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ESTIMATING DEPOSIT INTEREST RATE PASS-THROUGH IN CENTRAL AND EASTERN EUROPEAN COUNTRIES USING WAVELET TRANSFORM AND ERROR CORRECTION MODEL

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Estimating Deposit Interest Rate pass-through in Central and Eastern European Countries Using Wavelet Transform and Error Correction Model

(Betéti kamattranszmisszió becslése a közép-kelet-európai országokban wavelet-transzformáció és hibakorrekciós modell segítségével)

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Contents

Abstract

Our study deals with interest rate pass-through for household and corporate deposits in the Central and Eastern European (CEE) region, focusing on the tightening cycle starting in the middle of 2021. This period is of particular interest for interest rate pass-through, as the sharp hikes by central banks in response to a high inflation environment followed a period characterised by a significant abundance of liquidity. We examine the relationship between interbank and deposit rates using two methods: wavelet transform and error-correction models. Based on the wavelet analysis, we found a weakening of pass-through and a slowdown in the repricing of deposit rates in the current tightening cycle among the countries of the CEE region, particularly in the household segment. Based on the error-correction models, in the sample including the tightening cycle, a weakening in the degree and speed of interest rate pass-through is consistently observed in the Hungarian and Polish deposit markets; and the extent of pass-through of the benchmark rate declined most in the Hungarian household deposit market among the CEE countries. Furthermore, a comparison of the interest rate paths estimated on the basis of the transmission correlations for the period excluding the tightening cycle starting in 2021 and the actual interest rate time series shows that the pass-through of the benchmark rate is the least efficient in the Hungarian household deposit market among the countries of the CEE region.

Journal of Economic Literature (JEL) codes: C51, C69, E32, E43, E52
Keywords: deposit interest rates, interest rate pass-through, wavelet transform, error-correction model

Kivonat

Tanulmányunk a közép-kelet-európai régióban, a háztartási és vállalati betétek esetében megfigyelhető kamattranszmisszióval foglalkozik a 2021 közepén elinduló kamatemelési ciklusra fókuszálva. A kamatátgyűrűzés szempontjából különösen érdekes ez az időszak, hiszen a jegybankok magas inflációs környezetre válaszlépésként adott éles kamatemelései egy olyan periódus után következtek be, amelyet jelentős likviditásbőség jellemzett. A bankközi és betéti kamatok közötti kapcsolatot két módszerrel vizsgáljuk: egyrészt wavelet-transzformáció segítségével, másrészt hibakorrekciós modellekkel. A wavelet-analízis alapján a jelenlegi kamatemelési ciklusban a transzmisszió gyengülését és a betéti kamatok átárazódásának lassulását tapasztaltuk a közép-kelet-európai régió országaiban, kiemelten a háztartási szegmensben. A hibakorrekciós modellek alapján a kamatemelési ciklust is magában foglaló mintán a magyar és a lengyel betéti piacokon figyelhető meg egyöntetűen a kamattranszmisszió mértékének és gyorsaságának gyengülése, továbbá a referenciakamat átgyűrűzésének mértéke a közép-kelet-európai régió országai közül a magyar háztartási betéti piacon csökkent a legnagyobb mértékben. A 2021-ben kezdődő kamatemelési ciklust nem tartalmazó időszak transzmissziós összefüggései alapján becsült kamatpályák és a tényleges kamatidősorok összehasonlítása továbbá arról tanúskodik, hogy a referenciakamat átgyűrűzése a közép-kelet-európai régió országai közül a magyar háztartási betéti piacon a legkevésbé hatékony.

Journal of Economic Literature (JEL) kódok: C51, C69, E32, E43, E52
Kulcsszavak: betéti kamatok, kamatátgyűrűzés, wavelet-transzformáció, hibakorrekciós modell

1 Introduction

Monetary policy has an impact on the economy through a number of channels, one of the most important of which is influencing interest rates in different markets – and through that the saving, consumption and investment decisions of real economy actors. The central bank's decisions on the key policy rate first have an impact on short-term money markets (such as unsecured interbank loans or short-term government securities) and then on the interest rates of the main items on banks' balance sheets, including loans and deposits. The size of this effect for existing stocks depends mainly on the contracts already in place at the time of the base rate change (e.g. the contractual benchmark rate, length of the interest period, average maturity), while for newly contracted loans and deposits it is determined by economic conditions (e.g. banks' need for liquidity, savers' price elasticity in the case of deposits).

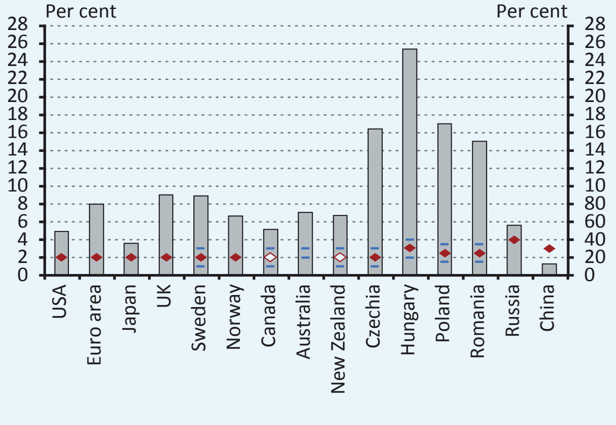
This study focuses specifically on the interest rate pass-through observed for household and corporate *deposits*, focusing on specific markets in the CEE region (Czech Republic, Poland, Hungary and Romania) and the interest rate hike cycle starting in mid-2021. In this paper, we examine the pass-through by country using wavelet transform and error correction models and find that the pass-through has weakened compared to trends in the period before 2021, especially in the Hungarian and Polish household deposit markets.

The period covered by this study is special in several respects. On the one hand, central banks in developed countries have been faced with the highest inflationary environment since the 1980s, to which they have responded by raising policy rates at unusually sharp rates. High inflation has hit Central and Eastern European countries even harder than developed countries (Chart 1), leading to a significant increase in central bank and interbank interest rates in this region as well (Chart 2). On the other hand, this sudden surge in inflation and short-term interest rates came after a period of liquidity abundance and expansion, and a massive increase in central bank and bank balance sheets (Chart 3). The liquidity abundance was also reflected in the banking system's balance sheets, with a decline in the loan-to-deposit ratio (Chart 4).[1] Third, early experiences suggest that deposit pass-through in several countries has been slower than usual in previous interest rate hike cycles (Deutsche Bundesbank 2023, Ferrer et al. 2023, MNB 2023).[2]

[1] Among the countries examined in the study, more significant increases in central bank balance sheet totals were observed in Hungary and Poland following the coronavirus pandemic, while the loan-to-deposit ratio has also declined significantly in Hungary, Romania and Poland over the past 15 years.

[2] The stickiness of deposit rates has also prompted policy makers to take action in several cases: the Polish government has repeatedly communicated on the issue (Reuters 2022), and the Hungarian government has also partly used low household deposit rates as an argument when introducing the extra profit tax on banks in 2022 (Portfolio 2022).

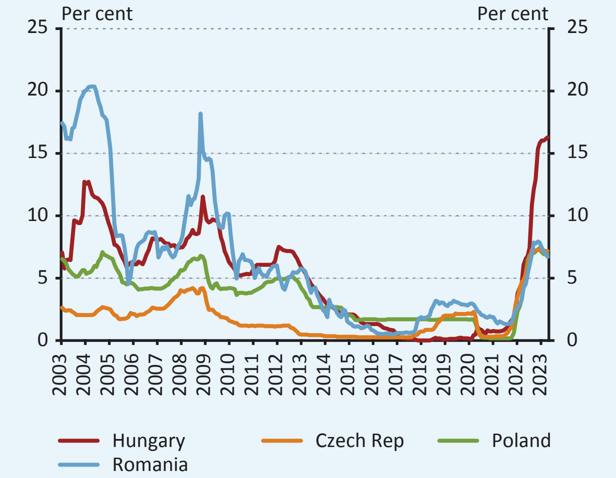
Chart 1
Central banks' inflation target and inflation developments



Note: The blue lines represent the inflation target range for Australia, Canada and New Zealand, and the tolerance band around the target for the other countries. For Canada and New Zealand, the centre of the range is emphasised and marked with an empty diamond.

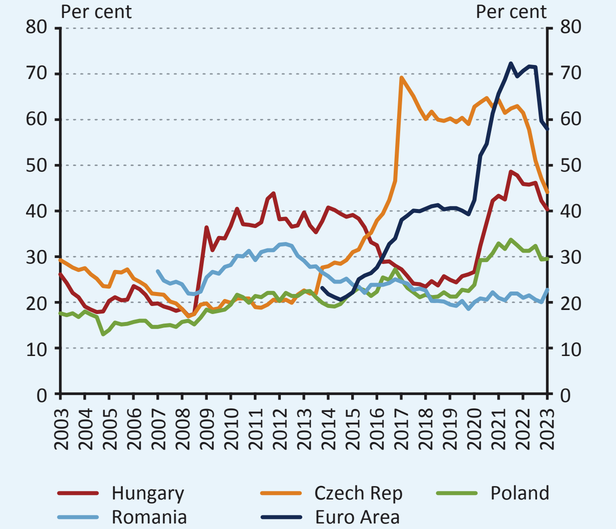
Source: OECD, FRED, National Institute of Statistics Romania, Statistics Sweden, Federal State Statistics Service.

Chart 2
Trends in interbank interest rates in the CEE countries covered by the study



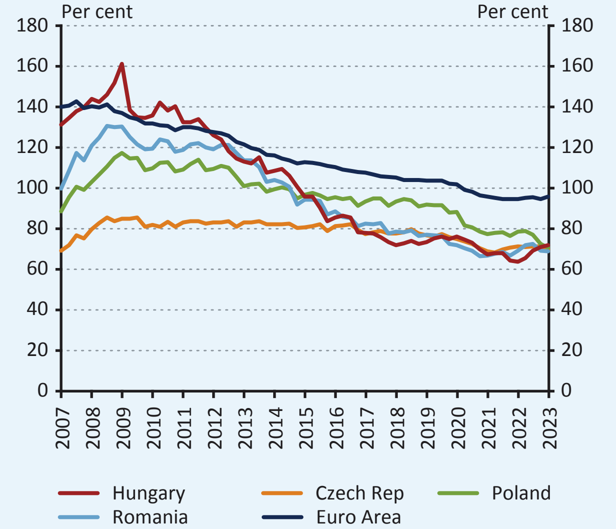
Source: Eurostat, MNB.

Chart 3
Balance sheet total of central banks as a proportion of GDP



Source: national central banks, ECB, MNB.

Chart 4
Evolution of the loan-to-deposit ratio for the countries covered by the study and the euro area



Source: ECB, MNB.

The rise in short-term interest rates and its spill-over into interest rates on other financial products is not only of particular relevance for inflation, but also has a material relevance for financial stability. The profitability of banks depends to a large extent on the average interest rate on their assets and liabilities and the net interest margin between the two. The size of this is largely influenced by the speed with which changes in the central bank's policy rate feed through to the level of interest rates on the asset and liability side of the bank balance sheet. According to the international literature, an increase in the interest rate environment typically has an upward effect on banks' net interest income (Borio et al. 2015), which is confirmed by the fact that the 2021–2022 interest rate hike also had a beneficial effect on European banks' profitability (ECB 2023, MNB 2023). The "stickiness" of the interest rate on deposits is particularly important in this respect. The failure of Silicon Valley Bank in March 2023, however, again highlighted that bank interest rate risk, i.e. the different sensitivity of assets and liabilities to changes in the interest rate environment, can be a source of severe stability tensions, especially when combined with significant liquidity risks (e.g. a high proportion of deposits not covered by deposit insurance) (Jiang et al. 2023). The pricing of deposits is therefore also crucial in this respect.

In this study, several segments of the bank deposit market in these CEE countries are examined. We also analyse the change in the average interest rate on *new* household and corporate deposits and the path of the average interest rates *weighted by the existing deposit stock*. The study also examines interest rates on demand deposits, where interest rate transmission has traditionally been almost negligible, even by historical standards, and therefore current period variations are less well identified.[3] In the analysis, we focus in particular on the extent to which interest rate transmission will work differently for the interest rate hikes starting in 2021 compared to previous changes in the interest rate environment.[4] The analysis follows two main methodologies: on the one hand, wavelet transforms are used to estimate wavelet coherences and phase differences, and on the other hand, error correction models are estimated to analyse the relationship between interbank and deposit rates.

In many countries, descriptive statistics already clearly show that interest rate transmission during the rate hike cycle starting in 2021 is partial and has slowed down compared to previous periods, which raises the question of how the use of more serious statistical methods contributes to the question under analysis. We believe that, on the one hand, the slowdown is not obvious in all countries and, on the other hand, where it is obvious, it is not trivial that the speed or the rate of transmission has changed compared to the past. We also consider it important to provide a numerical answer as to where the interest rates under investigation "*should*" be, based on the correlations estimated from the previous transmission relationship, and how much the deviation from this is. Thus, overall, we believe that the study of interest rate transmission justifies the use of more serious methodologies beyond descriptive statistics.

Our study is novel in that it uses wavelet analysis to examine interbank and deposit rates. Wavelet analysis, which examines the co-movement of parts of a time series at certain frequencies, can lead to different results from the time series econometric methods commonly used for estimating transmissions due to methodological differences. An argument in favour of the wavelet transform is that it allows the relationship between the deposit rate and the benchmark rate to be examined at different frequencies, even when the nature of the co-movement (magnitude, sign, delay structure) varies over time. However, it has the disadvantage that no short-run or long-run parameter is obtained for the *extent* to which the benchmark rates are spilling over into deposit rates, only the strength and speed of the co-movement is given by the coherence and phase difference.

Our main results are as follows: based on the wavelet analysis, we observed a weakening of transmission and a slowdown in the repricing of interest rates in the countries of the CEE region in the current rate hike cycle, especially in the household segment. Based on the error correction models, the sample including the interest rate hike cycle shows a consistent weakening of the magnitude and speed of interest rate transmission in the Hungarian and Polish deposit markets, while for Czech deposit rates the transmission is stronger than would be expected from the historical relationship. Moreover, a comparison of the interest rate paths estimated on the basis of the transmission correlations for the period without an interest rate hike cycle starting in 2021 and the actual interest rate time series shows that the spillover of the benchmark interest rate is the least efficient in the Hungarian household deposit market among the countries of the CEE region.

This study is composed of the following parts: Chapter 2 summarises the relevant literature. Chapter 3 presents the data used. In Chapter 4, we examine the relationship between interbank and deposit rates in selected countries in the CEE region using wavelet transform, and in Chapter 5 we estimate error-correction models that are used to compare the actual path of deposit rates with a forecast based on transmission relationships estimated from data prior to the current rate hike cycle. The study concludes with Chapter 6 outlining conclusions and directions for further research.

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[3] This does not mean, however, that the *importance* of this market is negligible: in Hungary, for example, in the period 2021–2023, 80 per cent of household deposits – with a minimal spread – consisted of demand deposits (MNB 2023). On the partial nature of the demand deposit interest rate transmission, refer to the literature summary.

[4] It is important to stress, however, that the time series in this study is until March 2023, so only the upward leg of the rate hike cycle starting in 2021 is included in our sample. This is important to highlight because some of the literature on the subject explicitly emphasises the differences in interest rate transmission between interest rate hikes and cuts (Andres and Billon 2016).

2 Summary of the literature

The vast majority of studies on interest rate transmission deal with markets for several financial products, often including not only deposits but also interest rates on loans. In the following sections, we summarise mainly the claims made in relevant studies on deposit rates.

Andres and Billon (2016) provide a systematic and thorough review of studies on interest rate transmission in the euro area, estimated coefficients, methodologies used and their shortcomings. Based on the data collected, the most commonly (but far from exclusively) used methodology to study interest rate transmission is the estimation of the cointegration equation and the error-correction model. Looking at the results, they point out that the spillover of the benchmark interest rate into deposit rates is typically lower than that of loans in the long run, as the price elasticity of loan demand is higher than that of deposit supply (i.e. the latter is less sensitive to the interest rate). However, for fixed-term deposits, transmission is still mostly close to complete, especially for longer maturities, while for shorter maturities the rate of transmission is typically lower, which may also be due to costs of switching banks and lower competition (De Bondt 2005).

However, the empirical results on the subject are very diverse, depending on the country and time period under study. For example, studies immediately after the birth of the euro area still typically reported partial interest rate transmission in the deposit market, especially for short-term and demand products. De Bondt (2002), looking at euro area markets, finds that the long-term adjustment of deposit rates lags behind full pass-through, while short-term adjustment has accelerated following the introduction of the single currency. De Bondt (2005) estimates total transmission for the euro area at 32 and 25 per cent for demand deposits with a maturity of up to 3 months, but over 100 per cent for deposits with a maturity of up to 2 years. De Graeve et al. (2007), looking at the Belgian deposit market, observe a stronger long-run adjustment for the stock of longer-term deposits (between 88 and 98 per cent), while the transmission is substantially lower for savings accounts and demand deposits (69 and 53 per cent). Kwapil and Scharler (2010) looked at the US and euro area deposit markets, finding time series cointegrated with the benchmark interest rate, which led them to find near complete long-run interest rate transmission in the US, but the euro area results were below this. According to ECB (2023), the transmission rate for household fixed deposits is 68 per cent (over the period 2007–2021), which is substantially lower than the 86 per cent observed for corporates. The difference may be due to the fact that companies are more likely to switch to alternative investments and that banks have offered negative deposit rates in recent years, while this has not been the case for households. Deutsche Bundesbank (2023) estimates a long-term transmission of 81 per cent for fixed-term deposits for Germany over a longer period, looking at households and corporates together.

Empirical results suggest that the coefficient of the short-term (1-month) adjustment is almost never complete in models describing the adjustment of deposit rates, which may also be driven by lower intensity of competition between banks (van Leuvensteijn et al. 2013), and that it takes shorter or longer for interest rates to return to equilibrium, depending on the product type. De Graeve et al. (2007) observed a short-term (one period) adjustment of 72–85 per cent in the Belgian fixed-term deposit market, while for demand and savings deposits these values are much lower (between 2 and 9 per cent). Hoffmann and Mizen (2001) found a similarly low short-term adjustment in their study of the UK market, but the authors found that the long-run pass-through of interest rates was almost complete. As with the long-term coefficient, the short-term coefficient is typically lower in the short-term deposit market relative to longer maturities (De Graeve et al. 2007).

The number of studies on interest rate transmission in the countries covered in this study, i.e. the non-euro area Visegrad countries and Romania, is relatively small in the literature. Empirical studies on these countries typically date back to the early 2000s or deal with the impact of the 2008 financial crisis. Tieman (2004) estimates long-term interest rate transmission in the longer-term deposit market at 49 per cent for the Czech Republic, 90 per cent for Hungary and Poland, and 78 per cent for Romania, based on data from the beginning of the millennium. Crespo-Cuaresma et al. (2004) also typically (with the exception of Poland) report partial transmission: around 84 per cent of changes in the base rate are passed through to fixed deposit rates in the Czech Republic, 89 per cent in Hungary and 94 per cent in Poland. Havranek et al. (2016), looking at Czech interest rate transmission data of the period around the financial crisis, find that the adjustment of Czech deposit rates to the benchmark interest rate was almost complete before the 2008 crisis, but fell to a fraction after the crisis.[5] According to Stanislawka (2015), Polish corporate deposit rates and household deposits with a maturity of 1–6 months are fully in line with the benchmark rates, while other household deposits have a 79–84 per cent transmission. Contrary to the findings of Havranek et al. (2016) for the Czech market, Stanislawka (2015) found that Polish deposit transmission improved after the 2008 crisis. Hungarian deposit interest rate transmission was also examined by Horváth et al. (2004) and Várhegyi (2003), and both studies observed partial interest rate transmission, but a fuller and faster adjustment of corporate deposits.

As in the euro area, the degree of short-term, one-period adjustment is not complete for these countries either. Among studies written in the more recent past, Stanislawka (2015) estimates a short-term coefficient of 52 per cent for household deposits and 53 per cent for corporate deposits, using Polish data from 2005 to 2013. Here too, it is true that, when the sample is split into two parts, the coefficients increase significantly after the 2008 financial crisis. Havranek et al. (2016) estimate a short-term adjustment of 28 per cent for Czech fixed-term deposits both before and after the financial crisis.

Some of the studies on interest rate transmission specifically examine the impact of a single event (such as the introduction of the euro or the financial crisis of 2007–2008) on the effectiveness of transmission. Some studies examine this on the basis of isolated samples, while other literatures compare the level of interest rates that actually materialise with the path expected by a previous model estimate *(forecasting approach*) (Andres and Billon 2016). This approach, which is also used in the present study, is applied by Jobst and Kwapil (2008) in analysing the impact of the financial tensions of 2007 on the Austrian credit market, by Deutsche Bundesbank (2009) in the context of the financial crisis, by Paries et al. (2014) also in analysing the impact of the financial crisis and the euro area debt crisis, by Deutsche Bundesbank (2023) and by Ferrer et al. (2023) in analysing the current interest rate hike cycle. Both studies conclude that the level of deposit rates in the countries under review is below what would be expected from past interest rate transmission.

The literature suggests that the speed of deposit interest rate transmission is influenced by several factors. One of the best supported findings is that higher liquidity is typically associated with lower transmission (De Graeve et al., Havranek et al. 2016, ECB 2023, Ferrer et al. 2023). In contrast, more intense competition between banks may help the efficiency of transmission, while higher market concentration may hinder it (De Bondt 2005, Kopecky and Van Hoose 2012, Ferrer et al. 2023). However, the results are ambiguous on this issue, for example, De Graeve et al. (2007) find no relationship between banks' market share and deposit pricing. The results on the impact of banks' capital position are also mixed, with De Graeve et al. (2007) associating stronger capital position with weaker interest rate transmission, Havranek et al. (2016) with stronger interest rate transmission, and Stanislawka (2015) estimating different directional effects across products. The effect of bank size is also questionable: some studies find a lower degree of pass-through of changes in the central bank base rate to deposit rates for larger banks (Havranek et al. 2016, ECB 2023), but other studies find no significant effect (Gambacorta 2008). Banks with a higher weight of deposits in liabilities also experience slower transmission compared to institutions that are more reliant on alternative sources of funding (Gambacorta 2008).

[5] However, the study points out that the short time span of four years limits the interpretation and generalisation of the results, especially when analysing such a turbulent period.

3 Data used

For our transmission estimates, we use monthly frequency deposit rate time series downloaded from the European Central Bank's data warehouse and the monthly average 3-month unsecured interbank lending rate.[6] The sample ends with data for March 2023 for all four countries, while the first data point in the time series is January 2003 for Hungary, January 2004 for the Czech data, January 2005 for the Polish time series and January 2007 for Romanian deposit rates.

In our analysis, we look at several deposit rates. For new deposits, we look at products with a maturity of one year or less, for both the corporate and household markets. However, these statistics are distorted in several respects, especially for household deposits.

- In all cases, the deposit rates in the statistics reflect the average deposit rate weighted by the amount of deposits, so if there is a positive correlation between the *amount of deposits* and the available interest rate, the interest rates in the statistics are not necessarily representative of the entire deposit market, which is available to the broader public.[7]

- This problem is exacerbated if there is also a correlation between the *length of the deposit* and the level of interest rates available. The frequency of the statistic is monthly, but the length of the deposits can be shorter and each deposit, regardless of its length, is given full weight in the statistic. In other words, assuming an extreme case, a daily rolled-over deposit can be as much as thirty times more weighted in the statistics, with the consequence that the averages reflect interest rate conditions relevant to a narrow, specific group of persons. This bias can be captured in two ways: first, it is worth looking at the difference between the average interest rate on new deposits and the average interest rate on outstanding deposits, since the latter is also only weighted once (by the end-month balance). On the other hand, the aggregate gross contracted volume of new deposits and the ratio of the outstanding stock and its change can also provide valuable information on the degree of bias. Based on these indicators, this bias is clearly the highest for Hungary among the countries surveyed, where the average interest rate spread between new deposits and outstanding stock is close to 6 percentage points and the ratio of new deposits to outstanding stock is above 100 per cent (Appendix A, Table 5).

- The household sector also includes data from self-employed individuals and non-profit enterprises that assist households, who are able to achieve interest rate conditions that differ substantially from those of household savers.[8]

In order to address some of the above biases, the average interest rate on outstanding deposits is included in the analysis alongside the interest rate on new deposits. For these, data are available for deposits with a maturity of up to two years in a comparable way. The time series examined by country are shown in Chart 13 in Appendix A.

[6] To capture monetary policy changes, we consider changes in interbank interest rates to be appropriate because these rates sometimes reflect changes in central bank policy stance even better than the base rate, as they also reflect the impact of changes in monetary policy instruments outside the base rate.

[7] In Hungary, for example, the average interest rate on new household deposits reached double digits during 2022, while household savers were consistently faced with interest rates close to 0 per cent in the list of terms and conditions of major commercial banks. This was because double-digit interest rates were typically only available to private bank customers with large savings (MNB 2023).

[8] The Hungarian interest rate statistics show separately the interest rates on household deposits within households, and the difference is indeed significant: In March 2023, the average interest rate on new deposits (up to 1 year maturity) of the household sector as a whole was 13.5 per cent, while the average interest rate on household deposits was only 9.4 per cent.

4 Transmission analysis with continuous wavelet transform

Various studies have investigated deposit transmission using time series methods (ECM, VECM, SVAR). The relationship between the variables analysed may change over time, i.e. structural breaks may occur, which these approaches may also be able to handle. However, the relationship between the variables may differ when looking at different frequencies, which cannot be detected by purely time series methods, and frequency filtering methods are required for such studies. In this chapter, we will analyse the deposit transmission using the wavelet transform, which maps the relationships between variables in time-frequency space. This may answer the question – not yet discussed in the literature – whether it is important to obtain new information on the deposit transmission by investigating it at different frequencies.

4.1. METHODOLOGY

There are also several frequency filtering methods available, the first such methods in economics were based on the Fourier transform (e.g. Baxter and King (1999), or Christiano and Fitzgerald (2003)). The Fourier transform produces an arbitrary time series as an aggregate of sine and cosine functions, and thus answers the question of how the time series evolution is related to different frequencies:

$$F_x(\omega) = \int_{-\infty}^{\infty} x(t)[cos(\omega t) - i \cdot sin(\omega t)]dt, \quad (1)$$

where ω is the angular frequency. The disadvantage of Fourier transform-based methods is that they assume a constant frequency resolution in time (the result is independent of t), i.e. they cannot be used to analyse time-varying time series. To deal with this problem, the short-time Fourier transform was invented, which splits the time series into equal parts and performs the transform on each of these separately. An important shortcoming of this method is that there is a trade-off between low frequencies and accurate analysis of temporal changes, with short time windows making the former more inaccurate and longer ones making the latter more inaccurate.

The wavelet transform tries to address the trade-off of the short-time Fourier transform by adjusting the width of the time window to the frequency length: a shorter time window at higher frequencies and a longer time window at lower frequencies (the difference is illustrated in Chart 5). Transform of a continuous wavelet[9] of the square-integrable time series x(t) at time τ with window width s ($s, \tau \in \mathbb{R}, s \neq 0$):

$$W_x(\tau, s) = \int_{-\infty}^{\infty} x(t)\psi^*_{\tau,s}(t)dt, \quad (2)$$

where $\psi^*_{\tau,s}(t)$ denotes the complex conjugate of the wavelet. A wavelet is produced from the so-called mother wavelet in the following way:

$$\psi_{\tau,s}(t) = s^{-0.5}\psi\left(\frac{t-\tau}{s}\right). \quad (3)$$

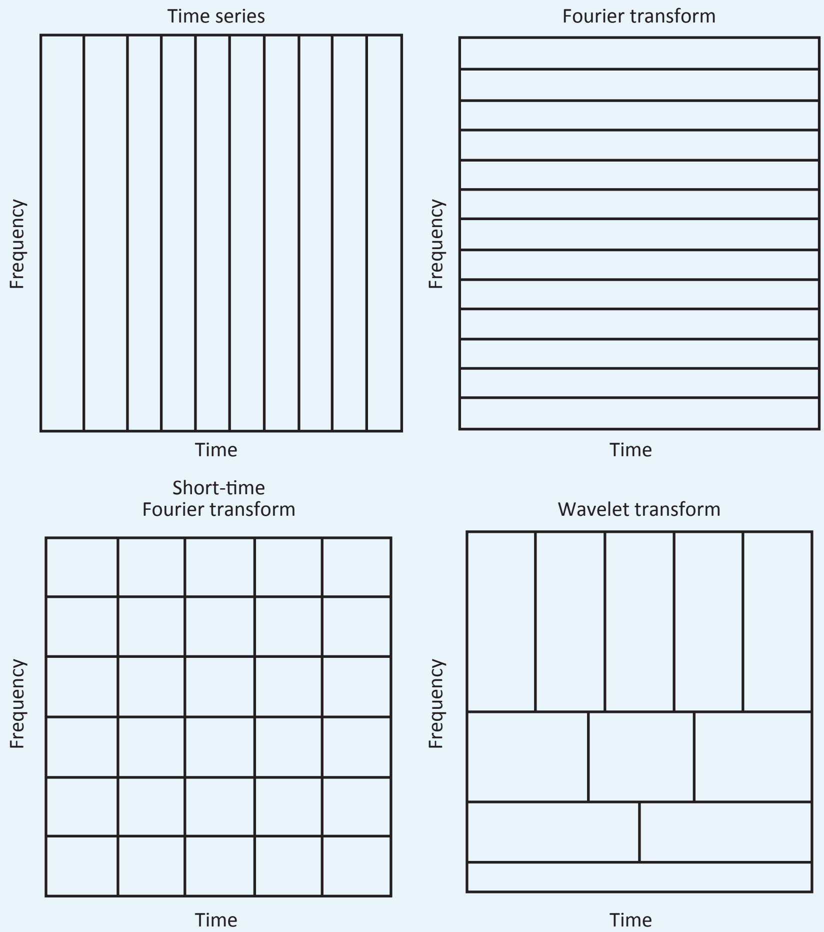
[9] The literature distinguishes between discrete and continuous wavelet transforms, in this study we use the latter, so we present that in more detail.

In the formula s, the so-called scale parameter, at a low value the time window under investigation is small and the high frequencies are investigated, at a high value the low frequencies are detected. The mother wavelet must satisfy certain properties (for example, it must be square integrable), and the most commonly used mother wavelet in economics applications is the so-called Morlet wavelet, which can be written in the following form:

$$\psi(t) = \frac{\pi^{-0.25} e^{-0.5t^2}}{cos(\omega_0 t) - i \cdot sin(\omega_0 t)} \quad (4)$$

The parameter ω_0 in the formula allows us to specify how fine a resolution we intend to have in the time-frequency domain; with a lower value, the time resolution will be more accurate, with a higher value, the frequency resolution will be more accurate. Previous studies have shown that 6 is a reasonable choice for economic time series, so we have made the same assumption. For more details and a thorough review of the methodology, see for example Schleicher (2002), Crowley (2005), Rua (2012) and Aguiar-Conraira and Soares (2014).

Chart 5
Comparison of time-frequency resolutions for different procedures



Source: Uliha (2016).

At a given time and frequency, the wavelet coherence measures the strength of the relationship between two variables, which can be calculated from the wavelet transform, the cross-wavelet transform and a smoothing function*(S()*) as follows:

$$R_{x,y}(\tau,s)=\frac{\left|S(W_{x,y}(\tau,s))\right|}{\left\{S[|W_x(\tau,s)|^2]S\left[\left|W_y(\tau,s)\right|^2\right]\right\}^{0.5}} \tag{5}$$

where the cross-wavelet is:

$$W_{x,y}(\tau,s)=W_x(\tau,s)W*_y(\tau,s). \tag{6}$$

The wavelet coherence takes a value between 0 and 1, the higher the value, the stronger the connection (regardless of its direction). Although coherence only measures the strength of the co-movement between variables, further calculations can be used to obtain the direction and delay structure of this co-movement, namely the phase difference. Its formula (the imaginary part in the numerator, the real part in the denominator):

$$\phi_{x,y}(\tau,s)=arctan\left(\frac{\Im\left(S\left(W_{x,y}(\tau,s)\right)\right)}{\Re\left(S\left(W_{x,y}(\tau,s)\right)\right)}\right) \tag{7}$$

Its value falls within the interval $[-\pi,\pi]$ and the following conclusion may be drawn:

• if $\phi_{x,y}(\tau,s)\in(-\pi,-\pi/2)$: negative relationship, *Y* "follows" *X*,

• if $\phi_{x,y}(\tau,s)\in(-\pi/2,0)$: positive relationship, *X* "follows" *Y*,

• if $\phi_{x,y}(\tau,s)\in(0,\pi/2)$: positive relationship, *Y* "follows" *X*,

• finally, if $\phi_{x,y}(\tau,s)\in(\pi/2,\pi)$: the relationship is negative, *X* "follows" *Y*.

It is important to note that, for the relationships examined by the wavelet method, although resolved in time-frequency domain, it can only measure co-movement between variables, not causality. It is therefore of limited use for drawing economic conclusions.

Although transmission through deposit rates has not, to the best of our knowledge, been investigated using wavelet transforms, the technique is becoming more and more common for other economic issues, especially when examining business and financial cycles. In economics, Ramsey and Lampart first used (discrete) wavelet transforms to analyse the relationship between money supply and GDP (Ramsey and Lampart 1998a) and between income and consumption (Ramsey and Lampart 1998b). Using continuous wavelet transforms, the alignment of business cycles (and its variation over time) across countries in the euro area or the European Union has been analysed by Crowley and Mayes (2008), Aguiar-Conraira and Soares (2011) and Hanus and Vacha (2015). As an example of answering monetary policy questions with wavelet transforms, Aguiar-Conraira et al. (2018) estimate Taylor's rule for the US in the time-frequency domain, and Aguiar-Conraira et al. (2012) investigate whether the introduction of the euro has changed the impact of oil price shocks on the macroeconomy in the euro area countries.

In the next chapter of our study, we will investigate the transmission through deposit rates by estimating ECMs, which is also the most widely used method in the literature to analyse our research question, so it is worth comparing the two methods with their advantages and disadvantages. The argument in favour of the wavelet transform, as mentioned above, is that it allows the relationship between the deposit rate and the benchmark rate to be examined at different frequencies, even when the nature of the co-movement (magnitude, sign, delay structure) varies over time. Furthermore, we do not need to make any extra assumptions about the change of the relationship over time, in the case of a structural break, the methodology detects this by itself as opposed to the ECM.[10] Another advantage of the wavelet methodology is that since we can narrow the analysis to the relevant frequency range for monetary policy, i.e. the length of business cycles (around 2–8 years), higher frequency events (e.g. outliers, seasonality) and lower frequency parts (longer cycles, trend) do not distort the results. However, it has the disadvantage that no short-run or long-run parameter is obtained for the extent to which the benchmark rates are spilling over into deposit rates, only the strength and speed of the co-movement is given by the coherence and phase difference. The extent of long-term spillovers is therefore indirectly quantified in this chapter.

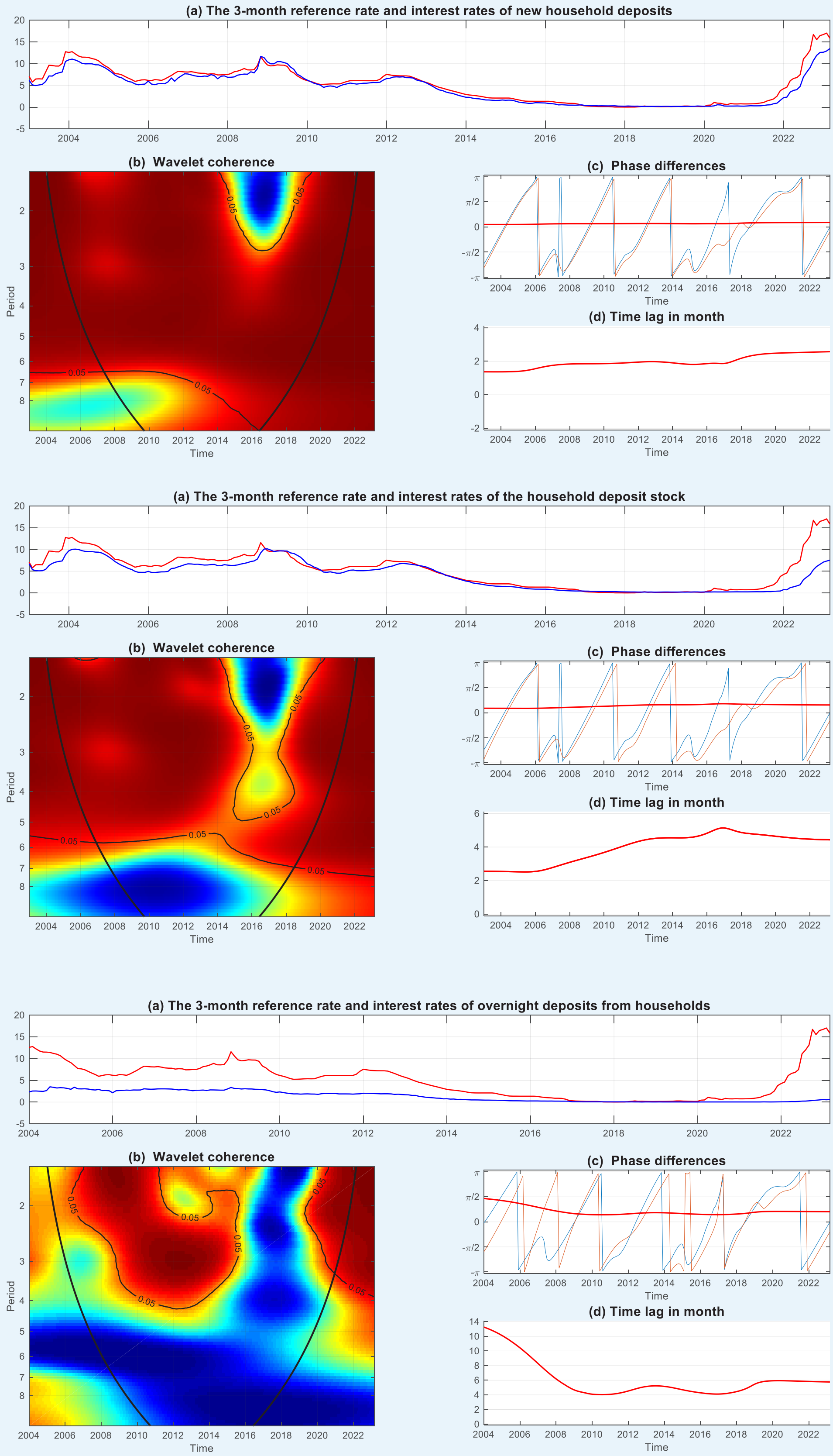
4.2. FINDINGS

The presentation of the results starts with the presentation and analysis of the wavelet coherences and phase differences by country and by population (for reasons of space, only the charts for Hungary, for which the largest temporal variation was observed, are presented in this chapter, the other charts are presented in Appendix B). The wavelet coherence (Chart 6.b) thus shows the strength of the relationship between the two variables at a given time and frequency (cycle length), with the greater the co-movement between the interest rates, the redder the colour in the chart (the bluish shade indicates a weak relationship). Areas significant at the 5 per cent level are bounded by a thin black line. The thick black lines on either side of the chart represent the "padding" boundaries. Since wavelet coherence uses a time window estimator, the points at the beginning (end) of the sample must be extended to allow enough observations before (after) the point in the time window, an extension called padding in the literature.[11] The lower the frequency and the more "on the edge" a time point is located in the sample, the more artificial data are needed to calculate coherence at that point. For points inside the thick black line, no artificial data are needed, but for parts outside the thick black line, they are needed and therefore those should be treated with caution (best left out of the analysis). The results should therefore be considered from around 2008 to 2018 (which depends on where the sample started in the different countries). However, due to the time window estimation, the 2018 values (especially for the lower frequencies) use the data from the most recent interest rate hike cycle, so the results also incorporate this information. The phase differences (Chart 6.c) show the direction of the relationship and the lag structure between the two variables. For simplicity, we transformed the phase difference from the interval $[-\pi, \pi]$ to a scale in months (Chart 6.d) with a median frequency length (5 years), so that this figure shows with how many months lag the benchmark rate cycle is followed by the deposit rate cycle.

[10] In this study, we estimate ECMs with constant coefficients in time.

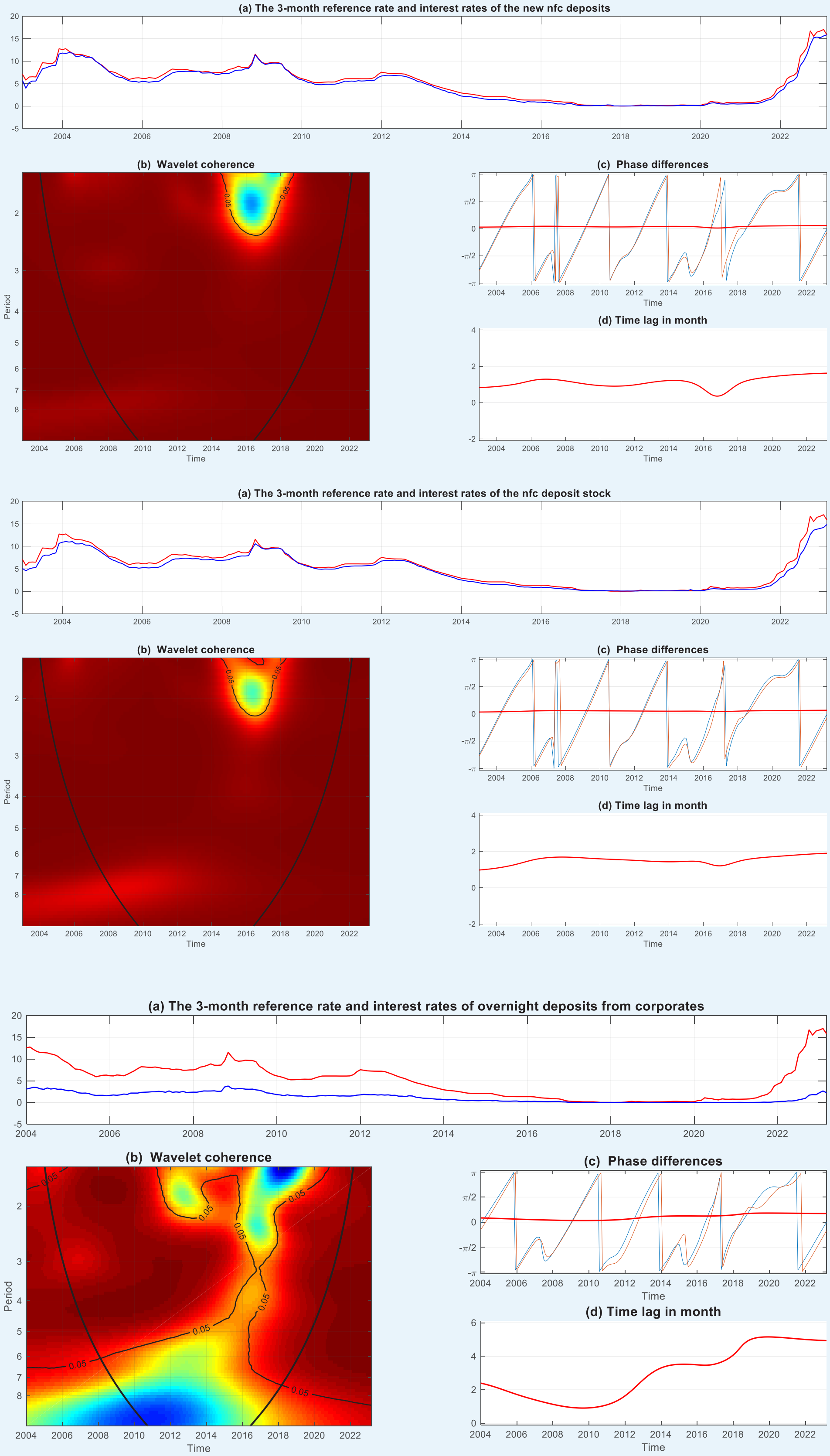
[11] Generating artificial data is usually done in a very simple way, typically by adding "zero" observations, mirroring the sample, or – as in this case – by dragging the last observation forward in a constant manner.

Chart 6
Wavelet analysis between Hungarian deposit rates and the benchmark rate



Source: own calculation based on ECB data.

Chart 6
Wavelet analysis between Hungarian deposit rates and the benchmark rate



Source: own calculation based on ECB data.

As expected, the coherences suggest a strong and significant co-movement between new deposits and fixed deposit rates and benchmark rates for all countries. Corporate deposit rates show stronger co-movement than household deposit rates. The relationship between new deposit rates and the benchmark rate is significant for all countries over almost the entire time and frequency range, with a temporary weakening in the co-movement observed for fixed deposit rates, especially in the household segment and in the period of low interest rate environment (around 2013–2017). The relationship between demand deposit rates and the benchmark rate is weaker than for the other two stocks, with a significant relationship being observed over at least some frequencies close to the full time horizon only for Czech household and corporate, Hungarian and Romanian corporate demand deposits. In the first half of the sample, the interest rates on Hungarian and Romanian household deposits and on Polish corporate demand deposits show a significant relationship with the benchmark rate, while for Polish household deposits there are only small significant areas, indicating a very partial relationship.

Phase differences can be used to analyse the rate of transmission and its variation, but only in periods where the coherence shows a significant relationship. Of course, economic logic would expect the relationship between interest rates to be positive, and deposit rates to follow the change in the benchmark rate with some lag. Our results are in line with these expectations: in all periods of all time series, phase differences between interest rate time series indeed show a positive relationship, and in the significant periods, deposit rates follow the benchmark rate by a few months.[12]

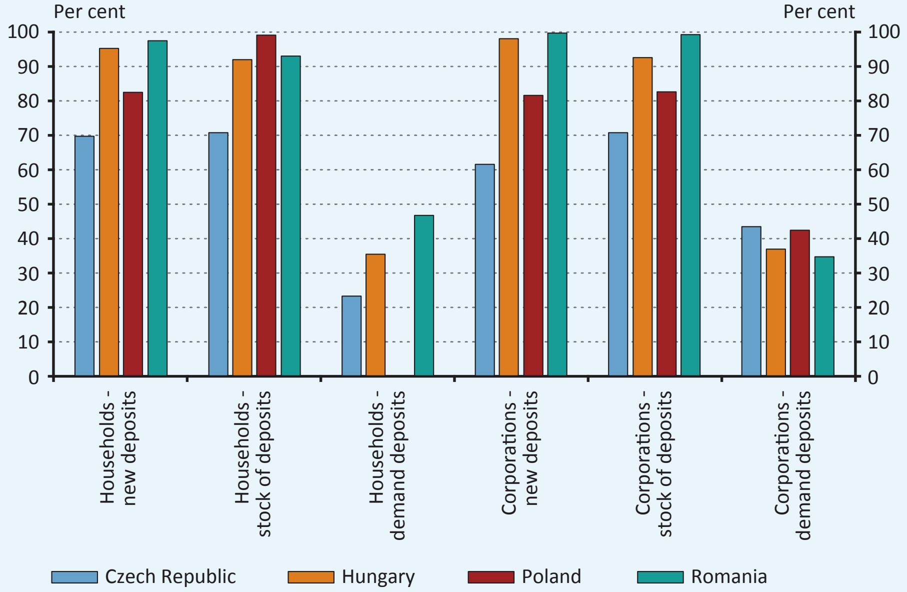
The speed of repricing of new household deposits is fastest in the Czech Republic at less than 1 month, followed by Hungary at 2 months, and slowest in Poland and Romania at 3–4 months. In the first three countries, the speed of transmission has slowed down slightly compared to the previous rate hike cycle (2008–2010), while in Romania it has improved substantially. The repricing of household deposits is significantly slower than that of new deposits. For the Czech Republic and Hungary, the end of the sample is around 4 months, while for Poland and Romania it is over 7 months. With the exception of Poland, stock repricing slowed down in the other three countries by 2–3 months compared to the previous cycle. In Poland, it accelerated, but started from a very high level, catching up only with the speed observed for Romanian interest rates. The transmission rate for household demand deposits in the Czech Republic is about 6 months over the whole time horizon. In the case of Hungary and Romania, there is no significant relationship between the interest rate time series in the second half of the sample, with repricing rates of 4 and 2 months respectively until 2010.

For new corporate deposits, repricing is even faster than for households. Once again, the situation is the most favourable in the Czech Republic, with less than 1 month, while the other 3 countries typically have a duration of between 1 and 2 months. Compared to the previous rate hike period, we are again seeing a slight deterioration, with the exception of Romania, where repricing has accelerated slightly. Transmission is also rapid in the corporate stock, with around 2 months at the end of the observation period in 3 countries and 3 months in Poland. There is little difference in the speed of repricing compared to the previous cycle, with a deterioration in 3 countries and an improvement in Romania. For corporate demand deposits, the transmission speed was around 2 months in the first half of the sample in all countries. For the current cycle of interest rate hike cycles, the Polish time series no longer show a significant relationship, while in the other countries the speed of repricing has slowed to 4 months.

Unfortunately, the wavelet analysis does not provide an answer to the *extent* of transmission, i.e. the percentage of interest rate increases that are reflected in deposit rates in the longer run, but some additional assumptions and calculations can be used to obtain such information, although these are less reliable estimates than the coefficients obtained with the ECM. The rate of transmission was calculated using the lag structure obtained from the phase differences, for example, if we were given that the repricing rate was 3 months, we looked at what percentage of the benchmark rate 3 months earlier the deposit rates were. As we were also interested in whether the transmission rate had changed, we estimated its value at two points in time: at the end of the post-2008 crisis rate hike cycle and at the end of the current rate hikes, i.e. the first 3 months of 2010 and the first three months of 2023. As the phase differences obtained for 2023 may be biased due to the use of artificial data, the repricing rates obtained for the last year without bias, i.e. 2018, were used for the 2023 interest rates.

[12] The only exception to this is the Czech Republic, where, following the 2008 crisis, deposit rates seem to follow the evolution of the benchmark rate. This oddity can be attributed to the entry of new, smaller banks after the crisis, which tried to gain market share by offering high deposit rates above the benchmark rate (Havranek et al. 2016).

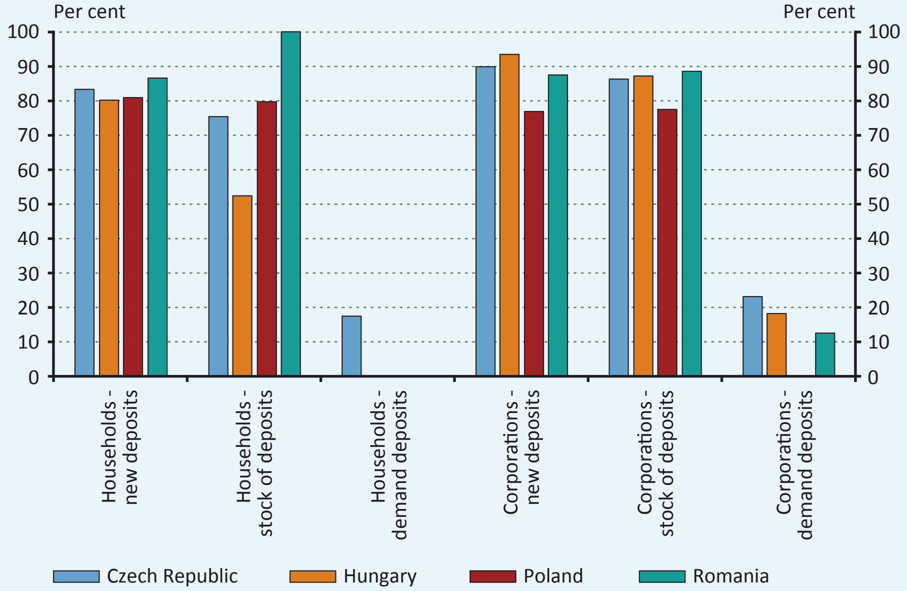
Chart 7
Estimated rate of transmission in 2010 in deposit interest rates



Source: own calculation based on ECB data.

Chart 7 shows that over the previous interest rate cycle, both the corporate and household new deposits and fixed-term deposits in Hungary and Romania have been subject to a benchmark rate above 90 per cent, indicating a strong transmission. Poland had a slightly weaker but also significant spill-over of deposit rates, above 80 per cent, while the Czech Republic had the weakest transmission, around 70 per cent.[13] For demand deposits, the spillover is significantly weaker, 23–47 per cent for the household segment and 35–43 per cent for the corporate segment. in 2023 (Chart 8), the spillover rate between new deposits and fixed-term deposits for the Romanian time series and the Hungarian corporate data

Chart 8
Estimated rate of transmission in 2023 in deposit interest rates



Source: own calculation based on ECB data.

[13] However, as mentioned earlier, in the case of the Czech Republic, the results may be biased due to price competition from small banks that are new entrants.

deteriorated slightly, but remained close to 90 per cent. Czech transmission has caught up with the other CEE countries, while Polish stocks have deteriorated slightly but still show a transmission of nearly 80 per cent. However, the situation deteriorated sharply for Hungarian household deposits, with the transmission rate on the fixed-term deposit portfolio falling to 50 per cent. Furthermore, in both segments of each country (where co-movement remained significant at all), the transmission on interest rates on demand deposits deteriorated significantly by around 20 per cent.

For ease of reference, the differences between the two dates are summarised in Table 1.

Table 1
The difference between the observed spillover rates in 2010 and 2023

		Czech Republic	**Hungary**	**Poland**	**Romania**
Household	New deposits	13	-15	-2	-11
	Stock of deposits	4	-40	-20	7
	Demand deposits	-6	-	-	-
Corporations	New deposits	28	-5	-5	-13
	Stock of deposits	15	-6	-5	-11
	Demand deposits	-20	-19	-	-22

Source: own calculation based on ECB data.

Overall, therefore, the wavelet analysis suggests a weakening of the transmission in the CEE countries, as on the one hand, especially in the household segment, and in particular for the demand deposit rates, we observe a weakening of the co-movement with the benchmark rate, and in some cases an insignificance of the relationship. On the other hand, the repricing of interest rates has slowed down in most cases in response to the current rate hike cycle, especially for household fixed-term and demand deposits. In terms of the rate of transmission, there is a strengthening in the Czech Republic and a weakening in the other countries, with a particularly large decline in Hungarian household fixed-term deposits and a general deterioration in all countries in the area of demand deposit rates.

5 Transmission analysis with error-correction model

5.1. METHODOLOGY

To further investigate the relationship between benchmark interest rates and deposit rates, error-correction models (ECMs) were also estimated separately for the CEE markets in the focus of the analysis. The error-correction model allows us to observe the long-run transmission relationship between interbank rates and deposit rates, i.e. the *overall* extent to which a unit increase in interbank rates is reflected in deposit rates, and the dynamics of this process. Since interest rate transmission is characterised by the fact that the variables have a lagged effect on the dependent variable, we include lagged variables in our regressions.

A necessary condition for the application of the error-correction model is that interbank interest rates and deposit rates are in a long-run equilibrium – cointegrating – relationship. In our study, we test the cointegration relationships using the method introduced by Pesaran (2001) (ARDL bounds testing), which also takes into account the lagged values of the time series. The optimal number of delays is chosen based on the model with the smallest Bayesian Information Criterion (BIC) value, from all possible delay combinations between one and six periods. If there is a cointegration relationship between the time series, the optimal delay number of the variables obtained in this way is included in the error correction equations.

The error-correction model can be written as follows:

$$\Delta Y_t = \lambda Y_{t-1} - \lambda\beta X_{t-1} + \phi_1 \Delta Y_{t-1} \dots + \phi_q \Delta Y_{t-q} + \omega_0 \Delta X_t + \omega_1 \Delta X_{t-1} + \dots + \omega_p \Delta X_{t-p} + \epsilon_t \qquad (8)$$

where Y_t is the level of the deposit rate, X_t is the level of interbank interest rates in period t, β represents the long-run relationship between the two interest rate series in equilibrium (i.e. the long-run pass-through of the unit change in interbank interest rates to the level of deposit rates). The lags of Y and X also appear in the equation, since the change in the deposit rate may be affected by changes in interbank interest rates in recent periods, in addition to interbank interest rates, just as past changes in itself may affect changes in t over time. Their effects are given by their coefficients Φ and ω, while p and q denote the maximum delay. And the dynamics of the adjustment to the long-run equilibrium is represented by the parameter λ.

In our study, we applied the model specification presented in the previous paragraph to analyse the rate of the interest rate transmission of corporate and household deposits in the Czech Republic, Poland, Hungary and Romania. Our empirical strategy is as follows: for each country, we examine the existence of cointegrating relationships on data prior to the current interest rate hike cycle[14] and on the full sample available. Where the cointegration relationship is confirmed, we also estimate an error correction model. The actual evolution of deposit rates since the start of the rate hike cycle is then compared with the deposit rate path estimated over a narrower time horizon by a model that does not include the current rate hike cycle.

5.2. FINDINGS

For each country, the deposit transmission is analysed using the error correction model presented in the previous section, allowing a maximum of six periodic lags, with a lag structure selected using the Bayesian information criterion. Looking at the time series for fixed deposit rates for all countries, in most cases a cointegrating relationship can be identified

[14] The rate hike cycle that is the focus of our analysis started in the Czech Republic and Hungary in June 2021, in Romania in August 2021 and in Poland in October 2021.

both for the full time series (including the period of the current rate hike cycle) and for the narrowed time series (ending with 2021 data) (Table 2). Exceptions to this are the full time series for new household deposit interest rates in the Czech Republic and the narrowed time series for existing household deposit interest rates in the Czech Republic.[15] In contrast, no cointegrating relationship between the demand deposit rates and the benchmark rates can be identified in half of the cases: no significant equilibrium relationship was found for Hungarian household and corporate, Romanian household and Polish corporate demand deposits over the full time horizon, and for Romanian household, Hungarian, Czech and Polish corporate demand deposits over the restricted sample.

Table 2
Cointegration test results and optimal delays

	Entire time series (Data up until March 2023.)		Truncated time series (Not including the interest rate cycle beginning in 2021)	
	Cointegration	**Optimal lag (y,x)**	**Cointegration**	**Optimal lag (y,x)**
New household deposits				
Hungary	does occur	3.2	does occur	2.2
Czech Republic	does not occur	-	does occur	1.1
Poland	does occur	1.1	does occur	1.2
Romania	does occur	1.1	does occur	1.1
Stock of household deposits				
Hungary	does occur	1.1	does occur	1.2
Czech Republic	does occur	3.1	does not occur	-
Poland	does occur	3.3	does occur	3.2
Romania	does occur	4.6	does occur	4.6
New corporate deposits				
Hungary	does occur	2.5	does occur	4.2
Czech Republic	does occur	1.1	does occur	1.1
Poland	does occur	1.2	does occur	2.2
Romania	does occur	1.4	does occur	1.4
Stock of corporate deposits				
Hungary	does occur	4.2	does occur	4.2
Czech Republic	does occur	1.3	does occur	1.2
Poland	does occur	2.1	does occur	2.1
Romania	does occur	3.5	does occur	3.5
Household demand deposits				
Hungary	does not occur	-	does occur	1.1
Czech Republic	does occur	3.2	does occur	1.2
Poland	does occur	1.1	does occur	1.1
Romania	does not occur	-	does not occur	3.3
Corporate demand deposits				
Hungary	does not occur	-	does not occur	-
Czech Republic	does occur	1.1	does not occur	-
Poland	does not occur	-	does not occur	-
Romania	does occur	1.4	does occur	1.4

Source: own calculation based on ECB data.

[15] As noted in the previous chapter, one possible explanation for this is that the changes in the banking market in the Czech Republic following the 2008 crisis have disrupted the co-movement between time series.

We estimated the error correction model for each time series where a cointegrating relationship between the deposit rate and the interbank rate can be identified (the estimation results are presented in Table 3).[16] For fixed-term deposits, the coefficient measuring the long-term relationship typically reaches values above 80 per cent for both new deposits and outstanding stock in most countries and sectors, indicating that transmission is almost complete. A lower coefficient is observed in all narrowed time series for the Czech deposits (72–74 per cent), which may be explained by the prolonged interest rate environment around zero. Furthermore, both samples show full or near-full (at least 94 per cent) spillovers in the Hungarian household and corporate new deposits market, as well as in all four Romanian deposit segments. The long-run relationship between demand deposit rates and the benchmark rate is substantially weaker, with estimated coefficients ranging from 26 to 39 per cent, suggesting partial transmission.

In terms of the coefficients (ω_0)[17] capturing the impact of the instantaneous, month-to-month impact of benchmark yields on deposit rates, known in the literature as instantaneous or short-term[18], it can be generally concluded that transmission is faster in the corporate new deposit and corporate outstanding stock markets than in the household new deposit and household outstanding stock segments. It can also be said that the adjustment of deposit rates is not complete in the short term in any segment, and that it will take a shorter or longer period for rates to return to equilibrium. We observed a high immediate spillover of over 70 per cent in the Hungarian and Czech new corporate deposits markets on the full and the narrowed down sample, and in the Hungarian household new deposits market on the narrowed down time series. In these segments, therefore, a significant part of the change in the benchmark yield is already reflected in the deposit rates in the given month. In contrast, we measured single-digit short-term coefficients in the Romanian household segments and in the Polish household stock interest rates[19] for both samples. In the market for demand deposits, we also estimated a slow immediate transmission of between 5–16 per cent[20] in both segments.

The results for the error correction coefficient are also in line with expectations: the error correction coefficient for new deposits is higher than for outstanding deposits and demand deposit rates in all countries, in both the corporate and household segments and in both periods. This is intuitive, since, when deposit rates change, new deposits can be fixed almost immediately at the changed rate, while for the existing stock, repricing (the "replacement" of the stock) takes time. Among the different sectors, it is clear that outstanding household deposits are the least adjusted to the equilibrium interest rate over a period. Also, corporate deposits typically adjust faster than the household segment. It is also observed that deposit rates typically adjust to their equilibrium level by single-digit percentage points within a month, except for the rates on outstanding corporate stock and new deposits in Romania, which are in the range of 13–15 per cent.

[16] In the table, we have not included estimation results for cases (e.g. new household deposits in the Czech Republic over the whole time series, or demand deposits for several countries and samples) where we did not identify cointegration between interbank and deposit rates. For the non-cointegrating time series, it would have been possible to estimate an ARDL model to identify short-term effects, but given that one of our main concerns is to compare the results estimated over the two time periods, we did not consider it appropriate to compare estimates using different methodologies.

[17] It is important to stress, however, that the coefficient estimate capturing the impact of a simultaneous change in the benchmark rates is consistent only if the change in the benchmark rates is exogenous to the change in deposit rates, i.e., for example, there are no banking system shocks that affect both deposit rates and the base rate (and hence interbank yields). We believe that, although such shocks are conceivable, their occurrence is sufficiently rare that this bias is not significant. However, the possibility of such shocks should be taken into account when interpreting the coefficient.

[18] See for example Paries et al. (2014), Stanisławska (2015).

[19] The short-term coefficient with negative sign estimated on the full sample is not significant.

[20] We estimated a short-term coefficient with a negative sign on Polish household demand deposits.

Table 3
Results of error correction models

	Entire time series (Data up until March 2023.)			Truncated time series (Not including the interest rate cycle beginning in 2021)		
	ECT (λ)	Short-term (ω_0)	Long-term (β)	ECT (λ)	Short-term (ω_0)	Long-term (β)
New household deposits						
Hungary	-0.032	0.642***	0.944	-0.066*	0.745***	0.946*
Czech Republic	-	-	-	-0.056*	0.629***	0.744*
Poland	-0.086***	0.170***	0.890***	-0.057**	0.361***	0.912**
Romania	-0.056***	0.045**	1.018***	-0.050***	0.037*	1.023***
Stock of household deposits						
Hungary	0.007	0.325***	0.916***	-0.034**	0.339***	0.811***
Czech Republic	-0.008	0.258***	1.410**	-	-	-
Poland	-0.039**	-0.055	0.910***	-0.035**	0.051	0.929**
Romania	-0.020**	0.010	0.994**	-0.018*	0.006	0.988*
New corporate deposits						
Hungary	-0.052	0.748***	0.947	-0.071*	0.817***	0.950*
Czech Republic	-0.098**	0.794***	0.842**	-0.123**	0.776***	0.723**
Poland	-0.078**	0.499***	0.813**	-0.077*	0.576***	0.825*
Romania	-0.143***	0.405***	0.967***	-0.145***	0.399***	0.978***
Stock of corporate deposits						
Hungary	-0.059	0.644***	0.914*	-0.059*	0.698***	0.928*
Czech Republic	-0.057.	0.589***	0.860*	-0.065*	0.586***	0.735*
Poland	-0.051**	0.219***	0.893**	-0.051**	0.242***	0.915**
Romania	-0.135***	0.194***	0.951***	-0.134***	0.186***	0.951***
Household demand deposits						
Hungary	-	-	-	-0.065***	0.100***	0.310***
Czech Republic	-0.012*	0.051***	0.386***	-0.013**	0.052***	0.312**
Poland	-0.017**	-0.044*	0.335**	-0.024*	-0.050*	0.358*
Romania	-	-	-	-	-	-
Corporate demand deposits						
Hungary	-	-	-	-	-	-
Czech Republic	-0.092***	0.115***	0.277***	-	-	-
Poland	-	-	-	-	-	-
Romania	0.038	0.145***	0.268	-0.085*	0.156***	0.301*

*Note: Levels of significance: ***<0.001 **<0.01 *<0.05 .<0.1. Source: own calculation based on ECB data.*

Although the time horizon considered in our study differs from the international literature, our empirical results in the deposit markets of the countries and segments studied are in many cases consistent with the conclusions of other analyses. In respect of the long-run spillovers, for example, Tieman (2004) estimates an efficient, almost full transmission in the Hungarian, Polish and Romanian long-term deposit markets, while the Czech deposit market has a substantially weaker total transmission of 49 per cent. Crespo-Cuaresma et al. (2004) observe a transmission of over 80 per cent in the Czech fixed deposit market in addition to the Hungarian and Polish markets, which is roughly in line with our own estimates using the full sample. Our results on long-run adjustment are similar to estimates based on data from other countries, with De Graeve et al. (2007) measuring a long-run adjustment of between 88 and 98 per cent for the Belgian fixed-term deposits market and Deutsche Bundesbank (2023) observing a long-run transmission of 81 per cent for German fixed-term deposits when considering households and corporates together. Furthermore, consistent with our own results, there is a general consistency in the literature that the total spillover in the market for demand deposits is substantially lower than in the market for fixed-term deposits: De Bondt (2005) estimated an interest rate transmission of between 25 and 32 per cent on euro area data and De Graeve et al. (2007) estimated an interest rate transmission of between 53 and 69 per cent on Belgian data, while our estimates suggest coefficients ranging from 21 to 44 per cent across the countries studied. Short-run adjustment is almost never complete in models describing the adjustment of deposit rates, based on the literature, which is consistent with our own empirical experience. Stanislawka (2015) estimated an immediate spillover of 52 and 53 per cent in the household and corporate deposit markets, respectively, on Polish data between 2005 and 2013, and Havranek et al. (2016) estimated a short-term adjustment of 28 per cent in the Czech fixed-term deposit market.

One of the main objectives of our study is to examine whether the transmission rate has changed over the period including the interest rate hike cycle starting in 2021. The differences between the coefficients estimated on the narrowed and full sample are summarised in Table 4 for the cases where we were able to estimate an error correction model for both samples. Overall, the comparison of the estimates suggests that the estimated coefficients of the long-run relationship are typically smaller for Hungarian and Polish deposit rates – with the exception of the Hungarian outstanding stock rates – over the full time-sample, i.e. the sample including the rate hike cycle shows less complete interest rate transmission, while the same cannot be said uniformly for the coefficients estimated over the time series of the other two countries. In the case of Romania, the new deposit rates and the corporate demand deposit market show a weakening of the transmission in the full sample, while the estimated long-run spillover parameter is larger for Czech deposit rates in all comparable cases. Also in terms of instantaneous spillovers, coefficients estimated on the Hungarian and Polish fixed-term deposit markets show a moderation based on the full sample estimates, while the Czech and Romanian deposit markets show the opposite relationship of coefficients.

Table 4
Difference between the coefficients of the error correction model estimated on the two samples (full – narrowed sample)

	ECT (λ)	Short-term (ω_0)	Long-term (β)
New household deposits			
Hungary	0.034	-0.103	-0.002
Czech Republic			
Poland	-0.029	-0.191	-0.022
Romania	-0.005	0.008	-0.005
Outstanding household deposits			
Hungary		-0.014	0.105
Czech Republic			
Poland	-0.004	-0.106	-0.019
Romania	-0.002	0.004	0.006
New corporate deposits			
Hungary	0.019	-0.069	-0.003
Czech Republic	0.025	0.018	0.119
Poland	-0.001	-0.077	-0.012
Romania	0.002	0.006	-0.011
Outstanding corporate deposits			
Hungary	0.000	-0.054	-0.014
Czech Republic	0.008	0.003	0.125
Poland	0.000	-0.023	-0.022
Romania	-0.001	0.008	0.000
Household demand deposits			
Hungary			
Czech Republic	0.001	-0.001	0.074
Poland	0.007	0.006	-0.023
Romania			
Corporate demand deposits			
Hungary			
Czech Republic			
Poland			
Romania	0.047	-0.011	-0.033

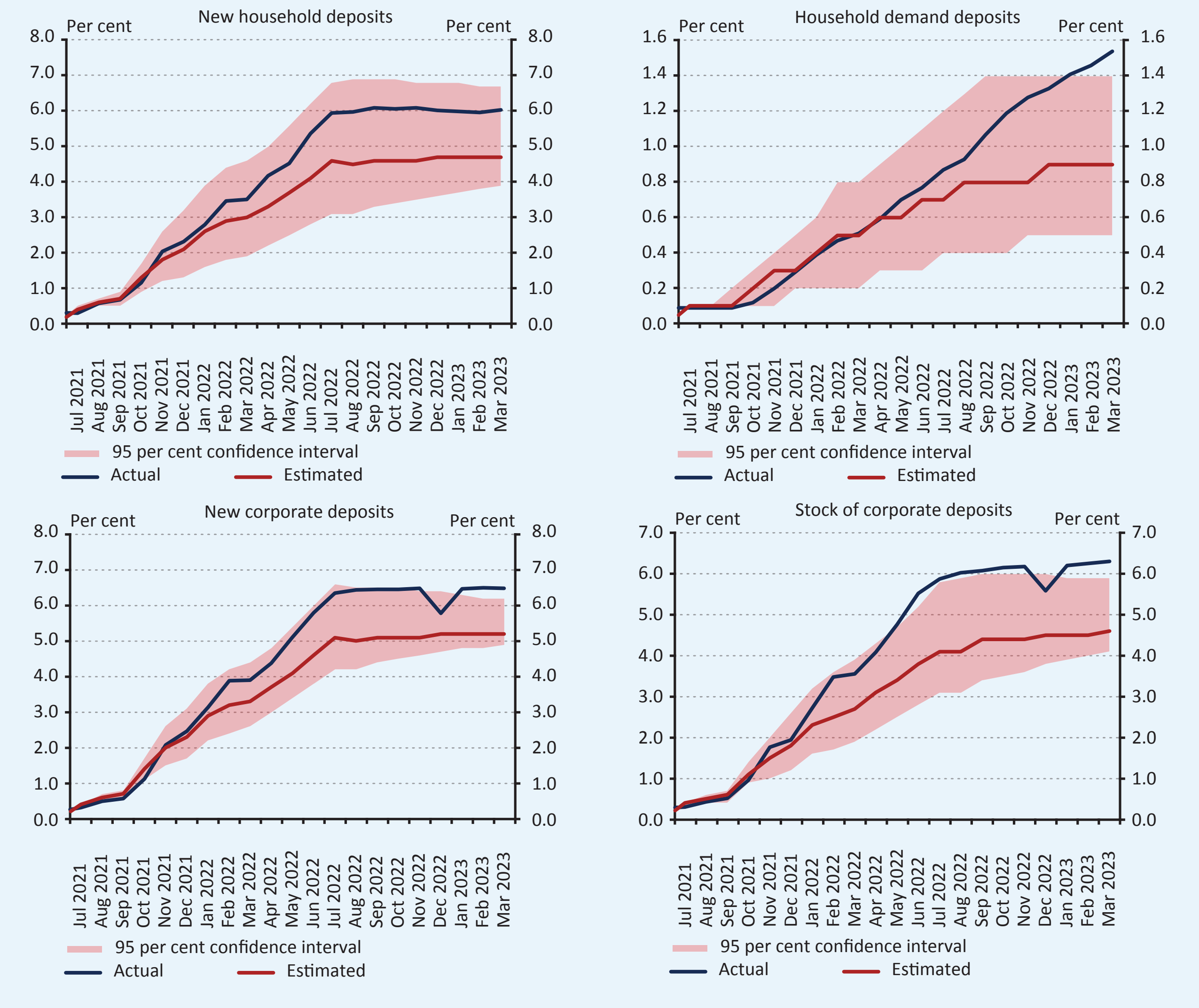
Note: There is uncertainty in comparing segments where no cointegration relationship was found in any of the samples (Czech household fixed-term deposit segments and several demand deposit segments). Source: own calculation based on ECB data.

5.3. ESTIMATION OF THE DEPOSIT RATE BASED ON THE PREVIOUS INTEREST RATE TRANSMISSION

In the following sections, we estimate the "justified" interest rates for the different sectors of the countries under study, based on historical relationships, and compare them with actual interest rates, using the transmission relationships for periods without an interest rate hike cycle starting in 2021.

Chart 9 shows the interest rate projections for the Czech Republic. No estimate is made for the fixed-term deposits and demand deposits of households, as their transmission cannot be estimated by an error correction model in the absence of cointegration. In the other four segments, the actual level of deposit rates exceeds the level estimated on the basis of the ex-ante relationship, i.e. the Czech deposit transmission has strengthened over this period. The most dynamic transmission compared to that estimated by the model occurred in the interest rates on outstanding corporate stocks, where the difference between the actual and the estimated interest rate level reached 100 basis points on average over the time period considered.

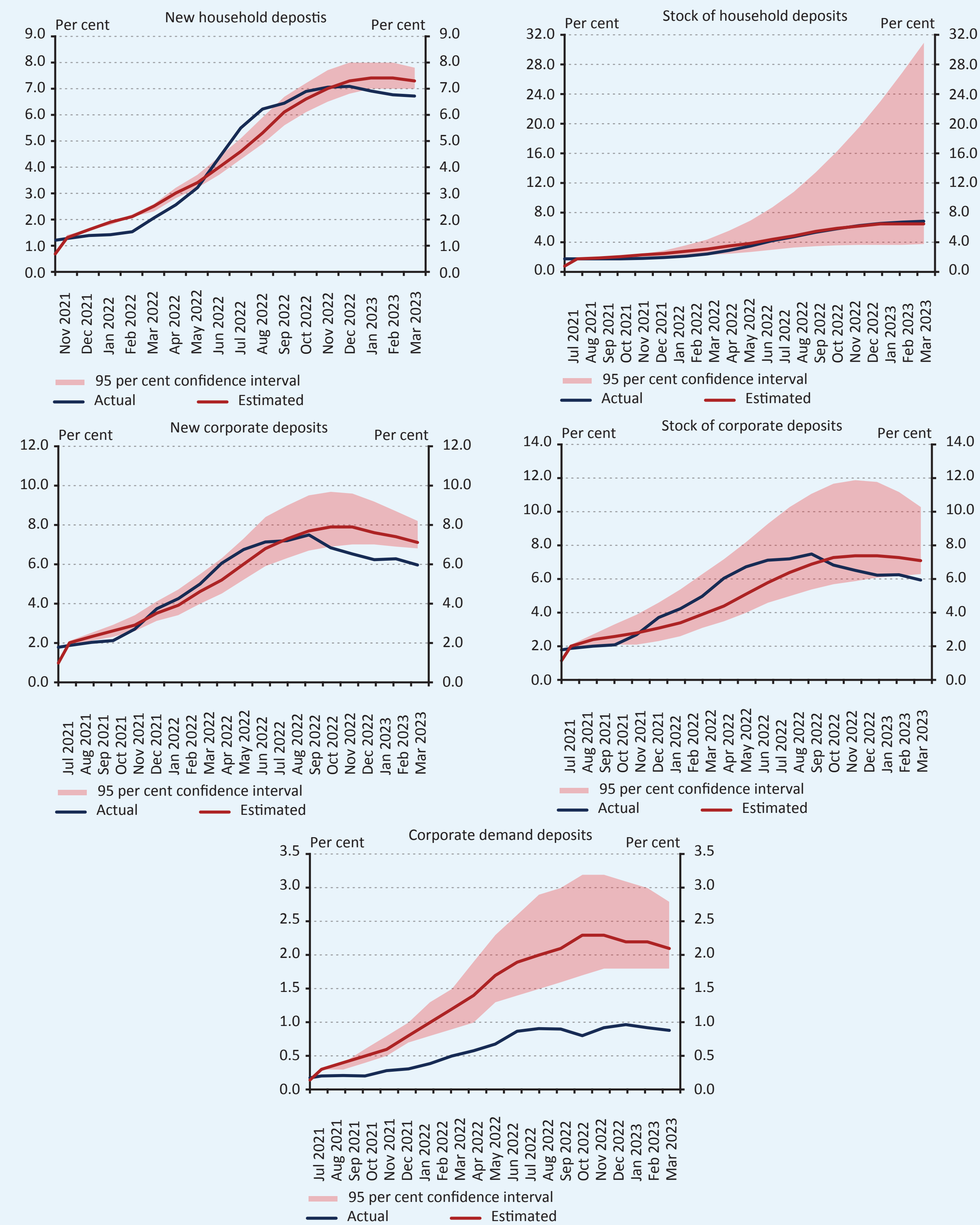
Chart 9
Estimated and actual interest rates in the Czech deposit market



Source: own calculation based on ECB data.

Of the countries examined, the Romanian transmission changed the least, based on the difference between the path estimated from past experience and the actual rise in the interest rate (Chart 10). In the case of fixed-term deposits, interest rates in all four sectors have typically remained close to, or in some months above, the predicted level over the examined horizon. In contrast, the interest rate on corporate demand deposits is significantly below the level estimated on the basis of the ex-ante relationship.

Chart 10
Estimated and actual interest rates in the Romanian deposit market



Source: own calculation based on ECB data.

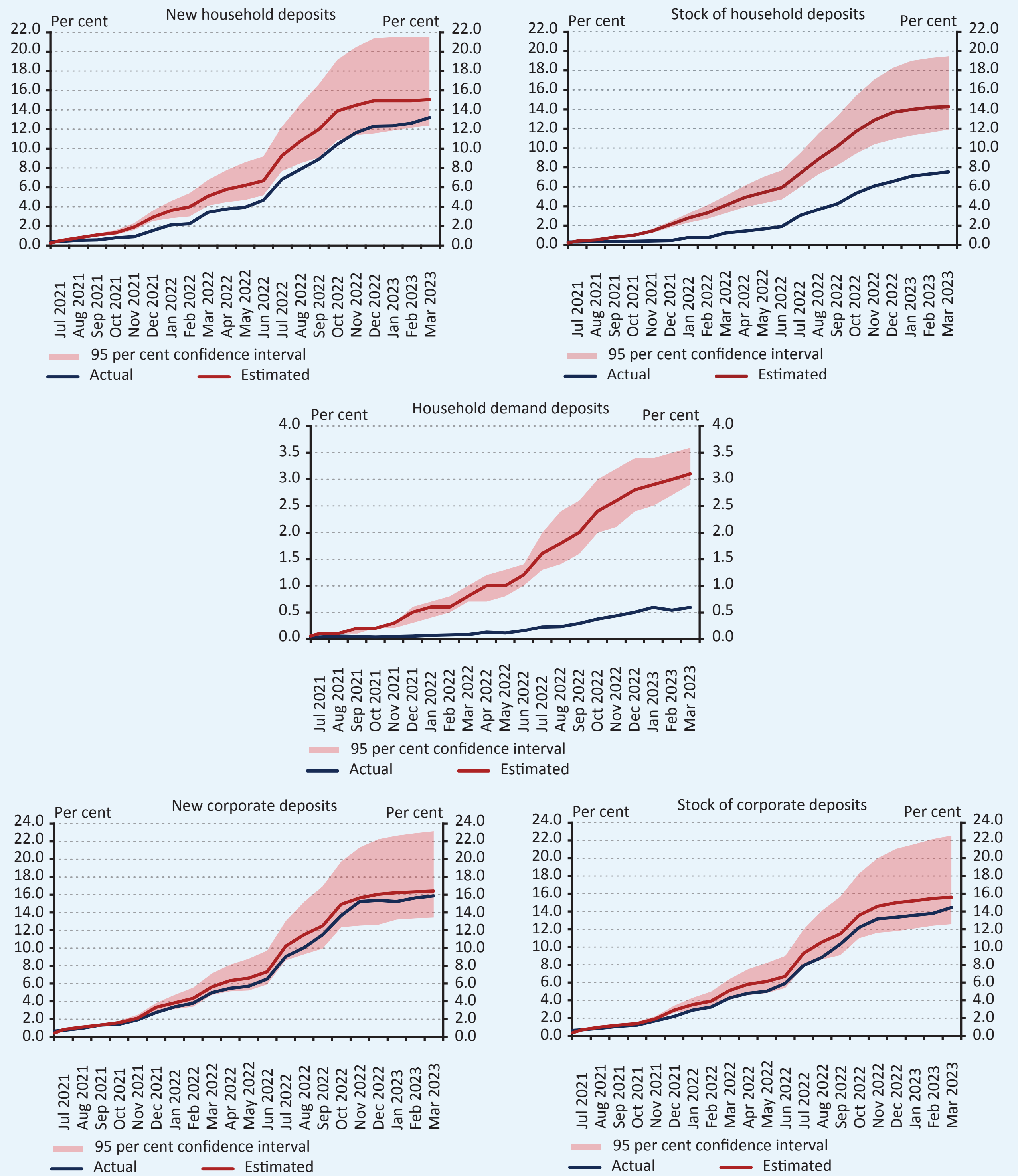
For Polish deposit rates, there is also a small difference between the actual deposit rate increase and the path estimated on the basis of historical data (Chart 11). The actual interest rate level in both segments of corporate fixed-term deposits was on average 50 basis points below the predicted level in March 2023, and remained in a narrow range over the entire time horizon under review, averaging 65 basis points. For household fixed-term deposits, new deposits were only 34 basis points below the historical estimate at the end of the period, the average interest rate on outstanding deposits was 53 basis points below, and the average interest rate on demand deposits was 52 basis points below the historical estimate. These differences can be considered marginal in the light of the negative spread observed in the household deposit market at the start of the rate hike cycle.

Chart 11
Estimated and actual interest rates in the Polish deposit market

Source: own calculation based on ECB data.

In the case of household deposits, the difference between the Hungarian time series and their projection is more significant than in the three previous countries (Chart 12). The interest rate transmission of the corporate segment is not particularly weak by international standards, given the more radical changes in the Hungarian interest rate environment. Newly committed corporate interest rates rose by 54 basis points less by March 2023 than would be expected from an estimate based on historical data, and the difference between the estimated and actual interest rate level averaged 65 basis points over the entire period under review. However, the 15.6 per cent rate estimated for the interest rate on corporate

Chart 12
Estimated and actual interest rates in the Hungarian deposit market



Source: own calculation based on ECB data.

fixed-term deposits was already 114 basis points higher in March 2023 than the 14.5 per cent level in real terms, averaging 93 basis points.

The radical change in deposit transmission is seen when examining household deposits. For household demand deposits, the transmission based on projected interest rates was significantly weaker than in the other countries examined. Moreover, the actual level of new household deposits of 13.3 per cent is almost 2 percentage points below the estimated level of 15.1 per cent. It is important to point out, however, that the interest rate on new deposits, unlike in other countries, is significantly biased by large amount one-off deposits by wealthy households (see Chapter 3). The outstanding stock of household fixed-term deposits follows the benchmark rate with a very high interest rate spread, suggesting a weak and slow interest rate transmission. The average interest rate on Hungarian households' deposits stood at 7.6 per cent in March 2023, while the projected path based on the previous transmission relationship would have justified a level of 14.0 per cent. This is a difference of more than 6.5 percentage points, and the average deviation over the period under review is also more than 3.5 percentage points, suggesting a significant weakening of Hungarian interest rate pass-through.

6 Conclusions

Our study examined interest rate pass-through of household and corporate deposits for four CEE countries, focusing on the interest rate hike cycle starting in mid-2021. The relationship between interbank and deposit rates was investigated using two methods: on the one hand, wavelet transforms were used to estimate wavelet coherences and phase differences, and on the other hand, error correction models were estimated. Based on the wavelet analysis, we observed a weakening of transmission and a slowdown in the repricing of deposit interest rates in the countries of the CEE region in the current rate hike cycle, especially in the household segment. Based on the error correction models, the sample including the interest rate hike cycle shows a consistent weakening of the magnitude and speed of interest rate transmission in the Hungarian and Polish deposit markets. Moreover, a comparison of the projected deposit rate paths and actual interest rate time series based on the transmission correlations for the period without an interest rate hike cycle starting in 2021 shows that the Hungarian household deposit market has experienced the largest reduction in the benchmark rate spillover among the countries in the CEE region.

Wavelet and cointegration analysis may give different results due to methodological differences. In addition to the theoretical considerations presented so far, a further difference in testing the significance of the relationships may be that the ECM tests a cointegration relationship, while the wavelet tests the co-movement of parts of the time series at certain frequencies. In addition, the comparison of past and recent interest rate hike cycles is not made on the same sample (for methodological reasons) in the two cases: the ECM performs estimates on a narrowed and full sample, while the wavelet performs estimates on two disjunct periods at the beginning and end of the sample. Thus, while it is not worth comparing the individual figures of the two analyses quantitatively, it is possible to compare them qualitatively in terms of magnitude and change.

In our study, the two methodologies have the same results in that corporate stocks are repriced faster than household stocks and transmission is more efficient for new deposits than for existing or demand deposit stocks. Also, both procedures show a much lower (10–40 per cent) long-run spillover in interest rates on demand deposits compared to other deposit rates (70–100 per cent), although there are differences in the significance of the relationships. The sign of the change in transmission is also almost identical in the two cases (Table 1 versus Charts 5–8): apart from the Czech corporate demand deposit rates, the wavelet analysis shows deterioration in the same cases where the interest rate path projected by the ECM is higher than the actual one, i.e. also indicating weaker transmission. In addition, the results are also consistent in that there has been a large deterioration in the interest rates on Hungarian outstanding stocks.

In our study, we did not examine the reasons for the deterioration in the effectiveness of deposit interest rate pass-through in countries where they occurred. This will be an important research issue in the coming years. Among the potential causes, a liquidity abundance as a consequence of the unconventional monetary policy of the 2010s could play a prominent role, which, combined with competitive weaknesses, could easily lead to deposit rates being stuck at low levels. However, we did not have sufficient data to identify these factors in this study.

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Appendix

APPENDIX A: TIME SERIES OF FIXED DEPOSIT INTEREST RATES INCLUDED IN THE ANALYSIS BY COUNTRY

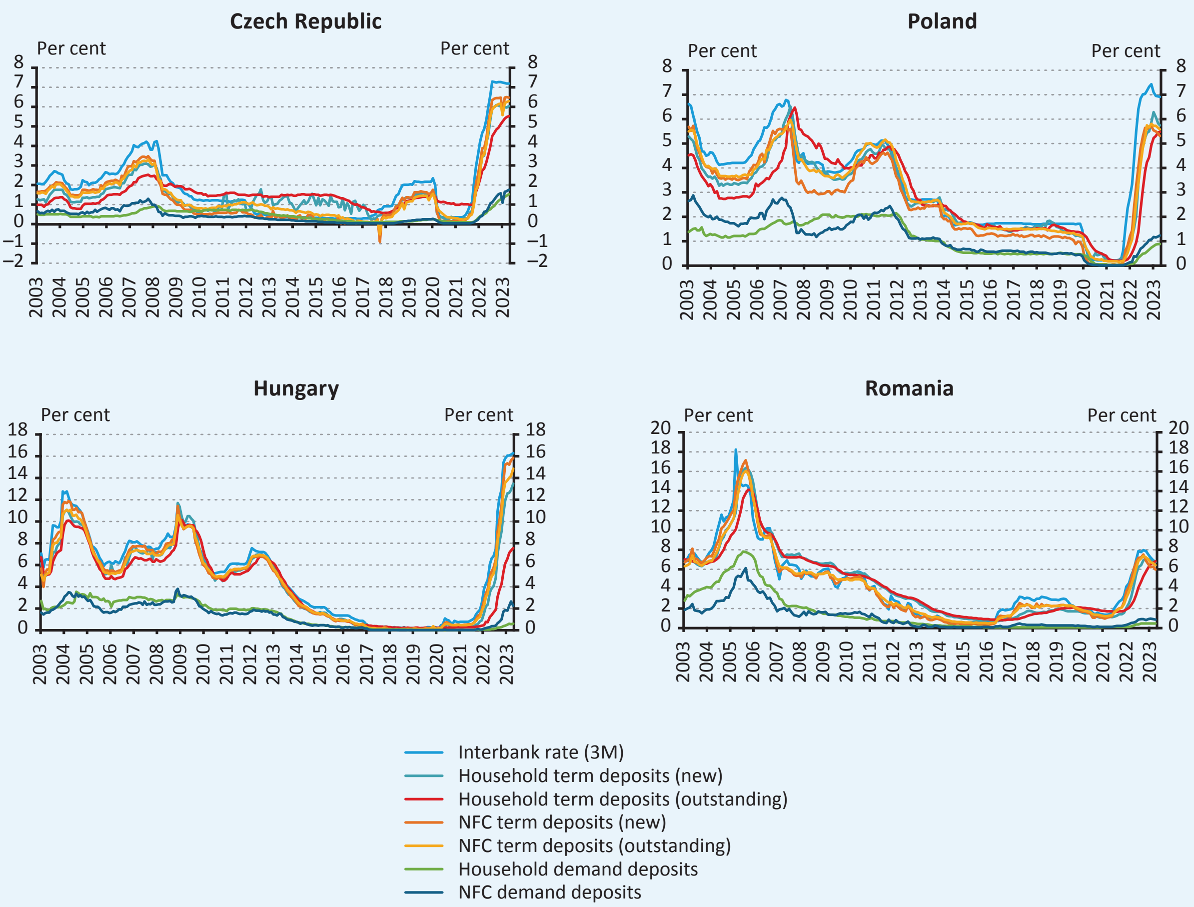
Table 5
An assessment of certain statistical biases in the interest rate level of new household deposits

	Interbank rates (3M) (per cent)	Mean interest rate on new deposits (per cent)	Deposit rates weighted by stock outstanding deposits (per cent)	Difference between interest rates on new deposits and the mean interest rate on outstanding deposits (percentage points)	Proportion of gross new deposits to the stock of outstanding deposits (per cent)	Long-term proportion of gross new deposits to the stock of outstanding deposits (per cent)
Hungary	16.3	13.4	7.5	5.9	117.1	24.6
Czech Republic	7.1	6.0	5.5	0.5	23.1	17.4
Poland	6.9	5.7	5.4	0.2	21.0	19.0
Romania	6.7	6.7	6.8	-0.0	14.2	12.6

Note: Data from March 2023 The long-term average of the ratio of gross new deposits to existing deposits per country was calculated on the total available sample (data between 2003–2023 for Hungary, 2004–2023 for the Czech Republic, 2005–2023 for Poland and 2007–2023 for Romania).

Source: ECB, national central banks.

Chart 13
Time series of interbank interest rates and fixed deposit interest rates included in the analysis by country



Source: ECB, national central banks.

APPENDIX B: WAVELET COHERENCIES AND PHASE DIFFERENCES FOR CZECH, POLISH AND ROMANIAN DEPOSIT INTEREST RATES

Chart 14
Wavelet analysis between deposit interest rates and the benchmark interest rate in the Czech Republic

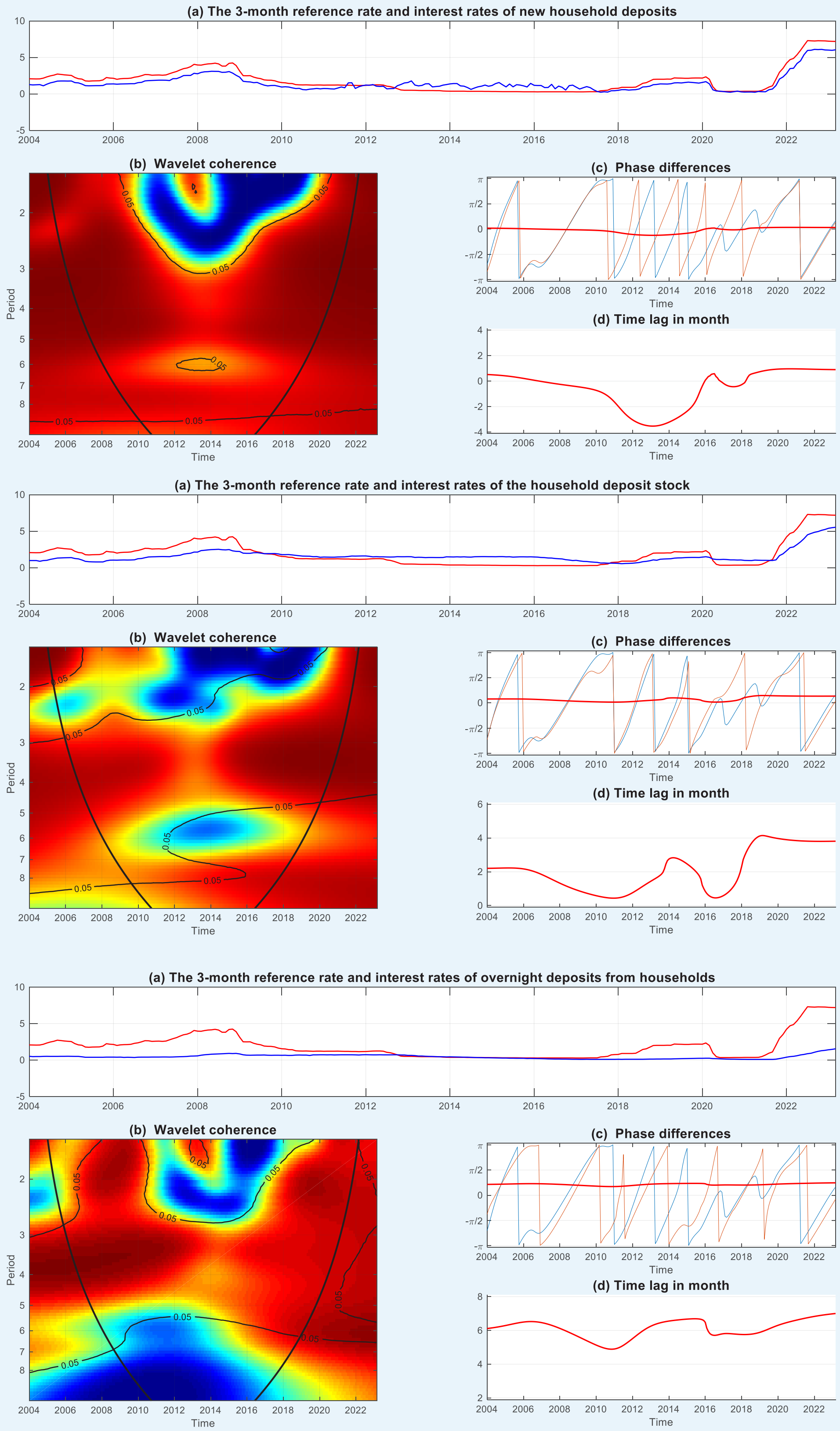
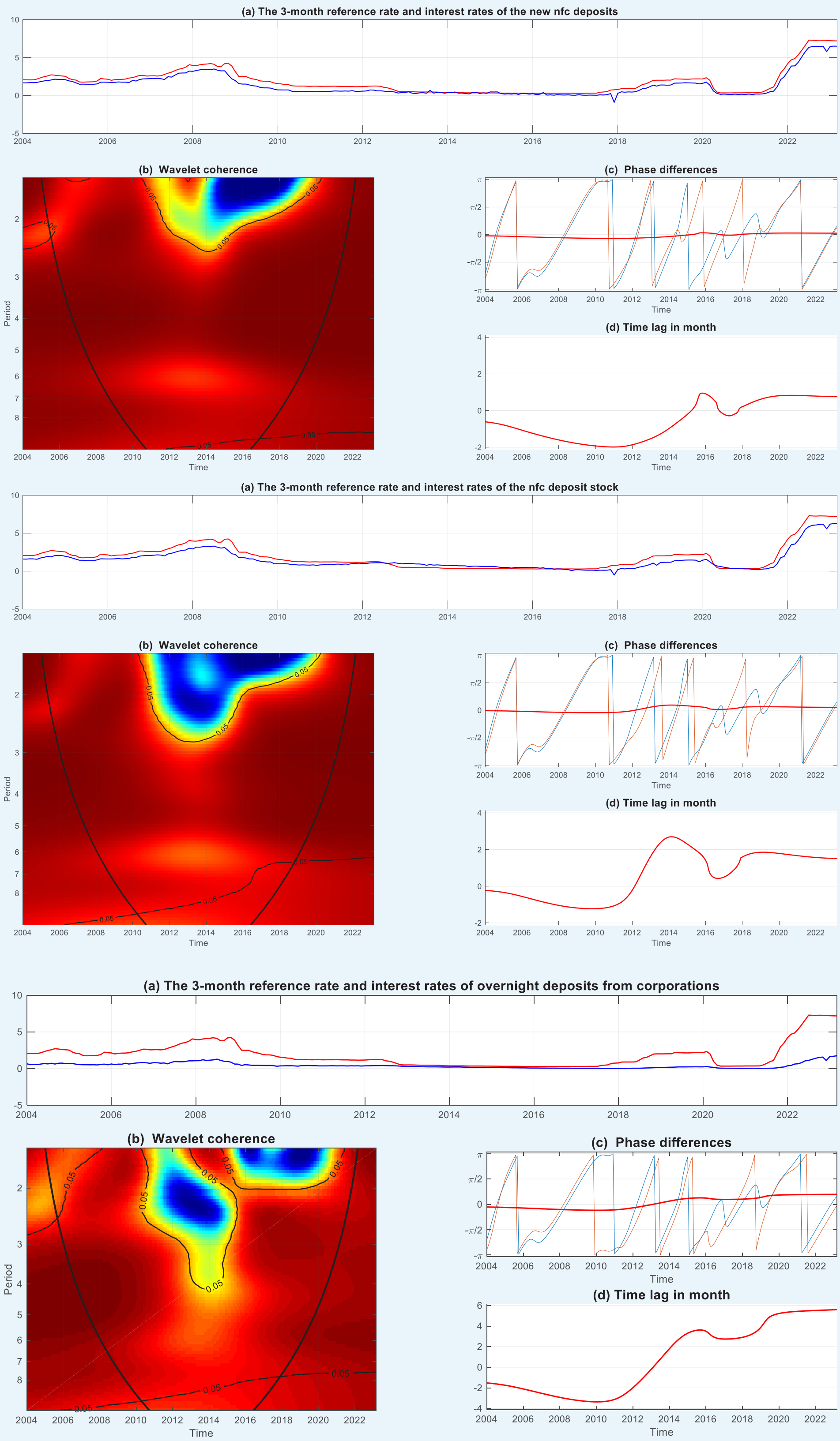


Chart 14
Wavelet analysis between deposit interest rates and the benchmark interest rate in the Czech Republic



Source: own calculation based on ECB data.

Chart 15
Wavelet analysis between Polish deposit interest rates and the benchmark interest rate

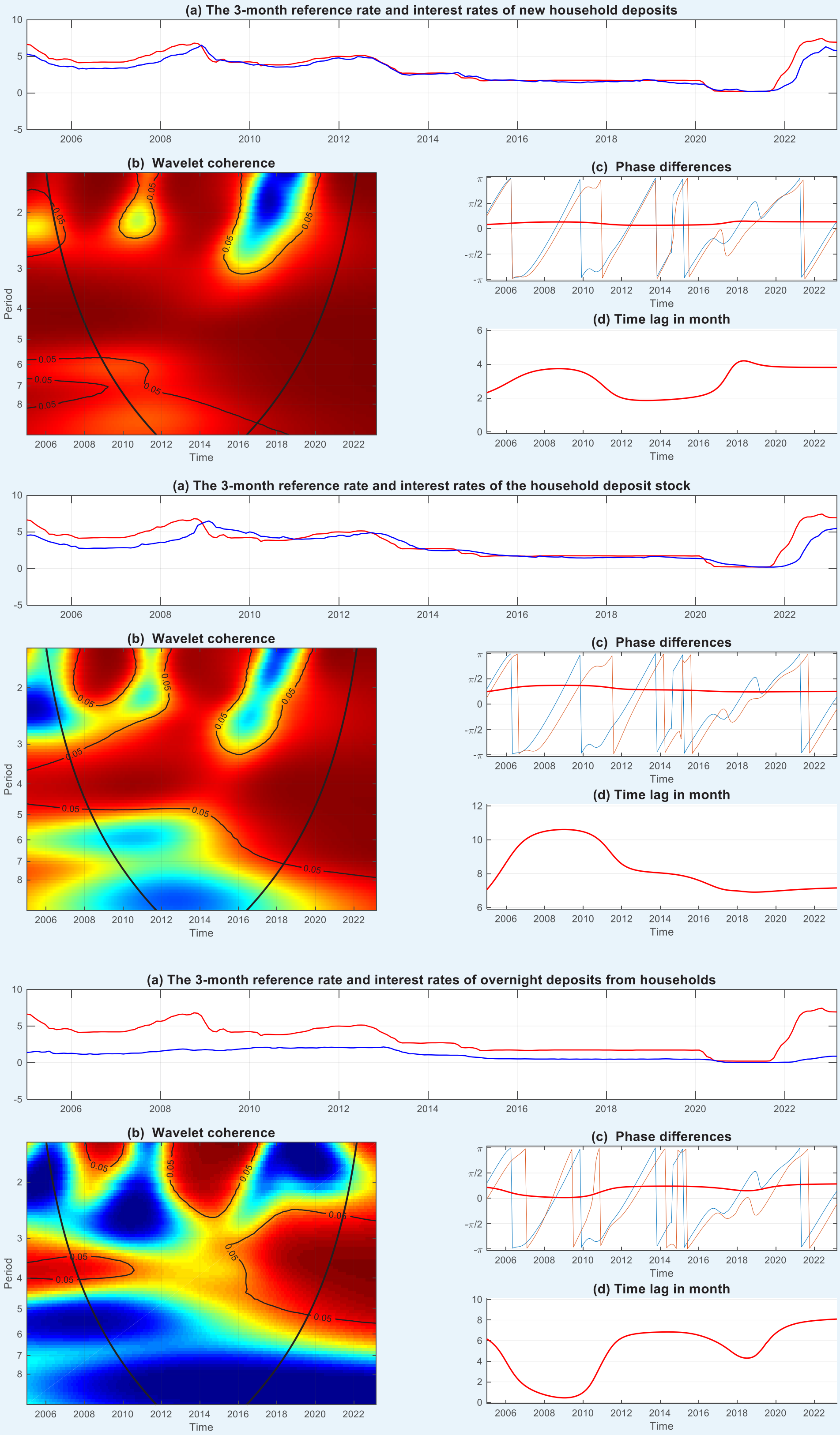
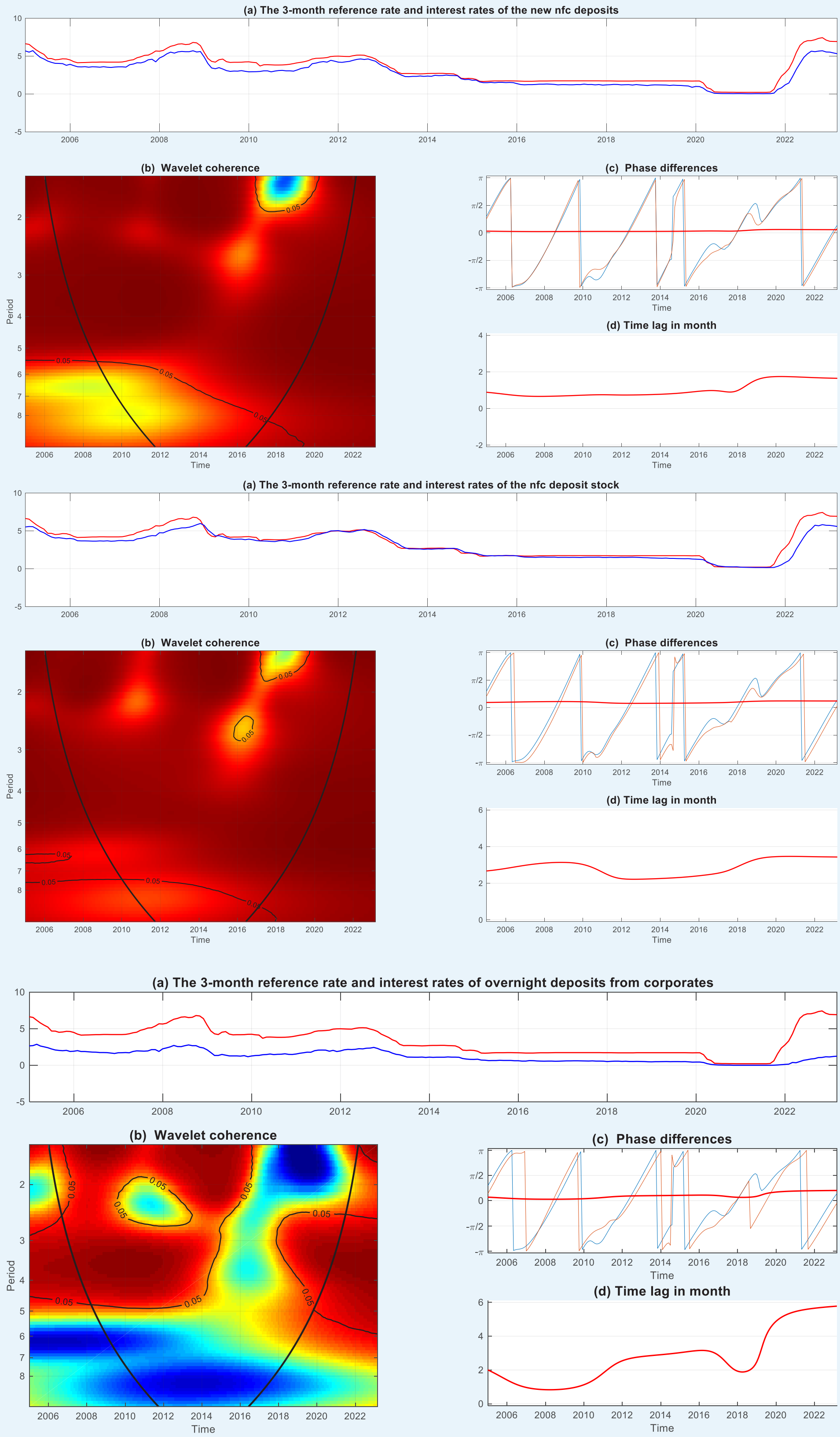


Chart 15
Wavelet analysis between Polish deposit interest rates and the benchmark interest rate



Source: own calculation based on ECB data.

Chart 16
Wavelet analysis between Romanian deposit interest rates and the benchmark interest rate

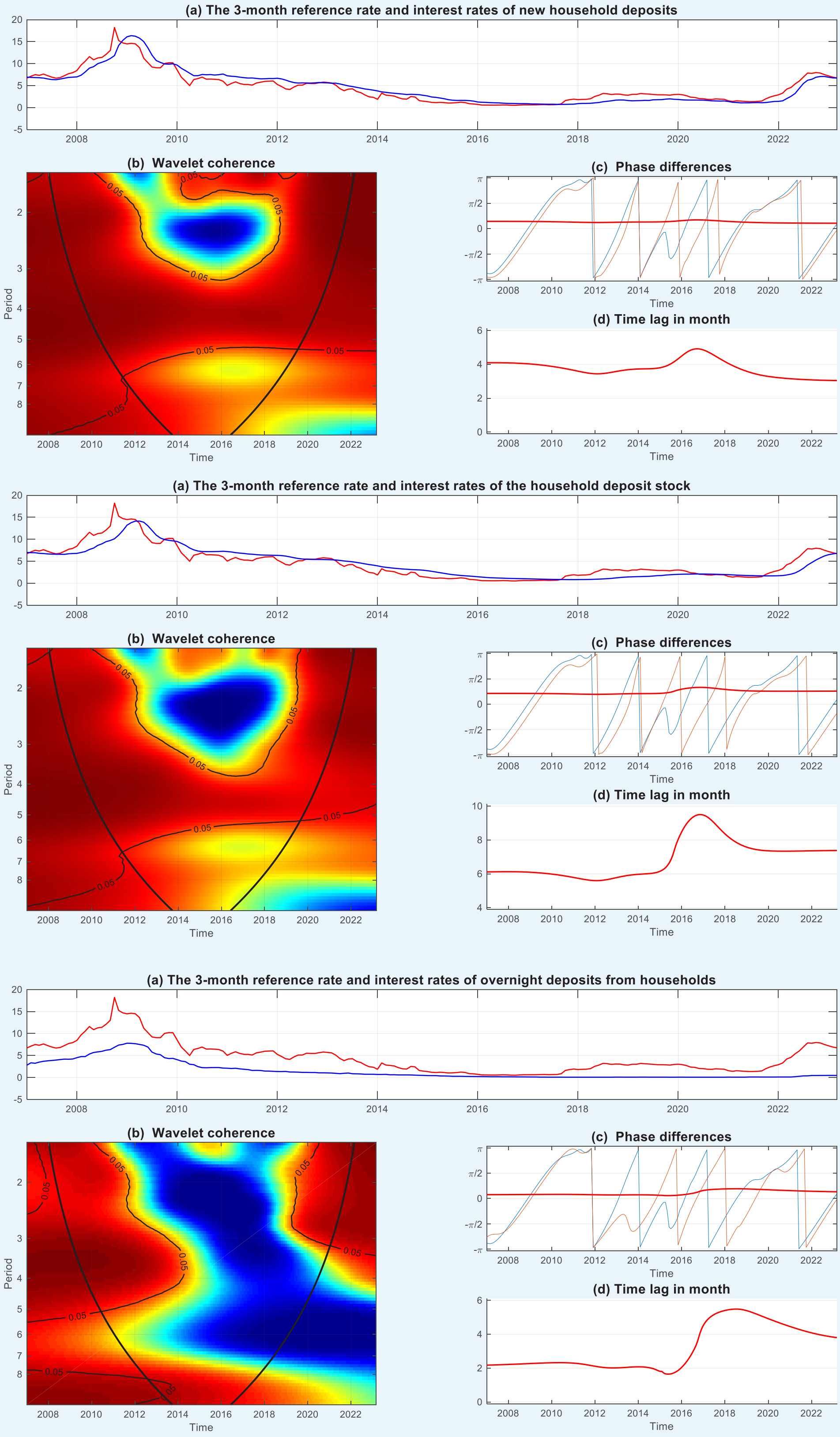
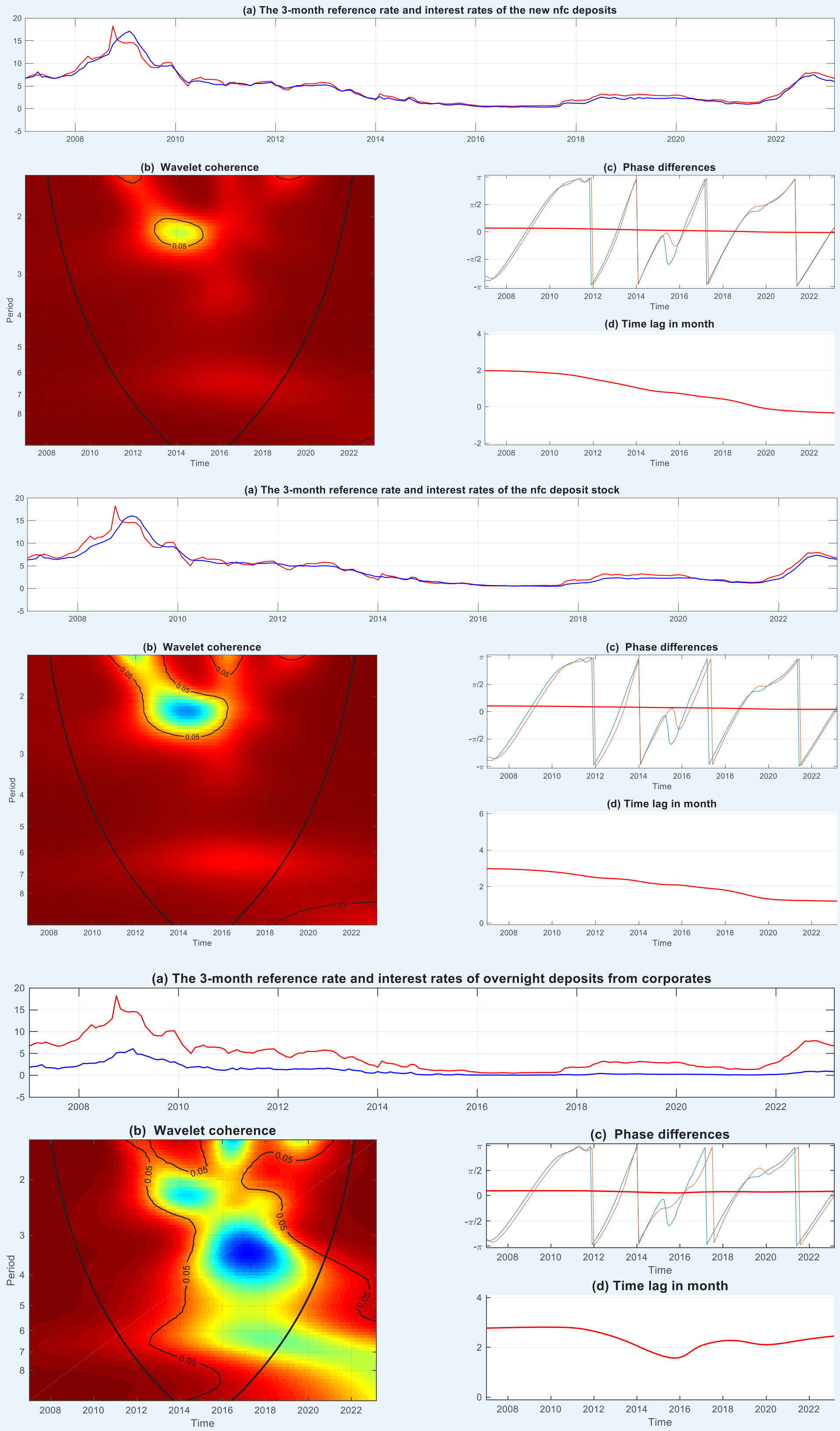


Chart 16
Wavelet analysis between Romanian deposit interest rates and the benchmark interest rate



Source: own calculation based on ECB data.

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