THE EFFECT OF QUANTITATIVE EASING ON REAL ESTATE PRICES

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Author: Laura Lyytinen
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Supervisor: Juha-Pekka Junttila

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

ABSTRACT

Author Laura Lyytinen	
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Abstract

This study assesses the impact of quantitative easing on real estate prices in the US and in the Euro area between the years 2003 and 2021. The recent real estate price inflation coinciding with the expansionary monetary policy of central banks has raised questions of the interconnectedness of quantitative easing and real estate prices. This study employs the factor-augmented vector autoregressive model and a rich dataset of 72 variables to distinguish whether the large-scale asset purchases of central banks are causing changes in real estate prices. The effects are considered separately for the residential and the commercial real estate sectors.

The results reveal that quantitative easing of the Federal Reserve is a key driver of US house prices, especially after the Global Financial Crisis. This notion holds even after controlling the result for 32 factor variables reflecting real estate price formation and the macroeconomy. Also, quantitative easing seems to be a separate factor from other, conventional monetary policy channels impacting real estate prices. Interestingly, Euro area house prices are not affected by the balance sheet fluctuations of the European Central Bank. While both the US and the Euro area commercial real estate prices seem to be affected by quantitative easing in a standard bivariate vector autoregressive model, this impact is diminished after adding the factor variables to the model, proving the relevance of the factor-augmented model in monetary policy research.

The greater response of US house prices to quantitative easing compared to the Euro area is expected based on the previous literature. First, the Federal Reserve has provided significantly more aid to the mortgage market than the European Central Bank as the two central banks have somewhat different objectives. Second, the monetary aid might have a larger impact on mortgage markets that are highly leveraged and securitized, as the US market is. As the aid was directed mostly towards the residential – not commercial – real estate market, the more muted response of the US commercial real estate sector is logical.

Key words
Unconventional monetary policy, quantitative easing, real estate

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Tiivistelmä

Tämä tutkimus arvioi määrällisen elvytyksen vaikutusta kiinteistöjen hintoihin Yhdysvalloissa ja euroalueella vuosina 2003–2021. Yhtäaikainen kiinteistöjen hintojen nousu ja keskuspankkien elvyttävä rahapolitiikka on herättänyt kysymyksiä näiden muuttujien välisestä yhteydestä. Tämä tutkimus hyödyntää faktorianalyysiin perustuvaa vektoriautoregressiivistä mallia sekä 72 muuttujan tutkimusaineistoa eritelläkseen keskuspankkien laajojen arvopaperiostojen vaikutuksia kiinteistöjen hinnanmuodostukseen. Vaikutuksia arvioidaan erikseen asuin- ja liikekiinteistösektoreiden osalta.

Tulokset paljastavat, että Yhdysvaltain keskuspankin harjoittama määrällinen elvytys on keskeinen tekijä maan asuinkiinteistöjen hinnanmuodostuksessa, erityisesti finanssikriisin jälkeen. Tulos säilyy voimassa silloinkin, kun siitä poistetaan makrotaloutta ja kiinteistöjen hinnanmuodostusta kuvaavien faktorimuuttujien vaikutus. Määrällinen elvytys näyttää olevan erillinen kiinteistöjen hintoihin vaikuttava kanavansa, joka on erotettavissa tavanomaisen rahapolitiikan vaikutuskanavista. Euroopan keskuspankin taseen vaihtelut eivät puolestaan näytä vaikuttavan euroalueen asuinkiinteistöjen hintoihin. Vaikka määrällinen elvytys näyttää vaikuttavan sekä Yhdysvaltojen että euroalueen liikekiinteistöjen hintoihin kahden muuttujan vektoriautoregressiivisessä mallissa, vaikutus häviää, kun malliin lisätään faktorimuuttujat. Tämä osoittaa faktorianalyysin merkityksen rahapolitiikan tutkimuksessa.

Yhdysvaltojen asuinkiinteistöjen hintojen suurempi reaktio määrälliseen elvytykseen verrattuna euroalueeseen on odotettua. Ensinnäkin Yhdysvaltain keskuspankki on antanut maansa asuntolainamarkkinoille enemmän tukea kuin Euroopan keskuspankki johtuen keskuspankkien erilaisista prioriteeteistä. Toiseksi rahallisella tuella voi olla suurempi vaikutus markkinoilla, joissa on Yhdysvaltain kaltaiset pitkälle velkavivutetut ja arvopaperistetut lainamarkkinat. Yhdysvaltojen liikekiinteistösektorin vaimeampi reaktio määrälliseen elvytykseen on loogista, koska tuki suunnattiin enimmäkseen asuinkiinteistöille.

Asiasanat Epätavanomainen rahapolitiikka, määrällinen elvytys, kiinteistöt	
Säilytyspaikka Jyväskylän yliopiston kirjasto	

CONTENTS

1 INTRODUCTION

This master's thesis assesses the impact of quantitative easing on real estate prices in the US and in the Euro area. In the era of unconventional monetary policy, the balance sheets of the Federal Reserve and the European Central Bank have expanded enormously due to the large-scale asset purchases executed by the central banks. The simultaneous growth in real estate prices has led to an intensive discussion on the interconnectedness of the quantitative easing of central banks and the development of real estate market prices. This study employs the factor-augmented vector autoregressive (FAVAR) model and a rich dataset of 72 variables to effectively distinguish the effect of the large-scale asset purchases on real estate prices. In contrast to most existing studies, both residential and commercial real estate prices are considered separately to observe any potential differences between the two property classes.

1.1 Background

Ever since the Global Financial Crisis (GFC) started in 2008, the global economy has been rather stagnant to this day. Especially in advanced economies, such as in the US and in the Euro area, low levels of investments have hampered economic growth and the weak macroeconomic development seems to have been persistent even after the acute crisis (Chen, Mrkaic & Nabar, 2019). In 2020, the Covid-19 pandemic created new challenges: restrictions on gatherings and other measures implemented to prevent the virus from spreading have seriously disrupted employment, consumption, supply chains and economic confidence, just to name a few (Brodeur et al., 2021).

From the viewpoint of central banks, a distinctive feature of the post-GFC era is the dysfunction of conventional monetary policy. According to the Taylor rule (Taylor, 2007), interest rates were set to zero – or even negative – because the recession caused by the GFC was deep and lengthy. In addition, the uncertainty within the banking sector was prominent, deducting banks' willingness to engage in risky activities and eventually slowing down lending (Joyce et al., 2012). Thus, the transmission channels of conventional monetary policies were somewhat impaired, giving rise to new, unconventional monetary policies. Unconventional monetary policy refers to monetary policy tools that are implemented when the use of conventional tools, such as manipulating the discount rate, fail to attain desired results (Bernanke, 2020).

The most prominent part of unconventional monetary policy is the so-called quantitative easing. Quantitative easing refers to large-scale asset purchases (LSAPs) made by central banks that inject central bank money into circulation, thus boosting lending and investments (Bernanke, 2020). Quantitative easing became popular in developed economies especially after the GFC, and consequently the balance sheets of the Federal Reserve and the European Central Bank have expanded enormously (European Central Bank, 2022a; Federal Reserve Bank of New York, n.d.). The Covid-19 pandemic outbreak in 2020 further delayed the normalization of monetary policy as stimulative monetary policy was once again needed to fight economic slowdown (European Central Bank, 2022b; Federal Reserve Board, 2020). The unprecedented amount of money in circulation has raised several questions and concerns both in public and within the research community.

There exists a substantial branch of literature examining the relationship between interest rates and asset prices, and especially whether lowering of interest rates is associated with asset price bubbles (see, for example, Galí, 2014 and McDonald & Stokes, 2013). In recent years, as the normalization of monetary policy has been prolonged, the impact of quantitative easing has also sparked a debate within researchers. Some studies have examined its effects on inflation and GDP (see, for example, Mouabbi & Sahuc, 2019), whereas others on bank lending (see, for example, Acharya et al., 2019). The responsiveness of asset prices to these new tools has also gained wide attention but the studies have focused more on bond yields and stock prices (see, for example, Rogers, Scotti & Wright, 2014 and Swanson, 2021) than on real estate, posing a gap in literature which this study strives to contribute to. The neglect of the real estate sector in recent monetary policy research is rather surprising as real estate is a large asset class that has an extensive impact on the economy. Leamer (2015), for example, has argued that housing is the single most important driver of business cycles, and hence, recessions in the US.

Lately, concerns about real estate overvaluation in some developed countries have been raised. The European Central Bank (2021a) stated that in the second quarter of 2021, nominal house prices in the Euro area increased at a higher rate than ever before in the last 15 years (see figure 1). In the US, during the four months of April to August in 2020, median house prices grew even faster than during the pre-GFC housing boom, as shown in figure 2 (Zhao, 2021). There are supposed to be numerous explanations for this: most notably, low interest rates encouraged home ownership and substantial government aids supported the solvency of households while remote work encouraged homeowners to invest in larger – and more valuable – houses (Duca, Hoesli & Montezuma, 2021; European Central Bank, 2021).

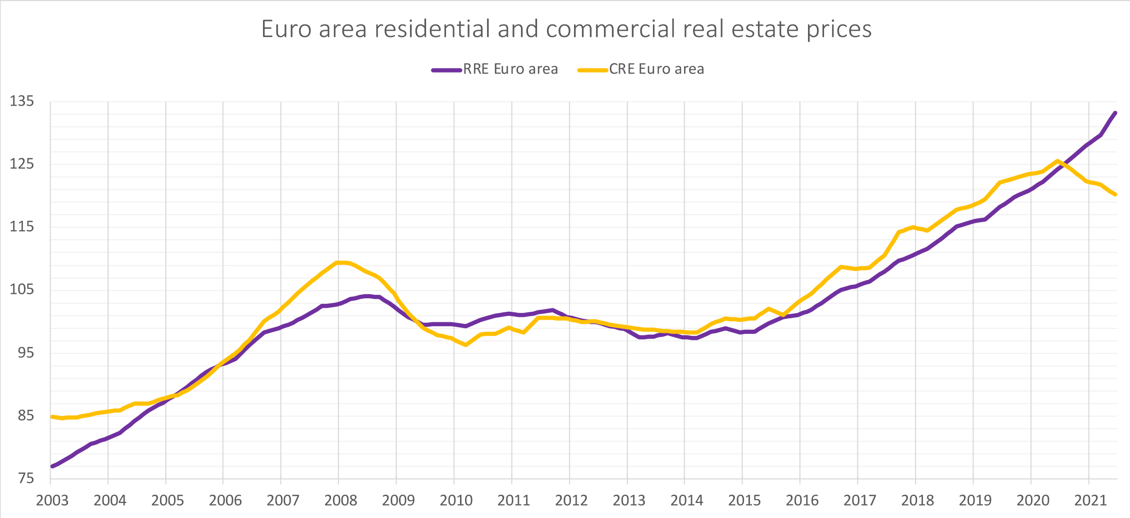

FIGURE 1 Euro area residential and commercial real estate prices. Data sourced from the ECB Statistical Data Warehouse (SDW).

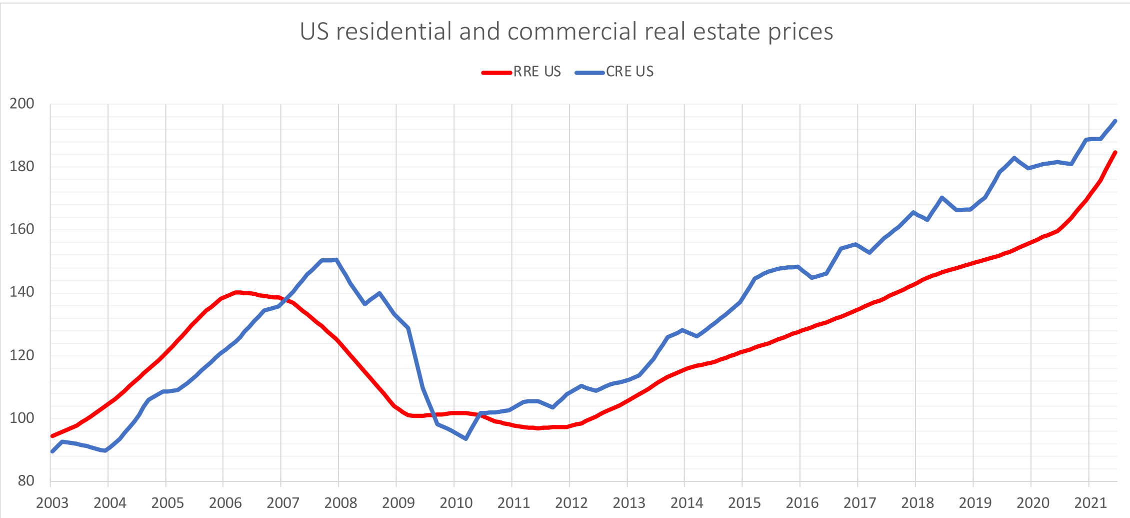

FIGURE 2 US residential and commercial real estate prices. Data sourced from the Bank of International Settlements (BIS).

If real estate price inflation is based on fundamentals, it is not a sign of a bubble but rather a sign of effective expansive fiscal and monetary policy. The question of whether the current real estate inflation is based on fundamentals or not is what determines the success of quantitative easing used by the Fed and the ECB in recent years. A common method for detecting real estate bubbles is to model price-to-rent ratios. High price-to-rent ratios indicate that the profitability of home ownership has decreased compared to renting and might thus suggest that valuations are detached from fundamentals (see, for example, Duca, Muellbauer & Murphy, 2021). Both in the US and in the Euro area, price-to-rent ratios in housing have increased in recent years, posing a threat of overvaluation (Duca, Hoesli & Montezuma, 2021; European Central Bank, 2021).

In terms of commercial real estate, the prices have increased substantially in many developed countries after the GFC. The lowered yield levels could imply overvaluation but, on the hand, the development is somewhat consistent with bond yields. More recently, new evidence suggests that commercial real estate prices have started to diverge from fundamentals, raising concerns of overvaluation. (IMF, 2021.) Similar to residential real estate, the relation of net operating income (reflecting rents and operating expenses) and property prices has increased in 2020 (Deghi, Mok & Tsuruga, 2021).

It is worth noting, however, that the real estate market is very heterogeneous across areas and segments, especially in the Euro area, where the economic structure and legislation vary greatly between countries. Duca, Hoesli & Montezuma (2021), for example, argue that countries highly dependent on tourism – such as Greece, Portugal, and Spain – have experienced only modest or even negative growth in house prices. In commercial real estate, the market is quite polarized, creating challenges in the overall assessment of the sector. The retail segment, for example, seems to have larger misalignments in prices than the office segment, perhaps due to a sluggish adjustment to the sharp decline in fundamentals (IMF, 2021). Although the valuations of some real estate segments in certain areas have decreased, it is worth asking whether the decline is enough to cover the substantial deterioration in fundamentals caused by not only the pandemic but also by the structural change in the economy.

The question of real estate overvaluation, on one hand, and quantitative easing, on the other hand, is extremely topical after the recent developments in the economy. The few studies assessing the interconnectedness of quantitative easing and real estate are usually focused only on housing. This study compares not only the two real estate classes – residential and commercial real estate – but also two different monetary areas, the US and the Euro area. Furthermore, the study considers a large set of variables potentially impacting real estate prices by applying the FAVAR method and a rich monthly dataset of 32 final factor variables for both monetary areas from 01/2003 to 06/2021.

1.2 Motivation for the study

What practical implications does the assessment of the relationship between quantitative easing and real estate prices provide? **The first implication** is that if real estate prices are artificially boosted because of overly expansionary monetary policy, price corrections after the boom may cause financial instability. The IMF (2017, 2021) has repeatedly raised concerns about the prolonged expansionary monetary policy in their financial stability reports. In 2017, the IMF argued that low interest rate levels have pushed investors towards highly leveraged, more risky assets as the bond market yields have shrunk. They concluded that the tightening of monetary policy, although probably necessary, might cause a sudden increase of risk exposure for investors and households and thus increase volatility and financial instability. If asset prices are not entirely based on fundamentals, the drop in prices will be more prominent and cause more tension in the financial markets.

In 2021, the IMF noted that while relaxed monetary conditions are essential to the prosperity of the commercial real estate sector, without appropriate macroprudential control they might also lead to price misalignments and excess volatility. The European Central Bank (2021a) warned that also in the residential real estate market, the risk of price corrections in the medium term has increased significantly: a housing bubble caused by highly leveraged households might be forthcoming and increasing interest rates will create challenges to mortgage repayment, especially within the most vulnerable borrowers. Ideal monetary conditions are thus a constant act of balancing between easy credit and reasonable valuation levels.

This leads to **the second implication:** Overvaluation of real estate has been a major contributor in recent financial crises. As the real estate market is a highly leveraged market and a large share of household wealth around the globe is tied to it, any price shocks are likely to have wide macroeconomic consequences (Duca, Muellbauer & Murphy, 2021). Housing booms can be excellent predictors of financial crises and the effect has become greater in magnitude after World War 2 (Jordà, Schularick & Taylor, 2015). Leamer (2015) argued that nine out of the 11 US recession between the years 1949 and 2008 were caused by a decline in house prices. He further deduced that monetary policy is a key factor in controlling the housing market – and thus business – cycles and appropriate monetary policy can dampen the housing market bubbles, although any policy cannot prevent them completely.

The third implication is that even if the volatility of real estate prices does not lead to a financial crisis, it has large spillover effects on the economy. Lower real estate values hurt the real estate demand and create a vicious cycle: first, a price decline in real estate causes credit losses for banks due to rise in foreclosures and customer insolvency. This will hinder bank lending as bank capital is weakened. Also, the collapse of collateral values hampers the borrowing of households and investors. Altogether, both the willingness and the ability of households and investors to invest in real estate is further reduced, creating a downward spiral of low demand. (Duca, Muellbauer & Murphy, 2021; IMF, 2021.) In addition, real estate losses often lead to more stringent macroprudential policies, such as tightening of collateral requirements that reduce the purchasing power of households (Iacoviello & Neri, 2010). Duca, Muellbauer & Murphy (2021) argue that a fall in the real estate prices hurts the economy also by decreasing the profits of the construction sector and other real estate related industries, such as brokerage and moving services.

The fourth implication, often assessed in the media, is related to wealth inequality. If real estate prices increase above fundamentals due to quantitative easing, people already on the property ladder benefit the most, boosting wealth inequality between renters and homeowners. Evgenidis & Fasianos (2021), for example, argue that unconventional monetary policy shocks have widened the wealth gap in the UK as unprecedented low interest rates have pushed investors from bonds towards riskier assets, such as housing, fueling their appreciation. However, some ECB researchers disagree on this: the paper by Lenza & Slacalek (2018) stated that the actions of the central bank decreased inequality because unemployment was reduced. They also argue that household wealth is "quite homogeneously distributed", and that the moderate house price inflation has not thus increased wealth inequality.

Overall, some studies argue that quantitative easing has fueled employment and thus decreased inequality, whereas others claim that this effect has been canceled out by the appreciation of financial and housing wealth, mostly possessed by the wealthy population (Colciago, Samarina & de Haan, 2019). The relationship between quantitative easing and wealth inequality is still vague but most researchers agree that the wealth inequality issues are at least smaller in magnitude than the public discussion around the topic would suggest. It is also argued that as inequality in the world is more related to structural issues than economic cycles, controlling it should not be a priority of central banks. (Bernanke, 2020). Nonetheless, understanding how quantitative easing has redistributed housing wealth could be valuable information for governments.

1.3 Research questions

The **first** research question of this study can be summarized as follows:

1. How quantitative easing affects real estate prices?

The two following sub-questions aim to reveal potential differences in the effects between the two analyzed monetary authorities – the European Central Bank operating in the Euro area and the Federal Reserve operating in the US – and the two asset classes, residential real estate (i.e., housing) and commercial real estate. The **second** and **third** research questions can be specified as:

2. How do the effects differ between the US and the Euro area?
3. How do the effects differ between residential and commercial properties?

The **second** research question examines how the real estate markets of the US and the Euro area differ from each other. More importantly, the potentially heterogeneous results may uncover important policy implications from the viewpoint of central banks as the Fed and the ECB launched LSAPs at different times and in different quantities. While the Fed included a large amount of mortgage-backed securities (MBS) in their LSAPs, the amount of real estate backed securities bought by the ECB was significantly smaller (Federal Reserve Bank of New

York, n.d.; European Central Bank, 2022a). The US housing market is more developed than the Euro area market in regard to mortgage securitization. This is one of the reasons, alongside other differences in taxation and legislation, behind the higher mortgage debt to GDP ratio in the US (Musso, Neri & Stracca, 2011). Intuitively, this would lead to the US housing market being more vulnerable to monetary shocks and thus financial crises.

Cerutti, Dagher, and Dell'Ariccia (2017) indeed found that countries with high loan-to-value ratios on housing and developed mortgage securitization tend to be more exposed to housing booms and busts. Furthermore, macroprudential tools aiming to constraint asset price bubbles are not quite as developed in the US as they are in many other monetary areas (Bernanke, 2020). Consistently, Castro & Sousa (2012) found that ECB tends to monitor the cumulation of housing wealth more precisely than the Fed. Hence, the risk of a real estate price bubble in the US is highlighted when compared to the Euro area.

The **third** research question stems from the large, yet often overlooked effects of commercial real estate on the macroeconomy. The emphasis of research considering the GFC from a real estate perspective has been widely on housing – perhaps due to its tangible impact on regular people – even though commercial real estate was just as important a factor in the real estate boom and bust (Duca & Ling, 2020). Recently, the IMF (2021) has raised concerns about the high valuation levels of commercial real estate that are not always based on fundamentals. They noted that the excess volatility in commercial real estate valuations may have significant effects on the global financial instability as commercial real estate is a large, highly leveraged asset class with many cross-border investors. The European Central Bank (2021a) has warned that a decline in the commercial real estate prices would hurt the financial sector through exposure to loans, collateral values, and direct investments. In addition, insurance companies and pension funds tend to have large possessions of low-quality office and retail properties which are expected to suffer the most from the potential downturn.

2 THEORETICAL FRAMEWORK

2.1 Asset price channel of quantitative easing

Research has shown an increasing amount of interest in the interconnectedness of monetary policy and asset prices in the 21st century. This is largely due to the Global Financial Crisis that started in 2008. The crisis has been attributed to overvaluation of real estate, along with extreme risk taking of financial institutions (Joyce et al., 2012). Taylor (2007), for example, argued that deviations from the appropriate interest rate policy in the US between the years 2002 and 2005 contributed to the real estate bubble burst in the midst of the GFC. His findings suggest that monetary policy might be a key factor in asset pricing and thus asset price bubbles. More recently, the economic crisis caused by the Covid-19 pandemic has potentially revealed some interesting linkages between monetary policy and asset prices, as the new large-scale asset purchases of central banks coincided with the expansion of asset prices in many countries (European Central Bank, 2021; European Central Bank, 2022b; Federal Reserve Board, 2020; Zhao, 2020).

Traditionally, central banks have been able to stabilize the economy by manipulating the discount rate and the reserve requirement rate, as well as by executing open market operations. These tools are used in a countercyclical manner to either expand and contract the economy and thus smooth the economic cycles. In times of recession, central banks stimulate lending, investments, and overall economic growth by lowering the short-term interest rates and reserve requirements. Short-term interest rates are further depressed through open market purchases of central banks targeted towards short-term assets that increase the amount of liquidity in the banking system. (Mishkin, 2016.)

After the GFC, these conventional monetary policy instruments were not enough to stimulate the economy. As the short-term interest rates were already set to zero but uncertainty within the financial markets continued to linger, open market operations larger in quantity were needed to promote lending and investments (Joyce et al., 2012). These large-scale asset purchases (LSAPs), often referred to as quantitative easing, are the most prominent part of the new, unconventional monetary policy strategies implemented by many central banks around the globe. The LSAPs are a more aggressive approach to traditional open market operations as they are targeted towards longer-term financial assets in contrast to short-term assets normally purchased by central banks. While most of the assets included in the LSAPs were backed by the government, some central banks also included corporate bonds and other, non-government related assets in their purchases. (Bernanke, 2020.)

The Fed executed three rounds of LSAPs between the years 2008 and 2014 to fight the recession caused by the GFC. Almost ten years later, in 2017, they began the normalization of monetary policy by restricting further LSAPs but were forced to enter the programs again in 2020 to tackle the economic consequences of the Covid-19 pandemic. (Federal Reserve Board, 2020; Federal Reserve Bank of New York, n.d.) The ECB has also launched multiple LSAP programs from 2014 onwards to support the stalled economy in the Euro area, first caused by the GFC and the European sovereign debt crisis and later by the Covid-19 pandemic (European Central Bank, 2022a; European Central Bank, 2022b). Consequently, the balance sheet of the Fed has increased more than sevenfold between the years 2007 and 2021, as shown in figure 3 (Federal Reserve Bank of New York, n.d.). The balance sheet of the Eurosystem (the European Central Bank and the national Euro area central banks) has grown around 500 % respectively, as shown in figure 4 (European Central Bank, 2022a).

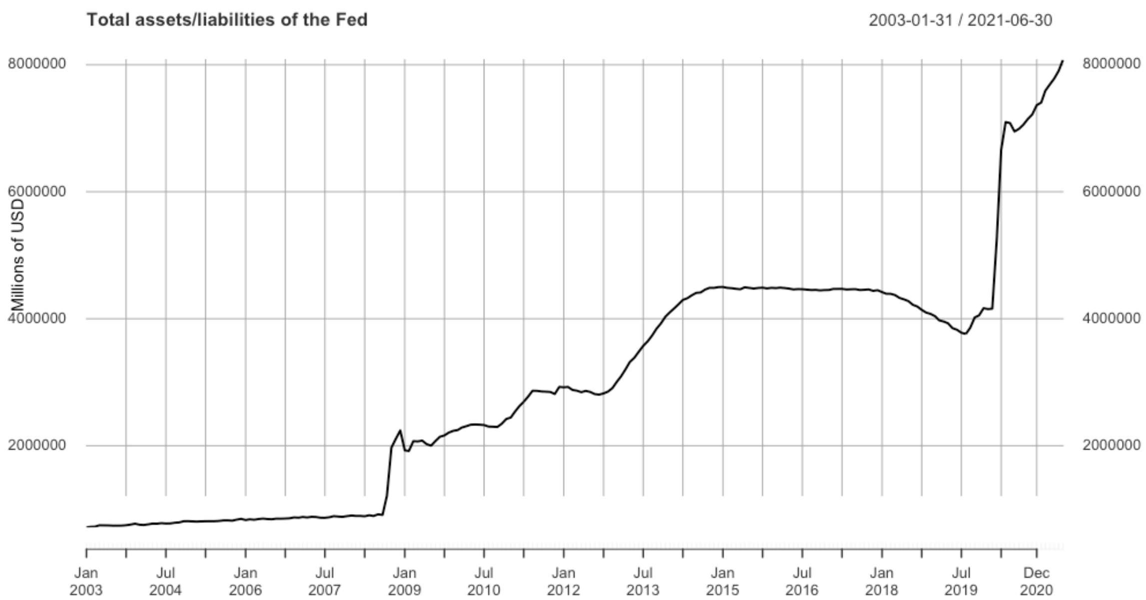

FIGURE 3 Balance sheet growth of the Fed. Data sourced from the Federal Reserve Economic Data (FRED).

FIGURE 4 Balance sheet growth of the Eurosystem. Data sourced from the ECB Statistical Data Warehouse (SDW).

The transmission channels of quantitative easing on asset prices are quite complex. In general, the LSAPs were targeted towards bonds of different kinds. The government's involvement in the bond market decreased the supply of these bonds while also increasing liquidity. This resulted in lowered yield levels and thus higher prices for any assets included in the LSAPs. (Gagnon et al., 2010.) As central banks did not include properties in their asset purchases, the transmission channel of the asset purchases on real estate is indirect. Gagnon et al. (2010) indeed argue that the LSAPs had spillover effects that also boosted the prices of other asset classes not included in the LSAPs. Spillovers may even reach other countries not directly affected by quantitative easing (Dahlhaus, Hess & Reza, 2018). The spillover effects manifested through multiple channels.

The main transmission channel of LSAPs on other asset prices is the **portfolio balance channel**. The portfolio balance hypothesis states that if the yield of one asset class is lowered, investors will turn to other assets in their search for higher yield (Joyce, Liu & Tonks, 2017). The evidence on the portfolio balance channel is somewhat conflicting but, for example, Albertazzi, Becker & Boucinha (2018) found that the government's involvement with safer assets weighs down the yields of riskier assets. This logic suggests that investors will acquire more real estate when the yields of other assets, such as government bonds, included in the LSAPs have been lowered. This growth in demand will obviously increase prices.

Another transmission channel of LSAPs is called the **liquidity channel**. By launching aggressive buying programs, central banks created enormous amounts of liquidity to the bond markets. As investors tend to prefer assets that are more liquid, one could assume that they would now value these assets higher. (Gagnon et al., 2010.) Whether investors see the intervention of central banks as a good sign in terms of liquidity, is nonetheless controversial: central banks create more demand and liquidity by buying assets aggressively but at the same time, it is unclear what will happen to the values of these bonds when they eventually withdraw from the market (Hancock & Passmore, 2015). It is also unclear how the liquidity channel affects real estate. On one hand, the LSAPs have not directly increased liquidity in the real estate market. On the other hand, the increase of liquidity in the bond markets could ease lending and thus create more demand for real estate as well.

Although quite similar to the portfolio balance and liquidity channels, some researchers have emphasized the importance of the **risk-taking channel**. Introduced by Borio & Zhu (2012), the risk-taking channel suggests that investors become more risk tolerant in times of loose monetary policy. As the liquidity in the financial markets increases, the risk of not being able to sell assets quickly at a fair price is diminished. This allows investors to acquire more risky assets, such as real estate. Furthermore, when lending and borrowing is encouraged through low or even negative interest rates and loose macroprudential constraints, financing these risky assets becomes easier. Borio & Zhu (2012) also explore the link between asset valuations and risk: because wealth and risk tolerance are somewhat positively correlated, the asset price inflation caused by expansionary monetary policy may in itself increase the risk appetite of market participants.

The mechanisms described above may be amplified through expectations, often referred to as the **signaling channel.** If investors have a good reason to believe that the central banks will continue to execute asset purchases, they will assume that both the liquidity and valuations of riskier assets will continue to rise which is reflected in higher prices today (Gagnon et al., 2010). It is unlikely that the central banks would withdraw from the LSAP programs prematurely as it is important for the policymakers to maintain a financial environment that is sound and predictable (Bernanke, 2020). Hancock & Passmore (2015) argue that the LSAPs also signal to investors that the central banks are willing to keep the interest rate at a lower level than the fundamentals would suggest. As the expected long-term financing costs are very low, investors and households might be tempted to acquire highly leveraged assets which real estate is.

The signaling channel is a similar concept to the **confidence channel**. As the central banks are actively executing LSAPs and communicating about their future involvement with the market, it is easy for the investors to believe that the stance of loose monetary policy will continue and the valuations of assets will thus stay high (Hesse, Hofmann & Weber, 2018). By pouring confidence into investors, the central banks are able to ensure that the market is active also in the future. Most notably, the then leader of the ECB Mario Draghi (2012) told the public in July 2012 that “within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough”. In his speech, Draghi clearly communicated to investors that they can rely on the central bank to guarantee high liquidity and functionality of the markets, even in times of crises.

The impact and necessity of LSAPs has been a topic of debate. LSAPs are believed to boost asset prices – at least in times of zero lower bound – but it is controversial to what extent this is desirable. On one hand, risk taking should be encouraged in hopes of asset price inflation in times of economic downturn, as in 2008 and 2020 (Bernanke, 2020). However, if the valuations are not based on fundamentals or the behavior of market participants is somehow distorted, financial instability may follow (Rodnyansky & Darmouni, 2017).

It also appears that the first LSAP programs were more effective than the later ones, perhaps due to their initial "shock value". In later stages, the market was anticipating future LSAP rounds, and their effect was thus already incorporated into asset prices – at least to some extent. (Bernanke, 2020.) Hence, it can be argued that quantitative easing has recently lost some of its power and credibility. At the same time, concerns about the potentially undesirable consequences of quantitative easing, such as asset bubbles and the unequal distribution of wealth, have increased.

Most of the research considering quantitative easing and asset prices has been focused on either equities or bonds (see, for example, Rogers et al., 2014 and Swanson, 2021). This may be due to the priorities of central banks. Castro & Sousa (2012) argue that both in the US and in the Euro area, central banks put more emphasis on financial wealth composition than housing wealth composition. However, when inflation is higher, especially the ECB takes a more active role in monitoring the developments of housing wealth. Nonetheless, these concerns are secondary to central banks as they tend to stress inflation in their policymaking. This might help to explain why the impact of LSAPs on real estate has not been as widely studied. The existing literature studying the dynamics between quantitative easing and real estate prices is presented more precisely in chapter 3.

2.2 Formation of real estate prices

Before assessing how quantitative easing may influence real estate valuations, it is useful to examine how real estate prices are formed. Previous research largely agrees that real estate prices are based on multiple, external fundamentals, as well as some internal and behavior-related factors (Duca, Muellbauer & Murphy 2021). Hence, the prices are dependent on many exogenous and endogenous variables. Nevertheless, even after controlling for a large number of potential contributing factors, previous research has not been able to fully discover the formula behind real estate price cycles (Iacoviello & Neri, 2010; Duca & Ling, 2020). It seems that the real estate price cycles are driven partly by either unknown or irrational forces but some general guidelines for determining supply and demand can still be outlined.

Duca, Muellbauer & Murphy (2021) argue that real estate price inflation is often based on favorable changes in macroeconomic and financial fundamentals. Moreover, the shifts are often amplified due to some behavior-related attributes of real estate markets. Changes in fundamentals can be caused by unprecedented macroeconomic shocks, such as prominent shifts in trade, exchange rates or oil prices. These shocks may affect either the demand- or the supply side of real estate markets and thus the equilibrium price. Another set of fundamentals impacting the prices is related to financial factors: overvaluation can be caused by highly risky or even fraudulent procedures in lending, as well as loose regulation enabling excessive levels of leverage.

More precisely, on the demand side, the most prominent factor contributing to real estate prices is the ability of households and investors to borrow. Relaxed lending conditions, such as low interest rates and collateral requirements, increase the pool of potential borrowers (Iacoviello & Neri, 2010; Duca & Ling, 2020). When more people are granted mortgages, the demand for real estate obviously increases. Cerutti et al. (2017) found that countries with higher loan-to-value ratios on mortgages are more prone to housing bubbles. They also concluded that countries with highly securitized mortgage markets usually hold more housing credit, and the risk of a real estate boom is thus accelerated. Consistent with Cerutti et al. (2017), Agnello & Schuknecht (2011) found that house price inflation is often associated with growth in credit, along with loose regulation of banks.

When real estate is acquired for investing purposes, another important component is the expected cash flow of tenants (Duca & Ling, 2020; Duca, Muellbauer & Murphy, 2021). Intuitively, low unemployment rate and economic growth should decrease the probability of insolvency of tenants. Especially in commercial real estate, business cycles and structural changes in the economy may seriously affect the ability of lessees to pay rent and furthermore, commit to long, fixed-term rental agreements. The outbreak of the Covid-19 pandemic and the gathering restrictions that followed are an extreme example of a sudden macroeconomic shock that led to insolvency of many commercial lessees (Deghi et al., 2021). The lowered vacancy rates of properties ultimately lead to value deterioration.

On the supply side, Iacoviello & Neri (2010) argue that prices are mostly affected by the profitability of building real estate. This, in turn, is dependent on the supply of land and productivity of construction, to name a few. When the land available is very limited or building is expensive, real estate prices rise, as one would expect. In the long run, the supply will adjust but as the real estate supply tends to be quite inelastic, the adjustment will take time (Coen, Lefebvre & Simon, 2018). Indeed, areas with more inelastic supply appear to be more exposed to real estate booms and busts (Duca, Muellbauer & Murphy, 2021).

These macroeconomic and financial variables are external sources of valuation, but real estate prices are also partly explained through internal factors that stem from the intrinsic properties of the real estate markets. Geanakoplos (2010) explains how both over- and undervaluation of real estate are natural states of the market due to collateral requirements: when real estate prices rise, collateral is released, leading to easing of leverage constraints and again fueling the real estate price growth. Geanakoplos (2010) refers to this process as **the leverage cycle** and notes that the cycle works in both directions. The magnitude of the leverage cycle can be, however, controlled by government policies related to taxation, regulation, credit standards and so forth.

Especially in housing, there also exists a tendency for people to overemphasize momentum and thus expect prices to increase even further, often leading to overvaluation (Duca, Muellbauer & Murphy, 2021). This phenomenon is related to the well-known momentum effect first introduced by De Bondt & Thaler (1985), suggesting investors tend to overestimate the impact of past performance when assessing the future performance of asset prices. Furthermore, real estate cannot be easily sold short due to high illiquidity and transaction costs (Saffi & Vergara, 2020). This might disturb the market mechanism as the price corrections are sluggish, even when there exists a somewhat common consent of overvaluation (Herring & Wachter, 1999).

2.3 Real estate booms

As discussed above, there are multiple factors contributing to the formation of real estate prices. From the viewpoint of the policymakers, it is noteworthy to distinguish which factors are most likely to give rise to overvaluation because the inherently volatile, cyclical, and highly leveraged market of real estate is a fruitful soil for financial instability. Controlling the overvaluation of real estate is an essential part of macroprudential policy aiming to create a sound and stable financial environment.

Just before the GFC hit the global economy, Taylor (2007) introduced the idea of monetary policy deviations leading to a housing boom in the early 2000's. As the real estate bubble burst in 2008, a greater attention was paid to the impact of monetary policy in real estate boom and bust cycles. A debate about the magnitude of monetary policy as an impacting factor is on-going but there seems to be a consensus that the role of monetary policy has grown. Intuitively, this seems logical as the monetary policy tools used in the 21st century are unprecedentedly powerful.

Iacoviello & Neri (2010) studied the history of housing booms in the US. They argue that price increases of real estate can be partly attributed to the rather slow development of productivity in construction, as well as to monetary shocks. The limited availability of land also puts upward pressure on real estate prices. They found that in the 1970's and 1980's, the expansion in housing prices was mainly tied to supply side factors, such as stagnant housing technology. In the early 2000's, on the other hand, the boom was more related to favorable monetary policy which fueled the demand for real estate.

The idea of low interest rates being an essential factor in the real estate boom before the GFC has gained support from many economists. McDonald & Stokes (2013) argued that in the US, the federal funds rate is inversely related to housing prices and a large enough decline in the rate would thus ultimately lead to a housing bubble. Jordà et al. (2015) found that in advanced economies, low interest rates fuel extensive mortgage lending and thus house prices. They also note, similar to the leverage cycle introduced by Geanakoplos (2010), that increasing house prices release collateral in banks, again stimulating mortgage lending and further increasing house prices.

Along with interest rates, the growth of the monetary base has also been studied as the source of real estate price inflation, leading to the subject of quantitative easing. Goodhart & Hofmann (2008) found that there exists a significant correlation between monetary base and house prices in developed countries, though noting that the link is bidirectional. The correlations are stronger in times of booms. Ryczkowski (2019) agrees with the results, adding that the causality reversed from money growth being the explanatory factor to money growth being the explaining factor after the introduction of LSAPs. White (2015) argues that also in the UK, money growth results in higher house prices and notes that the effect seems to be quite persistent. The link between real estate prices and growth of the monetary base is reviewed more closely in chapter 3.

Opposing views have also been introduced: Hendershott, Hendershott & Shilling (2010) argue that the pre-GFC housing boom in the US resulted from the government's encouragement for low-income households to acquire housing and the resulting securitization of subprime loans. In their analysis, they largely dismiss the impact of the federal funds rate on the bubble but rather highlight the weak regulation of the financial sector. Eickmeier & Hofmann (2013) deduced that expansionary monetary policy shocks indeed deepened and prolonged the pre-GFC housing boom in the US but may not have been the trigger as housing prices began to rise already before the shocks were present. Del Negro & Otrok (2007) note that the monetary policy in the US before the GFC was more expansionary than the norms would expect but the monetary policy shocks did not in themselves trigger the housing boom.

The recent increase in house prices started in 2020, at the beginning of the Covid-19 pandemic (European Central Bank, 2021; Zhao, 2020). On the demand side, the house price inflation is believed to be due to low interest rates and both fiscal and monetary aid to households, as well as to changes in housing preferences from small to big houses (Duca, Hoesli & Montezuma, 2021; European Central Bank, 2021). In addition, behavioral factors might be involved: people are worried that they will miss out on the much-discussed price inflation if they do not buy immediately (Zhao, 2021). On the supply side, a significant increase in cost of construction is evident. Construction cost inflation affects housing prices positively as the profitability of building new homes requires higher nominal prices than before (Duca, Muellbauer & Murphy, 2021). Also, restrictions at gatherings might have hampered the listing process of sellers (Zhao, 2021). Increasing price-to-rent ratios have raised concerns of housing overvaluation in some developed countries but so far, there is no concrete evidence of a housing bubble (Duca, Hoesli & Montezuma, 2021; European Central Bank, 2021).

Similar views can be found when assessing the commercial real estate market, even though less studied. Duca & Ling (2020) found that the growth of commercial real estate valuations in the US from the mid-90's to 2008 was tied to the reduction of risk premium. They argue that the lower risk premium can be traced to low interest rates and relaxed capital requirements of banks that enabled the popularity of commercial mortgage-backed securities (CMBS). CMBS offered a route for financial institutions to allow higher leverage ratios and thus reduce the market risk premia. In line with the previously mentioned dynamics between exogenous and endogenous factors, Duca & Ling (2020) found the overvaluation caused by these external factors to be amplified through the internal expectations of the real estate market.

After the GFC, capital requirements were tightened to reduce excessive risk taking of financial institutions. Nevertheless, commercial real estate valuations recovered quickly and have continued to rise at a fast pace in many countries (IMF, 2021). Duca & Ling (2020) found that the high valuations of commercial real estate in the US after the GFC were now an outcome of the historically low levels of long-term treasury yields. IMF (2021) agrees and notes that the portfolio balance channel might explain the suppressed yields of commercial real estate, and the price inflation does not thus necessarily imply overvaluation. However, since 2020, there are new signs of price misalignments as the commercial real estate prices have not fully reflected the sharp decline in fundamentals. The deterioration of fundamentals is mainly evident through high vacancy rates and low net operating profits. (IMF, 2021.)

3 LITERATURE REVIEW

Out of all the variables impacting real estate prices, monetary policy seems to be an essential factor, especially during the last 20 years. Furthermore, expansionary monetary policy is often thought to be an important cause of overvaluation of asset prices. This section looks more closely at the relationship between monetary policy and real estate prices. The emphasis of the literature review is on quantitative easing as it has been a prominent trend within policymakers worldwide for the past almost 15 years and is thus also the focus of this study. Moreover, the expansionary power of quantitative easing is unprecedented and is hence believed to have intriguing consequences on asset prices.

The previous literature on linkages between conventional monetary policy and real estate markets is quite extensive but the literature focusing especially on unconventional monetary policy and real estate valuation is rather scarce. This implies that there is a need for further research on the topic. The previous studies agree that both the expansionary conventional and unconventional monetary policy should result in house price inflation, but the transmission channels are somewhat different (Rosenberg, 2019).

As discussed in chapter 2.1, the implementation of LSAPs along with other unconventional monetary policy measures, such as negative interest rates, created enormous liquidity to the financial markets. The sudden, large increase in liquidity should lead to growing demand for real estate as the borrowing costs are extremely low (Iacoviello & Neri, 2010; Duca & Ling, 2020). Moreover, low interest rates and LSAPs result in a search for yield within investors, forcing them to turn to more riskier assets, such as real estate, to gain even moderate returns for their investments (Gagnon et al., 2010; IMF, 2017). Intuitively, this lowers the required yield level of real estate and thus increases prices. As the markets tend to develop towards equilibrium, the supply of real estate will eventually follow the demand. This will, however, take some time because the supply of real estate is slow to adjust, and real estate prices will therefore increase at least in the short term (Coen et al., 2018).

TABLE 1 Previous literature focusing on whether unconventional monetary policy has resulted in real estate price growth.

	US	*Euro area*	*Others*
Ahmed at al. (2019)	-	Yes	-
Coen et al. (2018)	-	-	Yes (UK)
Gabriel & Lutz (2017)	Yes	-	-

Huber & Punzi (2020)	Yes	Yes (weak)	
Jawadi et al. (2017)	Yes	-	-
Rahal (2016)	Yes	Yes (weak)	
Rosenberg (2019)	-	-	Yes (Sweden, Denmark, Norway)
Rosenberg (2020)	-	Yes (weak)	-
Ryczkowski (2019)	Yes	No	

There exists also empirical evidence for this reasoning. Jawadi, Sousa & Traverso (2017) examined how the growth in central bank reserves affected industrial production, consumer prices and asset prices in the US between the years 2008 and 2013. A positive shock to the central bank reserves was used as a proxy for unconventional monetary policy. They found that an unconventional monetary policy shock resulted in both stock price and house price inflation while it did not significantly affect production or consumer prices. The study hence concluded that unconventional monetary policy stimulates the economy mainly through an increase in asset prices with portfolio balance channel being the most important transmission mechanism.

While most studies have focused on house prices, Gabriel & Lutz (2014) studied how unconventional monetary policy actions affected the US real estate market as a whole. They examined how mortgage interest rates, returns of homebuilders and real estate investment trusts, costs of insuring subprime mortgage debt and commercial real estate debt, and housing distress reacted to unconventional monetary policy shocks. After a monetary policy shock, the mortgage interest rates fell, the excess returns of homebuilders and REITs rose, the cost of insuring real estate debt decreased, and the housing distress lowered. The results thus suggest that unconventional monetary policy has a stimulating effect on the real estate market that is reflected through multiple channels. They also found that the results were asymmetric across states and risk levels and the stimulating effects were rather short-term.

Some studies have included both the US and the Euro area in their analysis and discovered heterogeneity between the monetary areas. Rahal (2016) studied how the central banks' balance sheet shocks affected house prices in the US and in the Euro area, as well as in six other currency areas. The results suggest a positive reaction of house prices to the balance sheet expansion within the time span of one to two years in all areas, albeit the reaction being significantly weaker in the Euro area compared to the US. Huber & Punzi (2020) received similar results.

Ryczkowski (2019) studied the interconnectedness of money growth and house prices in developed countries and found that in most countries, house price inflation was followed by an increase in money and credit. However, after the introduction of LSAPs, the causality of money growth and house price inflation reversed in the US, suggesting that quantitative easing was now causing higher house prices, not vice versa. In the Euro area, quantitative easing did not seem to induce house price inflation in a similar manner.

These results discussed above suggest that the impact of quantitative easing on house prices is stronger in the US than in the Euro area. Nonetheless, the evidence regarding the Euro area is somewhat conflicting, perhaps because the monetary area consists of multiple, heterogeneous countries. Ahmed et al. (2020) found that quantitative easing shocks of the ECB resulted in higher real estate prices in Italy. Hence, they concluded that the unconventional monetary policy of the ECB has successfully contributed to the real estate growth in the Euro area. Rosenberg (2020) studied another Euro area country, Finland, and found that an expansion in the ECB's balance sheet caused house price inflation but the effect was very small in magnitude and lasted only for a short period.

Rosenberg (2019) also examined how the house prices of three European countries not included in the Euro area – Sweden, Denmark, and Norway – reacted to conventional and unconventional monetary policy shocks caused by their national central banks. Both the conventional and unconventional monetary policy shocks seemed to lead to house price inflation in all three countries. The reaction of house prices to unconventional monetary policy shocks was stronger and more persistent than the reaction to conventional monetary policy shocks in all three countries.

An interesting remark regarding the transmission channels of quantitative easing arises: Rosenberg (2019) notes that the results are interestingly similar within the three currency areas even though the monetary policies of the countries concerned are very different. Only Sweden has officially implemented unconventional monetary policies, but the balance sheets of central banks have experienced growth also in Denmark and Norway. This could imply that the signaling channel of quantitative easing introduced by, for example, Hancock & Passmore (2015) has not been a relevant transmission channel of unconventional monetary policy at least in Denmark and Norway.

In terms of commercial real estate, the literature on the impact of unconventional monetary policy is extremely limited. One could assume that the impact would be fairly similar to housing as the determinants of commercial real estate prices are mostly the same. A study made by Coen et al. (2018) examined how the risk premium of the London office market reacted to the changes in monetary base. They found that an increase in money supply reduced the risk premium. The results imply that quantitative easing can decrease the risk of holding commercial real estate properties and hence increase their valuations. It is, however, worth noting that the study assesses the actions of the Bank of England, and the results may not hold in the US or in the Euro area.

In conclusion, quantitative easing seems to cause at least moderate real estate price inflation. This is true especially for housing while the impact on commercial real estate is more unclear as the research is very scarce. Most studies suggest that the effect is due to the portfolio balance channel: as interest rates fall, in their search for yield, investors turn to stocks and real estate, driving up their prices. The impact of other transmission channels, such as the signaling channel, is not as evident. There also seems to exist a consensus that the impact is much stronger in the US than in the Euro area. The results considering the Euro area are, however, somewhat conflicting as the monetary area consists of multiple, heterogeneous countries.

4 METHODOLOGY

In this study, I use the factor-augmented vector autoregressive (FAVAR) model to examine the effects of quantitative easing on real estate prices. FAVAR models, as presented by Bernanke, Boivin & Eliasz (2005), are an extension to the traditional VAR models that combine the benefits of factor analysis and VAR models. Factor analysis is employed to increase the information set used in a VAR model without increasing the number of actual (endogenous) variables in the system.

Vector autoregressive (VAR) models were first presented by Christopher Sims (1980) more than 40 years ago and ever since, they have been widely used in economic research. VAR models are able to capture the time-varying dynamic relationships between two or more variables by focusing on the effects of the lagged values of each variable to the variable itself, as well as to the other variables in the regression model (Stock & Watson, 2001). VAR models are not very restricted because all variables in the system can be treated as endogenous (Sims, 1980). Hence, the direction of the causality does not have to be predetermined which is very useful when studying macroeconomics. As the simplest example, for a two-variable vector representation of the model can be given as

$$\begin{pmatrix} Y_{1t} \\ Y_{2t} \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} + \begin{pmatrix} \alpha_{1,1} & \alpha_{1,2} \\ \alpha_{2,1} & \alpha_{2,2} \end{pmatrix} \begin{pmatrix} Y_{1t-1} \\ Y_{2t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}. \qquad (1)$$

The equation (1) above represents a bivariate VAR model consisting of two variables and an error term. Y_t is a vector of endogenous variables, c is a vector of constant terms, α is a matrix of coefficients for the lagged values Y_{t-1}, and ε is a vector of error terms with mean zero and no serial correlation.

Results obtained from the estimation of the VAR equation can be interpreted by examining Granger-causality, impulse response functions and forecast error variance decomposition. The Granger-causality tests examine the causality between the analyzed two variables in both directions. It assesses whether the past values of a variable can be useful in forecasting the future development of the other variables at a given significance level. The impulse responses, on the other hand, demonstrate how a shock in one variable affects the short-term fluctuations of another variable. Finally, the forecast error variance describes how much of the variance of forecasting error is determined by the variable itself and how much is due to other variables in the system. (Stock & Watson, 2001.)

The simple, standard VAR models are unrestricted and easy-to-use models that are rather straightforward to interpret. However, the regression model can easily become quite large if multiple variables and longer lags of them are considered. Usually, a maximum of six to eight variables are included in the regressions because of issues related to degrees of freedom that will arise with too many variables (Stock & Watson, 2005). As understanding the dynamics of macroeconomy often calls for a more extensive consideration, there might be a need to incorporate tens or even hundreds of variables into the system. This is where factor analysis is needed.

First introduced by Spearman (1904), factor analysis strives to combine the information contained in multiple variables into a smaller number of factors. In this way, the most essential bits of information from a large dataset can be extracted and compressed into, say, five factors. Now the number of variables needed in the actual analysis is minimized and the regressions are thus more manageable. In practice, this method has been proved to be quite effective. Stock & Watson (2002), for example, found that only six factors are needed to seize the main dynamics of more than 200 macroeconomic variables. Bernanke et al. (2005) found the optimal number of factors to be even smaller, three, for a set of 120 macroeconomic variables.

Combining these two methods lays the ground for FAVAR models. By augmenting the factor variables into a standard VAR model, Bernanke et al. (2005) were able to develop a rather simple VAR model that still captures the dynamics of hundreds of variables. The reasoning behind adding the factor variables to the traditional VAR model is the reduction of distortion: when studying monetary policy, a large number of economic factors should be considered to obtain robust results. This is extremely useful when trying to distinguish the impact of one specific variable – in this case, quantitative easing – from a large set of macroeconomic variables that may all play a role in monetary policy decisions.

Furthermore, factors are able to capture complex dynamics, such as economic activity or market sentiment, by combining several variables into a one component (Bernanke at al., 2005). These abstract concepts could not be explained by only a single variable. Hence, FAVAR models have been widely used when studying the effects of monetary policy as the central banks are known to consider a large number of economic indicators in their policymaking. Moreover, FAVAR models have been commonly used in the previous research studying the impact of monetary policy on real estate prices, such as in the studies of Vargas-Silva (2008), Gupta, Jurgilas & Kabundi (2010) and Eickmeier & Hofmann (2013).

This study replicates the FAVAR model presented by Bernanke et al. (2005) to ensure the validity of estimations. In the equation (2) below, Y_t is an M x 1 vector of **observable** variables that would be estimated in a standard VAR model. F_t on the other hand, is a K x 1 vector of **unobservable** variables that also play a role in the dynamics analyzed but are not included in Y_t. To put it differently, F_t aggregates several variables that together might reflect rather abstract concepts in the economy that cannot be explained solely through a singular time series. $\phi\ (L)$ denotes the lag polynomial with a finite order p, and υ_t is the vector of error terms with mean zero and a covariance matrix of Q. Hence, the model is given as

$$\begin{pmatrix} F_t \\ Y_t \end{pmatrix} = \phi\ (L) \begin{pmatrix} F_{t-1} \\ Y_{t-1} \end{pmatrix} + \upsilon_t. \quad (2)$$

As the unobservable variables are not itemized, a standard estimation procedure, such as the ordinary least squares method, cannot be applied directly. Hence, factor analysis is needed to estimate the effects of information contained in the F_t. There are two possible estimation methods for this: the one-step Bayesian method and the two-step principal component method. Bernanke et al. (2005) finds both approaches equally as good so in this study, I use the more popular two-step approach, as in Vargas-Silva (2008), Gupta et al. (2010) and many other FAVAR studies. Stock & Watson (1998) also note that the principal component method allows for some cross-correlation in the error term, and in overall terms, possesses fewer assumptions than the Bayesian method.

According to Bernanke et al. (2005), the observable Y_t and the unobservable F_t should explain the dynamics of X_t when combined, as in the equation (3) presented below. X_t is defined as the vector of N x 1 with the number of time series in N being large. Λ^f is an N x K matrix of factor loadings, Λ^y is an N x M matrix, and e_t is the N x 1 vector of error terms. The error terms should be mean zero but can be weakly cross correlated (Stock & Watson, 1998). Hence, we may write the overall model for the FAVAR representation as

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t. \tag{3}$$

Before the principal component analysis, the variables in X_t are divided into fast- and slow-moving ones. In general, the slow-moving variables are variables reflecting the real economy, such as consumption or employment, whereas the fast-moving variables, such as the stock market prices, react more promptly to the shifts in the economic environment. It can be thought that the slow-moving variables determine the state of the economy and are thus observed and followed by the central banks when conducting monetary policy decisions, while the fast-moving variables then react to the monetary policy decisions being made. Hence, one of the key assumptions for the FAVAR representations utilized for monetary policy analyses is that the slow-moving variables are not affected by Y_t (see also Bernanke et al, 2005 for more details).

Most of the variables in this study are similar to the variables in the study of Bernanke et al. (2005) and are thus divided accordingly. The few variables not included in the study of Bernanke at al. (2005) are divided following the general logic of their division. Consumer confidence, economic policy uncertainty, and building permits reflecting confidence are assumed to be fast moving, as are the real estate prices and stock market volatility. The trade variables, energy prices and mortgage loans, on the other hand, are assumed to be slow-moving, similar to the study of Laine (2020). However, it is worth noting that the energy prices have been rather fast-moving recently so in future research, assigning them to the fast-moving variables might be more accurate.

At the first step of the analysis, the principal components are extracted from the information on all variables, and then, from the data on only the slow-moving variables. Next, the effect of Y_t is cleaned from the principal components extracted. $\widehat{F_t}$, the estimated representation of F_t, is then obtained. In the second step, the equation (3) is estimated using the ordinary least squares method as in the standard VAR models by replacing the unobservable F_t with the now estimated $\widehat{F_t}$. (Bernanke et al., 2005.) After estimating the FAVAR model, the impulse responses and forecast error variance decompositions can be computed for the endogenous variables. When producing impulse responses, the bootstrapping method of Kilian (1998) is used to obtain the confidence intervals for the impulse response functions.

In the extraction of principal components, it is crucial to consider how many components are allowed in the model. As every new component potentially improves the explanatory power of the model, the lower the number of allowed principal components is, the less the model is able to explain. On the other hand, too many components will lead to overfitting of the model. (Bai and Ng, 2002.) To utilize the fundamental benefit of factor analysis – reduction of the amount of information used for the estimations – the number of variables should be limited to a reasonable value. Some tests have been developed to find the optimal number of principal components (see, for example, Bai and Ng, 2002). Forni et al. (2000) suggest that the first eigenvalues obtained from a spectral density matrix can be used to determine the number of principal components, and new components can be added until the variance explained by the next component is less than 5 %. This technique was used in the study of Gupta et al. (2010), for example, and was employed also in this study.

5 DATA

The main variables of interest in this study are the residential and commercial real estate indices, as well as the level of total assets/liabilities of the Fed and the ECB that measure quantitative easing. The total assets/liabilities of central banks are a powerful proxy for quantitative easing as a round of LSAPs substantially increases the central bank balance sheet size. Of course, the size of the balance sheet fluctuates inherently due to the standard open market operations, too, but the movements caused by the LSAP programs are manyfold. The central bank balance sheet size has been used as a proxy for unconventional monetary policy also in the studies of Rahal (2016) and Rosenberg (2019), for example. Another option to measure the size of quantitative easing would be to track the LSAP announcements made by central banks, as in the study of Gabriel & Lutz (2017).

Real estate prices are modeled by real estate price indices. The indices are utilized in the empirical analysis separately for the residential and commercial properties to distinguish any differences between these two property classes, but the indices share the same base date to maintain comparability. The US residential index retrieved from the Bank of International Settlements (BIS) covers existing single-family homes while the Euro area residential index from the ECB Statistical Data Warehouse (SDW) covers all dwelling types, new and existing. Both commercial indices cover all commercial property types. All indices are nominal as inflation is taken into consideration in the factor-augmented part of the model by including consumer price index as a factor variable. The indices are based on average pure price (as opposed to price per square foot/meter). Real estate indices are often used to measure the macro level changes in real estate prices, for example in the studies of Del Negro & Otrok (2007), Eickmeier & Hofmann (2013) and Musso et al. (2011).

In addition, a total of 32 factor variables for both the US and the Euro area are included for the factor analysis part. The number of factors must be large and at least exceed the number of principal components used in the FAVAR model (Stock & Watson, 1998). As the number of principal components in the models was five (discussed in more detail in chapter 6.2), the amount of factor variables is sufficient. Of course, adding more factor variables would further enhance the model. Nonetheless, even 32 factor variables will add a large amount of new information to the regression when compared to a standard bivariate VAR model.

The factor variables aim to grasp the main dynamics of real estate price formation discussed in chapter 2.2 to control for distortion in the results. The factor variables are partly derived from the study of Bernanke et al. (2005) but only include the variables supposed to be the most relevant to this study based on the previous studies on the theme. First, the short- and long-term interest rates from the overnight interest rates all the way to 10-year rates are included as they provide vital information on the stance of conventional monetary policy. The unemployment rate, consumer price index and industrial production reflect the overall state of the economy. In addition, indices tracking the development of share prices, stock market volatility and dividend yields are included to capture the impact of the common stocks. Also, the (nominal) exchange rates of the four most important trade partners of each monetary area, as well as the SDR indices and real effective exchange rates are included in the factor information set.

In addition to the variables in the dataset of Bernanke et al. (2005), few other macroeconomic variables are added to the model. First of all, the aggregate output of the economies is measured by the nominal Gross Domestic Product (GDP). The GDP is also disaggregated to its components as some components, like real investments of the private sector and household consumption, might be more relevant in the real estate price formation than others. To consider the international trade side of the economy, both the imports and exports are included into the set of factor information. In addition, consumer confidence and economic policy uncertainty are introduced, too, to capture the overall level of trust within the household and enterprise sectors.

Furthermore, some more real estate market specific variables are added. First, future building activity is proxied via building permits granted for residential properties. Second, the level of mortgage loans is included to measure the volume of loan granting of the banks which seriously affects the demand of real estate. Third, on the supply side, construction and material cost indices are included to capture the recent sharp increase in the construction costs that obviously places an upward pressure on real estate prices. Finally, oil and gas market prices are included, too, as they are assumed to affect the real estate market by increasing construction costs and decreasing the purchasing power of households (Duca, Muellbauer & Murphy, 2021).

A detailed description of the data is presented in Appendices 1 and 2. The time series were collected from multiple sources, most notably from the Refinitiv Eikon, the Federal Reserve Economic Data (FRED) and the ECB Statistical Data Warehouse (SDW). Most of the data are monthly observations, and the quarterly data were interpolated by calculating the change between quarterly observations and dividing the change equally for the corresponding months. For the weekly observations of central banks' total assets and liabilities, the last observation of each month was used as the proxy for the monthly observation. Daily data were converted by calculating monthly averages. All data are reported in local currencies, except for the oil prices that are reported in US dollars for both the US and the Euro area.

Any non-stationary series were transformed to stationary through differencing. The presence of unit root was measured using various test procedures, such as the Augmented Dickey–Fuller test and the Kwiatkowski–Phillips–Schmidt–Shin test. In terms of the residential real estate indices, differencing the log returns was necessary to achieve a stationary representation of the data. The log returns of commercial real estate indices were barely stationary according to the unit root tests used so these series were also differenced to test whether this more stationary representation of the data yielded different results. However, for commercial real estate, the results were quite robust against differencing.

While defining the US as a geographic area is simple, the definition of the Euro area is less clear. The Euro area or the Eurozone consists of the 19 European Union member countries that have adopted euro as their primary currency. The monetary authority of these countries is the Eurosystem, formed by the ECB and the 19 national central banks. The data were collected mostly from all the current 19 Eurozone countries even though the countries have joined the Eurozone at different times, and hence, they have not all been part of the system from the beginning of the time frame examined. However, it would be challenging to collect data that exclude the countries joined later as the more recent datasets obviously include all the current member countries. For some variables, however, there was a changing composition of the Eurozone countries included. In terms of economic policy uncertainty, the data are reported for all European countries because the data are not available for the Euro countries only.

The time frame of the study is from 01/2003 to 06/2021 as the interval captures the two most recent boom phases of real estate prices: the pre-GFC boom in the beginning of the 21st century, as well as the boom that started in 2020 in the midst of the Covid-19 pandemic. The beginning of the time frame is restricted to the early 2000's due to unavailable data especially for the Euro area. In addition, the unconventional monetary policy actions were introduced only after the GFC and as the focus of this study is on quantitative easing, analyzing any previous real estate booms would not be relevant.

6 RESULTS

The simultaneous growth in real estate prices and central banks' balance sheets observed in recent years has sparked a question of whether the two factors are correlated – and more importantly, whether one has caused the other. Intuitively, the LSAPs of central banks could give rise to real estate price growth through the transmission channels discussed in chapter 2.1, whereas the theoretical reasoning for the reverse causality would not be quite as well-grounded. Indeed, there seems to have existed a positive correlation between the quantitative easing actions and real estate prices, as reported in table 2. As shown in table 2, quantitative easing and real estate prices in the US are moderately correlated (the Spearman correlation coefficient is 0,46 for the residential real estate and 0,70 for the commercial real estate), whereas in the Euro area, the correlation is even stronger (0,81 and 0,80, respectively). The cross-correlations between the two areas and property classes are also high.

TABLE 2 Correlation matrix between quantitative easing and real estate prices.

	QE US	**QE Euro**	**RRE US**	**RRE Euro**	**CRE US**	**CRE Euro**
QE US	1,00**	0,88**	0,46**	0,67**	0,70**	0,70**
QE Euro	0,88**	1,00**	0,53**	0,81**	0,74**	0,80**
RRE US	0,46**	0,53**	1,00**	0,74**	0,87**	0,75**
RRE Euro	0,67**	0,81**	0,74**	1,00**	0,87**	0,94**
CRE US	0,70**	0,74**	0,87**	0,87**	1,00**	0,92**
CRE Euro	0,70**	0,80**	0,75**	0,94**	0,92**	1,00**

*Notes: ** Correlation is significant at the 0,05 level. Variables QE US and QE Euro refer to quantitative easing in the US and in the Euro area respectively, variables RRE US and RRE Euro refer to residential real estate prices in the US and in the Euro area respectively, and variables CRE US and CRE Euro refer to commercial real estate prices in the US and in the Euro area respectively. The time period of the study is from 01/2003 to 06/2021.*

6.1 VAR results

As the statistical correlation between variables is not a proof of causality, the correlation coefficients do not in themselves serve as evidence of a cause-and-effect relationship. To gain a preliminary understanding of the dynamics between quantitative easing and real estate prices, a standard vector autoregressive model between the variables was first formed. A separate bivariate VAR was formed for both the residential and commercial real estate prices, as well as for both monetary areas. The models were used to test for Granger-causality, as well as for constructing the forecast error variances of the respective variables. The variance decomposition graphs from the bivariate VAR models are displayed in Appendix 3. The impulse response functions are drawn only for the FAVAR models and are presented in chapter 6.2.

The series were first made stationary through differencing. The appropriate lag length was then decided based on four tests: the Akaike information criterion, the Hannan Quinn criterion, the Schwarz information criterion, and the final prediction error. Different lag lengths were tested to obtain the most parsimonious, yet informative model. In all four models, the lag length suggested by both the Akaike information criterion, and the final prediction error was ultimately employed.

First, looking at the dynamics between quantitative easing and residential real estate prices in the US, quantitative easing seems to have Granger-caused residential real estate prices at less than 0,1 % risk level. The residential real estate prices, however, have not Granger-caused quantitative easing. This result was supported by the forecast error variance decomposition results suggesting that even 37 % of the forecast error variance of residential real estate prices was explained by quantitative easing around the ten-month mark, then leveling off. The forecast error variance of quantitative easing, on the other hand, was not explained by residential real estate prices almost at all. Hence, there seems to have existed a definitive causal relationship from quantitative easing to house prices, and there was no evidence of reverse causality.

Also in the commercial real estate markets, there existed Granger-causality at less than 0,1 % risk level from quantitative easing to commercial real estate prices but not the other way around. The variance decomposition results revealed that quantitative easing explained 8 % of the forecast error variance of commercial real estate prices at the 10-month mark but even 14 % at the 18-month mark, suggesting that the effect is even longer-lasting compared to the residential real estate market. Commercial real estate prices explained around 8 % of the forecast error variance of quantitative easing at the 19-month mark, then leveling off. The effect is arguably quite small but still contradicts the findings from the residential real estate market which showed no sign of real estate prices affecting quantitative easing.

For the part of the Euro area, quantitative easing of the ECB did not Granger-cause residential real estate price development nor did residential real estate prices cause quantitative easing. The forecast error variance of residential real estate prices was, however, explained by quantitative easing at 7,5 % level at the 10-month mark. On the other hand, around 4 % of the forecast error variance of quantitative easing was explained by residential real estate prices at the 15-month mark. Yet, there was no concrete evidence of causal relationship between the Euro area house prices and the quantitative easing of the ECB based on the Granger-causality results.

In contrast to the results for the residential real estate market, quantitative easing seemed to Granger-cause commercial real estate prices at 5 % risk level. Also in this case, commercial real estate prices did not Granger-cause quantitative easing, adding up to the evidence of unidirectional causality. Around 8 % of the forecast error variance of commercial real estate prices was explained by quantitative easing after 12 months, then leveling off. Commercial real estate prices explained only about 2% of the forecast error variance of quantitative easing, consistent with the Granger causality results.

Regarding the robustness of the results, there was no multicollinearity detected in any of the models whilst heteroskedasticity was observed in all four models. In addition, the Euro area residential real estate model possessed serial correlation which may have biased the results. Hence, as the factor models are generally allowed to display serial correlation (Stock & Watson, 1998), the FAVAR model may lead to more robust results.

6.2 FAVAR results

To test whether the results discussed above hold even after incorporating a set of new factors to the regression analysis, the FAVAR approach was next employed. When building the FAVAR models, the data were standardized to have mean of zero and standard deviation of one. The optimal number of principal components was determined based on the share of variances they explained: any components explaining less than 5 % of the variance were excluded from the models. Of course, each new component would have entailed more information to the model, but the model was built keeping in mind the goal of parsimony. For both the US and the Euro area, the optimal number of principal components was revealed to be five. The explained variance graphs can be found in Appendix 4.

The optimal lag length was chosen by following the final prediction error approach, as in the study of Gupta et al. (2010), while the Akaike information criterion suggested the same lag length for all the other models except for the Euro area commercial real estate market. The Hannan-Quinn criterion and the Schwarz information criterion suggested shorter lag lengths which were tested as well. However, these models excluded significant information regarding the effect of quantitative easing on real estate prices that was revealed only after more lags were included. Increasing the lag length further, on the other hand, would have led to overfitting of the models. The models exhibited autocorrelation, as could be assumed. However, this is generally not considered a problem in factor analysis (Stock & Watson, 2002).

For the US residential real estate market, the baseline model was conducted using five principal components and seven lags. The results of quantitative easing Granger-causing residential real estate prices were robust to the addition of the 32 factor variables – quantitative easing still Granger-caused residential real estate prices at less than 0,1 % risk level. Around 22 % of the forecast error variance of the residential real estate market prices was explained by quantitative easing at the 8-month mark, then leveling off. As 57 % of the forecast error variance of the house price development was explained by the variable itself, the factor variables explained roughly the same amount (21 %) of the variance as quantitative easing did. These results suggest that quantitative easing is one of the key drivers of house prices in the US. Residential real estate prices explained only around 2 % of forecast error variance of quantitative easing, consistent with the results of the bivariate VAR. The variance decomposition graphs are presented in Appendix 3.

The impulse response functions (see figure 5) showed a rather jagged but positive reaction of residential real estate prices after a shock in quantitative easing. The initial positive reaction was followed by a drop similar in magnitude. With the time span of 5 to 9 months, there were three spikes in residential real estate prices, each of them accompanied by a smaller drop afterwards. The spikes and the drops decreased in magnitude as more time passed. After a year, the curve had flattened.

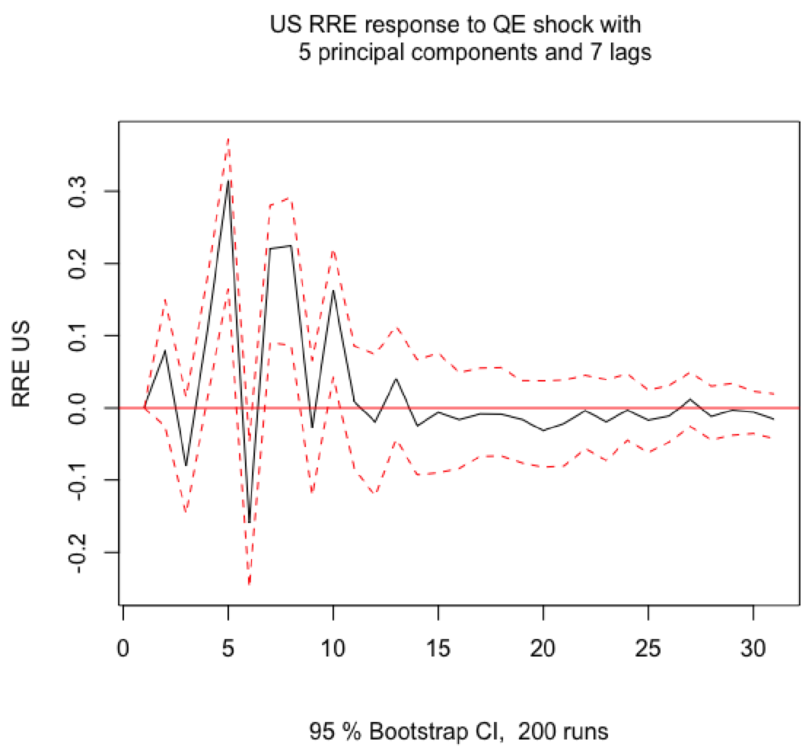

FIGURE 5 Impulse response function graph of the response of US residential real estate prices to a shock in quantitative easing in the FAVAR model.

For the US commercial real estate market, the baseline model was built using five principal components and seven lags. Adding the factor variables to the equation seemed to decrease the effect of quantitative easing on commercial real estate prices but not remove it completely. Quantitative easing still Granger-caused commercial real estate prices at 5 % risk level. Now, around 8 % of the forecast error variance of commercial real estate prices was explained by quantitative easing of the Fed at the 11-month mark, then leveling off. Commercial real estate price development explained only around 4 % of the forecast error variance of quantitative easing from eight months onwards. Hence, when the factor variables are included in the equation, the explanatory power of quantitative easing halves compared to the bivariate VAR. The impulse response functions (see figure 6) were jagged, but they still indicate that a shock in quantitative easing is followed by a drop in commercial real estate prices after 7 months. This contradicts the results from the residential real estate model where the impulse response functions showed an increase in prices after a shock in quantitative easing.

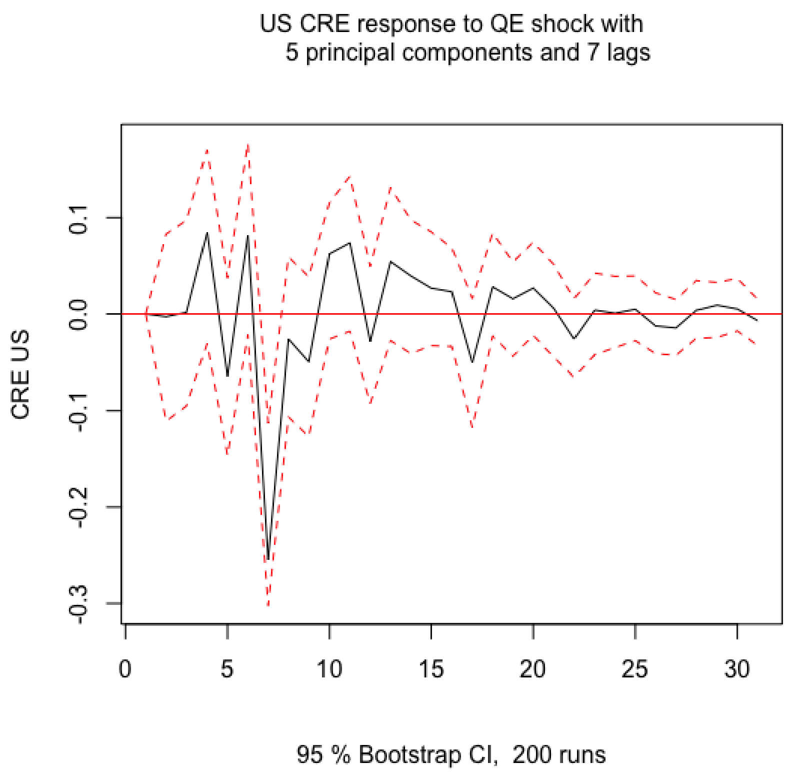

FIGURE 6 Impulse response function graph of the response of US commercial real estate prices to a shock in quantitative easing in the FAVAR model.

For the Euro area, the effect of quantitative easing on residential real estate price development seemed to disappear completely after incorporating the factor variables into the equation. The baseline model was determined to include five principal components and six lags. There was no significant Granger-causality from either direction. Based on the impulse response functions (see figure 7), a shock in quantitative easing did not result in any significant response in the Euro area house prices. Less than 1 % of the forecast error variance of residential real estate prices was explained by quantitative easing. Reversely, the effect was around 2 %. The lag length of 6 was suggested by the Akaike information criterion and the final prediction error approach. Changing the lag length to 1 as suggested by the Hannan Quinn criterion and the Schwarz information criterion resulted in even more insignificant results, stating that the explanatory power of quantitative easing on house prices was virtually zero.

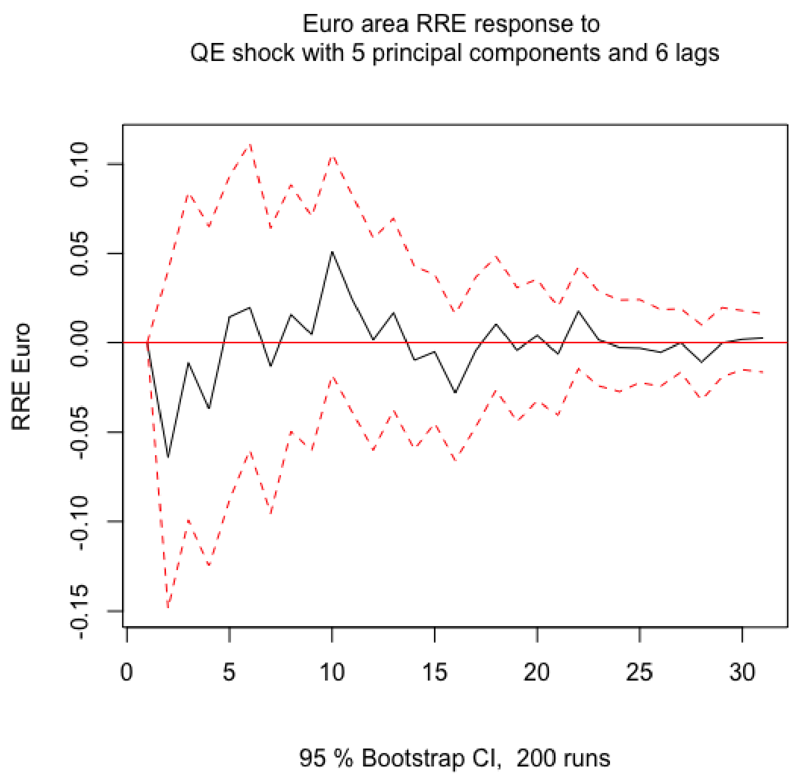

FIGURE 7 Impulse response function graph of the response of Euro area residential real estate prices to a shock in quantitative easing in the FAVAR model.

For the part of the Euro area commercial real estate market, the baseline model consisted of five principal components and four lags, as suggested by the final prediction error. Adding the factors to the regression decreased the effect of quantitative easing on commercial real estate prices. Now, quantitative easing Granger-caused commercial real estate prices only at 10 % risk level. Once again, there was no reverse causality. Around 2,2 % of the forecast error variance of commercial real estate prices was explained by quantitative easing after six months, then leveling off. Conversely, the share was 1,3 % after eight months. Impulse response functions (see figure 8) provided very minimal evidence of any causality between quantitative easing and commercial real estate prices. The results received from the bivariate VAR are thus almost completely diminished when the factor variables are included in the model.

The Akaike information criterion suggested a lag length of 12 which would probably be too long from an economic perspective. Also, the previous studies that have usually employed a maximum lag length of seven, as in Bernanke et al (2005), for example. Notwithstanding, the lag length of 12 was tested. In this model, the share of forecast error variance explained by other variables naturally increased: now around 5 % of the forecast error variance of both commercial real estate prices and quantitative easing was explained by the respective variable. The impulse response functions showed only very minimal fluctuations. Overall, the impact of quantitative easing on commercial real estate prices appears to be very small.

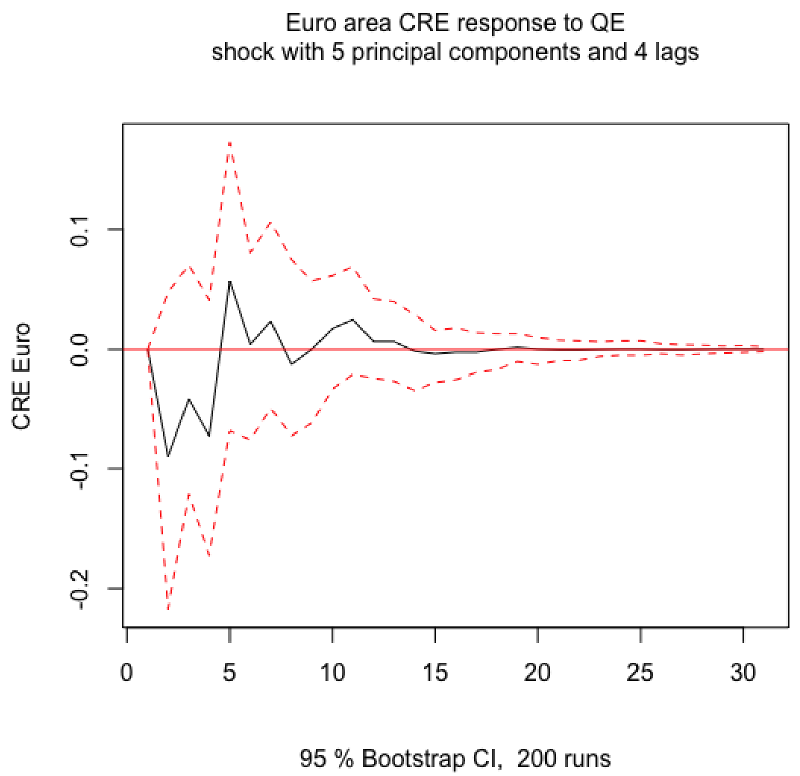

FIGURE 8 Impulse response function graph of the response of Euro area commercial real estate prices to a shock in quantitative easing in the FAVAR model.

6.3 Further considerations

In the FAVAR models, as with any principal component analysis, the contents of each principal component are unobserved. In other words, each principal component combines the dynamics of multiple time series so the effect of one factor variable cannot be itemized from the regression. As it would be interesting to know which of the factor variables have the biggest impact on real estate prices besides quantitative easing, some theoretical concepts were tested by omitting certain variables from the original FAVAR model. Excluding a variable from the regression is the only way to distinguish its effect on the system.

One interesting consideration is the impact of Taylor rule variables on the equation. The Taylor rule, as proposed by John B. Taylor (1993) is a widely used tool in modern monetary policy decision-making of central banks. The Taylor rule proposes that the nominal interest rate level should be determined based on the spread between the actual inflation and target inflation, as well as the spread between current GDP and the potential GDP. The Taylor rule has been a fundamental monetary policy tool in many economics, although in the 21st century, the interest rate has been often set to a lower level than the rule would suggest (Taylor 2007). Hence, the variables included in the Taylor rule equation and thus arguably in the policymaking of central banks may have a significant impact on the dynamics between quantitative easing and real estate prices.

As the only significant causality after incorporating the factor variables seemed to exist between the Federal Reserve quantitative easing and the US real estate prices, the robustness of the US results was tested against the exclusion of the Taylor rule variables, i.e., the GDP components and inflation. After omitting the Taylor rule variables, quantitative easing still Granger-caused US house prices at less than 0,1 % risk level but commercial real estate prices only at 10 % risk level. These results suggest that the effect of quantitative easing on real estate house prices is not explained solely by the interest rate developments – the most prominent part of conventional monetary policy – but they have a separate dynamic on their own. Nonetheless, the discount rate is another important factor that plays a role in the real estate price formation and the joint dynamics of these two monetary factors must be carefully distinguished from each other to obtain credible results.

Another interesting consideration is the impact of the GFC on monetary policy. As discussed, unconventional monetary policy became relevant in the US and Euro area policy making only after 2008. It is often assumed that the main transmission channel of quantitative easing on real estate prices is the portfolio balance channel where investors are believed to transfer their investments from bonds to stocks and real estate due to lowered bond yields. Hence, the impact of central bank balance sheet fluctuations on the real estate market should be relevant only after the balance sheet has grown enough to actually lower the bond yields, i.e., in times of quantitative easing.

To test this intuition, the US dataset was divided into two subsamples: 01/2003 – 12/2008 and 01/2009 – 06/2021. The two FAVAR models were run using both of the subsamples separately. For the second subsample (01/2009 – 06/2021), quantitative easing Granger-caused residential real estate prices at less than 0,1 % risk level, as expected. Consistent with the theoretical concepts, quantitative easing did not, however, Granger-cause residential real estate prices for the first subsample (01/2003 – 12/2008). This result goes to show that while the central bank balance sheet fluctuations caused by the standard open market operations do not affect US house prices, quantitative easing again puts an upward pressure on residential real estate valuations. On the contrary, this pattern was not evident in US commercial real estate prices. Potential explanations for these results are discussed more thoroughly in chapter 7.

7 DISCUSSION

During the last few years, both the media and the scientific community have debated over the interconnectedness of the extremely loose monetary policy and the increased valuations of real estate. This connection is evident also in the dataset analyzed in this study when examining the correlation coefficients between the extensions of central banks' aggregate balance sheets as the measure of quantitative easing and the development of real estate prices. However, it is controversial whether quantitative easing has actually caused the real estate price inflation or if there are other more significant factors in the economy fueling the price growth. Moreover, it is not clear whether the price inflation is based on fundamentals – and thus desired by the central banks – or is it at least partly speculative, and hence, possibly hazardous to property owners and the whole economy. Answering these two questions may help to assess the viability of the unconventional monetary policy exercised by the central banks from the asset price viewpoint.

The empirical analysis was started by formulating a bivariate VAR model for the utilized measure of quantitative easing and both the residential and commercial real estate price indices for the US and the Euro area. Based on the VAR results, quantitative easing seemed to Granger-cause US house price developments, as well as the developments of commercial real estate prices in both areas. In addition, the forecast error variance decompositions showcased that quantitative easing played a role in the real estate price formation. The results were statistically most significant for the US residential real estate market while the effect of quantitative easing on Euro area house prices was almost nonexistent. The evidence for reverse causality was overall very minimal.

As expected, when the factor variables capturing the role of other economic variables in the analysis were added to the regression model, the explanatory power of quantitative easing on real estate prices decreased. Yet, even after controlling the result for the 32 economic series, quantitative easing is still a vigorous factor in the US house price formation. This proves that real estate prices can be affected by quantitative easing – a remark central banks should mind when exercising monetary policy actions. Nonetheless, in the Euro area, quantitative easing has resulted in only very negligible real estate price growth, although this relationship has been much discussed by the public.

Two important remarks arise from the FAVAR results. First of all, the impact of quantitative easing is significantly more powerful in the US than in the Euro area. Second, after augmenting the factor variables into the regressions, the US commercial real estate prices are not nearly as much affected by the central bank balance sheet fluctuations as the house prices are. The first finding is expected based on the previous studies, and it is also supported by some theoretical findings. Rationalizing the second observation is more challenging because the commercial real estate market has not been much studied in the context of monetary policy. Next, the results are compared to the previous literature and potential explanations for different results between the four models are discussed more in detail. Some avenues for future research are also presented. Finally, practical implications are drawn.

Comparison to the previous literature

The results obtained from the residential FAVAR models are mainly in line with the literature, while the existing literature is almost nonexistent regarding quantitative easing and commercial real estate markets. The significant, positive reaction of the US residential real estate price development to the quantitative easing of the Fed is consistently recorded in the previous literature assessing the relationship between house prices and monetary policy. Examples of such studies include the papers of Gabriel & Lutz (2017), Huber & Punzi (2020), Jawadi et al. (2017), Rahal (2016) and Ryczkowski (2019). The methods and variables used in monetary policy research vary greatly, potentially impacting the results obtained. The papers of Rahal (2016) and Jawadi et al. (2017) are the most similar to this study as they employ VAR models and use the overall central bank balance sheet development as the proxy for quantitative easing. Both of the studies found that an increase in quantitative easing leads to a positive response in US house prices.

The existing literature of the Euro area residential real estate market is more conflicting. Consistent with this study, Ryczkowski (2019) argues that quantitative easing of the ECB has not been successful in inflating the Euro area house prices. Using the wavelet approach, he found that while M3 and house prices are correlated, house price growth rather leads money growth, not the other way around. Rahal (2016), using a similar approach to this study, found that a positive shock in the central bank balance sheet is followed by an increase in house prices but the increase is smaller in magnitude than in many other developed countries, including the US. Huber & Punzi (2020) also argue that unconventional monetary policy, proxied by the shadow interest rates, resulted in rather weak house price inflation in the Euro area. There are some other, country-specific studies that have received conflicting results, largely dependent on which Euro country they have examined. Overall, most studies have found a somewhat significant, positive response of Euro area house prices to quantitative easing, but the effect seems to be significantly more muted than in the US.

Only few studies have employed the FAVAR approach in their assessment of unconventional monetary policy and US/Euro area house prices, namely the paper of Gabriel & Lutz (2017). With respect to the US, the already very consistent literature is even more supported by the FAVAR results obtained from this study. The impact of quantitative easing on US house prices holds even after controlling the model for 32 factor variables. Hence, the previous finding of LSAPs being a significant driver of US house prices after the GFC seems to be a robust one.

In the Euro area, in turn, the inclusion of the factor variables may help to explain why the results of this study were quite negligible compared to some previous studies. The co-movements of the central bank balance sheet and house prices are evident also in the Euro area, but a detailed assessment of all potentially impacting factors is necessary to draw any conclusions about causality. On the other hand, it must be noted that the impact of quantitative easing on Euro area house prices was very minimal even in the bivariate model. However, adding the factor variables further diminished the explanatory power of quantitative easing. Hence, it could be that some previous studies have overestimated the impact of quantitative easing in Euro area house price formation due to underfitting of the model. In addition, quantitative easing is sometimes proxied by variables other than central bank balance sheet growth, such as by the shadow interest rates (see, for example, Huber & Punzi, 2014). This alteration in variables will obviously lead to dissenting results.

Distinctions between the US and the Euro area real estate markets

The US real estate market is often assumed to be more sensitive to the changes in monetary policy, consistent with the results of this study. This difference between the US and the Euro area is due to many factors. Most notably, the US real estate market is more leveraged with mortgage debt to GDP ratios being historically much higher than in the Euro area (Musso et al., 2011). Hence, any changes in the financing costs of real estate – mainly driven by monetary policy – would affect real estate prices more vigorously. This reasoning is empirically supported: studies have found that economies with high loan-to-value ratios on housing are more prone to house price booms and busts (Agnello & Schuknecht 2011; Cerutti et al., 2017). Moreover, economies with highly developed mortgage markets show a stronger reaction of house prices to quantitative easing (Rahal, 2016).

Why are houses more leveraged in the US than they are in the Euro area? In her study considering the pre-GFC housing bubble in the US, Ellis (2008) assessed some key distinguishing factors of the US housing market. First, some tax regulations, such as the deductibility of mortgage interest rates, promotes home owning and excessive borrowing. Although mortgage interest rates can be tax deducted also in some other developed countries, overall, the US tax system encourages home ownership more than the tax systems of many other countries. Furthermore, in contrast to some other countries, the US tax system does not push investors to let the properties to gain tax benefits but rather allows for tax reliefs also in the case of flipping. This is another incentive for home ownership.

Moving to the role of borrowing, Ellis (2008) argues that the US legal system does not punish for defaults as heavily as many other countries. This, along with the rather loose financial regulation enabling structured lending, might lead to excessive risk taking of borrowers. In addition, positive credit reporting may lead to households being tempted to maneuver borrowing to improve their credit score and thus acquire mortgages more easily. Ellis (2008) also notes that US households can refinance their mortgages rather inexpensively and cash out some of the equity while doing so. Cash-outs lead to decreased home equity and thus higher loan-to-value ratios.

In addition to these stylized facts related to the US real estate market, there are also some government related distinctions between the two monetary areas. Bernanke (2020) argues that the macroprudential tools are rather underdeveloped in the US compared to the Euro area. Castro & Sousa (2012) found that the ECB monitors the cumulation of housing wealth more actively and might thus be more prepared to take action when a housing bubble is building up. Generally, it seems that the ECB considers house price developments more carefully than the Fed in their policy making. This might indicate that the Euro countries have adopted a more conservative approach to housing inflation and are thus more shielded from changes in monetary policy.

Another important notion is the distinction between the LSAPs of the two central banks. The Fed purposely supported the housing market by including a massive amount of mortgage-backed securities and housing debt in their asset purchases after the GFC (Federal Reserve Bank of New York, n.d.). This was done not only because the crisis was rooted from the deterioration of house price fundamentals, but also because the house price stimulus was believed to boost overall private consumption (Reisenbichler, 2020). The ECB took a more conservative approach by supporting the housing market relatively much less. The share of asset-backed securities and covered bonds in the LSAPs was very small compared to the US (European Central Bank, 2022a). In addition, the covered bonds of the ECB were backed not only by real estate, but also by other assets (Reisenbichler, 2020). It seems that house price inflation was not part of the monetary policy strategy of the ECB but rather an unwanted side effect that the central bank was worried about.

This distinction between the asset purchasing programs suggests that the quantitative easing of the Fed would have a larger impact on real estate prices, as demonstrated in this study. Reisenbichler (2020) argues that the different priorities of the two central banks are due to their inherently different economies: the US economy is largely driven by credit and consumption which calls for a highly functional mortgage market, whereas many of the most powerful Euro countries are more export-driven and thus the mortgage and housing markets are not as much emphasized in policy making. Germany, most notably, has adopted a policy of low house price volatility to distinguish housing price developments from any disturbances related to the financial markets (Voigtländer, 2014). Hence, the decentralized nature of the Euro area housing market may cause the ECB to withdraw from intensive housing aid as increasing house prices is not a priority for some of the Euro countries.

As the Euro area real estate market is extremely heterogeneous, comparing the US market with Euro countries would call for detailed consideration of each 19 Euro countries separately. This remains to be done in future research. Moreover, as most Euro area time series are weighted, the biggest Euro economies – such as Germany and France – are most likely to dominate the aggregate results. Nonetheless, it can be argued that certain characteristics of the US real estate market, most notably related to lending, regulation, and fiscal and monetary objectives, result in US house prices being more sensitive to boom and bust cycles. Some individual Euro countries – presumably those with more liberal approach to lending and house price developments – might still need to pay attention to the connection between quantitative easing and house price inflation. Furthermore, studying the cross effects of the US and Euro area monetary policy could yield some interesting insights on the spillover effects of quantitative easing on real estate prices.

Distinctions between residential and commercial real estate

The results also differed in terms of the two property types. In the bivariate VAR models, there seemed to exist causality from quantitative easing to commercial real estate prices in the Euro area, but the causality was diminished after augmenting the factor variables into the regressions. For the Euro area, any definitive conclusions about the differences between the two property classes cannot be drawn since in the FAVAR models the effect of quantitative easing on both asset classes was very minimal. In the US, however, residential and commercial real estate prices seem to react to quantitative easing somewhat differently.

Both in the bivariate VAR models and in the FAVAR models, the effect of quantitative easing on US commercial real estate prices was significantly smaller. The reaction was further decreased when the Taylor rule variables were excluded from the equation. Also, while the impact of central bank balance sheet fluctuations on the US residential real estate market was evident only after the implementation of the LSAPs, a similar pattern was not detected for commercial real estate prices. It seems that although the balance sheet of the Fed has some impact also on commercial real estate prices, the impact might not be caused by the LSAPs per se.

The existing literature provides very little reasoning for this phenomenon. The dynamics of commercial real estate prices have not been studied from the monetary policy perspective as widely as house prices. Moreover, there are no previous studies comparing how residential and commercial real estate prices react to quantitative easing. Nonetheless, there are some theoretical concepts that might help to explain the results obtained.

In their LSAPs, the Fed purchased large quantities of mortgage-backed securities. The MBS can be backed by either residential or commercial loans. However, the Fed made commercial mortgage-backed security purchases only in 2021 (worth around 10 billion) resulting in residential mortgages-backed securities (RMBS) being purchased substantially more throughout the last 15 years (The Federal Reserve Bank of New York, 2021). Hence, quantitative easing provided substantially more aid to housing markets than to commercial real estate markets. Furthermore, the CMBS bought in 2021 were still partly backed by multifamily home mortgages, a type of residential property (The Federal Reserve Bank of New York, 2021). The unequal treatment of RMBS and CMBS by the Fed might explain why quantitative easing inflated mainly residential real estate prices. It would be interesting to examine whether commercial real estate prices were inflated after the CMBS purchase of the Fed in 2021, but unfortunately the sample of this study is too short for such examination.

In addition, the residential real estate market is often more leveraged than the commercial real estate market. The average loan-to-value ratios for US commercial properties are usually around 60-70 %, depending on the property type and whether the loan is securitized or not (An & Pivo, 2020; Black, Krainer & Nichols, 2017; Glancy & Kurtzman, 2022). For residential real estate, in turn, the average loan-to-value ratios are around 80 % (Federal Housing Finance Agency, 2022). Moreover, only around 20 % of the US commercial real estate mortgages are securitized (Black et al., 2017), compared to 65 % in residential mortgages (Fuster, Lucca & Vickery, 2022). Cerutti et al. (2017) argued that countries with high loan-to-value ratios and a high level of mortgage securitization are more prone to housing bubbles. As housing bubbles are quite often due to monetary factors, it would be interesting to evaluate whether property types with higher leverage ratios and higher level of securitization have a stronger reaction to a LSAP shock. If so, this could potentially explain the different reaction of US residential and commercial real estate to quantitative easing.

Conventional versus unconventional monetary policy

When assessing the effect of quantitative easing on asset prices, it is often difficult to distinguish its impact from other monetary policy tools as the actions tend to overlap and be accelerated by each other (Swanson, 2021). Hence, it can be challenging to make a clear distinction between the effect that, first, LSAPs and, second, low interest rates have on asset prices. Arguably, low interest rates in themselves inflate asset prices (Iacoviello & Neri, 2010) but the question is whether the recent asset price inflation is fueled solely by the low interest rates or do LSAP per se play a role in the development.

Employing the FAVAR method allows us to distinguish the effect of central bank balance sheet growth on real estate prices by controlling the result for 32 macroeconomic series. To attend to the issue even further, the robustness of the results was tested against the exclusion of Taylor rule variables. As the Taylor rule is widely used as a guideline when setting the discount rate, this consideration reveals whether the impact of LSAPs on real estate prices is evident beyond low interest rates. Consistent with the differences of residential and commercial real estate in the era of unconventional monetary policy, excluding the Taylor rule variables significantly decreased the forecasting power of quantitative easing on US commercial real estate prices but not on residential real estate prices. Hence, quantitative easing has a bigger role in house price formation, whereas the co-movements of the central bank balance sheet and commercial real estate prices might be more driven by the zero lower bound. This is logical as the Fed subsidized the housing market substantially more in their LSAP programs.

The power of quantitative easing was assessed also by dividing the US dataset into two subsamples. The first subsample (01/2003 – 12/2008) covers the era before the GFC and the second subsample (01/2009 – 06/2021) the era of unconventional monetary policy. The purpose of the division was to examine whether central bank balance sheet fluctuations forecasted real estate prices even before the LSAPs or was the effect evident only after the substantial increase in liquidity. The latter would be more logical from the viewpoint of the monetary transmission channels explored in chapter 2.1. Indeed, the effect of quantitative easing on house prices was evident only in the second subsample, suggesting that LSAPs drive house prices in the US. However, a similar pattern was not detected with US commercial real estate prices.

The residential real estate result is consistent with the study of Ryczkowski (2019) who found that the causality between quantitative easing and US house prices was reversed in 2008 after which quantitative easing began leading house prices. This might be due to, first, the contents of the LSAPs and, second, the magnitude of the LSAPs. As the balance sheet expansion of the Fed shows, the amount of securities bought by the Fed in the era of unconventional monetary policy is enormous. This alone would aid the economy and thus support the housing market more than before. In addition, quantitative easing was especially targeted towards MBS. Supporting the MBS market should, in turn, ease mortgage lending and thus increase house prices.

The latter argument might also explain why US commercial real estate prices did not respond to the introduction of the LSAPs: in contrast to RMBS, CMBS were not bought by the Fed before 2021. Nonetheless, there seems to exist a rather ambiguous causality between US commercial real estate prices and the balance sheet size of the Fed that is not at least unanimously explained by the LSAPs. Perhaps standard open market operations even prior to the GFC reflect the overall state of the economy and thus seem to impact commercial real estate prices. It can also be that there exists a confounding factor not taken into account in this study that explains the co-movements of these two variables.

Practical implications

If house prices are inflated by quantitative easing, concerns of overvaluation (i.e., bubbles) naturally arise. LSAPs were implemented to increase asset prices (Gagnon et al., 2010) so in one sense, the results of this study can be interpreted as a sign of successful, expansionary policy making of the US. However, quantitative easing can be seen as a somewhat artificial and temporary maneuver that boosts asset prices but does not necessarily improve the underlying fundamentals. If house prices are not based on fundamentals but on temporary monetary policy and speculation, the current house price inflation is not preservable. This will lead to value deterioration and hurt the real estate and lending markets.

In May 2022, the Fed announced that they will continue to withdraw from the LSAPs by reducing their holdings of securities (including MBS) to hinder inflation (Federal Reserve Board, 2022a). If part of the growth in US house prices can be assigned to quantitative easing, stopping these programs would mean value deterioration of house prices. This effect is further accelerated via increasing interest rates (Federal Reserve Board, 2022b) that increase the financing costs of real estate and thus puts a downward pressure on prices (Iacoviello & Neri, 2010). A sudden value deterioration, in turn, will decrease market prices, increase volatility, and create financial instability (IMF, 2021). This is something the policymakers should be particularly concerned about since the bursting of the latest house price bubble manifested an extensive economic crisis.

Furthermore, the long-term impact of quantitative easing on US house prices is quite unknown as quantitative easing has been in the toolkit of the Fed only during the last 15 years. The previous house price inflation periods have been assigned to other factors, such as low interest rates, predatory mortgage lending, and stagnant housing supply (Hendershott et al., 2010; Iacoviello & Neri, 2010; Taylor, 2007). Hence, the magnitude of possible price corrections is hard to estimate. In Japan, quantitative easing was used already in the 1990s to aid the bursting of a real estate bubble (Joyce et al, 2012). Nonetheless, Japan is also one of the few western countries that has experienced a significant drop in house prices in the 21st century (Knoll, Schularick & Steger, 2017). Although the Japanese housing market is not fully comparable with the US, this lesson from history might be something policymakers should be aware of.

On the other hand, quantitative easing fueling house prices can also be seen as a sign of successful, expansionary monetary policy. In their LSAP programs, the Fed supposedly intended asset prices – including house prices – to increase to aid the stalled housing market (Gagnon et al., 2010). This was seen as an important priority of the Fed because housing is a key driver of the US business cycle (Reisenbichler, 2020). Thus, the results of this study may not be worrying but rather desirable from the viewpoint of the US policymakers. Some even refer to the LSAP programs of the ECB as "unsuccessful" (see, for example, Ryczkowski, 2019) as they were unable to direct funds towards real estate prices. The difference between the LSAP programs might be due to different priorities of the two central banks, as well as to different growth models of the two economies (Reisenbichler, 2020). Consequently, it can be argued that both central banks were successful in their own mandates: the Fed successfully boosted house prices, and the ECB was able to prevent the housing market from overheating – at least in some Euro countries.

Beyond worries related to asset price inflation, the results of this study provide useful notions for policymakers and researchers from a methodological perspective. Including the 32 factor variables to the bivariate VAR model substantially altered the results. If the factor variables were omitted, the power of the LSAPs on real estate prices would be overestimated. Hence, it can be argued that a simple bivariate VAR model is not sufficient when studying asset price formation and using such model would lead to underfitting. In addition, dividing the data into two subsamples provides useful information on how the GFC has shifted the dynamics of some economic variables. In the future, it would be useful to study whether the results are robust to the addition of even more macroeconomic variables. In their fundamental study, Bernanke et al. (2005) found that only after increasing the number of factors beyond 120, the results were not altered. As the number of factors in this study is only 32, adding more factors could potentially dampen the results obtained.

8 CONCLUSIONS

The unconventional monetary policy tools used by many central banks after the GFC have been a topic of intense research within the last 15 years. The large-scale asset purchases of central banks, i.e., quantitative easing, have had intriguing effects on the economy as enormous amounts of liquidity has been poured to the asset markets. Quantitative easing is believed to have spillover effects also on other asset classes not directly included in the LSAPs, such as real estate. The spillover effects have manifested through multiple transmission channels, portfolio balance channel being the most prominent one. When the yields of the assets included in the LSAPs are suppressed, investors must rebalance their portfolio by buying other assets in their search for yield. This increase in demand should translate into higher prices for real estate today.

Just by looking at the recent developments of real estate prices and the central bank balance sheets, one can observe that these two variables seem to comove. This is not, however, a proof of causality. In this study, the dynamics of quantitative easing and both residential and commercial real estate were examined by employing the factor-augmented vector autoregressive model. The FAVAR model effectively distinguished the explanatory power of central bank balance sheet growth on real estate valuations from other potentially affecting factors. The control variables, i.e., factors, included a wide range of economic time series related to monetary policy and real estate price formation for the US and the Euro area.

The FAVAR results revealed that the quantitative easing of the Fed is a key driver of US house prices. The transmission channel of quantitative easing is separate from the conventional monetary policy channels, and it is evident only after the GFC, as expected. However, quantitative easing does not seem to drive commercial real estate prices in a similar manner. For the Euro area, neither the residential nor commercial real estate prices were significantly affected by the quantitative easing of the ECB. Interestingly, commercial real estate prices of both monetary areas seemed to be affected by quantitative easing in a standard bivariate VAR model, but the effects were diminished after adding the factors into the models. This proves the importance of factor analysis in VAR modeling when studying complex dynamics, such as monetary policy and asset price formation.

The dissenting results of the US and the Euro area can be attributed to few key differences between the monetary areas. First, the LSAP programs of the Fed and the ECB had a clear difference from a real estate perspective: the Fed included a large amount of mortgage-backed securities in their asset purchases while the ECB did not. By buying MBS, the Fed purposely promoted the housing market of the US by allowing more liquidity to the mortgage markets while the ECB adopted a more conservative approach. This difference might be due to different growth models of the two areas: while many Euro countries are export driven, the US economy is consumption and credit driven and thus dependent on the prosperity of the housing sector. This creates different priorities for the two central banks. In addition, the US housing market is highly leveraged and securitized, making it more responsive – and vulnerable – to changes in monetary policy.

The previous literature does not provide many explanations for the more muted response of US commercial real estate to quantitative easing. This is because the commercial real estate sector is not nearly as much studied as the housing sector. One obvious remark is that the Fed included mainly residential mortgage-backed securities in their LSAPs. Thus, the aid was directed almost completely towards the residential real estate market. As the Fed finally included commercial mortgage-backed securities in their asset purchases during 2021, it would be interesting to test this hypothesis in future studies by examining whether quantitative easing has affected US commercial real estate prices more from 2021 onwards.

As the US economy is inherently different compared to the Euro area economy, the dissenting results between the two areas are logical. Not only has the Fed supported the mortgage sector more vigorously, the responsiveness of US real estate prices to monetary aid is also higher. On one hand, the Fed has successfully promoted the prosperity of the housing market and thus accelerated the growth of the whole economy after the financial crisis. On the other hand, that might lead to real estate overvaluation. The ECB has taken a more stringent approach to asset price inflation. Yet especially the Covid-19 pandemic and the recession that followed evoked worries related to housing bubbles also in the Euro area. The balancing act between fueling economic growth and restraining asset price bubbles is a challenging, yet critical task of the central banks also in the future.

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APPENDIX 1: Data for the US

Variable	Description	Source	Frequency	Treatment
Quantitative Easing				
Central bank balance sheet	Total assets/liabilities of the Fed in millions of US Dollars	FRED	W	Log. ret.
Real estate prices				
Residential real estate prices	United States, Residential Property Prices, Nominal, Index, 2010 = 100	BIS	Q	Log. dif.
Commercial real estate prices	United States, Commercial Property Prices, All Properties, Pure Price, Index, 2010 = 100	BIS	Q	Log. dif.
Short term interest rate				
Discount rate	Federal funds effective rate, Not SA	FRED	M	Dif.
1M interest rate	4WK Treasury Bill Secondary Market Rate, Not SA	FRED	M	Dif.
3M interest rate	3M Treasury Bill Secondary Market Rate, Not SA	FRED	M	Dif.
6M interest rate	6M Treasury Bill Secondary Market Rate, Not SA	FRED	M	Dif.
1Y interest rate	Market Yield on U.S. Treasury Securities at 1Y Constant Maturity	FRED	M	Dif.
Long term interest rate				
5Y interest rate	Market Yield on U.S. Treasury Securities at 5Y Constant Maturity	FRED	M	Dif.
10Y interest rate	Market Yield on U.S. Treasury Securities at 10Y Constant Maturity	FRED	M	Dif.
Stock prices				
Share index	Standard and Poor's 500 Composite US Dollar	S&P	M	Log. ret.
Stock market volatility	CBOE SPX Volatility VIX US Dollar	S&P	M	–
Dividend yield	Standard and Poors, 500 Composite Dividend Yield US Dollar	S&P	M	Log. ret.
Confidence				
Consumer confidence	United States, Consumer Surveys, Conference Board, Consumer Confidence, SA, Index, 1985 = 100	The Conference Board	M	Log. ret.
Economic policy uncertainty	US News-Based Policy Uncertainty Index	www.policyuncertainty.com	M	–
Real activity				
GDP*	United States, National Product Account, Gross Domestic Product, Overall, Total, Current Prices, AR, SA, in billions of US dollars	BEA	Q	Log. ret.

Industrial production*	United States, Production, Overall, Total, SA, Index, 2017 = 100	FED	M	Log. ret.
Private consumption*	United States, Personal Outlays, Personal Consumption Expenditure, Overall, Total, Current Prices, AR, SA, in millions of US dollars	BEA	Q	Log. ret.
Public consumption*	United States, Government Expenditures Account, Consumption Expenditures and Gross Investments, Overall, Total, Current Prices, AR, SA, in millions of US dollars	BEA	Q	Log. ret.
Investments*	United States, Investment Account, Private Fixed Investment, Overall, Total, Current Prices, AR, SA, in millions of US dollars	BEA	Q	Log. ret.
Exchange rates				
Nominal exchange rate	USD/CAD	Refinitiv	D	Log. ret.
	USD/CNY	Refinitiv	D	Log. ret.
	USD/EUR	Refinitiv	D	Log. ret.
	USD/Pound	Refinitiv	D	Log. ret.
SDR index	SDR per USD	imf.org	D	Log. ret.
Real effective exchange rates	Real Broad Effective Exchange Rate for United States	FRED	M	Log. ret.
Commodities				
Oil price*	Crude Oil West Texas Intermediate Free on Board Cushing US Dollar Per Barrel	Refinitiv	D	Log. ret.
Natural gas*	Natural Gas Henry Hub Day Ahead CST Gulf Coast US Dollar per MMBtu	SNL	D	Log. ret.
Trade				
Exports*	Exports US, in billions of US Dollars	OECD.Stat	M	Log. ret.
Imports*	Imports US, in billions of US Dollars	OECD.Stat	M	Log. ret.
Inflation				
Consumer prices*	CPI, US, All Urban Consumers, not SA, 1982-1984 = 100	BLS	M	Log. ret.
Mortgage loans				
Mortgage loans*	All Sectors; Total Mortgages; Asset, Level, Millions of US Dollars, Not SA	FRED	Q	Log. dif.
Construction				
Cost of construction*	US, Construction and Materials, US Dollar	FTSE	M	Log. ret.

Building permits	United States, Building Permits, Total, AR, SA, Change Period Over Period	USCB	M	–
Employment				
Unemployment*	Unemployed, Rate, US, Total, SA	USCB	M	Log. ret.

*Notes: *Variable is assumed to be slow-moving. Q refers to quarterly, M to monthly, W to weekly and D to daily frequency of the data. Treatment refers to processing of the data that was necessary to obtain stationarity (– = no processing, dif. = differencing, log. ret. = logarithmic returns, and log. dif. = differencing logarithmic returns).*

APPENDIX 2: Data for the Euro area

Variable	Description	Source	Frequency	Treatment
Quantitative Easing				
Central bank balance sheet	Total assets/liabilities of the Eurosystem in millions of Euros	SDW	W	Log. ret.
Real estate prices				
Residential real estate prices	Residential property price index, Euro area (19), 01/2015 = 100	SDW	Q	Log. dif.
Commercial real estate prices	Commercial property price index, Euro area (19), 01/2015 = 100	SDW	Q	Log. dif.
Short term interest rate				
Discount rate	Eonia rate	SDW	M	Dif.
1M interest rate	Euribor 1M	SDW	M	Dif.
3M interest rate	Euribor 3M	SDW	M	Dif.
6M interest rate	Euribor 6M	SDW	M	Dif.
1Y interest rate	Euribor 12M	SDW	M	Dif.
Long term interest rate				
5Y interest rate	European Monetary Union, Government Bond Yield, 5Y, not SA	ECB	M	Dif.
10Y interest rate	European Monetary Union, Government Bond Yield, 10Y, not SA	ECB	M	Dif.
Stock prices				
Share index	EURO STOXX 600 Euro	STOXX	M	Log. ret.
Stock market volatility	VSTOXX Volatility Index Euro	STOXX	M	–
Dividend yield	EURO STOXX 600 Dividend Yield Euro	STOXX	M	–
Confidence				
Consumer confidence	Eurozone, Consumer Survey, All Respondents, Total, Consumer Confidence Indicator, Consumer Confidence Indicator - EA, SA	DG ECFIN	M	Dif.
Economic policy uncertainty	European News-Based Policy Uncertainty Index	www.policyuncertainty.com	M	–
Real activity				
GDP*	Eurostat, Euro Zone, Expenditure Approach, Gross Domestic Product,	Eurostat	Q	Log. ret.

	Market Prices (EA19), ESA2010, Current Prices, Calendar Adjusted, SA, in billions of Euros			
Industrial production*	Euro area 19 - Industrial Production Index, Total Industry, Working day and seasonally adjusted, 2015 = 100	SDW	M	Log. ret.
Private consumption*	Private final consumption, Euro area, NPISH, current prices, calendar and seasonally adjusted data, in millions of Euros	SDW	Q	Log. ret.
Public consumption*	Government final consumption, Euro area, current prices, calendar and seasonally adjusted data, in millions of Euros	SDW	Q	Log. ret.
Investments*	Gross fixed capital formation, Euro area, Fixed assets, current prices, calendar and seasonally adjusted data, in millions of Euros	SDW	Q	Log. ret.
Exchange rates				
Nominal exchange rate	EUR/USD	Refinitiv	D	Log. ret.
	EUR/CNY	Refinitiv	D	Log. ret.
	EUR/POUND	Refinitiv	D	Log. ret.
	EUR/CHF	Refinitiv	D	Log. ret.
SDR index	SDR per EUR	imf.org	D	Log. ret.
Real effective exchange rates	Real Broad Effective Exchange Rate for Euro Area	FRED	M	Log. ret.
Commodities				
Oil price*	Crude Oil North Sea BFO Free on Board US Dollar Per Barrel	Refinitiv	D	Log. ret.
Natural gas*	Natural Gas Title Transfer Facility Netherlands First Futures Month Euro Per Megawatt Hour	Refinitiv	D	Log. ret.
Trade				
Exports*	Exports Euro area, in billions of Euros	OECD.Stat	M	Log. ret.
Imports*	Imports Euro area, in billions of Euros	OECD.Stat	M	Log. ret.
Inflation				
Consumer prices*	HIPC, Euro area (changing composition), overall index, not SA, 2015 = 100	SDW	M	Log. ret.
Mortgage loans				
Mortgage loans*	Euro Zone, Monetary Financial Institutions, Loans, Households and	ECB	Q	Log. dif.

	Non-Profit Institutions Serving Households, Lending For House Purchase, Amount Outstanding, not SA, in millions Euro			
Construction				
Cost of construction*	Eurozone, Construction and Materials, Euro	FTSE	M	Log. ret.
Building permits	Euro Area, Construction, Permits Issued, Dwellings, Residential Buildings, Permits Issued For Dwellings, SA, Change Period Over Period	Main Economic Indicators OECD	M	–
Employment				
Unemployment*	Unemployed, Rate, Euro area (19), Total, SA	SDW	M	Log. ret.

*Notes: *Variable is assumed to be slow-moving. Q refers to quarterly, M to monthly, W to weekly and D to daily frequency of the data. Treatment refers to processing of the data that was necessary to obtain stationarity (– = no processing, dif. = differencing, log. ret. = logarithmic returns, and log. dif. = differencing logarithmic returns).*

APPENDIX 3: Variance decomposition graphs

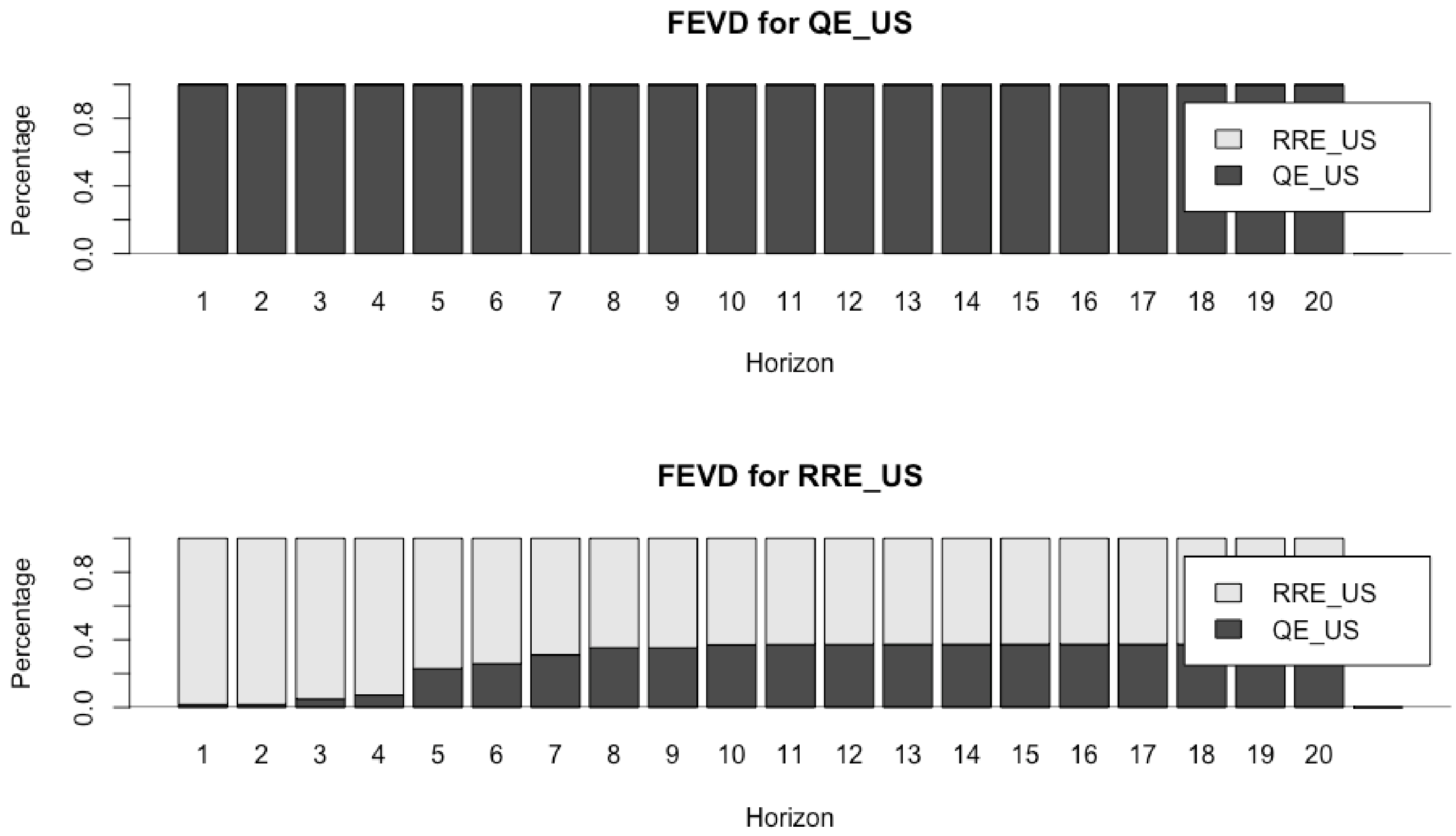

FIGURE 9 Variance decomposition graphs of US residential real estate in the bivariate VAR model.

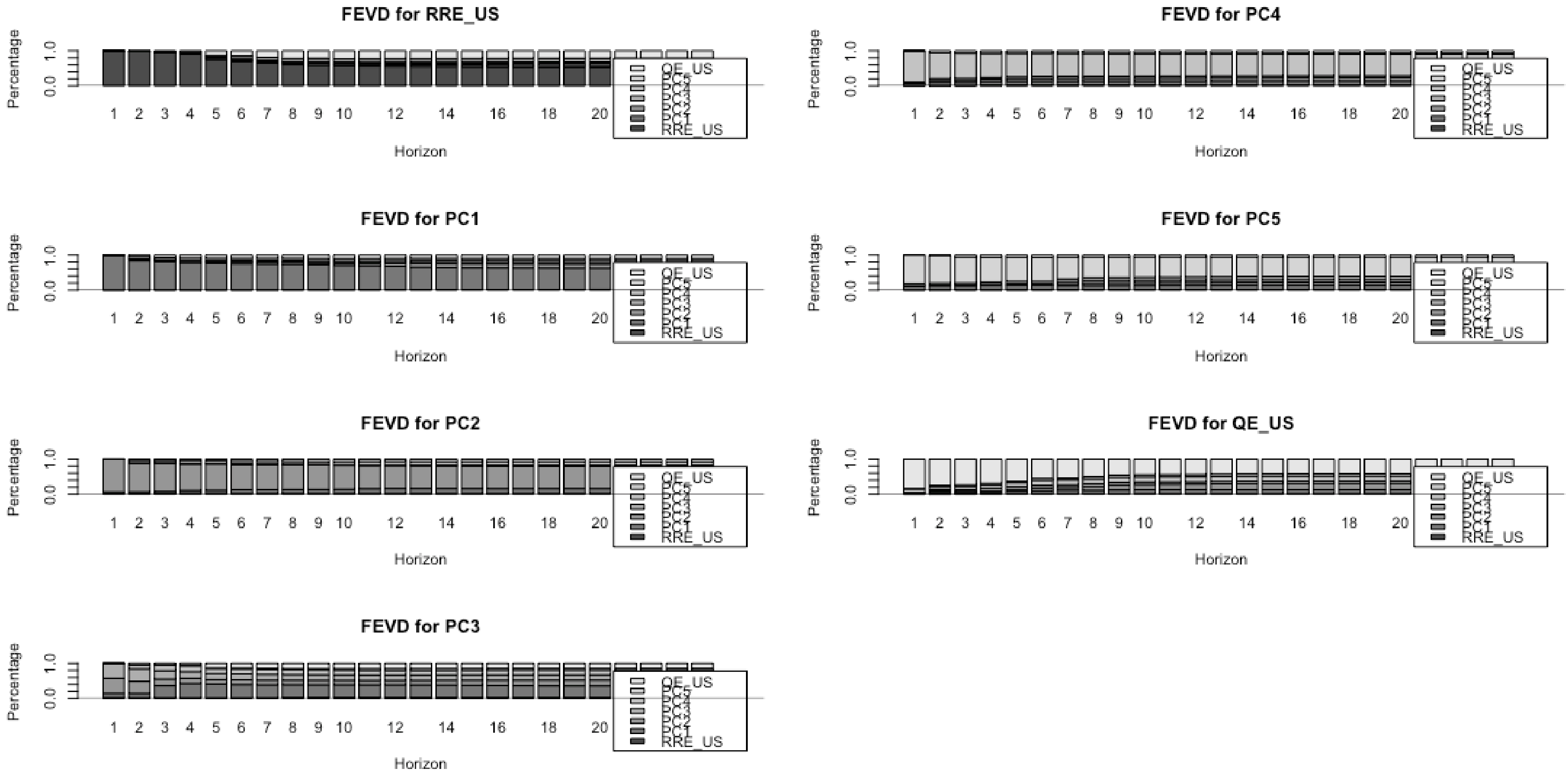

FIGURE 10 Variance decomposition graphs of US residential real estate in the FAVAR model.

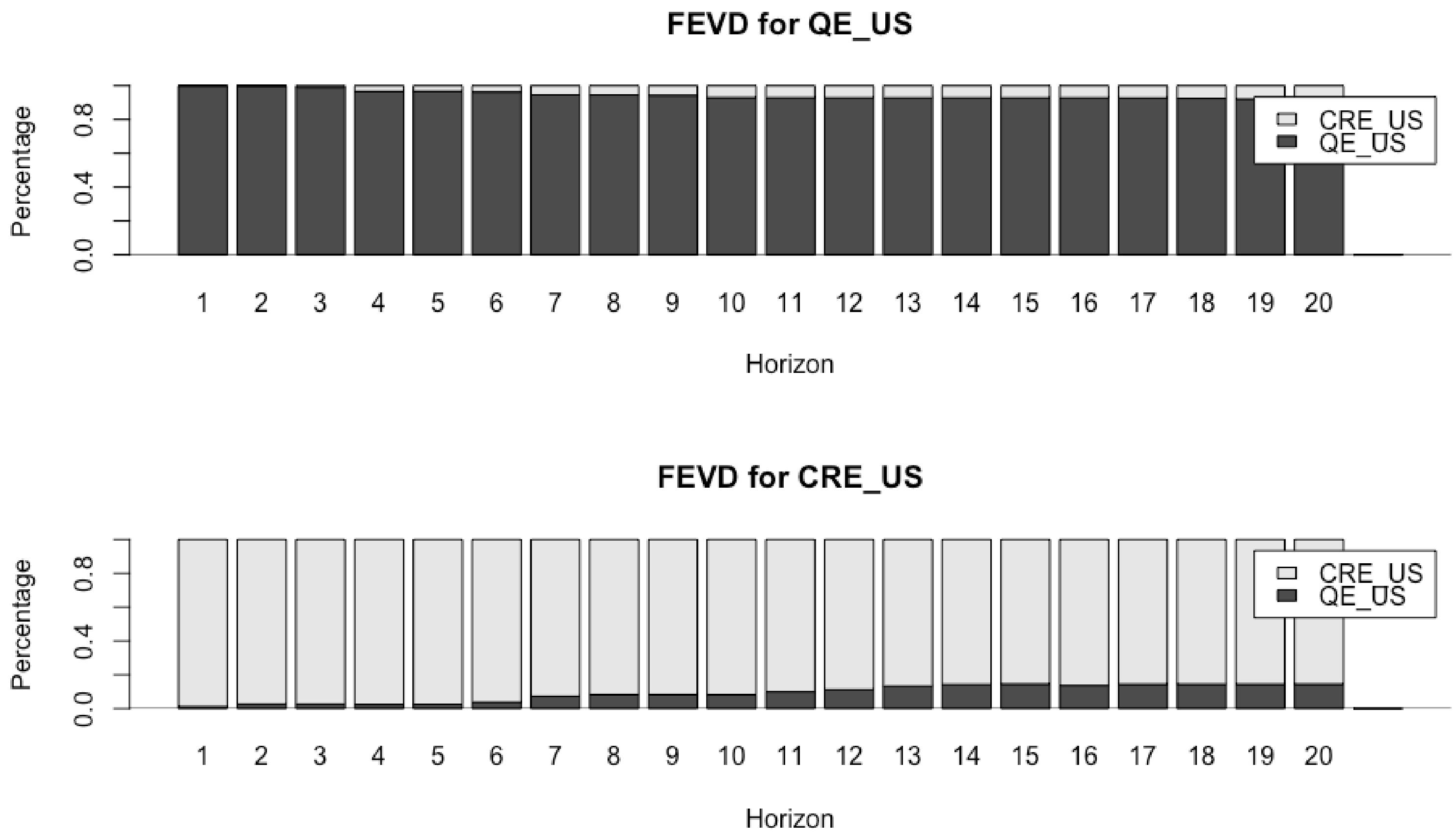

FIGURE 11 Variance decomposition graphs of US commercial real estate in the bivariate VAR model.

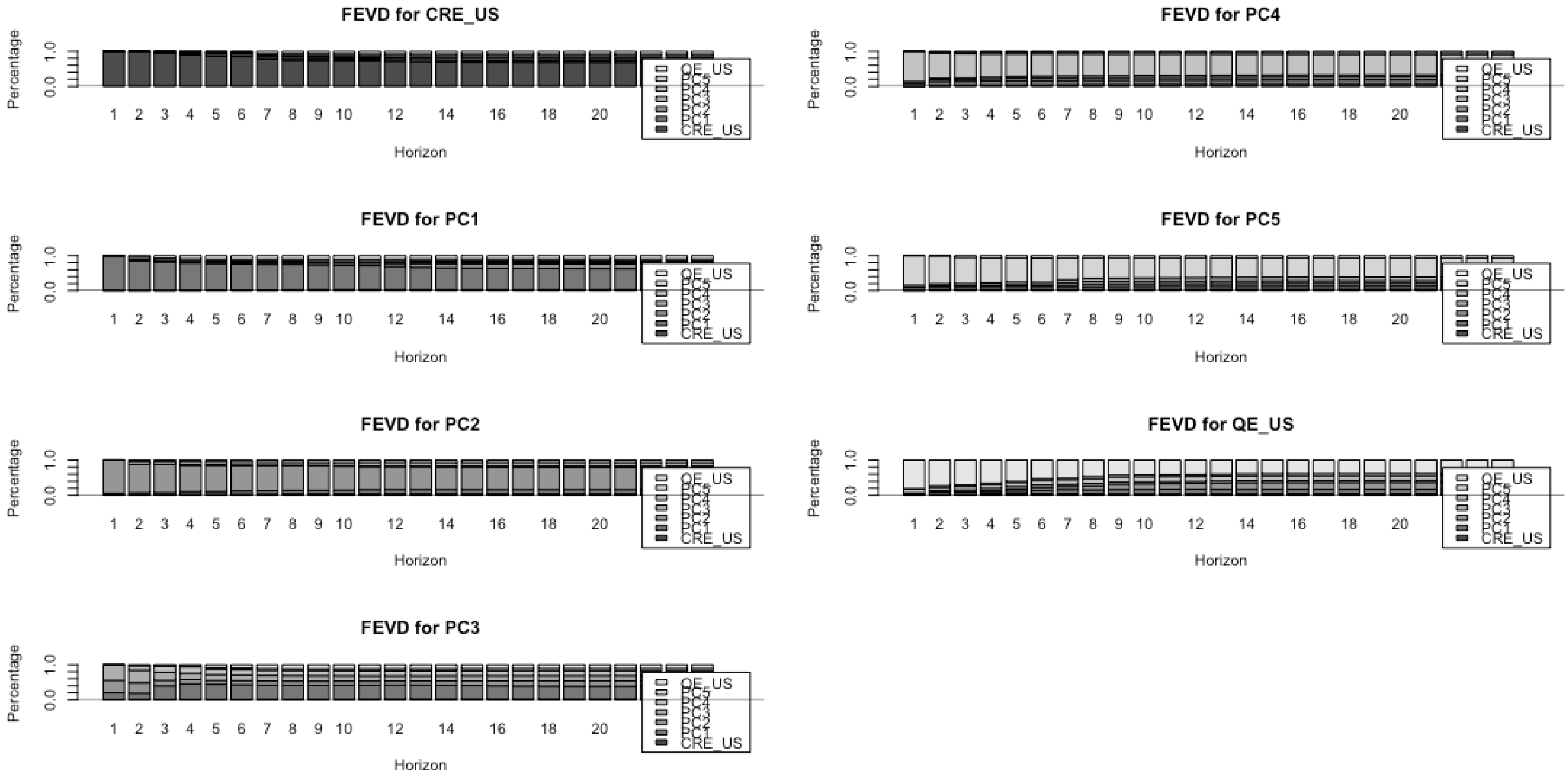

FIGURE 12 Variance decomposition graphs of US commercial real estate in the FAVAR model.

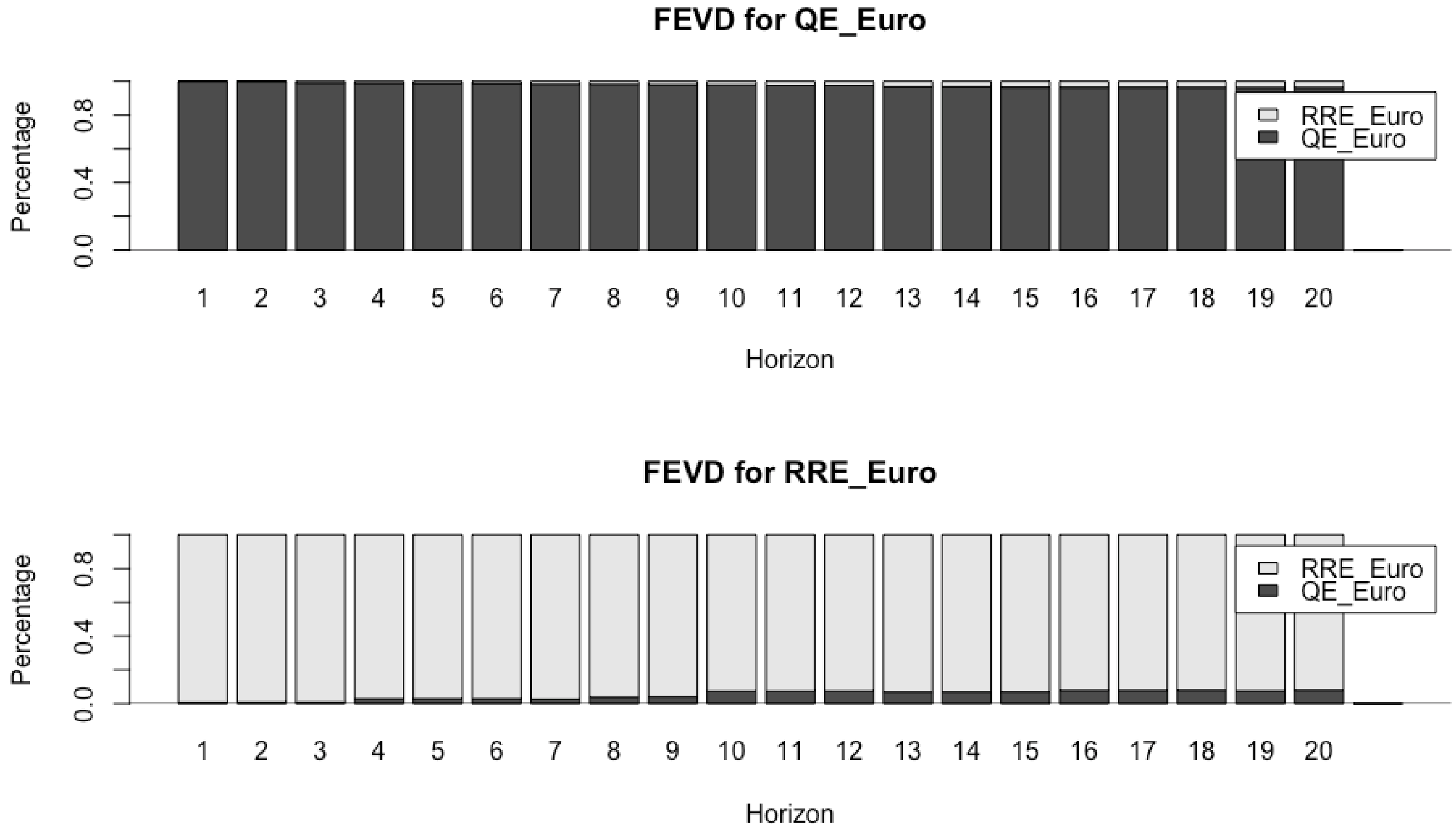

FIGURE 13 Variance decomposition graphs of Euro area residential real estate in the bivariate VAR model.

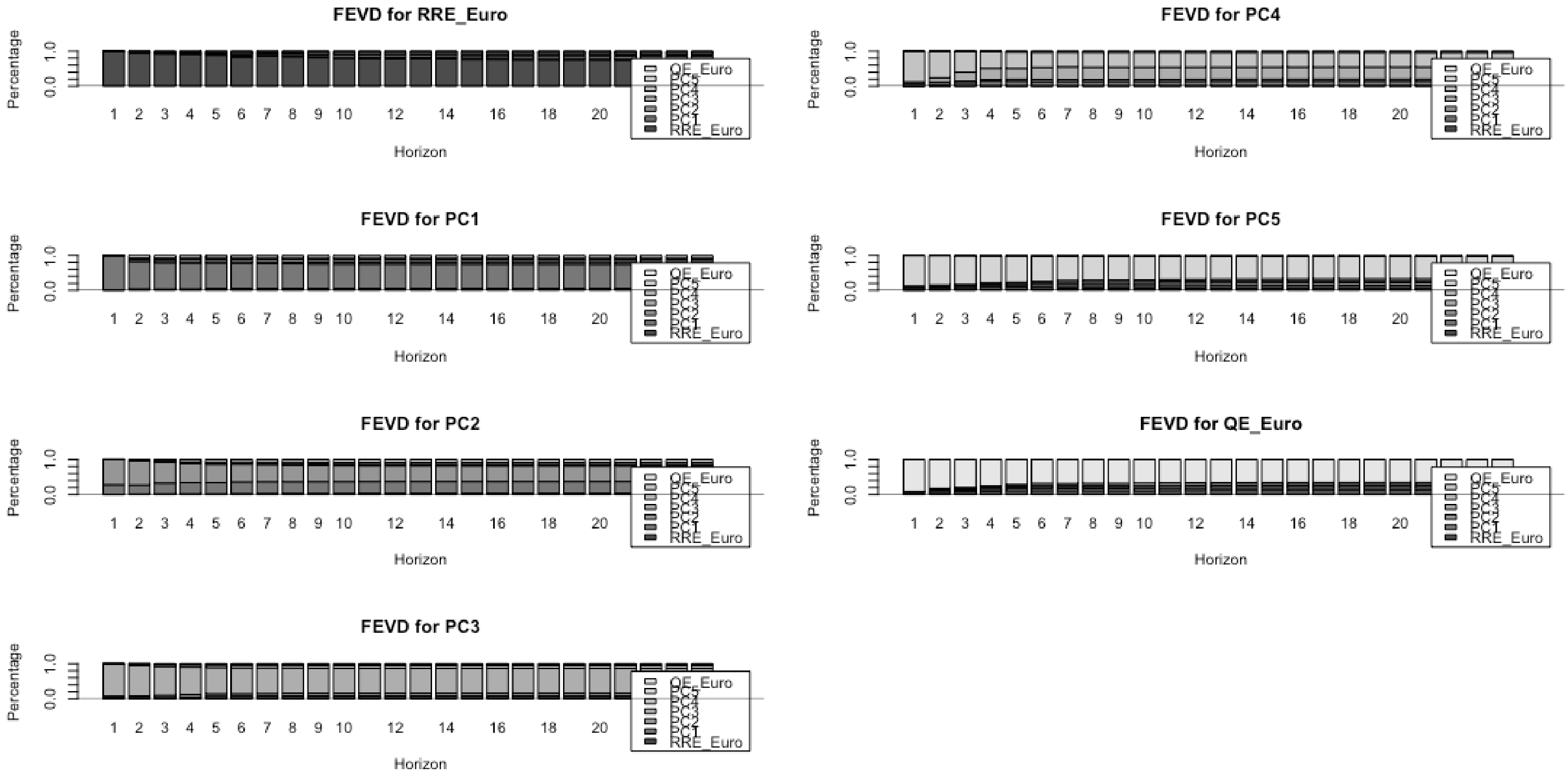

FIGURE 14 Variance decomposition graphs of Euro area residential real estate in the FAVAR model.

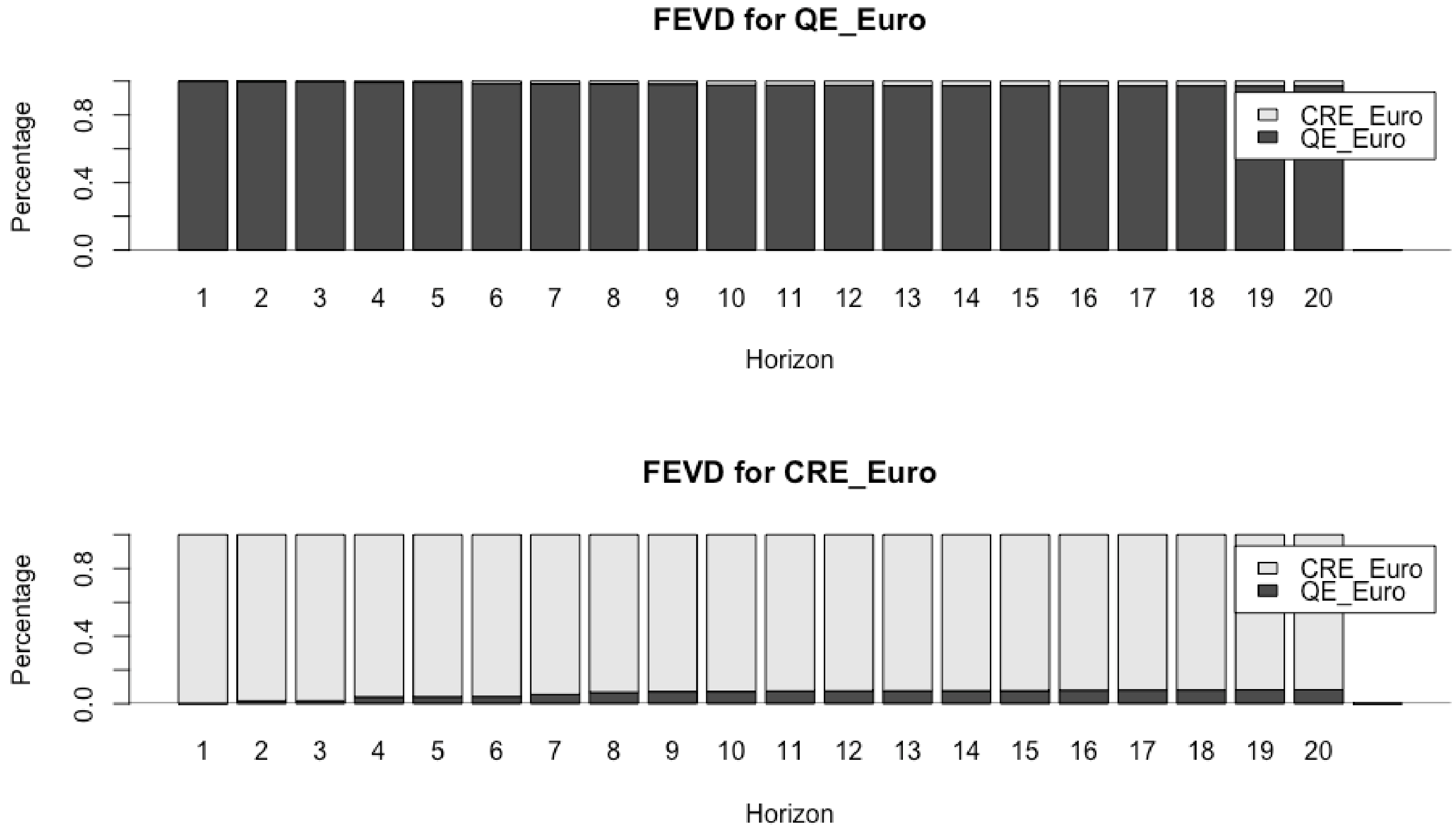

FIGURE 15 Variance decomposition graphs of Euro area commercial real estate in the bivariate VAR model.

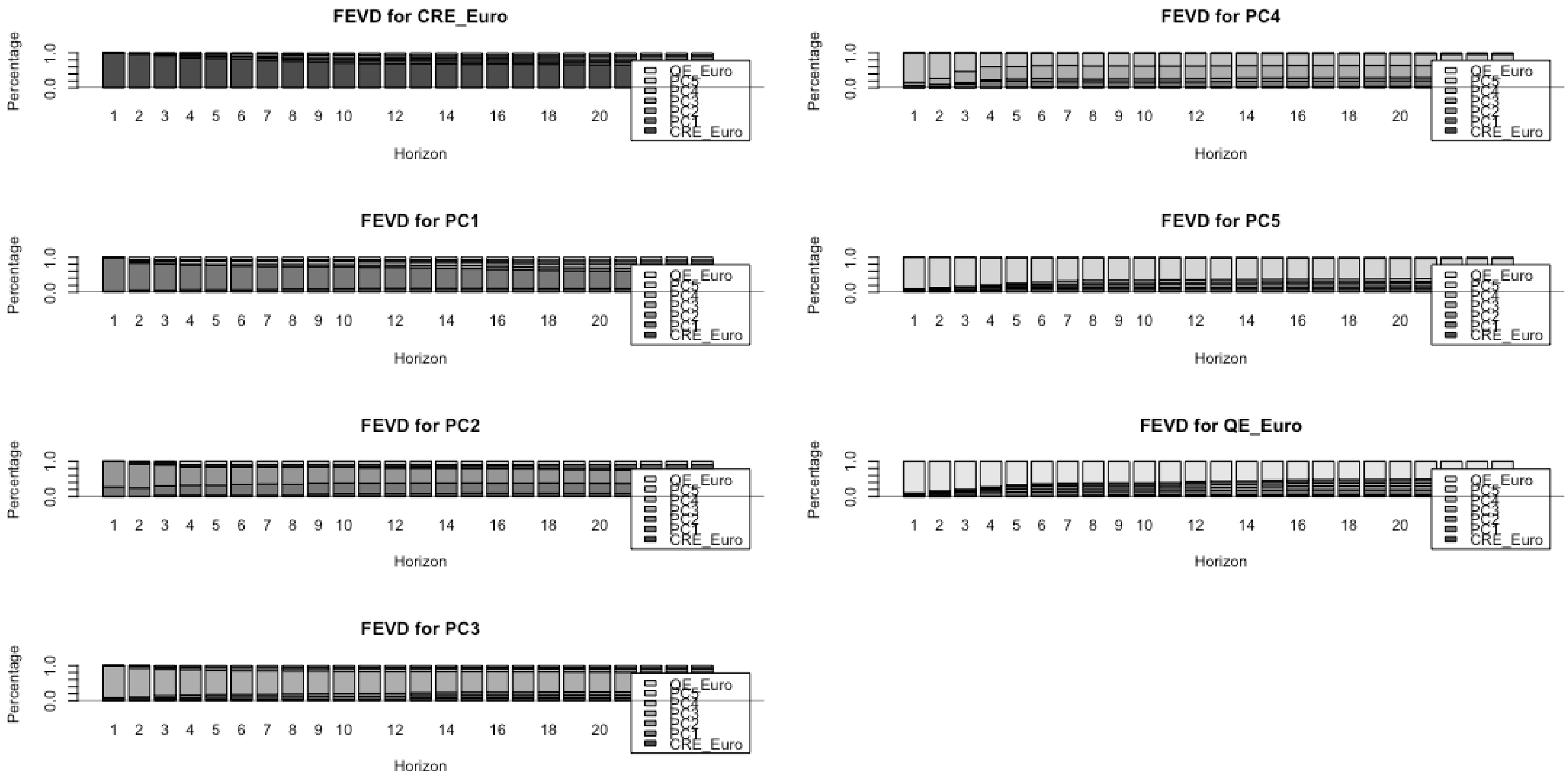

FIGURE 16 Variance decomposition graphs of Euro area commercial real estate in the bivariate VAR model.

APPENDIX 4: Explained variance graphs

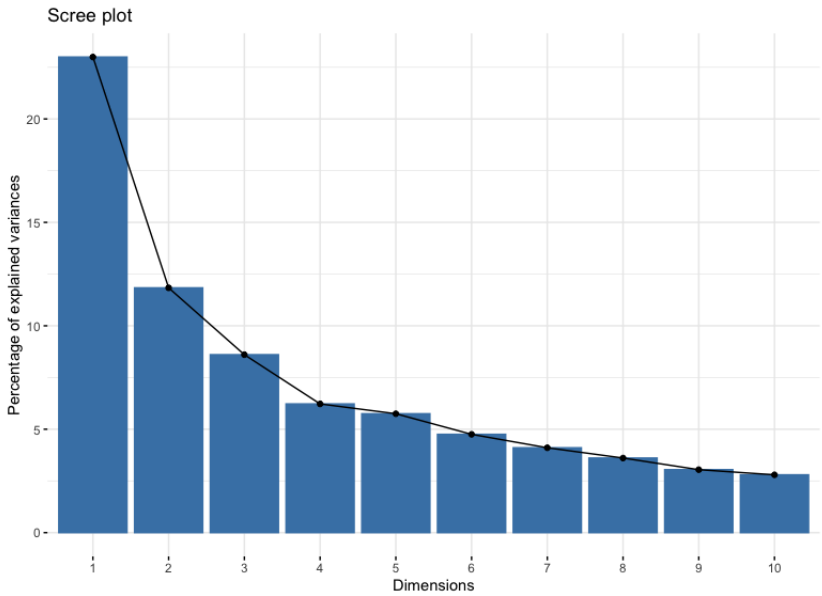

FIGURE 17 Variance explained by the first 10 principal components of the US residential real estate price changes.

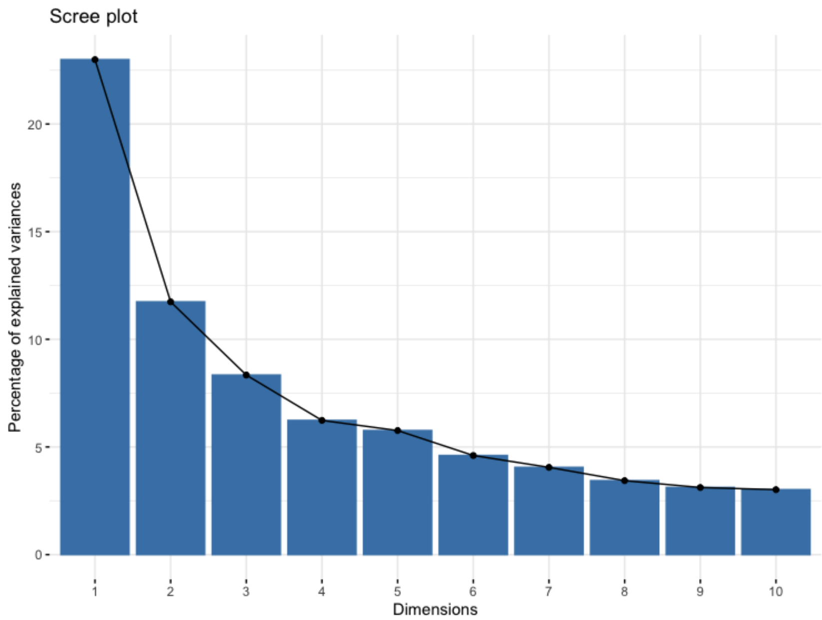

FIGURE 18 Variance explained by the first 10 principal components of the US commercial real estate price changes.

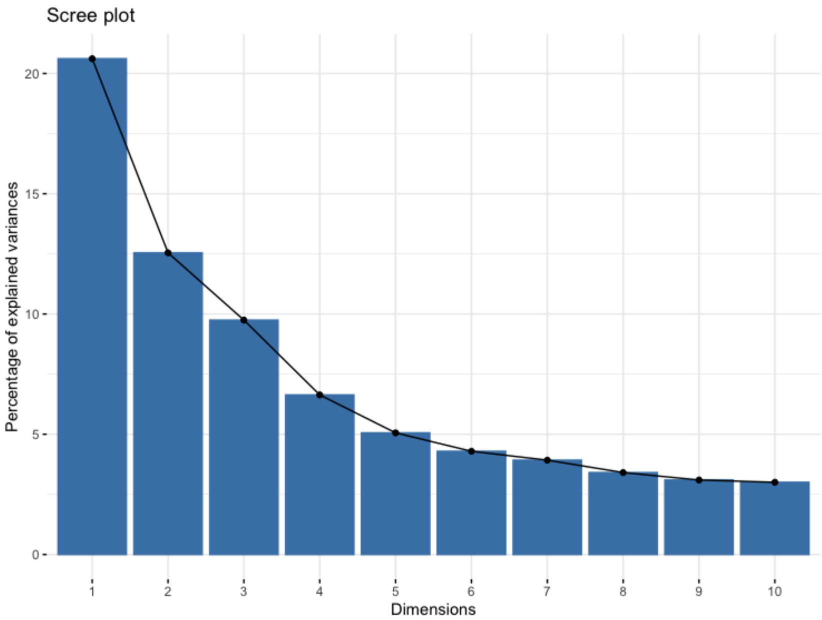

FIGURE 19 Variance explained by the first 10 principal components of the Euro area residential real estate price changes.

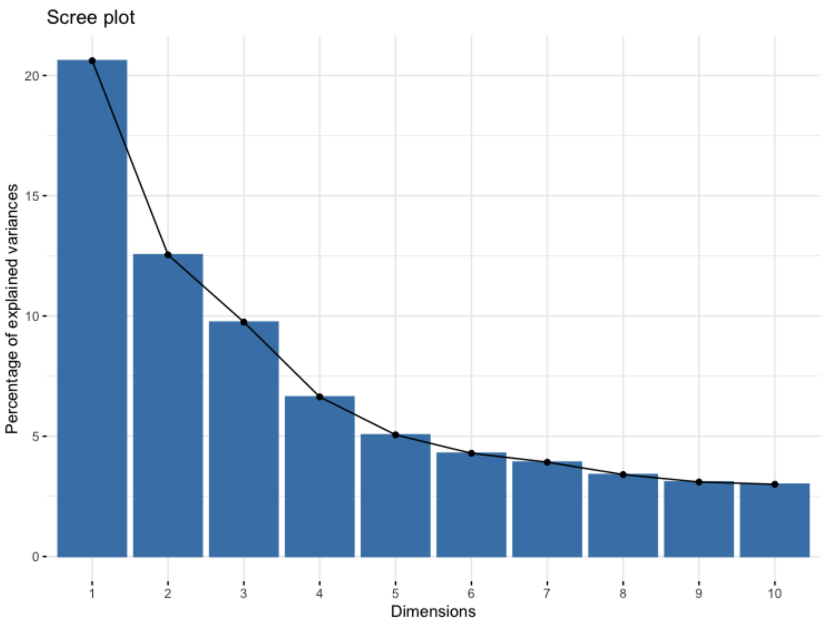

FIGURE 20 Variance explained by the first 10 principal components of the Euro area commercial real estate price changes.