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Spillover effects of the unconventional monetary policy of the European Central Bank

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ABSTRACT

We analyze the effects of the European Central Bank's (ECB) unconventional monetary policy spillovers on the inflation-targeting Central Eastern European (CEE) countries using daily panel data from 2000 to 2019. We perform an exercise to identify these spillovers on the monetary market, calculate instantaneous short rates and term spreads, and use both Bayesian averaging panel and time-series approaches. Overall, we find that the spillovers from the unconventional ECB policy are not different from the conventional spillovers and are generally insignificant. While we find a significant reaction to inflation and an insignificant reaction to the output gap, we find that none of our ECB policy measures affect the instantaneous short interest rate nor the long-run term spreads. Our main result is that the international spillovers manifest themselves through the risk-taking channel, not the bond/interest rate channel, and have the form of volatility co-movement.

1. Introduction

The article aims to analyze the effects of the European Central Bank (ECB) unconventional monetary policy spillovers in the environment of nominal interest rates close to zero bound. The euro area countries act as both the dominant trade partner and capital supplier to the CEE region. In addition, there are substantial cross-border banking flows particularly prior to the global crisis as 60% of its banking sector assets are foreign-controlled, mainly by financial institutions from the eurozone as documented in Brzoza-Brzezina et al. (2018). For these reasons, the article is focused on a current and important issue. Assessing the impact of the unconventional monetary policy of the European Central Bank is of great interest for both researchers and policymakers, and is the main goal of the paper. In contrast to the existing literature, we focus on the unconventional monetary policy of the European Central Bank pass-through to the interest rate yield curve, which operates as the main channel for monetary policy to affect the economy.

As Aizenman (2015) notes, the assumption that the monetary policy of the countries that could be considered financial centers may have significant unintended externalities for smaller economies is not new. Similar assumptions were already made in the case of debt crises in the 1980 s in Latin America and Africa and during several currency crises in the 1990s in Latin America and Asia (Maćkowiak 2007). At that time, however, following the Mundell-Fleming paradigm, it was considered that the observed transfer of interest rates from the most developed countries is a consequence of the constant exchange regimes prevailing at the time and the inability to accommodate these shocks with the use of the monetary policy. Since then, many small open economies have decided to switch to floating regimes, linked to the strategy of direct inflation targeting, which in principle should isolate from external shocks caused by the unintended effects of monetary policy in global financial centers.

In reality, however, the degree of dependence of small economies open to external factors through financial and banking flows with dominant financial markets turned out to be significant (Rey, 2015; Bruno and Shin 2015). In the case of two economically large and, in the first instance, financially strong, large, and small economies, this would mean that financial policies of financial centers should be taken into account in shaping domestic interest rates (Edwards, 2015). On the other hand, the convergence of central bank activities may be the result of similar disruptions experienced by globally integrated economies, their similar structures, or because of the convergence of business cycles. Therefore, there is a need to separate internal factors rigorously for a given economy from external factors in the form of monetary policy measures used by the monetary authorities of the dominant countries and global factors.

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We focus on the Central Eastern Europe (CEE) region to see in what way the unconventional monetary policy of the European Central Bank spills over the yield curves of the CEE countries with floating exchange rates. In this part of the article, we develop an original methodology that includes Bayesian averaging of Mean Group panel estimates.

2. Outline of the problem and the review of the literature

The article refers to the main trends of macroeconomic research after the financial crisis in the last years of the first decade in the XXI century. One of them is the analysis of the unconventional monetary policy when the interest rates are close to the zero bound. In particular, the controversy concerns the analysis of the international externalities of monetary policy of large countries for small spillovers, such as Poland, and the ability of these countries to pursue independent monetary policy (in the sense fully based on the national objectives of this policy Aizenman et al., 2016).

The ECB has commenced a large-scale unconventional monetary policy intervention to restore macroeconomic and financial stability in the euro area. This has been primarily intended to impact the euro area macroeconomy, however, given the high degree of financial and trade integration in the European Union, these measures are likely to have non-negligible spillovers to non-euro EU members.

The analysis of the external effects of the Federal Reserve policy (FED) is analyzed in several recent publications, including Fratzscher et al. (2016), Bauer and Neely (2014), Chen et al. (2016), Neely (2015), Dedola et al. (2017), Hanisch (2019). In contrast to the analysis of the FED policy, the analysis of similar monetary policy measures used by the ECB is to the best of our knowledge limited to the works of Babecka-Kucharcukova et al. (2016), Hajek and Horvath (2016), Horvath and Voslarova (2017) and Potjagailo (2017).

It should be pointed out that in all the cases these analyses are carried out with the use of global vector-autoregressive models, which by definition underestimate the actual size of the cross-dependent effects (Georgiadis, 2015). To address these doubts, we continue the research with the use of the second generation autoregressive panel methods (Bond & Eberhardt, 2009; Eberhardt & Teal, 2010) and Bayesian model averaging (Próchniak & Witkowski, 2012). With the use of this spectrum of methods, we refer to the broader international literature of transferring foreign interest rates through the financial flows channel (Aizenman et al., 2013–2016) and the global financial cycle (Rey, 2013–2015; Edwards, 2015) to analyze the effects of unconventional monetary policy ECB for Poland and countries of our region. In particular, we compare the estimates of the impact of the ECB policy with the use of the second generation panel cointegration methods. Then we refer to Uribe and Yue (2006) and Fernández-Villaverd et al. (2013) to support the theoretical reason for the transfer of interest rate volatility induced by the unconventional ECB policy for Poland and the countries of the region.

The reasons for the potential relevance of the spillovers have already been discussed in the literature. The seminal papers of Rey (2015, 2016) argue that the boom and bust pattern of capital flows is determined by a global financial cycle, which depends mainly on the monetary conditions of the countries with the largest financial centers. These monetary conditions are then transmitted to the rest of the world through gross credit flows, credit premiums, bank lending, and leverage, regardless of the exchange rate regime. Therefore, monetary policy heterogeneity might be observed among countries other than the largest Central Banks (the FED, the ECB) (Obstfeld & Ostry, & Qureshi, 2017). The objectives of those countries' monetary policies may be similar in the long term to the other central banks' policies, but in the short run, the monetary policies in those countries are country-specific and, thus, divergent.

Jordà et al. (2018) document that international house prices are also more correlated today than they have been over the last 150 years. More importantly, they find that the equity price correlation approaches unity since the 1990 s, which is particularly striking as it, exceeds even the correlation in asset prices during the declines associated with the Great Depression. The co-movement in credit, house prices, and equity prices are higher in the past few decades than in previous periods. In this sense, the authors argue about a global financial cycle among developed economies that are also related to housing prices. The authors also establish that variations in risk premiums, and not risk-free rates and dividends, explain a large part of the equity price synchronization.

The research of the lower interest rate bound has until recently been poorly represented in domestic monetary policy surveys. In the most recent publications, Brzoza-Brzezina, Kolasa et al. (2016) analyze the probability of Poland reaching zero interest rate bound. The authors, based on a series of simulations based on dynamic stochastic general equilibrium models (DSGE), determine this probability as low. Brzoza-Brzezina (2016) compares the impact of low-interest rates on the small and large open economy with the use of the DSGE model. The author argues that the event in the form of reaching the zero interest rate limit has a greater impact on the large economy than on the small one. Both studies described above, however, concern the potential introduction of unconventional monetary policy and its effects in Poland, and not its transfer from abroad to Poland.

The issue of the spillovers of monetary policy was analyzed by Brzoza-Brzezina, et al. (2017). In particular, the impact of foreign ownership in the banking sector was analyzed, which, as indicated, increases the transfer of external monetary and precautionary effects. Indirectly, Gradzewicz and Makarski (2009) refer indirectly to the subject of the monetary policy transfer, pointing out that the independence of interest rates has important prosperity effects. The transmission of foreign interest rates was examined in the article by Goczek and Mycielska (2017). The authors state that there is a significant transfer of European interest rates on the interbank market to Poland, and the strength of this influence is close to one-to-one. However, the analysis does not allow identifying the reasons for this state of affairs. It may result from the similarity of the business cycle as well as fears of liquidity, i.e. attempts to manage international financial flows using interest rates. Mackiewicz-Łyziak (2016) examines the impact of foreign interest rates and the exchange rate on the monetary policy of the CEE countries. The author states that there are two monetary policy regimes. The first is characterized by passivity and high smoothing, while the second is active. The reaction to events in the economy is more violent in the latter. In the case of Poland, the model did not show a significant improvement in the estimate due to the introduction of external variables into the model.

The investigation closest in spirit to ours is McQuade, et al. (2015) who used daily data to concentrate on the financial market effects in major non-euro area EU countries of Central and Eastern Europe (namely the Czech Republic, Hungary, Poland, and Romania). They find evidence for strong spillover effects from the ECB's non-standard policies on these countries' financial markets, particularly on bond yields and the exchange rate. However, the method used is an Ordinary Least Squares regression without any lagged terms in the specification, not accounting for heteroscedasticity, autocorrelation, or endogeneity inherent in such financial market settings, especially given the daily frequency of the data, which raises certain doubts regarding the credibility of the results. On the contrary, a more recent paper, by Kolasa and Wesołowski (2018) investigates a two-country DSGE model where agents can trade long- and short-term government bonds issued by the large and small open economy. The unconventional monetary policy decreases term premia in both areas as financial capital flows from the dominant area to the small economy. In this way the program is expansionary as lower long-term interest rates stimulate aggregate demand, however, the massive inflow of foreign capital leads to a persistent appreciation of its real exchange rate, which is contractionary.

A natural question to ask is what can be done to insulate monetary policy from these external spillovers. Klein and Shambaugh (2015) argue that monetary independence requires the country to either allow the exchange rate to float or to restrict international capital movement; however, they find that exchange rate flexibility plays a greater role than capital controls unless the latter are quite extensive. In line with this argument, Aizenman et al. (2016) find that spillovers are stronger when countries are more financially integrated with the core country. Moreover, Ligonnierea (2018) argues that sensitivity to the global financial cycle depends less on the fluctuations of financial forces than on the presence of global investors and global banks. Because the level of financial integration is high and capital accounts are fully liberalized in the analyzed European countries, we should focus on floating exchange rate regimes and assess the degree to which they grant monetary independence.

Frankel et al. (2004) show that developing countries operating within floating exchange rate systems have not enjoyed full monetary policy independence, even in the short run. They also show that independent monetary policy can be achieved in the long run by only three economies (United States, Japan, and the euro area). Other countries' long-term monetary policy is therefore strongly determined by and dependent on the dominant economies' policies. The extent to which a country can preserve the independence of its monetary policy depends on its degree of economic and financial integration with dominant economies (Ehrmann & Fratzscher, 2002). This dependence is particularly important in the European case. In this sense, whether the monetary policy of countries such as the UK, Sweden, Italy, the Netherlands, or France had any independence from decisions introduced by the Bundesbank before the adoption of the euro remains an empirical question (Reade and Volz, 2011).

Recently, the degree to which floating exchange rates have failed to insulate monetary policy from external developments has been studied by Agrippino and Rey (2015), Rey (2015, 2016), as well as Bruno and Shin (2015). Although these authors focus on different channels of financial market integration – the international credit channel, the risk-taking channel, the bank leverage cycle, and the exchange rate "fear of floating" phenomenon – they reach similar conclusions. While the trilemma guarantees independent monetary policy if countries allow their currencies to float, spillovers coming from financial markets may constrain a central bank's effective independence, even under floating exchange rates.

In none of the presented studies, the analysis concerned the transfer of unconventional monetary policy itself, therefore shadow rates were not used, or the volatility channel was not taken into account. The only exemption is the study of Bluwsteina and Canova (2016), who show that ECB monetary policy surprise does not have quantifiable effects on domestic output or inflation. Output responses to euro-area UMP shocks are quite heterogeneous. While in advanced countries responses are persistently positive and significantly larger than in the euro area after two weeks, those in the CEE countries are insignificant and the authors associate the result with floating exchange rate insolation. However, Dedola et al. (2017), who study the US. Spillovers find no straightforward relation between country responses and country characteristics, such as their income level, dollar exchange rate flexibility, financial openness, trade openness, dollar exposure in foreign assets and liabilities, and incidence of commodity exports.

Baumeister and Benati (2013) and assume that large-scale purchases of longer-term securities result in a compression of the yield curve in the euro area. That central banks use unconventional measures to reduce interest rate spreads such as the term spread has been argued in Blinder (2012) and empirically validated for the euro area by Ambler and Rumler (2016), Altavilla et al. (2016), Feldkircher et al. (2017) who find that as a consequence of asset purchases by ECB, longer-term yields in the euro area decline, and spreads between euro area long-term yields narrow. Consequently, we separate the impact on the instantaneous and long-run interest rate, as it is expected that the unconventional policy spills over on the right-hand side of the yield curve as it concerns more distant maturities.

Therefore, the main hypothesis of the article is the occurrence of unintended external effects of unconventional activities of the ECB in the environment of interest rates close to zero for the conditions of central banking and conducting monetary policy in Poland and the CEE region. Hypothetical effects are manifested in the scope of:

1. transferring volatility through a financial risk channel,
2. international transfer of interest rates.

Both factors require a series of hypotheses to separate the impact of the ECB's unconventional monetary policy on the behavior of interest rates in other countries through financial channels, on the extent to which the relationship between monetary policies of the ECB and other countries results from information global or internal product gap and expected inflation. For this purpose, we use Taylor's rule to formulate hypotheses of optimal reaction functions of central bank policy. This kind of study of the behavior of a dynamic system composed of interest rates, inflation, and the output gap is one of the basic methods of empirically measuring the central bank's reaction function in literature. It is also hypothesized that there is a common global process to which central banks react jointly. This requires the application of methods that enable separating the monetary policy response to shocks coming from within the economies examined from the external effects of the ECB's monetary policy while controlling the problem of endogeneity (reverse causation and unobservable dynamic global effects).

The use of these methods requires validation of several operational, methodological hypotheses such as:

3. There is a significant spatial dependence (in the sense of cross-sectional dependency, not the spatial correlation) between the observed units. In consequence, a set of methods robust to such type of dependency needs to be applied.
4. The change of the deterministic component (constant, trend), as well as the number of delays or the form of short- and long-term dependencies may entail significantly different conclusions from the estimated models, thus it is necessary to use Bayesian averaging.
5. There is a need to analyze the volatility of monetary policy using various measures of variability, including the grouping of variances (conditional heteroscedasticity).

The ultimate goal of these steps is to answer whether the ECB policy spills over to countries of the region. In what follows we look at spillovers from financial developments in the euro area induced by unconventional monetary policy steps.

3. Data and methodology

3.1. Introduction and general approach

The study employs two methods based on the Short Shadow Rate (SSR) concept to measure unconventional monetary policy measures, i.e. Krippner (2013–2015) and Wu and Xi (2014–2016). Other macroeconomic data, described in detail in Table 1 refer to the output gap, inflation, risk (VXO), and theoretical interest rates calculated based on the yield curve. The source of these data is the Central Statistical Office of Poland, the National Bank of Poland

Table 1
Description of variables Source: own.

Group	Variables	Explanation
Eurozone	*hicp_EUR,*	Harmonized Indices of Consumer Prices - inflation in the Eurozone and interpolated using cubic spline to daily frequency based on data from the Eurostat.
	output_gap_EUR	The output gap in the Eurozone calculated using Hodrick-Prescott filter and interpolated using cubic spline to daily frequency based on data from the Eurostat.
ECB	*ecb_mro*	Main Refinancing Operation rate from the ECB.
	ecb_krippner	ECB Shadow rate estimates are obtained with the Krippner (2013)- (2015) shadow/lower bound framework with two factors, i.e. the K-ANSM(2), a fixed 12.5 basis point lower bound, and yield curve data with maturities from 0.25 to 30 years with the sample beginning in 1995.
	ecb_wuxi	ECB Shadow rate estimates are obtained with the shadow-rate term structure model (SRTSM) to describe the economic environment with negative interest rates. Wu and Xia (2016) apply the model to the Euro area, and investigate the effect of a change in the Effective Lower Bound (ELB).
	ecb_krippner_varresid	We estimate a series of VAR models depicting the Taylor Rule with Uhlig's (2005) agnostic approach and *ecb_krippner* by imposing sign restrictions on the impulse responses of a monetary policy shock to measure ECB unconventional policy stance.
	ecb_wuxi:varresid	We estimate a series of VAR models depicting the Taylor Rule with Uhlig's (2005) agnostic approach and *ecb_wuxi* by imposing sign restrictions on the impulse responses of a monetary policy shock to measure ECB unconventional policy stance.
	ecb_surprise_krippner	First, we estimate a series of n + 1 day forecasts of *ecb_krippner* from a 100 observation rolling window of an automatically selected s ARIMA (0, 0, 0–12, 2, 12) regressions with specifications based on the Schwarz-BIC criterion. Second, we calculate the difference between the forecast and actual observation as an ECB policy surprise.
	ecb_surprise_wuxi	First, we estimate a series of n + 1 day forecasts of *ecb_wuxi* from a 100 observation rolling window of an automatically selected s ARIMA (0, 0, 0–12, 2, 12) regressions with specifications based on the Schwarz-BIC criterion. Second, we calculate the difference between the forecast and actual observation as an ECB policy surprise.
Poland control variables	*output_gap*	Output gap calculated using Hodrick-Prescott filter and interpolated using cubic spline to daily frequency.
	hicp	HICP inflation (Eurostat) and interpolated using cubic spline to daily frequency.
Polish monetary market	*shortrate*	We fit yield curve using Svensson (1994) methodology to calculate the theoretical instantaneous short rate using data on interest rates on different maturities from TR Datastream.
	termspread	We fit yield curve using Svensson (1994) methodology to calculate the term spread using data on interest rates on different maturities from TR Datastream.
	surprise_short	First, we estimate a series of n + 1 day forecasts of *shortrate* from a 100 observation rolling window of an automatically selected s ARIMA (0, 0, 0–12, 2, 12) regressions with specifications based on the Schwarz-BIC criterion. Second, we calculate the difference between the forecast and actual observation as a policy surprise.
	surprise_spread	First, we estimate a series of n + 1 day forecasts of *termspread* from a 100 observation rolling window of an automatically selected s ARIMA (0, 0, 0–12, 2, 12) regressions with specifications based on the Schwarz-BIC criterion. Second, we calculate the difference between the forecast and actual observation as a policy surprise.
Financial spillovers	*vxocls*	Chicago Board Options Exchange, CBOE S&P 100 Volatility Index: VXO, retrieved from FRED, Federal Reserve Bank of St. Louis.
	forex_pln_connecti	Stock market conditional volatility grouping obtained with methods described in Diebold and Yilmaz (2009, 2015). We use a generalized vector autoregressive framework in which forecast-error variance decompositions are invariant to variable ordering, to obtain measures of volatility spillovers.
	stock_wig_connect	Forex market conditional volatility grouping obtained with methods described in Diebold and Yilmaz (2009, 2015). We use a generalized vector autoregressive framework in which forecast-error variance decompositions are invariant to variable ordering, to obtain measures of volatility spillovers.

(NBP), Federal Reserve Economic Data (FRED), Bank of New Zealand, TR Datastream and the OECD.

The final form of restrictions regarding spatial dependencies and the deterministic component of the cointegrating equation were examined with the use of Bayesian averaging methods. This is a valid approach because, in particular, the set of deterministic components in the real process of generating data (constant/trends) is unknown and the problem arises to identify them among the six options proposed by Dickey-Fuller/Johanssen in this aspect. Unit root testing does not apply to the Bayesian VAR estimation, as unit-roots do not affect the likelihood function (Sims et al., 1990).

3.2. ECB monetary policy

We investigate the unconventional ECB monetary policy captured by the shadow interest rates. The corresponding shadow rate of those monetary policy actions estimated by Krippner (2013) and Wu and Xia (2016) differ considerably. Krippner's (2013) shadow rate is much more negative and volatile than the one calculated by Wu and Xia (2016), as they rely on different term structure models. Therefore, we consider each of them separately. Next, we analyze the difference between "conventional" and "unconventional" monetary policy by comparing impulse responses between the MRO rate and the two "shadow" measures. Fig. 1 presents the ECB MRO as compared to the two shadow rates. (Fig. 2).

However, to properly measure changes in the monetary policy stance of the ECB, several critiques can be raised against employing the Shadow Rate "as it is" to measure spillovers. ECB may react to the disturbances in the own Eurozone economy and the monetary policy stance in the Eurozone can be influenced by the real or nominal developments. It is difficult to discern how much any change in Shadow Rate owes to changes in policy and how much to the remarkable changes in the financial environment that followed the financial crisis. Therefore, one needs an identification strategy, to take account of these developments.

Two approaches have been applied in the article. The first one consists in estimating a series of VAR models depicting the Taylor Rule with Uhlig's (2005) agnostic approach by imposing sign restrictions on the impulse responses of in response to a monetary policy shock. A series of variables were obtained that measure ECB unconventional policy stance have been constructed with the use of this approach (*ecb_krippner_varresid* and *ecb_wuxi:varresid*). Fig. 3 depicts the average impulse response over the whole sample period. The responses of the *hicp_EUR*, *output_gap_EUR* have been restricted to non-positive numbers and the ECB rate – to remain non-negative in months 0;.;5 after the shock.

The second approach was to take account of expectations. In this approach, we assess policy surprises in the spirit of Romer and Romer (2004). The Authors develop a measure of monetary policy shocks that is relatively free of endogenous and anticipatory movements. Quantitative and narrative records are used to infer the

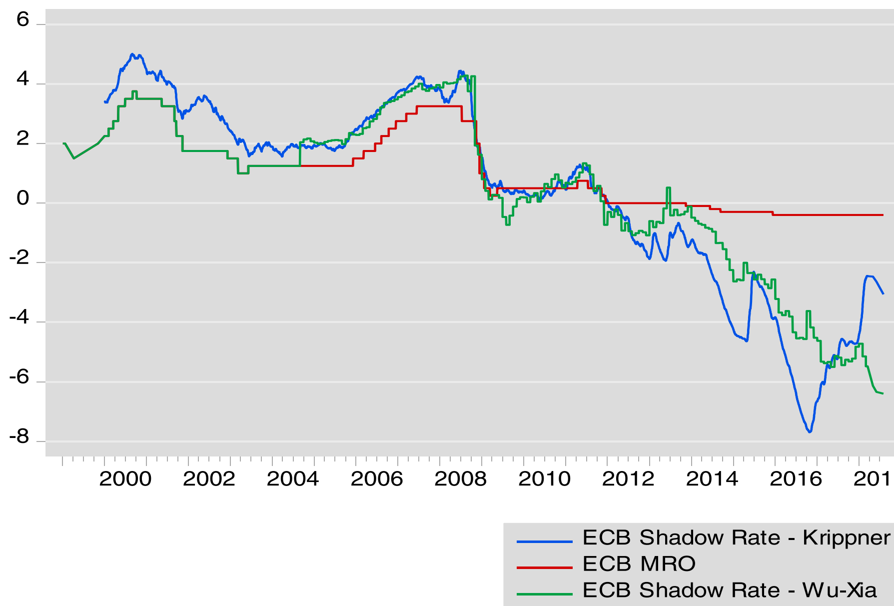

Fig. 1. ECB Interest Rates,
Source: ECB, FED, Bank of New Zealand.

Federal Reserve's intentions for the federal funds rate. This series is regressed on the Federal Reserve's internal forecasts to derive a measure free of systematic responses to information about future developments. However, instead of using internal central bank forecasts, first, we estimate a series of n + 1 day forecasts from a 100 observation rolling window of an automatically selected s ARIMA (0, 0, 0–12, 2, 12) regressions with specifications based on the Schwarz-BIC criterion. Second, we calculate the difference between the forecast and actual observation as an ECB policy surprise (variables *ecb_surprise_krippner* and *ecb_surprise_wuxi*).

3.3. Finacial market

We then trace the impact of the exogenous ECB policy on the Polish (and CEE countries' in the panel investigation) yield curve. Let us start by observing that longer-term bond yields can be decomposed into two components: the expected average short-term interest rate and the term premium, which denotes compensation for the risk of holding the bond. In principle, conventional monetary policy affects bond yields and financial conditions more generally by affecting the instantaneous short-term interest rate and the expected path of short rates in the future. To investigate these effects, we estimate the yield curves using all market interest maturities available on the market as in TR Datastream. We start with the approach of Nelson and Siegel (1987) who proposed the shape of the yield curve described by the following function:

$$y(t) = \beta_1 + \beta_2\left(\frac{1-\exp(-t/\lambda)}{t/\lambda}\right) + \beta_3\left(\frac{1-\exp(-t/\lambda)}{t/\lambda} - \exp(-t/\lambda)\right) \quad (1)$$

where t stands for the time to maturity, while the β_1, β_2, β_3, λ are the parameters of the model. The β_1 is independent of time to maturity and as such, it is interpreted as the long-term yield. The component multiplied by β_2 is equal to 1 for $t = 0$ and decreases exponentially towards zero. Consequently, this component only affects the value of the function for t close to zero that is to short time to maturity. Finally, the component multiplied by β_3 increases from zero (when $t = 0$), but then decreases back to zero, which adds a hump to the function shape. It is then the λ that determines the proportion of the second and third components, and thus locates the hump on the curve. Given the meaning of the particular parameters, we have that $\beta_1 > 0$ and $\beta_1 + \beta_2 > 0$ so as to keep the economic sense of the parameters concerning the different time to maturity yields. In addition, it must be that $\lambda > 0$.

Svensson (1994) extended the earlier proposal of Nelson and Siegel (1987) by adding a component to the Nelson and Siegel curve:

$$y(t) = \beta_1 + \beta_2\left(\frac{1-\exp\left(-\frac{t}{\lambda_1}\right)}{\frac{t}{\lambda_1}}\right) + \beta_3\left(\frac{1-\exp\left(-\frac{t}{\lambda_1}\right)}{\frac{t}{\lambda_1}} - \exp\left(-\frac{t}{\lambda_1}\right)\right) + +\beta_4\left(\frac{1-\exp(-t/\lambda_2)}{t/\lambda_2} - \exp(-t/\lambda_2)\right) \quad (2)$$

In the case of Nelson-Siegel-Svensson curve, the set of parameters to be estimated extends to β_1, β_2, β_3, β_4, λ_1, λ_2. The component by the β_4 adds a second hump to the curve and the λ_1, λ_2 decide the position of the humps along the curves.

The Nelson, Siegel, and Svensson model is the more common one, in particular due to its greater flexibility: as it is easy to notice, Nelson and Siegel formula is nested within the former. We follow the mainstream literature and estimate the parameters of then Nelson, Siegel and Svensson model for each of the considered countries each day, in order to compute the daily time series of parameters and fitted rates for each country in the considered period.

The estimation of the parameters of the function is by no means simple and there exists quite an amount of empirical literature on this issue. Notably, the number of periods in the time series for each of the considered countries is between three and five thousand, which means that the yield curve needs to be estimated over a dozen thousand times. That means that the applied estimation technique needs to be both computationally feasible, but also time efficient.

One of the strategies that is applied is the simple OLS estimation conditional upon the values of λ_1, λ_2. The later are determined with the grid-search approach. In the end, the estimates of the parameters are the estimated β's for such values of λ_1, λ_2 that allow to obtained the lowest sum of squared residuals. Obviously even if very small ranges for the potential values of λ_1, λ_2 are considered and the frequency of the considered values of λ_1, λ_2 is limited, the number of estimations gets increased notably: while considering, say, 20 potential values for

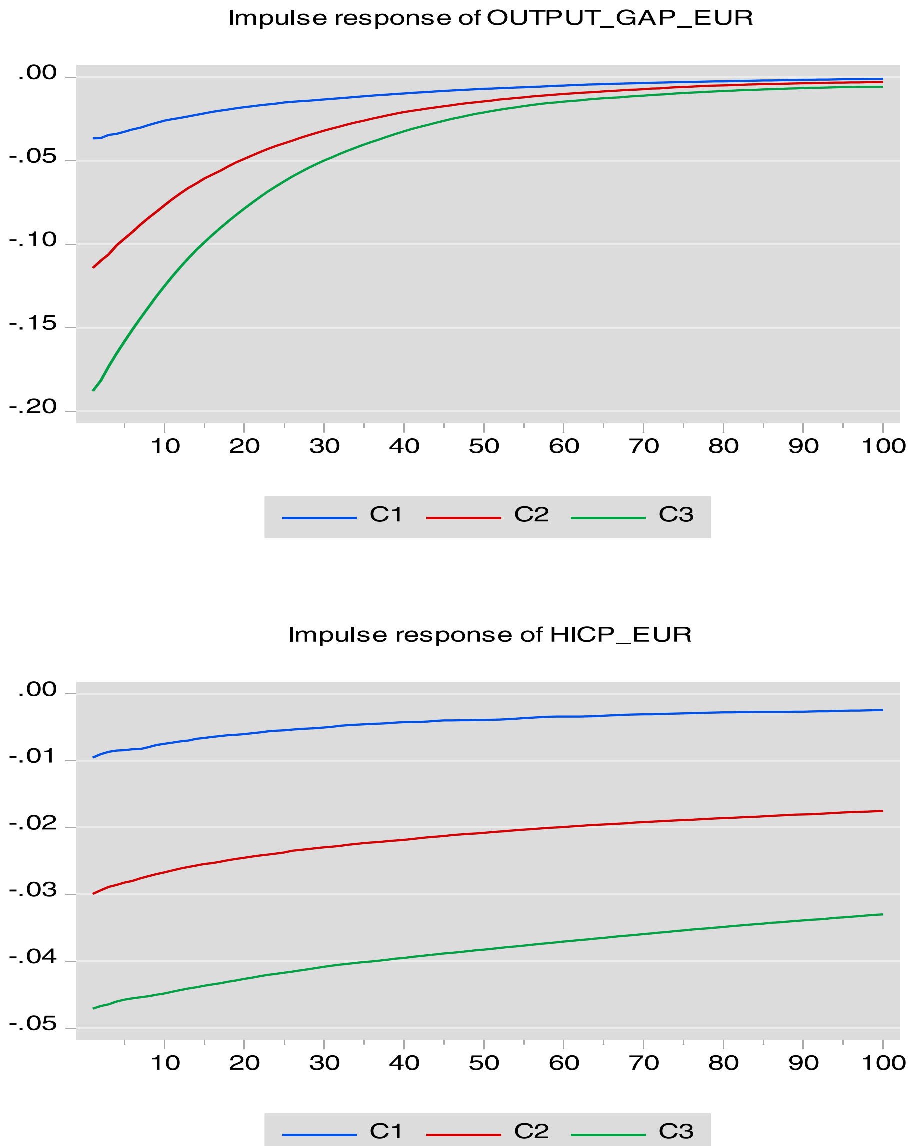

Fig. 2. Imposing sign restrictions on the impulse responses of in response to a monetary policy shock as in Uhlig (2005),
Source: ECB, FED, Bank of New Zealand, Eurostat, own transformations.

each of the λ_1, λ_2, the number of estimations is increased 400 times. Yet given the simplicity of the OLS approach, the process would still not be time-consuming. Unfortunately, this strategy does not imply the non-negativity of the estimated value of β_1. In fact, in the estimated models in many cases the estimate of β_1 turned out to be negative, thus it is essential to impose $\beta_1 > 0$ constraints by replacing the β_1 with the $\ln(\exp(\beta_1))$ in the yield function. In such a case, for any real value of β_1 the entire long-term yield now represented by the $\ln(\exp(\beta_1))$ remains positive. However, the estimated model remains non-linear and cannot be linearized, thus the second step after the grid search algorithm is estimating the β_1, β_2, β_3, β_4 conditional upon the values of λ_1, λ_2 with the NLS (Non-linear Least Squares).

Unfortunately, the NLS estimation is typically quite slow due to lack of a closed-form of the estimator and the necessity to run a number of iterations while solving the least-squares minimization equation numerically for each of the observations. It would thus be infeasible to perform the grid search for each daily observation for each country with the NLS estimation of β_1, β_2, β_3, β_4. Instead, we adopted a mixed approach. We first estimated the parameters of the yield function with the grid search-OLS approach. In the grid the values of $\lambda_1 \in <4;6>$ and $\lambda_2 \in <14;16>$ were considered because this range of parameters allows a range of plausible shapes of the yield functions and enables them to catch all possible shapes (namely the normal, flat, inverted, and humped shapes).

Fig. 3 plots these basic yield functions for several values of lambdas.

It could be observed, that in each case the values allowing for global minimization of the sum of squared residuals were $\hat{\lambda}_1 = 6$ and $\hat{\lambda}_2 = 15$. This was confirmed for a number of estimations with the NLS estimator for different countries in a few random time periods. We thus adopt the latter values of the λ_1, λ_2 and further estimate β_1, β_2, β_3, β_4 for each country and each labor day with the use of NLS.

Using the obtained fitted yield curve, we calculate the theoretical instantaneous short rate (*shortrate*) and the term spread (*termspread*). In addition, we take account of expectations similar to the ECB case: we estimate a 100 observation rolling window of an automatically selected ARIMA (0,0,0−12,2,12) regressions n + 1 day forecasts with specifications optimizing Schwarz-BIC Bayes criterion and calculate

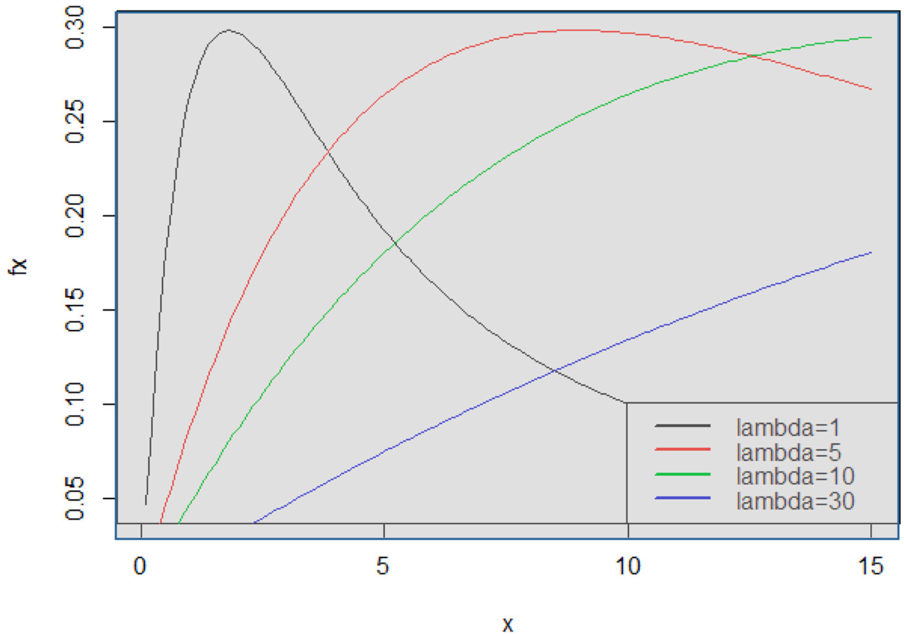

Fig. 3. Yield curve shape given different lambda assumptions,
Source: own.

the difference between the forecast and actual observation to obtain *surprise surprise_short* and *surprise_spread* variables.

We use the short rate as our measure of short term monetary policy expectations. The discount function, which determines the value of all future nominal payments, is the most basic building block of finance and is typically inferred from the yield curve. Two important maturity points for which this consideration applies is zero and infinity. The risk-free short-term interest rate (usually an instantaneous interest rate or perhaps an overnight interest rate) plays a critical role in the most financial model that the market participants use (Gürkaynak et al., 2007). The primary news for market participants is not what the central bank just did, but is instead new information about what the is the bank going to do in the nearest future and how will this impact the long-term priced instruments such as mortgages. Such revisions in these anticipations show up instantaneously in the pricing of monetary instruments. The transmission of monetary policy is conventionally viewed as running from short-term interest rates managed by central banks to longer-term rates that influence aggregate demand. A central bank's leverage over longer-term rates comes from the fact that the market determines these as the average expected level of short rates over the infinite horizon. Reversely, the long term rate contains a premium for expected inflation and, therefore, works as an indicator of the credibility of a central bank's low inflation. While these concepts are purely theoretical as no one intervenes/trades at zero or infinity horizons in the financial markets, these measures serve as implicit market expectations.

This reflects a general trend of shift towards daily data in monetary policy since central banks began to have a direct impact on the expectations of financial markets, such as Gertler and Karadi (2015), Hamilton (2008), Miranda-Agrippino and Ricco (2018), who develop methods to take into account information frictions present in the transmission of monetary shocks in a one-day window.

3.4. Financial spillovers

Finally, we turn to the analysis of financial volatility spillovers. We use three measures to assess this phenomenon. The first approach is to use the implied volatility indices of short-term at-the-money options on the S&P 100 index. This is the basis of the original VIX and this series is now designated the VXO, available from the Federal Bank of St. Lois website. In theory, the VXO is forward-looking.

The second and third measures from Table 1 (*forex_pln_connecti*, *stock_wig_connect*) are obtained with the use of Forex market conditional volatility grouping and stock market conditional volatility grouping, respectively using methods described in Diebold and Yilmaz (2009, 2015). We use a generalized vector autoregressive framework in which forecast-error variance decompositions are invariant to variable ordering, to obtain measures of both total volatility spillovers.

We measure spillovers in a generalized VAR framework robust to the ordering of variables. Following this methodology, we define spillovers as the fractions of the H-step-ahead error variances in forecasting x_i that is due to shocks to x_j $(i \neq j)$ for $i, j = 1, 2, \ldots, N$. Where x_i and x_j represent the rates of change of stock or pairs of exchange rates series i and j, and N is the total number of these time series.

Consider a covariance stationary N-variable VAR(p), $x_t = \sum_{i=1}^{p} \phi_i x_{t-i} + \varepsilon_t$, where x_i is the $N \times 1$ vector of the endogenous variables, $\varepsilon \sim (0, \Sigma)$ is a vector of independently and identically distributed disturbances. The moving average representation is written as $x_t = \sum_{j=0}^{\infty} A_j \varepsilon_{t-j}$, where the$N \times N$ coefficient matrices A_j follow a recursion of the formula $A_j = \sum_{j=1}^{p} \phi_j A_{j-p}$, with A_0 being a $N \times N$ identity matrix and $A_j = 0$ for $j < 0$..

The spillovers we intend to measure can be defined by generalized forecast error variance decompositions of the moving average representation of the VAR model. The H-step-ahead generalized forecast error variance decomposition is the following:

$$\theta_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}, \quad (3)$$

where Σ is the variance matrix of the vector of errors ε. σ_{jj} is the standard deviation of the error term of the j^{th} equation, and e_i and e_j are selection vector with a value of one for the i^{th} and j^{th}elements, respectively, and zero otherwise.

Since the own- and cross-variable variance contribution shares do not sum to one under the generalized decomposition, each entry

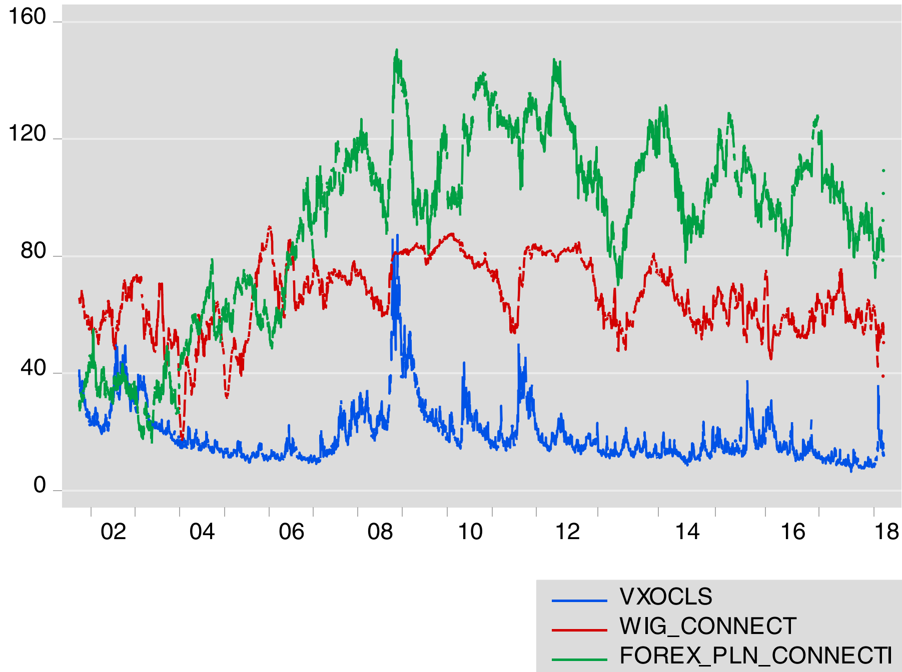

Fig. 4. Indices of volatility spillovers.
Source: FED, TR Datastream, own transformations.

of the variance decomposition matrix is normalized by its row sum as follows:

$$\tilde{\theta}_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{N}\theta_{ij}(H)}, \tag{4}$$

By construction, $\sum_{j=1}^{N}\tilde{\theta}_{ij}(H) = 1$ and $\sum_{i,j=1}^{N}\tilde{\theta}_{ij}(H) = N$..

Thus, a total spillover (*TS*) index can be defined as:

$$TS(H) = \frac{\sum_{i,j=1,i\neq j}^{N}\tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{N}\tilde{\theta}_{ij}(H)} \times 100 = \frac{\sum_{i,j=1,i\neq j}^{N}\tilde{\theta}_{ij}(H)}{N} \times 100. \tag{5}$$

We adopt these methods to characterize daily volatility spillovers across CEE stock and forex markets to the total forecast error variance, from January 2000 through March 2018.

Fig. 4 plots the three variables over time.

4. Panel data-based analysis of the CEE inflation targeters

4.1. Methodology

Two approaches based on the Short Shadow Rate concept to measure unconventional monetary policy measures, i.e. Krippner (2013–2015) and Wu and Xi (2014–2016) are used in the panel study.

The panel itself covers data for four countries of the region that pursue inflation targeting strategy, namely Poland, Czechia, Hungary, and Romania. In order to remain consistent across these countries, as the data on interest rate term structure was limited at the beginning of the 21st century, the analyzed sample starts in 2004 and ends in 2018.

Currently, the most commonly used method of estimating dynamic macroeconomic models on panel data is a variant of the generalized Blundell Bond moment method (1998) and Kiviet's approach (2001) in the version described by Bruno (2005). Nevertheless, it can be concluded that both estimators are abused in macroeconomic applications. While the problem of the first estimator is the need to have a wide panel (where the number of units is greater than the panel periods) and a large number of observations to meet the assumptions about the disappearance of the initial conditions, the assumption of the exogeneity of all macroeconomic variables in the model is unrealistic. Most importantly, however, from the point of view of the article, the above estimations were made assuming the homogeneity of coefficients in the short and long term, which contradicts the main idea of the tested macroeconomic models, even more so as one of the fundamental findings in the "long" econometric literature. there is incorrectness of the assumption about the homogeneity of parameters - already Pesaran et al. (1999) noticed that in particular in the short term this may not be true, as a result of which typically used estimators requiring the homogeneity of coefficients in the short and long run may not be consistent. For these reasons and to distinguish the effects in the short and long term, the family of panel generators of second-generation cointegration is used in the empirical analysis: Mean Group (MG: Pesaran & Smith, 1995), Pooled Mean Group (PMG: Pesaran and others 1999) and Dynamic Fixed Effect method.

Due to the heterogeneity of the observation units, the Westerlund approach (2007) was applied. Then, depending on the short- and long-term assumptions, it is possible to estimate the parameters of the panel dynamic error correction model.

The use of the model of the error correction mechanism and the admission of the possibility of different adjustment coefficients for different countries makes it possible to estimate separately the short-term and long-term dynamics. Short-term adjustment factors for correction by interest rate error may be different for different countries, however, interest rates may change at the same time due to the occurrence of global shocks resulting from strong spatial dependence.

Common or global dependencies of this kind are often examined with the use of global vector autoregression models (GVAR), a series of independently estimated autoregressive models (VARs) with global variables for each country, without interaction between individual models. In contrast to this approach, we use a research methodology that combines the advantages of traditional VAR modeling in terms of integrating endogeneity with the advantages of a panel approach. Georgiadis (2015) indicates that analyzes carried

Table 2
Variable description and modeling strategy.

Dependent variable $y_{i,t}$	Regressors $x_{i,t}$			Deterministic components
	group A: Inflation & output gap	Group B: ECB policy measures	group C: Volatility	
shortrate *termspread* *surprise_short* *surprise_spread*	*hicp* *output_gap*	*ECB_krippner_varresid* *ECB_wuxi:varresid*	*vxocls* *connect_forex* *connect_stock*	trend constant
Four groups of models, one of the dependent variables in each	both variables in each model	at least one of the ECB regressors in each model	any subset of the group of regressors in each model (including the empty set)	trend or constant or trend and constant in each model

Source: Own.

out with the help of global vector-autoregressive models by definition underestimate the real size of these global effects. Additionally, this approach allows common or global effects in macroeconomic variables and cross-sectional dependency across countries to be included. In the literature, this issue is often examined with Global Vector Autoregression (GVARs) models, which are an estimated VAR model that includes global variables for each country (Caporale, Girardi 2013, Eickmeier, Ng 2015). In contrast, we employ a research methodology that combines the advantages of traditional VAR modeling in terms of endogeneity with the advantages of a panel-data approach. In our framework, we estimate one set of parameters in the end, but we allow the heterogeneity in each country and pool the information across the panel dimension (not one set for each country, as in the GVAR) while allowing for a country-specific unobserved heterogeneity (fixed effects) and cross-sectional dependence. We also examine spillover effects and control for endogeneity (reverse causality and global dynamic unobserved effects). Consequently, the models thus allow us to employ the richness of daily frequency data (in contrast to the monthly data used in most studies), to help us identify the richness of unconventional policy shocks that could not be visible in monthly data.

Furthermore, the approach can be significantly improved through our paper's contribution of incorporating newer econometric techniques available in the field – most notably, the introduction of the second-generation cointegrated panel model framework. This method makes it possible to move the problem to a panel framework, leading to significant progress from a single-country study. Moving to the panel framework potentially allows us to control for spillover effects, as well as global shocks and change in global interest rates. It also allows for more general inference, including accounting for the apparent co-movement of interest rates.

Individual models that belong to the discussed family differ in their assumptions. The PMG model assumes that the estimated long-term coefficients are equal for all groups. This method of averaging results gives effective and consistent estimators of the searched parameters when the assumptions about equality are true. Most often, however, the hypothesis of the same slope coefficients is rejected based on data. If the real equation is heterogeneous, the estimators in the PMG model are not consistent, and the MG model is the right model, which does not imply the assumption of the equality of long-term coefficients between countries.

Both the final form of restrictions regarding spatial dependencies and the deterministic component of the cointegrating equation are examined using Bayesian averaging methods. This is a valid approach in particular because the set of deterministic components in the real process of generating data is unknown and the problem arises to identify them among the six options proposed by Johanssen in this aspect. In the study, the results are reached with the typical BMA approach, based on the averaging of the estimates obtained for different sets of assumptions with individual deterministic components.

The general rationale is based on a panel VECM model is:

$$\Delta(yx)_{it} = \alpha(\beta y_{i,t-1} + \theta x_{i,t} + \mu + \rho t) + \boldsymbol{\Gamma}_1 \Delta(yx)_{i,t-1} + \cdots \\ + + \boldsymbol{\Gamma_p} \Delta(yx)_{i,t-p} + \gamma + \tau t + \boldsymbol{u}_t, \quad (6)$$

where:

$y_{i,t}$ - the dependent variable of interest for i-th country in period t,

$x_{i,t}$ - vector of regressors,

$\Delta(y\,x)_{it}$ - vector of first differences of the dependent variable and the regressors with the most recent previous labor day being the t-1 period,

$\boldsymbol{\alpha}, \boldsymbol{\beta}, \theta, \boldsymbol{\Gamma}_1 \ldots \boldsymbol{\Gamma_p}$ - parameters of the model; $\boldsymbol{u}_t$ is the error term,

$\mu + \rho t$ and $\gamma + \tau t$ – constant and trend part of the model.

We consider four separate models with four different dependent variables $y_{i,t}$:

1) *shortrate*
2) *termspread*
3) *surprise_short*
4) *surprise_spread*

All of the variables and variable names are explained in the 2 sections of the article.

Each of the models 1–4 is considered separately, yet each follows the same rules regarding the regressors selection and estimation strategy. Firstly, while it is economically sound to consider models with constant and first order lags (especially in the case of lower frequency data) of the regressors ($p = 1$), we also consider models with the element of trend and without a constant, as well as different lag length, differing between $p = 0, \ldots, 5$, with the relatively long considered maximum lag length due to high frequency of the data.

As far as the $x_{i,t}$ is concerned, we adopt the following strategy. We assume that the *hicp* variable and the *output_gap* (are included in each considered model as relevant regressors. Additionally, we consider two measures of the ECB policy: *ECB_krippner_varresid* and the *ECB_wuxi:varresid*. For the other variables depicting ECB policy, we encountered numerical problems with the convergence of the estimates. However, below we provide some robustness testing for the choices we made.

While their significance should be understood as the relevance of the ECB policy for national monetary policy, each of the variables represents a different concept and we consider models with one or both of them. Finally, we include the regressors representing volatility spillovers: *vxocls*, *connect_forex* and *connect_stock*. We consider the models with every possible subset of the above variables, including the empty set. The scheme of the modeling strategy is presented in Table 2.

We adopt two estimation approaches: the mean group estimator (MG) and the dynamic fixed effects estimator (DFE). It should be

Table 3
Results of the determinants of the *shortrate*.

	1	2	3	4	5	6
Output_gap	-1.307	-1.666	-0.948	-2.815	-3.401	-2.229
	(0.47)	(0.45)	(0.49)	(0.31)	(0.24)	(0.39)
Hicp	8.211	9.443	6.980	11.983	13.654	10.313
	(0.05)**	(0.07)*	(0.02)*	(0.05)**	(0.09)*	(0.01)***
Ecbwuxi:varresid	643.996	626.334	661.657	851.737	881.760	821.712
	(0.41)	(0.41)	(0.41)	(0.31)	(0.29)	(0.33)
Ecbkrippner_varresid	-185.671	-16.924	-354.418	-1447.624	-1351.557	-1543.692
	(0.41)	(0.39)	(0.43)	(0.58)	(0.61)	(0.55)
Connect_stock	0.741	0.468	1.014	1.289	0.871	1.707
	(0.39)	(0.40)	(0.37)	(0.32)	(0.45)	(0.20)
Connect_forex	-0.123	0.028	-0.274	-0.565	-0.401	-0.729
	(0.55)	(0.56)	(0.53)	(0.25)	(0.37)	(0.13)
Vxocls	2.459	2.447	2.471	3.529	3.455	3.603
	(0.29)	(0.26)	(0.32)	(0.03)**	(0.03)**	(0.03)**
EC	-0.314	-0.275	-0.353	-0.062	-0.054	-0.069
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***

Source: Own
Standard errors in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01

noticed that the length of the time series is large enough to consider asymptotic properties of the DFE approach in the time dimension, nevertheless, there is no clear indication of which of the estimators should be preferred. In consequence, we consider models estimated with the use of both methods.

The methods have been limited to two, since, despite our numerous tries, the family of models based on the PMG method failed to converge in many instances. We have tried different optimization methods, starting points and even subsets of the models, however, for most of the PMG models, the likelihood functions did not have a local extreme. This is a numerical problem intrinsic to the data we have. Including the PMG results in the tables could potentially bias our results since we do not know, whether the process of "failing" of some instances of models was random or not and whether the "successful" models were representative of the total. Therefore we dropped the PMG model results.

While maximum likelihood may be applied to estimate a single model, a lack of clear preference of a single model and estimator suggests the use of Bayesian Model Averaging (BMA) of the estimates obtained for each of the considered structures and estimation methods. The following steps are thus taken:

1) For each considered dependent variable all possible considered models $M_j, j = 1, \ldots, J$ are estimated (any non-empty set of regressors from group B, any set of regressors from group C, any trend-constant structure except for the model with the trend only, any number of lags between 0 and 5, estimation technique: MG or DFE).

2) For each $M_j, j = 1, \ldots, J$ the prior probability of its relevance p_j needs to be adopted. This should coincide with the researcher's knowledge of the phenomenon or preassumed chance of the given structure being the correct one. In the general case, we do not apply any preferences to particular models or sets of assumptions required for the use of particular estimation techniques, thus we apply equal prior probability to each $M_j, j = 1, \ldots, J$ that essentially equals $p_j = 1/J$. However, as stated before, we have a certain economic preference for the models with a single lag, a constant and no trend, yet it is difficult to quantify how much these models could potentially be preferred. In consequence, we separately consider this subset of M_j and provide additional results based on averaging in this subset of models only.

3) The posterior probability of relevance is computed for each $M_j, j = 1, \ldots, J$ following Ye et al. (2004). As they showed, it can be computed as

$$P_j = \frac{\exp(-0.5\Delta KIC_j)p_j}{\sum_{l=1}^{J}\exp(-0.5\Delta KIC_l)p_l}, \tag{7}$$

$$\Delta KIC_j = KIC_j - KIC_{\min},$$

where KIC_j is the Kashyap (1982) information criterion and the ΔKIC_j is the difference of KIC_j for model M_j and the minimum value of KIC_j among the considered models. However, Kashyap's criterion is computationally challenging and Ye et al. (2004) show, that alternatively Schwarz's BIC could be used as long as there is sufficient disproportion between the sample size and the number of compared cases. Since this is the case, we apply the simplified version of the criterion, namely

$$P_j = \frac{\exp(-0.5\Delta BIC_j)p_j}{\sum_{l=1}^{J}\exp(-0.5\Delta BIC_l)p_l}, \tag{8}$$

$$\Delta BIC_j = BIC_j - BIC_{\min},$$

where BIC_j is the Schwarz's criterion for M_j.

4) In order to check for the relevance of particular regressors, one might use different approaches. One of them is the posterior probabilities: the regressor is found relevant if the sum of posterior probabilities for the models that contain the regressor of interest exceeds the prior probability. However, this does not shade any light on the relevance of the variables considered ex-ante relevant and thus included in each regression: in their case, the use of posterior probabilities shall simply always confirmed the choice made by the researcher. Thus, we apply the concept based on weighted p values. Let $p(Hn)_j$ be the p value in the test of certain hypothesis computed on the basis of the test statistic calculated for the model M_j. Following the metaanalysis rationale, we use

$$p(Hn) = \sum_{j=1}^{J} p(Hn)_j \cdot P_J, \tag{9}$$

to compute the $p(Hn)$, that is the joint p value in the test of hypothesis Hn based on all the considered models $M_j, j = 1, \ldots, J$.

5) Additionally, we provide the value of $p(Hn)$ for the subsets of models $M_j, j = 1, \ldots, J$: the models estimated with single lag, with no trend and with a constant, models estimated with the MG estimator, models estimated with the DFE estimator. These not only play a role of a robustness check, but most of all correspond to the doubts regarding equal prior probabilities for all models, discussed in point 2.

To back our empirical strategy, based on the above models we observe that our datasets belong to the family of long macroeconometric panels. Studies have recognized that in such panels, even after conditioning on unit-specific regressors, individual units, in general, need not be cross-sectionally independent. Thus, actual information from macroeconometric panels is often overstated since long data are likely to exhibit many types of cross-sectional and

Table 4
Results of the determinants of the *Termspread*.

	1	2	3	4	5	6
Output_gap	2.662	3.374	1.949	3.341	3.986	2.696
	(0.42)	(0.34)	(0.49)	(0.30)	(0.23)	(0.37)
Hicp	-10.872	-12.390	-9.355	-11.202	-12.862	-9.541
	(0.08)*	(0.12)	(0.04)**	(0.08)*	(0.12)	(0.04)**
Ecbwuxi:varresid	-1004.204	-975.217	-1033.192	-992.912	-1012.860	-972.965
	(0.35)	(0.37)	(0.33)	(0.31)	(0.30)	(0.32)
Ecbkrippner_varresid	295.640	-120.399	711.678	1149.051	908.283	1389.819
	(0.47)	(0.48)	(0.45)	(0.68)	(0.76)	(0.60)
Connect_stock	-1.080	-0.640	-1.520	-1.269	-0.825	-1.714
	(0.35)	(0.49)	(0.22)	(0.34)	(0.48)	(0.21)
Connect_forex	0.221	0.002	0.440	0.628	0.492	0.764
	(0.33)	(0.35)	(0.32)	(0.28)	(0.41)	(0.14)
Vxocls	-4.325	-4.390	-4.259	-4.035	-4.047	-4.024
	(0.02)**	(0.03)**	(0.02)**	(0.02)**	(0.02)**	(0.02)**
EC	-0.061	-0.049	-0.073	-0.059	-0.049	-0.069
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***

Source: Own
Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

temporal dependencies (Cameron and Trivedi 2005). Therefore, erroneously ignoring the possible correlation of regression disturbances over time and between subjects can lead to biased statistical inferences (Petersen 2009). The literature employs a variety of tests for cross-sectional dependence, of which we use the following:

- Breusch-Pagan's (1980) LM
- Pesaran's (2004) scaled LM
- Baltagi, Feng, and Kao's (2012) bias-corrected scaled LM
- Pesaran's (2007) CD

In Appendix A, Tables A1-A4 show the results of these tests for the four variables. The results indicate a serious problem of cross-dependency disturbances in the panel data. The presence of such cross-dependency can cause a significant loss of power for panel cointegration tests and in general biases in results of methods not taking into account this cross-dependency. As a response, we use Westerlund (2007) test for cointegration, who developed four new panel cointegration tests based on structural rather than residual dynamics. The results of these tests have been provided in Tables A5-A8 (in Appendix A). All the calculated test statistics indicate rejection of the null hypothesis of no cointegration and provide a backing for our empirical model as portrayed by the Eq. (6).

4.2. Results

Tables 3–6 present the results of the EC equations and the short-run error correction coefficient for four different response variables:

1) *shortrate,*
2) *termspread,*
3) *surprise_short,*
4) *surprise_spread.*

The columns contain the results of an exercise in the limitations of the number of averaged models since we intend to verify the possible impact of some of the relatively less probable models based on economic theory. Therefore, all of the above tables have the following six columns:

Column 1 - averages of all results, lag 0–5, with or without trend, with or without constant, DFE or MG method,

Column 2 - as above, but only for the MG method,

Column 3 - as above, but only for the DFE method,

Column 4 - averages of models with lags= 1, without trend, with constant, DFE or MG method,

Column 5 - MG method, models with lags = 1, with constant, no trend,

Column 6 - DFE method, models with lags = 1, with constant, no trend.

In all of the obtained results, the system showed convergence to the steady-state, as the EC term remained consistently significant and negative. The results of all other short-run coefficients have been relegated to the appendix to Tables A1-A3.

This framework allows also for tackling the reverse causality problem. A single cointegrating vector may be interpreted as the indication of the long-run relationship between shadow interest rates and stock markets. The properties of this relationship can be verified using a parametric test that concerns the coefficients in the adjustment matrix. If one of the variables does not adjust to the cointegration vector, then there is support for unidirectional causality in the cointegration framework. In the analyzed case, we expect that the stock market indices do not adjust to the cointegration relationship, but interest rates do. We also expect that the domestic rate reacts positively to stock market booms in the long run but does not in the short run. The applied method and identification scheme allow concluding causality in the Granger sense, not just correlations.

Across all averaged specifications for the *shortrate* determinants (Table 2), the most important regressor of the *shortrate* was the HICP inflation. The value of the coefficient is higher than one and points to a significant overreaction of domestic rates to the inflation rate shock that can be associated with the disinflationary period at the beginning of the sample in some of the investigated countries.

Similarities in the behavior of the central banks could be caused by a common business cycle. To control for these effects, we include an *output_gap* variable, which was insignificant across all specifications. Thus, it seems that the output gap does not have statistically significant effects on the short rates, which is striking, because some of the central banks respond to the domestic business cycle. This result, however, points to the general credibility of the inflation target in the investigated countries.

The variables of interest that aim to assess the influence of the shadow rate on the instantaneous interest rate in the countries of the region both came out as insignificant. This was true for both the *Ecbwuxi:varresid* and the *Ecbkrippner_varresid* variables (shown in Grey), This allows pointing to the lack of spillovers from the unconventional monetary policy in the very short run to the money markets of the CEE countries.

It seems that the other important determinant of the *shortrate* is implied volatility. Caggiano et al. (2018) suggest that the US monetary policy rate gap (understood by the part of interest rate variance

Table 5
Results of the determinants of the surprises to the instantaneous interest rate (*surprise_shortrate*).

	1	2	3	4	5	6
Output_gap	-3.004	-3.516	-2.492	-3.001	-3.727	-2.276
	(0.23)	(0.18)	(0.27)	(0.29)	(0.23)	(0.35)
Hicp	8.054	10.164	5.943	7.935	10.418	5.452
	(0.16)	(0.15)	(0.18)	(0.20)	(0.16)	(0.24)
Ecbwuxi:varresid	-259.645	-233.494	-285.797	-58.380	-24.981	-91.779
	(0.40)	(0.49)	(0.32)	(0.60)	(0.84)	(0.36)
Ecbkrippner_varresid	-542.004	-567.104	-516.904	-323.166	-337.076	-309.257
	(0.38)	(0.46)	(0.30)	(0.43)	(0.65)	(0.20)
Connect_stock	1.078	0.708	1.447	1.121	0.778	1.463
	(0.21)	(0.32)	(0.11)	(0.19)	(0.29)	(0.09)*
Connect_forex	-0.255	-0.044	-0.467	-0.204	-0.010	-0.399
	(0.34)	(0.43)	(0.26)	(0.36)	(0.38)	(0.34)
Vxocls	1.956	1.868	2.043	2.276	2.271	2.280
	(0.05)**	(0.06)*	(0.04)**	(0.00)***	(0.00)***	(0.01)***
EC	-0.212	-0.121	-0.302	-0.252	-0.138	-0.365
	(0.04)**	(0.08)*	(0.00)*	(0.06)*	(0.12)	(0.00)***

Source: Own
Standard errors in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01

Table 6
Results of the determinants of the surprises to the term spread (*surprise_termspread*).

	1	2	3	4	5	6
Output_gap	3.963	4.529	3.397	3.556	4.417	2.695
	(0.21)	(0.17)	(0.26)	(0.31)	(0.25)	(0.37)
Hicp	-7.525	-9.121	-5.930	-7.426	-9.666	-5.186
	(0.20)	(0.19)	(0.22)	(0.26)	(0.23)	(0.30)
Ecbwuxi:varresid	297.379	253.683	341.074	116.242	75.859	156.625
	(0.44)	(0.52)	(0.35)	(0.52)	(0.70)	(0.34)
Ecbkrippner_varresid	1345.366	1492.485	1198.247	641.210	537.975	744.444
	(0.21)	(0.27)	(0.14)	(0.38)	(0.63)	(0.14)
Connect_stock	-1.078	-0.749	-1.407	-1.111	-0.807	-1.415
	(0.18)	(0.27)	(0.09)	(0.14)	(0.22)	(0.07)
Connect_forex	0.148	-0.093	0.389	0.102	-0.140	0.345
	(0.40)	(0.51)	(0.30)	(0.45)	(0.50)	(0.40)
Vxocls	-1.524	-1.402	-1.645	-1.895	-1.838	-1.951
	(0.15)	(0.16)	(0.15)	(0.01)	(0.01)	(0.02)
EC	-0.121	-0.077	-0.165	-0.140	-0.087	-0.193
	(0.02)**	(0.04)**	(0.00)***	(0.03)**	(0.06)*	(0.00)***

Source: Own
Standard errors in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01

unexplained by inflation and output gap, interpreted as exercising the discretion on top of the systematic component of the monetary policy) to be driven by market risk management and reaction to uncertainty in financial markets. Uncertainty as in Caggiano et al. (2018) is measured by option implied volatility index (*Vxocls*). We find that the *Vxocls* variable is significant in the specifications not accounting for the trend in the steady-state equation. However, these volatility spillovers were transferred through neither stock market nor the forex market, as both of our co-movement variables were shown to be insignificant.

In contrast to the *shortrate* analysis, the HICP inflation is not found to be as robustly significant as the *termspread* determinant (Table 3). Again, the value of the coefficient is higher than one and points to a significant overreaction of domestic rates to the inflation rate shock that can be associated with the disinflationary period at the beginning of the sample in some of the investigated countries. Similarly, to the previous investigation, the *output_gap* variable, was insignificant across all specifications. This was also found for both the *Ecbwuxi:varresid* and the *Ecbkrippner_varresid* variables. This allows arguing for the lack of spillovers from the ECB's unconventional monetary policy to the term spread of the CEE countries.

It seems that the most important determinant of the *termspread* is implied volatility. Again, this spillover behavior is not connected to the stock market or the foreign exchange market.

Turning to the analysis of the policy surprises, the main results carry over to the investigation of instantaneous interest rate surprises (Table 4.3). Once more, the measures of the ECB policy do not spill over to the markets and do not influence our surprise terms. In addition, none of the Taylor Rule variables to catch the 'normal' monetary policy was significant. It appears that the major determinant of short-run monetary market surprises as captured by the *surprise_shortrate* is the implied risk term.

In contrast to the instantaneous interest rate surprises examination, the investigation of the term spread surprises did not yield any significant responses.

Overall, the results were generally robust to the limitations in the number of averaged models.

5. Conclusions and policy recommendations

The purpose of the article was to examine the effects of the European Central Bank (ECB) unconventional monetary policy spillovers in the environment of nominal interest rates close to zero bound. In particular, the article estimates the effects of these measures on the countries in the CEE region in terms of volatility and interest rate shifting. For these reasons, the article investigated a recent and significant topic.

Two approaches based on the Short Shadow Rate concept to measure unconventional monetary policy measures, i.e. Krippner (2013–2015) and Wu and Xi (2014–2016) were used in the panel study in a series of Bayesian Averaged cointegrated VARs.

We find that the spillovers from the unconventional ECB policy are no different from conventional monetary spillovers and are generally insignificant. Considering policy surprises changes the result only marginally, as the ECB surprises are also insignificant. While we find a significant reaction to inflation and an insignificant reaction to the output gap, we find that none of our measures of the ECB policy affects neither the instantaneous short interest rate nor the long-run term spread. Our expectations, that the conventional policy would spill over to instantaneous short rate and that the unconventional policy would spill over to the term spread were not confirmed.

Our main result of the panel study is that the international spillovers manifest themselves through the risk-taking channel, not the bond/interest rate channel, and have the form of volatility comovement. While in Poland they are associated with foreign exchange market volatility pressures, this is not the case in the region. This is also not attributed to the stock market volatilities connectedness. We hypothesize, that this can be interpreted as general insignificance of the relatively small stock markets and shallow forex markets of the region. The core idea when it comes to implied risk, however, is that general market sentiment toward uncertainty as captured by global implied risk is the main determinant of both the short and long parts of the yield curve. Therefore, we find that global uncertainty is more important than policy choices made by individual countries for their macroeconomic stability.

Our hypothesis to explain the results, which needs further investigation in other studies, suggests that there is a certain vulnerability of most of the economies open to capital flows as the task to insure against global risks to the economy seems to be even harder than expected. Thereby, the results illustrate the importance of accounting for global factors in the country-level investigation and underline the importance of heterogeneity of monetary policy responses. In addition, these results could point to a "financial trilemma" posed in Obstfeld (2015): "countries can pick at most two from financial stability, open capital markets, and autonomy over domestic financial policy". Because of the financial trilemma, domestic monetary policy in an economy open to international flows and floating exchange rates faces a trade-off between conventional macroeconomic goals (as controlled by our inflation, output variables) and financial stability (as captured by the risk component). The estimated yield curve reaction could be an indication of adhering behavior to this constraint.

In light of the obtained risk measures, the spillovers show themselves through the financial risk-taking channel, not the security/loan cost channel. This is in concurrence with Bruno and Shin (2015) and Bekaert et al. (2013), who contend that the principle channel of unpredictable ECB approach overflow through suggested investor risk aversion. Feroli et al. (2014); Agrippino and Rey (2015) Jordà et al. (2018) demonstrate that this risk is becoming more and more procyclical and comoving, thereby this conduct may expand the dangers of monetary spillovers in the future and exacerbate contagion effects.

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Appendix A. Diagnostic tests

(See here Appendix Tables A1-A8).

Table A1
Panel cross-section dependence test results.

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Models	*shortrate*			
0	889,87	2645,29	3499,75	55278,64
	(0.00)	(0.00)	(0.00)	(0.00)
1	1063,01	6343,24	6950,30	20318,78
	(0.00)	(0.00)	(0.00)	(0.00)
2	517,40	39.43	39.42	55127,90
	(0.00)	(0.00)	(0.00)	(0.00)
3	477,45	64043,07	44916,19	18779,18
	(0.00)	(0.00)	(0.00)	(0.00)
4	2337,55	92730,14	65782,10	240917,26
	(0.00)	(0.00)	(0.00)	(0.03)
5	2491,64	242560,28	242388,21	30961,94
	(0.00)	(0.00)	(0.00)	(0.00)
6	14802,11	1666,28	1666,26	13816,02
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Table A2
Panel cross-section dependence test results.

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Models	*surprise_shortrate*			
0	888,53	2643,83	3498,52	55277,37
	(0.00)	(0.00)	(0.00)	(0.00)
1	1061,85	6340,08	6947,94	20317,62
	(0.00)	(0.00)	(0.00)	(0.00)
2	515,89	39.43	39.42	55126,53
	(0.00)	(0.00)	(0.00)	(0.00)
3	476,12	64041,61	44914,96	18777,92
	(0.00)	(0.00)	(0.00)	(0.00)
4	2336,22	92728,68	65780,87	240914,91
	(0.00)	(0.00)	(0.00)	(0.03)
5	2489,96	242557,92	242385,85	30960,45
	(0.00)	(0.00)	(0.00)	(0.00)
6	14800,08	1664,90	1664,88	13814,31
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Table A3
Panel cross-section dependence test results.

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Models	*termspread*			
0	667,07	1811,85	2845,32	43629,55
	(0.00)	(0.00)	(0.00)	(0.00)
1	916,39	2009,90	2950,04	17561,61
	(0.00)	(0.00)	(0.00)	(0.00)
2	343,10	39.43	39.42	40034,79
	(0.00)	(0.00)	(0.00)	(0.00)
3	357,91	43865,12	36517,22	14821,77
	(0.00)	(0.00)	(0.00)	(0.00)
4	1752,29	63513,80	53481,38	102256,90
	(0.00)	(0.00)	(0.00)	(0.00)
5	1481,35	102954,28	102881,24	20821,75
	(0.00)	(0.00)	(0.00)	(0.00)
6	7291,68	1210,08	1210,07	8093,74
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Table A4
Panel cross-section dependence test results.

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Models	*surprise_termspread*			
0	500,05	1240,99	2313,27	34435,32
	(0.00)	(0.00)	(0.00)	(0.00)
1	789,99	636,85	1252,14	15178,57
	(0.00)	(0.00)	(0.00)	(0.00)
2	227,52	39.43	39.42	29073,92
	(0.00)	(0.00)	(0.00)	(0.00)
3	268,30	30044,60	29688,80	11698,32
	(0.00)	(0.00)	(0.00)	(0.00)
4	1313,56	43502,60	43480,80	43402,76
	(0.00)	(0.00)	(0.00)	(0.03)
5	880,71	43698,76	43667,76	14002,52
	(0.00)	(0.00)	(0.00)	(0.00)
6	3591,96	878,78	878,77	4741,50
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Table A5
Westerlund (2007) panel cointegration test statistics (p-value in parentheses).

	shortrate			
	Gt	Ga	Pt	Pa
0	-9,97	-204,74	-21,67	-187,53
	(0.00)	(0.00)	(0.00)	(0.00)
1	-10,14	-299,04	-18,94	-274,94
	(0.00)	(0.00)	(0.00)	(0.00)
2	-8,99	-354,96	-18,40	-318,92
	(0.00)	(0.00)	(0.00)	(0.00)
3	-10,27	-308,54	-18,67	-283,53
	(0.00)	(0.00)	(0.00)	(0.00)
4	-8,67	-300,24	-18,67	-329,54
	(0.00)	(0.00)	(0.00)	(0.00)
5	-9,72	-355,04	-15,14	-344,01
	(0.00)	(0.00)	(0.00)	(0.00)
6	-8,77	-449,92	-17,82	-448,39
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Table A6
Westerlund (2007) panel cointegration test statistics (p-value in parentheses).

	Surprise_shortrate			
	Gt	Ga	Pt	Pa
0	-13,29	-298,92	-26,65	-237,60
	(0.00)	(0.00)	(0.00)	(0.00)
1	-11,76	-943,78	-44,63	-318,11
	(0.00)	(0.00)	(0.00)	(0.00)
2	-13,56	-793,70	-20,31	-439,16
	(0.00)	(0.00)	(0.00)	(0.00)
3	-13,69	-450,47	-22,96	-359,24
	(0.00)	(0.00)	(0.00)	(0.00)
4	-11,56	-438,35	-22,96	-776,41
	(0.00)	(0.00)	(0.00)	(0.00)
5	-16,35	-836,48	-35,68	-511,55
	(0.00)	(0.00)	(0.00)	(0.00)
6	-17,80	-619,54	-24,54	-765,41
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Table A7
Westerlund (2007) panel cointegration test statistics (p-value in parentheses).

	termspread			
	Gt	Ga	Pt	Pa
0	-16,41	-302,51	-29,40	-240,48
	(0.00)	(0.00)	(0.00)	(0.00)
1	-14,27	-956,90	-52,54	-320,60
	(0.00)	(0.00)	(0.00)	(0.00)
2	-17,34	-800,94	-22,63	-442,43
	(0.00)	(0.00)	(0.00)	(0.00)
3	-16,81	-454,06	-25,71	-362,11
	(0.00)	(0.00)	(0.00)	(0.00)
4	-14,67	-441,94	-25,71	-784,31
	(0.00)	(0.00)	(0.00)	(0.00)
5	-20,86	-844,39	-43,59	-515,25
	(0.00)	(0.00)	(0.00)	(0.00)
6	-23,95	-622,82	-27,82	-770,03
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Table A8
Westerlund (2007) panel cointegration test statistics (p-value in parentheses).

	surprise_termspread			
	Gt	Ga	Pt	Pa
0	-21,89	-441,67	-36,16	-304,68
	(0.00)	(0.00)	(0.00)	(0.00)
1	-16,55	-3019,97	-123,78	-370,94
	(0.00)	(0.00)	(0.00)	(0.00)
2	-26,15	-1790,89	-24,99	-609,23
	(0.00)	(0.00)	(0.00)	(0.00)
3	-22,42	-662,93	-31,62	-458,79
	(0.00)	(0.00)	(0.00)	(0.00)
4	-19,58	-645,24	-31,62	-1847,84
	(0.00)	(0.00)	(0.00)	(0.00)
5	-35,08	-1989,38	-102,69	-766,17
	(0.00)	(0.00)	(0.00)	(0.00)
6	-48,63	-857,62	-38,30	-1314,44
	(0.00)	(0.00)	(0.00)	(0.00)

Note: p-values in parentheses
Source: own

Appendix B. Results continued

(See here Appendix Tables B1-B4).

Table B1
Detailed results of the determinants of the *shortrate* variable.

	1	2	3	4	5	6
l1d_shortrate	0.017	0.027	0.006			
	(0.46)	(0.69)	(0.22)			
l2d_shortrate	-0.003	-0.003	-0.004			
	(0.50)	(0.78)	(0.22)			
l3d_shortrate	0.017	0.005	0.029			
	(0.43)	(0.81)	(0.04)			
l4d_shortrate	0.043	0.024	0.062			
	(0.20)	(0.40)	(0.00)			
l5d_shortrate	0.004	-0.010	0.018			
	(0.25)	(0.51)	(0.00)			
l0d_output_gap	-3.134	-2.690	-3.577	-4.120	-3.557	-4.683
	(0.18)	(0.16)	(0.19)	(0.18)	(0.18)	(0.18)
l1d_output_gap	0.749	0.562	0.937	1.155	0.902	1.408
	(0.52)	(0.52)	(0.52)	(0.41)	(0.48)	(0.34)
l2d_output_gap	-0.506	-0.373	-0.639			
	(0.51)	(0.57)	(0.46)			
l3d_output_gap	-1.016	-0.221	-1.811			
	(0.54)	(0.70)	(0.39)			
l4d_output_gap	1.006	0.890	1.123			
	(0.49)	(0.46)	(0.53)			
l5d_output_gap	-1.775	-1.176	-2.374			
	(0.38)	(0.51)	(0.25)			
l0d_hicp	3.202	2.096	4.309	5.502	3.586	7.417
	(0.17)	(0.21)	(0.12)	(0.20)	(0.30)	(0.10)
l1d_hicp	-1.203	-1.128	-1.279	-0.015	0.138	-0.168
	(0.39)	(0.46)	(0.33)	(0.58)	(0.67)	(0.49)
l2d_hicp	2.429	2.038	2.821			
	(0.06)	(0.12)	(0.01)			
l3d_hicp	-2.636	-1.771	-3.501			
	(0.44)	(0.49)	(0.39)			
l4d_hicp	3.441	2.296	4.586			
	(0.23)	(0.26)	(0.21)			
l5d_hicp	-2.842	-1.548	-4.136			
	(0.47)	(0.62)	(0.32)			
l0d_vxocls	0.389	0.369	0.409	0.589	0.591	0.586
	(0.41)	(0.42)	(0.39)	(0.41)	(0.40)	(0.42)
l1d_vxocls	-0.037	-0.039	-0.035	-0.052	-0.037	-0.067
	(0.49)	(0.53)	(0.46)	(0.54)	(0.57)	(0.51)
l2d_vxocls	-0.443	-0.480	-0.406			
	(0.17)	(0.19)	(0.16)			
l3d_vxocls	1.053	1.035	1.071			
	(0.18)	(0.19)	(0.18)			

(*continued on next page*)

Table B1 (*continued*)

	1	2	3	4	5	6
l4d_vxocls	-0.952	-0.967	-0.937			
	(0.30)	(0.22)	(0.38)			
l5d_vxocls	-0.516	-0.536	-0.497			
	(0.25)	(0.37)	(0.12)			
l0d_connect_forex	0.330	0.291	0.369	0.541	0.477	0.605
	(0.47)	(0.49)	(0.46)	(0.25)	(0.27)	(0.24)
l1d_connect_forex	0.377	0.348	0.406	0.428	0.379	0.478
	(0.29)	(0.25)	(0.32)	(0.16)	(0.15)	(0.17)
l2d_connect_forex	0.293	0.285	0.301			
	(0.13)	(0.13)	(0.14)			
l3d_connect_forex	-0.084	-0.082	-0.085			
	(0.10)	(0.12)	(0.08)			
l4d_connect_forex	-0.084	-0.066	-0.103			
	(0.39)	(0.40)	(0.37)			
l5d_connect_forex	-0.319	-0.276	-0.361			
	(0.41)	(0.45)	(0.38)			
l0d_connect_stock	0.133	0.096	0.170	0.187	0.141	0.233
	(0.37)	(0.41)	(0.32)	(0.25)	(0.32)	(0.18)
l1d_connect_stock	0.344	0.297	0.391	0.510	0.415	0.605
	(0.17)	(0.22)	(0.12)	(0.04)	(0.06)	(0.03)
l2d_connect_stock	0.022	0.025	0.019			
	(0.39)	(0.48)	(0.31)			
l3d_connect_stock	-0.643	-0.463	-0.824			
	(0.33)	(0.47)	(0.20)			
l4d_connect_stock	0.193	0.137	0.249			
	(0.30)	(0.35)	(0.25)			
l5d_connect_stock	0.097	0.111	0.083			
	(0.20)	(0.30)	(0.10)			
l0d_eckrippner_varresid	71.936	61.280	82.593	176.867	172.473	181.261
	(0.52)	(0.49)	(0.55)	(0.44)	(0.45)	(0.42)
l1d_eckrippner_varresid	73.559	67.406	79.712	187.428	184.289	190.567
	(0.35)	(0.33)	(0.37)	(0.31)	(0.32)	(0.31)
l2d_eckrippner_varresid	-73.876	-78.651	-69.102			
	(0.35)	(0.33)	(0.37)			
l3d_eckrippner_varresid	-199.114	-202.708	-195.519			
	(0.34)	(0.31)	(0.38)			
l4d_eckrippner_varresid	-45.029	-48.827	-41.232			
	(0.25)	(0.27)	(0.24)			
l5d_eckrippner_varresid	2.753	1.491	4.016			
	(0.71)	(0.74)	(0.68)			
l0d_ecwuxi:varresid	-57.364	-57.295	-57.434	-63.514	-63.800	-63.229
	(0.37)	(0.37)	(0.37)	(0.26)	(0.26)	(0.26)
l1d_ecwuxi:varresid	-35.692	-35.399	-35.986	-32.664	-32.869	-32.459
	(0.33)	(0.33)	(0.33)	(0.23)	(0.22)	(0.23)
l2d_ecwuxi:varresid	-19.042	-18.270	-19.815			
	(0.50)	(0.51)	(0.48)			
l3d_ecwuxi:varresid	-12.385	-12.402	-12.367			
	(0.55)	(0.56)	(0.54)			
l4d_ecwuxi:varresid	-3.591	-4.049	-3.134			
	(0.58)	(0.58)	(0.58)			
l5d_ecwuxi:varresid	-6.334	-6.474	-6.193			
	(0.37)	(0.35)	(0.38)			
TREND	-0.980	-0.975	-0.984			
	(0.00)	(0.00)	(0.00)			

Bayesian averaged results are provided is the subsequent columns: Column 1 - averages of all results, lags 0–5, with or without trend, with or without constant, DFE or MG method; Column 2 - as above, but only for the MG method; Column 3 - as above, but only for the DFE method; Column 4 - averages of models with lags=1, without trend, with constant, DFE or MG method; Column 5 - MG method, models with lags = 1, with constant, no trend; Column 6 - DFE method, models with lags = 1, with constant, no trend; Averaged p-values for the *t* test of significance are given in brackets; lxd_*var* stands for the *x*-period-lagged difference of the variable *var*; constant, EC and long term relation estimates omitted.

Table B2
Detailed results of the determinants of the *termspread* variable.

	1	2	3	4	5	6
l1d_termspread	-0.019	-0.011	-0.026			
	(0.46)	(0.88)	(0.04)			
l2d_termspread	-0.010	-0.015	-0.006			
	(0.42)	(0.62)	(0.21)			
l3d_termspread	0.036	0.012	0.060			
	(0.38)	(0.77)	(0.00)			
l4d_termspread	0.049	0.024	0.074			
	(0.22)	(0.44)	(0.00)			
l5d_termspread	0.008	-0.013	0.028			
	(0.29)	(0.58)	(0.00)			
l0d_output_gap	4.413	3.700	5.126	4.199	3.624	4.774
	(0.21)	(0.23)	(0.19)	(0.19)	(0.20)	(0.19)
l1d_output_gap	-1.223	-1.017	-1.429	-1.137	-0.940	-1.333
	(0.37)	(0.41)	(0.32)	(0.39)	(0.44)	(0.34)
l2d_output_gap	0.253	0.138	0.368			
	(0.66)	(0.62)	(0.69)			
l3d_output_gap	1.636	0.666	2.606			
	(0.64)	(0.83)	(0.45)			
l4d_output_gap	-1.522	-1.382	-1.662			
	(0.31)	(0.30)	(0.32)			
l5d_output_gap	2.413	1.646	3.180			
	(0.42)	(0.54)	(0.29)			
l0d_hicp	-6.060	-4.357	-7.764	-5.441	-3.715	-7.167
	(0.16)	(0.24)	(0.08)	(0.17)	(0.26)	(0.08)
l1d_hicp	-0.591	-0.381	-0.801	-0.864	-0.901	-0.826
	(0.60)	(0.64)	(0.56)	(0.55)	(0.54)	(0.55)
l2d_hicp	-5.825	-4.498	-7.152			
	(0.04)	(0.07)	(0.01)			
l3d_hicp	2.552	1.384	3.720			
	(0.68)	(0.80)	(0.57)			
l4d_hicp	-6.694	-4.917	-8.471			
	(0.26)	(0.32)	(0.19)			
l5d_hicp	-0.864	-1.516	-0.212			
	(0.80)	(0.72)	(0.87)			
l0d_vxocls	-0.628	-0.650	-0.605	-0.679	-0.693	-0.665
	(0.47)	(0.45)	(0.50)	(0.41)	(0.40)	(0.43)
l1d_vxocls	-0.276	-0.307	-0.245	-0.649	-0.672	-0.625
	(0.40)	(0.34)	(0.47)	(0.29)	(0.27)	(0.32)
l2d_vxocls	0.780	0.783	0.778			
	(0.16)	(0.16)	(0.16)			
l3d_vxocls	-1.155	-1.163	-1.147			
	(0.22)	(0.22)	(0.23)			
l4d_vxocls	0.926	0.901	0.951			
	(0.14)	(0.15)	(0.12)			
l5d_vxocls	1.075	1.064	1.087			
	(0.15)	(0.15)	(0.15)			
l0d_connect_forex	-0.503	-0.436	-0.569	-0.494	-0.431	-0.557
	(0.25)	(0.26)	(0.23)	(0.25)	(0.27)	(0.24)
l1d_connect_forex	-0.451	-0.394	-0.508	-0.380	-0.333	-0.427
	(0.18)	(0.16)	(0.19)	(0.19)	(0.19)	(0.19)
l2d_connect_forex	-0.247	-0.238	-0.255			
	(0.10)	(0.08)	(0.11)			
l3d_connect_forex	0.387	0.364	0.410			
	(0.11)	(0.13)	(0.08)			
l4d_connect_forex	0.139	0.124	0.154			
	(0.42)	(0.40)	(0.43)			
l5d_connect_forex	0.420	0.357	0.482			
	(0.16)	(0.18)	(0.13)			
l0d_connect_stock	-0.149	-0.100	-0.197	-0.113	-0.073	-0.153
	(0.42)	(0.54)	(0.30)	(0.37)	(0.54)	(0.19)
l1d_connect_stock	-0.588	-0.480	-0.696	-0.585	-0.475	-0.696
	(0.05)	(0.07)	(0.03)	(0.05)	(0.07)	(0.03)
l2d_connect_stock	-0.062	-0.047	-0.077			
	(0.45)	(0.51)	(0.40)			
l3d_connect_stock	0.842	0.624	1.059			
	(0.35)	(0.42)	(0.28)			
l4d_connect_stock	-0.353	-0.262	-0.445			
	(0.42)	(0.50)	(0.35)			
l5d_connect_stock	-0.315	-0.275	-0.355			
	(0.11)	(0.13)	(0.09)			
l0d_eckrippner_varresid	-117.690	-111.959	-123.422	-154.313	-151.097	-157.529
	(0.49)	(0.52)	(0.45)	(0.46)	(0.47)	(0.45)
l1d_eckrippner_varresid	-68.627	-63.961	-73.293	-106.983	-104.829	-109.136
	(0.33)	(0.30)	(0.36)	(0.33)	(0.34)	(0.32)
l2d_eckrippner_varresid	127.178	130.912	123.444			

(*continued on next page*)

Table B2 (*continued*)

	1	2	3	4	5	6
	(0.30)	(0.29)	(0.31)			
l3d_eckrippner_varresid	283.875	285.757	281.992			
	(0.30)	(0.29)	(0.31)			
l4d_eckrippner_varresid	89.017	89.003	89.031			
	(0.19)	(0.17)	(0.20)			
l5d_eckrippner_varresid	-14.247	-18.271	-10.222			
	(0.80)	(0.79)	(0.81)			
l0d_ecwuxi:varresid	90.792	90.608	90.977	73.832	74.109	73.556
	(0.29)	(0.29)	(0.29)	(0.27)	(0.27)	(0.27)
l1d_ecwuxi:varresid	59.762	59.199	60.325	43.579	43.724	43.434
	(0.29)	(0.29)	(0.28)	(0.25)	(0.25)	(0.25)
l2d_ecwuxi:varresid	17.488	16.458	18.519			
	(0.39)	(0.43)	(0.34)			
l3d_ecwuxi:varresid	15.003	15.004	15.002			
	(0.43)	(0.43)	(0.44)			
l4d_ecwuxi:varresid	0.754	0.930	0.579			
	(0.28)	(0.24)	(0.32)			
l5d_ecwuxi:varresid	-5.813	-5.824	-5.802			
	(0.25)	(0.25)	(0.26)			

Bayesian averaged results are provided is the subsequent columns: Column 1 - averages of all results, lags 0–5, with or without trend, with or without constant, DFE or MG method; Column 2 - as above, but only for the MG method; Column 3 - as above, but only for the DFE method; Column 4 - averages of models with lags=1, without trend, with constant, DFE or MG method; Column 5 - MG method, models with lags = 1, with constant, no trend; Column 6 - DFE method, models with lags = 1, with constant, no trend; Averaged p-values for the *t* test of significance are given in brackets; lxd_*var* stands for the *x*-period-lagged difference of the variable *var*; constant, EC and long term relation estimates omitted.

Table B3
Detailed results of the determinants of the *surprise_shortrate* variable.

	1	2	3	4	5	6
l1d_surprise_short	-0.495	-0.366	-0.623			
	(0.02)	(0.05)	(0.00)			
l2d_surprise_short	-0.317	-0.205	-0.429			
	(0.06)	(0.12)	(0.00)			
l3d_surprise_short	-0.244	-0.160	-0.329			
	(0.04)	(0.07)	(0.00)			
l4d_surprise_short	-0.224	-0.164	-0.285			
	(0.00)	(0.00)	(0.00)			
l5d_surprise_short	-0.135	-0.123	-0.146			
	(0.00)	(0.00)	(0.00)			
l0d_output_gap	5.416	4.838	5.993	6.338	5.674	7.002
	(0.19)	(0.19)	(0.20)	(0.20)	(0.19)	(0.20)
l1d_output_gap	1.860	1.822	1.899	0.922	1.109	0.734
	(0.18)	(0.17)	(0.19)	(0.30)	(0.26)	(0.34)
l2d_output_gap	0.901	0.759	1.042			
	(0.34)	(0.36)	(0.32)			
l3d_output_gap	0.938	0.696	1.180			
	(0.37)	(0.41)	(0.34)			
l4d_output_gap	-1.375	-0.989	-1.761			
	(0.26)	(0.38)	(0.13)			
l5d_output_gap	-1.105	-0.927	-1.283			
	(0.06)	(0.09)	(0.03)			
l0d_hicp	11.495	9.264	13.727	16.739	12.750	20.727
	(0.08)	(0.10)	(0.06)	(0.08)	(0.11)	(0.05)
l1d_hicp	5.331	3.782	6.881	-6.447	-4.618	-8.275
	(0.16)	(0.22)	(0.10)	(0.36)	(0.43)	(0.29)
l2d_hicp	-0.002	0.136	-0.140			
	(0.45)	(0.51)	(0.40)			
l3d_hicp	-7.500	-5.745	-9.256			
	(0.38)	(0.41)	(0.36)			
l4d_hicp	-11.083	-7.697	-14.469			
	(0.44)	(0.53)	(0.36)			
l5d_hicp	-8.308	-6.152	-10.464			
	(0.32)	(0.34)	(0.30)			
l0d_vxocls	-0.203	-0.112	-0.294	-0.369	-0.214	-0.523
	(0.26)	(0.31)	(0.21)	(0.14)	(0.24)	(0.04)
l1d_vxocls	-0.005	0.086	-0.095	-0.171	-0.046	-0.297
	(0.40)	(0.39)	(0.42)	(0.31)	(0.41)	(0.20)
l2d_vxocls	-0.136	-0.030	-0.241			
	(0.27)	(0.34)	(0.19)			
l3d_vxocls	-0.309	-0.233	-0.386			
	(0.18)	(0.25)	(0.10)			

(*continued on next page*)

Table B3 (*continued*)

	1	2	3	4	5	6
l4d_vxocls	0.518	0.590	0.447			
	(0.27)	(0.17)	(0.36)			
l5d_vxocls	0.558	0.566	0.550			
	(0.28)	(0.25)	(0.31)			
l0d_connect_forex	-0.033	-0.087	0.021	-0.087	-0.124	-0.049
	(0.64)	(0.57)	(0.72)	(0.50)	(0.35)	(0.66)
l1d_connect_forex	-0.477	-0.427	-0.527	-0.401	-0.416	-0.386
	(0.20)	(0.22)	(0.19)	(0.22)	(0.22)	(0.23)
l2d_connect_forex	-0.946	-0.846	-1.045			
	(0.28)	(0.30)	(0.26)			
l3d_connect_forex	0.138	0.127	0.149			
	(0.21)	(0.23)	(0.19)			
l4d_connect_forex	0.520	0.377	0.663			
	(0.32)	(0.40)	(0.25)			
l5d_connect_forex	0.663	0.548	0.777			
	(0.27)	(0.31)	(0.24)			
l0d_connect_stock	-1.262	-1.000	-1.523	-1.703	-1.317	-2.088
	(0.25)	(0.29)	(0.21)	(0.24)	(0.29)	(0.18)
l1d_connect_stock	1.282	0.994	1.569	1.465	1.126	1.803
	(0.30)	(0.36)	(0.25)	(0.29)	(0.35)	(0.24)
l2d_connect_stock	0.341	0.285	0.397			
	(0.22)	(0.24)	(0.20)			
l3d_connect_stock	0.251	0.159	0.343			
	(0.56)	(0.66)	(0.45)			
l4d_connect_stock	-1.830	-1.470	-2.190			
	(0.21)	(0.24)	(0.17)			
l5d_connect_stock	0.678	0.571	0.786			
	(0.21)	(0.22)	(0.20)			
l0d_eckrippner_varresid	31.737	21.536	41.939	4.498	-0.010	9.005
	(0.45)	(0.48)	(0.41)	(0.46)	(0.59)	(0.34)
l1d_eckrippner_varresid	135.698	124.838	146.558	39.633	40.185	39.081
	(0.29)	(0.30)	(0.27)	(0.32)	(0.21)	(0.43)
l2d_eckrippner_varresid	91.734	81.378	102.091			
	(0.38)	(0.41)	(0.35)			
l3d_eckrippner_varresid	219.936	215.239	224.633			
	(0.39)	(0.40)	(0.38)			
l4d_eckrippner_varresid	251.335	254.138	248.532			
	(0.35)	(0.34)	(0.37)			
l5d_eckrippner_varresid	300.359	300.702	300.016			
	(0.34)	(0.33)	(0.34)			
l0d_ecwuxi:varresid	57.716	58.630	56.802	18.408	19.774	17.043
	(0.33)	(0.32)	(0.34)	(0.43)	(0.39)	(0.48)
l1d_ecwuxi:varresid	41.923	43.040	40.807	11.840	12.433	11.247
	(0.32)	(0.31)	(0.34)	(0.39)	(0.36)	(0.42)
l2d_ecwuxi:varresid	32.882	33.854	31.909			
	(0.26)	(0.25)	(0.27)			
l3d_ecwuxi:varresid	24.954	25.203	24.705			
	(0.25)	(0.25)	(0.26)			
l4d_ecwuxi:varresid	20.679	20.284	21.073			
	(0.29)	(0.30)	(0.28)			
l5d_ecwuxi:varresid	11.378	10.664	12.092			
	(0.26)	(0.29)	(0.22)			
TREND	-0.250	-0.374	-0.126			
	(0.00)	(0.00)	(0.00)			

Bayesian averaged results are provided is the subsequent columns: Column 1 - averages of all results, lags 0–5, with or without trend, with or without constant, DFE or MG method; Column 2 - as above, but only for the MG method; Column 3 - as above, but only for the DFE method; Column 4 - averages of models with lags=1, without trend, with constant, DFE or MG method; Column 5 - MG method, models with lags = 1, with constant, no trend; Column 6 - DFE method, models with lags = 1, with constant, no trend; Averaged p-values for the *t* test of significance are given in brackets; l*x*d_*var* stands for the *x*-period-lagged difference of the variable *var*; constant, EC and long term relation estimates omitted.

Table B4
Detailed results of the determinants of the *surprise_termspread* variable.

	1	2	3	4	5	6
l1d_surprise_spread	-0.390	-0.220	-0.561			
	(0.08)	(0.16)	(0.00)			
l2d_surprise_spread	-0.280	-0.201	-0.359			
	(0.03)	(0.06)	(0.00)			
l3d_surprise_spread	-0.170	-0.113	-0.226			
	(0.06)	(0.12)	(0.00)			
l4d_surprise_spread	-0.089	-0.060	-0.118			
	(0.05)	(0.10)	(0.00)			
l5d_surprise_spread	-0.051	-0.036	-0.065			
	(0.08)	(0.17)	(0.00)			
l0d_output_gap	-3.353	-3.060	-3.646	-3.684	-3.418	-3.950
	(0.18)	(0.17)	(0.19)	(0.17)	(0.15)	(0.20)
l1d_output_gap	0.151	-0.153	0.455	0.567	0.217	0.916
	(0.75)	(0.83)	(0.67)	(0.67)	(0.87)	(0.47)
l2d_output_gap	-0.245	-0.429	-0.061			
	(0.71)	(0.62)	(0.80)			
l3d_output_gap	-1.268	-0.900	-1.637			
	(0.35)	(0.43)	(0.28)			
l4d_output_gap	1.863	1.386	2.339			
	(0.29)	(0.38)	(0.19)			
l5d_output_gap	1.082	1.189	0.975			
	(0.12)	(0.17)	(0.08)			
l0d_hicp	-1.833	-1.063	-2.604	-3.553	-2.674	-4.432
	(0.35)	(0.43)	(0.28)	(0.13)	(0.20)	(0.06)
l1d_hicp	-2.091	-2.864	-1.318	3.772	2.190	5.355
	(0.38)	(0.43)	(0.33)	(0.53)	(0.66)	(0.39)
l2d_hicp	5.349	4.202	6.496			
	(0.41)	(0.44)	(0.38)			
l3d_hicp	5.663	3.277	8.049			
	(0.50)	(0.64)	(0.37)			
l4d_hicp	10.399	7.295	13.503			
	(0.42)	(0.50)	(0.34)			
l5d_hicp	7.496	5.417	9.576			
	(0.35)	(0.39)	(0.30)			
l0d_vxocls	0.161	0.146	0.177	0.251	0.202	0.299
	(0.40)	(0.46)	(0.33)	(0.23)	(0.32)	(0.13)
l1d_vxocls	0.235	0.176	0.295	0.547	0.481	0.614
	(0.26)	(0.38)	(0.13)	(0.17)	(0.24)	(0.10)
l2d_vxocls	0.253	0.202	0.303			
	(0.08)	(0.14)	(0.03)			
l3d_vxocls	0.387	0.341	0.432			
	(0.07)	(0.10)	(0.04)			
l4d_vxocls	-0.251	-0.293	-0.209			
	(0.29)	(0.16)	(0.41)			
l5d_vxocls	-0.469	-0.459	-0.479			
	(0.20)	(0.20)	(0.19)			
l0d_connect_forex	0.146	0.142	0.150	0.182	0.160	0.205
	(0.28)	(0.21)	(0.35)	(0.09)	(0.09)	(0.09)
l1d_connect_forex	0.488	0.426	0.551	0.405	0.367	0.443
	(0.28)	(0.31)	(0.25)	(0.33)	(0.37)	(0.29)
l2d_connect_forex	0.523	0.504	0.543			
	(0.27)	(0.25)	(0.29)			
l3d_connect_forex	-0.243	-0.184	-0.302			
	(0.40)	(0.50)	(0.30)			
l4d_connect_forex	-0.430	-0.319	-0.542			
	(0.33)	(0.40)	(0.26)			
l5d_connect_forex	-0.358	-0.295	-0.420			
	(0.17)	(0.18)	(0.17)			
l0d_connect_stock	1.467	1.102	1.831	1.824	1.351	2.296
	(0.28)	(0.34)	(0.22)	(0.27)	(0.33)	(0.20)
l1d_connect_stock	-1.285	-0.924	-1.645	-1.547	-1.118	-1.976
	(0.34)	(0.42)	(0.25)	(0.31)	(0.39)	(0.24)
l2d_connect_stock	-0.185	-0.162	-0.207			
	(0.25)	(0.29)	(0.22)			
l3d_connect_stock	-0.302	-0.225	-0.379			
	(0.42)	(0.52)	(0.32)			
l4d_connect_stock	1.788	1.409	2.168			
	(0.21)	(0.25)	(0.18)			
l5d_connect_stock	-0.974	-0.751	-1.198			
	(0.22)	(0.27)	(0.18)			
l0d_eckrippner_varresid	-93.447	-83.414	-103.480	-38.994	-22.209	-55.779
	(0.38)	(0.39)	(0.37)	(0.60)	(0.68)	(0.52)
l1d_eckrippner_varresid	-116.668	-114.592	-118.744	-7.041	1.334	-15.415
	(0.37)	(0.39)	(0.35)	(0.45)	(0.43)	(0.46)
l2d_eckrippner_varresid	-116.346	-128.207	-104.485			

(*continued on next page*)

Table B4 (*continued*)

	1	2	3	4	5	6
	(0.36)	(0.34)	(0.38)			
l3d_eckrippner_varresid	-168.398	-177.849	-158.947			
	(0.41)	(0.37)	(0.44)			
l4d_eckrippner_varresid	-155.110	-161.864	-148.356			
	(0.35)	(0.33)	(0.37)			
l5d_eckrippner_varresid	-60.954	-63.363	-58.546			
	(0.49)	(0.47)	(0.50)			
l0d_ecwuxi:varresid	-50.504	-52.453	-48.555	-29.156	-30.366	-27.945
	(0.29)	(0.28)	(0.30)	(0.29)	(0.27)	(0.30)
l1d_ecwuxi:varresid	-36.245	-37.353	-35.136	-18.368	-18.403	-18.332
	(0.28)	(0.27)	(0.28)	(0.25)	(0.26)	(0.25)
l2d_ecwuxi:varresid	-20.684	-21.777	-19.592			
	(0.25)	(0.23)	(0.27)			
l3d_ecwuxi:varresid	-13.960	-15.055	-12.865			
	(0.24)	(0.20)	(0.28)			
l4d_ecwuxi:varresid	-9.328	-9.974	-8.682			
	(0.32)	(0.28)	(0.36)			
l5d_ecwuxi:varresid	0.443	0.098	0.787			
	(0.69)	(0.77)	(0.62)			
TREND	0.243	0.418	0.068			
	(0.01)	(0.01)	(0.02)			

Bayesian averaged results are provided is the subsequent columns: Column 1 - averages of all results, lags 0–5, with or without trend, with or without constant, DFE or MG method; Column 2 - as above, but only for the MG method; Column 3 - as above, but only for the DFE method; Column 4 - averages of models with lags=1, without trend, with constant, DFE or MG method; Column 5 - MG method, models with lags = 1, with constant, no trend; Column 6 - DFE method, models with lags = 1, with constant, no trend; Averaged p-values for the *t* test of significance are given in brackets; lxd_*var* stands for the *x*-period-lagged difference of the variable *var*; constant, EC and long term relation estimates omitted.

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