Research and Policy Notes —— 2/2023

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# How Does Interest Rate Pass-Through Change Over Time? Rolling Windows and the Role of the Credit Risk Premium in the Pricing of Czech Loans

Eva Hromádková, Ivana Kubicová, and Branislav Saxa*

## Abstract

We examine interest rate pass-through in the Czech Republic over the period of 2004–2022. We investigate the speed and completeness of the transmission of changes in reference market interest rates to lending rates on loans to non-financial companies and housing loans. The use of a rolling window approach enables us to examine changes in the pass-through over time. In the case of housing loans, the transmission of the 5-year interest rate swap rate to client rates is strong in the long term, although currently it is not complete. A 1 percentage point increase in the unemployment rate implies an approximately 0.2 percentage point increase in the risk premium for the interest rate on loans for house purchase. Our estimates for loans to non-financial companies confirm that changes in the 3M PRIBOR are passed on almost completely with minimal delay. A 1 percentage point reduction in the output gap implies an approximately 0.1 percentage point increase in the risk premium for the client interest rate on corporate loans.

## Abstrakt

V našem článku zkoumáme transmisi úrokových sazeb v České republice v období 2004–2022. Zaměřujeme se na analýzu rychlosti a úplnosti přenosu změn referenčních tržních úrokových sazeb do úrokových sazeb z úvěrů nefinančním podnikům a úvěrů na bydlení. Použití přístupu rolovacího okna nám umožňuje zkoumat změny transmise v čase. V případě úvěrů na bydlení je přenos pětileté úrokové swapové sazby do klientských sazeb dlouhodobě silný, i když v současnosti není úplný. Nárůst nezaměstnanosti o 1 p. b. implikuje zvýšení rizikové prémie k úroku z úvěrů na bydlení o cca 0,2 p. b. Odhady u úvěrů nefinančním podnikům potvrzují, že změna 3M PRIBOR se téměř kompletně přenáší do klientské sazby s minimálním zpožděním. Snížení produkční mezery o 1 p. b. implikuje zvýšení rizikové prémie u klientské úrokové sazby u korporátních úvěrů o cca 0,1 p. b.

**JEL Codes:** C2, E43, E52.

**Keywords:** ARDL model, credit premium, interest rate pass-through, rolling windows.

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# 1. Introduction

For monetary policy makers, functioning transmission of policy interest rates to the real economy and ultimately to inflation is of utmost importance. An essential element at the beginning of the transmission mechanism is the pass-through from policy interest rates to client rates. Conventionally, the central bank sets key policy rates and implements monetary policy via open market operations. This ensures that policy rates are transmitted to interbank and other market rates (the first part of the interest rate pass-through) and on to lending and deposit client rates (the second part of the interest rate pass-through). In particular, the second part of the described pass-through is not mechanistic and straightforward. Among other things, commercial banks' price-setting behavior is one of the important factors that can influence the speed and completeness of the pass-through. The goal of this paper is to examine the interest rate pass-through from policy to client lending rates in the Czech Republic, focusing on possible changes in the pass-through over time. More specifically, we estimate the speed and completeness of the second part of the described pass-through – that from market rates to client interest rates on loans to non-financial corporations and loans for house purchase.

The contribution of the paper is twofold. First, we show how to follow changes in interest rate pass-through in a way that is useful for policy makers. Second, we quantify the contribution of the risk premium to the price of loans for the Czech credit market.

The remainder of this paper is organized as follows. Section 2 describes the two main stages of interest rate pass-through and explains the focus on the second part. Section 3 describes the previous research, done mostly using data for the Czech Republic. Section 4 briefly describes the data and methodology used. In section 5 we provide the main estimation results. Robustness checks follow in section 6, and section 7 concludes.

# 2. Understanding the Stages of Interest Rate Pass-Through

## 2.1 First Part of Interest Rate Pass-Through: From Monetary Policy Rates to Reference Rates

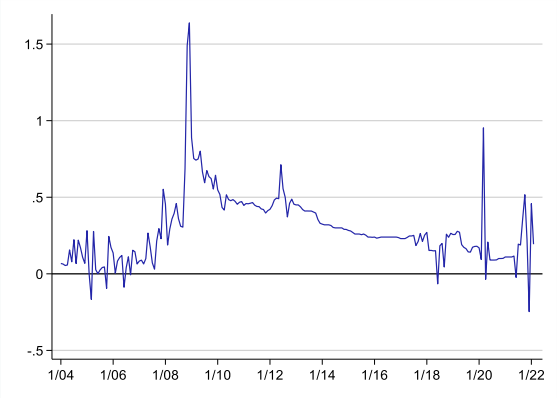
The interest rate pass-through estimates given in the main part of this paper show how reference interest rates on the financial markets influence client interest rates. For loans to non-financial corporations, we use the 3-month PRIBOR (3M PRIBOR) as the reference rate. For loans for house purchase, the 5-year interest rate swap (5Y IRS) rate serves as the reference rate.[1] In the following paragraphs, we discuss how monetary policy influences the rates that we use as reference rates, i.e., the 3M PRIBOR and 5Y IRS rates.

The pass-through from the key monetary policy 2-week repo rate to the 3M PRIBOR is relatively straightforward. Changes in the policy rate are reflected in the 3M PRIBOR practically immediately and almost fully. The spread between the 2-week repo rate and the 3M PRIBOR, shown in Figure 1,

[1] The choice of reference rates is explained in section 4.3 of the paper.

is driven mainly by the 3M credit risk premium[2] on the interbank market and by expectations of policy interest rate changes.

***Figure 1: Spread between 3M PRIBOR and 2-Week Repo Rate (in pp)***



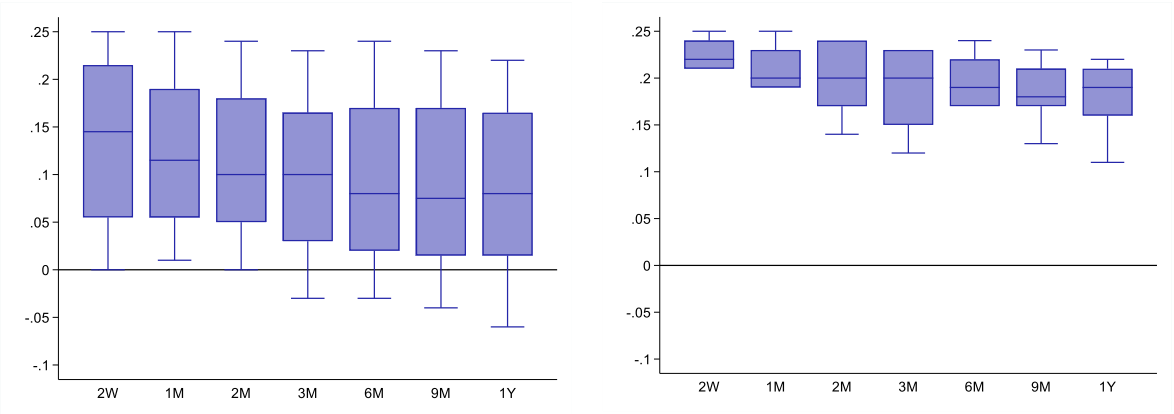

***Source:*** CNB

Figure 2 shows how changes in the policy rate transmit to interbank interest rates the same day. The left-hand subchart shows the average response of market rates to all the 25 basis point (bp) policy rate hikes implemented between January 2004 and August 2021. As most of these hikes were expected by market participants and priced in before the policy decisions were made, the average day-to-day increase in the 3M PRIBOR on the day of the policy change is only 10 bp. However, when we look at surprising 25 bp hikes only,[3] the average 3M PRIBOR increases by 21 bp on the same day (right-hand subchart).

***Figure 2: Changes in Money Market Rates in Reaction to Policy Rate Hike (in pp)***

Response of money market rates to all 25 bp hikes

Response of money market rates to surprising 25 bp hikes




***Source:*** CNB, own calculation

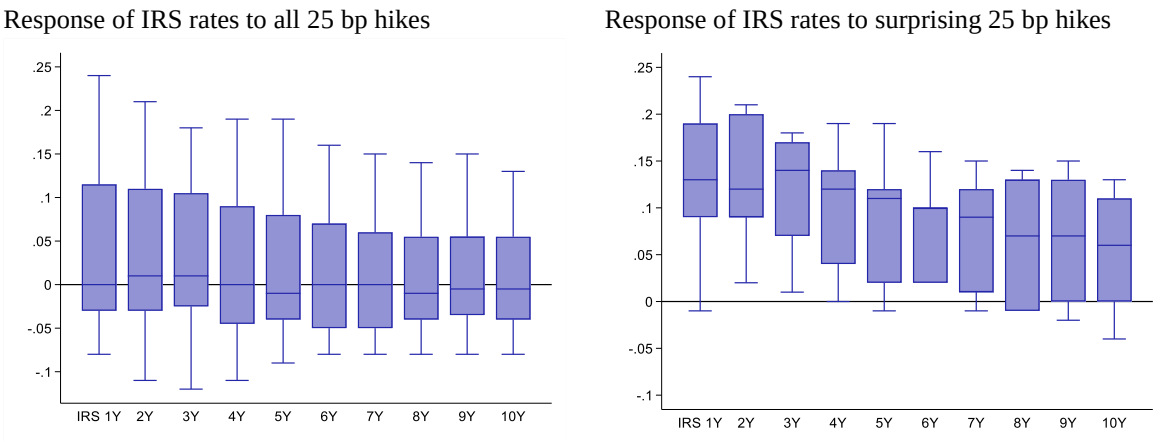
[2] Due to the unavailability of reliable data on the Czech OIS 3M spread, it is not possible to accompany Figure 1 with this indicator of the credit risk premium.

[3] We define surprising 25 bp hikes to be those that are accompanied by an increase of the 1W PRIBOR of more than 20 bp. Seven decisions in our sample are marked as surprising using this definition.

The pass-through from the key monetary policy 2-week repo rate to the 5Y IRS rate is more complicated. Essentially, the IRS rate incorporates forward expectations for the PRIBOR over the next 5 years, i.e., it depends on the future setting of the 2-week repo rate, but it also reflects, for example, bond yields, demand from end users of interest rate swaps (e.g., insurers, pension funds, and mortgage investors), and counterparty credit quality. A useful analysis of the IRS market is provided in a recent study by Khetan et al. (2023). Due to the high integration of international financial markets, IRS rates are strongly influenced by interest rate movements in foreign markets too (see, for example, Chatziantoniou et al., 2021).

Figure 3 shows how changes in the policy 2-week repo rate transmit to IRS rates the same day. The left-hand subchart shows the average response of IRS rates to all the 25 bp policy rate hikes implemented between January 2004 and August 2021. The difference between the reaction to all and surprising policy rate hikes is even more pronounced with IRS rates than with PRIBOR rates. While the average day-to-day reaction of the 5Y IRS to all policy rate hikes is almost zero (left-hand subchart), when we consider surprising 25 bp hikes only, the 5Y IRS increases by more than 10 bp on average on the same day (right-hand subchart).

***Figure 3: Changes in IRS Rates in Reaction to Policy Rate Hike (in pp)***




***Source:*** CNB, own calculation

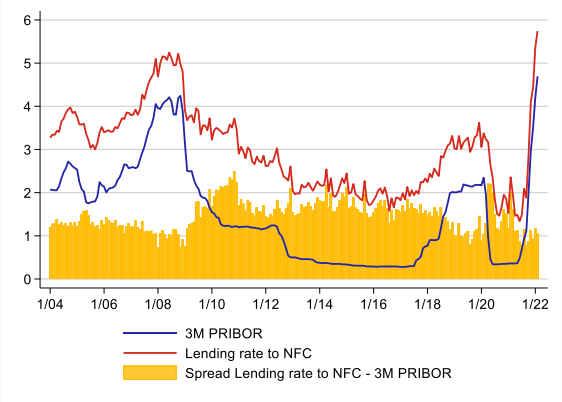
## 2.2 Second Part of Interest Rate Pass-Through: From Reference Rate to Lending Rate

The overall lending rate typically covers funding costs, operational expenses, cost of capital, and expected credit losses (e.g., Bundesbank, 2019). To estimate the transmission, we follow the literature (starting with Rousseas, 1985) and approximate funding costs with the reference market rate. To approximate expected credit losses, we use the unemployment rate in the case of loans for house purchase and the output gap in the case of corporate loans.

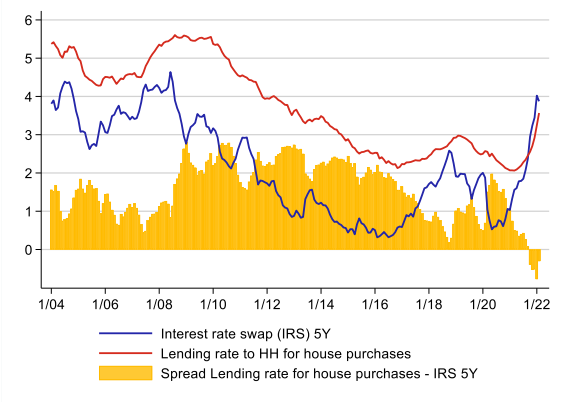
The importance of compensating for credit risk can be illustrated during periods of (expected) weaker economic activity. As Panel A in Figure 4 shows, the spread between the reference rate for corporate loans (3M PRIBOR) and the lending rate on corporate loans more than doubled in the Czech Republic after the outbreak of the global financial crisis in 2009 (from 1 percentage point to almost 2.5 percentage points).

***Figure 4: Spread between Reference and Client Lending Rates (in percent and pp)***

A. Non-financial firms lending spread (in % and pp)




B. Loans for house purchase lending spread (in % and pp)




***Source:*** CNB

Later in 2020, the shock related to the covid pandemic caused the spread to increase again, this time to slightly above 2 percentage points. This time, however, the high uncertainty did not affect the spread so dramatically. Unprecedented government help mitigated the risks either directly through credit guarantees or indirectly through generous assistance programs.

A slightly different pattern can be observed for rates on housing loans (Figure 2.4, Panel B). The spread increased after the beginning of the global financial crisis and remained elevated for years, despite a sizeable decline in both the reference rate and the client rate. Substantial increases in the 5Y IRS observed between 2016 and 2018 led to an increase in the client rate. However, strong competition and other market conditions at that time resulted in strong persistence of the client rate, and the spread narrowed substantially. After the outbreak of covid, the spread widened again, partly because of increased uncertainty, but also due to an abrupt and substantial decline in the reference rate.

## 3. Related Literature

Bank loan interest rate pass-through is often analyzed using the mark-up theory, according to which bank rates are determined by market rates and a constant mark-up (Rousseas, 1985). The majority of empirical studies on interest rate pass-through conclude that the pass-through of market interest rates to bank lending rates tends to be close to complete in the long term and incomplete in the short run, as shown, for example, on a sample of EU countries in De Bondt (2005).

The literature dealing with interest rate pass-through in the Czech Republic has two methodological streams. The first one, represented by Horváth and Podpiera (2012), Babecká-Kucharčuková et al. (2013), Havránek et al. (2016), and Brož and Hlaváček (2019), uses bank-level data. According to the results of Havránek et al. (2016), the long-term pass-through was close to complete before the financial crisis for both corporate loans and loans for house purchase. However, it weakened after the onset of the crisis, except in the case of mortgage loans. The second research stream, working with aggregated lending rates, is represented, for example, by Gregor and Melecký (2018). They focus on the long-run interest rate pass-through for consumer, mortgage, SME, and corporate loans.

In the pass-through for mortgage and corporate rates, the authors find significant structural shifts, which, according to them, can be entirely or largely explained by bank deleveraging. The authors also work with rolling pass-through coefficients that indicate greater stability of the pass-through to SME rates than to corporate and mortgage rates. In an important contribution to mapping the interest rate pass-through to loans in the Czech Republic, Brůha (2011) shows that macroeconomic risk explains a large part of the credit premium dynamics, especially for loans for house purchase.

Another strand of the literature is that on whether the interbank rate is an adequate measure of the marginal cost of funding. After the global financial crisis, a divergence emerged between the lending rate and the policy rate (the interbank rate). To overcome such a structural break, Illes et al. (2019) construct a broadly defined measure of funding costs which allows them to take into account various sources of funds (interest rates on deposits, securities, and central bank operations). They use the weighted average cost of liabilities (WACL) instead of the interbank rate to measure banks' effective funding costs and find stronger evidence for a stable relationship between the lending rate and the WACL than for policy rates. The lending rate might also be affected by macroprudential policy, especially by capital in excess of the minimum regulatory level. This topic is theoretically described in Benes and Kumhof (2015). For the Czech Republic, Ehrenbergová et al. (2020) use bank-level data to show that changes to the overall capital requirements did not force banks to alter their pricing policy, even in the case of less-capitalized banks and small banks. The lack of significant transmission of capital regulation to lending rates and interest margins is in contradiction to the mainstream literature on this subject.

# 4. Methodology and Data

## 4.1 Autoregressive Distributed Lag Model

To estimate the pass-through to client rates, we use the autoregressive distributed lag model (further referred to as the ARDL model) in its error correction model representation. While the ARDL model has been used in econometrics for decades, it has gained popularity in recent years as a method for disentangling the long-run relationship between variables from the short-run dynamics.

The basic ARDL(p,q) model for the dependent variable $y_t$ is specified as

$$y_t = c_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{i=0}^{q} \boldsymbol{\beta}_i' \mathbf{x}_{t-i} + u_t \qquad (1)$$

where $y_{t-i},\ i = 1, \dots, p$ are lagged values of the dependent variable, and $\boldsymbol{x}_{t-i},\ i = 0, \dots, q$ are the current and lagged values of the vector of independent variables $x_j,\ j = 1, \dots, K$, where we assume for simplicity that the lag order $q$ is the same for all variables in the K × 1 vector $\boldsymbol{x}_t$.

ARDL is in fact a special case of the structural error correction model (ECM) in the sense that it captures the conditional response of one variable to other, potentially endogenously determined, variables, while isolating a cointegration relationship among them. Moreover, two seminal contributions in this regard – Pesaran and Shin (1998) and Pesaran, Shin, and Smith (2001) – argue that ARDL models are especially advantageous in their ability to handle cointegration with inherent robustness to misspecification of the integration orders of the relevant variables.

Thus, in our estimation, we use the ECM reparameterization of ARDL in the form

$$\Delta y_t = c_0 + \alpha(y_{t-1} - \boldsymbol{\theta x}_{t-1}) + \sum_{i=1}^{p-1} \psi_{yi} \Delta y_{t-i} + \omega' \boldsymbol{\Delta x}_t + \sum_{i=1}^{q-1} \boldsymbol{\psi}'_{xi} \boldsymbol{\Delta x}_{t-i} + u_t \quad (2)$$

where the interpretation of the coefficients is the following:

- The vector of long-run coefficients $\boldsymbol{\theta} = \frac{\sum_{i=0}^{q} \boldsymbol{\beta}_i}{\alpha}$ represents the equilibrium effects of the independent variables on the dependent variable. In the presence of cointegration, it corresponds to the vector of cointegration coefficients.
- The speed of adjustment coefficient (negative) $\alpha$ measures how strongly a dependent variable reacts to a deviation from the equilibrium relationship and thus how fast this deviation is corrected.
- The short-run coefficients $\psi_{yi}, \boldsymbol{\omega}, \boldsymbol{\psi}_{xi}$ account for the magnitude of short-run fluctuations

As for the long-run relationship, the assumption is that the independent variables must be weakly exogenous with respect to the dependent variable, which in our case corresponds to the mechanics of interest rate pass-through. The weak exogeneity further implies that there is at most one cointegrating relationship involving the dependent variable.

Once the ECM specification is estimated, we test for its existence by performing the Pesaran, Shin, and Smith (2001) bounds test, which effectively tests whether the estimated coefficients $\alpha$ and $\beta_j$ for all the variables from vector $\boldsymbol{x}_t$ are significantly different from zero. The finite sample and asymptotic critical values (provided in Kripfganz and Schneider, 2018) vary based on the empirical specification (number of independent variables, integration order, number of lags, and inclusion of intercept and time trend).

In our application, we analyze the extent and speed of transmission of reference rates to client rates. We focus on two sectors. For households (equation 3 below), we estimate the pass-through of the 5-year IRS rate (reference rate, independent variable) to the interest rate on new loans for house purchase (dependent variable). The unemployment rate enters as a proxy for the credit risk premium in this loan segment. For non-financial corporations (equation 4 below), the dependent variable is the interest rate on total new loans as well as interest rates on small and large loans differentiated by the length of the fixed-rate period, and the independent variable is the 3M PRIBOR rate, our reference rate for the corporate segment. The credit risk proxy in this case is the output gap. We analyze the changes in the long-run coefficients $\boldsymbol{\theta}_1$ on the reference rate, which measure to what extent changes in the reference rate translate into client rates, with a value of 1 indicating full transmission and smaller values suggesting that the transmission is not complete. The other coefficient of interest is the speed of adjustment $\boldsymbol{\alpha}$, which describes how fast client rates adjust after a change in the reference rate. The long-run coefficient on the output gap $\boldsymbol{\theta_2}$ suggests how important

the credit risk premium is in pricing the loan. Finally, the short-run coefficient $\boldsymbol{\omega_1}$ measures the immediate past-through of the reference rate to client rates.

$$\begin{aligned}\Delta\text{hhouse\_lr}_t = {} & c_0 - \alpha(\text{hhouse\_lr}_{t-1} - \theta_1\text{IRS5Y}_{t-1} - \theta_2\text{unempl}_{t-1}) + \sum_{i=1}^{p-1}\psi_{y,i}\,\Delta\text{hhouse\_lr}_{t-i} \\ & + \omega_1\Delta\text{IRS5Y}_t + \omega_2\Delta\text{unempl}_t + \sum_{i=1}^{q-1}\psi_{x1,i}\,\Delta\text{IRS5Y}_{t-i} + \sum_{i=1}^{q-1}\psi_{x2,i}\,\Delta\text{unempl}_{t-i} \\ & + u_t\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta\text{corp\_lr}_t = {} & c_0 - \alpha(\text{corp\_lr}_{t-1} - \theta_1\text{PRIBOR3M}_{t-i} - \theta_2\text{outputgap}_{t-1}) + \omega_1\Delta\text{PRIBOR3M}_t \\ & + \omega_2\Delta\text{outputgap}_t + \sum_{i=1}^{p-1}\psi_{yi}\,\Delta\text{corp\_lr}_{\text{lr}_{t-i}} \\ & + \sum_{i=1}^{q-1}\left[\psi_{x1i}\Delta\text{PRIBOR3M}_{t-i} + \psi_{x2i}\Delta\text{outputgap}_{t-1}\right] + u_t\end{aligned} \tag{4}$$

### 4.2 Rolling Windows

In contrast to most of the available research, which estimates pass-through using the entire available time period or divides the entire period into a few subperiods, we estimate the coefficients for rolling time windows of a constant length of 8 years. This allows us to identify potential changes in the strength and speed of pass-through to client rates.

### 4.3 Data Description and Choice of Reference Rates

We use monthly data for the Czech Republic, aggregated across banks and covering the period from January 2004 to February 2022. The starting date is given by data availability. The lending rates are rates on newly provided loans. We estimate the pass-through coefficients using regressions (3) and (4) for the two most important loan segments in the Czech Republic – loans to households for house purchase and loans to non-financial companies.[4] The data sources are the CNB's ARAD database for lending rates, Refinitiv for market rates, and internal CNB sources for the smoothed output gap based on the Kalman filter and the unemployment rate.[5]

Based on discussions with banks, and backed by a correlation analysis,[6] we chose the 3M PRIBOR as the reference rate for corporate loans. As Figure 1.1 shows, the 3M PRIBOR is strongly linked to the current and expected future level of the main central bank policy rate, so it is also often used as a proxy for the monetary policy stance.[7] Lending rates on loans to non-financial corporations are often linked to interbank PRIBOR rates directly in the contract between the client and the bank. Further, the price of a loan includes surcharges, which, among other things, contain a stable margin

[4] As of the beginning of 2022, bank loans to households for house purchase and bank loans to non-financial companies represented 45% and 35%, respectively, of all bank loans provided to the private sector.

[5] Descriptive statistics for all the variables are available in Appendix A.

[6] For total loans the strongest correlation (0.96) is found for the 3M PRIBOR with no lag and the 6M PRIBOR with no lag. For the rate on small loans (up to CZK 30 million), the strongest correlation is found for the 2Y government bond yield with no lag (0.96) and the 1Y PRIBOR (0.95) with a one-month lag. Firm lending rates for large loans (over CZK 30 million) are found to be strongly correlated with the 6M PRIBOR (0.95) with no lag.

[7] The 3M PRIBOR is also the main interest rate used in the CNB's core macroeconomic model, and interest rate forecasts are communicated using this rate.

over time for the individual loan, primarily reflecting its riskiness evaluated at the time of credit approval.

Historically, and according to previous research,[8] lending rates on loans for house purchase are closely related to the 10-year Czech government bond yield. This finding is supported by the results of the correlation analysis, which, however, also shows a close relationship between lending rates on loans for house purchase and IRS rates. This is mainly due to the direct link between the pricing and financing of mortgage loans. A large proportion of the banks operating in the Czech Republic use the IRS of the same maturity as the fixed-rate period of the newly provided mortgage to hedge against interest rate risk. Alternative estimations using a recursive method (not reported here) confirm the increasing significance of IRS rates as the reference rate, especially in the last five years. Another reason for the preference for IRS rates over government bond yields is the fact that government bond prices were distorted by the exchange rate commitment in the period of 2013–2017. Our preferred reference rate for loans for house purchase is thus the 5-year IRS rate.[9]

## 5. Results

In the following paragraphs, we discuss the evolution of the coefficients shown in the charts. Numerical values of the coefficients estimated using the full sample and the last 8-year window are given in Appendix B.

### 5.1 Loans for House Purchase

The key long-run pass-through of the 5Y IRS rate is in the range of 0.6–1 throughout the estimation period (Figure 5, Panel A). It was strongest and almost complete (i.e., close to a value of one) in the 8-year rolling windows ending in the period of 2015–2017, i.e., in the period of approximately 2007–2017. The long-run coefficient on the unemployment rate is statistically significant in the time windows that cover the period from approximately 2010 to the present[10] (Figure 5, Panel B). The negative values of the coefficient with wider confidence intervals in the earlier time windows may be related to gradual growth in competition[11] and increasing pressure on margins. Over time, housing loan prices were thus pushed down to marginal costs, which consist mainly of the cost of funding and the price of risk. In recent years, the coefficient has been fluctuating around 0.2, i.e., a 1 percentage point increase in the unemployment rate implies an approximately 0.2 percentage point increase in the risk premium for the housing rate.

[8] Havránek et al. (2016), Babecká Kucharčuková et al. (2013)

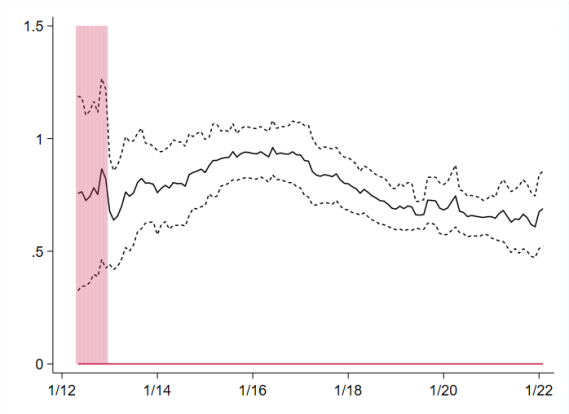
[9] Ehrenbergova et al. (2020) use weighted IRS rates as the reference rate in their analysis of Czech lending rates.

[10] In the chart, the coefficient becomes positive and significant in 2018, i.e., when the coefficient is estimated using the time window of 2010–2018.

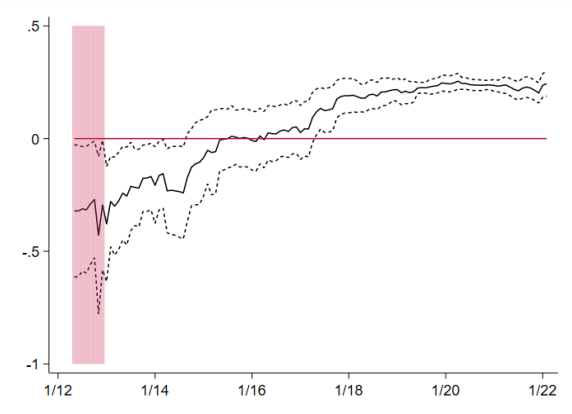
[11] This is supported by the evolution of the Herfindahl-Hirschman Index for mortgage loans (see the figure in Appendix C). It gradually fell until 2011, signaling increasing competition in the period up to that year.

***Figure 5: Time Evolution of Pass-Through Coefficients – Loans for House Purchase***

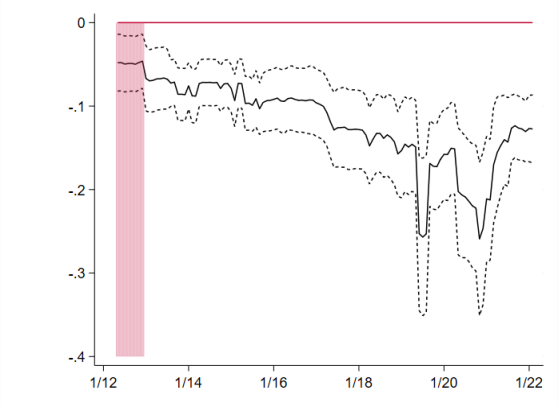
Panel A: Long-term coefficient on 5-year IRS rate ($\theta_1$)



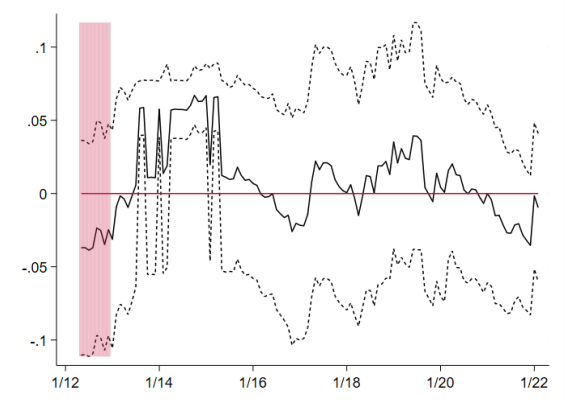

Panel B: Long-term coefficient on unemployment rate ($\theta_2$)




Panel C: Speed of adjustment ($\alpha$)




Panel D: Short-term coefficient on 5-year IRS rate ($\omega_1$)




***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

The persistence of housing loan rates is substantial. Both the correlation analysis and the lag length, which we select using the AIC information criterion, indicate that the typical lag between a change in the reference rate and the maximum impact on the client rate is 4 months. As expected, the estimated coefficient on the immediate pass-through from the 5Y IRS rate to the housing loan rate is around zero (Figure 5, Panel D). The substantial persistence of the loan price-setting policy is not surprising. Marketing campaigns in which banks offer specific client rates often run for long periods of time regardless of changes in the reference rate. Potential clients thus typically receive an offer that is valid for some time, creating a further lag in the pass-through to the client interest rate. A relatively long time can thus elapse between the offer and the actual signing of the loan agreement.

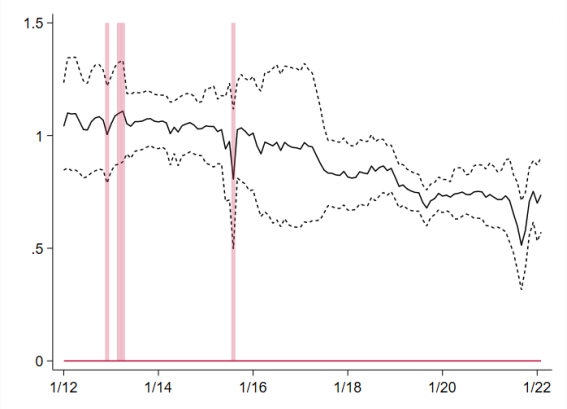
## 5.2 Loans to Non-Financial Corporations

The immediate pass-through of the 3M PRIBOR to client interest rates on **total loans to non-financial corporations** is statistically significant (Figure 6, Panel D), i.e., changes in the reference rate are transmitted to the client rate in the same month.[12] Until approximately 2015, the immediate pass-through of the 3M PRIBOR to the client rate hovered around one, but this fast part of the transmission subsequently weakened somewhat. According to our estimates, the long-run pass-through of the 3M PRIBOR to client interest rates was complete until 2017, after which the coefficient dropped slightly to around 0.8 (Figure 6, Panel A). This could be due to an increasing share of corporate loans with fixed interest rates rather than interest rates linked to the PRIBOR.[13] The coefficient on the output gap (an approximation of the risk premium for loans to non-financial enterprises) was relatively stable at slightly negative levels in the period before the covid pandemic started (Figure 6, Panel B). With a coefficient of -0.1, a 1 percentage point reduction in the output gap implies an approximately 1 percentage point increase in the risk premium for the client rate for corporate loans. The sharp change in the output gap coefficient to positive (and statistically insignificant) values in the windows ending after 2020 is temporary and caused by two factors. The first one is the extraordinary uncertainty associated with the estimation of the output gap during the covid pandemic. The second factor is the decoupling of the relationship between the performance of the economy and the evaluation of risk during this period, related to credit guarantees and government assistance programs, which limited the rise in interest rates.

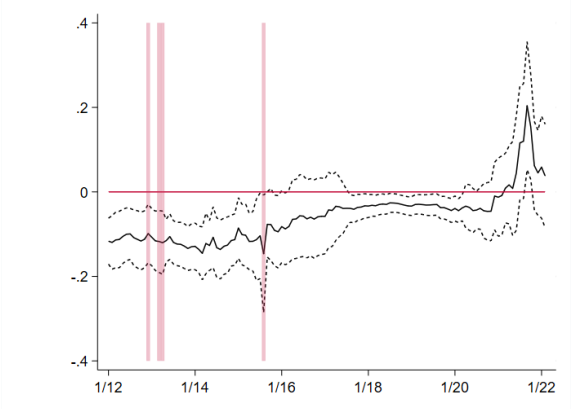
The speed of adjustment of the client rate rose over time as the absolute value of the coefficient increased (Figure 6, Panel C).

***Figure 6: Time Evolution of Pass-Through Coefficients – Total Loans to Non-Financial Corporations***

Panel A: Long-term coefficient on 3M PRIBOR ($\theta_1$)



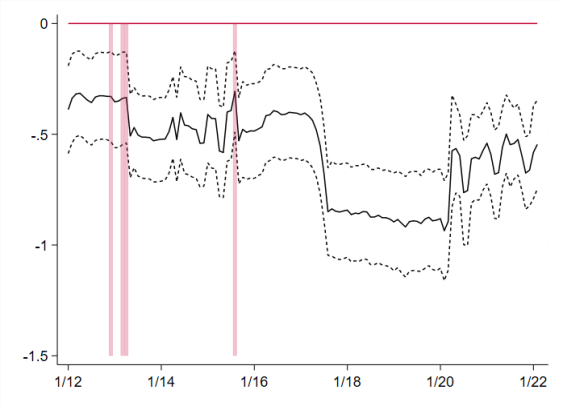

Panel B: Long-term coefficient on output gap ($\theta_2$)



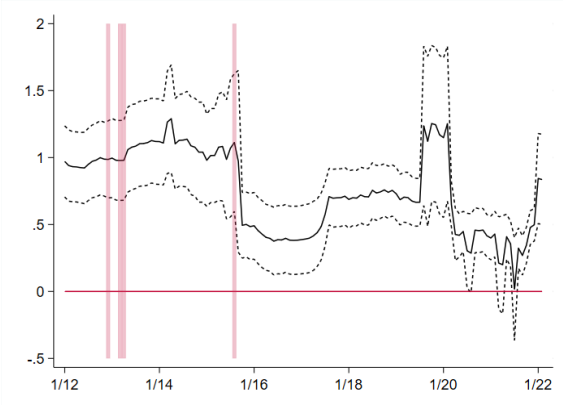

[12] This is confirmed by the correlation analysis, where the maximum is achieved at lag 0, and by the choice of lag in the model estimation, where the typical lag is 1.

[13] Methodologically, we decided to stick to using the 3M PRIBOR rate as the reference rate for the whole estimation period, as we wanted to keep the results comparable.

Panel C: Speed of adjustment (α)




Panel D: Short-term coefficient on 3M PRIBOR ($\omega_1$)



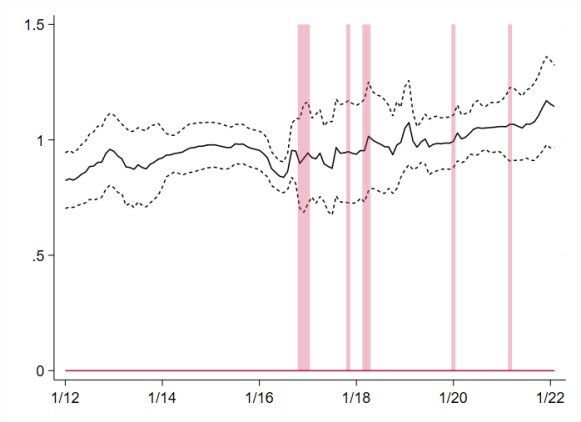

***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

The findings for **short-term loans (with maturity up to 1 year) divided by size** (up to CZK 30 million and over CZK 30 million) are summarized in Figure 7. In the case of small loans, the immediate reaction of banks as measured by the short-term coefficient on the 3M PRIBOR is relatively strong.[14] The long-run coefficient, indicating the completeness of transmission, is steadily increasing and the confidence interval almost always includes the value of one, i.e., the transmission is full. The role of the output gap as a proxy for the credit premium increased slightly over time. The magnitude is roughly in line with the size of this coefficient for the total loans category. The speed of adjustment decreases slightly over time, averaging 0.4 over the last two years.

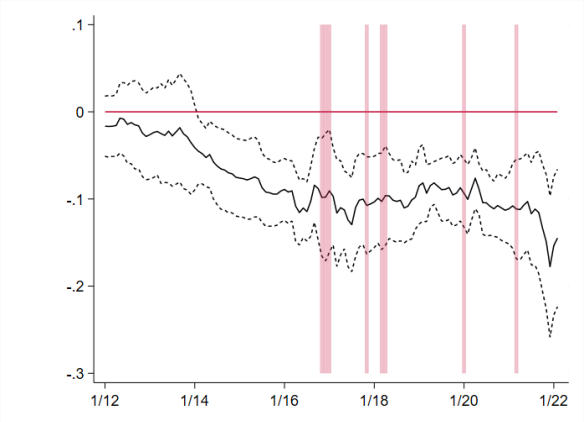
[14] Similarly to total loans, the maximum correlation between the time series of both short-term small loans and short-term large loans is achieved at lag 0. This translates to a typical lag choice of 0 to 1 for the ARDL model.

***Figure 7: Time Evolution of Pass-Through Coefficients – Loans to Non-Financial Corporations, Loan Size up to CZK 30 Million (Small Loans), Maturity up to 1 Year***

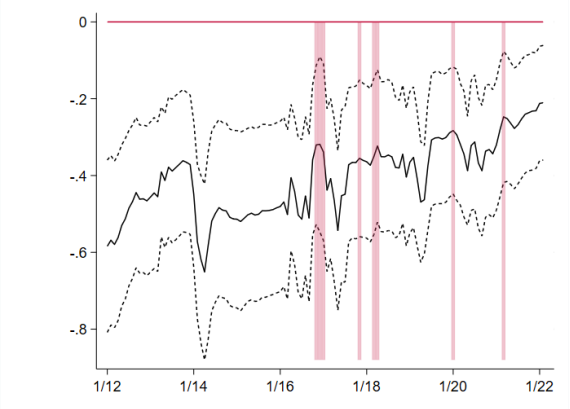
Panel A: Long-term coefficient on 3M PRIBOR ($\theta_1$)



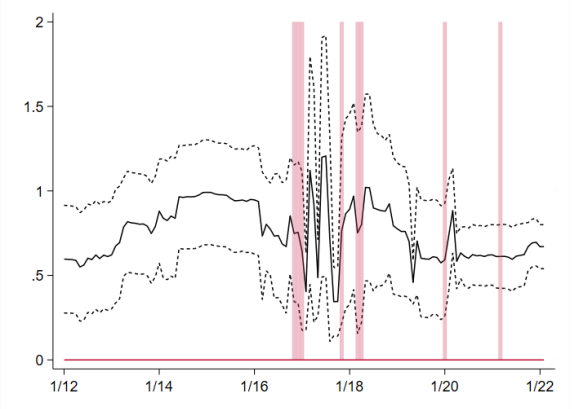

Panel B: Long-term coefficient on output gap ($\theta_2$)




Panel C: Speed of adjustment (α)




Panel D: Short-term coefficient on 3M PRIBOR ($\omega_1$)

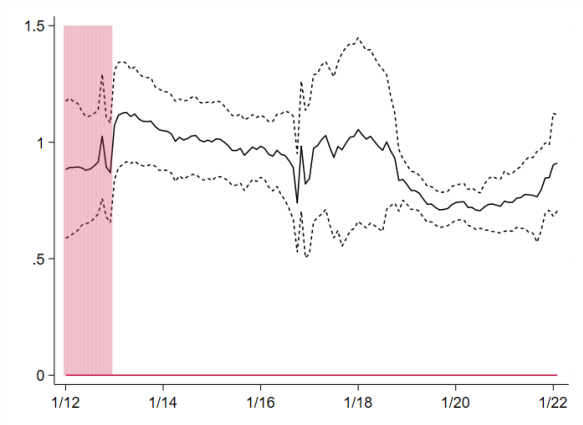



***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

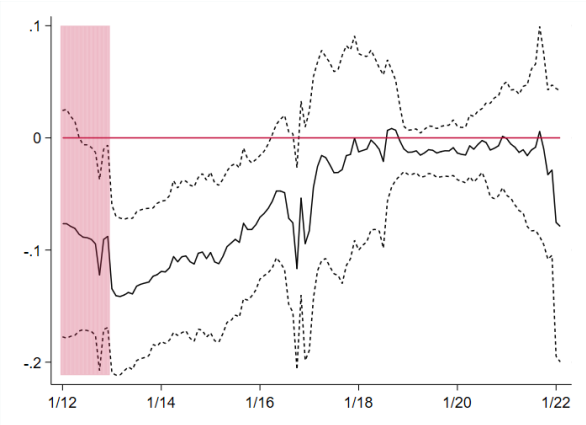
As in the case of total loans, **large loans** (over CZK 30 million) show similar results in terms of both the immediate reaction and the long-term relationship (see Figure 8 for a summary of the results). The speed of adjustment for any deviation from the long-run equilibrium for this segment is very high. The analysis in this segment is complicated by the fact that large loans with exceptionally low interest rates often enter the statistics. The treatment of time series with such observations is not straightforward. We do not treat them as outliers and keep them in the dataset.

***Figure 8: Time Evolution of Pass-Through Coefficients – Loans to Non-Financial Corporations, Loan Size over CZK 30 Million (Large Loans), Maturity up to 1 Year***

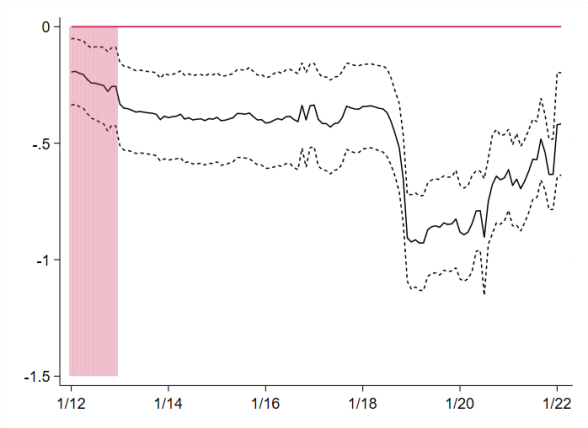
Panel A: Long-term coefficient on 3M PRIBOR ($\theta_1$)



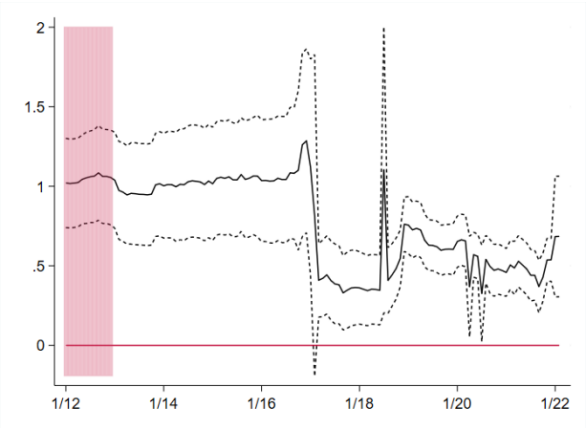

Panel B: Long-term coefficient on output gap ($\theta_2$)




Panel C: Speed of adjustment (α)




Panel D: Short-term coefficient on 3M PRIBOR ($\omega_1$)




***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

## 6. Robustness Checks

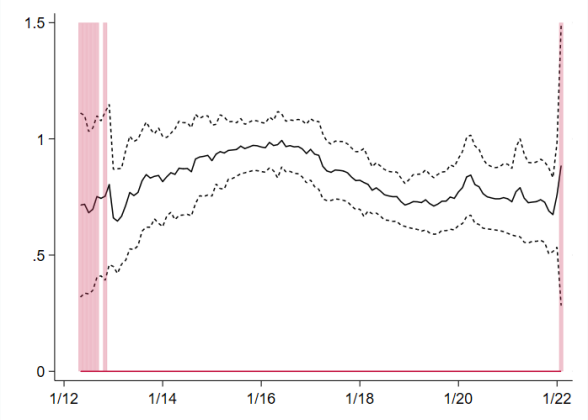
### 6.1 Reference Rate Selection

As a part of our robustness checks, we estimate the coefficients using two alternative rates for loans for house purchase – the 10-year IRS rate and the 10-year government bond rate – instead of the 5-year IRS rate as the reference rate. In the case of the IRS rate, the results are very similar to the baseline, and the choice of a 5-year reference rate thus relates more to the prevalent fixed interest periods of mortgages (Figure 9). In the case of the government bond rate, the general results are

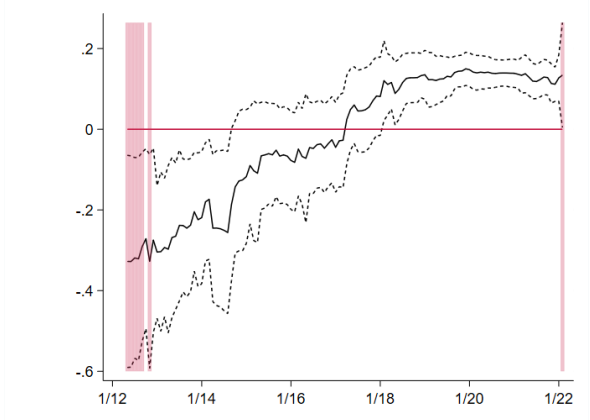
also similar. However, we see many more periods of an insignificant relationship and correspondingly greater variance of the coefficients (Figure 10).

***Figure 9: Estimation with 10-Year IRS Rate Used as Reference Rate***

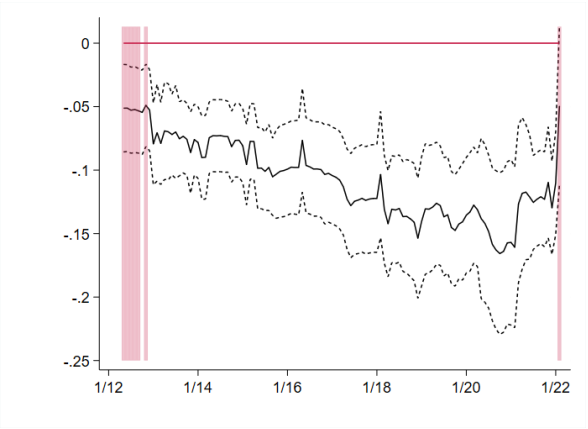
Panel A: Long-term coefficient on 10-year IRS rate ($\theta_1$)



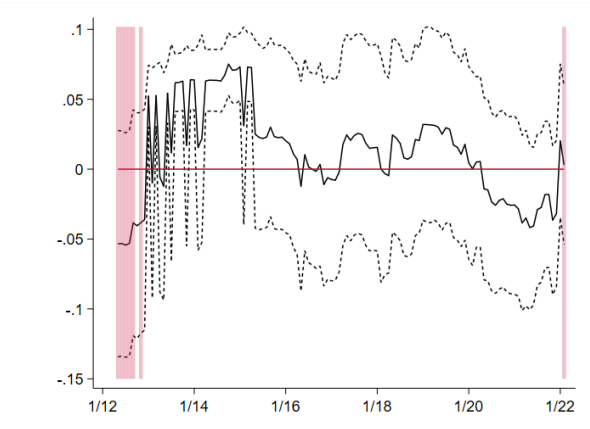

Panel B: Long-term coefficient on unemployment rate ($\theta_2$)




Panel C: Speed of adjustment ($\alpha$)



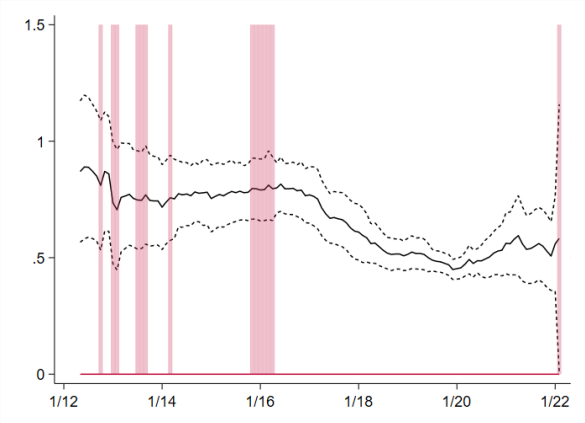

Panel D: Short-term coefficient on 10-year IRS rate ($\omega_1$)



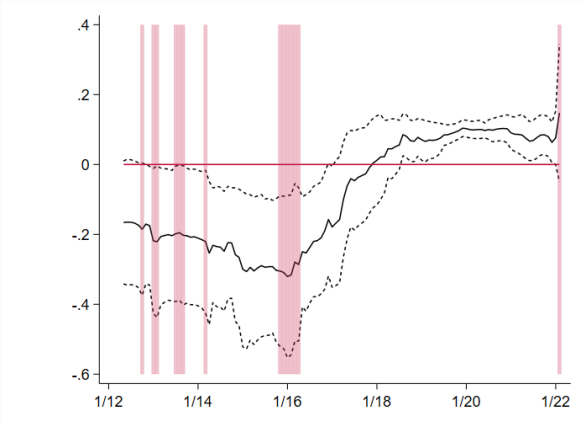

***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

***Figure 10: Estimation with 10-Year Government Bond Rate Used as Reference Rate***

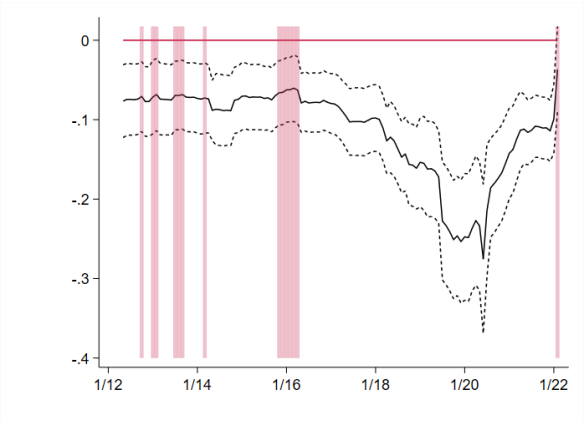
Panel A: Long-term coefficient on 10-year GB rate ($\theta_1$)



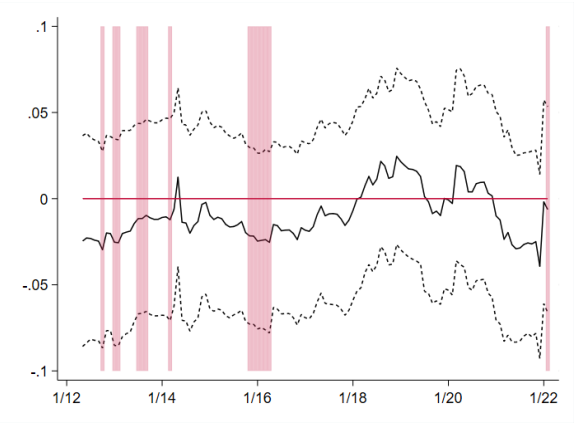

Panel B: Long-term coefficient on unemployment rate ($\theta_2$)




Panel C: Speed of adjustment ($\alpha$)




Panel D: Short-term coefficient on 10-year GB rate ($\omega_1$)

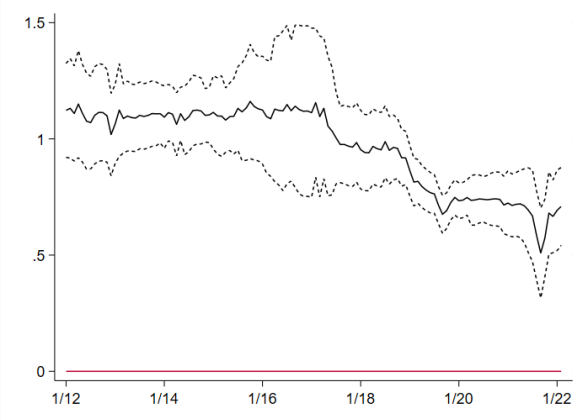



***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

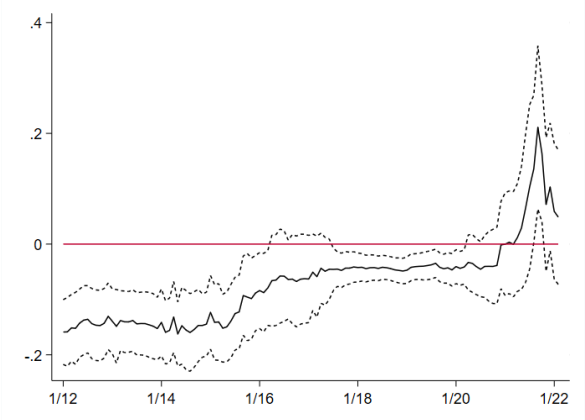
We also perform an alternative estimation for loans to non-financial corporations using the 1M PRIBOR as the reference rate. The motivation behind this choice is that the 1M PRIBOR is the rate used most frequently in loan contracts in the Czech Republic. Figure 11 shows that the results are very similar to the baseline estimation using the 3M PRIBOR, mainly because these two rates are almost perfectly correlated.

***Figure 11: Estimation with 1M PRIBOR Used as Reference Rate***

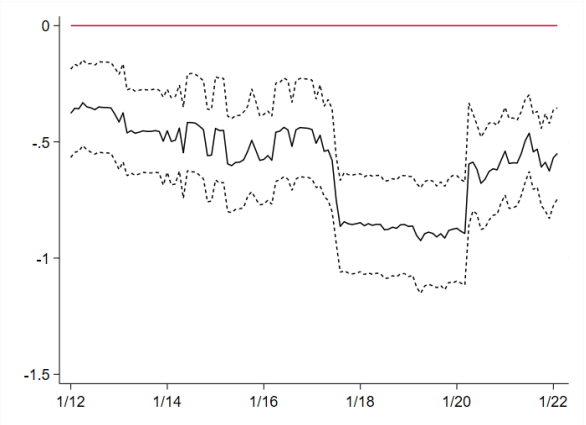
Panel A: Long-term coefficient on 1M PRIBOR ($\theta_1$)



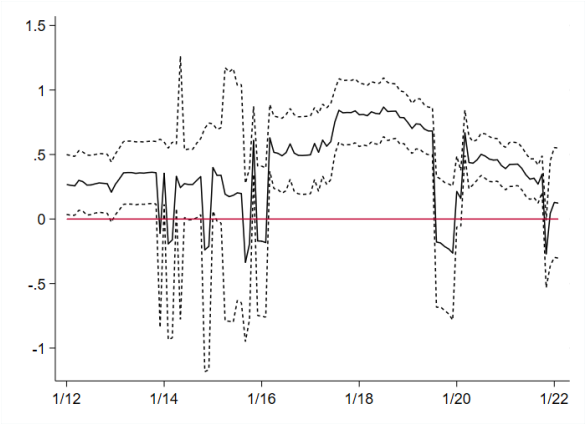

Panel B: Long-term coefficient on output gap ($\theta_2$)




Panel C: Speed of adjustment (α)




Panel D: Short-term coefficient on 1M PRIBOR ($\omega_1$)




***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

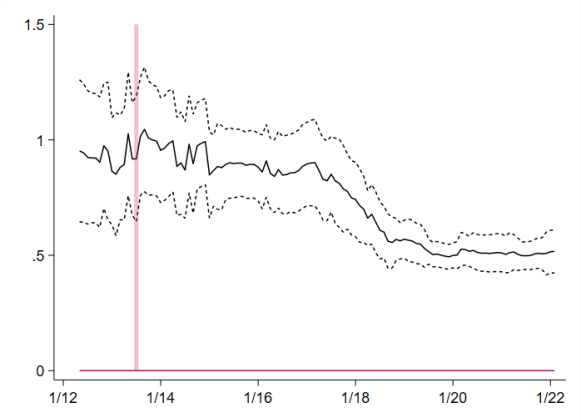
## 6.2 Proxy for Risk Premium

The literature on the determinants of the credit risk premium suggests that the non-performing loan (NPL) rate is a valid alternative measure to the unemployment rate and output gap employed in this paper. We performed the estimation using both the sector-specific NPL rate in the contemporaneous time period and the NPL rate moved 1 year ahead. One could argue that the NPL rate could be a better choice than the unemployment rate or output gap to approximate the credit risk premium. In the case of loans to non-financial corporations, the backward-looking character of the NPL rate means that it does not perform well in the interest rate pass-through estimations and does not provide timely signals of changes in the risk premium (even if the timing of the NPL rate in the regression

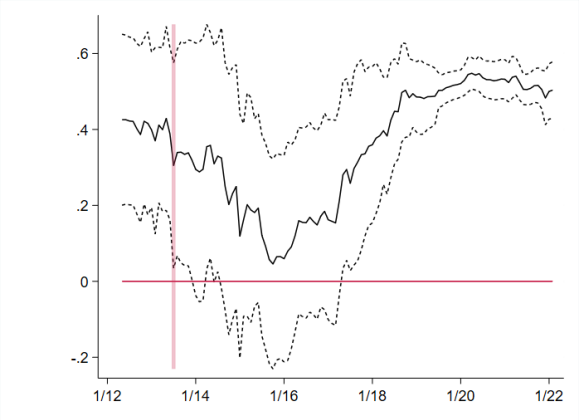
is adjusted). On the other hand, in the case of mortgages, the significance and precision of the estimates were improved by introducing the NPL rate, especially in the case of the 1-year ahead values (see Figure 12 for the results). This supports the view that banks' predictions of households' credit risk are in line with the NPL rate observed later.

***Figure 12: Estimation with Non-Performing Loans as Proxy for Credit Market Risk Premium, Loans for House Purchase***

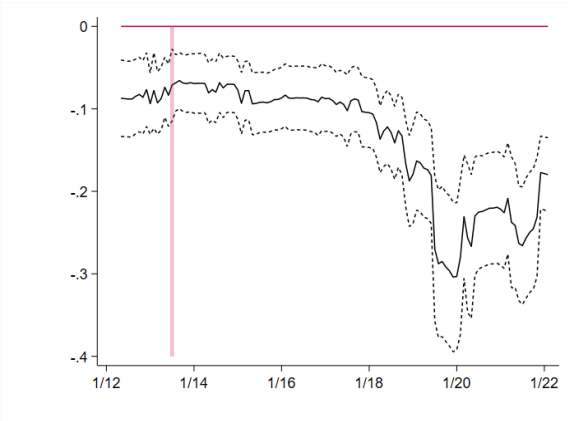
Panel A: Long-term coefficient on 10-year IRS rate ($\theta_1$)



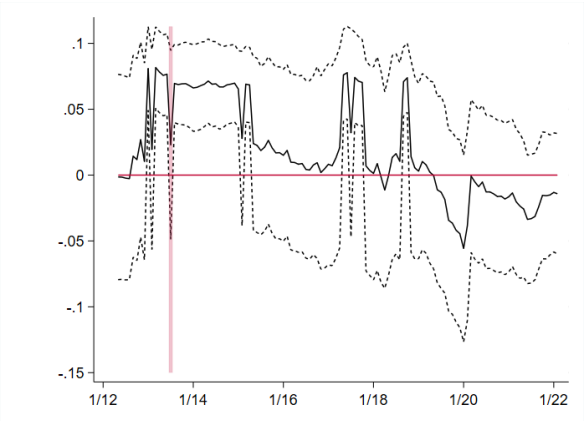

Panel B: Long-term coefficient on unemployment rate ($\theta_2$)




Panel C: Speed of adjustment ($\alpha$)




Panel D: Short-term coefficient on 10-year IRS rate ($\omega_1$)




***Note:*** The red areas denote periods in which the cointegration between the variables is NOT statistically significant, computed based on the F-statistics and t-statistics of the whole cointegration relationship. If both statistics are significant at least at the 10 percent level of significance, the long-term equilibrium is statistically significant. The dotted lines denote a confidence interval of two standard deviations on either side of the solid line.

## 6.3 Sensitivity to the Estimated Window Length

From a monetary policy perspective, it would be ideal to use a rather shorter estimation window in order to promptly describe changes in interest rate pass-through. However, in order to achieve satisfactory reliability of the estimates, it turns out to be necessary to use a window length of at least

80 observations. Below this threshold, the statistical significance of the estimates is sensitive to the window length, but the profiles of the trajectories and the interpretation are robust.

## 7. Conclusion

We use a rolling window approach to evaluate changes in interest rate pass-through for the two most important loan segments in the Czech Republic – loans to households for house purchase and loans to non-financial companies. In the case of housing loans, the pass-through of the 5Y IRS rate to client rates is strong in the long term, although it is not complete. Our estimates for loans to non-financial companies confirm a strong and immediate reaction of client interest rates to changes in the 3M PRIBOR, especially until 2015. The immediate pass-through weakened in the following years, but changes in the 3M PRIBOR remained almost completely passed on with minimal delay.

The risk premium, which we assume is linked to the unemployment rate for housing loans and to the output gap for corporate loans, contributes significantly to explaining the variation in client interest rates. A 1 percentage point increase in the unemployment rate implies an approximately 0.2 percentage point increase in the price of risk for housing loan rates. A 1 percentage point reduction in the output gap implies an approximately 0.1 percentage point increase in the risk premium for the client interest rate on corporate loans.

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# Appendix A: Summary Statistics

***Table A1: Summary Statistics of Variables Used in Estimation***

| Variable | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| Loans to households for house purchase (in %) | *3.73* | *1.18* | *2.06* | *5.6* |
| Loans to non-financial companies – total (in %) | *2.98* | *0.95* | *1.34* | *5.74* |
| - Up to CZK 30 million, < 1 year | *3.66* | *1.05* | *2.02* | *6.46* |
| - Over CZK 30 million, < 1 year | *2.73* | *0.95* | *1.06* | *5.82* |
| 5-year IRS (in %) | *2.17* | *1.24* | *0.32* | *4.64* |
| 10-year IRS (in %) | *2.51* | *1.28* | *0.49* | *5.01* |
| 3M PRIBOR (in %) | *1.51* | *1.13* | *0.28* | *4.69* |
| Unemployment rate (in %) | *5.33* | *2.10* | *1.76* | *8.54* |
| Output gap (in %) | *-0.23* | *2.30* | *-4.92* | *3.19* |

***Source:*** ARAD, G3 forecast, CZSO

# Appendix B: Selected Estimation Results

***Table B1: Estimates of ARDL Model on Full Sample and Last 8-Year Window***

| | Loans to households for house purchase | | Loans to non-financial corporations | |
|---|---|---|---|---|
| | *Full sample* | *Last 8-year window* | *Full sample* | *Last 8-year window* |
| LR coefficient – interest rate | *1.18**** | *0.68**** | *0.87**** | *0.81**** |
| | *(0.34)* | *(0.10)* | *(0.03)* | *(0.06)* |
| Speed of adjustment | *- 0.02** | *- 0.11**** | *- 0.39**** | *- 0.61**** |
| | *(0.01)* | *(0.03)* | *(0.06)* | *(0.07)* |
| LR coefficient – credit risk proxy | *- 0.07* | *0.22**** | *- 0.07**** | *- 0.06** |
| | *(0.20)* | *(0.04)* | *(0.20)* | *(0.03)* |
| SR coefficient – interest rate | *- 0.01* | *- 0.01* | *0.76**** | *0.49**** |
| | *(0.02)* | *(0.02)* | *(0.08)* | *(0.06)* |
| N | *214* | *96* | *214* | *96* |
| Adj R2 | *0.48* | *0.71* | *0.48* | *0.53* |

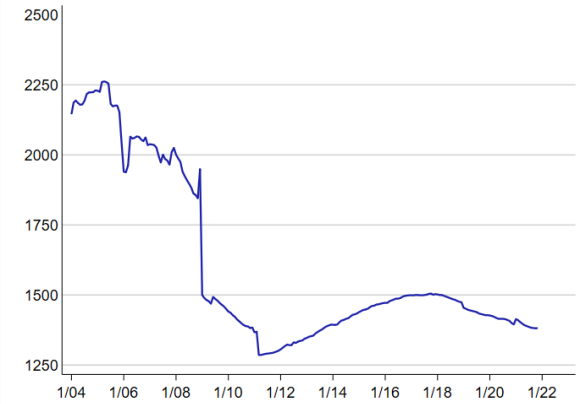
***Note:*** The table contains the coefficient values and SE for the estimates on the full sample (Jan 2004–Feb 2022) and the last estimated 8-year window (Feb 2014–Feb 2022). The symbols *, **, and *** denote significance at the 0.01, 0.05, and 0.10 levels, respectively.

## Appendix C: Herfindahl-Hirschman Index of Concentration

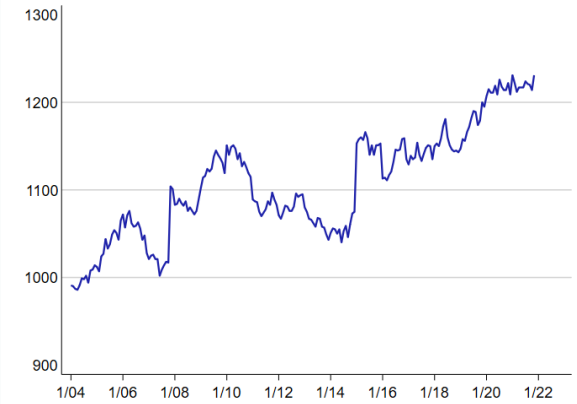
The Herfindahl-Hirschman index (HH index) is a measure of market concentration. It is defined as the sum of the squares of the market shares (in %). For a market operated by a single firm, the value of the HH index is 10,000. For less concentrated markets, the figure is lower. The HH index is also used as a proxy for competition, under the assumption that lower concentration, i.e., more market players, increases competition.

***Figure C1: Summary Statistics of Variables Used in Estimation***

HH index – mortgage loans




HH index – loans to non-financial corporations




***Source:*** ARAD

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