INTEREST RATE PASS-THROUGH:
A SYNTHESIS OF EMPIRICAL ANALYSES

Field of study: Economics

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INTEREST RATE PASS-THROUGH:  
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1 Introduction

The interest rate channel of monetary policy is an important transmission channel through which monetary policy affects the real economy. The strength of the pass-through from the monetary policy rate to bank lending rates shows how the policy helps manage economic activity and stabilize prices. Central bankers are thus greatly interested in understanding the extent of the transmission process and the factors that affect it.

Most empirical studies are bound to the pioneer work by Rousseas (1985), who proposed a simple theoretical model of the interest rate pass-through based on the markup-pricing theory. Assuming a perfectly competitive market with perfect information, bank lending rates would change one-to-one with the monetary policy rate (the cost of funding) and one would speak about a complete pass-through. In practice, however, the banking and financial market structures show rather monopolistically competitive or even oligopolistic behavior, which violates this assumption. Hence, the empirical evidence on the interest rate pass-through varies across countries and across different types of loans (Hofmann, 2006; Sorensen and Werner, 2006; Éger et al., 2007; Belke et al., 2013; van Leuvensteijn et al., 2013; Holton and d’Acri, 2015; Gambacorta et al., 2015). For instance, while Rocha (2012) finds a strong pass-through from money market rates to general lending rates for Portugal, Hofmann (2006) finds such pass-through weak for Germany. Further, Sorensen and Werner (2006) detect a higher interest rate pass-through for mortgages and a lower one for consumer loans in the Euro Area. Although Aristei and Gallo (2014) confirm the lowest pass-through for consumer loans rates in the Euro Area, they find the strongest pass-through to lending rates for large corporate loans. Overall, a preliminary survey of the literature may suggest an incomplete interest rate pass-through in general. To synthesize empirical evidence on the strength of the pass-through across countries and lending rates, the thesis conducts a meta-regression analysis of estimates from the existing literature. In doing so, it estimates the precise effect of the interest rate pass-through adjusted from the publication selection bias. Moreover, using the meta-regression analysis, it tests whether the broader economic environment and various macro-financial factors play could affect the interest rate transmission. Overall, the meta-analysis serves as a quantitative literature review thanks to which we can compare the estimation results specific for the Czech Republic to the prevailing results from the existing empirical literature.

The thesis contributes to the interest rate pass-through literature in three ways. First, to the best of our knowledge, the meta-regression analysis has not been used yet to review and synthesize the empirical literature on the interest rate transmission. Therefore, the thesis produces a unique quantitative survey and a new perspective of the topic. Second, the thesis tests the strength of the pass-through in the Czech Republic during the zero lower bound period and during the implementation of unconventional monetary policy in the form of FX interventions. There are only two empirical papers examining the interest rate pass-through solely for the Czech Republic. Horváth and Podpiera (2012) detect fast and almost complete pass-through for mortgages and firm lending rates using the pooled mean group estimation approach. They emphasize that factors such as the bank asset size, bank capital, the amount of deposits, and credit risk affect the pass-through. The study, however, does not cover much of the post GFC period including the use of unconventional monetary policy. Havránek et al. (2016) analyze the interest rate pass-through in the Czech Republic during 2004-13. They find a weaker interest rate pass-through for corporate loan rates and a stronger one for mortgage loan rates after the onset of the GFC. Nevertheless, the interest rate pass-through and its effectiveness in the Czech Republic after 2013 remains under-researched. Third, the thesis
examines the stability of the pass-through and considers possible structural shifts, as well as possible variation in the pass-through with the changing macro-financial environment.

2 Objective and Structure

The main goal of the thesis is fourfold:

- Assess how the monetary policy rate affects the interest rates on consumer, mortgage, small and medium enterprises (SME), and corporate loans in the Czech Republic.
- Compare the experience of the Czech Republic to that of the EU countries and other countries around the world for which comparable estimates of interest rate pass-through exist.
- Inform monetary and financial policy makers by producing the most up-to-date estimates for sample countries (mostly EU countries) and specifically for the Czech Republic, highlighting the structural factors and other policy interventions, which could materially affect the interest rate pass-through.
- Develop an analytical framework that researchers in policy making institutions, academia, and the private sector could use to periodically assess the pass-through, and that could be used to analyze the pass-through in the Financial Sector Assessment Programs run by the IMF and World Bank as well as build technical capacity for such analysis in central banks of less developed countries.

To meet this goal, the thesis postulates four research questions:

- Does the interest rate pass-through in the Czech Republic differ from that found in other countries?
- Does it vary according to the specific segment of loans—that is, mortgage, consumer, SME, and corporate loans?
- Are there any macro-financial factors that materially affect the interest rate pass-through in general and in the Czech Republic specifically?
- Has the interest rate transmission in the Czech Republic been stable over time?

To answer these research questions, the thesis continues to analyze the interest rate pass-through in the Czech Republic from January 2004 to March 2018 in four segments of loans. Moreover, we test whether the interest rate pass-through has been materially affected by the GFC—which had spillover effects on the Czech economy—as well as by the post crisis environment—which included significant financial market and policy adjustments. We also examine whether factors such as bank credit risk, bank competition, bank deposits structure, and foreign exchange interventions significantly influence the interest rate pass-through in the Czech Republic. Because of the possible substitution effect between making a risky loan to the private sector against a “risk-free” loan to the government sector, we further control for the effect of government bond yields. In addition, we test for possible non-linearities in the pass-through using the interaction of each macro-financial variable with the monetary policy rate. To verify the results, we perform several stability tests.

The dissertation thesis is structured into seven chapters. After the introduction, Chapter 2 presents theoretic overview of monetary policy. It offers a general description of the
monetary policy goals, tools, regimes and transmission channels. Chapter 3 presents the theoretic underpinning of the interest rate pass-through. More precisely, the chapter explains the Rousseas’ (1985) model of the interest rate pass-through based on the markup-pricing theory. This model plays a crucial role in the thesis because we extend its baseline specification and use the extended model for the estimation in Chapter 6.

Chapter 4 defines several approaches to the interest rate pass-through modelling used across the empirical literature. Thus, one may compare a different methodological approach across different studies. Chapter 5 systematically synthetizes the interest rate pass-through literature. At the beginning of the chapter, we outline the principles of meta-regression analysis and comment on several papers that offer an overview of the pass-through literature. Further, we describe the methodology of data collection and the typical (most common) paper on the interest rate pass-through, highlighting several relevant factors that might have been under-researched. To apply the meta-regression analysis, we first describe the data and specify the model. Then, we define the estimation results and perform several robustness tests. We conclude the chapter by a discussion of the results in a broader context.

Chapter 6 includes the analysis of the interest rate pass-through in the Czech Republic and as such forms the main part of the dissertation thesis. The chapter is divided into seven interconnected subsections. At the beginning, we briefly outline monetary policy conducted in the Czech Republic during the last decade. After the introduction, we follow up on the Rousseas’ (1985) model defined in Chapter 3. We extend this model to include several macro-financial determinants of banks’ interest rates, which breaks down Rousseas’ (1985) assumption about a time invariant spread between the interest rates. Further, we describe the data for the analysis of the interest rate pass-through and outline the summary statistics of those data series. In addition, we display a correlation matrix of the data series and perform several unit root tests. The fourth subsection defines the ARDL modelling approach. We discuss the advantages of this approach and describe a simple model. Then, we outline the estimation results. We start with the baseline model results, then we test for possible structural breaks, and lastly we examine the non-linear dependence of the estimated pass-through on varying macro-financial conditions. At the end of the chapter, we perform a variety of stability tests, and discuss the results.

Chapter 7 highlights the most important findings of the thesis, compares the general results of the meta-regression analysis with the analysis of the interest rate pass-through in the Czech Republic, and concludes the dissertation thesis.
3 Content of the Doctoral Thesis

1 Introduction
2 Monetary Policy Overview
   2.1 Unconventional Monetary Policy
   2.2 Monetary Policy Transmission Channels
3 The Markup-Pricing Theory by Rousseas
4 The Interest Rate Pass-Through Models across the Empirical Literature
5 Meta-Analysis of the Interest Rate Pass-Through
   5.1 Method for Paper Selection
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6 Analysis of the Interest Rate Pass-Through in the Czech Republic
   6.1 Monetary Policy in the Czech Republic
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   6.4 Estimation Methodology
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      6.5.2 Testing for Possible Structural Shifts (Breaks)
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   6.6 Stability Tests
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      6.6.2 The CUSUM and CUSUM of Squares Test
   6.7 Discussion
7 Summary and Conclusions
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List of Abbreviations
4 Procedure

The doctoral dissertation thesis is split into two main parts. In the first part, we apply meta-regression analysis to get deeper insights into the empirical research of the interest rate-pass-through. Meta-regression analysis (MRA) is a method for a quantitative literature review. It summarizes and explains the variation of different results across the same research phenomenon (Stanley et al., 2013). In the field of economics, this quantitative tool is useful in several areas. For instance, Crespo-Cuaresma et al. (2014) examine determinants of foreign currency loans in CESEE countries. Havránek et al. (2015) use the meta-analysis to test the social cost of carbon, and Arnold et al. (2014) examine the determinants of corporate hedging. The diverse use of the meta-regression analysis shows a strong interest and support for the use of this quantitative tool.

To the best of our knowledge, no study that uses the complex approach of the meta-regression analysis for the interest rate transmission has been published yet. Therefore, this thesis offers a unique view on the problem. Nevertheless, several recent studies summarize the empirical research on the interest rate pass-through. For instance, Sorensen and Werner (2006) survey 22 papers, covering aspects such as the type of data, econometric approach, reference rate, and time span. Andries and Billon (2016) review the empirical literature by comparing methodological approaches across studies and their implications for the estimated pass-through. Several papers also provide insights into the pass-through process from specific perspectives. For instance, Marotta (2009) reviews the literature on short-term business lending rates. Aziakpono and Wilson (2013) focus on the possible asymmetry in the interest rate pass-through, and Grigoli and Mota (2017) survey the pass-through studies for the Dominican Republic. The literature also analyses the transmission of changes in the monetary policy rate to deposit rates, which is documented to be weak on average. Nevertheless, we focus the survey only on the transmission to lending rates for a greater homogeneity of the meta-analysis.

For the meta-analysis, we collect the interest rate pass-through coefficients from empirical studies focusing on this topic. In doing so, we cover both publications in peer-reviewed journals and the gray literature (working and discussion papers), to address possible issues with publication bias and to consider the latest empirical research. The completed dataset includes 52 studies and 1040 extracted coefficients of the interest rate pass-through. To summarize the empirical estimates from the literature, we start by describing the typical paper on the interest rate pass-through and highlight several relevant factors that might have been under-researched.

The meta-analysis considers three types of factors affecting the pass-through estimates. First, it considers the individual characteristics of a study such as the functional form applied in the estimation, the type of data, and the impact factor of the journal/paper. Such consideration allows us to control for possible estimation biases due to different methodological approaches, data, and journal selectivity. Second, the meta-analysis considers the importance of the macro-financial environment. We use control variables for the level of economic development, openness of the economy, and financial depth, among others. Third, the meta-analysis considers monetary policy characteristics such as the central bank independence, monetary policy framework, and exchange rate regime. The macro-financial and monetary policy factors can help identify the economic and institutional environment that boosts or reduces the transmission of the monetary policy rate to bank lending rates.
In the second part of the dissertation thesis, we focus directly on analysis of the interest rate pass-through in the Czech Republic using data from January 2004 to March 2018. To be more specific, we estimate the pass-through for consumer, mortgage, SME, and corporate lending rates employing the ARDL modelling approach. The analysis is based on the model by Rousseas (1985). He defines a simple markup equation for commercial banks:

\[ i = k(u) \]  \hspace{1cm} (4.1)

where \( i \) is the bank lending rate, \( k \) is a bank market power (market concentration), and \( u \) is the unit prime cost of banks. Rousseas (1985) assumes that the bank can obtain funds through the financial market. Therefore, the unit prime cost of banks represents the interest paid on deposit and borrowed funds.

Higher market power and higher unit prime costs of the bank lead to an increase in bank lending rates. Since banking market structure is not perfectly competitive, one can assume a permanent markup over the bank costs of funds for lending rates. Assuming a constant markup, Equation 4.1 could be written in a linear form as:

\[ i = \alpha + \beta \cdot u, \]  \hspace{1cm} (4.2)

where \( \alpha \) is the interest rate spread (or markup over the bank cost of funds) and \( \beta \) is a degree of the pass-through from the bank cost of funds to its lending rate. Rousseas (1985) suggests approximating the cost of funds with the monetary policy rate (\( mpr \)). Hence, changes in the main monetary policy rate can determine bank lending rates:

\[ i_t = \alpha + \beta \cdot mpr_t. \]  \hspace{1cm} (4.3)

Further, Rousseas (1985) assumes that the mark up over the policy rate (\( \alpha \)) tends to be stable over time. However, the mark up may differ in time depending on variety of external factors. Thus, we extend Equation 4.3 to capture a time-varying spread:

\[ i_t = (\alpha_1 + \alpha_{2,t}) + \beta \cdot mpr_t, \]  \hspace{1cm} (4.4)

where \( \alpha_1 \) is a constant and \( \alpha_{2,t} \) is the time-varying spread. Failing to account for the possible time-varying component of the spread, \( \alpha_{2,t} \), could bias the \( \beta \) estimate. Therefore, \( \alpha_{2,t} \) is determined by vector \( X_t \) that includes variety of macro-financial factors:

\[ \alpha_{2,t} = \gamma X_t + \epsilon_t. \]  \hspace{1cm} (4.5)

In the thesis, we test for factors such as the bank competition, credit risk, spread of government bonds, structure of liabilities, and unconventional monetary policies.

The bank competition is probably the most commonly used co-determinant of the interest rate pass-through. For instance, Mojon (2000) and van Leuvensteijn et al. (2013) using different measures of bank competition find that the pass-through is faster and more complete at higher levels of bank competition. Consequently, we expect that a higher bank competition
boosts the transmission from the main monetary policy rate to the individual bank lending rate.

The credit risk premium is related to the problem of asymmetric information. Since commercial banks cannot easily distinguish between credit worthy borrowers and risky borrowers, they must assume default of some loans. The probability of default may rise when the lending rate rises. Stiglitz and Weiss (1981) differentiate two effects: (i) adverse selection and (ii) moral hazard. The adverse selection effect describes the situation when growing interest rates push out safer but less profitable loans, and, in contrast, attract riskier projects with higher expected returns.

The moral hazard effect concerns a borrower’s investment decision. Higher lending rates force the borrower to invest in riskier projects to obtain higher returns. As a result, banks, after reaching an optimal lending rate level, may be unwilling to further increase the interest rate because of the higher probability of default (credit rationing). This situation leads to upward stickiness of lending rates. However, banks do not have to ration the credit. Instead, they can increase the risk premium on loans (de Bondt, 2005), which would result in overestimating the retail rate pass-through ($\beta > 1$). To avoid this possible bias, we control for borrower’s credit risk.

Further, when the interest rates are at zero lower bound (ZLB), the credit risk could play a different role. In the post-crisis environment, banks usually tighten their lending standards and even though the monetary policy is eased, the supply of loans is restricted (Plašil et al., 2012-13; Bijsterbosch and Falagiarda, 2014; Altavilla, et al., 2015). Moreover, right after the crisis banks typically evaluate new loans with greater risk premium. This, in turn, leads to a downward stickiness of interest rates.

The alternative return from investing in government bonds is reflected by the spread between government bond yields and the repo rate and captures the impact of fiscal policy and time varying sovereign risks. Using government bonds as an alternative asset to loans may shift bank decisions from commercial lending to governments lending, especially in the post-GFC period. In addition, government bonds reflect the expectations about the future path of short-term rates, which further affect the setting of long-term lending rates (Hofmann and Mizen, 2004). Therefore, movements in the government bond markets, including because of external demand factors, could affect the pass-through of the monetary policy rate to lending rates. Focusing on the EU countries, Eller and Reininger (2016) report that long-term bond yields significantly affect the long-term lending rates in most Eurozone countries, but not in Central and Eastern European countries. In addition, Zoli (2013) examines the role of sovereign bond spread in Italy’s pass-through, and finds a significant effect on business lending rates. Darracq-Paries et al. (2014) concurs with Zoli’s finding, estimating a significant effect of the sovereign spread on households and corporate rates in Italy, Spain, and Portugal.

We also use two other co-determinants of the pass-through: bank deposits to assets ratio and stock of foreign currency reserves as a proxy for foreign exchange interventions. For both of these co-determinants, we expect a positive impact on lending rates.
5 Methods Applied

In the thesis, we use a series of regression models estimated using the ordinary least squares (OLS) method. First, to offer a quantitative review of the interest rate pass-through literature, and to determine factors that systematically affect the transmission process across conducted empirical studies, we use the meta-regression analysis (MRA). Namely, we conduct a panel regression analysis of available pass-through estimates with study fixed effects. For a robustness test, we also apply a model with random effects. Further, to analyze the interest rate pass-through in the Czech Republic, we use the Autoregressive Distributed Lag (ARDL) modelling approach. This approach allows identifying and estimating the short-run dynamic relationship as well as long-run co-integration relationship simultaneously. To verify the stability of our estimation results, we use the multiple-breakpoints test, rolling regressions, the cumulative sum (CUSUM) test, and the cumulative sum of squares test.

5.1 Meta Regression Analysis

In the literature, meta-regression analyses mostly apply the estimation methodology formulated by Stanley and Jarrell (1989):

\[ \beta_i = a + \sum_{k=1}^{K} c_k \cdot Z_{ik} + \epsilon_i, \]  

where \( \beta_i \) is the variable capturing the effect size of the research phenomenon—in the thesis the ith interest rate pass-through estimate, \( a \) is the constant that reflect the true size of the effect, \( Z_{ik} \) is a vector of control variables, and \( \epsilon_i \) is the error term. Subscript \( i \) stands for the number of pass-through coefficients in the sample, and \( k \) represents the number of conditioning variables. According to Stanley and Jarrell (1989) \( Z_{jk} \) might include: (i) dummy variables showing whether the original study includes or omits independent variables possibly relevant for the research; (ii) specification variables that capture the differences in methodology and data definitions or sources, (iii) variables reflecting the sample size, (iv) variables that capture specific authors’ characteristics, and (v) variables measuring the research or data quality.

We expand this model to add external factors such as macro-financial variables and monetary-policy characteristics to control for specific country context that could affect the interest rate pass-through. Moreover, to capture the effect of publication selectivity, we regress the extracted pass-through coefficients on its estimated standard errors as Stanley et al. (2008) and Havránek and Sedlaříková (2014) do as well:

\[ \beta_i = a + b \cdot se_i + \sum_{k=1}^{K} c_k \cdot Z_{ik} + \sum_{l=1}^{L} d_l \cdot M_{il} + \sum_{r=1}^{R} e_r \cdot P_{ir} + \epsilon_i, \]  

where \( \beta_i \) is the ith interest rate pass-through estimate extracted from the studies, \( a \) represents a constant measuring the true size of the interest rate pass through, \( b \) shows the publication selectivity bias, \( se_i \) is the estimated standard error of the ith interest rate pass-through estimate, \( Z_{ik} \) is a vector of study-specific factors, \( M_{il} \) is a vector of macro-financial factors specific to the studied country, \( P_{ir} \) is a vector of monetary policy factors specific to the studied country,
and $\epsilon_i$ represents the error term. Subscript $k$ represents the number of study-specific variables, subscript $l$ shows the number of macro-financial variables, and subscript $r$ defines the number of monetary policy variables.

To mitigate possible problems with heteroscedasticity, we weight all variables in the model by the standard errors of the pass-through coefficients extracted from the studies as in Stanley and Jarrell (1989), Havránek and Sedláříková (2014), and Havránek et al. (2015). In addition, the weighted model assigns greater weights to the estimates that are more precise, which ensures more robust results compared with the standard OLS (Gallet and Doucouliagos, 2014). Therefore, when divided by the standard error of the estimates, $se_i$, Equation 5.2 takes following form:

$$ t_{stat_i} \equiv \frac{\beta_i}{se_i} = a \left( \frac{1}{se_i} \right) + b + \sum_{k=1}^{K} \frac{c_k \cdot Z_{ik}}{se_i} + \sum_{l=1}^{L} \frac{d_l \cdot M_{il}}{se_i} + \sum_{r=1}^{R} \frac{e_r \cdot P_{ir}}{se_i} + \frac{\epsilon_i}{se_i}. $$

Nevertheless, the interpretation of the meta-regression coefficients does not change: $\alpha$ reflects the true size of the pass-through coefficient, and $\beta$ measures a possible asymmetry (publication selectivity) of the pass-through.

Some relevant study-specific factors may still be missing in the specification of meta-regression. Therefore, we organize the data into a panel and estimate a regression model with fixed effect (FE) to control for study-specific effects:

$$ t_{stat_{ij}} \equiv \frac{\beta_{ij}}{se_{ij}} = a \left( \frac{1}{se_{ij}} \right) + b + \sum_{k=1}^{K} \frac{c_k \cdot Z_{ijk}}{se_{ij}} + \sum_{l=1}^{L} \frac{d_l \cdot M_{ijl}}{se_{ij}} + \sum_{r=1}^{R} \frac{e_r \cdot P_{ijr}}{se_{ij}} + \omega_j + \frac{\xi_{ij}}{se_{ij}}, $$

where $\xi_{ij} = \frac{\epsilon_{ij}}{se_{ij}}$, $i$ stands for $i$th pass-through estimate, $j$ stands for studies, and $\omega_j$ is the study-specific fixed effect. In addition, we cluster standard errors at the study level to mitigate the problem of within group correlation. For this procedure, we use bootstrap standard errors (Cameron et al., 2008).

### 5.2 Autoregressive Distributed Lag Modelling Approach (ARDL)

In the second part of the dissertation thesis, we focus on the interest rate pass-through in the Czech Republic. In doing so, we employ the Autoregressive Distributed Lag (ARDL) model developed by Pesaran and Shin (1999) and Pesaran et al. (2001). Using this model, we estimate the assumed co-integration relationship and the associated short-run dynamics. The advantage of the model is that it allows to use stationary time series I(0) as well as first order integrated time series I(1). Moreover, we can distinguish between short-run and long-run

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1 To test the robustness of our estimates, we also employ the model with random effects.

2 Phillips (2018) using the Monte Carlo simulations demonstrates that the ARDL-Bounds testing procedure performs overall better than other co-integration tests such as the Johansen and Engle-Granger.
reaction of bank lending rates to changes in the monetary policy rate and determine the speed of adjustment toward the long-run equilibrium.

To describe the ARDL model, let’s assume an existing long-run co-integration relationship between variable $x$ and $y$:

$$y_t = \alpha + \beta x_t + \varepsilon_t.$$  \hfill (5.5)

The paper by Pesaran and Shin (1999) shows that the ARDL model exhibits consistency even if used variables are first order integrated, I(1). Hence, it is possible to estimate the co-integration relationship defined in equation (5.5) using the ARDL model. The basic ARDL $(p,q)$ model can be then written as follow:

$$y_t = \delta + \sum_{i=1}^{p} \mu_i y_{t-i} + \sum_{j=0}^{q} \psi_j x_{t-1} + \varepsilon_t,$$  \hfill (5.6)

where $y_t$ is dependent variable, $x_t$ is determining regressor, and $\varepsilon_t$ is an error term. Symbols $p$ and $q$ define lag structure of the model. The equation (5.6) can be further rewritten in the error correction form:

$$\Delta y_t = \sum_{i=1}^{p-1} \mu_i \Delta y_{t-i} + \sum_{j=0}^{q-1} \psi_j \Delta x_{t-j} + \lambda ECT_{t-1} + \varepsilon_t$$  \hfill (5.7)

where $ECT_{t-1}$ represents the error correction term:

$$ECT_{t-1} = (y_{t-1} - \alpha - \beta x_{t-1}).$$  \hfill (5.8)

From the equation (5.6) – (5.8), one can define the adjustment coefficient $\lambda$, and the long-run coefficients $\alpha$ and $\beta$:

$$\lambda = -\left(1 - \sum_{i=1}^{p} \mu_i\right), \alpha = \frac{\delta}{1 - \sum_{i=1}^{p} \mu_i}, \beta = \frac{\sum_{j=0}^{q} \psi_j}{1 - \sum_{i=1}^{p} \mu_i}.$$  \hfill (5.9)

The ECM equation displays the short run dynamics (terms with delta symbol) as well as the long run relationship (terms in parenthesis). The coefficient $\lambda$ represents the speed of adjustment toward the long-run equilibrium. Since we assume a return of the variable to their equilibrium level, the coefficient is expected to be negative and significant. In general, assuming $|\mu| < 1$, higher $\lambda$ (in absolute terms) means faster adjustment.

To confirm the existing co-integration relationship between variables, we use the Bound test proposed by Pesaran et al. (2001). It allows us to compare the estimated F-statistic (Wald statistic) value with border critical values for I(0) and I(1) time series. If the estimated value
of the F-statistic (Wald statistic) is higher than the upper bound value provided by Pesaran et al. (2001), then we can confirm the co-integration relationship. A value lying between the lower and upper bound suggests an inconclusive relationship, and a value that is below the lower bound rejects the co-integration relationship.

5.3 Multiple Break Point Tests

In the dissertation thesis, we also perform several tests of multiple breakpoints to identify any possible structural breaks in the estimated baseline models. For the description of the multiple breakpoint test, we follow the Bai and Perron (1998) framework that considers the regression model with \( m \) unknown breaks:

\[
y_t = X'_t \beta + Z'_t \delta_j + \epsilon_t, \quad t = T_{j-1} + 1, \ldots, T_j, \tag{5.10}
\]

for the regimes \( j = 0, \ldots, m \), and with the breakpoints set as \( T_0 = 1 \) and \( T_{m+1} = T + 1 \). The equation contains two set of variables. While \( X \) covers all non-breaking variables, \( Z \) contains variables, for which the coefficients might vary across the regimes. Accordingly, as Bai and Perron (1998) pointed out, one might differentiate a partial structural change model (Equation 5.10) and pure structural change model that omits the non-breaking variables (Equation 5.11):

\[
y_t = Z'_t \delta_j + \epsilon_t, \quad t = T_{j-1} + 1, \ldots, T_j. \tag{5.11}
\]

To determine an unknown number of break dates, one may employ various tests. Generally, Perron (2005) summarizes two broad approaches. The first follows a global maximizer procedure, which includes the double maximum tests: the UD max test and the WD max test. While the UD max test sets equal weights to all possible breaks, the WD max test sets the weights in such a way that the marginal p-values are equal across all breaks, which, in the case of higher number of breaks, increases the power of the test. Both tests examine the null hypothesis of no break against the alternative of unknown number of breaks. However, the pre-specified maximum of possible breaks, \( M \), limits the number of unknown breaks.

Furthermore, tests based on information criteria also belong to the approach of globally determined breaks. More precisely, one may employ the Schwarz information criterion and Liu-Wu-Zidek (LWZ) criterion, which modifies the Schwarz criterion. Bai and Perron (2003), however, shows that the tests based on information criteria perform worse in the simulation than the sequential and global maximizers tests. Therefore, in the thesis, information criteria tests serve only as control tests.

The second approach uses a sequential technique for the determination of break dates. Tests that use this technique include the Bai-Perron tests of \( l+1 \) versus \( l \) sequentially determined breaks and the Bai test of breaks in all recursively determined partitions. In general, the sequential tests are based on the parameter constancy test. First, it is necessary to define the first break. Then, using this break date, the sample can be split into two subsamples in which it is possible to search for an additional break using again parameter constancy test. Following this procedure, one would get two breakpoints (one for each subsample). The test,

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3 In the Bai and Perron (1998) framework, the equation is specify for regime \( j=1,\ldots,m+1 \) with unknown break dates \( (T_1,\ldots,T_m) \) where \( T_0=0 \) and \( T_{m+1}=T \). In the thesis, however, we do not follow this conventional method rather we use Eviews pre-specify set up.
however, chooses such a breakpoint that helps to diminish the sum of square residual the most. Repeating the whole process again, now using three subsamples, one may test for another break in each subsample and choose again the break date that would minimize the sum of square residuals the most. The whole process continues as long as the rejection of the null hypothesis of no additional break is possible.

Lastly, the Bai-Perron test of $l+1$ versus $l$ globally determined breaks is considered as a kind of hybrid test, which has features of both the sequential as well as the global maximizers tests. This test sets the null hypothesis as an $l$ existing breaks against the alternative of one more existing break ($l+1$). The determination of breakpoint dates lies upon the same principle as for the global maximizers tests. Thus, one uses a global minimization of the sum of square residuals to identify the break date. The difference, however, is that after this procedure, the test sequentially searches for an additional break in each segment.

In summary, there is a variety of available structural breakpoint tests. The sequential tests perform better than information criteria tests. However, they may suffer from the possibility of an early ending sequential procedure that may lead to a false conclusion about the true number of breaks. Perron (2005), thus, suggests using the double maximum tests. In determining the multiple unknown number of breaks, the double maximum tests should ensure slightly better results compared with the sequential and sequential hybrid tests. Therefore, the double maximum tests serve as our preferred tests.

5.4 Rolling Regression

To test the stability of our models in the doctoral thesis, we use a rolling regression. Considering a basic autoregressive model specified as:

$$y_t = \delta + \mu y_{t-1} + \psi x_t + \epsilon_t,$$

we can estimate the individual parameters $\delta, \mu, \psi$ for different period of time. Basically, we roll through the sample of $N$ observations using fixed window of $T$ observations assuming $T < N$, and with a step size set to $k$ observations, where $k = 1, ..., N - T$. Thus, we can derive $\frac{N - T}{k} + 1$ time-varying coefficients of independent variables. Significant deviation of obtain rolling coefficients from the mean value estimated for the whole sample $N$ may refer to a structural break in time series.

5.5 CUSUM and CUSUM of Square Tests

Lastly, we perform the CUSUM and CUSUM of square residual test proposed by Brown et al. (1975). The test uses the recursive residuals. To obtain the recursive residuals, we run the OLS estimation with the sample of $k+1$ observations, where $k$ represents the number of regressors in the model. Then, we add one observation repeatedly until we reach the full sample size model $T-k+1$. From each estimation, we use the estimated coefficients of independent variables to predict the future value of dependent variable. The recursive residuals, $w_t$, are, thus, the scaled forecast of the error term.
The CUSUM test plots the cumulative sum of the scaled recursive residuals:

\[ W_t = \frac{1}{\hat{\sigma}} \sum_{j=k+1}^{t} w_j \]  

against time \( t \) for \( t = k + 1, ..., T \), where \( \hat{\sigma} \) represents the standard deviation of the recursive residuals defined as \( \hat{\sigma} = \sqrt{S_T/(T-k)} \), and \( w_j \) represents the recursive residuals. Assuming constancy of the regressor parameters over the time, the recursive residuals would exhibit zero mean values. This condition, however, is rarely met. Therefore, to examine whether the deviation of the recursive residuals from the zero-mean value is statistically significant, it is necessary to define the critical values at priorly chosen significance level. The CUSUM test uses two symmetrical lines, which define the region for the acceptance of the null hypothesis of the coefficient stability at the chosen significance level. For the construction of the critical lines, Brown et al. (1975) use two end points: \( \{k, \pm a\sqrt{(T-k)}\} \), \( \{T, \pm 3a\sqrt{(T-k)}\} \). The values of \( a \) at the significance levels of 1%, 5%, and 10% are 1.143, 0.948, and 0.850, respectively. Following the standard approach in the econometrics, we choose the 5% significance level as the baseline specification of the critical lines. Therefore, the connecting endpoints for the construction of the critical lines are defined accordingly: \( \{k, \pm 0.948 \cdot \sqrt{(T-k)}\} \), \( \{T, \pm 3 \cdot 0.948 \cdot \sqrt{(T-k)}\} \). If the recursive residuals move outside the region defined by the two critical lines, then the test suggests a parameter instability of the regression model.

The CUSUM of squares test uses the recursive residuals as well but in square form:

\[ s_t = \frac{\sum_{j=k+1}^{t} w_j^2}{\sum_{j=k+1}^{T} w_j^2} \]  

where \( w_j \) represents the recursive residuals. Under the null hypothesis of parameter constancy, the \( s_t \) follows the beta distribution with mean defined as: \( \frac{(t-k)}{(T-k)} \). Therefore, the mean value moves from zero, if \( t \) equals to \( k \) \((t = k)\), to one when \( t \) equals to \( T \) \((t = T)\). Similarly as the CUSUM test, the CUSUM of squares test provides two symmetrical critical lines to determine whether one might accept or reject the null hypothesis. If the cumulative sum of squares residuals moves outside the two critical lines, we reject the null hypothesis of parameter constancy. In other words, the test would suggest a parameter or variance instability.
Summary of Results and Conclusion

The dissertation thesis focuses on the transmission of interest rates—the interest pass-through. In recent years, it has been a widely discussed topic in macroeconomics. For an effective implementation of monetary policy, central bankers need to know how commercial banks and other financial institutions react to changes in the monetary policy rate—the main instrument of monetary policy. During the last decade, the CNB faced difficult conditions. After the GFC, Europe was hit by a sovereign bond crisis, and because of fiscal austerity, the Czech economy fell into a recession. The threat of a very low inflation forced the CNB to lower the monetary policy rate to the zero lower bound. Nevertheless, this policy did not bring about the desired effect. Therefore, the CNB resorted to unconventional monetary policy in the form of foreign exchange interventions. The use of foreign exchange interventions as an alternative monetary policy tool was officially ended in April 2017. Subsequently, in August 2017, the CNB left the zero lower bound for the main monetary policy rate, which now slowly returns towards pre-2008 levels. Considering all these events, the presented analysis provided new insights in the transmission process governing interest rates in the specific context of the Czech Republic.

The thesis aimed to shed light at four research questions: Does the interest rate pass-through in the Czech Republic differ from that found for other countries? Does it vary according to the specific segment of loans—that is, mortgage, consumer, SME, and corporate loans? Are there any macro-financial factors that materially affect the interest rate pass-through in general and in the Czech Republic specifically? Has the interest rate transmission in the Czech Republic been stable over time? The following paragraphs address these questions in turn.

One, using the ARDL modelling approach, the thesis examined the size of the interest rate pass-through for the specific segment of loans in the Czech Republic from January 2004 to March 2018. The analysis revealed that the consumer lending rate does not show any significant pass-through from the reference rate (the repo rate). Banks in the Czech Republic could set their consumer lending rates largely independent of the monetary policy stance. In contrast, the thesis found a significant pass-through for mortgages, SME and corporate lending rates. More precisely, the estimations suggested a complete interest rate pass-through for mortgages prior 2007. After August 2007, however, the size of the pass-through dropped by half suggesting that the mortgage loan segment has been materially affected by the GFC or more precisely by the precautionary measures taken with the onset of the crisis in the EU. This contrasts with the findings by Havránek et al. (2016). Their results suggest a strengthening of the pass-through for mortgages after the crisis. Note that the presented analysis used a longer sample estimates, and Havránek et al. (2016) did not confirm a complete pass-through before the crisis. On the contrary, their results refer to a significantly incomplete interest rate pass-through prior the crisis equaling 0.45. Other difference might be the explicit setting of the break date due to the GFC in the thesis. While Havránek et al. (2016) assumed the beginning of the GFC in September 2008 (Lehman Brothers bankruptcy), we followed the results of the structural breakpoint test and marked the break date to August 2007. Including the second half of 2007 and especially the first half of 2008 in to the pre-crisis sample may weaken the pass-through estimated by Havránek et al. (2016). Overall, most empirical studies focusing on the European countries support our results. For instance, Hristov et al. (2014) and Aristei and Gallo (2014) find a stronger interest rate pass-through to mortgage lending rates prior the GFC.
The pass-through to SME lending rates depends significantly on the deposit structure of banks. The higher share of deposits reduces the strength of the pass-through. When the deposit to assets ratio reaches its mean value, the pass-through to SME lending rates equals only 0.36. Presumably, a higher share of deposits allows banks to act more independently from the monetary policy relying largely on their deposits base. Horváth and Podpiera (2012) detect a negative effect of bank deposits on the long-term pass-through in the Czech Republic as well, and offer a similar explanation. They conjecture that, after a monetary policy shock, banks with a relatively high and stable deposit base can smooth the lending rates because their cost of funding is less immediately affected.

The corporate lending rates exhibit the most robust pass-through, estimated at 0.95. Using the meta-regression analysis and the estimation results for the Czech Republic, we confirmed almost the same size of the pass-through. Thus, the estimates of the interest rate pass-through for the corporate lending rates seem to be robust across all estimations and methods, as well as largely similar across EU countries. They provide strong evidence in favor of nearly complete pass-through, which suggests the high effectiveness of monetary policy in the Czech Republic at least when considering the corporate loans’ segment.

Two, we tested whether the interest rate pass-through depends on the level of bank competition, bank leverage, borrower credit risk, bank deposit ratio, government bond spread, and the use of FX interventions. As for the direct impact on the size of the interest rate pass-through, we found that the deposit structure significantly affects the SME lending rates (see above). Similarly, the pass-through to corporate lending rates depends largely on the level of credit risk measured by the NPL ratio. When the NPL ratio increases (the materialization of credit risk rises), the pass-through tends to be lower. For instance, during the recession, commercial banks may not be willing to respond to the cut in the monetary policy rate in the same extent because they expect higher share of loan defaults in their portfolios. Thus, to compensate for higher risk, they increase the risk premiums, which may partly or fully offset the decline in the monetary policy rate. The conclusion holds well with the results by Gambacorta et al. (2015) and Illes and Lombardi (2013), who study the interest rate pass-through in Italy, Spain, the United Kingdom, and the United States.

In addition, the analysis revealed that several factors affect the lending rate markup (spread). The most important determinant of the markup seems to be the spread between the government bond rate and the monetary policy rate, which captures the influence of a changing term premium and sovereign risk. The increasing spread raises the lending rate markup for the mortgages by almost 0.5 and for the SME rates by 0.3. The pass-through literature supports these results, especially for the long-term lending rates such as the mortgage rates (Liu et al., 2008; Holton and d’Acri, 2015; and Eller and Reininger, 2016). Banks could price the loans based on their maturity structure, and the government bond yields affect the cost of funds for mortgage rates the most.

The markup for SME lending rates is also significantly influenced by the level of CNB foreign currency reserve (the proxy of FX interventions), though in a surprising way. One explanation could be that rising CNB deposits abroad and the foreign currency investments in Czech korunas might not have increased the supply of funds in the Czech economy if these koruna investments stayed abroad. Moreover, the funds that would otherwise flow into the Czech economy stayed invested (in the korunas) abroad. Further, and more in line with common thinking, the SME markup increases when the capital to assets ratio rises and banks deleverage. As for the corporate lending rate markup, we confirmed a significant effect only
for the credit risk (NPL ratio). Therefore, besides the monetary policy rate, credit risk seems to be a key determinant for the corporate lending rates influencing not only the size of the pass-through (see above) but also the markup function.

To shed some light on the macro-financial factors from the cross-country perspective, we outline the results based on the meta-regression analysis. The analysis suggests that more developed and liquid capital markets reduce the interest rate pass-through. Perhaps, during the period of low interest rates, commercial banks reduce the lending rates only partly and instead of granting new loans, they rather invest their excess liquidity in the stock market. The effect tends to be higher for more developed stock markets. In addition, a higher trade openness significantly reduces the interest rate pass-through. For instance, increasing trade openness from 30% to 60% of GDP reduces the pass-through by 0.04. This negative effect may find a good explanation in the increasing role of trade finance with higher levels of trade openness (Demirgüç-Kunt and Maksimovic, 2001; Casey and O'Toole, 2014; and Carbó-Valverde et al., 2016). Thus, more capital flows, trade financing and financing through supply chains lower the interest rate pass-through.

Third, this thesis tested the stability of the interest rate pass-through in the Czech Republic. Using the multiple breakpoints tests, we found significant structural shifts in the model of the interest rate pass-through for the mortgage, SME, and corporate lending rates. As we already mentioned, market expectations about the upcoming crisis caused the structural shift in the pass-through for the mortgage lending rates. For the SME rates, the structural shift can be fully explained, and the model stabilized by allowing the pass-through to vary with different levels of the deposit to assets ratio. For the corporate rates, allowing a similar interaction with the NLR ratio can explain much of the structural shifts—but not all of them. Namely, the markup for corporate rates experienced a structural shift in March 2009. This shift could be associated with the spillovers effect of the GFC.

To gain further insights into the stability of the estimated pass through, we outlined the rolling pass-through for each lending market segment. These rolling pass-through coefficients confirmed the results of the structural breakpoints tests. Therefore, for the baseline specification, the rolling pass-through suggested the instability of the pass-through estimates for all lending rates, especially after 2012. The most volatile rolling pass-through estimated for the consumer rates reflected the overall instability and the lack of the co-integration relationship. The results also confirmed that an increasing credit risk (NPL ratio) weakened the interest rate pass-through to corporate lending rates and, similarly, an increasing deposit to assets ratio reduced the pass-through to SME lending rates. The cumulative sum and the cumulative sum of squares tests confirmed overall stability of the best-fitting models.

The thesis and its finding also provide direction for further research. For instance, future research could test whether commercial banks react differently to the monetary policy rate using the non-linear modelling technique. An analysis based on micro (bank) level data could offer further insights into the examined problems. Especially, the interest rate pass-through to lending rates for clients in different regions could lead to interesting findings. This thesis, however, could not apply any of these approaches because of constraining data availability. Short time series and no access to bank level data limited the extent of the presented studies.

To conclude, this dissertation thesis presented a detailed analysis of the interest rate pass-through for the Czech Republic in the context of the cross-country estimates available in the literature. The results of the thesis can help inform monetary policy in the Czech Republic and
other EU countries, as well as unify market expectations. For instance, when the CNB rises the monetary policy rate, the market for a mortgage loan may expect that the average mortgage rate could increase only partly because of the dependence on the rate on government bond yields. In the same spirit, the CNB may expect that the pricing adjustments of mortgage loans may be slower and only partly effective. Therefore, to prevent an excessive mortgage expansion, the CNB may increase the monetary policy rate even more or use macro-prudential tools such as the limits on the loan to value (LTV) ratio, debt to income (DTI) ratio, and debt service to income (DSTI) ratio, if greater rate increases are not supported by the situation in the real economy.

Another important implication stems from the role of the credit risk in the segment of corporate loans. The CNB’s awareness of commercial banks being highly sensitive to the credit risk in their lending to corporations could help contain credit expansions when needed. Several studies show that lending standards are highly pro-cyclical (Asea and Blomberd, 1998; Dell’Ariccia et al., 2012; Basset et al., 2014). Thus, during economic contractions, banks toughen the lending standards but, during expansions, the standards tend to remain soft. For instance, if Europe falls into a recession and aggregate demand decreases, the CNB could react by cutting the policy rate. However, in such a situation, commercial banks would increase the credit risk premium, which could offset the cut of the policy rate. The resulting pass-through and stimulus would be much weaker than desired. To manage credit cycle more effectively, the CNB could complement the monetary policy easing with a release of countercyclical capital buffer, which has been accumulated during most recent expansion.

The conducted meta-analysis and its framework could be useful for policy makers and development practitioners—including development organizations such as the IMF, World Bank, and the European Bank for Reconstruction and Development (EBRD)—in periodically assessing the pass-through for countries undergoing FSAPs or requesting capacity building assistance in analyzing the expected impact of the monetary policy rate on bank lending rates. Academics and analysts are encouraged to further extend the model as the new knowledge and practical experience with interest rate pass-through becomes available.
8 List of References


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9 List of Author’s Publications and Research

Publications:

Journal Jimp


Journal Jsc


Proceedings contribution


Research Activities:

**Current projects**

2019 – 2021  
GA19-19485S - Spatial Dynamics and Inequality: The Role of Connectivity and Access to Finance

2019  

**Finished projects**

2016 – 2018  

2018  
SP2018/138 - Implications for Fiscal and Monetary Policy of Advanced Countries: an Econometric Approach

2017  

2016  
SP2016/101 - Monetary, Fiscal and Institutional Aspect of Economic Policy in Selected Countries

2015  
SP2015/115 - Institutional and Monetary Context of Economic Integration of European Countries Today
10 Summary

The interest rate pass-through describes how sensitive lending rates in an economy are to changes in the monetary policy rate. The effectiveness of the pass-through determines how successful the monetary policy could be in controlling the credit cycle, business cycle, and inflation. Therefore, central bankers around the world are greatly interested in assessing this transmission. There is no unified consensus about how strong this transmission is, including in different country’s contexts. The empirical literature reports different sizes of the pass-through across countries and lending rate categories. To synthesize the results of the literature, the thesis conducts a meta-regression analysis of available empirical estimates. The analysis suggests that pass-through tends to be incomplete in general and dependent on the level of financial development, trade openness and institutions. We examine whether the interest rate pass-through in the Czech Republic is similarly dependent on the macro-financial environment. Namely, the thesis examines how the monetary policy rate affects the interest rates on consumer, mortgage, small and medium enterprises (SME), and corporate loans in the Czech Republic. In addition, the thesis tests whether macro-financial factors such as the credit risk, government bonds rate, bank competition, foreign currency (FX) interventions, and deposit structure affect interest rate pass-through. It uses the autoregressive distributed lag (ARDL) modelling approach and verifies the reliability of the estimates for the Czech Republic using a battery of stability tests. The results imply that commercial banks price the consumer loans largely independent from the monetary policy rates. Banks could price the mortgage loans largely based on the government bonds yields, which represent the cost of funds for those loans. The pass-through to SME lending rates depends most on the bank deposit structure. A higher share of deposits lowers the pass-through to SME rates. The meta-regression results and ARDL estimates for the Czech Republic suggest a stable and nearly complete pass-through to the corporate lending rates. The pass-throughts to other lending rates could be more context dependent and less reliable. For instance, the pass-through to mortgage lending rates in the Czech Republic has been markedly affected by the onset of the global financial crisis (GFC). From among the structural factors, an increasing credit risk, trade openness, stock market capitalization, and independence of monetary policy may substantially reduce the strength of interest rate pass-through.

Keywords: Monetary Policy Rate, Bank Lending Rates, Interest Rate Pass-Through, Meta-Analysis, Auto Regressive Distributed Lag Model, Czech Republic.
11 Summary (CZ)


Klíčová slova: Měnově-politická úroková sazba, bankovní úroková sazba, transmise úrokových sazeb, meta-analýza, autoregresní model rozložených časových zpoždění, Česká republika.