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UNCONVENTIONAL MONETARY POLICY: UNIVERSAL CURE OR MODERN DECEPTION

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Abstract

This paper provides an empirical assessment of Unconventional Monetary Policy after the exogenous shock of 2020 - the COVID-19 crisis. The research investigates the impact of the recent financial market crash on primarily employed unconventional tools by discussing several effects in play. A Structural VAR model estimates the responses of stocks, corporate, and government bonds to the shock in Balance Sheets for seven major Central Banks. The model also investigates possible cross-asset and cross-country spillover effects to provide a complete picture of the unconventional monetary policies. The results confirm the positive impact on private assets prices and the negative on government yields. We also find a statistically significant reverse effect, which suggests a delayed and ongoing Central Banks' reaction to the negative shock in financial assets. Furthermore, we find that cross-asset spillovers from the government to private securities are significant and between short- and long-term government yields. The findings on international spillovers verify the Federal Reserve System's crucial role in the balance of the world economy. We conclude the paper by saying that exogenous shock from outside the financial system has not caused severe changes to Unconventional Monetary Policy tools' performance.

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1. Introduction

The year 2020 would be primarily associated with the crisis brought by rather an unusual disruption in financial system functioning. Starting from March, the global COVID-19 pandemic has forced many governments to introduce social distancing rules, stay-at-home policy, and temporary close borders to protect citizens and minimize the risk of virus exposure. Such a desperate action hampered international trade and travel, resulting in a wide-ranging impact on the financial markets - stock, bond, and commodity markets suffered a collapse. On March 18, 2020, the financial world experienced one of the most severe declines in its history, with the S&P 500 having the worst day since 1987 – a drop of 27% YTD (Wigglesworth, Lewis, Lockett, Smith, & Martin, 2020). On that March day, other world indexes followed the same trend: Germany's DAX down by 38% YTD, Japan's Nikkei by 29% YTD (Coy, 2020). The Managing Director of the International Monetary Fund concluded that the world faced the 'worst' financial crisis of the past decades (BBC, 2020). Central Banks (CBs) were forced to take some actions to bring the economy back to equilibrium.

For many years the most common way of supporting the households and the real economy was related to the conventional monetary policy (CMP) tool of lowering the interest rates. However, by the beginning of the 21st century, most developed economies' interest rates were either close or already below zero level bound (ZLB) (Appendix 1), suggesting further downward movement in the negative zone would create unnecessary anxiety over the current stance of the economy. Even though some countries, such as Germany and Switzerland, successfully adopted negative interest rates, others doubted the policy's rationality from the long-term perspective. They turned to the unconventional monetary policy (UMP) tool, such as injecting liquidity into the economy by purchasing financial assets and securities. The main difference between CMP and UMP is that unconventional means are temporary and apply when the conventional measures are not practical (Potter & Smets, 2019). The first historical case of UMP implementation happened between 2001 and 2006 when the Bank of Japan applied Quantitative Easing (QE), expanding total assets via long-term securities purchases. Later on, during the Great Financial Crisis (GFC) of 2007-2008, FED decided to build upon the existing success of Japan - they introduced the Large-Scale Asset Purchase (LSAP), and several researchers (Smaghi, 2009; Bernanke, 2009) called this type of monetary stimulus Credit Easing (CE). The difference lies in the main target of CE to reduce the real borrowing rates for the private agents rather than contain the long-term interest rates. Despite the difference in implementation and Asset Purchase program structures, both policies aim to restore the country's economic activity by injecting additional liquidity to the selected parties.

There exists broad literature on the impact of QE programs experienced by different countries during the GFC. However, given the contradicting results, the topic remains an active debate (Andrade et al., 2016; Haitsma, Unalmis, & Haan, 2016; Hosono & Isobe, 2014). Our work complements the existing scope of literature on UMP impact based on several reasons. Firstly, our methodology focuses on using the actual purchases tracked through the BSs of CBs that serve as a more accurate measure of the real activity than policy announcements with the event study approach or key government rates within a time-series model (Fratzscher, Duca, & Straub, 2013). Since the chosen methodology would not allow studying COVID-19 in isolation due to the limited number of observations, we want to see how an exogenous shock changed the perception of monetary policy impact, if at all. Secondly, our dataset includes the last 20 years of monthly data on actual changes to the Balance Sheet values of 7 major CBs. The dataset provides us with an exclusive opportunity to compare the results across different regions and, at the same time, study the potential spillover effects from huge players, such as FED and ECB. Lastly, we include the events of 2020 to analyze the impact of the largest UMP in economic history. A few authors already managed to explore them to some extent (Hartley & Rebucci, 2020; Peterson & Thankom, 2020; Selmi & Bouoiyour, 2020). But the research lacks deep investigation on the impact on several asset classes, e.g., the comparison of the effects on stocks relative to the effect on targeted corporate or government bonds. Summing it up, the research question addressed in the paper is constructed as follows: **How do large-scale asset purchases used by the major Central Banks impact the prices and returns of different asset classes?**

To cover UMP's full impact, we analyse the present evidence on its impact and relative performance over the last decade. The question to be addressed via the RQ mentioned above would entail investigating the direct effects of balance sheet expansion on prices and yields of major private and public assets (subquestion 1). Then we will study the reverse effect initiated in the assets to observe the speed and size of the CBs adjustment to their policies (subquestion 2). Furthermore, we attempt to investigate the cross-asset spillover effects (subquestion 3). Finally, we examine the presence of international spillovers coming from FED and ECB that are usually considered to be the sole ‘superpower’ (subquestion 4). Combining themes altogether, we present the final set of sub-questions that covers several topics:

1. *What are the effects of balance sheet expansion on stocks, corporate, and government bonds?*

2. *What is the impact of shocks in financial assets on the balance sheet values?*
3. *What are the potential cross-asset spillovers?*
4. *What are the cross-country spillovers from the Central Banks' usage of QE programs?*

The thesis consists of 8 major parts. Section 2 accumulates and analyzes the existing literature on the impact of unconventional monetary policies of CBs to construct our list of hypotheses. Section 3 elaborates on the data gathered and modified. Section 4 indicates data analysis methods used to test the constructed hypotheses. Section 5 introduces the empirical findings, examines their convergence/disagreement to the current UMP theory, and draws a conclusion on hypotheses. Section 6 concludes.

2. Literature review

This section establishes a theoretical framework in which we are going to operate throughout the whole research process. We start with explaining the main concepts and introducing the COVID-19 shock and its impact on the financial markets. We further discuss papers that have studied the effects of UMP on different asset classes. We continue with the topic of cross-asset and international spillover effects. Lastly, we form the list of hypotheses to be tested using the following sections' data and empirical model.

2.1. The appearance of UMP tools and their size in the recent pandemic

Significant changes to the sample of available monetary policies are associated with the period of 2007-2008. Before that, banks usually referred to traditional monetary policies, such as CMP, of cutting short-term interest rates. Even though Japan successfully implemented UMP at the beginning of the 21st century, the idea of using other monetary tools was yet to gain attention. But the time came during the GFC when the size of financial distress was too large to be handled by a quick and so far effective interest rate drop. Since many advanced economies had a nominal interest rate close to or at ZLB, FED and other economies were forced to take resembling actions. When "Central Banks ran out of conventional monetary policy ammunition to stimulate the economy" (Samarina & Apokoritis, 2020, p.2.), non-traditional emergency measures apply. For recovery stimulation, CBs resorted to 1) **forward guidance** defined as "communication to the public about the likely future course of monetary policy" (FED, 2015), and 2) **quantitative easing** – the extension of the balance sheet by the large-scale purchase of long-term financial assets (Bernanke, 2020). Through the use of different transmission channels, UMP tools aim at lowering the interest rate to offer cheaper financing for the economy. They also reduce the spread between short- and long-term rates at a time when a simple decrease in key borrowing rates is not feasible due to ZLB (Dell'Ariccia, Rabanal, & Sandri, 2018).

The level of liquidity support during the GFC can be seen from the Samarina and Apokoritis (2020) research, where balance sheets of CBs grew by 30% on average after the application of the QE tool. After some time passed, it was proved that decisions of CBs related to the implementation of quantitative easing and forward guidance were effective due to the positive effects on price stability and economic growth (Dell'Ariccia et al., 2018). Appendix 2 elaborates on the announcements of financial support in 2020 by CBs in the sample. Comparing the amount of announced QE purchase to the BSs' size at the beginning of 2020, we can understand the size of the monetary policy expansion seen in the year 2020 is to be at least equal, yet likely more substantial than a 30% shift faced during the GFC (Samarina & Apokoritis, 2020).

2.2. Quantitative Easing and its effects on the economy

When defining the UMP approach of injecting liquidity into the economy, it is crucial to distinguish two separate terms – quantitative easing and credit easing. The term QE was introduced by BoJ when during 2001 and 2006, it launched the first large-scale asset purchase program. During this period, the bank focused on the acquisition of long-term government bonds in particular. It aimed to increase the total amount of reserves the bank holds, i.e., the BS's liability side was growing. As a result, the long-term rate was affected (Bernanke, 2009; Smaghi, 2009). However, when FED decided to borrow the QE policy of BoJ, there were a few changes made to the monetary expansion. FED pursued a goal to improve credit conditions and, hence, to support the economy through "reducing the borrowing costs faced by private agents" (Dell'Ariccia et al., 2018, p.5). According to Bernanke (2009), there is a clear distinction between quantitative and credit easing: CE mainly focused on acquiring a mix of securities/loans to expand the asset side of the balance sheet.

In our work, we use both terms (QE and CE) interchangeably to indicate UMP's presence. It is also worth mentioning that the unconventional purchase of foreign assets and balance sheet expansion does not seem so unique as it seemed 10 or 15 years ago. What is relatively unconventional at the current moment is the size of balance sheet expansion that is not associated with any interest-rate changes. Hence, UMP differs from CMP due to the absence of any short-term interest rate adjustments made by those in power, mainly Central Banks or Federal Reserves (Gagnon, Bayoumi, Londono, Saborowski, & Sapriza, 2017).

2.3. The influence of COVID-19 pandemic on the stance of CBs

In the past year, the world became acquainted with the new COVID-19 virus that spread all over it in a matter of weeks and resulted in an unprecedented recession. The virus caused severe changes in social distancing rules, closed factories, offices, public places, remote work and education, event cancellation, and finally, a stay-at-home policy with the curfew. These actions raised fear both in consumer and investor minds; people started to doubt the rationale related to investing – financial markets were relatively unstable, and even major stock indices became volatile (Horowitz, 2020; Peterson & Thankom, 2020). However, Selmi and

Bouoiyour (2020) argued that the recession caused by the COVID-19 pandemic was not the primary source of the shrinkage in economic and financial activity. The economic growth in many economies was already unstable at that time, and the virus simply gave the last push.

Many governments faced a challenging spring of 2020 when the decision on which actions to undertake should have been made quickly. Most of the CBs applied QE or CE to increase the money supply, raise liquidity, and smoothen businesses' situation by providing monetary stimulus (Selmi & Bouoiyour, 2020; Appendix 3). The respective measure was chosen over simple interest rate cuts since rates were already close to ZLB for many developed economies, making the usual conventional tool ineffective (Aguilar, Arce, Hurtado, Martin, Nuno, & Thomas, 2020). Yet, the impact of that stimulus is not fully understood due to the nature of the pandemic. The caused disruption of international trade and extensive local measures to prevent the virus's spread was continuing dumping the local production level. Hence, one should carefully assess the impact of the COVID-19 pandemic on the whole model regarding the possible external factors to the financial system.

2.4. Formal theoretical model of QE

Before turning to other scholars' empirical findings extensively analysed in this section (Appendix 4), it is necessary to understand the general process of QE conversion into asset price changes. Based on the theoretical framework, asset purchases immediately generate disequilibrium on the market, resulting in quick asset price adjustments for bringing the balance back (Bridges & Thomas, 2012). An economist at Federal Reserve Bank Stephen Williamson (2017), refers to three macroeconomic theories when explaining the concept of QE policy. The first theory the author mentions is *Portfolio Balance Theory.* Based on this theory, long-term asset purchase programs held by the CBs are aimed at narrowing the gap between short and long-term yields. Additionally, the theory suggests that investors perceive government and private assets as imperfect substitutes and might ‘rebalance’ their portfolio towards riskier assets, causing a surge in their prices when sovereign yields are at their lowest. The second theory is *the Preferred Habitat Theory* which implies that market participants are not indifferent between short and long-term assets. From that follows that the market is segmented and a decrease in the supply of an asset of high demand will significantly decrease its yield. Lastly, according to *Signaling Theory,* every single action taken by the Central banks is assessed and taken into account by market participants even if there is no direct impact on the market. Additionally, this theory also explains why prior announcements related to the QE programs were immediately incorporated into price and yield changes on the financial market (Williamson, 2017).

Turning to the asset classes investigated in our work, asset purchase programs lower bonds' supply on the market that causes the yields to experience a significant drop. In some particular situations, investors might further decide to switch to another type of asset for achieving a higher yield, and such a decision could potentially harness some of the initial impact on the bond market (Bedikanli, 2019; Dobbs, Koller, & Lund, 2014). As for the stock markets, which usually have no direct linkage to the QE programs, the price conversion process can be explained differently. Asset purchase programs conducted by the CBs aim at injecting liquidity into the real economy. It provides businesses with lower interest rates on loans. Companies then continue their operations and stimulate revenue creation. At that time, investors get attracted by the growth of the company's performance, and it drives them to purchase stock - demand for the stocks of large firms goes up, and, therefore, we see stock attractiveness incorporated into price increase on the stock market (Iben, 2020; Dobbs et al., 2014). Additionally, Mamaysky (2018) notes that the asset classes that are not subject to the purchases of CBs might react with a delay. The delay in response to monetary stimulus suggests that many works investigating the QE impact in the 1 to 3 days window might provide incomplete results.

2.4.1. Government Bonds

Government bonds are major asset classes that academics have thoroughly investigated due to their direct linkage to almost any large-scale asset purchase program. QE announcements were immediately followed by the adverse reaction on the sovereign bond yields. Many investors preferred this instrument due to the guaranteed return with little exposure to risk (Bedikanli, 2019). The conclusions indicate that the effect averages -50 basis points, and the length of the effect is around a few months. Furthermore, we observe that the more significant number-wise impact corresponds to the emerging economies. The result is getting more potent as the maturity of bonds increases, the pattern seen especially in the medium and long-term bonds (Hartley & Rebucci, 2020; Koijen, Koulisher, Nguyen, & Yogo, 2016; Mamaysky, 2018). As to the duration of the effect, researchers argue that the observed effect is temporary, and within the next few months, bond yields will return to the initial level (Gros, 2018). Some authors believe the impact to last for only three weeks, but others found that a decrease in bond yields could be observable for half a year (Appendix 5).

2.4.2. Corporate Bonds

Corporate Bonds should be considered the 2nd most targeted asset class in the purchase programs initialized by CBs and close substitutes for government bonds. Hence, our expectations on the effect size and response time would be similar to the government bonds. The empirical literature suggests that investors are likely to switch from government to corporate bonds while making decisions on rebalancing their portfolios. What happens in practice is that demand for them increases, and it respectively leads to price increase and decline in yields– that is an outcome from the effective monetary policy imposition (Lasaosa, Joyce, Stevens, & Tong, 2011; Gagnon, Raskin, Remache, & Sack, 2011). The reaction on corporate bond yields is expected to appear immediately after the announcements and hold for approximately two months depending on investors' behaviour (Wright, 2011).

2.4.3. Stock indices

Unlike widely researched corporate and government bonds, there is a comparatively modest piece of empirical evidence examining the actual purchases' impact on stock prices. Research on stocks indicates a predominantly positive overall effect on prices. Andrade et al. (2016) and Haitsma et al. (2016) found a roughly +1% immediate average impact on stock prices related to QE implementation. Swanson (2017) reports the results of +0.1% that end up being not statistically significant. Several papers received an opposite effect with a negative relationship between a particular UMP tool and the stock market. According to Hosono and Isobe (2014), the ECB's asset purchase program brought a decrease in the prices of European stocks. Expectedly, there is also a third opinion: Bredin, Hyde, Nitzsche, and O'Reilly (2007) reported no impact on DAX at all (German Performance Index) after the QE policy was performed by the Deutsche Bundesbank.

Speaking about the length of the QE impact on stock prices, Bedikanli (2019), Mamaysky (2018), and Dimson, Marsh, and Staunton (2016) argue that positively directed volatility is observed for several weeks on stock prices. Additionally, during this period effect remains statistically significant for US, UK, and European countries. Moreover, some authors state that stock prices' reaction to a QE might come with a delay. In Mamaysky (2018), the strongest response materialized during the third week after the announcements. Most of the examined papers confirm the absence of a commonly agreed effect on stock prices, leaving room for a significant improvement.

2.4.4. Macroeconomic variables

The analysis of monetary policy impact would be incomplete without taking into account crucial macroeconomic variables. The reason for that is pretty straightforward. In line with the role of CBs identified back in the 19th century, the main goal of any monetary policy would be to restore the economy in the case of recession or boost this process by adding more liquidity and, hence, confidence in the whole system. In light of this, researchers usually add several macroeconomic factors to their models, such as GDP and the Consumer Price Index (CPI). Both real GDP and average price level turned out to be positively related to the asset purchases, effects reaching a maximum of +4.6% and +1.5%, respectively. The size of the impact for GDP and inflation was proportional to asset purchase programs in the United Kingdom. The QE1 program amounting to £200b brought the most significant impact to variables mentioned before (Bridges & Thomas, 2012; Churm, Joyce, Kapetanios, & Theodoridis, 2015).

There are several conclusions to be drawn at this point. The research on QE tools' impact is an ongoing process that adds more evidence and contradicts previous results each time a new study appears. Although most of the papers use policy announcements as a proxy for monetary policy impact, we aim to join the rising trend in the literature that proposes the usage of actual purchases. They are arguable of no less importance to the policy analysis and definitely out of the scope of simple event studies. Hypothesis 1 studies the impact of UMP during the sample period, while Hypothesis 2 estimates the response time of financial assets during which they absorb the full impact of QE:

Hypothesis 1: *UMP tools positively affect the prices of stocks and corporate bonds while decreasing government bonds' yields and causing a positive movement in the macroeconomic factors.*

Hypothesis 2: *The response time of stock prices to incorporate the changes brought by UMP is to be instantaneous with a lasting effect to be significant for the next several months.*

2.5. Responses of CBs to a shock in financial markets

According to the theory, the impact of the CBs actions on the financial markets does exist. Thus, there exist some signals that force CBs into preventive actions. The first important thing to note here is related to the fact that in recent years CBs changed the focus from targeting money growth to controlling the level of inflation in the state (Mathai, 2020). Using the inflation-targeting approach, governments can control economic performance and shortly resort to action (monetary policy) when the deviation appears (Rigobon & Sack, 2003;

Bernanke & Gertler, 2001). However, inflation is affected by many different aspects, and there appears a point in monitoring financial markets that could potentially lead to drastic changes in inflation. Rigobon and Sack (2003) have found that the 5% change in the price of the S&P 500 index resulted in a 2.5% higher probability of monetary policy implementation by FED. Findings of Fornari and Stracca (2013) argue that the adjustments followed shock in the financial markets in the interest rate. Therefore, when a situation that causes movements in inflation and other macroeconomic variables appears, CBs are likely to respond (Smets,1997). However, Bernanke and Gertler (2001) argue that the shock has to be large enough for CBs to notice changes in inflation, which is commonly considered a slow variable. Even if such shock occurred, monetary policy would be implemented to fix inflation expectations only. Summing it up, Hypothesis 3 addresses the presence of a connection between the response of CBs to the structural shock in financial assets:

Hypothesis 3: *A delayed positive UMP expansion follows a significant shock in asset prices or yields.*

2.6. Spillover effects

Understanding the spillover effects is very important for the realisation of any monetary policy. Direct injection of additional resources to the economy might impact the performance of other asset classes in the domestic area and significantly affect the prices in the international market. Therefore, careful assessment of risks and modelling spillover effect is one of the most crucial parts of new policy measures. The following subsection will discuss the role and significance of spillover effects in the context of different countries and asset classes with the primary purpose of establishing reliable hypotheses to be tested in our research.

2.6.1. Spillovers between asset classes

The direct impact of QE or CE programs that purchase pre-specified asset classes is straightforward - CBs decrease the supply of those assets in the economy, boosting the price upwards and yields downwards. Additionally, the investors’ willingness to purchase these assets might be affected by the upcoming UMP announcement, instantly impacting the demand for the targeted class. However, practice indicates that changes such as demand shifts occur not only in targeting type.

Gagnon et al. (2011) mention the portfolio balance effect plays a significant role in this transmission. From investors' perspective, bonds and indices are different asset classes that can be substituted by one another. Unattractive yield or low liquidity is likely to cause a severe outflow of the investors' demand from the particular asset. During QE programs, CBs aim at lowering sovereign yield, be it short- or long-term bonds, shifting some of the investors towards riskier assets, such as corporate bonds or equities. It is worth mentioning that QE programs' primary goal is to control yield on key bonds, and they are not introducing QE programs to shift some of the demand towards other asset classes specifically. At the same time, CBs are aware of the possible spillover effects to different classes and construct their purchase schemes accounting for those effects. Similar portfolio rebalancing effects are documented by D'Amico and Kaminska (2019) during CE programs that target corporate bonds specifically. They found that CE makes a significant contribution to the QE program, lowering the yield on corporate bonds and stimulating further corporate bond issuance. D'Amico and Kaminska (2019) argue that the persistence and transmission passage of spillover effects are yet to be well studied and analyzed, even though researchers confirm the presence of immediate pass-through effect from government bond purchases to corporate bonds.

However, not all QE or CE programs likely experience spillover effects. Krishnamurthy and Vissing-Jorgensen (2013) tested LSAP programs used by FED. They concluded that purchases of long-term Treasury Bonds had either a limited or no spillover effect on corporate (private) sector bond yield. Gilchrist, Lopez-Salido, and Zakrajsek (2015) employ a similar event-study approach to analyse QE's immediate impact on Treasury yields and corporate bonds. They successfully captured a 4 basis points decline in the 10-year Treasury Yield, which came a drop in 2-year Treasury yield caused by the monetary policy. Gilchrist et al. (2015) also documented a significant run-through effect towards corporate bonds that lowered the private yield by 7 basis points. These findings suggest mixed results for most studies that aim to investigate spillovers from sovereign to corporate bond yields.

Considering private assets, equities are not getting direct compensation for the difference in the yield between privately held assets and sovereign bonds. Instead, a lower sovereign bond yield increases the present value of future cash flows for a particular firm, implying a smaller discount. Joyce, Lasaosa, Stevens, and Tong (2010) combine discount and portfolio balance effects into the main reasons for equities to be subject to a shock in monetary policy. It can be either any of the impacts or a combination of those that should ideally cause a vertical movement in the equity prices. But it does not necessarily mean that equities are always ought to respond to the monetary policy shock in the described manner. Joyce et al. (2010) elaborate on the fact that equities derive the initial shock from the announcements of upcoming policy actions, which, in case it be worse than expected, might as well lower the price for the stock market index.

All the discussed findings bring a bit of ambiguity to the spillover effect we should test. The problem currently present in the literature on spillover channels can be characterised by limited data on the actual QE and CE programs and the difference in the approaches used to assess those programs. D'Amico and Kaminska (2019) suggest that the second reason lies in the speed of price adjustment mechanism in riskier economies, which require a different approach than the usual event study, e.g., actual purchases analysis performed in this paper. However, we should also acknowledge the notion of Joyce et al. (2010) that equity prices are likely to respond to the relative positivity of the QE or CE policies announcement, which is not captured by the changes in the total assets of CB. Thus, we construct the following hypotheses to represent an ideal theoretical result of the QE or CE programs to avoid potential misalignment with the literature. Hypothesis 4 tests the presence of linkage between sovereign and private yields. In contrast, Hypothesis 5 suggests a strong response of equity prices to the lower discount rate and portfolio balance mechanism due to a decline in both sovereign and corporate yields.

Hypothesis 4: *There exists a substantial spillover from the government to corporate bonds.*

Hypothesis 5: *There exists a strong spillover to equities from government and corporate bonds.*

2.6.2. International spillovers

International spillovers are the natural extension of the cross-asset effects. If the shock from QE or CE policy transmits through one asset class into the other, there also might be a transmission from one economy to another. While the amount of research done on monetary policy steadily increases over the years, most of the papers examine the impact of US monetary policy, essentially FED announcements or actual asset purchases (Gagnon et al., 2017; Neely, 2010; Rogers, Scotti, & Wright, 2014). The cross-country spillovers between the US and the rest of the world do exist, as was proved by Rogers et al. (2014) and Menzie (2013). Hence, the assumption on the influence of FED policies should be considered a strong one, reflecting on the US economy's role and US prices on the rest of the world. However, they are asymmetric in their impact. The effect of US easing on non-US yields is much more pronounced and significant than the opposite one, although the effect of the US dollar's decline against those non-US currencies is likely to be more powerful. A recent piece of research on the FED outlines international spillovers towards the Asian markets, including equities and long-term assets. Tran and Pham (2020) identified a significant surge in equity prices when UMP was in place, from the end of 2009 till the beginning of 2014. Simultaneously, the effect on long-term bond yield is negligibly small, suggesting the absence of impact on the Asian Market.

Contrary to Tran and Pham (2020), the evidence presented by Gagnon et al. (2017) illustrates a clear correlation between US sovereign yields and those of almost all advanced economies. In the case of few emerging economies with high default risk, the correlation is somewhat positive, i.e., announcements on the US economy followed by a surge in prices and a decline in yield will likely cause a decrease in risk compensation in most advanced economies as well. The impact on equities is also pretty uniformed and positive, though it is coming solely from US policies' announcements.

There is also a bunch of research that investigates the opposite effect. Most of it picks ECB as a force that can significantly impact the US yield and term premia. Curcuru, Kamin, Li, and Rodriguez (2018), among other questions, focus on the effect of ECB announcements on the US expected interest rates and term-premia separately. The paper findings suggest that the impact on the US expected short rates are minimal and negligible. The main result of Duca, Fratzscher, and Straub (2016) points out that despite a minor relative impact as that of FED, ECB asset purchases did play a significant role in reducing yields of the advanced and emerging economies. The effect is robust for equities, where Italy and Spain experienced a 5% while other EU countries with a high credit rating saw a 10% spike in the equity index price. Kearns, Schrimpf, and Xia (2019) used a sample of 7 advanced countries to study the international spillover effects towards advanced and emerging economies. Their idea is very close to this paper's goal to analyse the magnitude of the spillovers from the biggest CBs, being FED and ECB. They report an expected spillover from FED and ECB to other economies' long-term interest rates, yet the effect is not significant for the short-term rates. Additionally, the spillover's magnitude for other large CBs, such as BoJ or BoE, remains to be “mild at best” (Kearns et al., 2019, p. 21) according to the changes in the policy rates of respective CBs.

The following hypothesis summarises The literature on international spillover:

Hypothesis 6: *The strongest international spillovers are attributed to FED and ECB asset purchase programs. The magnitude of the effect is the strongest in sovereign yields, while the impact on equities and corporate bonds is weak.*

The existing research suggests that Hypothesis 6 will not be rejected for FED and ECB for at least some advanced economies. But we should be cautious in comparing the upcoming results of this paper to the previous investigations due to the significant differences in the methodologies and data sample. The usage of actual purchases allows us to observe the direct effect of supply and portfolio rebalancing effects. We explore the shortcomings of this approach later, in the section following the description of our sample.

3. Data

This section elaborates on the data employed in the paper. We mention sources of data, as well as challenges while gathering it. We also list the substitutes taken for some data points and sources of them.

3.1. Main Variables

We use five datasets to analyse whether COVID-19 related UMP events impacted the link between the QE and the asset classes' price changes. The first is the **balance sheets of Central Banks**. The decision of taking the BSs of CBs instead of initial announcements on acquisitions (event study approach widely used by many researchers: Krishnamurthy & Vissing-Jorgensen, 2011; Swanson, 2017; Hartley & Rebucci, 2020) was made based on the paper of Fratzscher et al. (2013), where authors state that the actual purchases might not follow announcements of CB. Additionally, reaction to announcements depends directly on the particular market's informational efficiency, which might change in times of distress. Moreover, during the first wave of COVID-19, CBs were pretty quick in their response to the declining economy and implemented extensive QE or CE programs straight away. The size of them, as seen in Appendix 2, is extraordinary. Therefore, from all facts mentioned above, BS could be a more accurate measure of asset acquisitions (Fratzscher et al., 2013). Due to the data availability and reporting standards, we take those banks that share updated BS weekly. As a sole exception to this methodology, we also gathered the data on the Bank of Japan, which has a 10-days reporting period and transmitted it into a weekly format via taking the weighted average of the closest data points for a specific weak. Therefore, the first dataset consists of the BSs of 7 major banks: FED, ECB, BoE, BoC, RBA, RBI, BoJ. The data was downloaded from the official websites of CBs with open public access. However, the official website of BoJ provided data starting only from 2010; therefore, we downloaded the rest of the data on total assets from FRED Economic Research. As to the period, we gather data on each CB starting from the first implementation of quantitative easing by the particular bank. Appendix 6 summarizes the exact dates of the introduction of QE. Additionally, Appendix 7 lists all adjustments on the data of BSs.

As for the second dataset, we take the main **stock index for each respective country** in our sample. First, we are aimed at the region-specific risk and not on the currency one. For this purpose, we choose indices that incorporate stocks issued on the domestic market and not the sum of all the home-currency-denominated stocks in different jurisdictions. Second, to address representativeness bias to some extent, we take indices with at least more than 100 stocks. We acquired the chosen indices' price levels (Appendix 8) from the Thomson Reuters database available at the Stockholm School of Economics in Riga for student use. Appendix 9 presents the evolution of prices on stock indices starting from the first implementation of QE by each country.

To analyse UMP's impact on corporate bonds, we retrieve price levels of the **corporate bond indices for each respective country.** During the research process, we use the same methodology as for stock market indices. The third dataset records corporate bond indices for the UK, Canada, Australia, EU, and Japan (S&P Global). Due to the data limitations, the S&P Eurozone Investment Grade Corporate Bond Index stands as a proxy for the European Union. Additionally, for the US and India, a corporate bond index is substituted with the iShares corporate bond ETFs obtained from Yahoo Finance. Appendix 10 displays price changes in corporate bond indices.

Furthermore, we took two different maturities of the government bonds for the government bonds dataset: short-term maturity of 3 months and long-term maturity of 10 years. We downloaded the monthly data on yields from the FRED Economic Research, European Central Bank, Bank of Canada, Bank of England, and Investing (2021). In the dataset, we substituted Australian short-term government bond yield with the Bank Accepted Bills/Negotiable Certificates of Deposit-3 months yield due to the absence of data of former assets (RBA, 2021). Additionally, to finalize all datasets on asset classes, we made several adjustments listed in Appendix 11, while Appendix 8 displays more detailed information on all assets chosen for our research.

3.2. Control variables

Most of the models examining monetary policies and their impact on asset classes employ additional parameters to account for the main things of concern to the CBs - economic activity and inflation. Due to our research's specificity based on the weekly and monthly balance sheet values of CBs, we were unable to extract the matching frequency data on a commonly used indicator of economic activity - GDP. An alternative approach for examining weekly and monthly economic activity would be to extrapolate the quarterly data into a higher frequency. The issue that would arise here concerns the parameters to base the extrapolation since most of the economy-related macroeconomic variables have a low frequency. Thus, we decided to use Industrial Production data. We downloaded data for 5 countries from OECD. Yet, for Australia and Canada, we could not find it in such a frequency, and, hence, took the normalized GDP OECD indicator downloaded from FRED Economic Research. As for inflation, we downloaded publicly available data on Consumer Price Indices for six countries from the OECD database; for Australia, we downloaded the data from the Federal Reserve Bank of St. Louis Economic Research (FRED, 2021).

4. Methods

This section elaborates on the chosen econometric model to examine Hypotheses. We start by stating the reasons for selecting the specific method over the others. We continue with the primary assumption and theoretical implications of the model. The main variables and coefficients of interest are stated further on. We conclude by listing possible limitations to the chosen methodology and encountered issues to be addressed in further research.

4.1. The choice of the model

As Chinn (2013) pointed out, the existing monetary policy investigations can be separated into two main groups. The first group sticks to UMP's announcements to gather evidence on instantaneous price changes within a short period. The second group employs a time-series analysis via taking key government rates or the actual CB's purchases. An extensive amount of the literature that we have already mentioned uses an event study model to analyse the immediate short-run impact of monetary policy announcements and forward guidance meetings (Gagnon et al., 2011; Hartley & Rebucci, 2020). This model's advantage lies in the high-frequency data that allows them to dig into immediate effects from CB announcements to stock prices and bond yields. However, there are several reasons to believe the actual purchases data will indicate a more precise response to the QE policies. Firstly, the message initially sent via announcements or forward guidance meetings might be incorrectly represented by the mass media or interpreted by investors. Secondly, the usage of the balance sheet as a "clearly observable and controllable instrument… as opposed to the term premium" (p.15) is justified by its direct linkage to the supply of targeted assets (Chinn, 2013). Thirdly, since changes to the balance sheet are happening post-factum, there is no need to assume the same characteristics for pre- and post-crisis periods used in the event study (Chinn, 2013). Lastly, the COVID-19 brought a significant discrepancy to the financial market that responded with a drastic price decline. QE and CE programs launched by CBs were one of the largest in UMP history, providing researchers with much more data on such a tremendous scale. Combining the potential advantages from the usage of actual CB purchases and the high-frequency requirement of the event study approach, we would join the second group of scholars who examine the UMP via analysis of actual purchases.

4.2. Structural VAR and modifications for spillover effects

Following similar concerns related to the event study approach, the autoregression model presents a handful of solutions to the monetary policy assessment. The motivation for using autoregression models lies in their ability to relate the current values of the variable to its past or lagged values. Stock and Watson (2011) claim that it is good to check for the past information in the variable if the one wants to provide a good prediction for the future. The most frequently used model for analysing the shock in the monetary policy is the Vector Autoregressive (VAR) or Structural Vector Autoregressive (SVAR) models (Lutkepohl & Netsunajev, 2018). Despite the high popularity of VAR-type models in the literature, Rudebusch (1998) has raised early concerns about the performance of VAR models when tested on the "obvious structural benchmarks" (p.929). He suggested that the VAR model practically fails at the correct identification of endogenous and exogenous variables. At the same time, Structural VAR allows for the instant contemporaneous effect to use a more precise estimation of economic structure and connections.

We start with a simple Structural VAR with two exogenous variables being Industrial Production and CPI:

$$\Delta TA_t = \alpha_0 + \sum_{l=1}^{n} \alpha_{1,t-l} * \Delta P_{t-l} + \sum_{l=1}^{n} \alpha_{2,t-l} * \Delta TA_{t-l} + \sum_{l=1}^{n} \alpha_{3,t-l} * \Delta X_t + \varepsilon_t \quad (1)$$

$$\Delta P_t = \beta_0 + \sum_{l=1}^{n} \beta_{1,t-l} * \Delta P_{t-l} + \sum_{l=1}^{n} \beta_{2,t-l} * \Delta TA_{t-l} + \sum_{l=1}^{n} \beta_{3,t-l} * \Delta X_t + \varepsilon_t \quad (2)$$

where ΔTA_t is the log growth of Central Bank's assets in month t, ΔP_t is a vector of financial assets' ($\Delta Stock\_Index_t$, $\Delta CorpBond\_Index_t$,$\Delta Sovereign\_Bond_t$), log growth in price in month t, and ΔX_t includes monthly log and monthly changes of macroeconomic variables in the sample, ΔIP_t and ΔCPI_t respectively. The model is estimated for each country in our sample, taking one unique asset class at a time. The main reason to include macroeconomic variables as exogenous factors in the estimated model is coming from Rigobon and Sack's (2003) research that introduced those variables to control for external shocks. Due to GDP, substituted by Industrial Production, and inflation, proxied by CPI, being of major concern to CBs, their presence captures the likely impact of CBs on those variables, which, if being omitted, would result in biased estimates for financial assets. Variables used in the SVAR model were constructed in the following way:

$$\Delta TA_t = ln\,(TA_t)\; - ln(TA_{t-1})$$

$$\Delta Stock\_Index_t = ln\,(Stock\_Index_t)\; - ln(Stock\_Index_{t-1})$$

$$\Delta CorpBond\_Index_t = ln\,(CorpBond\_Index_t)\; - ln(CorpBond\_Index_{t-1})$$

$$\Delta Sovereign\_Bond_t = \; Sovereign\_Bond_t - Sovereign\_Bond_{t-1}$$

$$\Delta IP_t = ln\,(IP_t)\; - ln(IP_{t-1})$$

$$\Delta CPI_t = CPI_t - CPI_{t-1}$$

where TA_t is the local currency value of the CB's Balance Sheet in month *t*, $Stock\_Index_t$ is the level of a respective country's stock index in month *t*, $CorpBond\_Index_t$ is the level of a respective country's corporate bond index in month *t*, $Sovereign\_Bond_t$ is the yield of the respective country's short and long-term government bonds in month *t*, IP_t is the industrial production level of the respective country in month *t*, and finally CPI_t is the Consumer Price Index of the respective country in month *t*.

Including lags in the model with exogenous macroeconomic variables allows us to outline several essential characteristics of the BS values and financial assets. First, TA's lagged values in equation 1 introduce the persistence of balance sheet changes over time, i.e., whether the Balance Sheet expansion follows a previous increase in TA values. In equation 2, we will see the response of variables to a shock in TA. Similarly, lags of financial assets in equation 2 illustrate the presence of well-known momentum in the asset returns that drive the asset's price during the bull market even further. Lags of financial assets in equation 1 will indicate the average impact and response time of the BS and to a shock in financial assets. We should also be careful in interpreting the results estimated in a logarithmic model. Stock and Watson (2011) outline the interpretation for change in natural logarithm as the percentage change in the respective variable return or growth multiplied by 100. This interpretation is valid for TA, Stock_Index, and Corporate_Index variables. Short- and long-term government bonds are loaded as first differences and are presented in units, i.e., percentage points.

There are several essential aspects of the model to be addressed here. Firstly, the SVAR model uses Bayesian Information Criterion (BIC or also SC) that penalizes for adding more lags (Stock & Watson, 2011). Initial tests of BoxPierce portmanteau statistics (as described by Mahdi and Mcleod, n.d.) for the optimal lag number inclusion indicated that models are usually adequate with no more than 15 lags, suggesting that putting maximum value to 12 would not harm the model. Moreover, BIC criteria usually included much fewer lags. Secondly, historical data must stay the same on average to yield an accurate forecast, meaning its mean, variance, and autocovariance are to remain the same over time (Stock & Watson, 2017). If that is not the case, the observed data is *non-stationary,* and the results tend to be biased. Therefore, it is crucial to check for the stationarity of our dataset via the Augmented Dickey-Fuller test. Stock and Watson (2017) suggest using the first difference of variables, i.e., the difference between current and previous value, to avoid the model's possible non-stationarity. We employed this approach and used the first difference of all variables, some of which were already in log levels. The initial tests on the stationarity of monthly differences resulted in all variables from the dataset being stationary. Lastly, we employ Breusch and Pagan (1980) approach to test serial correlation in residuals from time-series models that might negatively impact the estimation of true errors. Even though the results presented in Section 5.6. are pointing out the presence of serial correlation in some models, Cholesky decomposition described further allows us to tackle this issue.

Due to the cross-correlation between variables in the VAR model, the resulting coefficients' description makes little sense. Thus, for this type of model, one usually estimates Impulse Response Functions (IRF) that illustrate one variable's response to a system *shock* in the other one. To account for the contemporary relationship between the variables in the model, shocks are obtained through Cholesky factorization of the variance-covariance residuals matrix, removing autocorrelation in the model and allowing us to compute Orthogonal responses. The central premise of the Cholesky factorization (decomposition) states that the order of the variables in the sample matters. Cholesky decomposition of VAR model uses a lower-triangular matrix of simultaneous relationship. It suggests that the sample's first variable has a contemporaneous impact on all other variables, while it is not affected by any other variables instantaneously. Consequently, the second variable in the sample impacts the next ones, but not the first one. The last variable in the sample has no contemporaneous effect on other variables. This ordering is called recursive in line with the algorithm explained above. The end outcome of the sequence is a structural shock that provides us with a unique opportunity to observe the lagged asset-specific response to an unexpected increase or decrease in the other variable, e.g., Total Assets. The ordering for macroeconomic variables that we use is supported by the recursive approach used by Bacchiocchi, Castelnuovo, and Fanelli (2017), who ordered the financial instrument after the macroeconomic variables. The intuition employed by Bacchiocchi et al. (2017) and further used in this paper is based on the difference between slow-moving variables, such as macroeconomic ones, and fast-moving ones. Our sample consists of 'fast-moving' stock indices, corporate bond indices and ETFs, short- and long-term yields on government bonds. The financial assets are considered fast-moving since they quickly embed all the available information in the price and yield values available and updated at high frequency. At the same time, one can usually monitor macroeconomic variables several times a year or a quarter.

In the end, the algorithm for calculating IRFs starts with the recursive ordering of the sample, which is then used to estimate the VAR model. Coefficients are then adjusted using the respective order and Cholesky lower-triangular matrix to obtain the model's structural shock and estimate Orthogonal IRFs. We also accumulate individual Orthogonal IRFs to complete a long-run picture of the response to a structural shock in the given variable. We choose 24 periods for the IRFs to account for a slow adjustment in TA and macroeconomic factors. The standard confidence interval for the IRF is equal to 0.95 or 95%, yet we also test 90 and 99 per cent confidence intervals. We will not report or illustrate the effect of structural shock on macroeconomic variables since we primarily use them as exogenous variables in equations 1) and 2).

Hypotheses 4 and 5 introduce another dimension to the VAR model estimated via equations 1) and 2) to account for the possible cross-asset effects in a single country. The reasoning behind including one more asset class is the following: if there is a structural shock in one asset class, we are interested in the second one's response. According to the model specifications described further, the asset class in which the model introduces a structural shock is either government or corporate bonds, which are targets of QE and CE programs, respectively. Even though the spillover effect should ideally be estimated as a path-through effect from the initial shock in TA, we argue that the following specification is valid in the presence of the assumption that the shock in the asset class is purely structural and policy-induced, similar to the model of Gilchrist et al. (2015). Although we are using a time-series model, the logic still holds in that assumption's presence. If we assume a strong connection between government and corporate bonds, there is likely a spillover effect from one to the other in case of a policy-induced shock. Further in the paper, we use the term spillover, assuming the very same logic described above. Since we need to include one more asset to the VAR model, we now estimate three-equation SVAR:

$$\Delta TA_t = \alpha_0 + \sum_{l=1}^{n} \alpha_{1,t-l} * \Delta P1_{t-l} + \sum_{l=1}^{n} \alpha_{2,t-l} * \Delta P2_{t-l} + \sum_{l=1}^{n} \alpha_{3,t-l} * \Delta TA_{t-l} + \cdots \quad (3)$$

$$\Delta P1_t = \beta_0 + \sum_{l=1}^{n} \beta_{1,t-l} * \Delta P1_{t-l} + \sum_{l=1}^{n} \beta_{2,t-l} * \Delta P2_{t-l} + \sum_{l=1}^{n} \beta_{3,t-l} * \Delta TA_{t-l} + \cdots \quad (4)$$

$$\Delta P2_t = \gamma_0 + \sum_{l=1}^{n} \gamma_{1,t-l} * \Delta P1_{t-l} + \sum_{l=1}^{n} \gamma_{2,t-l} * \Delta P2_{t-l} + \sum_{l=1}^{n} y_{3,t-l} * \Delta TA_{t-l} + \cdots \quad (5)$$

where $\Delta P1_t$ and $\Delta P2_t$ are the pair of the financial assets from the list:

- *corporate bond* / *equity index, short-term sovereign bond* / *equity index,* and *long-term sovereign bond* / *equity index* study the presence of spillovers to equities
- *short-term sovereign bond* / *corporate bond,* and *long-term sovereign bond* / *corporate bond* investigate the spillovers to corporate bonds

The last pair, *short-term sovereign bond* / *long-term sovereign bond,* is primarily based on the evidence from Gilchrist et al. (2015) that suggested a significant path-through effect from short- to long-term sovereign bonds. The following pairs of equations are estimated individually for each country. We use the same approach as for the system of equations 1) and 2). We gather a series of Orthogonal responses to structural shocks in each pair's first asset (except the last one that we analysed both ways). The only significant difference from equations 1-2 lies in adding one more variable for recursive ordering, where the tested asset is still loaded the last, while a newly added sovereign or corporate bond is allowed to have an immediate impact on that asset, but not on CB.

To account for international spillovers and address Hypothesis 6, we return to the initial system of equation 1-2 and update it in the following way:

$$\Delta CB_t = \alpha_0 + \sum_{l=1}^{n} \alpha_{1,t-l} * \Delta P_{t-l} + \sum_{l=1}^{n} \alpha_{2,t-l} * \Delta CB_{t-l} + \sum_{l=1}^{n} \alpha_{3,t-l} * \Delta TA_{t-l} + \cdots \quad (6)$$

$$\Delta TA_t = \beta_0 + \sum_{l=1}^{n} \beta_{1,t-l} * \Delta P_{t-l} + \sum_{l=1}^{n} \beta_{2,t-l} * \Delta CB_{t-l} + \sum_{l=1}^{n} \beta_{3,t-l} * \Delta TA_{t-l} + \cdots \quad (7)$$

$$\Delta P_t = \gamma_0 + \sum_{l=1}^{n} \gamma_{1,t-l} * \Delta P_{t-l} + \sum_{l=1}^{n} \gamma_{2,t-l} * \Delta CB_{t-l} + \sum_{l=1}^{n} y_{3,t-l} * \Delta TA_{t-l} + \cdots \quad (8)$$

where ΔTA_t stands for the initial sample of Central Banks, while ΔCB_t introduces FED or ECB to the model. We use recursive ordering and put the ΔCB_t variable before the ΔTA_t values of local CB. This enables us to preserve the logic suggesting that FED and ECB actions are not affected by any changes in the foreign financial market, while they have an instantaneous impact on the financial assets and CBs of other advanced economies. The model employs a similar algorithm to estimate Orthogonal IRFs after accounting for contemporaneous effect via Cholesky decomposition of a lower triangular matrix. The results would provide us with a separate IRF for each financial asset in each country of our sample, indicating whether FED or ECB had any significant impact on the financial assets. The summary table (Table D) also includes the response of local CB to balance sheet expansion of FED and ECB separately.

4.3. Limitation of the study

The first limitation is associated with the data availability. Before dealing with the research's practical part, we discussed which countries to included in the sample. Since, for many CBs, the data on assets was neither publicly available nor had a required frequency, we included only 7 countries in the research. Next, we specifically investigate the impact of unconventional monetary policy tools. However, banks might have resorted to several monetary policy instruments in parallel. Like Rogers et al. (2014), we do not account for mixed-effects that might decrease the real impact of studied policy results in the results part. According to the International Capital Market Association (2021), as a response to the COVID-19 pandemic, CBs from our sample applied multiple policies to reduce the real economy's negative effect. Hence, capturing the impact from the QE or CE program in combination with lower borrowing costs would likely yield a better estimation for the size of both effects. Also, the absence of full-scale studies that employ data on actual purchases resulted in a likely overestimation of the pure announcement effect's possible outcomes.

There are several issues related to the employed econometric model that we address straight away. The primary concern is a lack of computational power coming from low-frequency data. The data on some asset classes, e.g., Corporate Bonds, are coming from 2013 or 2016 only, resulting in 50-60 observations on average. This fact forced us to limit the maximum number of lags to preserve the model's performance as a whole. Furthermore, as was briefly discussed in Section 4.2., the inclusion of another asset class does not account for the spillover effect. Instead, it assumes the present correlation between two asset classes that might enable a path-through effect from one class to the other in the presence of monetary policy shock. Another possibility would be to study the bond spread and examine its response to the policy-induced shock, yet the one also has to control for both yield's performance. Otherwise, the result would not point out the specific spillover effect. Lastly, we acknowledge the presence of more advanced models to estimate international spillovers, e.g., Panel or Global VAR. Yet, those models' technical complexity and the amount of necessary data for cross-country interaction forced us to stick to a more basic Structural VAR.

5. Results and Discussion

We start our empirical assessment with a quick visual scan of the trends in Total Assets of CBs and Stock indices throughout the last decade (Appendix 9). The first notable difference is in the relative increase in the assets of BoC during the coronavirus pandemic. We see that the total value of assets presented on the right vertical axis more than tripled within a minimal period. A similar jump in the value of total assets has been observed in the US, the UK, and Australia. The European Union and India have seen a more modest climb in their assets, while 2020 for BoJ does not seem to be any different from other years. Even though at first glance we see little to no spike in the BS values for BoJ, the nominal increase might be hidden under almost two decades of aggressive monetary policy expansion. According to Sano and Uetake's (2018) report, in early November 2018, BoJ's Balance Sheet reached the GDP of its economy. Even though we can acknowledge a higher rate of growth in the asset started with a decline in Japan Stock Market, we would expect few to zero significant correlations on Stock Indices' lags. Unlike the aggressive monetary policy of BoJ, a tremendous shift in the total assets for Canada seems to move closely beside the recovered national stock index. Although the visual check is not able to identify a causal effect of CB on the stock recovery of stock prices, we believe that the nominal size of BS and its recent upward trend would cause coefficients for FED, Canada, ECB, UK, Australia, and India to be somewhat into a positive zone. Unlike them, we expect Japan to show only a few significant effects due to its high monetary activity, the impact of which is not visible.

5.1. Hypothesis 1: responses of asset classes to shocks in CBs

In the first part of presenting the SVAR analysis results, we would like to elaborate on the responses of the asset classes to the structural shocks in CBs. An example of such shock in a CB can be an asset purchase program initiated by the CB to withstand the consequences of exogenous shock. The regressions' custom periods start with the first implementation of QE (Appendix 6) and end in August 2020.

Table A shows that the strength of the responses coming from stock indices ranged between -4.5 to +10 per cent. For Canada, the UK, Japan, and the US, the response was positive (+10, +1, +2, and +1.2 per cent, respectively). In comparison, the effect was statistically significant only for Canada (at 90 per cent confidence) and the US (at 95 per cent). As of the negative responses in Europe, Australia, and India, these could have been potentially caused by the timing inconsistency caused by low-frequency data. Since the monthly data is usually published on a particular day/week in a month, there might appear inconsistencies with how the stock market responded. Moreover, we might also argue that the positive shock from the CBs' policies might already capture the announcement's response, which we do not cover via our methodology. Thus, an event study approach is needed in these particular cases to investigate whether the immediate market response was too optimistic, i.e., that during the time of QE or CE, the prices were under correction due to an earlier overshooting.

When turning to the corporate bond investigation, it can be found that this asset class experienced a less pronounced impact than the stock indices: for most countries, the price change was around 1 per cent. The response was positive for Canada, the UK, Australia, and the US (+0.65, +1.3, +0.16, and +0.2 per cent, respectively). For Japan, the response of -0.05% was pretty close to zero and not statistically significant. The only country with extremely contradicting results was India, where the price of iShares MSCI India ETF went down by 5%. As seen from negative responses of stock and corporate bond indices, India's contradictory results might come from the following caveats in the data sample. The low number of observations for India (only 56 monthly data points) is a likely reason for such obscure results, considering that a significant portion of them (8) was gathered during the abnormal COVID-19 pandemic. Moreover, the BS data's visual check suggested a continuous monetary policy expansion of the RBI that potentially harnesses the positive impact of specific UMP events during exogenous crises. We present a discussion on the controversial results and their comparison to the literature further on.

Regarding the government bonds, the average response was negative for both maturities and all countries except for the UK 10y government bond. We derive statistically significant results for the 3-month government bonds for Europe, Australia, India, and the US. We observe that the short-term securities response was -0.039 pp on average, with the most substantial impact on Australia and the US. Appendix 12 presents a summary of the financial assets and FED's response to the structural shocks. When looking at the long-term government bonds, we see that all countries had insignificant results, and the effect was around -0.027 pp when accounting only for the negative responses.

Table A. Results of IRFs on the shock in CBs

The shock from BS to	*Canada*	*UK*	*Japan*	*EU*	*Australia*	*India*	*US*
stock index	+10%* (5.5 %)	+1% (0.9%)	+0.5% (3.2%)	-2% (2.4%)	-1.3%* (7%)	-4.5%*[from 2] (1.6%)	+1.2%** (3%)
corporate bond	+0.65%** (4%)	+1.3%*[4-12] (1%)	-0.05% (0.6%)	-0.2%*[1] (1.8%)	+0.16%* (6.7%)	-5%*[from 2] (1.65%)	+0.2% (2.9%)

3m gov. bond	-0.02 pp (4%)	-0.004 pp (0.6%)	-0.008 pp (1%)	-0.04 pp* (2.4%)	-0.1 pp* (7%)	-0.013 pp **from 3 (1.6%)	-0.09 pp** (3%)
10y gov. bond	-0.02 pp (4%)	+0.05 pp (0.8%)	-0.014 pp (3.2%)	-0.01 pp (2.4%)	-0.032 pp (7%)	-0.05 pp (1.6%)	-0.04 pp (3%)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value, significance sign, a period for significance (not stated if significant throughout the whole period), and the value of initial shock (in brackets)*

After briefly describing all the results, we would like to elaborate more on the size of the impact and compare it to what other researchers have established in the previously conducted research (Appendix 4). It is also worth mentioning that the comparison between our methodology of studying the impact from actual purchases and the event study method usually performed with a time-series analysis of key interest rates is not a perfect complement. However, the time-series approach should theoretically yield similar or at least close to accurate results because they are both based on the established theory for UMP's impact. Table A indicates that a positive shock in FED assets, e.g., a newly enforced CE policy to boost the domestic economy's recovery, of 4.2% brought a roughly 1.2% positive impact on S&P 500 price growth (Appendix 12). The results obtained are more potent than for Swanson (2017), who found a 0.1% increase. Additionally, our results were statistically significant, as mentioned above. Interestingly, we derived an adverse reaction of the STOXX Europe 600 price to a 4.8% shock in ECB. The expected result would be positive (Krishnamurthy, Nagel, & Vissing-Jorgensen, 2018) and significant, similar to what Andrade et al. (2016) have established as a 1.3% increase in the price of the same index during the QE programs launched in 2008. For the UK, we have derived a positive impact of +1% on the FTSE100 price, which is close to what has been derived by Haitsma et al. (2016), but, unfortunately, our response was not statistically significant. As for Japan and Canada, we see a positive response, which does not contradict our expectations.

Moving on to corporate bonds' responses, a positive effect on them was proven by Gagnon et al. (2011) and Lasaosa et al. (2011). We get a positive response for Canada, the UK, Australia, and the US, and the effect is significant for three of them. For the European Union, we see a similar pattern as with the stock index - the diminished S&P Eurozone Investment Grade Corporate Bond Index price by around 0.2%. A possible explanation for such ambiguity lies in the ECB's role as a monetary administrator of the whole European economy. The corporate bonds model was likely affected by abnormal events such as the COVID-19 pandemic and the absence of non-Euro countries in the corporate bond index.

As for the government bonds, 4.4% shock in FED was followed by the short-term yield decrease of around 0.09 pp at a significance level of 5% for the whole period. Long-term (10y) government bond yield also experienced a statistically insignificant reduction of approximately 0.04 pp. Numerically, our results coincide with the ones gathered in Appendix 4 - works performing the event study approach found that long-term government bond yields decreased by 38 bp (Gagnon et al., 2011) and 45 bp (D'Amico et al., 2012) after the announcement on the use of the UMP tool. For the European Union, a positive shock in ECB total assets of around 5% resulted in yields going down by 0.04 pp and 0.01 pp for short and long-term AAA-rated bonds. Results are statistically significant and are close to what Andrade et al. (2016) derived for the short-term maturity government bonds. The yields of Japanese bonds for both maturities went down in response to the increase in the size of the Balance Sheet of BoJ; numerically, we have obtained -0.008 pp and -0.014 pp for the short and long-term treasuries, respectively. Arai (2017) and Hausman and Wieland (2014) derived a decrease in the yield of 14bp and 11bp, respectively, close to our findings. Nonetheless, the responses are not significant for Japan considering its aggressive monetary policy stance (Appendix 3). We also note that there was a negative impact on both 3m and 10y government bond yields for Canada, Australia, and India. To sum up, all the countries' government bond yields behave predominantly negative, and for the 3m maturity, we have also obtained statistically significant responses.

In conclusion, we can say that Canada and the US displayed entirely consistent results, while for the UK, Japan, and Australia, three assets demonstrated an estimated response. The least strong results were obtained for Europe and India; however, it is not enough to reject Hypothesis 1. Table H presents a summary of the results for all hypotheses.

5.2. Hypothesis 2: persistence of the effect for assets

Another critical insight we have obtained from the structural VAR analysis and cumulative response functions is the effect's persistence. For the first group of assets, stock indices, the impact remained in place for an average of 4.3 months. S&P/TSX Composite index (Canada) had the most prolonged effect lasted for 5 months, while for Nikkei 225 (Japan), FTSE 100 (UK), and S&P 500 (US), it was 4 months respectively. The corporate bonds results show that the volatility in price is persistent for approximately 7.5 months for our country sample. Investigation of the impact on the government securities demonstrates that the short-term bonds' yield accumulated the total effect in around 4.6 months. For Europe, Australia, India, and the US - counties with the statistically significant results, impact remained persistent for 6, 5, 3, and 2 months. As for the long-term bonds, the average time for the effect to hold was around 4 months.

In general, we got very close results in terms of impact persistence for most of the responses that went in line with the literature according to the effect's sign. For the stock indices, stock price volatility holds for approximately four months, while Mamaysky (2018) observed the effect to stay for a few weeks. We believe that a considerable duration of post effect could be explained by a tremendous shock to the total assets of CBs this time compared to the GFC. To exemplify, the analysis of our data sample show that during 2008, FED assets increased by 130%, while in 2020 the increase was only 75%. However, the nominal increase during the year 2020 was larger than the size of FED BS back in 2008. Results on the lengths of the corporate bonds' impact are similar to the stock indices; we see that the response time during which the effect is wholly incorporated in the corporate index prices is much longer than what has been found by Wright (2011). Lastly, when evaluating the impact on government securities, we see that the results obtained are close to Neely's (2016) and Gros's (2018) investigations (Appendix 5); volatility in bond yields was persistent for approximately five months. The preliminary conclusion to be drawn here suggests that in most cases, the timing of the effect proposed in Hypothesis 2 is in line with the baseline model predictions (Table H); therefore, we can not reject Hypothesis 2.

5.3. Hypothesis 3: responses of CBs to shocks in asset classes

Another block of results that have been derived from the cumulative impulse response functions is related to the shock transposed from the asset classes to the BSs of the CBs. Referring to the theory, the CBs should be the opposite compared to the impact on asset classes described in Section 5.1. From the results summarized in Table B, we see that stock indices predominantly negatively affected the BSs. For the five banks from the sample (BoC, BoE, ECB, RBA, FED), the BS size went down by an average of 0.73%, with Europe and the US bearing a statistically significant impact. In general, we see that shock from the stock index has not exceeded 5.5%; the only deviation is present for the S&P/TSX Composite index where shock amounted to 50% that can be partly explained by the magnitude of an index price increase during the late events of 2020 (Appendix 9).

As for the corporate bonds' shock, the response to a structural shock was negative for everyone except Japan, likely due to their aggressive QE policy. The impact varied from +0.4% to -9.5%, and the obtained results remained significant for Europe and the US as for the stock indices, and Canada joined. The impact obtained from the government bonds shock is less promising. We observe that for the short-term maturity, there was a positive effect for Europe (+0.5%), Australia (+0.6%), and India (+0.3), meaning that an increase in bond yields contributed to the reduction of the BS size. At the same time, theoretically, it should be the opposite. However, the results were not significant at the 90% confidence level. The negative response of other countries could be attributed to the timing issues explained in Section 5.1. Another potential reason for such inconsistent results is likely to come from the CBs stance over the short-term increase against long-term rates. While CB might tolerate an increase in short-term bonds to some degree, since they largely control Treasury and other repo yields, long-term yields, such as the US 10-year government bond yield, are of particular concern. Scheid and Rocha (2020) highlight that significant changes to 10-year yields harm the borrowers via raising mortgage and other usual interest that derive most of their nominal rate from such benchmark yields. They also refer to the idea that FED might take a step back and not introduce any QE program or lower borrowing costs until some extreme level. Despite a joint agreement in the literature on the need for CBs to control key rates all the time, the real actions indicate that it might not hold in some cases. Another possible explanation for the controversial results for short-term yields is coming from the monetary policy definition, which also takes into account key sovereign yields that determine borrowing costs in a particular country. In case of a structural increase in the interest attributed to an aftershock restoration of the economy, CBs will decrease their balance sheets. For the long-term securities, the model yielded a positive impact for five countries, while for Europe, it was slightly negative, and for Canada, it reached -1.2%.

Table B. Results of IRFs on the shock in financial assets

Response of BS to	***Canada***	***UK***	***Japan***	***EU***	***Australia***	***India***	***US***
stock index	-0.9% (42%)	-1% (3.6%)	+0.1% (5.5%)	-0.8%** (4%)	-0.15% (4%)	+0.2% (4.7%)	-0.8%*** (4%)
corporate bond	-9.5%** (0.7%)	-0.3% (1.7%)	+0.4% (0.4%)	-1.3%** (0.65%)	-0.3% (0.45%)	-0.1% (5.2%)	-1%*** (1.85%)
3m gov. bond	-3%*** (0.16 pp)	-4%*** (0.07 pp)	-0.4% (0.055 pp)	+0.5 (0.08 pp)	+0.6% (0.15 pp)	+0.3% (0.19 pp)	-8%** (0.08 pp)
10y gov. bond	-1.2% (0.195 pp)	+1.2% (0.2 pp)	-0.2% (0.098 pp)	-0.1% (0.13 pp)	+0.2% (0.22 pp)	+0.4% (0.21 pp)	+0.22% (0.22 pp)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value, significance sign, a period for significance (not stated if significant throughout the whole period), and the value of initial shock (in brackets)*

When discussing opposite shocks directed from the assets, Smets (1997) proved that CBs are likely to respond, and the response should be the opposite to Hypothesis 1. As for the stock indices, we see that a 4% positive shock in S&P 500 caused a decrease in FED total assets by 0.8%; the effect remained significant at 99 per cent confidence. We obtain a similar response for ECB - a positive 4% shock on STOXX Europe 600 decreased total assets by 0.8% (95 per cent confidence). For BoE, BoC, and RBA, we also see a negative response; however, it remains insignificant. The shock from the corporate bond indices to the total assets of CBs is predominantly negative. The most vigorous negative response of -9.5% was observed in Canada, and it was followed by statistically significant results of -1.3% for the European Union. Structural shock in government bond yields would ideally cause an expansion of CB assets according to the basic theory of a negative relationship between products and prices. Still, we see that the theory holds only for India and Australia. Summing it up, the results are not homogenous across all countries. Yet, we do not reject Hypothesis 3 for six of them, with the only exception being Japan.

5.4. Hypotheses 4 and 5: cross-asset spillovers

After deriving results on the impact transmitted from the CBs purchases to the asset classes and vice versa, we have worked on computing the spillover effects between the asset classes (Table C) to address Hypotheses 4 and 5. We can see that a strong positive impact is present for the spillover from corporate bond indices to equity for all countries except for Japan. Strengths of the effect ranged from -1.2 to 3.7 per cent for Japan and Australia, respectively. The results obtained are significant for India (at 99 per cent confidence), the UK (at 95 per cent), Europe, Australia, and the US (at 90 per cent).

As for the spillover effect from government bonds to corporate bond indices, there is a predominantly strong negative relationship. However, the spillover on corporate bonds price is more significant for the longer maturity bond. Spillover from the 10-year bond to corporate bond was on average -0.78 per cent, and it was substantial at 99 per cent confidence for Canada, the UK, Japan, Europe, and the US. The most significant impact of -1.3% was established for the US, and the most negligible response was observed for Australia (-0.14%). The shock from the 3-month bond was negative for four countries from the sample: Canada, the UK, India, and the US (-0.45, -0.05, -1, -0.7 per cent respectively), while for Canada and the US, the impact also remained significant at 99 per cent confidence.

The shock from the government bonds to equity, in general, was varying across countries. Spillover from the 10y government bonds was in the range between -3.5 and +1.4 per cent. For three countries, it was negative (Canada, the UK, India), while for others, there was a positive response. For Japan, the spillover effect of +1.3% was significant at 90 per cent confidence, while for Australia (+1.2%) and the US (+1.4), it was 99 per cent. Response of equity to 3m government bonds was positive for all countries except for India. For the UK, Japan, Europe, Australia, and the US, the spillover has not exceeded 1%, while for Canada, it reached +6% at 90 per cent confidence.

Table C. Results of cross-asset IRFs on the shock in financial assets

Type of spillover	*Canada*	*UK*	*Japan*	*EU*	*Australia*	*India*	*US*
Shock from corp. bond to equity	+2.2% (0.6%)	+1.7%** from 2 (1.6%)	-1.2% (0.4%)	+0.9%*[1] (0.63%)	+0.9%* (0.45%)	+3.7%*** (5.3%)	+0.5%*[1] (1.8%)
Shock from 10y gov. bond to corp. bond	-0.63%*** (0.18 pp)	-1.2%*** (0.2 pp)	-0.73%*** (0.06 pp)	-0.48%*** (0.11 pp)	-0.14% (0.18 pp)	-1% (0.21 pp)	-1.3%*** (0.22 pp)
Shock from 10y gov. bond to equity	-3.5% (0.195 pp)	-0.5% (0.19 pp)	+1.3%*** (0.097 pp)	+0.15% (0.13 pp)	+1.2%*** (0.22 pp)	-0.4% (0.21 pp)	+1.4%*** (0.22 pp)
The shock from 3m gov. bond to corp. bond	-0.45%*** (0.088 pp)	-0.05% (0.08 pp)	+0.06% (0.06 pp)	+0.08% (0.06 pp)	+0.15%* (0.088 pp)	-1% (0.19 pp)	-0.7%*** from 2 (0.075 pp)
Shock from 3m gov. bond to equity	+6%*1 (0.17 pp)	+1% (0.065 pp)	+0.05% (0.054 pp)	+0.6% (0.08 pp)	+0.8% (0.15 pp)	-0.7% (0.19 pp)	+0.25% (0.08 pp)
Shock from 10y gov. bond to 3m gov. bond	+0.016 pp (0.185 pp)	+0.03 pp** (0.19 pp)	+0.005 pp (0.065 pp)	-0.01 pp (0.125 pp)	+0.04 pp** (0.21 pp)	-0.035pp (0.19 pp)	+0.015 pp (0.22 pp)
Shock from 3m gov. bond to 10y gov. bond	+0.047 pp *** (0.17 pp)	+0.05 pp (0.06 pp)	+0.005 pp (0.054 pp)	+0.046 pp*[1-3] (0.08 pp)	+0.09 pp*** (0.15 pp)	+0.09 pp*** (0.19 pp)	+0.07 pp*** (0.08 pp)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value, significance sign, a period for significance (not stated if significant throughout the whole period), and the value of initial shock (in brackets)*

Lastly, concerning spillovers between government bonds of different maturities, we obtained only two negative responses for the spillover from long to short-term government bonds in Japan and India, countries exercising an aggressive UMP. For other cases, we observe a significant positive response coming both ways, even though the marginal effect from the shock in short-term (3m) bonds is more powerful. To generalize, cross-asset spillovers' outcome ended up being more significant than individual responses of financial assets to QE or CE programs. According to Gagnon et al.'s (2011) ' proposition, in the event of unattractive yield, investors are likely to change the composition of their portfolios by shifting to more risky assets. It was indeed the opposite for the corporate bonds: favorable movement in sovereign yields likely caused a drop in the demand for corporate bonds, the price of which plummeted. Unlike this class of private assets that receive compensation for the spread in yields compared to sovereign bonds, equities are likely to get their value from portfolio balance and smaller cash flow discount value. Yet, we spot a positive correlation between a surge in yields and stock prices that might be partly caused by an overall negative public perception of the UMP announcements followed by actual purchases (Joyce et al., 2010). Moving on, since the ideal response of equities and corporate bond index prices should be negative in respect to the rise in sovereign yields, both private assets should have a positive correlation between them - precisely the result from the Orthogonal IRFs. Finally, similarly to Gilchrist et al. (2015), we find a positive relationship between short- and long-term sovereign yields with a spillover effect from short-term assets being larger. They reveal a 4 basis point decline in 10-year Treasury yields, while we have 7 basis points decline from a similar shock (though we have a shorter maturity of the second bond). Summing up the significant but, in some cases, ambiguous results (Table H), we conclude that cross-asset spillover is an essential determinant of future monetary policies due to a high degree of interconnections between various assets.

5.5. Hypothesis 6: international spillovers from FED and ECB

The final test using the SVAR model aims at examining Hypothesis 6 that suggests partial spillover from the major CBs, such as FED and ECB, to the financial assets of advanced economies. In reality, Table D and E highlight a much stronger response from advanced economies (and arguably India) to the shock in FED rather than that of ECB, with the only exception being the UK and its 3-month government bond. Although FED exercised more significance over the financial assets, the response of other CBs to the shock in either FED or ECB was significantly more unified, especially for the UK, Canada, and Australia, which have arguably the closest financial and trade linkages to both economies. Elaborating on FED's specific response, stock indices are generally experiencing a positive but not significant impact. The UK is seen as a clear outlier from this perspective, highlighting a significant negative response to private asset classes. Another contradicting result that we obtain suggests an almost immediate surge in the short-term Australian yield after a 2.8% shock coming from FED. The ideal response of foreign assets, as was discussed in Section 2.5.2., ought to be similar to the domestic response of US prices (yields) that surge (decline) after the implementation of QE or CE policy. Another force might also cause the issue in place that recently uplifted US yields from their record lows (Duguid, 2021) – investors' perception. After cutting borrowing costs to near-zero levels and launching a new QE program, the US experienced a severe outflow of funds from low-yield assets, such as government bonds, to a riskier investment. It caused a drop in the demand for sovereign bonds and boosted yields from their abnormally low level in 2020. Here, we would argue that Australian bonds, while not directly subject to the FED policy, still experienced the shift in demand and subsequent rise in yield that exceeded the potential impact from the monetary policy itself. Similarly, after the US stock prices skyrocketed after hitting the decade's lowest values, investors from the UK specifically might have switched to the US sector with strong government support, while Europe was still lagging in response. Thus, we would also argue that investors' individual preferences might differ for the countries regardless of their monetary and trade connections to the US.

Table D. Results of international IRFs on the shock in FED

Response to FED from	*Canada*	*UK*	*Japan*	*EU*	*Australia*	*India*
stock index	+4% (2.9%)	-1%**1-2 (3.2%)	+1.6% (3%)	-	+0.2% (2.6%)	+1% (4%)
corporate bond	-0.05%**1-3 (2.9%)	-0.7%**1 (4%)	-0.25% (3.3%)	-	-0.05% (2.4%)	+1% (4%)
3m gov. bond	-0.08 pp** (2.8%)	-0.06 pp* (3.2%)	-0.01 pp (3%)	+0.013 pp (2.5%)	+0.07 pp* (2.6%)	-0.20 pp** from2 (4%)
10y gov. bond	-0.04 pp (2.9%)	+0.003 pp (3.2%)	+0.015 pp (3%)	+0.02 pp (2.5%)	+0.018 pp (2.6%)	+0.005 pp (4%)
Balance Sheet	+9%** (2.9%)	+3.3%** from2 (3.4%)	+0.4% (3.1%)	+1.5% (2.5%)	+2.6%** (2.55%)	+1.2%** (4%)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value, significance sign, a period for significance (not stated if significant throughout the whole period), and the value of initial shock (in brackets). Two missing values for the EU represent an internal error in the model that we could not fix. Altering the maximum number of lags did not help in addressing the issue. Values for Balance Sheet response are calculated as averages of the response for each series of equations, i.e., as the average of 4 results*

Table E. Results of international IRFs on the shock in ECB

Response to ECB from	*Canada*	*UK*	*Japan*	*US*	*Australia*	*India*
stock index	-0.05% (2.5%)	-0.5% (2.7%)	-0.7% (2.5%)	-0.02% (2.8%)	-0.4% (2.8%)	+1.6% (2.5%)
corporate bond	-0.08% (2.8%)	+0.4% (2.5%)	-0.02% (2.8%)	+0.33% (2.8%)	-0.06% (2.9%)	+2.7% (2.6%)
3m gov. bond	+0.003 pp (2.4%)	-0.04 pp* (2.7%)	+0.005 pp (2.4%)	-0.015 pp (2.8%)	-0.003 pp (2.8%)	-0.055 pp (2.5%)
10y gov. bond	+0.007 pp (2.4%)	+0.02 pp (2.7%)	+0.009 pp (2.4%)	-0.02 pp (2.8%)	-0.015 pp (2.8%)	+0.005 pp (2.5%)
Balance Sheet	+3.6%**[1-3] (2.5%)	+3.3**[from 2] (2.65%)	+1.1%** (2.5%)	-0.2% (2.8%)	+2.3%** (2.8%)	+0.9% (2.5%)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value, significance sign, a period for significance (not stated if significant throughout the whole period), and the value of initial shock (in brackets). Values for Balance Sheet response are calculated as averages of the response for each series of equations, i.e., as the average of 4 results*

Even though we partly covered international spillovers via estimating the response of the foreign financial assets on FED and ECB policy measures, results outlined in the research of Gagnon et al. (2017) are coming from the changes in US sovereign yields, which we have two in our sample. Hence, we would like to elaborate on the international spillovers coming from the US and obtain the Orthogonal IRFs via including either 3-month (Table F) or 10-year (Table G) as the second asset, in a similar manner to equations (3) - (5). The logic for recursive ordering remains similar to the one employed in cross-asset regression, where the newly added ‘shock’ asset is not contemporaneously affected by the local bond or stock. Results ended up being much more promising than the shock in BS of FED. In both cases, foreign government yields have shown a positive correlation with the shock in US short- and long-term yields, with Canada's most exceptional case, which is not surprising considering it is the closest neighbour of the US. The path-through effect to corporate bonds is not that visible for 3-month bonds like it is significant for the 10-year yield. A positive shock to the US 10-year yield seems to attract investors worldwide, causing a decline in demand for corporate bonds in other countries. Notably, the effect is reversed for equities, illustrated by a significant increase in the stock index prices for both types of sovereign yields. We can partly attribute it to the previous discussion on the individual preferences that might have moved some investors out of ‘too’ risky bond markets towards equities that are arguably much riskier. The possible explanation might come from the argument that even though yields are rising, the current level is still not too high to cause severe worries over the inflation projections, etc. Thus, the stock market rally continues with a small yet significant boost from sovereign yields.

Table F. Results of international IRFs on the shock in US 3-month yield

Response to FED 3m bond from	***Canada***	***UK***	***Japan***	***EU***	***Australia***	***India***
stock index	-6% (0.15 pp)	+1%*[1-2] (0.15 pp)	+1.6%** (0.2 pp)	+0.2% (0.115 pp)	+1.6%** (0.2 pp)	+0.9%*[1] (0.18 pp)
corporate bond	-0.2% (0.14 pp)	+0.4% (0.18 pp)	+0.14% (0.15 pp)	-0.5% (0.1 pp)	-0.08% (0.13 pp)	+2% (0.18 pp)
3m gov. bond	+0.1 pp** (0.15 pp)	+0.066 pp** (0.15 pp)	+0.12 pp (0.2 pp)	+0.003 pp (0.11 pp)	+0.07 pp* (0.2 pp)	+0.26 pp** (0.18 pp)
10y gov. bond	+0.05 pp **[from 2] (0.15 pp)	-0.015 pp (0.15 pp)	+0.007 pp (0.2 pp)	-0.008 pp (0.11 pp)	+0.02 pp*[1-2] (0.2 pp)	+0.08 pp (0.17 pp)
Balance Sheet	-7%** (0.15 pp)	-1.9% (0.16 pp)	-0.8%** (0.19 pp)	-1.5% (0.11 pp)	-0.7% (0.18 pp)	-1.2%** (0.18 pp)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value, significance sign, a period for significance (not stated if significant throughout the whole period), and the value of initial shock (in brackets). Values for Balance Sheet response are calculated as averages of the response for each series of equations, i.e., as the average of 4 results*

Table G. Results of international IRFs on the shock in US 10-year yield

Response to FED 10y bond from	***Canada***	***UK***	***Japan***	***EU***	***Australia***	***India***
stock index	-5% (0.245 pp)	+0.7% (0.20 pp)	+1.7%** (0.245 pp)	+1%* (0.21 pp)	+0.7%* (0.235 pp)	+1.5% (0.21 pp)
corporate bond	-0.53%** (0.20 pp)	-0.5% (0.21 pp)	-0.32%** (0.2 pp)	-0.34**[from 2] (0.21 pp)	-0.17% (0.20 pp)	+1.7% (0.21 pp)
3m gov. bond	+0.057 pp** (0.24 pp)	+0.036 pp** (0.205 pp)	+0.50 pp (0.255 pp)	+0.019 pp (0.215 pp)	-0.012 pp (0.233 pp)	+0.10pp**[from 2] (0.21 pp)
10y gov. bond	+0.18 pp** (0.245 pp)	+0.11 pp** (0.18 pp)	+0.053 pp** (0.253 pp)	+0.145 pp** (0.215 pp)	+0.18 pp** (0.24 pp)	+0.05 pp (0.21 pp)
Balance Sheet	-1.4% (0.232 pp)	+1.7* (0.198 pp)	-1.4** (0.24 pp)	-0.4% (0.21 pp)	-0.4 (0.227 pp)	-1.2**[from 2] (0.21 pp)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value, significance sign, a period for significance (not stated if significant throughout the whole period), and the value of initial shock (in brackets). Values for Balance Sheet response are calculated as averages of the response for each series of equations, i.e., as the average of 4 results*

Major findings on international spillovers confirm two parts of Hypothesis 6 simultaneously. First, FED indeed has a high correlation with a monetary expansion of other advanced economies that follow its lead. As can be seen from positive coefficients in Table D. Second, we mostly see a positive correlation between FED shock and equity prices. The ECB shock has caused a significant impact only in a closely related BoE and the UK prices, while not being such an essential entity for other countries and the US in particular - the same conclusion drawn by Duca et al. (2016). By investigating the impact of the US sovereign yields, we found a strong response of other yields and prices in all countries, including the EU. In line with Gagnon et al. (2017), we highlight a clear correlation between US sovereign yields and those of other advanced economies.

Table H provides us with a quick overview of the results for 6 tested hypotheses in 7 countries. Canada, the UK, India, and the US have the highest success rate of over 70%, i.e., on average, we could not reject 4 out of 6 hypotheses. Australia performed the test relatively well while having more pronounced international effects than those of Japan, Europe, and even the US. Unfortunately, the EU's performance was not as good on both local and international levels, like caused by several aforementioned factors. Results for Japan met our expectations for the country that was the first to introduce UMP and continue its implementation for almost two decades.

Table H. Summary of empirical findings for Hypotheses 1-6

	Canada	*UK*	*Japan*	*EU*	*Australia*	*India*	*US*
Hypothesis 1	4/4**	3/4 *	3/4	2/4*	3/4**	2/4*	4/4**
Hypothesis 2	7.25 mon.	6.33 mon.	3.7 mon.	4.5 mon.	4 mon.	3.5 mon.	3.75 mon.
Hypothesis 3	2/4*	3/4	0/4	3/4**	4/4	3/4	3/4**
Hypothesis 4	2/2**	2/2*	1/2 *	1/2 *	1/2	2/2	2/2**
Hypothesis 5	2/3*	2/3*	0/3	1/3*	1/3*	3/3*	1/3*
Hypothesis 6	2/3**	2/3*	1/3	1/3**	3/3**	3/3	2/3**

*Notes. When approving Hypothesis 2 we rely only on the results that go in line with the literature review according to the impact's sign. The acceptance rate represents the total number of IRFs that went in line with the particular Hypothesis, while the significance sign illustrates the strength of the effect. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%.*

5.6. Robustness and serial correlation tests

The methods section has described an important test for the time-series model employed in this study. Wrong estimation of error terms would result in over/underestimation of regression coefficients. Initial misspecification tests (Table I) run via Breusch and Pagan LM test indicated that Cholesky decomposition was a crucial part of the model. LM test highlighted that models for the EU, the UK and several other short-term bond regression might have serially correlated errors. However, in the majority of the cases, the model showed promising numbers that would not allow us to reject the null hypothesis in the absence of serially correlated errors.

Table I. Results of serial.test on residuals from Table A and B

Equation series	*Canada*	*UK*	*Japan*	*EU*	*Australia*	*India*	*US*
stock index	0.3557	0.0011	0.6073	0.0008	0.2131	0.1795	0.0637
corporate bond	0.4259	0.3638	0.1221	0.0355	0.5113	0.2197	0.2628
3m gov. bond	0.1180	0.0113	0.0000	0.0000	0.0006	0.7981	0.0011
10y gov. bond	0.7405	0.0210	0.6615	0.0004	0.0598	0.4893	0.4157

Note: numbers are rounded up until the fourth digit after the comma

However, there is one more bias that can be attributed to an exogenous factor, being the COVID-19 pandemic. The paper has mentioned a few attributes of the pandemic that might have impacted our empirical results, such as extreme confidence in the power of CB and an enormous amount of QE or CE programs. Hence, it was decided to run a robustness test on the very same sample of countries and assets excluding the data from the year 2020. The results are presented in Table J.

Table J. Results of IRFs on the shock in CB and financial assets (data prior 2020)

The shock from BS to	*Canada*	*UK*	*Japan*	*EU*	*Australia*	*India*	*US*
stock index	+10% (+10%*)	-0.1% (+1 %)	+0.5% (+0.5%)	-0.05% (-2%)	-0.7% (-1.3%*)	-2.3%**$^{from\ 2}$ (-4.5%*$^{from\ 2}$)	+2%***$^{from\ 2}$ (+1.2%**)
corporate bond	-0.03% (+0.65%**)	-0.3% (+1.3%*$^{4-12}$)	+0.2% (-0.05%)	-0.07% (-0.2%*^{1})	+0.14%** (+0.16%*)	-2%**$^{from\ 2}$ (-5%*$^{from\ 2}$)	+0.55**$^{from\ 2}$ % (+0.2%)

3m gov. bond	-0.03 pp (-0.02 pp)	-0.001 pp (-0.004 pp)	+0.8 pp (-0.008 pp)	-0.05 pp* (-0.04 pp*)	-0.1 pp (-0.1 pp*)	-0.01 pp (-0.013 pp ** from 3)	-0.06 pp*** (-0.09 pp**)
10y gov. bond	-0.042 pp (-0.02 pp)	+0.05 pp (+0.05 pp)	-0.015 pp (-0.014 pp)	-0.02 pp (-0.01 pp)	-0.04 pp (-0.032 pp)	-0.025 pp (-0.05 pp)	-0.01 pp (-0.04 pp)

Response of BS to	***Canada***	***UK***	***Japan***	***EU***	***Australia***	***India***	***US***
stock index	-0.3% (-0.9%)	+0.2% (-1%)	+0.1% (+0.1%)	-0.7% (-0.8%**)	-0.5% (-0.15%)	+0.22% (+0.2%)	-0.5%* (-0.8%***)
corporate bond	-0.1% (-9.5%**)	-0.6% (-0.3%)	+1% (+0.4%)	-0.05% (-1.3%**)	0% (-0.3%)	+0.05% (-0.1%)	-1.3%*** (-1%***)
3m gov. bond	-0.3% (-3%***)	-0.3% (-4%***)	+0.3% (-0.4%)	+0.3 (+0.5%)	+0.5% (+0.6%)	+0.22% (+0.3%)	+0.6%** (-8%**)
10y gov. bond	+0.55% (-1.2%)	+0.05% (+1.2%)	-0.2% (-0.2%)	+0.2% (-0.1%)	+0.5% (+0.2%)	+0.3% (+0.4%)	+0.4% (+0.22%)

*Notes. *** means significant at 99% Bootstrap Confidence Interval, ** at 95%, * at 90%. Each cell contains the response value using data before 2020, significance sign, a period for significance (not stated if significant throughout the whole period), and the response value including data from 2020 (in brackets)*

We observe relatively similar coefficients to what has been seen in Table A and B. The response of stock indices remained the same for every country, except the UK, which now experienced a negative yet still insignificant shock. Although corporate bonds response has changed for some countries to the opposite sign, coefficients are not significant and, hence, we are not able to conclude on whether there were some structural changes in the year 2020. Impulse responses of short-term government bonds remained in the same area for every country, except Japan which has not shown a sign of significance. As to the long-term security, estimations perfectly coincide with the results obtained via the inclusion of COVID-19 in the model, suggesting that the response of CBs to a different crisis was still in line with the theoretical model. The reverse effect has been largely consistent with previous results, except for the response of FED to a shock in 3-month yield, which now has moved into a positive zone with 95% significance. Summing it up, we do not observe any significant changes to the results through removing COVID-19 related observations in 2020. Likely, the response of major CBs was precisely calculated and based on previous experience in similar events, such as the GFC of 2008 and the European Debt Crisis in 2011-2012.

6. Conclusion

The paper investigates the influence of the COVID-19 pandemic on the model of monetary policy, UMP in particular. The recent events with an unprecedented amount of CBs' purchases offered a possibility for immense research on the impact of the actual purchases, rather than a commonly used analysis of policy announcements. We utilize the opportunity to perform an extensive check on QE and CE's impact by estimating four different financial classes' local responses in seven countries. Furthermore, we elaborate on the presence of cross-asset and international spillover effects that are possible due to portfolio rebalancing of investors and cash flow discount reduction for private assets. The sample is constructed to take advantage of the existing time-series methods for assessing monetary policy impact.

The empirical findings suggest that UMP tools positively impact the prices of private assets while decreasing the sovereign yields, indirectly reducing borrowing costs. The response time of assets is usually swift, and if the shock in financial assets were significant enough, the response from a CB would come within the next few months, depending on the country. We were also able to capture substantial cross-asset spillovers mainly coming from sovereign yields towards private assets. The US proved to be an essential CB in the world economy, having a significant impact on other countries' assets and policies. In contrast, ECB had much less influence on other advanced economies. Overall, UMP appeared to be an effective tool in fighting adverse shocks, such as the COVID-19 crisis. Thus, we conclude that the most recent financial market crush has not caused any significant changes to UMP tools' performance.

We want to highlight that scholars should bring more attention to the existing cross-asset and cross-country connections that can conceal some unfavourable trends in prices. Therefore, there is an open space for further research on the topic that might include a different sample and a smaller period with more frequent data, as well as introducing a more advanced model capturing both cross-asset and cross-country effects simultaneously.

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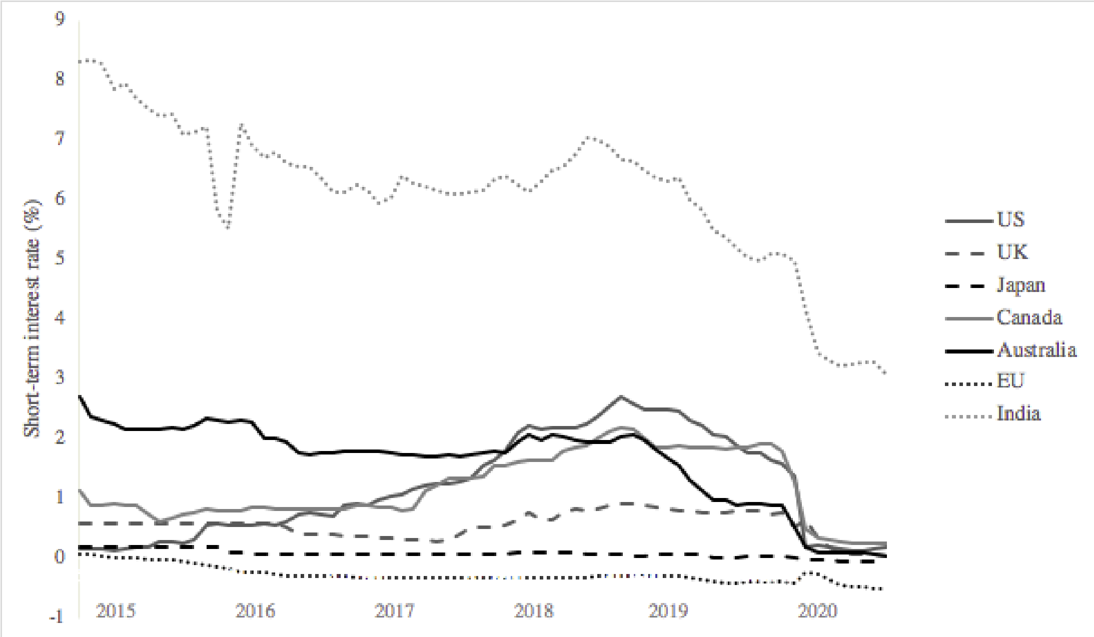
Appendices

Appendix 1

Short-term interest rates for the counties in the sample. Created by the authors (OECD, 2021)



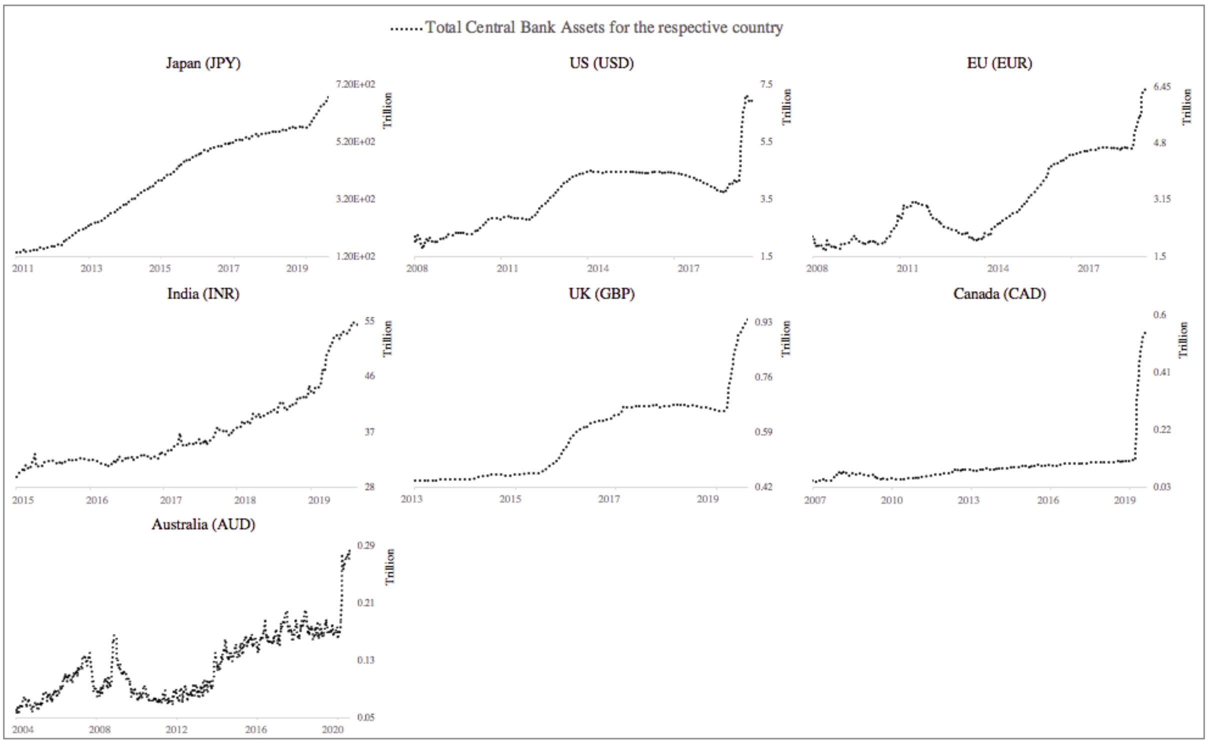
Appendix 2

Announcements and actual size of QE during COVID pandemic 2020. Created by the authors

Central Bank	*UMP start date*	*Size of announced QE purchase*	*Source*	*Size of actual QE purchase as of August 26, 2020*
Bank of Canada	March 27	3.5 billion USD per week	Hagan, 2020	388.226 billion USD
Bank of England	March 19	200 billion GBP	Bank of England	280.665 billion GBP
Bank of Japan	April 27	20 trillion JPY in corporate bonds; Unlimited JGBs and T-Bills	Bank of Japan	63.157 trillion JPY
European Central Bank	March 18	750 billion EUR	ECB	1,513 billion EUR
Reserve Bank of Australia	March 19	Unlimited	Reserve Bank of Australia	59.725 billion AUD
Reserve Bank of India	March 20	400 billion INR	Reserve Bank of India	735.669 billion INR
U.S. Federal Reserve	March 16; March 23	700 billion USD; Unlimited	Hartley & Rebucci, 2020	2,322 billion USD

Appendix 3

Evolution of Total Assets for the CBs in the sample. Created by the authors



Appendix 4

Effects of QE in different regions on macroeconomic variables and asset classes. Created by the authors.

Paper	*Description*	*Sovereign bond yields*	*Real GDP*	*Price level*	*Stock prices/Indices*
Euro Area					
Andrade et al., 2016	APP effect. DSGE models and time series	-45bp	+1.1%	+0.4% actual, +0.45% expected	+1.3% on average (2.8% increase in the STOXX Europe 600 Banks index) *Banks' stock prices
Cova et al., 2015	APP effect. DSGE model		+1.4%	+0.8%	
Koljen et al., 2016	APP effect on portfolio holdings	-13bp on average. Results vary between -2bp and -60bp; larger effect in distressed countries			
Krishnamurthy et al., 2018	UMP effect on European bond yields	For 2Y bonds: from -200bp (Italy, Spain) to -1000bp (Greece)			Positive effect
UK					
		-150bp	+2%	+1%	

Bridges & Thomas, 2012	Effects of QE1 (£200 bill). Money D&S model				
Christensen & Redebusch, 2012	Effects QE1 and QE2 (£275 bill in total)	Results vary between -50bp and -100bp			
Churm et al., 2015	Effects of QE2 and QE3 (£175 bill in total). VAR model	-45bp	+0.5% (QE2); +0.8% (QE3)	+0.6%	
Lasaosa et al, 2011	Effects of QE1 (£200 bill). Event study	-100bp			
Japan					
Arai, 2017	Effects of QQE1. Event study	-14bp			
Hausman & Wieland, 2014	Effects of QQE1 announcements. VAR model	-11bp	1%		
Kan et al., 2016	Effects of QQE1. Large-scale macroeconomic model		From +0.6% to +4.2%	From +0.3% to +1.5%	
FED					
Doh, 2010	Effects of QE1 ($600 bill). Event study	-24bp			
Gagnon et al., 2011	Effects of QE1 ($600 bill) announcements. Time series, event study	-38bp (duration adjusted model); -82bp (unadjusted model)			
Neely, 2013	QE1 ($600 bill) effect on foreign bond yields. Event study	-17bp (+-13bp)			
D'Amico et al., 2012	Effects of QE2. Event study	-45bp			
Swanson, 2017	Effects of QE1 ($600 bill) announcements	-12bp			+0.1% (not statistically significant)
Wright, 2012	Effects of QE announcements. VAR model	-25bp; for MBS -15bp			Positive effect
Different countries					
Haitsma et al., 2016	Effects of UMP announcements	-6bp			+0.5% on EURO STOXX 50 & FTSE100

Hartley & Rebucci, 2020	Effects of QE announcements during COVID	-23bp average single day impact; -31bp average 3-day impact (emerging markets have a greater effect)

Notes. The majority of works use announcements with the time series approach since authors were aimed at the short-run impact. We focus more on the long and medium-run effects; therefore, we allow our results to deviate from the ones presented in the table numerically. The respective table was strongly reliant on the Bhar, Malliaris, and Malliaris (2015) and Dell'Ariccia et al. (2018) paper materials.

Appendix 5

Persistence of the QE impact on the government bond yields. Created by the authors

Authors	***Persistence***
Doh, 2009	5 weeks
Wright, 2011	2 months
Gros, 2018	few months
Neely, 2016	6 months
Mamaysky, 2018	3 weeks

Appendix 6

Data periods for BS. Created by the authors

Name of the bank	***Period starting from***	***Source***
Bank of Japan	March 2001	Rogers et al., 2014
Bank of England	January 2014	Rogers et al., 2014
Reserve Bank of India	January 2016	Dua, 2020
Reserve Bank of Australia	January 2004	Derwin, 2020
Bank of Canada	January 2008	Rogers et al., 2014
European Central Bank	January 2009	Rogers et al., 2014
Federal Reserve System	November 2008	Rogers et al., 2014

Appendix 7

Adjustments made to the data on BSs. Created by the authors

- When comparing total assets, 52 observations were taken into account; if the year had 53 observations, then the last one was eliminated from the sample so that data from all banks follow a similar timeline;

- In the literature, it was mentioned that the first implementation of quantitative easing by the Bank of England happened in February 2009; however, due to the data availability, data on BSs was downloaded starting from the year 2014;
- BoE official website provided data on total assets only until September 24, 2014; therefore, to get the number of total assets, all available asset components were summed up, and then an additional adjustment of 3.5 % was made to replicate the pattern observed before the year 2014;
- Two datasets are containing the same CBs, but with different frequencies. The initial weekly data was accumulated into a monthly by taking an average of the weeks in each month. The second dataset is then used to complement the initial study with a simpler two-variable VAR model.

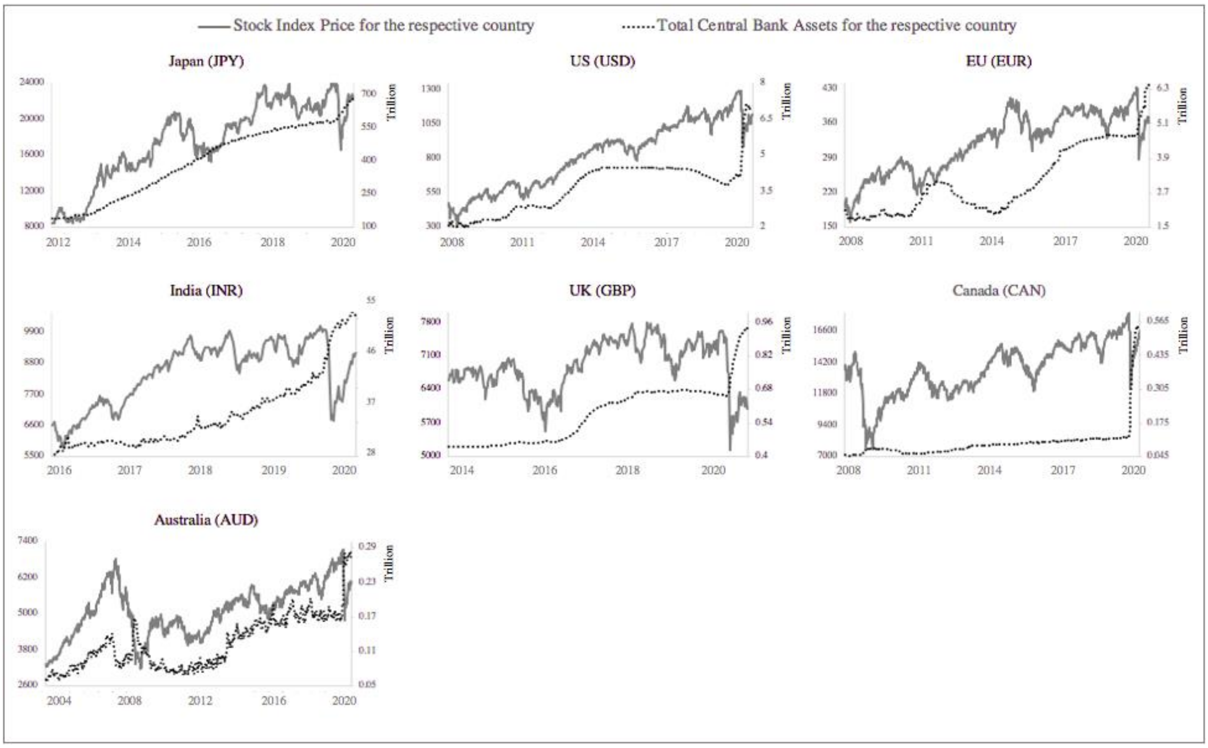
Appendix 8

The final dataset for asset classes and control variables. Created by the authors

Country/ Union	***Central Bank***	***Stock Index (price)***	***Corporate Bond Index (price)***	***Short-term Government Bond (yield)***	***Long-term Government Bond (yield)***	***CV for Economic Activity***	***CV for Inflation***
Canada	Bank of Canada	S&P/TSX Composite Index	S&P Canada Investment Grade Corporate Bond Index	Canadian 3m Bond	Canadian 10y Bond	Normalized GDP OECD indicator for Canada	CPI for Canada
England	Bank of England	FTSE 100	S&P U.K. Investment Grade Corporate Bond Index	UK 3m Bond	UK 10y Bond	Industrial production indicator for the UK	CPI for the UK
Japan	Bank of Japan	Nikkei 225	S&P Japan Bond Index	Japanese 3m Bond	Japanese 10y Bond	Industrial production indicator for Japan	CPI for Japan
European Union	ECB	STOXX Europe 600	S&P Eurozone Investment Grade Corporate Bond Index	EU 3m Bond (all issuer AAA rating)	EU 10y Bond (all issuer AAA rating)	Industrial production indicator for the EU	CPI for the EU
Australia	Reserve Bank of Australia	S&P/ASX 200	S&P/ASX Corporate Bond Index	Negotiable Certificates of Deposit-3 months	Australian 10y Bond	Normalized GDP OECD indicator for Australia	CPI for Australia
India	Reserve Bank of India	NIFTY 500	iShares MSCI India ETF (INDA)	Indian 3m Bond	Indian 10y Bond	Industrial production indicator for India	CPI for India
United States	FED	S&P 500	iShares iBoxx $ Investment Grade Corporate Bond ETF (LQD)	US 3m Bond	US 10y Bond	Industrial production indicator for the US	CPI for the US

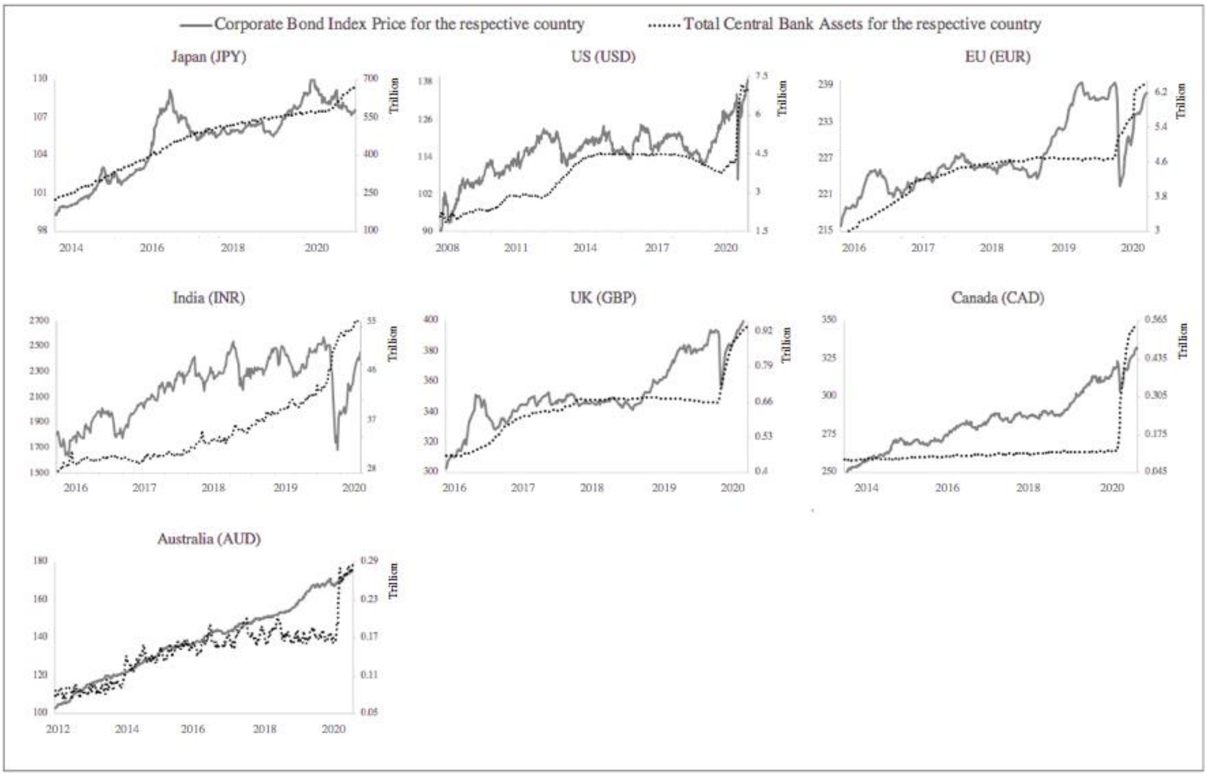
Appendix 9

Evolution of price levels of stock indices by country compared to the expansion of Total Asset values of CBs. Created by the authors



Appendix 10

Evolution of price levels of corporate bond indices by country compared to the expansion of Total Asset values of CBs. Created by the authors



Appendix 11

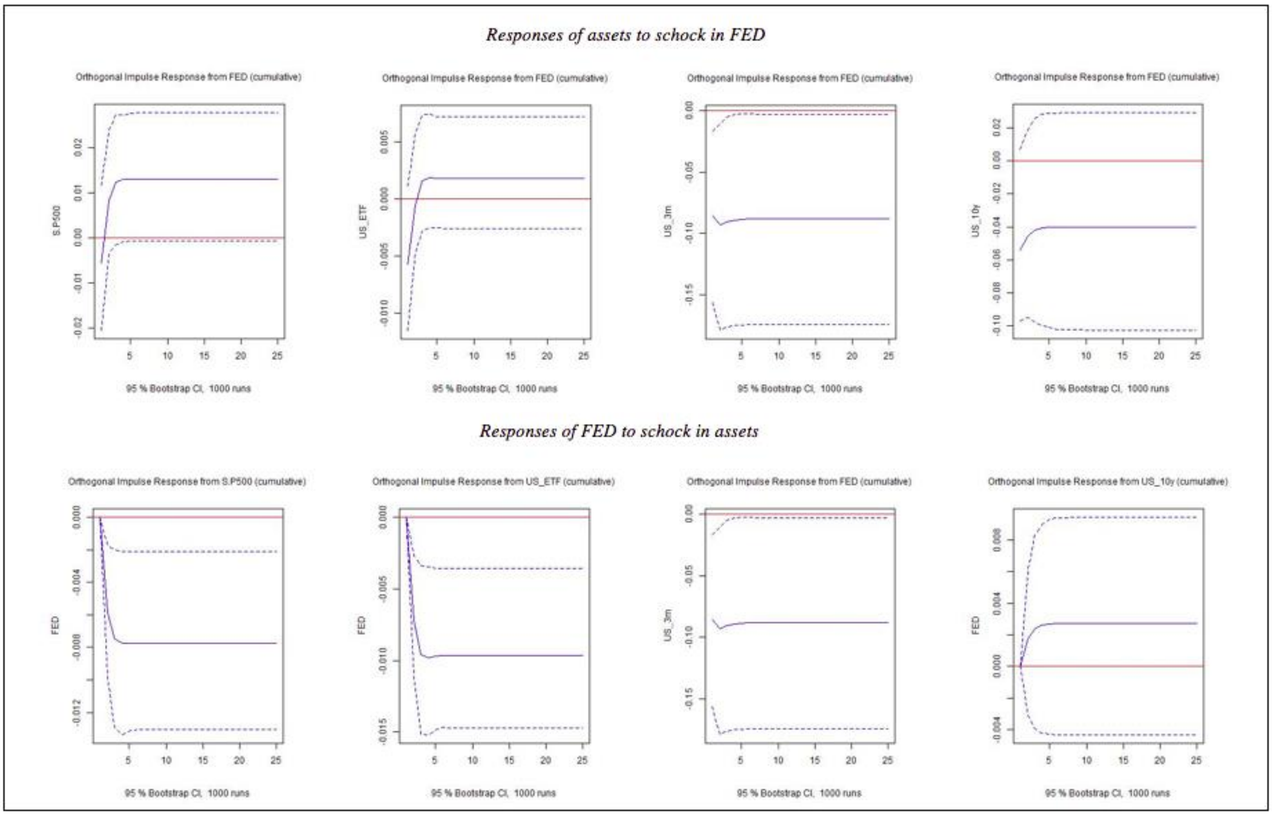
Adjustments made to the data on asset classes. Created by the authors

- All datasets were downloaded to match the period of the BS of the respective country. However, due to the data limitations, for some indices there might be covered a smaller period due to the late launch dates and no better substitutes available;
- Weekly/daily data downloaded for the different asset classes was transmitted into weekly and monthly average using the pivot table tool in the Excel Worksheet to match the frequency of the balance sheet updates;
- For international spillovers, we used the monthly available USD exchange rates obtained from FRED to convert the BS values for the other six countries.

Appendix 12

Orthogonal Impulse Responses for the US. Created by the authors

United States



Notes. The remaining Orthogonal IRFs for Hypotheses 1-6 can be found in a separate attachment to this paper. Tables A-G provide a complete summary of estimated IRFs