., 2012; *Maudos/Solis*, 2009; *Claeys/Vander Vennet*, 2008; *Carbo/Fernandez*, 2007). This strand of literature is highly supportive of our hypothesis, as a change in the NIM is likely to cause higher interest paid on liabilities and/or lower credit rates. However, the extent to which the pricing of liabilities or assets is affected cannot be observed by those studies given that the interest margin is calculated using ex-post accounting income and expense figures at the bank level (for this specific topic, see *Claeys/Vander Vennet*, 2008).

Thus, we build our first hypothesis: "Banks that operate more cost efficiently charge lower markups on market rates for loan products."

To provide insight into this theoretical link 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 offers more stable interest rates compared with its competitors (by adjusting 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 benefits bank borrowers. Banks shield their customers from sudden market movements and provide smooth interest rate adjustments (*Fuertes/Heffernan*, 2009; *Von Borstel*, 2008; *Mueller-Spahn*, 2008). Especially in the environment of increasing market interest rates between the fourth quarter of 2005 and the fourth quarter of 2008, bank borrowers will have appreciated interest rate smoothing.

As customers find it beneficial to seek lower markups and more stable interest rates, it could be attractive for banks seeking to maximize their profits to provide more stable interest rates in order to gain a higher market share. Note that cost-efficient banks may have higher overall price margins, although, compared with less efficient banks, they provide lower markups on market rates. This is due to the fact that the aim of markups on market rates is to cover operating costs in the loan business (*Busch/Memmel*, 2014). More efficient banks face lower operating costs per output entity. Therefore, we expect that this "cost efficiency buffer" enables more efficient banks to smooth their interest rates.

Thus, we build our second hypothesis. "Cost-efficient banks smooth interest rates for loan products."

The next section describes the data and presents evidence regarding their representativeness before our hypotheses are investigated in sections V. and VI.

IV. Data and Sample Representativeness

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 data regarding interest rates, balance sheets and profit and loss (P&L) accounts for the period from January 2003 to September 2008.[1] For information on interest rates, we employ the monthly MFI interest rate (MIR) statistics. We enhance the sample with publicly available market interest rates, which we obtain

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

from the Bundesbank.[2] In addition, we obtain balance sheet statistics ('BISTA') and information on P&L from the schedule of the auditor reports. 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 around 200 German banks. However, we request observations with consecutive, non-missing interest rate data for each bank and product to be able to analyze 150 banks, resulting in a total of 127,891 bank-product-month observations for the pass-through estimation. Table 1 presents the bank products and the corresponding summary statistics of their interest rates.

Our final sample consists of 24 commercial banks (Comms), including the 4 major German banks (large banks). Furthermore, we are able to analyze 82 savings banks (Savs), including their 11 supra-regional central banks ('Landesbanken'). Finally, our sample contains information on 44 cooperative banks (Coops), including their 2 supra-regional central banks.[3]

The German banking market consists of around 2,000 credit institutions[4] in total. We, therefore, have to address the question of whether the 150 banks analyzed are a representative sample because our study is limited to the banks reporting their MIR.[5] As a result, we must acknowledge the nature of the MIR statistics. The Bundesbank's selection of banks for the reports reflects the German banking market (i.e. banks are selected such that all German bank groups all over the country are represented).[6] Thus, the Bundesbank indicates that the sample of MIR-reporting banks constitutes a representative profile of the German banking market.

Furthermore, if we compare our sample with all German banks, it becomes evident that our sample represents a large portion of the German

[2] We use Euribor and government bond rates with varying maturities.

[3] Our sample is adjusted for mergers. To be precise, we treat a merged bank as two separate banks before the merger and as one new bank after the merger.

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

[5] Note that competition in the German banking market is influenced by the presence of a large number of small banks. We assume that the banks for which the MFI interest rate statistics fail to provide data behave similarly to the banks in the sample.

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

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			
		Mean	s.d.
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 require around 200 German banks to report on the above-stated interest rates on a monthly basis. 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 monthly MFI interest rates from January 2003 to September 2008. We present mean interest rates and their standard deviations for the 150 banks in our sample.

banking industry. Our sample banks account for around 62 % of all banks' total assets and for 66 % of all non-bank lending. In addition, the total assets of all German banks amount to around 25 % of all European banks' total assets.[7] Thus, we note that our sample is representative of Germany and even large parts of the European banking market.

V. Estimation Procedure and Econometric Considerations

1. Loan-pricing Behavior

This section describes the estimation of the interest rate pass-through (IPT) parameters that will be explained on the basis of 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-term adjustment coefficients that capture whether a pass-through is one-to-one. We select the market rates which exhibit the highest correlation with the development of bank interest rates on new business (e.g. *De Bondt*, 2005). Additionally, we require the market rate to be of a similar maturity as the bank product (see *De Graeve* et al., 2007; *Mueller-Spahn*, 2008). For short maturities, we employ public money market rates and rely on German government bond rates for maturities of more than one year.[8] In order to verify whether Error Correction Models apply, we test whether a cointegration relationship exists between the bank interest rate and the chosen market rate (see *Engle/Granger*, 1987 and *Johansen*, 1995, 1991). 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 only on bank and market interest rate time series that are cointegrated, with cointegration applying to more than 90 % (employing a 10 % significance level) of all available time series (the total number of time series being 2,146).

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

[8] 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.

Table 2

Interest Rate Pass-through Models – Preliminary Analysis

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 the frequencies of non-cointegrated time series per product. The total number of interest time series is 2,146.

Table 2 shows the distribution of the non-cointegrated time series. Most of these cases appear to occur with overdraft products for retail and corporate customers, which could be expected as the pricing of such products is the most rigid and is not driven by minor market movements.

Due to the fact that our main sample consists only of time series that are cointegrated, the error correction representation (ECM) is the standard approach for estimating the reaction of bank interest rates to changes in market interest rates (*Fuertes/Heffernan*, 2009; *Liu* et al., 2008; Weth, 2002). We use the two-step Engle and Granger (1987) method for each bank product in order to determine interest pass-through behavior. The two-step Engle and Granger model estimates two separate ordinary least squares (OLS) regressions: First, the error correction term '$br_{i,j,t} = \mu_{i,j} + \beta_{i,j} \cdot mr_{j,t} + u_{i,j,t}$' is estimated and, second, the obtained residuals are included with one lag in the error correction representation:

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

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); $i = 1,\ldots,150$ indexes the banks; $j = 1,\ldots,18$ 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 which market interest rate changes are passed through to bank rates.[9] $\mu_{i,j}$ 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 indicated by $\beta_{i,j}$, which measures whether a market interest rate change is completely passed on to bank rates in the long term. $\Lambda_{i,j,1}$ describes the short-term 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.

Table 3 presents the results of the Engle and Granger two-step estimation, which are in line with our expectations.[10] For example, overdraft products have a significantly higher markup and adjustment duration than loan products. Based on these estimates, the following section addresses our main question of whether the parameters differ with regard to cost efficiency.

2. *Cost Efficiency Measurement*

In order to measure cost efficiency, we utilize the stochastic frontier analysis (SFA) that was introduced by *Aigner* et al. (1977) and *Meeusen* and *Van den Broeck* (1977).

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 detail below. Our main bank efficiency measures are based on a common global frontier for all 150 banks that report MIR statistics and have sufficient

[9] Some studies (e.g., *De Graeve* 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 of the adjustment duration as defined above. However, note that the definition proposed by *De Graeve* et al. (2007) relies on the individual long and short-term pass-through behavior of a bank; the comparability across institutions is thus impaired.

[10] In unreported robustness tests we also estimated simultaneous (rather than the two-step approach) error correction models applying maximum likelihood estimation advocated by more recent research (*Liu* et al., 2008; *Hofman/Mizen*, 2004; *Johansen*, 1995). All results remain qualitatively unchanged.

Table 3

Estimation Results of the Interest Rate Pass-through Models

Panel A: Retail loan rates		Markup		Adj. duration		Adj. coef.		LTPT	
product group		mean	median*	mean	median*	mean	median*	mean	median*
Loans – overall	coef	3.61	3.17	2.09	1.53	–65.63	–65.35	66.24	63.50
	p-val	0.05	0.00	0.01	0.00	0.01	0.00	0.04	0.00
Overdraft	coef	7.94	9.19	3.35	2.96	–39.26	–33.82	69.15	69.13
	p-val	0.02	0.00	0.03	0.00	0.03	0.00	0.02	0.00
Consumer credits	coef	4.42	4.46	2.65	1.80	–56.96	–55.47	64.48	59.96
	p-val	0.08	0.00	0.03	0.00	0.03	0.00	0.11	0.00
Housing loans	coef	2.33	2.41	1.89	1.56	–64.82	–64.21	66.83	66.69
	p-val	0.05	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Other loans	coef	2.93	3.09	1.34	1.15	–85.48	–87.08	65.97	61.41
	p-val	0.05	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Panel B: Non–financial corporate loan rates									
Loans – overall	coef	2.97	2.75	1.48	1.18	–82.58	–84.19	70.43	69.95
	p-val	0.05	0.00	0.01	0.00	0.01	0.00	0.03	0.00
Overdraft	coef	5.19	5.46	2.57	2.62	–45.81	–38.22	63.86	60.19
	p-val	0.02	0.00	0.03	0.00	0.03	0.00	0.07	0.00
Loans up to €1 million	coef	2.77	2.84	1.21	1.09	–92.21	–92.06	67.22	62.60
	p-val	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Loans over €1 million	coef	1.85	1.57	1.23	1.12	–90.25	–89.57	80.80	85.01
	p-val	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00

Notes:

This table presents the coefficients of the two-step Engle and Granger (EG) estimation of interest rate pass-through. Panel A shows the results for retail loan rates, while Panel B reports the findings for corporate loan rates. We present average as well as median values for markup, adjustment duration, adjustment coefficient and long term pass-through (LTPT). We report coefficients (coef) and below p-values (p-val). '*' Due to confidentiality reasons, the reported medians represent the average values of three banks.

data.[11] Our approach relies on the intermediation approach, under which banks use deposits as inputs to transform them into loans and other types of output (*Berger/Humphrey*, 1997).[12]

As usual, we assume that banks have three traditional types of output: 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 engaged in off-balance sheet (obs) businesses (*Lozano-Vivas/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 proposed 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.[13] The dependent variable of the stochastic frontier function represents total operating costs, including the bank's financial costs (*TOC*) at time t. Finally, we assume that banks have three different types of input with corresponding input prices (e.g. *Altunbas* et al., 2002):[14] 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).

Table 4 presents summary statistics regarding the employed variables as well as the outputs and inputs as a percentage of total assets.[15] Each of the three cost efficiency specifications employs bank group indicator variables.

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[11] Note that banks do not necessarily share the same technology. Therefore, we have conducted robustness tests and calculate frontiers separately for each banking group (see section VII.).

[12] However, we acknowledge that due to the special structure of the German banking system not all banks might be direct competitors. We address this issues in the extensive robustness section (see section VII.).

[13] With regard to the definition of outputs we follow the literature cited above. Note that output differs from bank products in section IV.

[14] 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.

[15] 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 the average of 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 4

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
Input	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 personnel expenses) divided 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 the number of full-time employees
Output	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	(–)
Input	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	(–)
Output	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 the definitions of the variables used for stochastic frontier estimation. Panel B presents summary statistics of the variables used to estimate the stochastic frontier function. For each variable, we show average values, standard deviations and, if suitable, the value in relation to the bank's total assets ('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 of financing output 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).[16] According to *Lang* and *Welzel* (1997) and *Lozano-Vivas* and *Pasiouras* (2010), we divide TOC, w_1 and by w_3 to impose linear homogeneity restrictions.[17]

Specifying the multi-product translog function, consistent with *Bos* et al. (2005) and *Fiorentino* et al. (2006), our main stochastic frontier is estimated as follows:[18]

$$\begin{aligned} ln\left(\frac{TOC_{it}}{w_{3it}}\right) = {} & \beta_0 + \sum_l \beta_l \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) + \sum_l \beta_l \cdot \frac{1}{2}\left(ln\left(\frac{w_{lit}}{w_{3it}}\right)\right)^2 + \beta_l \cdot ln\left(\frac{w_{1it}}{w_{3it}}\right) \cdot ln\left(\frac{w_{2it}}{w_{3it}}\right) \\ & + \sum_l \beta_l \cdot ln(y_{lit}) + \sum_l \beta_l \cdot \frac{1}{2}\left(ln(y_{lit})\right)^2 \\ & + \sum_{\substack{m,n \\ m<n}} \beta_{mn} \cdot ln(y_{mit}) \cdot ln(y_{nit}) + \sum_j \sum_m \beta_{im} \cdot ln(y_{jit}) \cdot ln\left(\frac{w_{mit}}{w_{3it}}\right) \\ & + \beta_l \cdot ln(z_{ti}) + \beta_l \cdot \frac{1}{2}\left(ln(z_{it})\right)^2 + \sum_l \beta_l \cdot ln(z_{it}) \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) \\ & + \sum_l \beta_l \cdot ln(y_{lit}) \cdot ln(z_{it}) + \beta_l \cdot T + \beta_l \cdot T^2 + \sum_l \beta_l \cdot T \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) \\ & + \sum_l \beta_l \cdot T \cdot ln(y_{lit}) + \beta_l \cdot T + ln(z_{it}) + \sum_{k=1}^{2} \beta_k \cdot group_k + \underbrace{\varepsilon_{it}}_{:=v_{it}+u_i} \end{aligned}$$

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 $v_{i,t}$ 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

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

[17] 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.

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

Table 5

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)
(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

Notes:

This table presents summary statistics on estimated cost efficiency measures described in this section (i.e. section V.2). 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 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 an obs-activities proxy. The bold printed summaries highlight when our main efficiency measure was 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 banks reporting MIR statistics.

to be independent of v_i and iid $N^+\left(\mu,\sigma_u^2\right)$ (i.e. truncated-normally distributed, see *Fiordilisi* et al., 2011). Given that 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., $\mathbf{E}\left[exp\left(-u_i \mid \varepsilon_i\right)\right]$).[19] Cost efficiency is bounded between 0 and 1, where the latter indicates a best-practice or completely efficient bank. The estimation results for the main efficiency measure are presented in Appendix 1. Table 5 presents the summary and correlation

[19] We estimate a time-invariant model that u_i assumes that 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.

statistics for the efficiency measures that were obtained by different specifications.

Consistent with prior literature, the correlations are high and range from 64 % to 99 %.

3. *Further Bank Characteristics as Control Variables*

In addition to a bank's degree of operational efficiency, which 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 risk weighted assets times 8 %.[20] 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).[21] 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 Graeve* 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 Graeve* et al. (2007) and *Gambacorta* (2008), we include the ratio of 'deposit funding' as the amount of non-bank deposits divided by total assets. The reasoning behind this is that banks with a high fraction of costly deposit funding (compared with, for example, less expensive capital market funding) could be forced to charge higher loan rate markups.[22] 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.

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

[21] 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.

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

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 are able to exert market power and could establish prices less competitively, which may result in higher loan markups. Additionally, less stable price offers could be observed as 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 (e.g. *De Guevara* et al., 2005). Thus, our analysis includes different proxies for market power as well as competition and concentration in markets.[23] 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 volumes per bank divided by the sum of all new business volumes obtained from the MIR statistics (see, e.g., *De Graeve* 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.[24] 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 on the level of 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.[25] 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, which enables us to account for the size imbalances between banks. Table 6 provides summary statistics for the control variables of the models, which are comparable to the statistics of *De Graeve* et al. (2007) and *Claeys* 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 Graeve* et al., 2007).

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[23] See section VII. for details.

[24] See Appendix 2 for details on the Lerner estimation.

[25] Specifically, we use the ratio of loan charge-offs to total loans. Alternatively, we add a loan loss provision to the numerator.

Table 6

Summary Statistics of Control Variables (Percentage Points)

Variable	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

Notes:

This table presents summary statistics of control variables described in this section (i.e. section V.3.). We report mean values and the standard deviation of the employed variables.

Table 6 presents the mean and standard deviations of the control variables outlined above.

VI. 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.

In particular, we analyze which determinants influence the loan markup and the speed of adjustment using multivariate OLS regression models. Note that the ECM procedure (as part of which we introduced monthly interest rates) has produced bank-specific, but time-invariant values for the markups and the adjustment duration. Therefore, we move to a cross-sectional analysis, where bank-specific variables (which are available on a yearly basis) must be averaged over time. 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 regression models include the control variables outlined in section V.3. Additionally, each model includes indicator variables for the three major bank groups.[26] All results are presented in Table 7.

[26] The German banking market can be divided into the three pillars: i) commercial banks, ii) the savings bank sector, which consists of savings banks and their central institutions ("Landesbanken"), and iii) the cooperative bank sector, com-

Table 7

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 change (both pass–through parameters are estimated by Engle and Granger's procedure). The cost efficiency measure is based on the estimation of a common frontier, including time trend and obs–items (please refer to Table 5, Panel A). The control variables 'excess capital', 'liquidity', 'deposit funding', 'market share', 'size' and 'credit risk' are described in Table 6. 'comm. indicator' and 'coop. indicator' are dummy variables for the respective bank groups, while 'product indicator' shows the employment of dummy variables for each product.

The main models are (1) and (3). Furthermore, we estimate restricted models (2) and (4), which suppress the 'cost efficiency' variable. 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.

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 point (i.e. a reduction of an average markup

prising credit cooperatives and their central institutions. Consistent with *De Graeve* et al. (2007), the models include product indicator variables that account for structural differences among the analyzed products. Coefficient estimates are not tabulated.

of 3 % to 2.5 % above the market level). Hence, this finding supports our first hypothesis regarding the loan rate level. With regard to our control variables that present other relevant bank factors, we find that the significant variables behave as expected and are consistent with the findings of previous literature: for example, high liquidity reduces loan rate markups. A higher market share is expected to be associated with less competitive loan pricing. The results in Table 7 fail to verify a significant relationship. This could be due to the fact that most banks in the sample (savings and cooperative banks) operate locally and the market share in the whole German loan market is not appropriate for measuring the extent of competition. At this point, we refer to section VII., where we conduct various robustness checks. Other competition measures have been introduced as alternatives to market share. Results indicate that measures such as the Lerner index or a Herfindahl-Hirschmann index (HHI) which measure the concentration of total assets in a bank's local market (local market is defined by German postal codes) better represents the extent of competition. The coefficients of these variables show the expected sign (the greater the market power, the higher the markup) and statistical significance can be verified. 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 Table 7, model (2)). A Wald test emphasizes that the inclusion of cost efficiency significantly increases the model fit.

With regard to the second dimension of interest rate pass-through behavior, regulators and monetary policymakers are concerned with how rapidly banks adjust their prices following a change in market interest rates. From the perspective of bank customers, it is the steadiness of bank prices that 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 to borrowers. Cost efficiency provides a significant positive effect on the duration of loan rate adjustment, which means that 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).

In sum, we conclude that customers generally benefit from cost-efficient banking. Furthermore, we find evidence to support our research hypothesis that operational efficiency alters the interest-rate-setting behavior of German banks.

Table 8

Differentiation Between Customer Groups and Loan Products

		Markup coef.	*Duration* coef.
Panel A: Customer groups – overall			
Retail loans	cost efficiency	–0.022***	0.014***
	(all else as in Table 7)		
Non–financial corporate loans	cost efficiency	–0.008*	0.011***
	(all else as in Table 7)		
Panel B: Retail loan product classes			
Overdrafts	cost efficiency	0.0001	0.022*
	(all else as in Table 7)		
Consumer loans	cost efficiency	–0.037**	0.021**
	(all else as in Table 7)		
Housing loans	cost efficiency	–0.028***	0.011***
	(all else as in Table 7)		
Other loans	cost efficiency	–0.021**	0.010**
	(all else as in Table 7)		
Panel C: Non–financial corporate loan product classes			
Overdrafts	cost efficiency	–0.046*	0.019*
	(all else as in Table 7)		
Loans up to €1 million	cost efficiency	–0.015*	0.008***
	(all else as in Table 7)		
Loans over €1 million	cost efficiency	0.011	0.009***
	(all else as in Table 7)		

Notes:
This table contains re–estimated parameters of the main models from Table 7 based 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).

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

Panel A of Table 8 provides evidence that in general retail customers as well as corporate borrowers benefit from cost-efficient banking. We go on to explore the different loan products in greater detail. First of all, Panel B of Table 8 exhibits no significant relationship between cost efficiency and 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 are adjusted only to a minor extent when the bank's refinancing costs decrease. As overdrafts are used occasionally or may be used unconsciously by the borrower (i.e. in the case of a credit line for short-term financing), banks may find it inappropriate to pass on cost efficiency gains to set more attractive prices for this particular loan product.

However, focusing on 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). By contrast, corporate overdraft pricing is affected to the benefit of borrowers if the bank is able to operate more efficiently. The prior results cannot be verified for corporate loans with a volume exceeding €1 million. Bearing in mind that individual banks may not solely be responsible for the pricing of high-volume loans (in addition, there may also be important issues of syndication 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. On the whole, the efficiency effect on loan rate markups and adjustment speeds is established for almost all individual product groups.

VII. Further Empirical Analysis and Robustness

In this section, we briefly discuss the robustness of our main results.[27] 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). We therefore re-estimate our main models and continuously replace the independent variables. As competition is difficult to calculate with the help of only one single measure, we substitute market share by alternative competition measures such as the Lerner index (see Appendix 2) or the Herfindahl/Hirschmann-Index (HHI) which measure the concentration of assets in a bank's local market. We base the calculation on each Federal state and then on the finer-grained German postal codes. Thus, we account in

[27] Robustness checks are briefly presented due to space limitations and can be delivered upon request.

particular for concentration within local markets comprising savings and cooperative banks. The untabulated results show that the alternative measures always have the same directional effect on both loan markups and adjustment duration as on their equivalents in the main models. Cost efficiency consistently performs well.

Furthermore, we emphasize that our results are not driven by any particular estimation procedure for cost efficiency.[28] In doing so, we apply four different specifications of the SFA-model. First, we introduce fee income as output y_4 as an alternative to obs items to capture fee-based output. Second, we specify a model with only three types of output. Third, we re-estimate the SFA-model presented in section V.2. on the basis of the following alternative samples: i) separate local frontiers for each banking group and ii) one global frontier for all German banks. All our results are robust to the replacement of the cost efficiency estimates.

Besides modifications of cost efficiency estimates, we analyze the generated regressor problem. In other words, due to the fact that 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 errors (i.e. the efficiency coefficient may be skewed toward zero, *Hausman*, 2001). Using two-stage least squares (2sls), we address this issue and thoroughly analyze instrument tests and diagnostics regarding the validity of the instruments (*Murray*, 2006; *Hahn/Hausman*, 2003; *Stock* et al., 2002; *Hahn/Hausman*, 2002). Because the concept of cost efficiency evaluates whether a bank allocates its input in the best possible way for transforming it into its output portfolio, variables that reflect a bank's cost situation combined 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 suggested by *Hausman* (2001), the instrumental variable (IV.) estimation yields an increase in the absolute amounts of the cost efficiency coefficient. Overall, 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.

Furthermore, we 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

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

(see, e.g., *De Graeve* et al., 2007). Thus, we substitute our SFA-based cost efficiency measure with traditional accounting-based cost efficiency measures ('total costs to total assets', 'total costs to total revenues' or the 'cost-income ratio'). These measures are often criticized in literature (see, e.g., *Bauer*, 1998), because they do not fully capture cost efficiency (see *Brueckner*, 2007). As expected, 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 untabulated results also show that cost efficiency still significantly explains both markup behavior and adjustment duration when SFA-based cost efficiency is introduced in addition to traditional ratios.

Our cross-sectional regression approach closely resembles that of *De Graeve* et al. (2007). These authors also include product indicator variables in their regressions (see *De Graeve* 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.

In addition, all previously presented results regarding markup and duration are based on separate regressions. Given that 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.

In a next step, we include a longer period for estimation and extend the time series to September 2011 to cover the financial crises from September 2008 onwards. The results of the markup and adjustment duration regressions are again confirmed.

Finally, we acknowledge that the Landesbanken and the cooperative central banks as well as the four German large banks have a special status and cannot be easily compared to common savings and cooperative banks. For example, *Bos* et al. (2005) argue to only use banks with similar business models for the SFA estimation. Thus, we re-estimate all model variables based on the remaining 138 banks that do not belong to the above-mentioned special-status credit institutions and find that our results are not impaired in any way.

VIII. 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 is consistent with international research, German banks exhibit sluggish and sticky pricing behavior. Given the importance for monetary policy makers and bank regulators to assess how well the process of financial intermediation works and to what extent individual bank characteristics influence or prevent a perfect adjustment of product rates based on changes in 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 bank's operational efficiency and identify the degree to which changes in 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 rates, both of which are valued by their borrowers.

This study combines two streams of literature: the measurement of how banks establish interest rates and pass on changes in market conditions to their customers in addition to the thorough measurement of banks' cost efficiency, which is typically performed using a stochastic frontier analysis based on the assumption that this methodology is superior to traditional financial ratios. In this way, the study provides important insights into how changes in funding costs are transmitted to credit prices via the operating efficiency channel.

Appendix 1: SFA Estimates

Table A

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	$ln\left(\sigma_S^2\right)$	–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 time trend).

The variables are coded as presented in section V. 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.

Appendix 2: 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.

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

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 item (total assets) and three input items (capital, labor and deposits and borrowed funds).[29] *TOC* denotes total operating costs, and y is total assets. As in section V., $\boldsymbol{w}$ 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.

$$\begin{aligned} ln\left(\frac{TOC_{it}}{w_{3it}}\right) = {} & \beta_0 + \sum_{l=1}^{2}\beta_l \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) + \sum_{l=1}^{2}\gamma_l \cdot \frac{1}{2} \cdot \left(ln\left(\frac{w_{lit}}{w_{3it}}\right)\right)^2 + \delta_1 \cdot ln(y_{it}) \\ & + \delta_2 \cdot \frac{1}{2} \cdot \left(ln(y_{it})\right)^2 + \sum_{l=1}^{2}\varepsilon_l \cdot ln(y_{it}) \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) + \in_1 \cdot ln(z_{it}) \\ & + \in_2 \cdot \frac{1}{2}\left(ln(z_{it})\right)^2 + \sum_{l=1}^{2}\rho_l \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) \cdot ln(z_{it}) + \varphi_1 \cdot ln(y_{it}) \cdot ln(z_{it}) \\ & + \varphi_2 \cdot T + \varphi_3 \cdot T^2 + \varphi_4 \cdot T \cdot ln(y_{it}) + \varphi_4 \cdot T \cdot ln(z_{it}) \\ & + \sum_{l=1}^{2}\tau_l \cdot T \cdot ln\left(\frac{w_{lit}}{w_{3it}}\right) + \sum_{l=1}^{2}\omega_l \cdot group_i + \varepsilon_{it} \end{aligned}$$

As in section V., 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 have a truncated-normal distribution.[30]

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

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

[29] In line with other studies, e.g. *Maudos/De Guevara* (2004), we consider only one output.

[30] Similar results are obtained by calculating a time-varying decay model as suggested by *Battese/Coelli* (1992).

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