The effects of monetary policy response to the Covid-19 crisis on dynamic connectedness across financial markets in Central and Eastern Europe

Wojciech Grabowski, Jakub Janus, Ewa Stawasz-Grabowska

A B S T R A C T
Objective: This study investigates the effects of monetary policy interventions in Central and Eastern European (CEE) economies on shifts in financial market linkages during the Covid-19-induced crisis. We explore the market reaction to both standard and non-standard (e.g., quantitative easing) monetary policy announcements by central banks in Czechia, Hungary, Poland, and Romania, and analyse the way they affected sovereign bond and stock market linkages. The analysis is further extended to include international spill-over effects.
Research Design & Methods: We first quantify a set of time-varying asset correlations using asymmetric generalised DCC-GARCH models and daily data on financial asset returns. Going beyond the domestic stock-bond interdependencies, we explore cross-border connectedness between CEE economies, Germany, and the US. Next, we investigate the effects of detailed central bank announcements, as they unfolded during the Covid-19 crisis.
Findings: We find that, by and large, the CEE central bank interventions conducted in 2020 alleviated domestic and cross-border pressures in financial market linkages triggered by the global risk shock, such as contagion and flight-to-safety effects. However, monetary policies had largest impact at the height of the crisis when central banks in the region introduced substantial interest-rate cuts and unconventional measures, which were used by those banks for the first time or on such a wide scale.
Implications & Recommendations: Our results imply that monetary authorities may partly mitigate the transmission of global shocks to domestic financial markets, even when it comes to small open economies. However, the effects of monetary policies proved strongest at the onset of the crisis and seem to have been related to unconventional policy tools and aggressive interest rate cuts.
Contribution & Value Added: We examinee linkages across the two largest asset classes, sovereign bonds and equities, both within CEE economies and between each of them and Germany and the US (traditionally perceived as safe havens), while controlling for potential structural breaks, global risk measures, and Covid-19-related indicators, such as the number of Covid-19 cases and the government-response stringency indices. Event studies conducted in the article are based on a comprehensive dataset on policy interventions launched during 2020.

INTRODUCTION

One of the trademarks of the financial turmoil induced by the Covid-19 pandemic in 2020 was a deep uncertainty that quickly spread worldwide. Faced with deteriorating economic outlooks, market participants shifted their portfolios, both with respect to particular segments of financial markets and

geographical locations. Consequently, linkages across various asset classes strengthened, indicating an increase in the transmission of adverse shocks during the pandemic (Belaid, Ben Amar, Goutte, & Guesmi, 2021; Bouri, Gabauer, & Gupta, 2021; Halmai, 2022; Youssef, Mokni, & Ajmi, 2021). Those tendencies reflected both herding behaviour and contagion in financial markets, as well as capital flights from riskier to safer assets and countries. Such phenomena are increasingly well documented, both for domestic equity-bond flows and cross-border financial flows among economies (Chari, Dilts Stedman, & Lundblad, 2020; Papadamou, Fassas, Kenourgios, & Dimitriou, 2021). Additionally, recent studies such as Beirne Renzhi, Sugandi, and Volz (2021) show that the disrupting effects of the Covid-19 pandemic were not distributed equally and emerging economies (EMEs) were affected more heavily than advanced economies (AEs).

At the same time, the Covid-19 crisis created a serious challenge for central banks. Responding to adverse financial shocks and the freezing of economic activity, monetary authorities worldwide launched a broad set of measures, including unconventional monetary policies (Fratto, Harnoys Vannier, Mircheva, De Padua, & Poirson Ward, 2021; Rebucci, Hartley, & Jiménez, 2021; Grabowski, Janus, & Stawasz-Grabowska, 2023; Żak & Garncarz, 2020). Interestingly, before the 2020 crisis, non-standard monetary policy tools had not been widely used by central banks outside of the major AEs. It was the case for Central and Eastern European (CEE) countries, in particular Czechia, Hungary, Poland, and Romania, which we investigate in this article. In the first quarter of 2020, central banks in CEE economies initiated bold monetary policy interventions, going into the uncharted territory of the zero-lower bound, liquidity-providing operations, and quantitative easing (QE). This shift in monetary policies raises pressing questions about the effects of those actions. What makes empirical studies on the effects of monetary policies in CEE countries additionally worthwhile is that they are an important example of small, open economies that follow an inflation-targeting framework with floating exchange-rate regimes and occasional foreign-exchange interventions. Despite some differences in their level of economic and financial development, those post-transition countries are also financially integrated with the eurozone and global markets, which makes them susceptible to external shocks and policies.

The intersection of those observations leads us to the problem of the potential role of monetary policies in CEE in mitigating adverse shifts in financial market linkages triggered by the Covid-19 shock. Hence, in this article, we aim to capture the effects of monetary policy actions in the region through the lens of financial market connectedness. This approach contrasts with most studies in the area, which investigate the impact of central bank interventions during the Covid-19 crisis on asset returns, prices, or risk premia (Angosto-Fernández & Ferrández-Serrano, 2022; Sever, Goel, Drkopoulos, & Papageorgiou, 2020; Wei & Han, 2021). The empirical evidence on the potential role of CEE central banks in stabilising markets during the global turmoil will inform us about the effectiveness of their domestic monetary policy frameworks in maintaining or restoring financial stability. The asymmetric generalised DCC-GARCH models were estimated on daily data to retrieve time-varying correlations in the financial markets in Czechia, Hungary, Poland, and Romania. We examined linkages across the two largest asset classes, sovereign bonds and equities, both within CEE economies and between each of them and Germany and the US (traditionally perceived as safe havens), while controlling for potential structural breaks, global risk measures, and Covid-19-related indicators, such as the number of Covid-19 cases, and the government-response stringency indices (see, e.g., Dempere, 2021; Koca, 2022). The event studies were based on an original, comprehensive dataset on policy interventions launched in 2020.

The central finding of this article is that monetary policies undertaken in CEE economies during the Covid-19-induced crisis played a role in mitigating pressures that stemmed from changing financial market linkages. They alleviated flight-to-safety effects and provided a cushion against domestic stock-bond flights. They were also able – at least to some extent – to decrease tensions in the cross-border transmission of shocks in bond markets and contagion effects in equity markets. Our results imply that monetary authorities may partly mitigate the transmission of global shocks to domestic financial markets, even when it comes to small open economies. However, the effects of monetary policies proved strongest at the onset of the crisis, when CEE central banks deployed unconventional monetary measures and aggressively cut interest rates. Those effects seem to have run into diminishing returns and subsequent central bank actions proved to have smaller effects on financial market linkages.

The article contributes to the ongoing discussions in financial and international economics in two noteworthy ways. Firstly, it adds to the growing literature on the pandemic and connectedness among various asset classes. By investigating the influence of monetary policies, including unconventional ones, on the evolution of market correlations, it documents important sources of changes in those linkages during the Covid-19 crisis in CEE economies. The empirical strategy used in this study allowed us to demonstrate how the effects of monetary policies evolved as the pandemic progressed and further decisions were made by central banks. Secondly, the article explores the effects of central bank policies in the region for which the empirical evidence remains limited, namely in post-transition Europe, which is characterised by relatively low levels of financial development and a shorter history of the market economy. The results are chiefly relevant for European financial integration and policymaking but the study also carries more general implications of financial and monetary integration on the effects of global shocks on financial markets in post-transition economies.

The next section of the article reviews the recent literature on changes in financial market linkages that occurred during the Covid-19 turmoil and the monetary policy responses to this crisis. The third section introduces datasets used in the study and lays down our empirical methodology. The fourth section presents and discusses the empirical results, broken down into country-level analyses. Conclusions and policy recommendations are presented in the final section.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Our article can be linked to two main strands of recent research. Firstly, this article adds to the ample literature on the effects of the monetary policy response to the Covid-19-induced crisis. Within this framework, our research is closest to studies that employ event study methodology. In general, these studies suggest that the easing of monetary conditions and the launch of asset purchase programmes (APPs) in particular proved to be effective in calming the financial markets, especially in the sovereign bond segment. For example, Sever, Goel, Drakopoulos, and Papageorgiou (2020) investigate the impact of APP announcements on sovereign bond yields, exchange rates, and equity markets in 10 EMEs. They provide evidence that these announcements significantly reduced the long-term sovereign bond yields. At the same time, their effects on the US dollar exchange rates and equity markets were less pronounced, which the authors view in the context of the large role of global risk factors in shaping these markets. Comparable results were obtained by Arslan, Drehmann, and Hofmann (2020), who also find that domestic APP announcements strongly affected local currency bonds in 13 EMEs, while the response of the foreign exchange markets was ambiguous. In a related study, Rebucci *et al.* (2021) find that APP announcements successfully compressed sovereign bond yields in both AEs and EMEs. However, the effect was stronger in the latter group of countries, which the authors attribute to the surprise effect, as some of them had never resorted to a quantitative easing (QE) policy before the onset of the Covid-19 pandemic. Their results also point to a more divergent reaction of the foreign exchange markets in EMEs. Further, Klose and Tillmann (2021) investigate the response of the sovereign bond yields and stock prices to the monetary, fiscal, and European fiscal events of 29 European countries between 17 February and 24 April 2020. They conclude that monetary policy was effective in supporting the stock market and easing the pressure on public finances and point to a particular role of APP announcements in raising stock returns and lowering bond yields.

Studies devoted to the activities of the European Central Bank (ECB) account for a large share of the empirical literature in the area. They constitute a continuation of the frequently undertaken research trend in times of the sovereign debt crisis and the first unconventional actions of the ECB (Afonso, Jalles, & Kazemi, 2020; Altavilla, Carboni, & Motto, 2021; Falagiarda & Reitz, 2015). For example, Delatte and Guillaume (2020) provide an investigation into the determinants of sovereign bond spreads (vis-à-vis German yields) of 13 euro area countries for the period 2 January – 26 May 2020. Their results indicate that the ECB's announcement of the pandemic emergency purchase programme (PEPP) in March 2020 significantly reduced the spreads. Moreover, the easing of collateral requirements turned out to be effective in lowering the Greek, Italian, and Portuguese spreads. In a related study, Moessner and de Haan (2021) emphasise the role of the announcement effect channel via which

central bank APPs affect financial markets. They show that the 10-year sovereign bond term premia in 11 euro area countries were negatively affected by the ECB's announcement of PEPP. The strongest reactions (between 37 and 173 basis points) were observed in countries with higher sovereign risk (Spain, Portugal, Greece, and Italy). Interestingly, the authors identify a reverse reaction to the press conference of 12 March 2020, when Christine Lagarde declared that the ECB was 'not here to close the spreads.' However, in contrast to the literature dealing with the global financial crisis (GFC) period, such as Grabowski and Stawasz-Grabowska (2021), the problem of cross-border spillover effects of the ECB's monetary policy has not been readily undertaken in Covid-19-related studies.

Some studies attempt to identify the factors that improved or limited the effectiveness of monetary policy in mitigating financial distress during the pandemic shock. Notably, Fratto *et al.* (2021) carry out a study for EMEs and small AEs and show that APPs were generally effective in lowering sovereign bond yields. At the same time, they demonstrate that the magnitude of these effects depended not only on the characteristics of individual programs but also on the central bank's credibility and a share of (non-)resident holdings of government securities. The authors also find that the transmission of non-standard policy announcements across the sovereign yield curve was stronger than the effects of conventional interest-rate policy. Benmelech and Tzur-Ilan (2020) show that higher-income countries relied to a greater extent on unconventional monetary policy actions and lowered their interest rates less in comparison with low-income countries, while Yilmazkuday (2021) demonstrate that non-standard monetary (as well as fiscal) policies were more effective in countries with a zero lower bound on their interest rates. In a study devoted to the effect of the Covid-19 pandemic on global stock market volatility, Uddin, Chowdhury, Anderson, and Chaudhuri (2021) show that the policy interest rate cuts work only in EMEs, while in developed economies, these central bank measures resulted in an increase in the variance of returns and uncertainty. Finally, Elgin, Yalaman, Yasar, and Basbug (2021) find that countries with more independent central banks were less likely to resort to large cuts in the policy rate and the reserve requirement ratio. Instead, their response to the crisis relied on larger fiscal and macro-financial policy packages.

Finally, despite the fact that the majority of studies point to an important role of monetary policy response in curbing financial stress during the pandemic, a handful shows that its impact was negligible. For example, using an event-study methodology, Wei and Han (2021) investigate the effect of the Covid-19 shock on the transmission of monetary policy on government bonds, stocks, exchange rates, and CDS markets in 37 countries. Their results indicate that, in general, since the outbreak of the pandemic, the monetary policy measures, both within conventional and unconventional realms, have had no significant impact on all four financial markets.

The second major strand of the literature that the article is related to investigates various forms of shifts in financial market connectedness that occurred during the Covid-19 pandemic. There seems to be a general agreement that the uncertainty related to the outbreak of the pandemic was a source of the global financial shock that occurred in the first quarter of 2020, as reviewed by Yarovaya *et al.* (2022). This uncertainty concerned the potential impact of the pandemic on economic activity, job markets, international trade, and the future openness of economies (see Altig *et al.*, 2020). Dependencies between the returns on equity indices and government bond returns are examined extensively using various empirical frameworks. In one of the earlier studies, Zhang *et al.* (2020) demonstrate a change in the pattern of linkages among global stock markets in the first quarter of 2020 and a sudden jump in the intensity of cross-border market correlations. Youssef *et al.* (2021) show that the connectedness of stock markets in eight large economies responded to uncertainty regarding global economic policy. Pessimistic news about the virus was amplified by social media, which stimulated trading and caused extreme price movements. Interestingly, Wang, Li, and Huang (2022) indicate that volatility spillovers among large financial markets reached a historic peak in March 2020 and declined in the following months, possibly due to stabilising monetary and fiscal policies.

Numerous studies define and analyse international contagion effects during the 2020 crisis, mostly for stock markets. Belaid *et al.* (2021) document an increase in the transmission of uncertainty across stock markets using spillover indices. They emphasise the structural change in interlinkages that occurred around the pandemic outbreak and the role of the highly integrated European market as transmitters of volatility to the rest of the world. The study shows that financial markets in AEs and EMEs

reacted similarly to the Covid-19 shock, even though the pre-crisis connectedness was much smaller in the latter group of countries. This finding is confirmed by Beirne *et al.* (2021), who report that both Asian and European EMEs experienced the most substantial financial outflows directly linked to the Covid-19 shock. Those outflows were stronger in sovereign bond markets than in stock and exchange rate markets. On the other hand, Akhtaruzzaman, Boubaker, and Sensoy (2021) indicate that financial contagion between G7 economies and China, as approximated by an increase in the conditional correlation of respective stock returns, was driven chiefly by financial firms. Bouri *et al.* (2021) provide an extended investigation of contagion across various asset classes, including bonds. While equity and foreign exchange markets dominated global financial connectedness before the pandemic outbreak, the role of bond indices increased in the first quarter of 2020. Moreover, the article demonstrated that the events that triggered the contagion effects in this period were not country-specific, as they may have been linked to a global news-based index of uncertainty.

Additionally, the Covid-19 crisis triggered global flight-to-safety tendencies and raised questions about the safety properties of various assets, *i.e.*, the relative stability of their prices during market crashes. In this context, Papadamou *et al.* (2021) explore domestic stock-bond correlations during the outbreak of the Covid-19 pandemic for ten large AEs and EMEs. They demonstrate that this event put in motion a move from stock to bond markets when stock markets around the world collapsed. Moreover, the flights occurred simultaneously and were not country-specific. Chari *et al.* (2020) focus on capital outflows from EMEs, defining the Covid-19 event as a risk-off shock. They point out that equities and foreign-currency bonds are more susceptible to such shocks than local-currency bonds. Exploring dynamic relationships between EME and the US bond returns, Umar, Manel, Riaz, and Gubareva (2021) find that EME bond markets were more sensitive to Covid-19-related news, and their connectedness to US bonds significantly increased during the pandemic meltdown. Janus (2021), in turn, shows that heterogeneous effects observed in sovereign bond markets in the first quarter of 2020 can be explained by differences in macroeconomic fundamentals and their past sensitivity to global shocks, which may be related to a country's reputation among international investors.

There are but a few attempts to deal directly with financial market linkages in CEE economies during the pandemic. Aslam, Nougeiro, Brasil, Ferreira, Mughal, Bashir, and Latif (2021) narrow down their investigation to three CEE stock markets, the Czech, Hungarian, and Polish, during the onset of the 2020 crisis. They find that high-frequency data revealed strong multifractal patterns in CEE stock markets, which indicated substantial changes in market sentiments, pessimism among investors, and growing inefficiencies. However, those patterns appeared in CEE later than in the euro area countries, possibly due to the relatively lower development of financial markets in the former group. Covering the Covid-19 period and focusing on cross-border linkages in sovereign bond markets, Karkowska and Urjasz (2021) document strong volatility transmission to the region from the US and Germany, which catalysed systemic risk for the region during the crisis period. They also indicate that CEE bond markets are generally less integrated with global markets than corresponding markets in the euro area EU member states but strongly related to each other. It must be noted that the importance of the German market in the transmission of shocks to CEE may also be found in previous studies on dependencies across capital markets (see Grabowski, 2019; Pietrzak, Fałdziński, Balcerzak, Meluzin, & Zinecker, 2017).

Notwithstanding the fact that the number of studies representing both strands of research is vast and growing, as documented above, we believe that we can add to the existing literature in at least two ways. Firstly, in contrast to the previous studies, which primarily concentrated on the impact of Covid-19-related monetary policies on asset prices, returns, premia, and volatilities, we investigate the responsiveness of financial linkages among different asset classes (*i.e.* equities and sovereign bonds). We conduct our analysis at the national level, and later expand it to include international spill-over effects, *i.e.* changes in the magnitude and/or direction of financial market linkages between individual CEE countries and the US and Germany (perceived as traditional safe havens). To the best of our knowledge, such kind of global transmission of shocks during the Covid-19 pandemic has not been studied so far, and hence constitutes our second contribution.

Building on the literature devoted to the effects of the monetary policy response to the Covid-19 shock and the body of work related to shifts in financial market connectedness that occurred since the outbreak of the pandemic, we test the following hypotheses:

H1: Domestic monetary policy measures conducted in response to the Covid-19 pandemic significantly affected linkages among stock and sovereign bond markets of CEE countries.

More specifically,

H2: Domestic central banks were able to alleviate financial market tensions, thus reducing flows from domestic stock to bond markets.

H3: Domestic central banks were able to mitigate international flight to safety effects from CEE countries to safe havens.

DATA AND EMPIRICAL STRATEGY

This section describes the dataset used in the article, along with details on monetary policy events in the CEE economies investigated in this study. Next, the section maps out our empirical strategy based on conditional correlations derived from multivariate DCC-GARCH models.

Dataset Description

In this study, we aim to identify linkages between the stock and sovereign bond markets in four countries from the CEE region, *i.e.* Czechia, Hungary, Poland, and Romania, as well as two major economies, *i.e.* the United States and the euro area (represented by Germany, the most important economic counterpart to all of the analysed CEE countries) during the Covid-19 crisis. In particular, we are interested in checking whether contagion and flight-to-safety (or: flight-to-quality) effects were observed in this period, both between the two segments of the financial market as well as between the two groups of countries (the CEE economies, representing countries prone to capital outflows, and the US and Germany, perceived as traditional safe havens). Given that such phenomena were identified during earlier periods of global financial turbulence, like the GFC, we aim to investigate whether they were also present during the Covid-19 crisis.

In particular, we focus on the following linkages.

1. Linkages between the stock market and the sovereign bond market in individual CEE countries.
2. Linkages between the stock markets of individual CEE countries and the US or German stock market.
3. Linkages between the sovereign bond markets of individual CEE countries and the US or German sovereign bond market.
4. Linkages between the stock markets of individual CEE countries and the US or German sovereign bond market.

The data cover the leading stock market indices in the analysed countries. These include the Prague Stock Exchange Index (PX), the Budapest Stock Exchange Index (BUX), the Warsaw Stock Exchange Index (WIG20), the Bucharest Exchange Trading Index (BET), the German Stock Index (DAX), and the US Standard and Poor's 500 (S&P 500). The dataset also includes the 10-year local-currency sovereign bond yields of all countries considered in this study. The respective time series were sourced from the Refinitiv database.

Our main question of interest is whether the monetary policy measures introduced in the four CEE economies played a significant role in shaping financial market linkages during the Covid-19 crisis. The important consideration is that during the pandemic a broad-based monetary policy response, including unconventional monetary policy measures, was undertaken not only by the major central banks (the Fed and the ECB), but also by many central banks from the EMEs, including the Czech National Bank (CNB), the National Bank of Hungary (MNB), the National Bank of Poland (NBP), and the National Bank of Romania (NBR). Hence, to determine the impact of domestic monetary policy on financial linkages phenomena in the analysed countries, we gathered a comprehensive dataset on their central

banks' policy announcements. The monetary policy expansion of the CEE central banks during the pandemic comprised interest rate cuts, liquidity-enhancing measures, macroprudential tools, and the asset purchase programmes. Most of the anti-crisis measures were introduced in the first half of 2020, with the first important central bank announcements in March of 2020. During this month only, the NBP, and the NBR communicated substantial reductions in their interest rates while launching the first non-standard measures. However, the announcements of additional non-standard monetary policy measures continued well into 2020, with notable examples of the broadening of eligible collateral, new rounds of QE operations, further interest rate cuts, and repo lines to provide liquidity in the euro. A detailed description of monetary policy events used in the study is provided in Tables 1 through 4.

Table 1. Major Czech National Bank announcements in 2020

Date	Event
16 March 2020	CNB cuts its key interest rates (2W repo rate by 50 bps to 1.75%, the Lombard rate to 2.75%, and the discount rate to 0.75%), increases the number of liquidity-providing operations, and revises its earlier decision to increase the countercyclical capital buffer rate for exposures located in Czechia.
26 March 2020	CNB further cuts its key interest rates (2W repo rate by 75 bps to 1.00%, the Lombard rate to 2.00%, and the discount rate to 0.05%) and lowers the countercyclical capital buffer rate.
7 May 2020	CNB further cuts its key interest rates (2W rate by 75 bps to 0.25% and the Lombard rate to 1.00%), announces the broadening of the range of eligible collateral used in liquidity-providing operations, and introduces operations with 3-month maturity.
18 June 2020	CNB partially relaxes mortgage limits and lowers the countercyclical capital buffer rate.

Source: own elaboration based on the CNB's press releases.

Table 2. Major Hungarian National Bank announcements in 2020

Date	Event
16 March 2020	MNB expands the range of eligible collateral to include corporate loans.
18 March 2020	MNB considers restarting the mortgage bond purchase program, announces relief from maintenance of the systemic risk buffer, and suspends capital adequacy assessment.
24 March 2020	MNB expands the scope of collateral coverage and introduces additional one-week FX swap tenders.
30 March 2020	MNB maintains the zero per cent countercyclical capital buffer 'for longer'.
7 April 2020	MNB extends the interest rates corridor and launches QE, which involves purchases of government securities (in the secondary market) and mortgage bonds. It also launches two lending programs: Funding for Growth Scheme Go! and Bond Funding for Growth Scheme (FGS).
28 April 2020	MNB announces details on the long-term assets purchase program. One trillion HUF government bonds; 300 billion HUF mortgage (corporate) bonds. Focus on securities with at least three years to maturity.
4 May 2020	QE operations are launched at the weekly level of HUF 100 bn.
23 June 2020	MPC reduces the base rate by 15 bps to 0.75%.
21 July 2020	MPC reduces the base rate by 15 bps to 0.60%.
8 September 2020	Swap facility is added to the MNB's toolbox.
22 September 2020	The scale of BGS is increased to HUF 750 bn.
6 October 2020	MNB extends its QE program by increasing the maximum amount of purchased securities from 33% to 50% of available securities.
3 November 2020	MNB extends the maturity range of assets purchased under its QE program, prepares for green QE, and raises the total amount of FGS Go! by HUF 1000 bn.
8 December 2020	MNB announces FX swap tenders providing euro liquidity.

Source: own elaboration based on the MNB's press releases.

Table 3. Major National Bank of Poland announcements in 2020

Date	Event
16 March 2020	NBP introduces operations to supply banks with liquidity, large-scale purchase of Treasury bonds in the secondary market and discount credit for banks. The FSC[1] recommends an immediate repeal of the 3% systemic risk buffer for bank capital requirements.
17 March 2020	NBP cuts the reference rate by 0.5 pp to 1.00%, decreases the required reserve ratio from 3.5% to 0.5%, and increases the remuneration of the required reserves from 0.5% to the reference rate level.
8 April 2020	NBP cuts interest rates by 0.50 pp (the reference rate to 0.50%, Lombard rate to 1.00%, deposit rate to 0.00%, rediscount rate to 0.55%, discount rate to 0.60%). It expands the list of securities eligible for purchases in the secondary market to include government securities and government-guaranteed debt securities.
28 May 2020	NBP cuts interest rates (the reference rate to 0.10%, Lombard rate to 0.50%, rediscount rate to 0.11%, discount rate to 0.12%).
15 June 2020	FSC agrees with the request of the Chairman of the PFSA on postponing the implementation of Recommendation S on good practices with regard to managing mortgage-secured credit exposures until 30 June 2021.
13 July 2020	FSC recommends a reduction from 100% to 50% in the risk weights for exposures arising from loans secured on commercial property used for the borrower's own business and not generating rental income or profit on the sale.

Source: own elaboration based on the NBP's press releases.

Table 4. Major National Bank of Romania announcements in 2020

Date	Event
20 March 2020	NBR cuts the monetary policy rate (from 2.5% to 2.0%) and the lending facility rate (from 3.5% to 2.5%). It announces liquidity-providing repo transactions to support credit institutions and purchases of leu-denominated government securities on the secondary markets.
25 March 2020	NBR encourages banks, on an individual basis, to ease the rates on current loans and to facilitate access to new financing lines. Some relaxation in NPL treatment is announced.
27 March 2020	NBR postpones the deadline for collecting the annual contributions to the bank resolution fund for 2020 by three months, with the possibility of an extension of up to 6 months.
29 May 2020	NBR cuts the monetary policy rate (from 2.0% to 1.75%), the lending facility rate (from 2.5% to 2.25%), and the deposit facility rate (from 1.5% to 1.25%).
5 June 2020	ECB and NBR establish a repo line agreement to provide euro liquidity.
5 August 2020	NBR cuts the monetary policy rate (from 1.75% to 1.50%), the deposit facility rate (from 1.25% to 1.0%) and the lending facility rate (from 2.25% to 2.0%).
28 August 2020	ECB and NBR extend the framework arrangement to supply NBR with euro liquidity via a repo line.
12 November 2020	NBR cuts the minimum reserve requirement ratio on FX-denominated liabilities of credit institutions (from 6% to 5%).

Source: own elaboration based on the NBR's press releases.

Finally, a set of control variables was included in the empirical models. To take into account the impact of global financial shocks, we introduced the VIX index, based on the option prices of the S&P500 stock market index. Additionally, we added three control variables directly linked to the Covid-19 pandemic: the official daily counts of Covid-19 cases, the number of virus-related deaths in each of the countries, and the stringency index, all based on the Oxford Coronavirus Government Response Tracker. Those controls were introduced to disentangle the impact of the monetary policy response from the effects of the pandemic and elevated global risk aversion. The respective time series were derived from the Refinitiv database.

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[1] FSC stands for Financial Stability Committee, which is the Polish macroprudential authority. The FSC comprises NBP, the Polish Financial Supervision Authority (PFSA), the Ministry of Finance, and the Bank Guarantee Fund.

Conditional Correlations

We start the description of empirical models used in the study by writing down the vector demeaned rates of return on stock markets and changes in 10-year sovereign bond yields for six countries (Czechia, Hungary, Poland, Romania, Germany, the United States). Therefore, vector $\boldsymbol{y}_t$ consists of 12 elements.

In the first step, we calculate time-varying volatilities and correlations based on the estimation of the parameters of the following AGDCC-GARCH model:

$$\boldsymbol{y}_t = \boldsymbol{\varepsilon}_t, \tag{1.a}$$
$$E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t^T) = \boldsymbol{H}_t, \tag{1.b}$$
$$\boldsymbol{H}_t = \boldsymbol{D}_t \boldsymbol{R}_t \boldsymbol{D}_t, \tag{1.c}$$

Matrix $\boldsymbol{D}_t$ is defined as follows:

$$\boldsymbol{D}_t = diag\{\left[\sqrt{h_{1,t}} \quad \dots \quad \sqrt{h_{12,t}}\right]\}, \tag{1.d}$$

These variances are modelled using the GJR-GARCH(1,1) model:

$$h_{n,t} = \alpha_{0n} + \alpha_{1n}\varepsilon_{n,t-1}^2 + \gamma_{1n}\varepsilon_{n,t-1}^2 I\{\varepsilon_{n,t-1} < 0\} + \beta_{1n}h_{n,t-1}, \tag{1.e}$$

for each $n = 1,2,\dots,12$. The correlations between shocks are time-varying and depend on both positive and negative shocks:

$$\boldsymbol{R}_t = \left(diag(\boldsymbol{Q}_t)\right)^{(-1/2)} \boldsymbol{Q}_t \left(diag(\boldsymbol{Q}_t)\right)^{(-1/2)}, \tag{1.f}$$

$$\boldsymbol{Q}_t = \left(1 - \underline{\alpha}_1 - \underline{\beta}_1\right)\boldsymbol{Q} + \underline{\gamma}_1(Q - Q^-) + \underline{\alpha}_1 \boldsymbol{u}_{t-1}\boldsymbol{u}_{t-1}^T + \underline{\beta}_1 \boldsymbol{Q}_{t-1} + \underline{\gamma}_1 \boldsymbol{u}_{t-1}^- (\boldsymbol{u}_{t-1}^-)^T \tag{1.g}$$

The elements of vector $\boldsymbol{u}_t$ are defined as follows:

$$u_{n,t} = \frac{\varepsilon_{n,t}}{\sqrt{h_{n,t}}}. \tag{1.h}$$

The time-varying correlations retrieved from the estimated AGDCC-GARCH model illustrate changes in connectedness across financial markets. After calculating dynamic correlations between shocks of the stock and bond markets, the dates of structural changes in these series are identified using the Bai and Perron (2003) method. This method seems to be appropriate since it addresses the problem of estimation of the break dates and uses an efficient algorithm to obtain global minimizers of the sum of squared residuals.

Next, we apply the event study methodology based on MacKinlay (1997) to capture the impact of conventional and unconventional monetary policy measures on financial market correlations. It is assumed that financial market correlations depended on regimes and variables reflecting the course of the Covid-19 pandemic and approximating global risk aversion. The set of control variables $(\boldsymbol{cv}_t)$ consists of categories tracking the course of the Covid-19 pandemic (change in the level of epidemic restrictions adopted by the country, change in the number of Covid-19 confirmed cases, change in the number of Covid-19 related deaths) and approximating global risk aversion (VIX). The binary dummies for sub-periods $(U_{l,t})$ are based on the previously identified structural changes, while the abnormal correlations are calculated using the following linear regression model:

$$r_{mn,t} = \sum_{l=2}^{L} \kappa_l U_{l,t} + \boldsymbol{cv}_t \boldsymbol{\theta} + \xi_t, \tag{2}$$

where $L - 1$ is the number of detected structural changes, $U_{2,t}, \dots, U_{L,t}$ are binary variables that take the value of 1 in sub-periods of 'constant' correlations and 0 otherwise. $\kappa_2, \dots, \kappa_L$ denote parameters for binary variables, $\boldsymbol{\theta}$ is the vector of appropriate parameters, and ξ_t is the error term.

After estimating the parameters of the model (2), the abnormal correlations are calculated analogously to the abnormal returns (Campbell, 1991):

$$AC_{mn,t} = r_{mn,t} - \sum_{l=2}^{L} \hat{\kappa}_l U_{l,t} + \boldsymbol{cv}_t \widehat{\boldsymbol{\theta}}. \tag{3}$$

It can be seen that the variable defined by the formula (3) is the difference between the observed and theoretical correlations and can be interpreted as residual from the model (2).

Suppose now that an intervention is conducted on day s. Then the average cumulative abnormal correlations h days after the intervention are calculated according to the following formula:

$$CAC_s^+(h) = \frac{\sum_{\tau=0}^{h} AC_{mn,t+\tau}}{h+1}. \tag{4}$$

On the other hand, the average cumulative abnormal correlations h days before the intervention are calculated according to the following formula:

$$CAC_s^-(h) = \frac{\sum_{\tau=1}^{h} AC_{mn,t-\tau}}{h}. \tag{5}$$

Changes in the conditional correlations were investigated in event windows equal to six trading days before and six days after a given policy announcement. Estimation was based on daily data running from January 2019 to June 2021, and the events were introduced subsequently based on the database on monetary policy interventions.

RESULTS AND DISCUSSION

This section presents and discusses our empirical results. We start by exploring the behaviour of bond and stock market correlations and breakpoints. We then proceed to country-level analysis and discuss the impact of monetary policy measures on shifts in financial market linkages in the analysed CEE economies.

Shifts in the Bond and Stock Market Conditional Correlations

After estimating the parameters of the AGDCC-GARCH model, the time-varying correlations were obtained. As indicated, we focused on four types of series: domestic correlation between major stock indices and sovereign bond yields, as well as three international correlations in bond and stock markets between the four CEE economies and Germany/the US. We next ran the Bai-Perron breakpoint tests on the retrieved series and obtain break dates. The resulting series of conditional correlations, along with estimated breakpoints, are depicted in Figures 1 through 4.

In the majority of the retrieved correlation series, the Bai-Perron tests indicated three to five breaks. Usually, one of them fell around the beginning of the Covid-19-induced crisis and one in the summer of 2020 when the markets gradually became more tranquil. Most of the correlation series sharply increased in the run-up to the crisis, in the first quarter of 2020, when there was growing uncertainty concerning the social ramifications of the then-novel coronavirus. This indicates that the Covid-19 crisis did indeed bring about serious distortions in interdependencies across the main financial market segments, as discussed in the literature review (*e.g.*, Belaid *et al.*, 2021). Subsequent breaks were typically detected at the beginning of the third quarter of 2020, when the acute phase of the crisis was coming to an end, and the market participants were rebuilding confidence.

However, both the typical values of the correlations and their shifts were not uniform across series. For example, an increase in correlation at the beginning of the pandemic was strongest for the stock-bond series. Relatively large changes were observed in international correlations in bond yields, but they tended to quickly bounce back to the average value. Those observations align with the recent literature on bond and stock market volatility during the Covid-19 crisis (see, *e.g.*, Sever *et al.*, 2020). The results also point to a feature typical for the crisis period, when conditional volatilities evolve rapidly due to the flight-to-safety effects when investors quickly re-balance their portfolios and shed assets perceived as riskier.

Additionally, all four types of series differed across the CEE economies, both in terms of their average values and changes during the period under consideration. In general, Poland, the largest country in the region, was characterised by the strongest domestic stock-bond conditional correlations, with a mean value of 0.165. In February and March 2020, this value rose close to 0.3. The corresponding values for Czechia, Hungary, and Romania were 0.131, 0.024 and -0.064, respectively. Polish bond and stock markets were also more connected to the German and US markets, which was visible both in the values of correlations and their absolute changes in the first part of 2020.

Czechia

Turning to the results of the policy event studies, we start by reporting the regression results for the first of the four CEE economies, Czechia (Table 5). Domestic and international linkages in the Czech financial market were largely influenced by the anti-crisis monetary policy measures undertaken by the CNB. In particular, its first decision on 16 March 2020, which encompassed cuts in the key interest rates, an increase in the number of liquidity-providing operations, along with macroprudential policy easing, had a negative impact on the correlations between the Czech bond and stock markets, the Czech and German bond and stock markets, as well as the Czech stock and US bond markets. This might imply that the flight to safety observed between the two segments of the Czech financial market at the beginning of the Covid-19-induced crisis might have been mitigated by the introduction of the accommodative stance in Czech monetary policy. When it comes to cross-country correlations, the dependence between the Czech and German stock markets decreased significantly. Moreover, a significant decline in the two countries' cross-market linkages was recorded. Regarding the relationship between the Czech and US financial markets, we identified a significant impact only on the stock-bond correlation. Moreover, the effects of the CNB's subsequent measures were stronger for German than US cross-country dependencies, which seems to reflect a stronger integration of the Czech economy with the European financial markets.

The results for Czechia lead to another important conclusion. All monetary policy tools implemented by the Czech monetary authorities proved to play an important role in determining the correlation between the domestic stock and bond markets. With the exception of the decision from 26 March 2020, all announcements exerted a negative impact on the stock-bond correlation. This might indicate that the CNB was effective in mitigating the typical flight to safety effect, *i.e.* an escape from equities to sovereign bonds, which are regarded as a safer type of investment in times of heightened financial stress.

Hungary

The event-study results for the Hungarian central bank are presented in Table 6. Similarly to the Czech case, there was a clear pattern that the first monetary policy interventions turned out to have the most noticeable impact on the conditional correlations. The non-standard measures introduced by the MNB at the onset of the crisis (a series of actions between 16 March and 7 April 2020) were effective in lowering almost all the correlations, as shown by the negative estimates on the policy dummies for these periods. This indicates that strong, non-standard measures, such as QE, together with sharp interest-rate cuts, reduced the volatile market reaction to the Covid-19 shock and the flight-to-safety tendencies in Hungary.

The effects of the MNB announcements on the domestic stock-bond correlations turned out to be concentrated between March and June 2020, with a visibly stronger reaction of markets at the onset of the crisis. Apart from the decision made on 3 November 2020, the effects of interventions undertaken later, seem to be more ambiguous. The estimates are often insignificant or even have positive signs. The effects on international Hungarian bond correlations, both with Germany and the US, also subsided in the second part of 2020. Compared to more clear-cut results from the height of the crisis, this may be interpreted in two, nonexclusive ways. Firstly, the initial monetary policy could have been bolder than anticipated, and the financial markets were surprised by the swift reaction of the MNB, which calmed down the adverse reaction to the Covid-19 shock. Secondly, the market participants could have been more responsive to the central bank's actions when they came under the strain of the Covid-19 ramifications, *i.e.*, in the period of elevated uncertainty of March and April 2020.

Poland

The event study results for Poland are presented in Table 7. Much like in Czechia and Hungary, the policy measures adopted by the NBP had a considerable impact on the investigated conditional correlations. One should draw particular attention to the measures undertaken on 16 March 2020, as they affected linkages both at the country and international levels. This indicates that the NBP was able to effectively influence the market sentiment in this period. The subsequent measures proved to be somewhat less effective but non-negligible. The only exception is the last anti-crisis announcement

from 13 July 2020. This comes as no surprise given that it came in the form of a recommendation to further loosen macroprudential policy, for which NBP is only partially responsible. Moreover, the last measure was introduced in the summer of 2020, after the first wave of the Covid-19 shock, when it was largely believed that the most acute phase of the pandemic was over, and Poland had done relatively better in terms of protecting both its health sector and the economy when compared with its counterparties from the Western part of the EU.

More specifically, we found that the decisions from 16 March 2020 exerted a negative impact on the conditional correlation between Polish stock and bond markets, which might indicate the reduction in financial market tensions following this specific announcement. On this date, the NBP not only took decisive conventional monetary policy measures in the form of lowering its key policy interest rates, but it also launched its asset purchase program, *i.e.* a policy that had never been practised by Polish monetary authorities before. However, compared to Czechia and Hungary, Poland revealed weaker effects of monetary measures on domestic stock-bond correlations.

Regarding cross-country relationships, the negative impact of the NBP's first measures on correlations was observed between the Polish and German stock and sovereign bond markets, the Polish stock and US bond markets, and the Polish and US bond markets. Taking into account the previous literature, which provides considerable evidence of the positive effect of central banks' monetary policies on domestic asset prices (cf. Rebucci *et al.*, 2021; Tillmann, 2020), we may interpret the reduced correlations in the context of investors' returning trust to the Polish financial market (or at least a lower scale of capital withdrawal from Poland). Hence, the introduction of monetary measures helped mitigate flight-to-safety behaviour by boosting the confidence of bondholders and restoring the proper functioning of financial markets.
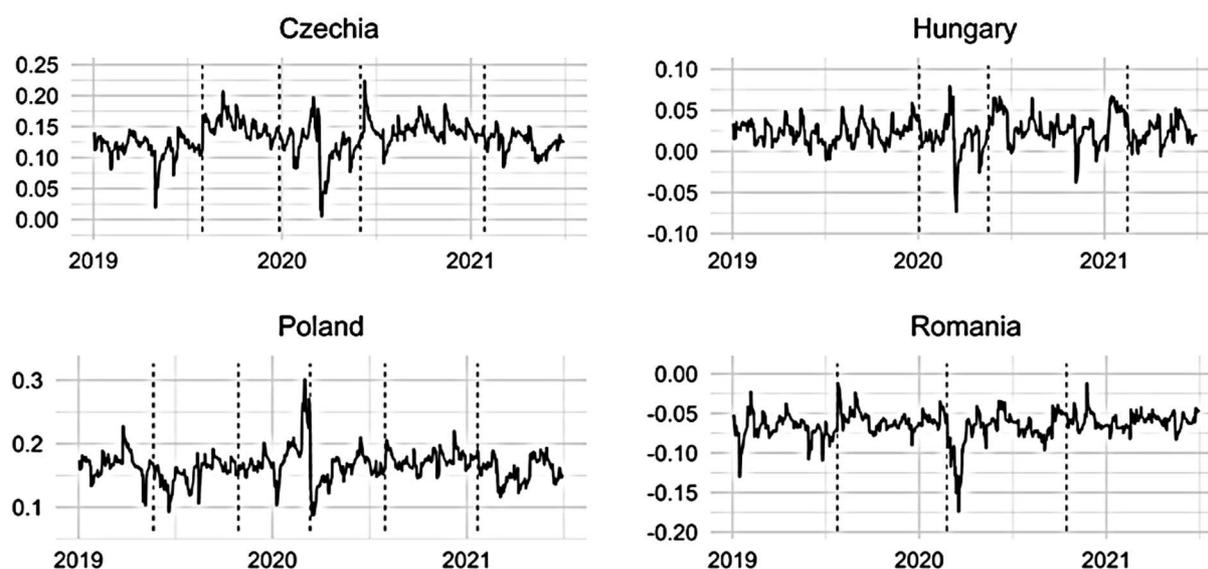
Figure 1. Stock-bond conditional correlations in CEE economies

Notes: solid lines depict conditional correlations estimated in the AGDCC-GARCH models. Dashed lines show breakpoint dates indicated by the Bai-Perron test.

Source: own elaboration.

Romania

Table 8 summarizes the event studies performed for Romania. Similarly to the other countries under consideration, the Romanian central bank began its monetary policy easing in March 2020 by announcing a series of anti-crisis measures. As in the previous cases, the first decision exerted the strongest impact on the financial market linkages, both at the domestic and international levels, in a series of policy interventions between 20 and 27 March, 2020. During this week, the NBR substantially cut its main interest rate and launched liquidity-providing operations. It also introduced an asset purchase programme, although of a smaller scale than Hungary and Poland. However, in the Romanian case, the effects of the

initial monetary easing on the conditional correlations were ambiguous when it comes to the direction of influence. Notably, we identified a positive impact of the NBR's monetary policy easing on correlations between the Romanian stock and bond markets, and the Romanian bond market and both German and US bond markets. In turn, negative signs of parameter estimates were obtained for the Romanian stock and German/US stock markets as well as the Romanian stock and German bond markets.

Moreover, we could not point to any clear pattern for subsequent policy actions in Romania. In contrast to the results for the other CEE countries, we found no further regularities with regard to either the individual measures or the cross-market or cross-country dependencies for Romania. In fact, most of the NBR's subsequently introduced policy measures proved to be insignificant in the event studies. This may be the effect of Romanian bond yields remaining at higher absolute levels than in other CEE economies. All of this points to a relatively smaller effectiveness of the transmission of the Romanian central bank interventions to the longer-end of the sovereign yield curve.
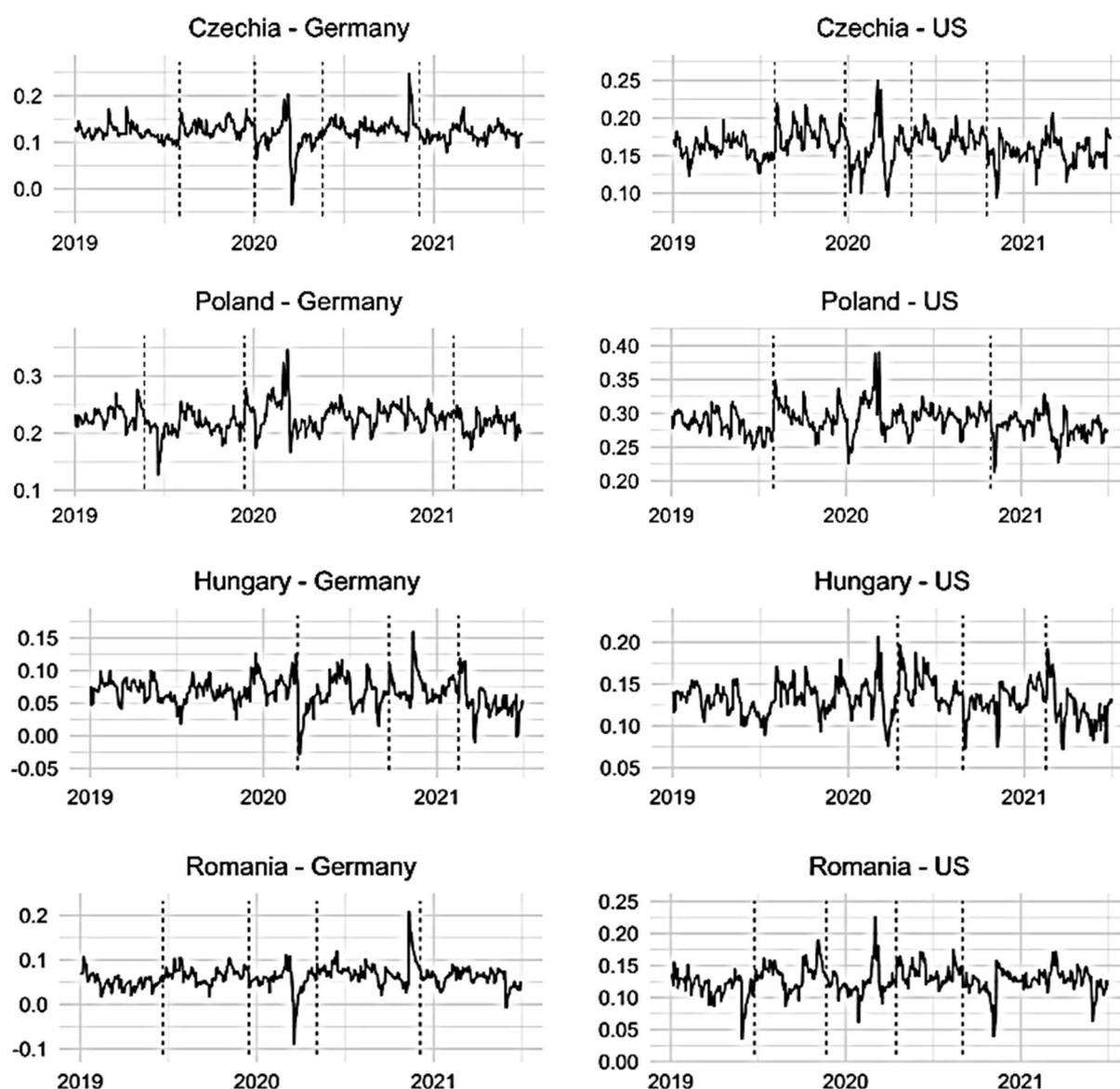
Figure 2. Bond-bond conditional correlations between CEE economies and Germany and the US
Notes: see Figure 1.
Source: own elaboration.
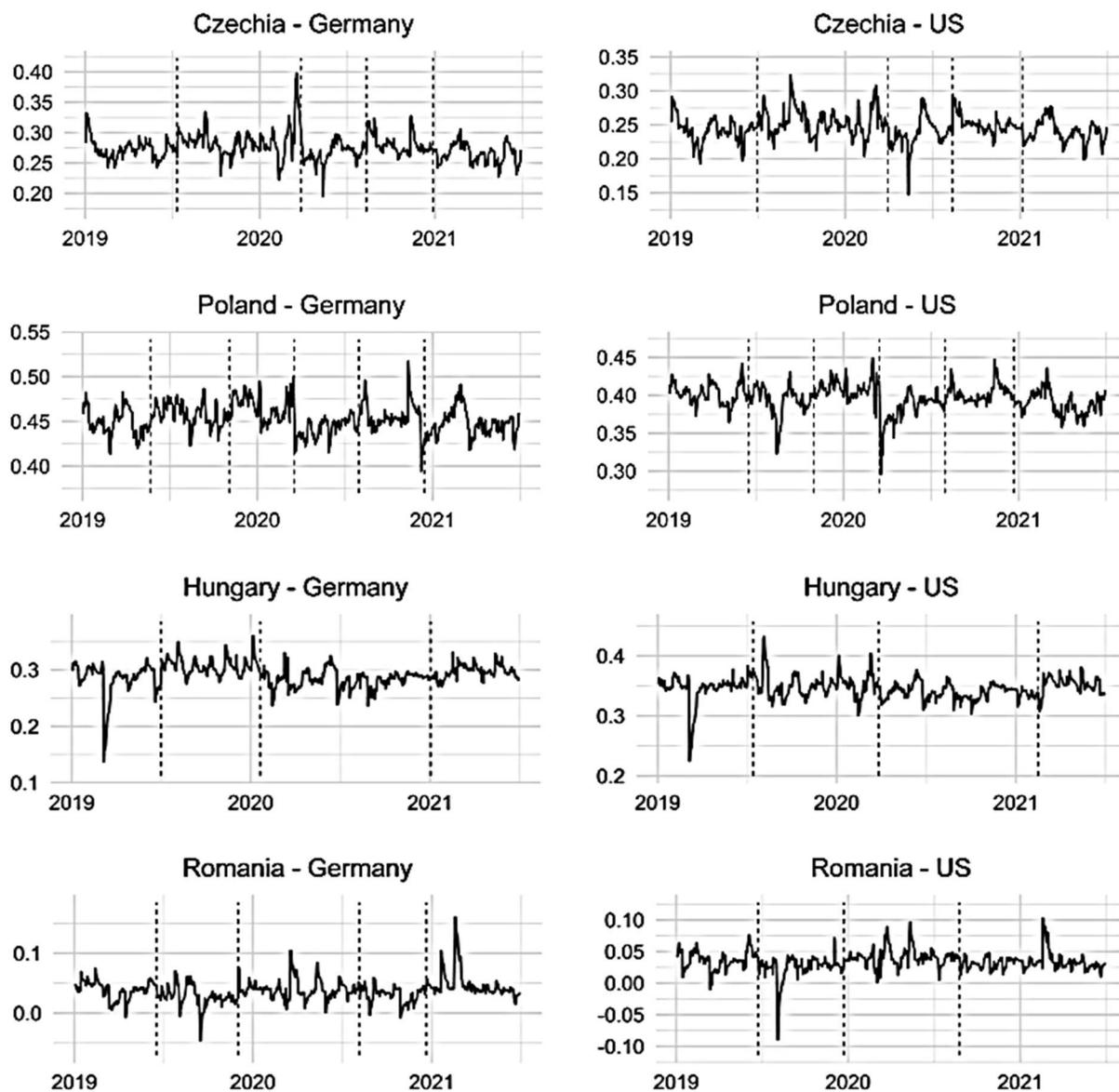
Figure 3. Stock-bond conditional correlations between CEE economies and Germany and the US
Notes: see Figure 1.
Source: own elaboration.
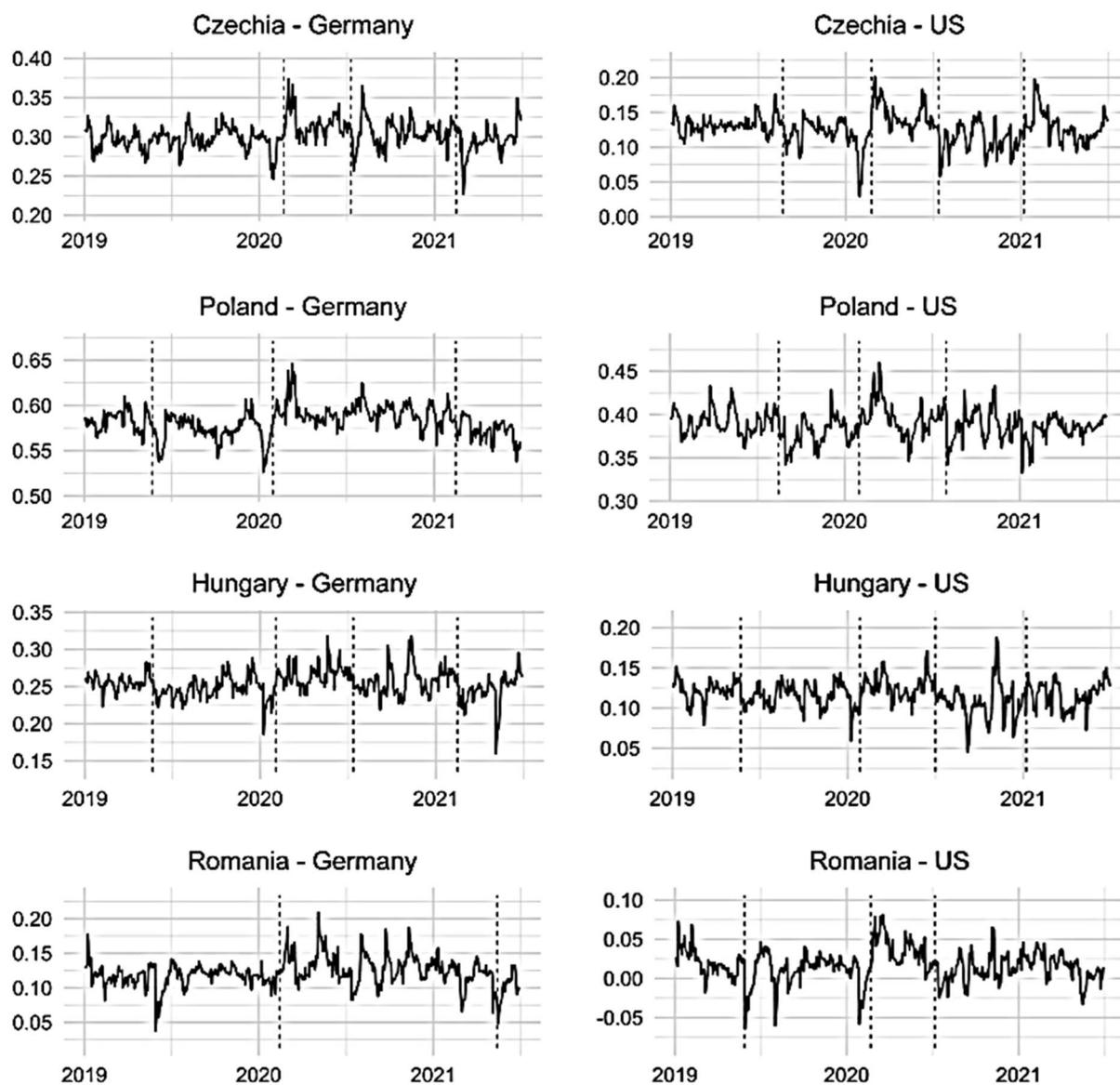
Figure 4. Stock-stock conditional correlations between CEE economies and Germany and the US
Notes: see Figure 1.
Source: own elaboration.

Table 5. Event study estimates for monetary policy responses to the Covid-19 crisis – Czechia

#	Dates	(1) Stock_CZ – Bond_CZ		(2) Bond_CZ – Bond_DE		(3) Bond_CZ – Bond_US		(4) Stock_CZ – Bond_DE		(5) Stock_CZ – Bond_US		(6) Stock_CZ – Stock_DE		(7) Stock_CZ – Stock_US	
		Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
1	16.03.2020	**-0.05005**	**0.000**	**0.05010**	**0.000**	0.00360	0.483	**-0.06378**	**0.000**	**-0.01995**	**0.001**	**-0.00903**	**0.089**	-0.00016	0.979
2	26.03.2020	**0.00917**	**0.081**	**-0.01558**	**0.001**	0.00136	0.751	**0.02246**	**0.000**	0.00585	0.215	-0.00256	0.569	-0.00059	0.234
3	07.05.2020	**-0.01173**	**0.051**	**-0.01436**	**0.008**	**-0.01899**	**0.000**	0.00353	0.589	0.00369	0.494	-0.00262	0.614	-0.00196	0.732
4	18.06.2020	**-0.01269**	**0.035**	-0.00463	0.392	**-0.00810**	**0.094**	-0.00717	0.271	**-0.00931**	**0.082**	**-0.01110**	**0.032**	**-0.01206**	**0.034**

Notes: the Table reports point estimates and p-values on monetary policy intervention dummies introduced to testing regressions. Full regression results that include control variables (global financial measures and pandemic-related indicators) are available upon request.
Source: own study.

Table 6. Event study estimates for monetary policy responses to the Covid-19 crisis – Hungary

#	Dates	(1) Stock_HU – Bond_HU		(2) Bond_HU – Bond_DE		(3) Bond_HU – Bond_US		(4) Stock_HU – Bond_DE		(5) Stock_HU – Bond_US		(6) Stock_HU – Stock_DE		(7) Stock_HU – Stock_US	
		Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
1	16.03 – 07.04.2020*	**-0.00684**	**0.093**	**-0.02240**	**0.000**	**-0.02160**	**0.000**	**-0.02002**	**0.001**	**-0.03315**	**0.000**	**-0.01028**	**0.011**	**-0.01028**	**0.011**
2	28.04 – 04.05.2020*	**-0.01731**	**0.000**	-0.00398	0.263	0.00499	0.143	**-0.00971**	**0.087**	**-0.01361**	**0.013**	-0.00365	0.442	-0.00365	0.442
3	23.06.2020	**-0.01405**	**0.010**	**-0.00190**	**0.000**	**-0.01488**	**0.000**	0.00288	0.661	-0.00050	0.937	-0.00252	0.644	-0.00252	0.644
4	21.07.2020	-0.00155	0.777	**-0.01285**	**0.002**	-0.00589	0.137	-0.00195	0.766	-0.00427	0.501	-0.00194	0.722	-0.00194	0.722
5	08.09.2020	-0.00157	0.774	-0.00156	0.705	-0.00385	0.333	0.00886	0.178	**0.01326**	**0.037**	-0.00721	0.186	-0.00721	0.186
6	22.09.2020	-0.00322	0.555	-0.00364	0.377	-0.00159	0.689	**0.01356**	**0.044**	0.00463	0.466	**0.02004**	**0.000**	**0.02004**	**0.000**
7	06.10.2020	-0.00700	0.200	0.00427	0.301	-0.00112	0.777	-0.00696	0.290	-0.00456	0.473	**-0.01404**	**0.010**	**-0.01403**	**0.010**
8	03.11.2020	**-0.02161**	**0.000**	-0.00486	0.243	-0.00026	0.949	**-0.01374**	**0.040**	**-0.01864**	**0.003**	**0.01972**	**0.000**	**0.01972**	**0.000**
9	08.12.2020	-0.00668	0.221	-0.00034	0.935	-0.00161	0.686	-0.00643	0.329	0.00336	0.597	0.00066	0.904	0.00066	0.904

Notes: see Table 5; * the time interval is due to the fact that monetary interventions were carried out frequently and their individual analysis would be impossible within the framework used in the study.
Source: own study.

Table 7. Event study estimates for monetary policy responses to the Covid-19 crisis – Poland

#	Dates	(1) Stock_PL – Bond_PL		(2) Bond_PL – Bond_DE		(3) Bond_PL – Bond_US		(4) Stock_PL – Bond_DE		(5) Stock_PL – Bond_US		(6) Stock_PL – Stock_DE		(7) Stock_PL – Stock_US	
		Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
1	16.03 - 17.03.2020*	**-0.01606**	**0.005**	0.00152	0.741	**-0.01079**	**0.031**	-0.05219	0.000	-0.03268	0.000	-0.01286	0.000	0.00204	0.656
2	08.04.2020	-0.00622	0.204	-0.00336	0.435	-0.00670	0.116	0.00727	0.216	**0.01089**	**0.045**	**0.00584**	**0.089**	**0.00880**	**0.047**
3	28.05.2020	0.00107	0.827	**-0.00989**	**0.021**	**-0.00903**	**0.034**	0.00241	0.682	-0.00526	0.334	-0.00544	0.113	0.00448	0.313
4	15.06.2020	**0.00875**	**0.073**	0.00092	0.830	0.00119	0.780	0.00207	0.725	-0.00558	0.304	**-0.00611**	**0.074**	**-0.01172**	**0.008**
5	13.07.2020	0.00156	0.750	0.00601	0.162	0.00414	0.330	-0.000	0.999	0.04919	0.366	0.00134	0.695	0.00223	0.616

Notes: see Tables 5 and 6.
Source: own study.

Table 8. Event study estimates for monetary policy responses to the Covid-19 crisis – Romania

#	Dates	(1) Stock_RO – Bond_RO		(2) Bond_RO – Bond_DE		(3) Bond_RO – Bond_US		(4) Stock_RO – Bond_DE		(5) Stock_RO – Bond_US		(6) Stock_RO – Stock_DE		(7) Stock_RO – Stock_US	
		Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
1	20.03 - 27.03.2020*	**0.00885**	**0.012**	**0.00840**	**0.073**	**0.00869**	**0.012**	**-0.01001**	**0.093**	-0.00756	0.121	**-0.01849**	**0.005**	**-0.00835**	**0.045**
2	29.05 - 05.06.2020*	**0.00847**	**0.016**	-0.00735	0.113	0.00124	0.717	**0.01127**	**0.052**	**0.01115**	**0.017**	-0.00026	0.961	0.00076	0.855
3	05.08.2020	-0.00385	0.354	0.00218	0.700	0.00047	0.908	-0.00063	0.928	-0.00361	0.517	**0.01109**	**0.079**	0.00260	0.595
4	28.08.2020	-0.00179	0.666	0.00084	0.879	-0.00025	0.951	0.00485	0.485	0.00424	0.454	-0.00774	0.221	0.00385	0.432
5	12.11.2020	-0.00137	0.743	0.00019	0.973	0.00153	0.709	**0.03863**	**0.000**	**0.03414**	**0.000**	0.00344	0.588	**-0.02289**	**0.000**

Notes: see Tables 5 and 6.
Source: own study.

CONCLUSIONS

This article investigated the impact of monetary policies in four CEE countries on shifts in financial market connectedness during the Covid-19-induced crisis. Firstly, using the DCC-GARCH models, we estimated the time-varying conditional correlations for CEE economies based on stock market returns and sovereign bond yields. Next, we performed a series of event studies based on the daily dataset of standard and unconventional monetary interventions. We found that policies introduced by the central banks of CEE countries contributed to stabilizing or reducing tensions that stemmed from an increase in financial market dependencies during the turmoil, in particular when it comes to the domestic stock-bond and cross-border bond market linkages. Hence, using a different empirical framework, our results support evidence from recent studies that anti-crisis policy measures, including non-standard ones, significantly affected market returns (Arslan *et al.*, 2020; Rebucci *et al.*, 2021). This seems to be the case also when such measures were implemented not only by the major central banks, such as the Fed or the ECB, but also by monetary authorities in small and emerging market economies.

The empirical results substantiate the main hypothesis of the study, which states that the domestic Covid-19 monetary policy response significantly affected linkages among stock and sovereign bond markets in the countries under consideration. More specifically, our findings allow us to claim that, in general, the anti-crisis policy measures announced by domestic central banks in CEE economies in 2020 exerted mitigating effects on an increase in the financial market connectedness triggered by the Covid-19 turmoil. The important caveat, however, is that these effects were not uniform across financial market segments and CEE countries. They turned out to be notably stronger for correlations that involved bond markets and relatively smaller in Romania compared to the remaining CEEs.

The validity of the second hypothesis, which concerned the ability of the central banks in CEEs to reduce flows from domestic stock to bond markets, was partly confirmed by the obtained results. In some cases, due to monetary interventions, the central banks of Czechia, Hungary, Poland, and Romania were able to alleviate financial market tensions, thus reducing flows from domestic stock to bond markets. However, a detailed analysis reveals differences across the CEE countries. While, in the case of Czechia, all monetary interventions turned out to have a statistically significant impact on the level of correlation between stock market returns and changes in sovereign bond yields, in the case of Hungary, Poland, and Romania, the measures launched at the beginning of the Covid-19 pandemic turned out to be much more effective than the interventions introduced in the third and fourth quarter of 2020. Similarly, the validity of the third hypothesis, which stated that the CEE central banks were able to mitigate international flight-to-safety effects from CEE countries, was only partially confirmed. More specifically, we found that such effects were contained by the first monetary interventions. The impact of the subsequent measures differed with regard to its direction and magnitude across the CEE countries.

Our results may be additionally interpreted in the context of the effectiveness of monetary policy interventions under uncertainty in financial markets. This theoretical debate on whether monetary policy is more or less effective during a crisis than in 'normal' times is still not settled (Jannsen, Potjagailo, & Wolters, 2019; see also Wei & Han, 2021). On the one hand, one could argue that the high market volatility and substantial balance-sheet adjustments of the market participants impair the monetary transmission mechanism, and central bank interventions may be expected to generate muted reactions. On the other hand, one may posit that financial constraints, which are binding during crises, increase a central bank's chances of influencing market premia and stabilizing expectations. Our results lean towards the latter theoretical prediction and support recent empirical findings of studies which show that non-standard monetary policies had significant effects on the financial market even at the height of the pandemic shock (Fratto *et al.*, 2021; Sever *et al.*, 2020).

The relative effectiveness of monetary policies in CEE countries in 2020 may be ascribed to a speedy reaction of the central banks to the pandemic shock, but also the fact that anti-crisis monetary measures were introduced worldwide, easing the adverse effects of the global shock. Special times call for special measures, and the CEE central banks, much like the monetary authorities in major AEs, significantly departed from their regular practice of conducting monetary policies. A close-to-zero policy rate, QE, and

other unconventional measures increased their chances of reducing market risk premia and boosting investor confidence. In this respect, our results are supportive of recent studies by Moessner and de Haan (2021) for the euro area, who highlight the role of the announcement effect and communication in the way that central banks affect financial markets, but also of previous studies that document the announcement effects, for example in sovereign bond markets (Afonso *et al.*, 2020). At the same time, the empirical results obtained in the study evoke the problem of the weakening in effects of successive monetary policy actions. The pattern we found shows that the first series of central bank decisions had the strongest market impact. When it comes to policy implications, our results provide a rationale to utilize stabilization tools, including unconventional ones, during periods of financial instability generated by external shocks. Given the connection of CEE countries' financial markets with the euro area and the US and its susceptibility to external shocks, central banks in the region should be prepared to react to potential natural and man-made disasters that may periodically reappear in the global economy. However, it must be noted that efforts to preserve financial stability may come at the long-term cost of undesirable complications when the reversal from extraordinary policies is postponed for too long. In CEE economies, those problems may include the central bank's institutional standing, political economy issues and relationship with the government, and a build-up of inflationary expectations.

There are at least three important limitations to this study that should motivate further work in the area. Firstly, the article leaves aside an important but controversial policy measure used during the Covid-19 crisis, namely the foreign-exchange interventions. Considering the active efforts of some CEE countries to influence the value of their currencies in 2020 and 2021, the issue of the 'second instrument' of central banks (Ghosh, Ostry, & Chamon, 2016) in open economies seems worth exploring in this context. In particular, studies could explore the impact of interventions on CEE economies' exchange rates vis-à-vis major currencies, the US dollar and the euro. The second limitation of the article is related to its empirical approach, based on the DCC-GARCH model and event studies of monetary policy announcements. Specifically, it would be advisable to look more closely into the differences between the effects of standard and non-standard monetary policy tools implemented in CEEs in 2020. The original database of monetary policy interventions in CEE economies prepared for this study may serve as a starting point for further research in this direction. Moreover, as new methods are developed in this active field, one could complement the results presented here with alternative empirical approaches, such as the time-varying parameter VAR models. Thirdly, this study focused on the effects of anti-crisis policy measures implemented at the onset of the Covid-19 crisis in CEE countries. However, increasing inflation rates in 2022 bring about new challenges for central banking in the region. Domestic and international effects of exiting the monetary stimulus in 2022, including their impact on inflation rates in CEE economies, also warrant further investigation.

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Authors

The contribution share of authors is equal and amounted to 1/3 for each of them.

Wojciech Grabowski

PhD in economics (2011); Associate Professor (2020) at the Department of Econometric Models and Forecasts, University of Lodz (Poland). His research interests concentrate mainly on econometric methods of analysis of non-stationary and high-frequency data.

Correspondence to: Prof. UŁ, dr hab. Wojciech Grabowski, University of Lodz, ul. Rewolucji 1905 r. 37/39, 90-214 Lodz, Poland, email: wojciech.grabowski@uni.lodz.pl

ORCID ⬤ http://orcid.org/0000-0002-6707-3736

Jakub Janus

PhD in economics (2018); Assistant Professor at the Department of Macroeconomics, Krakow University of Economics (Poland). His research interests include monetary and international economics.

Correspondence to: Dr Jakub Janus, Krakow University of Economics, Department of Macroeconomics, ul. Rakowicka 27, 31-510 Krakow, Poland, email: jakub.janus@uek.krakow.pl

ORCID http://orcid.org/0000-0002-2131-6077

Ewa Stawasz-Grabowska

PhD in finance (2017); Assistant Professor at the Department of International Finance and Investment, University of Lodz (Poland). Her research interests concentrate mainly on monetary and financial policy in the euro area.

Correspondence to: Dr Ewa Stawasz-Grabowska, University of Lodz, ul. POW 3/5, 90-255 Lodz, Poland, email: ewa.grabowska@uni.lodz.pl

ORCID http://orcid.org/0000-0002-2456-552X

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.