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Heterogeneity in Bank Pricing Policies: The Czech Evidence

Roman Horváth and Anca Podpiera*

Abstract

In this paper, we estimate the interest rate pass-through from money market to bank interest rates using various heterogeneous panel cointegration techniques to address bank heterogeneity. Based on our micro-level data from the Czech Republic, the results indicate that the nature of interest rate pass-through differs across banks in the short term (rendering estimators that constrain coefficients across groups to be identical inconsistent) and becomes homogeneous across banks only in the long term, supporting the notion of the law of one price. Mortgage rates and firm rates typically adjust to money market changes, but often less than fully in the long run. Large corporate loans have a smaller mark-up than small loans. Consumer rates have a high mark-up and are not found to exhibit a cointegration relationship with money market rates. Next, we examine how bank characteristics determine the nature of interest rate pass-through in a cross-section of Czech banks. We find evidence for relationship lending, as banks with a stable pool of deposits smooth interest rates and require a higher spread as compensation. Large banks are not found to price their products less competitively. Greater credit risk increases vulnerability to money market shocks.

JEL Codes: E43, E58, G21.
Keywords: Bank pricing policies, financial structure, monetary transmission.

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Non-technical summary

This piece of research examines the effectiveness of monetary policy transmission in the Czech Republic based on a detailed bank level dataset in January 2004–December 2008. Specifically, we analyze how the money market rate, which is typically largely driven by the monetary policy rate, affects bank interest rates (e.g. interest rate pass-through or bank pricing policies more generally) and which factors matter for the nature of the pass-through. In contrast to many other papers in this stream of literature, we try to account for bank heterogeneity in a comprehensive manner. Studies within this stream of literature typically introduce bank heterogeneity only via a bank dummy, but otherwise force all banks to react identically to money market rate changes. This is, as we show, an inadequate assumption leading to inconsistent estimates about the interest rate pass-through. Therefore, we employ a more general estimation framework that relaxes the imposition of identical reaction of bank interest rates to money market rate changes – so-called heterogeneous panel data estimators – in order to account for heterogeneity in a fuller manner.

Our results suggest that the interest rate pass-through differs across banks in the short term. On the other hand, banks' pricing policies are found to be homogeneous in the long term, supporting the notion that the law of one price prevails in the long run.

Bank interest rates (both on loans as well as deposits) are found to adjust to money market changes relatively fast, but often less than fully in the long run. Our results indicate that interest rate pass-through from the money market to bank interest rates in the Czech Republic typically took 1-3 months in 2004-2008. The results show that large corporate loans have a smaller mark-up than small loans. Consumer rates have a high mark-up and are not found to exhibit a cointegration relationship with the money market rate.

We also examine how the bank characteristics influence the nature of interest rate pass-through. We find evidence for relationship lending. Banks, which funding depends more heavily on deposits, smooth bank interest rates and require a higher spread as compensation. Credit risk is found to increase the spread between bank interest rates and money market rates and also to increase sensitivity to money market shocks.

As regards the effect of the 2008-2009 global financial crisis on the interest rate pass-through, for certain loan categories we find some evidence for slower interest rate pass-through. Looking at the distributions of bank interest rates, we can see greater heterogeneity in terms of the interest rates charged for a given loan category, which probably reflects increased bank prudence in response to the deterioration in borrowers' risk profiles. Nevertheless, it has to be emphasized that our sample consists of data up to December 2008 and a fuller examination of the effect of 2008-2009 global financial crisis on the interest rate pass-through is left for further research.

1. Introduction

Understanding the effectiveness of monetary transmission is crucial in order for central banks to pursue their policies. Central banks typically exert a strong influence on short-term interest rates, which in turn affect commercial banks' pricing policies and, subsequently, the financing conditions of the corporate and household sector.

In this paper, we examine how the money market rate, which is typically largely driven by the monetary policy rate, affects bank interest rates (e.g. interest rate pass-through) during the period January 2004–December 2008 and which factors matter for the nature of the pass-through based on bank-level data. Bank-level data seem to be preferable for this kind of exercise for two main reasons. First, recent theoretical and empirical research has emphasized that the speed of adjustment in dynamic relationships (e.g. how fast a money market rate shock is absorbed into the bank interest rate in our case) observed at the aggregate/macroeconomic level may be affected by aggregation bias (see Granger, 1980, and Zaffaroni, 2004) and by the fact that idiosyncratic shocks will tend to disappear when a substantial number of series are aggregated (Altissimo, Mojon and Zaffaroni, 2009).[1] This suggests that there is a risk that estimates based on aggregate data may underestimate the speed of interest rate pass-through. The second reason for preferring bank-level data over aggregate data is that it allows us to examine the determinants of the nature of interest rate pass-through.

A characteristic feature of this paper is that it accounts for bank heterogeneity in a comprehensive manner. Studies within this stream of literature typically introduce bank heterogeneity only via a bank dummy, but otherwise force all banks to react identically to money market shocks.[2] This is, as we show, an inadequate assumption leading to inconsistent estimates of the speed of interest rate pass-through. Therefore, we introduce a more general framework in order to account for heterogeneity in a fuller manner.

In terms of results, we find that the nature of interest rate pass-through differs across banks in the short term (rendering estimators that impose common slopes inconsistent). On the other hand, pricing policies are found to be homogeneous in the long term, supporting the notion that the law of one price prevails in the long run (see Gambacorta, 2008, for similar evidence on Italian banks).

The estimations performed show the existence of an equilibrium-restoring relationship for all categories of bank interest rates on deposits, corporate loans and household loans except consumer loans. Bank interest rates typically adjust to money market changes relatively fast, but often less than fully in the long run. Our estimates suggest that for corporate rates it takes typically only one month on average for banks to pass money market rate changes through. The results indicate that large corporate loans have a smaller mark-up than small loans. Consumer rates have a high mark-up and do not exhibit a relationship with the money market rate even in the

[1] See also Bernanke and Blinder (1992), who show that it is impossible to identify a bank lending channel based on macroeconomic time series.

[2] De Graeve et al. (2007) seem to be the exception. Compared to De Graeve et al. (2007), we apply different econometric estimators.

long run. We also examine how the financial structure influences the nature of interest rate pass-through in a cross-section of Czech banks. We find evidence for relationship lending. Banks with a stable pool of deposits smooth interest rates and require a higher spread as compensation for interest rate stability (this is in line with US evidence, see Berlin and Mester, 1999). Credit risk is found to increase the spread and also to increase sensitivity to money market shocks.

The paper is structured as follows. In section 2, we briefly discuss the related literature. Section 3 describes our data. Section 4 introduces our empirical framework. We use three heterogeneous panel data estimators to shed light on the nature of interest rate pass-through. Section 5 presents our results. Section 6 offers concluding remarks. An appendix with a data description and additional results follows.

2. Related Literature

Numerous papers dealing with interest rate pass-through have emerged over the past two decades. Hannan and Berger (1991) and Neumark and Sharpe (1992) focus on an analysis of the US banking sector. Cross-country studies to reveal and explain the similarities and differences among the interest rate pass-through mechanisms in various countries were pioneered by Cottarelli and Kourelis (1994) and Borio and Fritz (1995). The eventual adoption of a common currency increased interest in monetary transmission across the euro area countries (see Mojon, 2000; Bondt, Mojon and Valla, 2005; de Bondt, 2005). Typically, these studies evaluate the nature of interest rate pass-through within an error-correction framework. Specifically, they focus on the long-term relationship between bank interest rates and the money market rate, the short-term response of bank interest rates to a change in the money market rate, and the speed of adjustment.

One stylized fact of these studies is that there is sluggish adjustment of bank interest rates, but over the long term the pass-through from the policy interest rate or money market rates to bank interest rates is often complete (see de Bondt, 2005, for a recent survey within this stream of literature) but not always so (De Graeve et al., 2007). Several theories have been put forward to account for the sluggishness of bank interest rates. First, switching costs, such as the costs of acquiring information, may be a hindrance to instantaneous adjustment of the bank interest rate (Sharpe, 1997). Second, asymmetric information costs are likely to be present in the banking sector. Consequently, banks may not increase their lending rates proportionately in response to a shock, as they fear attracting customers with more risky activities (the adverse selection problem). Another observation drawn from the results is that consumer rates are found to react the slowest, as asymmetric information costs seem to be the most pertinent in this market segment.

Next, several studies investigate asymmetries in the interest rate pass-through, i.e. whether bank interest rates react differently according to the sign or size of the money market change or according to whether the bank interest rate is above or below its equilibrium value inferred from the error-correction mechanism. The evidence on asymmetries is mixed. While some studies document asymmetric adjustment of bank interest rates to money market rates (Scholnick, 1996; Gropp et al., 2007), others fail to find evidence for asymmetry (Sander and Kleimeier, 2004, 2006). More specifically, bank interest rates have been found to react differently according to whether money market interest rates were rising or falling (or were located under or above the

"equilibrium" interest rate) or not to have a proportional reaction to changes of different sizes in money market rates. The non-linear reaction of banks can be backed by various theoretical explanations related to nominal rigidities, transaction costs, market structure or asymmetric information problems (De Graeve et al., 2007).

Several contributions focus on the question of which factors are behind the heterogeneity in interest rate pass-through. Sander and Kleimeier (2004, 2006) estimate single-country error-correction models for several European countries and report that market concentration, bank performance, foreign bank participation, macroeconomic environment and monetary policy regime matter for the convergence of interest rate pass-through across countries. Similarly, using a novel measure of competition Leuvensteijn et al. (2008) document that the degree of competition matters for interest rate pass-through in the euro area, with higher competition inducing bank pricing policies to be more in line with money market conditions. Gropp et al. (2007) concentrate on the determinants of bank spreads in the euro area and find that spreads are driven by bank soundness, credit risk and interest rate risk. The speed of interest rate pass-through is also affected by the degree of competition and financial innovations. De Bondt (2005) and De Bondt et al. (2005) find that the interest rate pass-through speeded up after the introduction of the euro. Gambacorta (2008) shows that the heterogeneity of bank pricing policies in Italy is influenced by liquidity, capital adequacy and relationship lending, but these factors are important only in the short run.

A different approach to modeling interest rate pass-through is proposed in De Graeve et al. (2007). Their empirical framework accounts for bank heterogeneity in a fuller manner, as it allows heterogeneity in the slopes and constant in the regression. They estimate the average long-run pass-through using the Philips and Moon (1999) estimator, and for the average short-run pass-through (including the speed of adjustment) they apply a random coefficient estimation method (Swamy, 1970). Different slope coefficients allow banks to react differently to changes in money market rates, and they show that this is indeed the case. This signals that estimators that impose a common slope (an identical reaction by the banks) are inconsistent. De Graeve et al. (2007) find that the interest rate pass-through in the Belgian market is often incomplete and the adjustment of bank interest rates to money market changes is typically symmetric (with the exception of large deviations from the equilibrium interest rate). Similarly to Gambacorta (2008), their results indicate certain evidence for relationship banking and that well capitalized and liquid banks are less prone to money market changes. We follow De Graeve et al. (2007) and model the banking sector as heterogeneous. On the other hand, we apply different heterogeneous nonstationary panel estimators and in comparison to De Graeve et al. (2007) investigate a larger set of determinants of interest rate pass-through.

The enlargement of the EU in 2004 and 2007 and the prospect of joining the monetary union gave rise to further interest in the monetary transmission of the new EU member states. Egert and MacDonald (2009) survey the characteristics of monetary transmission, and in particular the interest rate channel, in these countries as ensuing from the latest research at the country level. There are few studies addressing interest rate transmission in the Czech Republic. All these studies make use of aggregate data, namely, the averages of bank interest rates as published by the Czech National Bank. Crespo-Cuaresma, Egert and Reininger (2004) include the Czech Republic in a study meant to unveil the interest rate pass-through in the Czech Republic, Hungary and Poland between 1994 and mid-2003. They focus on three bank interest rates (the household

deposit rate, the enterprise new loans rate with maturity less than 12 months, and the enterprise new loan rate with maturity more than 12 months). They find incomplete pass-through for all the rates and confirm the existence of an equilibrium relationship between the bank interest rates analyzed and the 12-month money market rate. Recursive estimates show a general upward trend in long-run elasticities, albeit still having values under unity. The paper seems not to focus on short-term pass-through.

Egert, Crespo-Cuaresma and Reininger (2007) also account for the Czech Republic when studying pass-through within a panel of five Central and Eastern European countries and compare it with that in selected euro area countries during the period 1994–2005. This time the authors use a larger spectrum of bank interest rates, including both those on the stock of loans and those applied to newly extended loans. They find no significant pass-through for aggregate household loans and more pronounced (even close to unity) pass-through for long-term corporate loans than for short-term corporate loans.

Tieman (2004) includes the Czech Republic when analyzing the interest rate pass-through in Romania and several other Central European countries using data from January 1995 to February 2004. The data for the Czech Republic cover the average monthly short- and long-term loan rate (for both outstanding loans and new loans) and the deposit rate. The long-term pass-through for outstanding loans is below unity for both the short- and long-term rate. For rates on newly issued loans, the results show a pass-through close to unity for short rates and a pass-through significantly under unity for long rates. Regarding the immediate pass-through, only in the case of the short rate for newly issued loans can a significant reaction be observed. To sum up, all previous studies based on aggregate data suggest that the long-run pass-through is incomplete in the Czech Republic. A survey of monetary transmission in Central Europe is available in Egert and MacDonald (2009), and a description of Czech monetary policy is available in Borys Morgese et al. (2009).

3. Data

We conduct individual analyses regarding the pass-through of money market rates to interest rates on new loans granted to the non-financial sector and to the household sector, and to new deposits over the period January 2004–December 2008 (note that earlier micro-level data are not available due to changes in the reporting of interest rates). We make use of bank-level contract-based interest rates. We consider the bank-level data for all commercial banks[3] for which data are available. In this respect, we use a panel of 18 commercial banks for the analysis of loans to the non-financial sector, 13 commercial banks for the analysis of loans to the household sector and 20 commercial banks for the analysis of deposits.[4] In general, these banks grant more than 95% of

[3] To be more precise, the sample consists of banks, building societies and branches of foreign banks. In general, the sample includes all large banks with the exception of one merger. Building societies operate within a somewhat different institutional framework and we therefore include dummy variables in the following regression analysis to control for it.

[4] There was one acquisition during our sample period and we decided to drop these observations for simplicity. Note that all the banks were privatized well before our sample starts and the share of foreign ownership is about 97% (Financial Stability Report 2008/2009).

loans in the Czech Republic. The source of all our data is the internal Czech National Bank dataset on banks, containing detailed financial statements of banks and their lending activity.

For money market rates, we use 1M PRIBOR, 3M PRIBOR, 6M PRIBOR and 1Y PRIBOR. Out of these PRIBOR rates, we choose – in line with de Bondt (2005) – the one with the highest correlation with the given bank interest rates for our regression analysis (see Table A3 in the Appendix).

According to EU regulations, data concerning loans to the non-financial sector are distinguished according to the loan amount and the time span for which the interest rate is fixed; data concerning loans to households are split into loans for consumption purchases and for mortgages, while data regarding deposits are displayed according to the maturity of the deposits. For convenience, we provide the categorization of loans and deposits in the tables below.

Categorization of Loans to Non-financial Sector (Firms)

Small loan, floating rate	Loan amount up to 30 million Czech crowns, rate floating or fixed up to 1 year
Small loan, fixed rate	Loan amount up to 30 million Czech crowns, rate fixed more than 1 year
Large loan, floating rate	Loan amount more than 30 million Czech crowns, rate floating or fixed up to 1 year
Large loan, fixed rate	Loan amount more than 30 million Czech crowns, rate fixed more than 1 year

Categorization of Loans to Households

Mortgage rate	Loan for house or apartment purchase
Consumer rate	Loan for households, typically for durable goods

Categorization of Deposits

SR deposit rate	Deposits with maturity above one day and less than two years
LR deposit rate	Deposits with maturity above two years

All the loans are in the domestic currency; loans in foreign currencies are excluded. Note that foreign currency lending, contrary to other Central and Eastern European countries, is quite limited. The shares of foreign currency lending for households and firms stand at around 0.5% and 20%, respectively (Financial Stability Report, 2008/2009).

Both the weighted average and the median bank-specific interest rate are included in our analysis. Weighted average rates are typically used in other studies in this stream of literature (as these are reported by central banks or statistical offices), as the median rate is not readily available and has to be constructed from individual contract-level data.

A normality test performed on the monthly distributions – the skewness/kurtosis test (conceptually similar to the Jarque-Bera test) – systematically rejects the null hypothesis of normal distribution. Therefore, we choose to use the median as a representative statistic for the monthly bank interest rates in the following regressions. Note that median interest rates can be

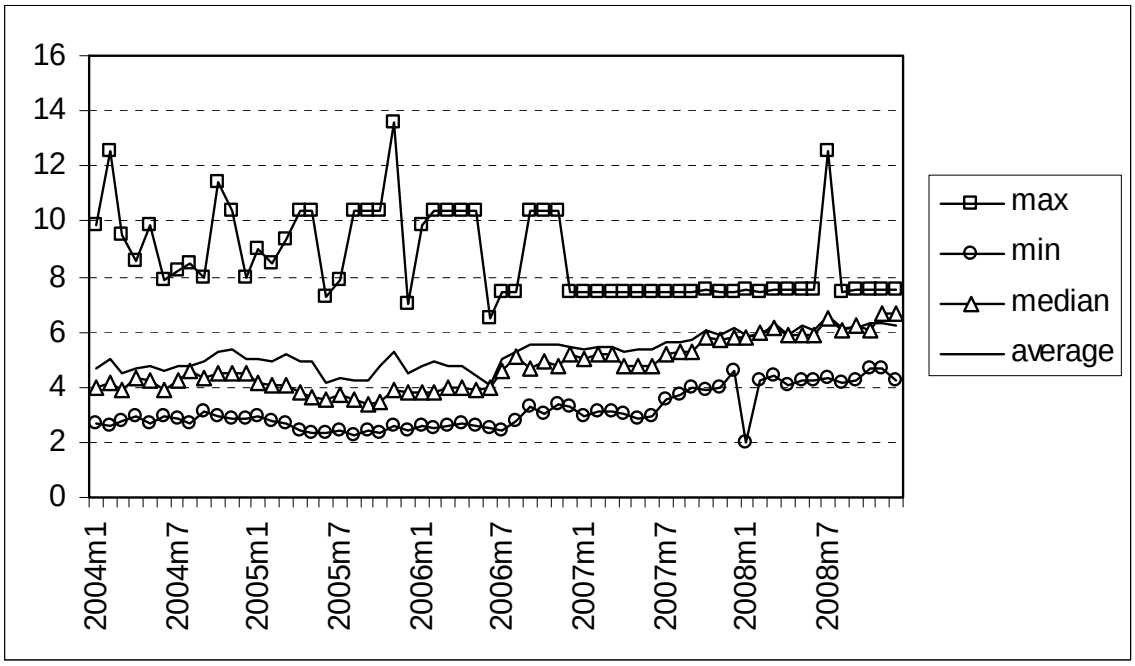
calculated, as our underlying dataset contains almost entirely individual contract-level data (in general, we have information available on all the loans granted in the Czech Republic; only contracts with identical characteristics are grouped together). To our knowledge, evidence based on median bank interest rates is missing in the literature.

In consequence, we have a panel of bank-level data for each of the bank interest rates mentioned above. We test these panel data for non-stationarity. The Hadri (2000) panel unit root test, which tests the stationarity in heterogeneous panels and has the null hypothesis of stationarity in any of the series in the panel, strongly rejects the null in favor of a unit root. The results are available upon request. We have chosen to base our conclusion about (non-)stationarity on this test as the results were the most unambiguous. The other tests suitable for a heterogeneous panel, such as Im, Pesaran and Shin (2003) or Fisher-type tests, give mixed results contingent on including or excluding individual specific trends. The loss of power of these tests in the case of individual specific trends is well documented in the literature (see Baltagi and Kao, 2000). At the same time, we employ the Pedroni (1999) residual cointegration test to test for panel cointegration between the bank interest rates and the money market rates to which they are the most correlated (see Table A3 in the Appendix). With the exception of consumer retail rates, in all cases the null of "no cointegration" is rejected.[5]

The descriptive statistics (Tables A1 and A2) and selected figures (Figures A2–A8) are available in the Appendix. It is evident that the mortgage rate is lower than the consumer rate; this is in line with the fact that consumer rates are perceived to be more risky. As concerns corporate loans, small loans exhibit higher rates than large loans, reflecting higher unit monitoring costs for small loans (typically granted to small firms), and, at the same time, loans with longer fixation periods are more expensive than loans of similar size but with floating interest rates. This suggests that banks charge less to customers that are willing to accept more risk. Figures 2A–8A show the link between the weighted average and median bank-specific rates for the various loan categories. Clearly, the average and median rates are strongly correlated in most cases, but certain differences between them are apparent, especially for higher rates granted to more risky customers. Figure 1 presents the paths of the median, average, minimum and maximum interest rates for the loan category of small loans with floating interest rates. It suggests great variation in terms of interest rates across different banks. For example, the difference between the minimum and maximum interest rate on small loans with floating interest rates in January 2004 was more than 7 percentage points.

[5] The results of these tests are available upon request.

Figure 1 – Interest Rate Heterogeneity across Banks: An Example Maximum, Minimum, Median and Average



Note: The figure presents the maximum, minimum, median and average lending rate for the category of small loans with floating interest rates over time and reveals large bank heterogeneity in terms of the interest rates charged on largely identical products by different banks.

Next, data on bank characteristics were collected in order to assess the underlying factors affecting the nature of interest rate pass-through.

Bank characteristics

$Size_{i,j}$	Assets of i-th bank/median bank assets
$Inefficiency_{i,j}$	Costs/income
$Liquidity_{i,j}$	Liquid assets/assets
$Capital\ Adequacy_{i,j}$	Capital/risk-weighted assets
$Deposit_{i,j}$	Deposits/(deposit and non-deposit funding)
$Credit\ Risk_{i,j}$	Non-performing loans/assets

4. Empirical Methodology

A straightforward underlying link between money market rates and bank interest rates – the so-called "cost of funds/marginal cost" approach (de Bondt, 2005) – emerges from the fact that banks borrow on the money market to secure their lending. The theoretical underpinnings of this "mark-up" model are provided by Freixas and Rochet (2008), whose model implies that in an imperfectly competitive environment the long-term relationship between the bank interest rate and the money

market rate can be expressed as $br = mr + \mu$, where br stands for the bank interest rate, mr represents the money market rate and μ denotes the spread. The size of the spread is obviously driven by a number of factors related to risk and competition.

Whether lending rates follow moves in market rates one-to-one depends on numerous factors, such as the elasticity of demand with respect to bank interest rates, market power and the presence of asymmetric information. In the same line of reasoning, the link between deposits and money market rates emerges from the fact that banks can borrow either on the money market or from depositors to fund their lending activities, so either way the money market rate or the deposit rate can represent a marginal cost for the bank, and this brings about their interlinking. In addition, depositors can choose either to deposit money with banks or to invest in securities. In consequence, it might appear that different bank interest rates are more linked to some market rates than to others and this fact is obviously contingent on the term structure.

The link between market rates and bank interest rates – the interest rate pass-through – is typically evaluated within an error correction framework, given the non-stationarity of bank-level bank interest rate panels and the market rate as described by equation (1).

$$\Delta br_{i,t} = \sum_{j=0}^{q-1} \alpha_0 \Delta mr_t + \sum_{j=1}^{p-1} \alpha_1 \Delta br_{t-1} + \beta_{0,i}(br_{i,t-1} - \beta_1 mr_{t-1} - \mu) + \varepsilon_{it} \qquad (1)$$

where br_{it} denotes the *i*-th bank interest rate at time *t*, mr_t represents the money market rate and μ is a constant that assesses the spread of bank interest rates vis-à-vis money market rates. Eq. (1) captures both the long-term and short-term dynamics of the money market pass-through to bank interest rates. The long-term pass-through is described by coefficient β_1. If $\beta_1 = 1$, the pass-through is regarded as complete. Coefficient α_0 reflects the short-term dynamics, while coefficient β_0 stands for the speed of adjustment. Hendry (1995) asserts that $(\beta_1 - \alpha_0)/\beta_0$ indicates the mean adjustment lag at which the market rate is fully passed through to the bank rate.

In our study, we employ three heterogeneous panel data estimators to shed light on the interest rate pass-through and to deal with bank heterogeneity in a comprehensive manner. We apply 1) the mean group estimator (Pesaran and Smith, 1995) and 2) the pooled mean group estimator (Pesaran, Shin and Smith, 1999). These estimators are designed for "large *N*, large *T*" panels where *N* and *T* are of the same order of magnitude (see Pesaran, Shin and Smith, 1999). Our *N* – i.e. the number of banks – is typically around 18 and *T* – i.e. the time dimension – is equal to 60. Thus, we have employed these methods on two shorter spans (January 2004–June 2006 and July 2006–December 2008) in order to have *N* and *T* of a similar order of magnitude. As a consequence, we evaluate if the transmission changes over time. 3) We estimate the long-run relationship, namely coefficients β_1 and μ, by dynamic OLS (DOLS) as put forward by Stock and Watson (1993) and the short-term specification by Swamy's (1970) random coefficient.

Note that even for the sub-samples our sample size is thus largely similar to the original application of Pesaran et al. (1999), where they study consumption dynamics in OECD countries with N=24 and T=32. As concerns the time coverage, our results (see section 4 of this paper) indicate that the speed of interest rate pass-through is rather high, so full adjustment of bank

interest rates to money market rates is realized several times during our sample period. Furthermore, the results even for the subsample of 2004:1–2006:6 suggest complete pass-through (see section 4 of this paper), which tends to support the supposition that the time horizon for the analysis is not so short.

We introduce a more general framework for the empirical investigation than the one from Eq. (1). While in the case of the mean group estimator all the coefficients are allowed to vary freely across banks, the pooled mean group estimator and DOLS-Swamy's random coefficient estimator allow intercepts, short-run coefficients and error variances to vary freely, but the long-run coefficients are constrained to be identical. In the following equations we describe our methodology formally.

Mean group estimator:

$$\Delta br_{i,t} = \sum_{j=0}^{q-1} \alpha_{0,i} \Delta mr_t + \sum_{j=1}^{p-1} \alpha_{1,i} \Delta br_{t-1} + \beta_{0,i} (br_{i,t-1} - \beta_{1,i} mr_{t-1} - \mu_i) + \varepsilon_{it} \qquad (2)$$

Pooled mean group estimator:

$$\Delta br_{i,t} = \sum_{j=0}^{q-1} \alpha_{0,i} \Delta mr_t + \sum_{j=1}^{p-1} \alpha_{1,i} \Delta br_{t-1} + \beta_{0,i} (br_{i,t-1} - \beta_1 mr_{t-1} - \mu) + \varepsilon_{it} \qquad (3)$$

By employing the mean group estimator and pooled mean group estimator we aim, apart from getting a picture of the monetary transmission in the sub-periods, to find out whether the law of one price holds and we can consequently carry out the estimations under this assumption for the entire period using the third methodology we have described. The pooled mean group estimator assumes bank pricing policies to be heterogeneous in the short run. Therefore, $\alpha_{0,i}$ and $\beta_{0,i}$ may differ from bank to bank, but β_1 and μ are identical for all banks. The mean group estimator is less restrictive and allows the coefficients to differ bank by bank even in the long run (therefore, we obtain a bank-specific spread, μ_i, and a bank-specific long-term pass-through, $\beta_{1,i}$). On the other hand, the mean group estimator is less efficient. We employ the Hausman test to assess whether the long-run slope homogeneity condition holds.

As mentioned, for the entire time span January 2004–December 2008 we employ the third methodology (DOLS-Swamy hereinafter). We choose DOLS for the following reasons.[6] Kao and Chiang (2000) investigate the finite sample properties of the OLS of Pedroni (2000), the Fully Modified OLS (FMOLS) of Philips and Moon (1999) and DOLS and conclude that the OLS estimator has a non-negligible bias in finite samples, that FMOLS does not improve over OLS in general and that DOLS may be more promising than OLS and FMOLS for the estimation of panel cointegration.

[6] We also investigated whether there are any asymmetries in the interest rate pass-through, but failed to find any systematic evidence for asymmetry. These results are available upon request.

The DOLS estimator for heterogeneous panels, $\hat{\beta}$, can be obtained by running the following regression (Kao and Chiang, 2000):

$$br_{i,t} = \mu_i + \beta mr_t + \sum_{j=-q_i}^{q_i} c_{i,j} \Delta mr_{t+j} + \upsilon_{i,t} \qquad (4)$$

So, besides a bank-dummy to account for the fixed heterogeneity and the contemporaneous level of the explanatory variable, it adds leads and lags of its first differences. Practically, we chose a maximum of 4 lags and leads and then eliminated the insignificant variables.

Concerning the short-term dynamics, Swamy's (1970) random coefficient model captures the dynamic heterogeneity. The estimated coefficients are a weighted average of the bank-specific coefficients, where the weights are based on the estimated covariances (Swamy, 1970). In addition, when performing the estimations, the short-term specification was enriched with a bank-dummy for fixed heterogeneity, the lags of differenced money market rates and the lags of differenced bank interest rates.

Estimation of the pass-through represents the first part of our analysis. In the second part, we study which factors contribute to the heterogeneity of interest rate pass-through (in some sense this is similar to the two-step approach pursued in Kashyap and Stein, 2000).[7] Note that there are two basic approaches to investigating the role of bank characteristics for interest rate pass-through. The first approach analyzes the determinants (bank characteristics) of the estimated parameters from interest rate pass-through regressions (such as the one in Eq. (1)). The second approach includes the bank characteristics directly in the interest rate pass-through regression. These two approaches are related in the sense that they both investigate how bank characteristics matter for interest rate pass-through, but it is noteworthy that they aim to tackle two distinct issues. While the first approach examines how bank characteristics matter for, for example, long-term pass-through, the second approach investigates whether bank characteristics matter for changes in bank interest rates (i.e. the dependent variable in Eq. (1)). In this paper, we opt for the first approach and leave the second one for further research.

The set of determinants consists of bank characteristics and is in line with De Graeve et al. (2007). Nevertheless, we include a fuller set of determinants to provide additional insights into the nature of interest rate pass-through. First, we investigate the determinants of the spread, μ_i,[8] estimating the following regression for all loan products stacked together:

$$\mu_{i,j} = f\left(liquidity_i, capital_i, size_i, deposits_i, inefficiency_i, creditrisk_i\right) \qquad (5)$$

j and *i* stand for the *j*-th loan product and *i*-th bank, respectively. $Liquidity_i$ is the ratio of liquidity to assets and its effect on the spread is likely to be negative. $Capital_i$ stands for capital adequacy

[7] A related stream of research investigates the effect of monetary policy shocks on bank lending. Recent evidence on Central and Eastern European countries is available in Matoušek and Sarantis (2009).

[8] The spread and long-term pass-through estimates come from the mean group estimates.

(capital over risk-weighted assets). A positive link between $capital_i$ and spread can be expected according to Ho and Saunders (1981). Their dealership model predicts a positive relationship, as net interest rate margins should increase the capital base as the exposure to risk increases. On the other hand, Brock and Franken (2003) claim that less capitalized banks have the motivation to accept more risk (associated with a higher spread) in order to receive higher returns. Analogously, more capitalized banks invest more cautiously, as there is more capital at risk (Brock and Franken, 2003).

We include bank size to proxy for the industry structure. The effect of $size_i$ (the ratio between one bank's assets and the median assets of banks) is not clear-cut. On the one hand, larger banks may exercise market power and charge higher rates. For example, Berger (1995) notes that banks with a large market share may price their products less competitively. On the other hand, the size of a bank may also reflect its efficiency and thus its ability to offer a smaller spread (Claeys and Vander Vennet, 2008).

Next, we include the variable $deposits_i$ to assess the possible effects of relationship lending. The hypothesis originally raised by Berlin and Mester (1999) is that banks with a stable pool of deposits will smooth market shocks (and thus their interest rates) for customers and will maintain a higher spread as compensation for stable bank interest rates. In line with De Graeve et al. (2007), $deposits_i$ is calculated as deposits over deposit and non-deposit funding.

We include $inefficiency_i$ [9] (costs over income) to investigate the hypothesis of whether less efficient banks charge a larger spread and thus pass their inefficiency on to customers. The effect of $creditrisk_i$ (non-performing loans over assets[10]) is expected to be positive, as a more risky loan portfolio is typically associated with a higher yield (Wong, 1997; Gambacorta, 2008). The definitions of the explanatory variables are also available in the data section.

Similarly, the determinants of long-term pass-through, $\beta_{1,i}$, are examined:

$$\beta_{1,i,j} = f\left(liquidity_i, capital_i, size_i, deposits_i, inefficiency_i, creditrisk_i\right) \qquad (4)$$

Less liquid and less capitalized banks are more prone to market shocks and thus are likely to exhibit fuller long-term pass-through (Kashyap and Stein, 2000). Larger banks may use their market power and react less to market conditions (Berger, 1995). Banks with larger credit risk are likely to be more vulnerable to market conditions.

Note that similarly to De Graeve et al. (2007), $\beta_{1,i,j}$ differs across banks *i* and across loan products *j*. However, we should mention that the mean group estimator (which is less efficient than the pooled mean group estimator) is used for this exercise, but this does not influence the

[9] We resort to a simplistic measure of *inefficiency*, as an analysis of frontier efficiency (see Berger and Humphrey, 1997, for a survey) is not among the aims of this paper.

[10] We are aware that this measure is a rather backward-looking proxy of credit risk, but on the other hand it is bank-specific. Credit default swaps on bank debt data, which would be a more forward-looking indicator, are unfortunately available only for a few large banks.

estimated coefficients, as we find that the estimated parameters do not differ statistically significantly according to the Hausman test results in Table A6 in the Appendix.

It is worth emphasizing that examining the determinants of pass-through in a cross-section of banks, we use bank-specific averages over the sample period. As argued by De Graeve et al. (2007), this is possible because the bank characteristics considered, such as market position, are largely structural and typically do not change substantially over time.

Following De Graeve et al. (2007), we do not investigate the determinants of the short-term reaction of bank interest rates to money market rates, as they find that these are driven by largely the same factors as for the long-term pass-through. Next, to deal with the heteroscedasticity arising from bank and product heterogeneity, De Graeve et al. (2007) opt for the generalized least squares estimator. In contrast to them, we deal with these issues by employing robust regression (see Rousseeuw and Leroy, 1987). In addition, we include dummy variables for different loan products and a dummy for building societies, but fail to find it significant once bank characteristics are included.[11]

4. Results

The pooled mean group estimates are provided in Table 1 and Table 2 for the sub-periods Jan 2004–Jun 2006 and Jul 2006–Dec 2008, respectively. The DOLS-Swamy estimates for the full sample (Jan 2004–Dec 2008) are presented in Table 3 and Table 4.

The pooled mean group estimates in Tables 1 and 2 indicate that bank interest rates typically adjust to money market changes relatively fast, but often less than fully in the long run. This is in line with evidence for the Belgian market by de Greave et al. (2007) as well as with previous evidence based on the Czech data by Egert, Crespo-Cuaresma and Reininger (2007). Mortgage rates adjust fully to money market rate shocks in about 2–3 months. Consumer rates exhibit a high mark-up, which corresponds with the fact that consumer loans are typically more risky than other types of loans. Consumer rates are not found to have a cointegration relationship with money market rates.[12] Our supposition for this finding is that the pricing of consumer loans is dominated by their risk and that short-term interest rates are less important in this respect. Furthermore, this market is rather concentrated and, at the same time, much less important for banks in comparison to the market for mortgages.

The short-term reaction of corporate loans with floating interest rates is faster than that of household rates and has a large value, suggesting that most money market shocks are absorbed within a month. The short-term reaction of corporate loans with fixed interest rates is insignificant. Large loans typically exhibit smaller mark-ups than small loans. This may suggest some relationship lending; we deal with this issue more comprehensively below.

[11] Consumer loans estimates are excluded from the analysis of the determinants of interest rate pass-through due to their lack of cointegration with money market rates.

[12] The results confirm the cointegration test findings, namely, that we cannot reject the null hypothesis that there is not a cointegration relation between policy-induced rates and consumer rates.

The results in Table 1 (based on the 2004:1–2006:6 data) are similar to those presented in Table 2 (based on the 2006:7–2008:12 data) except that the long-term pass-through seems to decrease somewhat in the later period. The pass-through decreases slightly for the corporate sector, but substantially for households. The decrease for households seems to have been caused by the financial crisis and increased bank prudence and only partially by yield curve effects (for example, the difference between 10-year government bond and PRIBOR rates decreased only modestly during our sample period). The results based on average rates are in most cases similar to those based on median rates and are available upon request. As for this latter period, we also introduce a "global financial crisis" dummy into the long-term equation to investigate if the spread between the money market and bank interest rate increases statistically significantly during the period of financial distress (as the exact date of the financial crisis is not clear, we first use a dummy variable that takes the value of one in 2008:1–2008:12 and alternatively 2008:6–2008:12, and zero otherwise). The dummy variable is never found to be significant, although for certain interest rates on corporate loans the corresponding p-values are between 0.11 and 0.15.

The mean group estimates, as presented in Tables A4 and A5 in the Appendix, typically confirm our previous findings based on the pooled mean group estimator, except that the standard errors are sometimes larger. This is in line with the results of the Hausman test, which are reported in Table A6 in the Appendix.[13] Except for a few cases, we do not reject the null hypothesis that the pooled mean group estimator is more efficient than the mean group estimator. This allows us to assume homogeneous long-run slopes, which implies that banks exhibit homogeneous pricing behavior in the long term, hence supporting the notion of the law of one price.

We also test for coefficient equality across the individual banks and reject the null of common slope coefficients in the short term for all loan categories. This implies that the short-term reaction of bank interest rates to money market shocks is heterogeneous, i.e. it differs bank by bank. The results are reported in Table A7 in the Appendix. Therefore, panel data estimators that impose a common slope, which is typical of this stream of literature with the exception of a few studies (De Graeve et al., 2007), are likely to be inconsistent. Our findings are also in line with Gambacorta (2008), who finds that bank pricing policies are heterogeneous in the short term but homogeneous in the long run in a sample of Italian banks.

[13] See Pesaran et al. (1999) and Blackburne and Frank (2007) for the Hausman test in the context of the pooled mean group and mean group estimation techniques.

Table 1: Interest Rate Pass-Through Estimates: Pooled Mean Group Estimator, 2004:1–2006:6, Median Rate

	Pooled mean group estimates				
Household rates	$\alpha_{0,i}$	$\beta_{0,i}$	β_1	μ	Mean adjustment lag
Mortgage rate	0.18 (0.27)	-0.23*** (0.09)	0.90*** (0.22)	2.44*** (0.51)	3 months
Consumer rate	-0.66 (0.75)	-0.41*** (0.13)	0.33 (0.58)	6.46*** (1.30)	---
Firm rates					
Small loan, floating rate	0.73** (0.32)	-0.35*** (0.07)	0.86*** (0.11)	1.90*** (0.22)	1 month
Small loan, fixed rate	-0.26 (0.60)	-0.30 (0.30)	0.73*** (0.16)	3.22*** (0.40)	3 months
Large loan, floating rate	0.87* (0.53)	-0.51*** (0.10)	1.24*** (0.11)	0.24 (0.22)	1 month

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. The mean adjustment lag is calculated as $(\beta_1 - \alpha_0)/\beta_0$. The resulting number is rounded. The mean adjustment lag is calculated only for series that have a significant long-run relationship.

Table 2: Interest Rate Pass-Through Estimates: Pooled Mean Group Estimator, 2006:7–2008:12, Median Rate

	Pooled mean group estimates				
Household rates	$\alpha_{0,i}$	$\beta_{0,i}$	β_1	μ	Mean adjustment lag
Mortgage rate	0.03 (0.16)	-0.19** (0.08)	0.36*** (0.09)	3.87*** (0.24)	2 months
Consumer rate	0.15 (0.37)	-0.45*** (0.14)	0.31 (0.19)	6.31*** (0.49)	---
Firm rates					
Small loan, floating rate	0.58*** (0.12)	-0.15*** (0.06)	0.77*** (0.06)	2.83*** (0.23)	1 month
Small loan, fixed rate	-0.10 (0.88)	-0.29*** (0.09)	0.57*** (0.12)	2.98*** (0.41)	2 months
Large loan, floating rate	0.45** (0.18)	-0.50*** (0.08)	0.96*** (0.04)	0.56*** (0.15)	1 month

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. The mean adjustment lag is calculated as $(\beta_1 - \alpha_0)/\beta_0$. The resulting number is rounded. The mean adjustment lag is calculated only for series that have a significant long-run relationship.

Table 3: Interest Rate Pass-Through Estimates:DOLS-Swamy Estimator, 2004:1–2008:12, Median Rate on Loans

Household rates	$\alpha_{0,i}$	$\beta_{0,i}$	β_1	μ	Mean adjustment lag
Mortgage rate	-0.13	-0.34**	0.62***	3.2***	2 months
	(0.23)	(0.11)	(0.03)	(0.09)	
Consumer rate	0.2	-0.4***	-0.33	12.04***	---
	(1.13)	(0.12)	(0.20)	(0.44)	
Firm rates					
Small loan, floating rate	0.70**	-0.54***	0.94***	2.50***	1 month
	(0.15)	(0.11)	(0.06)	(0.15)	
Small loan, fixed rate	0.52	-0.49***	0.95***	2.85***	1 month
	(0.44)	(0.2)	(0.9)	(0.3)	
Large loan, floating rate	0.90***	-0.53***	0.81***	0.17***	< 1 month
	(0.27)	(0.1)	(0.03)	(0.1)	
Large loan, fixed rate	0.90	-0.80***	0.78***	2.40***	< 1 month
	(2.2)	(0.27)	(0.08)	(0.22)	

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. The mean adjustment lag is calculated as $(\beta_1 - \alpha_0)/\beta_0$. The resulting number is rounded.

Table 4: Interest Rate Pass-Through Estimates:DOLS-Swamy Estimator, 2004:1–2008:12, Median Rate on Deposits

Deposit rates	$\alpha_{0,i}$	$\beta_{0,i}$	β_1	μ	Mean adjustment lag
Maturity up to 2 years	0.66***	-0.61***	0.93***	-0.35***	< 1 month
	(0.09)	(0.09)	(0.02)	(0.03)	
Maturity above 2 years	0.68	-0.28*	0.47***	1.06	< 1 month
	(0.63)	(0.14)	(0.06)	(0.18)	

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. The mean adjustment lag is calculated as $(\beta_1 - \alpha_0)/\beta_0$. The resulting number is rounded.

Tables 3 and 4 present the results of the DOLS-Swamy methodology applied to the period 2004:1–2008:12. Regarding the results concerning loans (see Table 3), the error correction coefficient – the so-called "speed of adjustment" – is significant and negative in all cases considered, showing the presence of a mechanism to bring bank interest rates back to their long-term equilibrium. For bank interest rates to non-financial corporates**,** all four rates have a significant long-run pass-through parameter (β_1), but the long-run transmission is complete only for small loans. The fact that for large loans the long-term parameter is smaller than one, meaning incomplete pass-through, may indicate the presence of relationship lending between banks and clients in the case of large loans.

Regarding the immediate pass-through, α_0, within one month, we notice positive and highly significant coefficients for the loan categories with floating rates for both small and large loans, confirming that floating rates follow money market rates very closely. 70% of the transmission for

small loans and 90% for large loans takes place within a month. On the other hand, bank interest rates which are set for more than one year do not respond within one month. The constant term in the equilibrium relation indicates the mark-up of the bank embedding the competitive conditions in the market, risk, the elasticity of demand, regulatory factors or maturity (de Bondt, 2005). Similarly to the results for the sub-periods in Tables 1 and 2, the results indicate that large loans exhibit smaller mark-ups than small loans.[14] Table 4 presents the estimates of the interest rate pass-through for deposit rates. There is a clear error-correcting mechanism for both categories and the speed of interest rate pass-through seems to be high.

Interest rates on mortgage loans have a long-term coefficient that is significant but suggesting incomplete transmission. Mortgage loans do not respond to policy-induced loans within one month. The results for interest rates on consumer loans confirm the findings from Tables 1 and 2 and reveal a very high mark-up signaling the perceived high risk associated with this type of loan.

In the context of the global financial crisis, we also compared the coefficients for the period January 2008–December 2008 with those for the whole period under observation to capture any difference in the pass-through.[15] Regarding corporate loans with floating rates we notice a slightly smaller pass-through for small loans and a smaller speed of adjustment for large loans. In the case of loans with fixed rates, we do not see any significant difference. The only difference in the case of household loans, i.e. mortgage loans, pertains also to the speed of adjustment, namely, a lower speed of adjustment. In the context of decreasing market rates, these findings could signal banks' reluctance to follow money rates as a result of strengthened bank prudence and the aim to avoid too risky projects.[16]

As a further sensitivity analysis, we also include euro area short-term interest rates in Eq(3) and Eq(4) (both in levels and in changes). A small open economy such as the Czech Republic, which is in the process of integrating into European Union structures, exhibits a very high penetration of foreign banks. In consequence, euro area money market interest rates and not only domestic rates might be important for the determination of domestic bank interest rates, too. Nevertheless, our results (available upon request) suggest that euro area money market rates do not matter for Czech interest rate pass-through. This probably reflects the fact that loans are typically granted in the domestic currency (for example, there are virtually no mortgages granted in foreign currency, see Financial Stability Report, 2007), and the ratio of deposits to deposit and non-deposit funding is in general rather high.

[14] For the category of large loans with fixed rates, we have data for only seven banks (similarly for deposits with maturity above two years), as many small banks grant this type of loan irregularly. Therefore, the estimates for this category are provided only in Table 3 and not in Tables 1 and 2. We apply the pooled mean group estimator in Tables 1 and 2, which relies on the assumption of large N and large T, which is obviously not met for N=7. The share of corporate loans with fixed interest rates is not high and amounts only to about 10% (Financial Stability Report, 2007). Therefore, the results on loans with floating rates are much more important from the macroeconomic perspective. Next, we also estimate the interest rate pass-through with data on three large banks only, but do not find any systematic differences.

[15] Practically, we tested whether the coefficients for the period 2008:1–2008:12 are somehow different from the results covering the whole time span.

[16] An analysis of the average standard deviation over large banks' standard deviations of the monthly distributions shows an increasing trend in the second half of 2008 for floating rates. This probably indicates that banks are differentiating between clients as a result of a deterioration in borrowers' risk profiles and increasing bank prudence. The results are available upon request.

It is noteworthy that our results concerning interest rates on loans to the non-financial sector are not fully comparable with the literature, and in particular with studies for the euro area (i.e. de Bondt, 2005) because our data are structured not according to loan maturity (like the data used in most of the previous literature), but according to the time span for which the interest rate is fixed, as the current EU standards require.

Table 5: Determinants of Interest Rate Pass-Through, Cross-section of Czech Banks, Robust Regression

Sample	2004:1–2006:6		2006:7–2008:12	
	Dependent variable		Dependent variable	
	Spread	LT PT	Spread	LT PT
Liquidity	-0.04*	0.03*	-0.05	0.01*
	(0.02)	(0.02)	(0.03)	(0.01)
Capital Adequacy	-0.08*	-0.12	0.18	-0.03
	(0.04)	(0.22)	(0.15)	(0.03)
Inefficiency	0.48	-0.56	-0.69	-0.26
	(0.91)	(2.25)	(1.39)	(0.27)
Deposits	5.25***	-2.59***	8.3***	-2.01***
	(1.67)	(0.64)	(2.73)	(0.49)
Bank Size	-0.08**	0.03***	-0.01	0.01
	(0.03)	(0.01)	(0.01)	(0.01)
Credit Risk	2.01	0.28**	1.55	1.25
	(2.69)	(0.13)	(5.73)	(1.11)
No. of observations	45	45	45	45
Adjusted R-squared	0.45	0.43	0.26	0.34

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. LT PT stands for long-term pass-through, $\beta_{1,i,j}$. The spread, $\mu_{i,j}$, is a constant from the error correction equation. Different loan products are stacked together.

We present the results on how bank characteristics influence the nature of interest rate pass-through in Table 5. We chose to apply robust regression instead of the more typical ordinary least squares, as the sample size is not large and we spotted some outliers among the bank characteristics. Following Goodall (1983), the tune for the robust regression is chosen to be 7.

We provide results on the determinants of the spread as well as the long-term pass-through. The choice of determinants follows de Graeve et al. (2007), who analyze the determinants of pass-through in the Belgian market. In addition to their set of explanatory variables, we include credit risk as an additional potential determinant of interest rate pass-through. As the bank characteristics are averages over the sample period, we divide the full sample into two parts: 2004:1–2006:6 and 2006:7–2008:12.

As concerns the spread in the period 2004:1–2006:6, we find that more capitalized banks charge a lower spread. This contrasts with the prediction of Ho and Saunders' (1981) dealership model,

where net interest rate margins should increase the capital base as the exposure to risk increases. Our finding is rather in line with the hypothesis raised by Brock and Franken (2003), who put forward that less capitalized banks have the motivation to accept more risk (associated with a higher spread) in order to receive higher returns. Analogously, more capitalized banks invest more cautiously, as there is more capital at risk (Brock and Franken, 2003). Banks exhibit larger spreads if their funding depends more heavily on deposits (our proxy for relationship lending). This complies with the hypothesis put forward by Berlin and Mester (1999) that banks with a stable pool of deposits smooth market shocks for customers and maintain a higher spread as compensation for stable bank interest rates. Indeed, our results for the long-term pass-through support this supposition, as we find that $deposit_{i,j}$ have a negative effect on the long-term pass-through, i.e. evidence that banks provide loan rate smoothing. Large banks set lower margins, which is suggestive of economies of scale (see Horvath, 2009, on related evidence on which factors drive the net interest margins of Czech banks). Inefficiency[17] and credit risk are found to increase the spread, but their effects are not statistically significant (if we use credit risk as a single regressor, it becomes significant). All in all, the results show that bank financial characteristics affect the spread. The results for the period 2006:7–2008:12 confirm these findings to a certain extent. The difference is that the standard errors are larger and the R-squared decreases somewhat.

As regards the long-term pass-through in the period 2004:1–2006:6, the evidence suggests that there is some loan rate smoothing, as the variable $deposit_{i,j}$ has a negative sign. In other words, the results imply that a bank with a greater degree of relationship lending smooths loan rates more (Berlin and Mester, 1999, and Gambacorta, 2008) and broadly support the findings of Geršl and Jakubík (2009) on relationship banking in the Czech Republic. Nevertheless, this result stands in contrast to evidence on Belgium which does not find relationship lending to be significant (De Graeve et al., 2007). The results also indicate that large banks' pricing policies are more sensitive to money market shocks in comparison to small banks. This is likely to be a consequence of the composition of our sample, where several small banks are actually branches of foreign banks. Interestingly, the effect of liquidity is positive, which is at variance with the findings of Kashyap and Stein (2000) and Pruteanu-Podpiera (2007) that less liquid banks are more vulnerable to market conditions (see also De Graeve et al., 2007, who find a negative effect of liquidity). We hypothesize that this finding is due to the high liquidity that Czech banks maintained during our sample period (see Financial Stability Report, 2007). Greater credit risk increases sensitivity to money market shocks, but we fail to find it significant for the latter period.

5. Concluding Remarks

In this paper we estimate the interest rate pass-through from money market to bank interest rates using various heterogeneous panel cointegration techniques to address bank heterogeneity. Based on our data from the Czech Republic, the results indicate that the interest rate pass-through differs across banks in the short term (rendering estimators that impose common slope parameters inconsistent) and the pricing becomes homogeneous in the long term, supporting the notion of the

[17] The results on inefficiency should be taken with caution, as they may be due to the overly simplistic (although commonly used) measure of inefficiency we use.

law of one price (see Gambacorta, 2008, for similar evidence on Italian banks). Mortgage rates and firm rates typically adjust to money market changes relatively fast, but less than fully in the long run (this is in line with Belgian evidence by de Greave et al., 2007). The results suggest that interest rate pass-through from money market to bank interest rates in the Czech Republic typically took 1-3 months in 2004-2008. Large corporate loans have a smaller mark-up than small loans. Consumer rates have a high mark-up and do not exhibit a cointegration relationship with money market rates.

Next, we investigate how bank characteristics influence the nature of interest rate pass-through in a cross-section of Czech banks. There is evidence for relationship lending, as banks with a stable pool of deposits smooth bank interest rates and require a higher spread as compensation. We find no evidence that large banks price their products less competitively. Greater credit risk increases vulnerability to money market shocks.

We also examine the potential effect of the 2008-2009 global financial crisis on the interest rate pass-through in the Czech Republic. The results indicate that there is some evidence for slower interest rate pass-through for certain loan categories and greater heterogeneity in terms of the interest rates charged for a given loan category can be observed. This is likely to reflect increased bank prudence in response to the deterioration in borrowers' risk profiles. Nevertheless, it has to be emphasized that our sample consists of data up to 2008 and a fuller examination of the effect of 2008-2009 global financial crisis on the interest rate pass-through is left for further research.

In terms of future research, we propose the following direction for empirical investigation. The literature on interest rate pass-through focuses solely on the pass-through from *domestic* short-term interest rates to *domestic* bank interest rates. This is somewhat surprising, as there are many small open economies with high penetration of foreign banks, a significant share of foreign currency lending to firms as well as to households, and with banks that seek external finance in foreign markets. In consequence, it is likely that foreign short-term interest rates will be a vital determinant of domestic bank interest rates.

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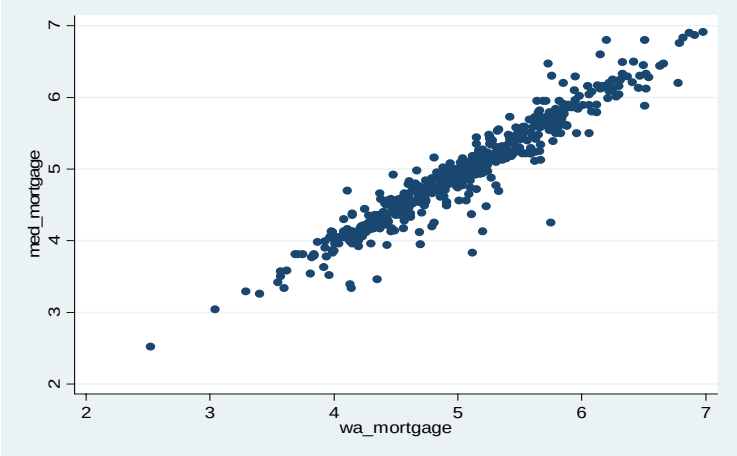
Appendix

Descriptive Statistics Households

Table A1: Descriptive Statistics

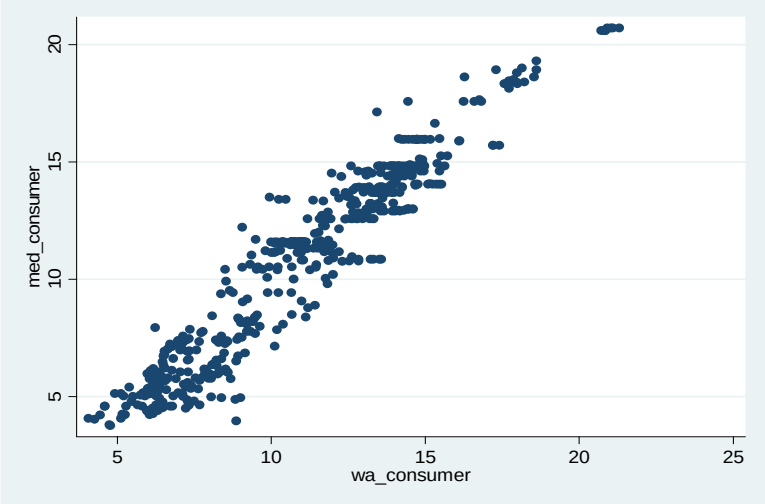
Interest rate	Mean	St. Dev.	Min	Max
Mortgage – weighted average	5.04	0.71	2.52	6.98
Mortgage – median	4.94	0.76	2.52	6.91
Consumer – weighted average	11.05	3.55	4.07	21.31
Consumer – median	10.78	4.10	3.76	20.70

Figure A2: Mortgage Rates – Bank-Specific Average vs. Median Rates



Note: med stands for median rates and wa for weighted average rates.

Figure A3: Consumer Rates – Bank-Specific Average vs. Median Rates



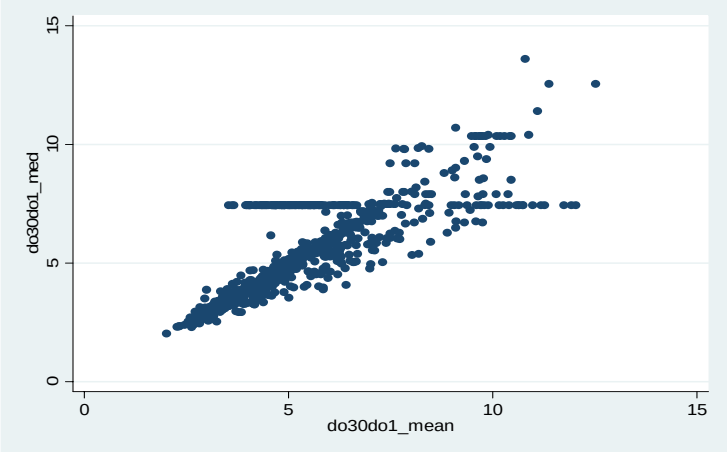
Note: med stands for median rates and wa for weighted average rates.

Firms and Deposits

Table A2:Descriptive Statistics

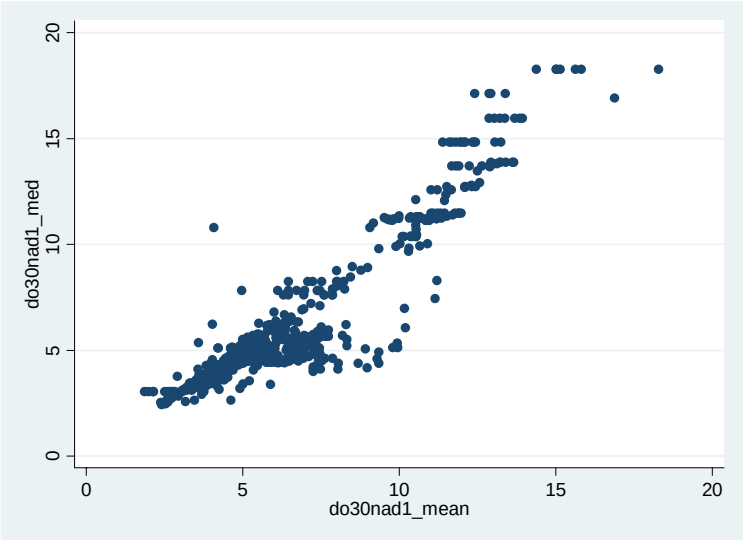
Interest rate	Mean	St. Dev.	Min	Max
Small loan, floating rate – median	5.25	1.88	2.02	13.6
Small loan, floating rate – weighted average	5.22	1.89	0.29	12.53
Small loan, fixed rate – median	6.16	3.25	2.43	18.27
Small loan, fixed rate – weighted average	6.46	2.75	1.86	18.29
Large loan, floating rate – median	3.98	1.28	1.10	15.94
Large loan, floating rate – weighted average	4.08	1.23	0.66	15.02
Large loan, fixed rate – median	4.50	1.26	2.00	10.47
Large loan, fixed rate – weighted average	4.57	1.20	0.44	9.77
Short-term deposits	2.10	0.72	0.80	4.83
Long-term deposits	2.47	0.88	0.50	4.60

Figure A4: Small Loans, Floating Rate – Bank-Specific Average vs. Median Rates



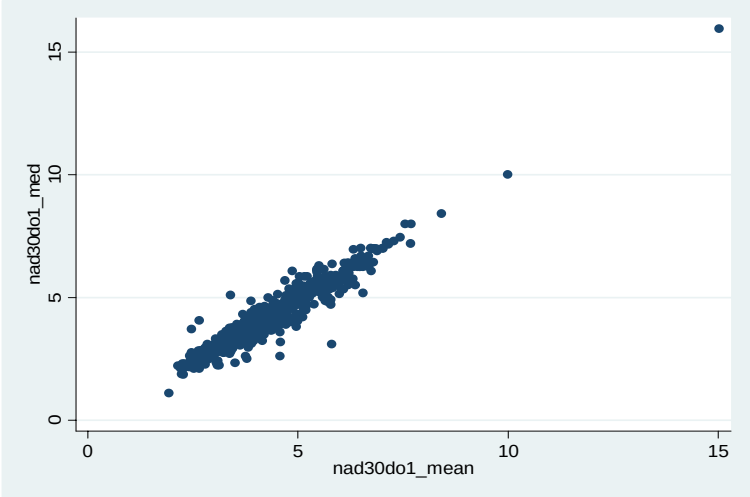
Note: med stands for median rates and mean for weighted average rates.

Figure A5: Small Loans, Fixed Rate – Bank-Specific Average vs. Median Rates



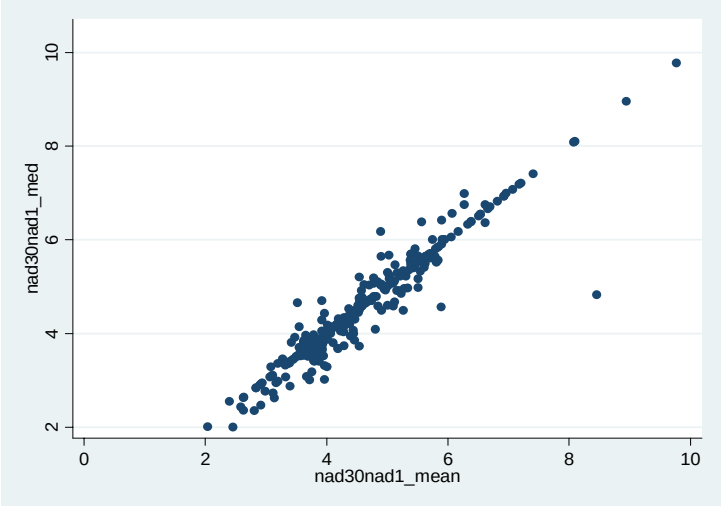
Note: med stands for median rates and mean for weighted average rates.

Figure A6: Large Loans, Floating Rate – Bank-Specific Average vs. Median Rates



Note: med stands for median rates and mean for weighted average rates.

Figure A7: Large Loans, Fixed Rate – Bank-Specific Average vs. Median Rates



Note: med stands for median rates and mean for weighted average rates.

Figure A8: Money Market Rates

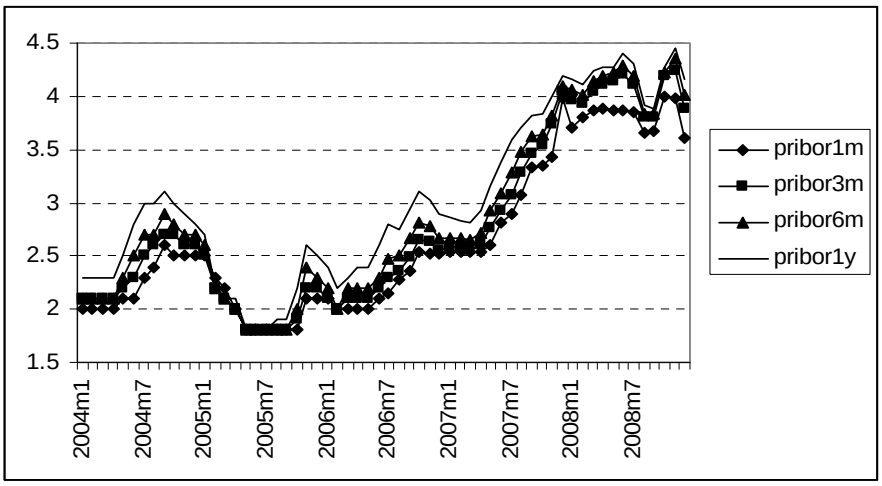


Table A3: Average Correlations with Market Rates of Different Maturities

Bank rates	**1MPRIBOR**	**3MPRIBOR**	**6MPRIBOR**	**1YPRIBOR**
Deposit rates				
Maturity up to 2 years	**0.932**	0.921	0.91	0.876
Maturity over 2 years	0.600	**0.614**	0.61	0.611
Loan rates				
Non-financial sector				
Up to 30 mil CZK				
floating and fixed to 1y	**0.816**	0.811	0.801	0.779
fixed more than 1y	0.594	0.602	0.607	**0.614**
More than 30 mil CZK				
floating and fixed to 1y	**0.685**	0.681	0.68	0.67
fixed more than 1y	0.598	**0.599**	0.557	0.555
Household sector				
Mortgage loans	**0.617**	0.614	0.602	0.583

Note: All correlations are significant at the 5% level.

Table A4: Interest Rate Pass-Through Estimates:Mean Group Estimator, 2004:1–2006:6, Median Rate

	Mean group estimates				
Household rates	$\alpha_{0,i}$	$\beta_{0,i}$	$\beta_{1,i}$	μ	Mean adjustment lag
Mortgage rate	0.21 (0.24)	0.34*** (0.10)	1.59 (1.49)	0.67 (4.55)	---
Consumer rate	-0.39 (1.18)	0.82*** (0.22)	-27.1 (27.3)	76.4 (66.5)	---
Firm rates					
Small loan, floating rate	0.73** (0.32)	0.35*** (0.07)	0.86*** (0.11)	1.90*** (0.22)	1 month
Small loan, fixed rate	-0.29 (0.65)	0.48 (0.32)	0.39 (0.37)	4.99*** (0.40)	---
Large loan, floating rate	2.31** (1.14)	1.02*** (0.11)	5.32 (4.44)	-12.02 (13.72)	---

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. The mean adjustment lag is calculated as $(\beta_1 - \alpha_0)/\beta_0$. The resulting number is rounded. The mean adjustment lag is calculated only for series that have a significant long-run relationship.

Table A5: Interest Rate Pass-Through Estimates: Mean Group Estimator, 2006:7–2008:12, Median Rate

	Pooled mean group estimates				
Household rates	$\alpha_{0,i}$	$\beta_{0,i}$	β_1	μ	Mean adjustment lag
Mortgage rate	0.17 (0.12)	0.29*** (0.10)	0.88 (0.62)	2.95* (1.79)	2 months
Consumer rate	0.05 (0.49)	0.66*** (0.20)	-2.09 (1.64)	16.24*** (5.70)	---
Firm rates					
Small loan, floating rate	0.65*** (0.09)	0.63*** (0.09)	1.02*** (0.11)	1.81*** (0.58)	1 month
Small loan, fixed rate	-0.30 (0.66)	0.68*** (0.09)	0.75** (0.29)	4.19*** (0.95)	2 months
Large loan, floating rate	0.54*** (0.16)	0.85*** (0.07)	0.77*** (0.15)	1.69*** (0.63)	1 month

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. The mean adjustment lag is calculated as $(\beta_1 - \alpha_0)/\beta_0$. The resulting number is rounded. The mean adjustment lag is calculated only for series that have a significant long-run relationship.

Table A6: Interest Rate Pass-Through, Hausman Test, 2004:1–2006:6 (H0: Pooled Mean Group Estimator is More Efficient)

	Hausman statistic	P-value		Hausman statistic	P-value
Mortgage – median	3.11	0.21	Small loan, floating rate – median	1.28	0.52
Mortgage – average	1.86	0.39	Small loan, floating rate – average	6.97**	0.03
Consumer – median	9.16**	0.01	Small loan, fixed rate – median	3.14	0.21
Consumer – average	7.33*	0.03	Small loan, fixed rate – average	1.54	0.46
Large loan, fixed rate – median	2.12	0.35	Large loan, floating rate – median	3.27	0.20
Large loan, fixed rate – average	1.86	0.39	Large loan, floating rate – average	4.27	0.11

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively.

Table A7: Do Bank Pricing Policies Differ in the Short Term? Wald Test of Equality of Coefficients, 2004:1–2006:6
(H0: Bank Pricing Policies are Homogeneous in the Short Term)

	$\alpha_{0,i}$	$\beta_{0,i}$
Household rates		
Mortgage – median	32.65**	62.19***
	(0.02)	(0.00)
Consumer – median	9.59	117.33***
	(0.56)	(0.00)
Firm rates		
Small loan, floating rate – median	14.49	100.64***
	(0.75)	(0.00)
Small loan, fixed rate – median	4.03	34.24***
	(0.40)	(0.00)
Large loan, floating rate – median	16.45	107.50***
	(0.62)	(0.00)
Large loan, fixed rate – median	6.42	1.45
	(0.18)	(0.81)

Note: ***, **, and * denote significance at 1 percent, 5 percent, and 10 percent, respectively. The null hypothesis is that all coefficients across banks are equal. The test statistic is distributed as chi-square with *n-1* degrees of freedom. The test statistic, with p-value in brackets, is presented.

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