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How monetary ECB expansion influences the Dutch housing market

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Abstract

In recent years, the European Central Bank has pursued an expansionary monetary policy. The assets on the balance sheet increased from 2.2 trillion euros in 2014 to almost 7 trillion by February 2021 (European Central Bank, 2021). House prices in the Netherlands also rose significantly during this period (Centraal Bureau Statistiek, 2021). This paper tries to answer the question if the Dutch increase in housing real estate prices is partly due to European monetary policy in the period 2014-2021? An impulse response analysis with a vector autoregressive model and at a later stage a vector error correction model show that there is a significant positive relationship between the quantitative monetary easing and the Dutch housing real estate prices.

1. Introduction

On March 22, 2021 Dutch news organization Het Parool published an article in which data from the Dutch Central Bureau of Statistics (CBS) showed that residential real estate prices had risen by 15 percent in February compared to the previous year in the Netherlands. This is the largest increase in 20 years. This causes problems for starters on the housing market. Their income is often below 40,000 euros, the upper limit income of social rental housing, but the waiting time for social housing is several years (Rijksoverheid, 2021). Buying a house is also difficult with their limited financial resources. As a result, starters most likely end up renting while research points out that, over the long term, buying your home is more profitable for an individual (Tabner, 2016).

The CBS (2021) furthermore reported that the price of goods and services rose by an average of 54 percent in the period between 1996 and 2019. The selling price of existing owner-occupied homes on the other hand rose by 280 percent in the same period. This raised the question whether house prices should be taken into account in the calculations of inflation, so that wages associated with inflation can rise. Then inflation would be slightly higher, according to economist Daniel Gros (2018) in calculations he reported to the European Parliament.

This increase in residential property prices can have several causes. One being the plan of the Dutch government that persons younger than the age of thirty-five who buy a home under 400,000 euros, do not have to pay transfer tax (Ministerie van Algemene Zaken, 2021). Another cause may be that the current construction rate doesn't match the deficit of 331,000 homes in 2020 and the future deficit of 845,000 in 2030 (Rijksoverheid, 2021). There is also the influence of the ECB's policies. The ECB tripled the value of their balance sheets in the period between 2014 and 2020. This was done to meet the main objective of the ECB to keep inflation below, but close to, 2% per annum over the medium term (European Central Bank, 2021).

Existing literature and reports coming from the national government mainly focus on the housing market leading into the financial crisis of 2008 and describing the consequences of the current housing crisis, whereas this paper searches for possible causes for the current crisis. To do so, the paper will delve deeper into monetary policy. This paper will investigate whether there is a relationship between the increased residential property prices in the Netherlands and European monetary policy based on the following research question:

Is the Dutch increase in housing real estate prices partly due to European monetary policy in the period 2014-2021?

The paper will use three sub-question in order to provide a well-founded answer to the main question. These are further discussed in the *Theoretical framework* and later on tested in the empirical chapters. The first sub-question is as follows: what is the relationship between monetary policy and house prices? From this section it will become clear whether the current literature has already found a linkage between the two. Then the second sub-question is: what are the most important determinants of residential property prices in the Netherlands on macroeconomic level? This sub-question is important when choosing the variables in the *Data* chapter. The second sub-question so delves deeper into supply, demand, institutions and alternative investments as determinants of prices. The third sub-question focuses on the role and impact of the ECB's policy in the Dutch housing market.

Monetary policy in this paper is approached from two sides. One side being the nine individual components of the ECB's balance sheet. The other are the three base interest rates set by the ECB: interest rate on the main refinancing operations, deposit facility and marginal lending facility (European Central Bank, 2021) which are also explained in more detail in the *Theoretical framework* chapter.

The empirical research will consist of a vector autoregressive model with an index for the house price as a dependent variable. ECB balance items will form independent variables and control variables will be added for alternative investments and macro-economic trends. The data comes from open data sources as: Statline, Eurostat, the Statistical Data Warehouse and the Dutch Central Bank.

The social relevance mainly concerns being able to answer the question if ECB monetary policy has an influence on Dutch housing prices and suggesting possible policy changes to ease the Dutch housing market. The scientific relevance is addressed by contributing to the current literature, which now often focuses on the pre-financial crisis period and is also not specifically on the Netherlands.

To answer the research question, the paper will first provide a *Theoretical framework* on the three sub-questions. Subsequently, in the *Data* section are the variables and data sources discussed and in the *Methodology* chapter will the mathematical basis of the model and the design of the analysis be described. Then can a *Conclusion* be drawn about the research question on the basis of the quantitative results. Together with the conclusion are some limitations on the conducted research and recommendations for future research discussed.

2. Theoretical framework

Some concepts have to be explained in more detail to get a good idea of the conditions surrounding the main question. Before getting into the technical analysis, a theoretical framework is built to provide a clear and fundamental theoretical basis. This is all done while providing reasoning behind the forms of monetary policy, alternative investments and the housing market. The chapter is divided into three parts on the basis of the sub-questions discussed in Chapter 1.

2.1 Relation between monetary policy and house prices

To determine what is the relationship between monetary policy and house prices, available literature should be cited. Most literature that covers the relationship between monetary and house prices is about the pre-financial crisis era. However, there are relevant papers for the intended research domain.

There is clear evidence that monetary policy influences house prices. In 2011 John McDonald and Houston Stokes wrote about the positive relation in the United States between monetary expansion policy and house prices. The research period was before the financial crisis. Del Negro and Otrok (2005) also conducted research on this topic with quarterly data coming from the United States during the period 1986 to 2005. Del Negro and Otrok found that monetary policies impact residential housing prices and explain a total of 13 percent of the price variance. The relationship between monetary policy and house prices in the United Sates has been scientifically proven. There are also studies focused on the judged region: Europe and specifically the Netherlands. It was investigated how monetary policy stance and mortgage market structure affect non-fundamental house price movements in eleven Euro area countries, including the Netherlands, during the period 1992 until 2012 (Betzinger et al, 2017). They concluded that a one-time monetary-easing shock could significantly trigger house price booms in Euro area countries with liberal mortgage markets. Betzinger et al were not the only ones with this result, Calza et al (2013) also found that the impact of monetary policy shocks to residential investment and house prices is significantly stronger in those countries with larger flexibility of mortgage markets. They further showed that transmission to consumption is stronger only in those countries where mortgage equity release is common and mortgage contracts are predominantly of the variable-rate type (Calza et al, 2013).

Monetary policy can be expansionary and restrictive. Detken and Smets (2004) found a relation with heavy increases in real estate prices and loosening (expansionary) monetary policy over the period of the increase. Money growth can be part of a loosening monetary policy. The effect of this has also been investigated. Money growth has a significant effect on house prices and credit, credit influences money and house prices, and house prices influence both credit and money (Goodhart & Hofmann, 2008). The effects of shocks to money and credit on house prices are stronger when house prices are booming than otherwise. Furthermore, shocks to house prices, credit, and money all have significant repercussions on economic activity and aggregate price inflation (Goodhart & Hofmann, 2008). Demary (2010) went into more detail on the consequences for macroeconomic aggregates. Demary examined the interplay between output, inflation, interest rates and house prices in 10 OECD countries by applying vector autoregressions. The results indicated that housing markets have a stronger impact onto macroeconomic variables compared to the impact of macroeconomic variables onto housing markets. The last component that academics demonstrated as having an effect in monetary policy are interest rates. Interest rates are negatively correlated with the mortgage market. When interest rates fall, more households buy a house and therefore more mortgages are issued (Jiménez et al, 2014). Hirata et al (2012) found a similar result 2 years earlier that interest rate shocks tend to have a significant effect on global house prices in most developed countries. The authors also found that monetary policy cannot be the sole reason explaining the boom-bust behavior of house prices in advanced economies (name). Hirata et al (2012) also look at the effect of uncertainty shocks and show that uncertainty shocks tend to have a significant impact on global house price movements.

All in all, available literature states that there is a relationship between monetary policy and house prices, with Del Negro and Otrok (2005) even concluding that 13 percent of the price variance could be explained by monetary policy.

2.2 Determinants of residential property prices in the Netherlands on macroeconomic level

There is more explanation needed to discuss what the most important determinants of residential property prices are in the Netherlands. To do so, an overview of the market must be formed and this paper will make use of the supply-demand-institutions design. This is done because in *Beyond Supply and Demand: The Framework of the Market Economy* it is discussed that institutions also influence markets by determining the rules of the game (Boarman, 1994). This paper will look at the average house price on the macroeconomic level.

Starting with the supply. On the supply side can land-use planning controls, the tax system, and the structure of government all have large effects on housing supply (Muellbauer & Murphy, 2008). Glaeser et al (2008) conducted a model of housing bubbles that predicts that places with more elastic housing supply have fewer and shorter bubbles with smaller price increases. The paper by Vermeulen and Rouwendal can be cited to determine the consequences for the Dutch housing market. Vermeulen and Rouwendal (2007) found that housing supply in the Netherlands is almost fully inelastic in the short-run. Their estimates suggest that new construction in the owner-occupier sector rises with 0.04% after a 1% price increase in the same year. A similar result was achieved by Glaeser et al in 2005 that building new homes would result in a price decrease for already existing homes. So it's safe to say that an increase in supply would result in a decrease of prices. Because the supply side has been shown to have a significant influence on the house price, several supply variables will be included in Chapter 3.

Housing demand is price inelastic according to Polinsky (1977) and can consist of several parts. The demand among other things consist of the formal housing needs, availability of loans, and the presence of alternative investments. In 2020 amounted the formal housing need to 8,212,000 houses in the Netherlands, while there were only 7,881,000 homes available (Rijksoverheid, 2021). That results in a total shortage of 331,000 houses. This surplus of demand is exacerbated by the supply side problems surrounding nitrogen, poly- and perfluoroalkyl substances and a lack of construction sites (Rijksoverheid, 2021). Heavy increases in home prices and so demand since the late 1990s has it operating as a classic speculative bubble, driven largely by extravagant expectations for future price increases (Shiller, 2007). The case studies above suggest that there are a wide variety of considerations and emotions that impact on a decision whether or not to buy a house. The psychological expectations' coordination problem appears to be a major factor in explaining the extreme momentum of home price increases (Shiller, 2007).

The mortgage market also affects demand. As indicated earlier did Betzinger et al (2017) investigate the impact of mortgage market structure on housing prices. The paper found out that a one-time monetary-easing shock can significantly trigger house price booms in Euro area countries with liberal mortgage markets. On the other hand did Mian and Sufi write in 2009 about the consequences of mortgage credit expansion in which the authors found evidence from the mortgage default crisis in the United States. Beyond financial consequences, higher mortgage indebteness can also lead to profound psychosocial consequences for those who have direct experience of it, which was described by Nettleton and Burrows (1998). So the quantity of a mortgage is also limited on the demand side.

Mortgage expenditures are excluded from the price index because that would lead to a positive correlation between the inflation target and the policy instrument, with higher housing prices leading to higher inflation which would lead to higher interest rates and so on (European Central Bank, 2018). This paper will include variables controlling for alternative investments as homeownership is seen as an investment. The Dutch Authority Financial

Markets (AFM) published survey results that 16 percent of Dutch inhabitants invest by themselves and most employees being indirectly involved in investing through retirement funds (Autoriteit Financiële Markten, 2020).

Decisions at the government level and those of commercial market parties also influence the price. Vermeulen and Rouwendal (2007) found out that institutions on the housing market have to deal with lags of over a decade, which results in supply inelasticity. Demand or supply can be adjusted at the institutional level through policy adjustments. For example, the supply was depressed because on May 29, 2019 the Nitrogen Approach Program launched which made construction in the vicinity of nature reserves more difficult (Ministerie van Binnenlandse Zaken en Koninkrijkrelaties, 2020). Empirical investigations of the local costs and benefits of restricting building generally conclude that the negative externalities are not nearly large enough to justify the costs of regulation (Gleaser & Gyourko, 2018). The government has an influence on the functioning of the market. In the period between 2011 and 2013, the Dutch government influenced the housing market by imposing new tax programs, making it more difficult to get a mortgage and the guarantee fund was lowered, which overall mainly negatively impacted starters (Boelhouwer, 2017). Other literature takes a closer look at institutional changes. Institutional changes tend to come in connection to the speculative psychology, not just as exogenous advances in financial or bureaucratic technology (Shiller, 2007).

In conclusion, is the price of Dutch residential property mainly determined by the inelastic supply, an existing demand surplus and institutional policy adjustments.

2.3 Impact ECB policy on Dutch housing market and pandemic consequences

The current policy will be explained before describing the impact ECB policy on Dutch housing market and pandemic consequences. On January 1st 1999, the ECB assumed responsibility for monetary policy in the euro area. The main objective of the ECB is to maintain price stability by keeping inflation below, but close to, 2% per annum over the medium term (European Central Bank, 2021). Price stability is essential for economic growth and job creation, two of the objectives of the European Union (European Central Bank, 2021). The Eurosystem is responsible for: determining and implementing monetary policy, conducting foreign exchange operations, holding and managing the foreign reserves of the euro area and to promote the smooth operation of the payment system (European Central Bank, 2021). There are standard and non-standard measures.

Standard refers to the three main interest rates. The first is the interest rate on the main refinancing operations (European Central Bank, 2021). With these banks can borrow against collateral. The second is the rate on the deposit facility for overnight deposits at the ECB (European Central Bank, 2021). At last there is the rate on the marginal lending facility for overnight credit to banks (European Central Bank, 2021). The main purpose of the standing facilities is to restrict the volatility of short-term money market interest rates. As there are no limits on access to these facilities (except for collateral requirements for the marginal lending facility), the marginal lending rate and the deposit rate normally provide a ceiling and a floor, respectively, for the overnight interest rate in the money market (Österreichische Nationalbank, 2021). These three interest rates will return as variables in Chapter 3.

A number of non-standard policy measures have been developed since the beginning of the financial crisis. At the start of the crisis, the main objective of the ECB was to provide liquidity to banks and keep markets functioning (European Central Bank, 2021). In 2008 the interbank market fell silent and to improve this, the ECB launched the fixed-rate full allotment (European Central Bank, 2021). With this, banks can get unlimited credit at a fixed interest rate. Furthermore, more types of assets could serve as collateral for refinancing operations (European Central Bank, 2021). Subsequently, the ECB focused on solving markets' malfunctioning and reducing differences in financing conditions faced by businesses and households in euro area countries (European Central Bank, 2021). This came into effect with the Securities Markets Programme, very long-term refinancing operations (VLTROs) and Outright Monetary Transactions (OMT). At last the non-standard measure tried to avoid the risk of deflation (European Central Bank, 2021). Short term interest rates were already close to zero so the following non-standard financial measures came in place: negative interest rate on the deposit facility, targeted longer-term refinancing operations to support lending to business and households and asset purchase programme (APP) (European Central Bank, 2021). With the start of the SARS-CoV-2 pandemic, the pandemic emergency purchase programme (PEPP) was launched to deal with the risk for the monetary policy transmission mechanism. The change in policy is clearly visible in an overview of the ECB's balance sheet in Appendix A Figure 1.

Fratzscher et al (2016) conducted research on non-standard monetary policy measures between 2007 and 2012. The paper found that ECB policies boosted equity prices and lowered bond market fragmentation. Georgiadis & Gräb (2016) also wrote about how the effects of the ECB's asset purchase program boosted equity prices by supporting investor confidence and reducing the risk of deflation. Other literature points out that interest rates influence price changes in the housing market.

During the period from 2002 to 2005, the short term interest rate path deviated significantly from what this two decade experience would suggest is appropriate (Taylor, 2007). A counterfactual simulation with a simple model of the housing market showed that this deviation may have been a cause of the boom and bust in housing starts and inflation in the last two years in the United States. However, the poor credit assessments on subprime mortgages may also have been caused by this deviation. Capel and Houben (1998) investigated the relationship between real estate prices and monetary policy in the Netherlands over the period 1973 to 1997. The authors found that there was little indication for asset inflation in the housing market through monetary policy at present. Nominal house price deflated by the nominal GDP growth rate house prices had barely gone up in recent years. According to Capel and Houben (1998), the increase in housing prices was due to: demographic developments, the quality of existing houses has been improved and the underlying value of houses for owner occupation should have risen because the costs of homeownership have fallen and so the costs of renting a house. The Dutch stock market on the other hand showed signs of asset inflation (Capel & Houben (1998). Changes in monetary policy can be distributed into the economic system through banks. Foreign monetary policy significantly affects banks mortgage lending in the Netherlands, so real estate prices (Everett et al, 2021). Other empirical work presented that in the Netherlands housing prices and mortgage lending are interdependent in the Netherlands (De Greef & De Haas, 2000).

All in all do ECB monetary policy measures impact the Dutch real estate market via banks that provide mortgages more easily when there is easing in monetary policy.

3. Data

Chapter 4 will elaborate more on the proposed vector autoregressive model that uses multiple variables in relation to monetary policy, macro-economic factors and alternative investments with the residential housing price index in the Netherlands. The following variables will be used and explained in chapter 3: *(Dutch) residential property price index* is going to be the dependent variable. With the variables *securities balance sheet*, *lending balance sheet* and *share other balance items* as independent variables. The model will use *(Dutch) consumer price index (CPI), index of housing rent prices, housing scarcity, total mortgage costs, property tax, Bitcoin, AEX, deposit facility, marginal lending facility and main refinancing operations* as control variables*.* The data has a monthly frequency and will be coming from January 1st, 2014 until February 28th 2021. With the observation being from January 1st, 2014 until February 28th 2021 results in 87 observations for each variable. Each variable is a time series of data. From Appendix A Figure 1 it becomes clear that s*ecurities balance sheet* and *lending balance sheet* are one of the few items on the balance sheet to undergo a significant change. Due to a limit of variables within a vector autoregressive model, only those two will be considered separately. Data sources for all variables together with available time period and selected period can be seen in Appendix K Figure 30. The time period between January 2014 and February 2021 was chosen because the variable *(Dutch) residential property price index* experienced a sharp increase during that period in the perspective of the total timeframe from January 1995 to March 2021. The variable contains the official Dutch price index for sold houses as determined by the Centraal Bureau Statistiek (CBS). The index starts with a value of 100 for January 1st, 2015 and then measures all other months against this starting point. The data from CBS has been used because it is first of all reliable. Further, is the data on macroeconomic level which is the intended research scope. *Securities balance sheet* are securities held for monetary policy purposes. Securities refer to a fungible, negotiable financial instrument that holds some type of monetary value measured in millions of euros (European Central Bank, 2021). As visible in Appendix A Figure 1 does the variable have a big increase over the same period as for *(Dutch) residential property price index.* Because of this visible trend is the variable included to estimate potential causality between the two. Then there is *lending balance sheet.* Lending is done to European credit institutions. Within Europe are credit institutions defined by whose business is to receive deposits or other repayable funds from the public and to grant credits for its own account (European Central Bank, 2021). This lending relates to monetary policy operations. The variable is included because of a similar large increase over the intended research period as visible in Appendix A Figure 1. *Share other balance items* is the last dependent variable. This variable is an aggregate of 7 other European Central Bank (ECB) balance sheet variables which are also visible in Appendix K Table 30. *Gold and gold receivables* shows the gold holdings (both physical and non-physical gold) of the Eurosystem central banks at previous period-end market value and the value of any transactions (purchases and sales) settled since the previous period-end (European Central Bank, 2021). Then there are *claims on non-euro area residents in foreign currency.* A credit claim means pecuniary claims arising out of an agreement whereby a credit institution that directive, grants credit in the form of a loan (European Central Bank, 2021). This variable includes every currency except the euro and is converted to euros at any data point. Furthermore, this variable only applies to countries in which the euro is not the official currency. *Claims on euro area residents in foreign currency* is completely the same as *claims on non-euro area residents in foreign currency*, but only the claims are included if the counterparty comes from a country where the euro is the official currency. *Claims on non-euro area residents in euro* are also largely the same as *claims on non-euro area residents in foreign currency*, but this concerns people in countries that do not have the euro as their official currency but have a debt in euros to the ECB. *Other claims on euro area credit institutions in euro* relate to the same plane, only in this case there is no lending as a monetary operation. *General government debt* is a government debt. Government debt is a stock of government liabilities at the end of the period (European Central Bank, 2021). *Other assets* are remaining assets like; fixed assets, other financial assets, off-balance-sheet instruments revaluation differences, accruals and prepaid expenditure in millions of euros (Eesti Pank, 2021). The variable *share other balance items* can be retrieved from the described data. This is done by dividing all balance items except *securities balance sheet* and *lending balance sheet* with the total balance sheet of the ECB. The total balance sheet of the ECB includes all 9 described balance items. This returns the number between 0 and 1 that measures the proportion of the remaining balance items. *Share other balance items* is issued to control for the relative size of the other balance items and measure potential counter effects.

(Dutch) consumer price index (CPI) is a macro-economic variable added to control for price inflation coming from European monetary policy. As indicated in Chapter 1 is this limited in the way that not every element of the economy is included. *(Dutch) residential property price index* for example, is not included because this will lead to an irreversible direction of monetary policy (European Central Bank, 2018). *Index of housing rent prices* measures the increase of rent price on macroeconomic level. The variable is added because it could have a relation with (*Dutch) residential property price index* in the proposed model. This data was given as a percentage change from the previous year and there was only 1 data point at the end of the year. This had to be transformed into monthly data with statistical

software. To do this, an index was calculated that started at 100 in 2014 and was multiplied by the percentage increase. The indexes of the new year were reduced by the old year and divided this difference by twelve adding up to the empty data points. For filling January and February 2021 it is assumed that the same percentage increase as in 2020 is suitable. *Housing scarcity* is a variable which is calculated by dividing the houses for sale by the number of homes every month. Higher scarcity relates to an increase in price, keeping everything else constant. The result is measured as a number between 0 and 1. For filling January and February 2021 it is assumed that the same percentage increase as in 2020 is suitable. *Total mortgage cost* is calculated by multiplying the total amount of mortgages in the Netherlands by the average mortgage rate. This is done because the interest rate determines the true cost of a mortgage. From the literature study in Chapter 2 became clear that lower interest rates relate to higher residential property prices. *Property tax* is the tax that is paid when purchasing a piece of land or a property. In the selected period it varied between 0 and 8 percent (Belastingdienst, 2021). This is related to the housing market because a lower property tax means lower costs and thus a higher price, keeping everything else constant. Another consideration to add this variable is the fact that institutions influence demand as discussed in Chapter 2. Moving on to the selected alternative investments. The first variable is *AEX.* AEX is an index which inhales the 25 most traded companies on the Amsterdam Stock Exchange. The choice for the AEX instead of, for example the S&P500 stems from the fact that the research area is the Dutch market. The other alternative investment is *Bitcoin*. This variable is chosen because the cryptocurrency is seen as the opposite of centralized monetary policy that the ECB implements (Urquhart, 2016). A disadvantage with the chosen alternative investments is that only purchase and selling prices are considered. Things like dividends or staking of cryptocurrency for extra returns are not included. The last three variables are the official interest rates for policy implementations. The variable *deposit facility* is the percentage rate which is paid to banks for overnight deposits at the ECB. *Main refinancing operations* is a variable measured as a percentage that relates to most of the liquidity provided to the banks. The last interest variable is the *marginal lending facility*, which is the opposite of the deposit facility with providing overnight credit to banks and also measured in percentage. These variables flow through lenders into a country's economic system as described in Chapter 2.

The descriptive statistics of the variables can be seen in Appendix B Table 3. Certain variables have to undergo a transformation to be used in empirical research. Starting with transformations for the following variables; *(Dutch) residential property price index, index of housing rent prices* and *total mortgage costs.* These must undergo a transformation from nominal to real value. This can be done by dividing this data with the *(Dutch) consumer price index (CPI)* variable. Every variable must be stationary in order to use a vector autoregressive model from Chapter 4 onwards. There are multiple solutions to resolve the stationarity. These are differencing, calculating the returns for equity items and detrending. This paper chooses to calculate returns for the variables: *(Dutch) residential property price index, (Dutch) consumer price index (CPI), deposit facility, index of housing rent prices, total mortgage costs AEX, Bitcoin, securities balance sheet*, *lending balance sheet* and *share other balance items*. The first difference is taken from*: property tax, marginal lending facility* and *main refinancing operations.* The variable *housing scarcity* is detrended. To find out whether the data contains a random walk or correlation between residuals after all transformations, an Augmented-Dickey-Fuller (ADF) test is performed (Cheung & Lai, 1995). With Dickey Fuller, it is checked whether the sum of all VAR coefficients is equal to 1. The test has the following design:

$$H_0: \textit{Time series is a random walk}$$

$$H_1: \textit{Time series is stationary}$$

$$\begin{aligned} &\text{Test 1: } \Delta y_t = \gamma y_{t-1} + \varepsilon_t\,; \\ &\text{Test 2: } \Delta y_t = \alpha + \gamma y_{t-1} + \varepsilon_t\,; \\ &\text{Test 3: } \Delta y_t = \alpha + \lambda t + \gamma y_{t-1} + \varepsilon_t\,. \end{aligned} \tag{1}$$

For all the three tests in formula (1) does γ stand for the unit root and α being the constant. *t* indicates the period number and ε the error term. If the average of the scatter is around zero, the first test should be chosen. The second test is suitable if the average is around elsewhere. In the case where there is no clear average, the third test is the best fit. All variables need to be stationary at first difference. ADF removes autocorrelation and is performed in the same manner and has the following formula:

$$\Delta yt = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \ldots + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t \tag{2}$$

In formula (2) is α the constant. β is the coefficient that is on a time trend. With *p* dealing with lag of the autoregressive process. The unit root test is performed to test the null hypothesis that γ =0 with the alternative hypothesis being γ <0. The null hypothesis will be rejected if the test statistic turns out to be lower than the critical value. The test statistic has the following form:

$$DF = \frac{(\hat{\gamma})}{SE(\hat{\gamma})} \tag{3}$$

The results of the transformed variables by taking the first difference or calculating the returns can be seen in Appendix C. The augmented Dickey Fuller and a MacKinnon approximate p-value for Z (t) for each variable are shown in the same appendix section. The variable satisfies the conditions if the absolute values of the Augmented Dickey Fuller test statistics are larger than the 5% critical values and the MacKinnon approximate p-value for Z(t) is smaller than 0.05.

4. Methodology

This paper amplifies to investigate if there is a relation between European monetary policy and Dutch residential property prices. Like existing research from Del Negro and Otrok (2005) and Demary (2010) will a vector autoregressive model form the basis of the research. The vector autoregressive model is suited for allowing relationships between multiple variables (Hashimzade & Thornton, 2013). This makes it possible to control for variables that are both correlated with the dependent variable and the independent variables that would lead to a biased estimator when using a linear model like an OLS model.

The vector autoregressive model is used to test if $\beta_{z,z}$ significantly differs from zero. The proposed vector autoregressive model will use multiple variables in relation to macro-economic factors and alternative investments with the residential housing price index in the Netherlands. Within vector autoregression is each variable regressed on a constant, its own lags and the lags of other variables (Hashimzade & Thornton, 2013). As a result is it possible for the variables to be endogenous and have an impact on other variables. There may be no exogenous variables in the model. Expected adjustment to changes in prices are slow, given the lead times in construction and conversion and the delayed mobility response to price changes (Quigley, 2002).

This paper will use monthly data, so a criterion is needed to determine the best lag length. It is possible to choose the model with the lowest Bayesian information criterion (BIC), Akaike information criteria (AIC) or Hannan-Quinn Information Criterion value. This paper uses the multivariate (BIC) because the BIC generally penalizes free parameters more strongly than the AIC (Kenneth & David, 2004). The penalty reflects on the number of degrees of freedom which the model losses by including additional lag and a bonus for the decreasing sum of squared residuals (SSR) in the model (Kenneth & David, 2004). The vector autoregressive model will look like the following in formula (4):

$$\begin{pmatrix} \gamma_{1,t} \\ \gamma_{2,t} \\ \cdots \\ \gamma_{z,t} \end{pmatrix} = \begin{pmatrix} \beta_{0,1} \\ \beta_{0,2} \\ \cdots \\ \beta_{0,z} \end{pmatrix} + \begin{pmatrix} \beta^1_{1,1} & \beta^1_{2,2} & \cdots & \beta^1_{1,z} \\ \beta^1_{2,1} & \beta^1_{2,2} & \cdots & \beta^1_{2,z} \\ \cdots & \cdots & \cdots & \cdots \\ \beta^1_{z,1} & \beta^1_{z,2} & \cdots & \beta^1_{z,z} \end{pmatrix} \begin{pmatrix} \gamma_{1,t-1} \\ \gamma_{1,t-1} \\ \cdots \\ \gamma_{1,t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \beta^p_{1,1} & \beta^p_{2,2} & \cdots & \beta^p_{1,z} \\ \beta^p_{2,1} & \beta^p_{2,2} & \cdots & \beta^p_{2,z} \\ \cdots & \cdots & \cdots & \cdots \\ \beta^1_{z,1} & \beta^p_{z,2} & \cdots & \beta^p_{z,z} \end{pmatrix} \begin{pmatrix} \gamma_{1,t-p} \\ \gamma_{2,t-p} \\ \cdots \\ \gamma_{z,t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \cdots \\ \varepsilon_{z,t} \end{pmatrix}$$

In formula (4) are $\beta_{z,z}$ the coefficients and ε being equal to the error term. *p* stands for the number of lags.

Just as in the case of a single equation, for a multiple equation model the paper chooses the specification which has the smallest BIC(z). There is monthly data, so this test is performed on twelve lags in total. The BIC(z) formula is as follows:

$$BIC(z) = log[det(\widehat{\Sigma_u}] + z(zk + 1)\frac{log(T)}{T} \tag{5}$$

Within formula (5) is Σ_u the estimated covariance matrix of the vector autoregressive error and det() being the determinant. T is equal to the sample size. K is the number of regressors and *z* are the determinants.

This paper will use the F test to interpret the results. Doing this because the t-test would lead to ambiguity because of the number of parameters (Stock & Watson, 2005). The F-test is able to estimate if the joint effect of the independent variables on the dependent variable are significant. The test has the following design:

$$\begin{aligned} &H_0 : \beta_0 = \beta_1 = ... = \beta_p \\ &H_1 : \beta_z \ \ are\ not\ equal \\ &F - test = (\tfrac{SSR-USSR}{USSR})(\tfrac{Q-m}{L}) \end{aligned} \tag{6}$$

In formula (6) are SSR the sum of the square residuals where $\beta_{z,z}$ are assumed to be equal to zero. The USSR is the sum of squared residual in the model without any restrictions. L is the number of restrictions within the model. Q is the total number of observations and m is the number of regressors in the unrestricted model.

The F-test is able to estimate the significance of variables but not able to estimate the direction (Stock & Watson, 2005). Literature suggests using the Granger Causality test to know which variables significantly forecasts another of the vector autoregressive variables (Rossi & Wang, 2019). With the F-test and Granger Causality test it is not possible to determine any causal relations. In order to determine the best approach, the correlation between the error terms must be established. This paper will use impulse response analysis to determine the direction as described by Koop et al (1996). Impulse response analysis (IRA) describes the development of a model's variables in reaction to a shock in one or more variables. With this, single shocks can be traced down and causality can be determined. The use of the impulse response function has a number of conditions (Koop et al, 1996). Residuals have to be contemporaneously uncorrelated. To orthogonalize will Choleski be used as substantiated by Lütkepohl and Poskitt (1991). When using this, the order of the variables is important.

Different sequences of variables lead to different results. The paper will use the following sequence of described variables: *Securities balance sheet, lending balance sheet, share other balance items, deposit facility, marginal lending facility, main refinancing operations, (Dutch) consumer price index (CPI), AEX, Bitcoin, total mortgage costs, housing scarcity, (Dutch) residential property price index, index of house rent prices* and *property tax.* This order has been chosen because the variables are assumed to respond to the ECB policy measures and form expectations about it in this order. As argued in Chapter 2, the shocks begin with the ECB's monetary interventions. Starting with monetary easing via the ECB assets and the official interest rates subsequently to support the policy. With the execution of ECB policy are the variables *(Dutch) consumer price index (CPI), AEX* and *Bitcoin* assumed to respond relatively fast as result of the described asset inflation in Chapter 2. Housing market variables follow at a respective distance due to inelasticity: *total mortgage costs, housing scarcity, (Dutch) residential property price index* and *index of house rent prices.* Finally, it is assumed that the variable *property tax* is used as a last resort to lighten or aggravate the housing market and therefore only change after movement in the housing market. Variance decomposition will be used to estimate the residential property price variance caused by monetary policy measures (Grömping, 2007). To orthogonalize the residuals again Choleski will be used (Lütkepohl & Poskitt, 1991). Exactly the same sequences will be used as discussed for the impulse response function.

OLS is suitable to estimate each equation in a VAR model (Stock & Watson, 2001). The results are ceteris-paribus effects and inference can be based on the usual OLS standard errors and test statistics. All five assumptions of OLS need to be respected to use OLS as it was described by Williams et al (2013). The first is that the sample should contain random observations with the error terms being normally distributed. The error term must be random for the dependent variables to be random. The Skewness Kurtosis test is done to find out if this holds (Bai & Ng, 2005).

$$Test\ statistic\ =\ \frac{((\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^4)}{(((\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2)^2)} - 3 \tag{7}$$

In formula (7) is $\bar{x}$ the sample mean and *n* the number of residuals. Minus 3 relates to the correction to make the distribution zero at the end. The second assumption is that the conditional mean should be zero. For this, the average values of the errors term must be equal to zero. In the proposed model would this be $E(\varepsilon_{k,t}) = 0$. Furthermore, must there be no multicollinearity or perfect collinearity. In a simple linear model, this automatically holds because there is one independent variable. With multiple independent variables there may be no correlation between the independent variables. Also, must the linear model not contain non-linearity in its parameters. At last there may be no autocorrelation and homoscedasticity. Which entails that the variance of all error terms should be constant. In the model this looks like the following: $variance(\varepsilon_{k,t}) = \sigma^2 < \infty$. Autocorrelation can be tested by the Breusch–Godfrey test. The advantage over the Durbin Watson is that this test is less sensitive to distribution and that Breusch–Godfrey tests for serial correlation between number of lags instead of one lag. The null hypothesis states that there is no serial correlation to the lag of *p.* The formula can be seen below:

$$H_0 : \rho_1 = \rho_2 = \ldots = \rho_\rho = 0$$
$$H_a : \textit{serial correlation to the lag of } p \tag{8}$$
$$\textit{Test statistic} : LM = (n - p) * R \sim X_p^2$$

In formula (8) n is the number of available data points and p the number of lags. *R* is based on the R-squared of the model. There should also be no heteroscedasticity because then there would be another linear estimator that uses the data better with a lower variance. The model is tested for heteroscedasticity with the White's test (White, 1980). The form of the vector autoregressive residuals heteroscedasticity test will be used.

$$H_0 : \textit{homoscedasticity}$$
$$H_a : \textit{unrestricted heteroscedasticity}$$
$$F = \frac{\left(\frac{R^2_{s^2}}{n-q+1}\right)}{\left(\frac{1-R^2_{s^2}}{n-q}\right)} \tag{9}$$

Within formula (9) is q equal to the degrees of freedom and n the number of data points. $R^2_{s^2}$ is based on the R-squared of an OLS regression for the error terms of the normal model.

If the results of the VAR model are far from the hypothesis and insignificant, the vector error correction model (VECM) will be used to still estimate the sign of the relationship between monetary policy and the *(Dutch) residential property price index*. This insignificance in a VAR model could come from a random walk between two coefficients which are significant to each other but are not related. In the VECM is a term is added that represents the prior disequilibrium in the long run equation in which residuals would be zero. The process results in an adjustment term. This changes the interpretation of the VECM compared to the VAR model that only the sign of the impact of a variable to Dutch housing prices can be established (while keeping everything else constant). In short is VECM just a representation of a co-integrated VAR. Quantifying the results is not possible. The adjustment term can indicate at what convergence speed the previous year's deviation from the long run equilibrium are corrected for in the current year. The VECM model has the ability to perform a short run and a long run model while VAR is only suitable for interpretending shocks in the short term. With use of the earlier impulse response function, the direction of the recurrence of the *(Dutch) residential property price index* can be estimated by means of a shock of the impulse variable. The use of the VECM model has the same assumptions as the VAR model in regard to stationarity, heterogeneity and a normal distribution of residuals. The stability of the model must also be tested before the results can be discussed. The VECM has the additional condition that in the optimal model with the selected variables there is co-integration. Co-integration is the statistical property of variables used in a time series (Kremers et al., 1992). The variables need to be integrated of a *t* order. Then will a linear combination of the variables be made which is of an order less than *t.* This results in co-integration (Kremers et al., 1992). Johansen's method will be used to determine whether there is a determining co-integration (Johansen, 1992). The null hypothesis at rank zero is that there is no co-integration. This can be rejected if the trace statistic is smaller than the 5% critical value and that the max statistic is smaller than the critical value. For the other ranks is the null hypothesis that there is a co-integration of equation 1. This again can be rejected if the trace statistic is smaller than the 5% critical value and that the max statistic is smaller than the critical value. With both results combined can the optimal lag length for no co-integration be determined. If a certain lag is suitable, the vector error correction model (VECM) is used to calculate the short and long term coefficients. Then, on the basis of impulse response analysis, the significant direction of the house price index is determined when there is a shock in the impulse variable. In the VECM is again Choleski used to orthodolize (Lütkepohl & Poskitt, 1991). The same order as the VAR model is maintained because the economic interaction between variables does not change after using a new model. At last is variance decomposition used to estimate the residential property price variance caused by monetary policy measures (Grömping, 2007).

5. Results

In order to run a correct vector autoregressive model, the raw data must be transformed. In this paper this is done by taking the first difference, detrending or calculating returns for asset items. In Appendix C are all variables plotted, and it can be checked whether there is autocorrelation. There is no autocorrelation, when the standard errors move around the zero line. Appendix C also gives the results of the Augmented Dickey Fuller test and the MacKinnon approximate p-value for Z (t) for each variable over a period of 12 lags. This shows that every variable satisfies the conditions because all the absolute values of Augmented Dickey Fuller Test Statistics are larger than the 5% critical values and the MacKinnon approximate p-value for Z(t) is always smaller than 0.05.

Autocorrelation so appears to be absent in all variables and will be tested with the Breusch–Godfrey test. The results of the test can be seen in Appendix D Table 18. It can be seen from the table that the chi-squared with 2 degrees of freedom (chi2) is larger than 0.05 with 0.075 > 0.05, so the null hypothesis can not be rejected. This means that there is no serial autocorrelation of the residuals to the 12th lag. So, $\beta_{z,z}$ is unbiased and efficient. The Skewness Kurtosis test is performed to test whether the residuals are normally distributed. The results are visualized in Appendix D Table 19. The probability of skewness is 0.997 implying that the skewness is asymptotically distributed (0.997 > 0.05). The same is the case for the probability of Kurtosis test with a p-value of 0.972. The chi-squared with two degrees of freedom value is 0.999. With 0.999 being larger than 0.05 means that the null hypothesis cannot be rejected. So the residuals show a normal distribution. The histogram of the residuals can also be seen in Appendix D Figure 16. The figure confirms the result that there is a normal distribution of the residuals. At last is the heteroscedasticity of the residuals tested with the White's test. The results are stated in Appendix D Table 20. As mentioned in Chapter 4 is the null hypothesis that there is homockedasticity. The p-value of 0.245 indicates that it is not possible to reject the null hypothesis on 0.05 significance. So all variables have passed the conditions and can now be used in the vector autoregressive model.

In chapter 4 it was explained that the optimal amount of lags must first be determined before starting with a vector autoregressive model. With the BIC criteria it can be established that 12 lags is the optimal choice. The results of the BIC criteria can be seen in Appendix E Table 21. The AIC and the Hannan-Quinn Information Criterion test have also been added. The results of the AIC and the Hannan-Quinn Information Criterion test too point to the 12th lag, so that strengthens expectations. From Appendix G Figure 17 it becomes clear that all the eigenvalues of the VAR model lie inside the unit circle. This means that the vector autoregressive models stability condition is satisfied. So the model is stable.

The prerequisites and the stability conditions have been met, thus now the vector autoregressive estimates can be calculated. The F-test is used to determine significance because of the amount of parameters. The results of the VAR model variables for the ECB balance items can be seen in Table 1. The results for all other variables are visualized in Appendix F Table 22.

Table 1: Estimates VAR model variables of ECB balance items

Equation	Parameters	Root mean square deviation	R-squared	Chi2	P > chi2
Return (Dutch) property price index	13	0.818	0.572	95.037	0.000
Return lending operations	13	13.000	0.238	22.207	0.035
Return securities	13	2.059	0.297	29.980	0.003
Return share other ECB balance items	13	3.535	0.176	15.170	0.252

Notes: The VAR model has a joint significant effect for a variable if the statistic P > chi2 is less than 0.05. Chi2 stands for chi-squared with 2 degrees of freedom.

Table 1 indicates that there is a joint significant effect for both *lending balance sheet* and *securities balance sheet. Share other balance items* on the other hand, is not jointly significant. An R-squared of 0.572 for *(Dutch) property price index* indicates that the vector autoregressive model explains 0.572 of the variation in Dutch property prices. When looking at Appendix F Table 22 it becomes clear that the model has no joint significant effect for *AEX* either. All other variables have a joint significant effect. *Property tax* and *marginal lending facility* were dropped because of collinearity. This could be because these variables have undergone hardly any changes between 2014 and 2021 and show a lot of similarities with the other interest variables. As indicated in Chapter 4, will the Granger Causality now be performed. In contrast to Table 1, Table 2 has to do with a lot less significance. Further, shows Table 23 that only the housing scarcity and all variables together can be used to significantly forecast another variable of the vector autoregressive variables. So *Lending balance sheet*, *securities balance sheet* and *share other ECB balance items* can not be used to forecast Dutch property prices in response to changes in monetary policy.

Table 2: Granger causality Wald test only intended variables included

Equation	Excluded	chi2	Degrees of freedom	P > chi2
Return property price index	Return lending balance sheet	0.047	1	0.829
Return property price index	Return securities balance sheet	0.488	1	0.485
Return property price index	Return share other balance items	1.027	1	0.311

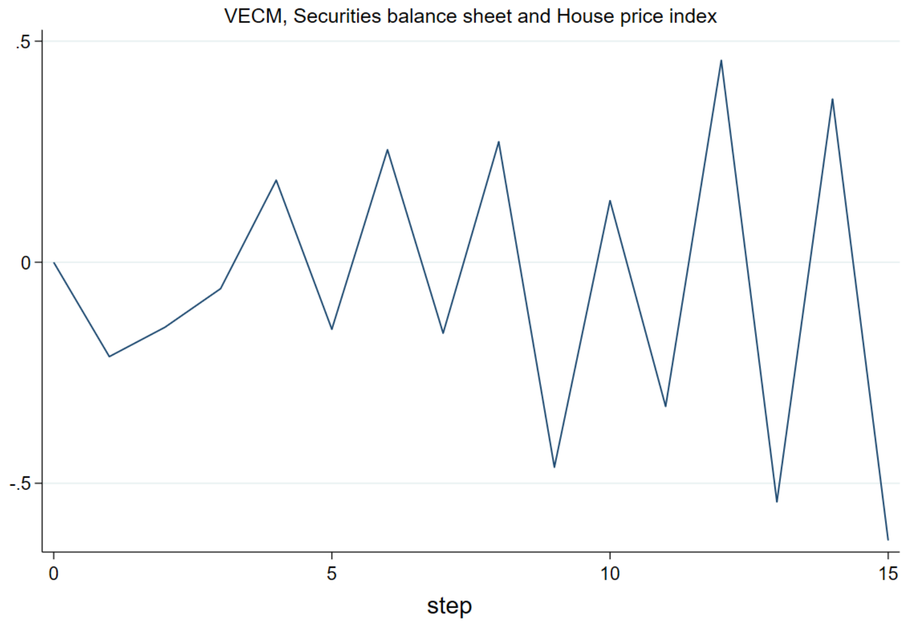
Notes: The VAR model is Granger causal for a variable if the statistic P > chi2 is less than 0.05. Chi2 stands for chi-squared with 2 degrees of freedom.

The results in Tables 1 and 2 are also not usable because from Tables 29A, 29B en 29C in Appendix J it becomes clear that there is correlation between the variables used in the time series. If there were significant results from the Granger Causality test, impulse response could be used to determine the true relationship.

Now that it has been shown that the variables related to the policy of the ECB do not have a numerically significant influence on the price, it can be referred back to Chapter 4. The Johansen's method will be used to determine whether there is a determining co-integration (Johansen, 1992). If so, the vector error correction model (VECM) is used to calculate the short and long term direction of coefficients. The same steps as with the VAR model are used for this. The results of the Johansen test can be seen in Appendix I Table 24. The null hypothesis at rank zero is that there is no co-integration. This can be rejected if the trace statistic is smaller than the 5% critical value and that the max statistic is smaller than the critical value. For the other ranks is the null hypothesis that there is a co-integration of equation 1. This again can be rejected if the trace statistic is smaller than the 5% critical value and that the max statistic is smaller than the critical value. Appendix I Table 24 and 25 indicate that the optimal lag length for no co-integration is 8 lags. Only the variables *(Dutch) residential property price index, securities balance sheet*, *lending balance sheet, share other balance items*, *(Dutch) consumer price index (CPI), index of housing rent prices, housing shortage, total mortgage costs, Bitcoin, AEX* are used in the VECM. *Property tax, deposit facility, marginal lending facility* and *main refinancing operations* were perfectly collinear with each other, so not suited for the short and long run equilibrium estimations. Like the VAR model, the VECM model is stable as shown in Appendix I Figure 18. The Lagrange-multiplier test is performed to indicate potential autocorrelation. The null hypothesis of no autocorrelation at lag order is rejected is p > chi2 is lower than 0.05. This holds for none of the lags in Appendix I Table 26, so there is no autocorrelation at lag order. The VECM has the capacity of estimating the two equilibria. One in the short and one in the long term. An overview of the total model can be found in Appendix I Table 27. The short-term equilibrium turned out to be far from significant so should not be considered within the model. Appendix I Table 28 shows the long-term balance, which shows that the monetary policy has a significant influence on the index Dutch residential property prices within the model.

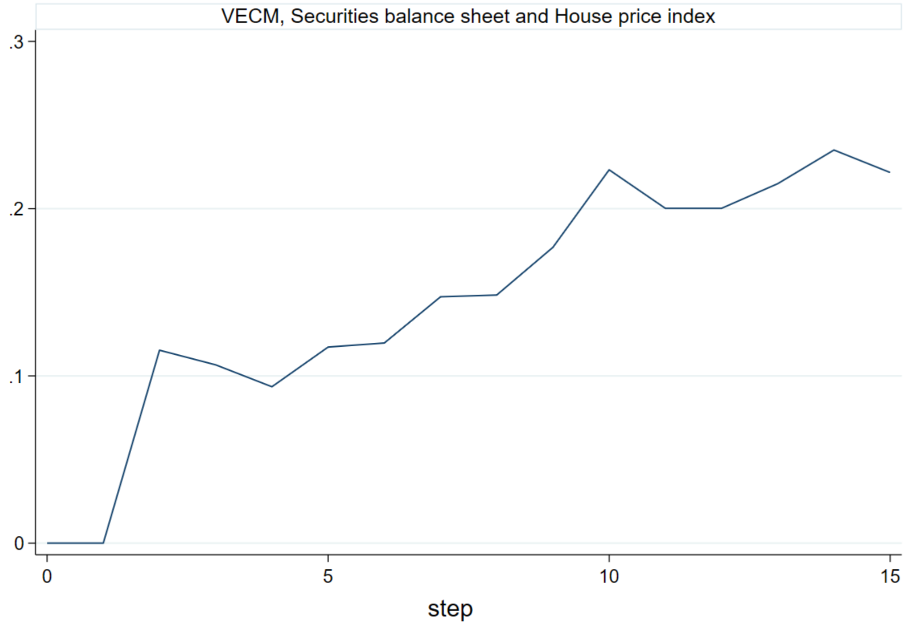
The last part of Chapter 4 is now performed with the impulse response analysis. Impulse response for a VAR model is a lot better suited than a VECM but given the insignificant result of VAR it will be performed. The results of VECM impulse response are less useful because they are not in level. Statistical software will automatically take the first difference when computing a VECM model. The VECM will show if monetary shocks result in an increase or decrease of residential property prices in the Netherlands in the chosen period. The results can be used in determining the sign of the significant relationship. Choleski decomposition is used to orthodologize before and after. Figure 19 to Figure 26 together show the impulse response function of the VECM, the variance decomposition which allows to quantify the variance of the house price index caused by changes in monetary policy.

Figure 19: Orthogonalized IRF of securities balance sheet on house price index



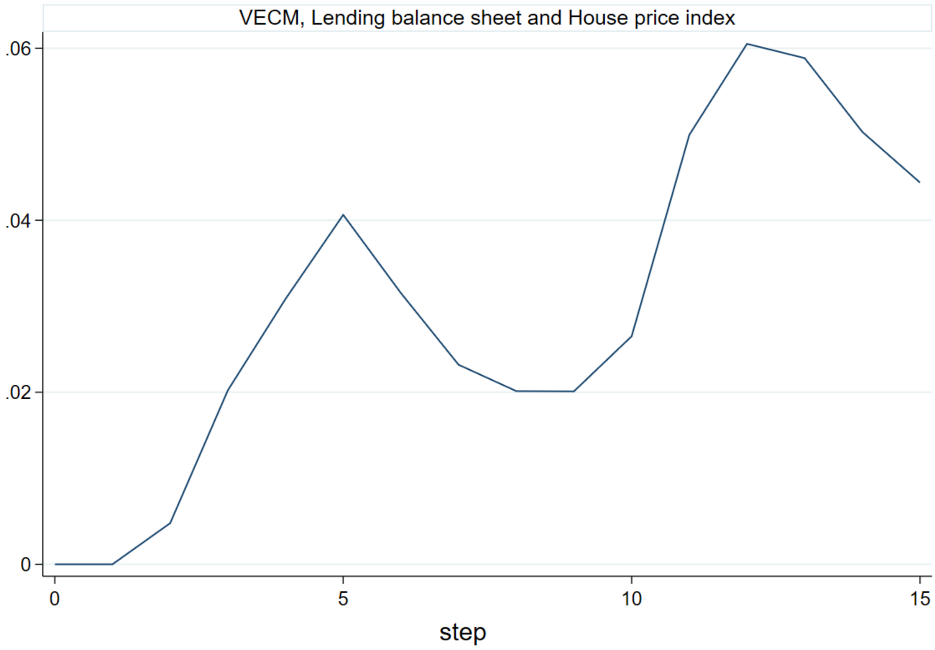
Notes: Figure 19 shows by what percentage the variable *house price index* will change after a 1% change of *securities balance sheet* in the chosen timeframe.

Figure 20: Variance decomposition of securities balance sheet on house price index



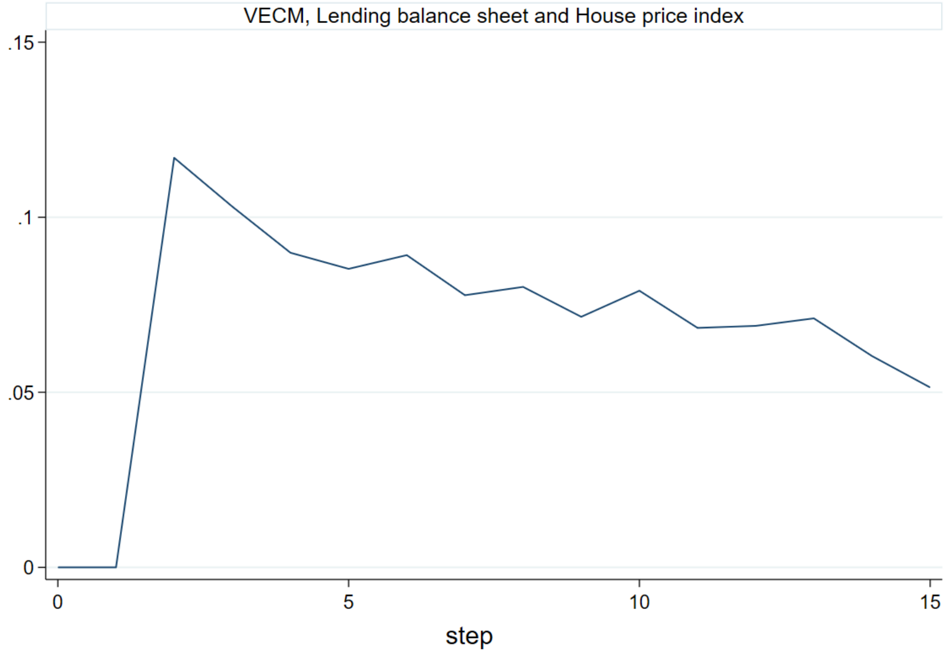
Notes: Figure 20 shows how many percent of the variation of the variable *house price index* is explained by changes in the variable *securities balance sheet*.

Figure 21: Orthogonalized IRF of lending balance sheet on house price index



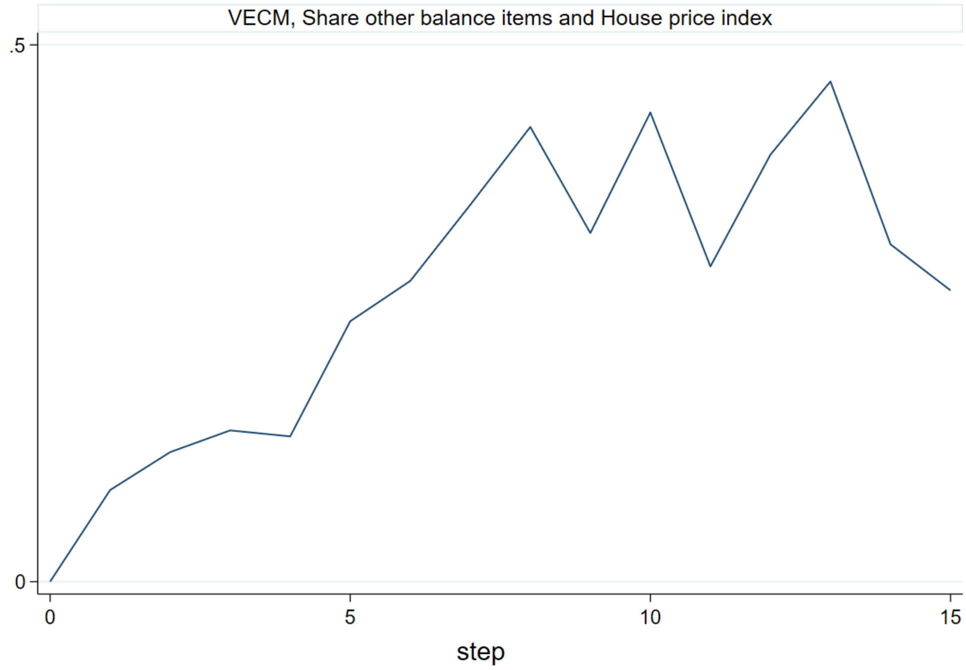
Notes: Figure 21 shows by what percentage the variable *house price index* will change after a 1% change of *lending balance sheet* in the chosen timeframe

Figure 22: Variance decomposition of lending balance sheet on house price index



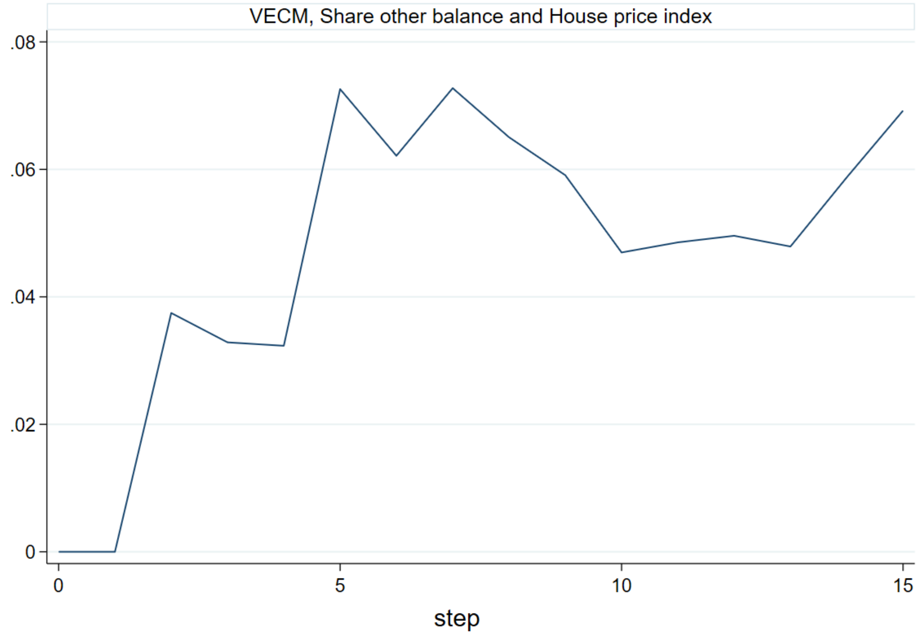
Notes: Figure 22 shows how many percent of the variation of the variable *house price index* is explained by changes in the variable *lending balance sheet*.

Figure 23: Orthogonalized IRF of share other balance sheet items on house price index



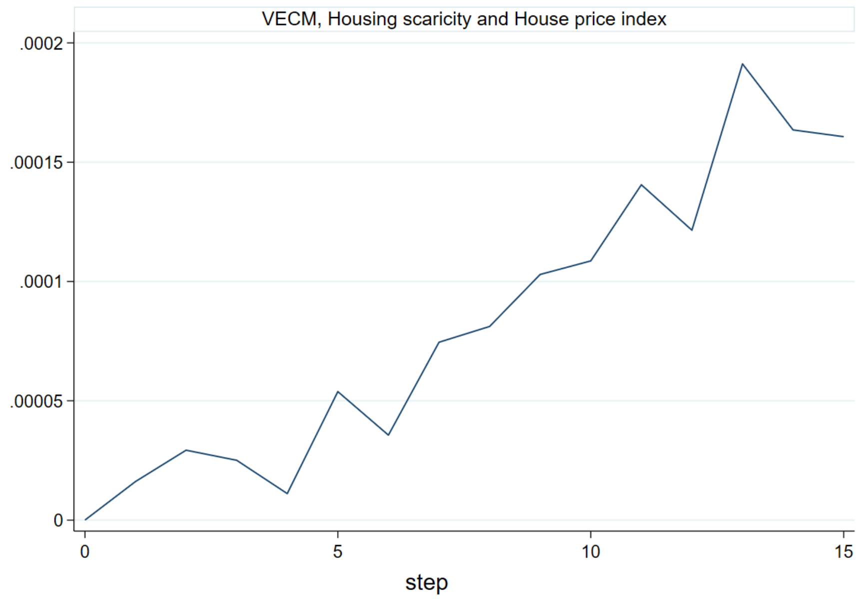
Notes: Figure 23 shows by what percentage the variable *house price index* will change after a 1% change of *share other balance items* in the chosen timeframe

Figure 24: Variance decomposition of share other balance items on house price index



Notes: Figure 24 shows how many percent of the variation of the variable *house price index* is explained by changes in the variable *share other balance items*.

Figure 25: Orthogonalized IRF of housing scarcity on house price index



Notes: Figure 25 shows by what percentage the variable *house price index* will change after a 1% change of *housing scarcity* in the chosen timeframe

Figure 26: Variance decomposition of housing scarcity on house price index

Notes: Figure 26 shows how many percent of the variation of the variable *house price index* is explained by changes in the variable *housing scarcity*.

From studying Figures 19 to 26 it becomes clear that the *securities balance sheet* doesn't have clear interpretable results in the chosen timeframe. *Lending balance sheet* on the other hand shows in Figure 21 that within the timeframe an increase of lending on balance sheet by 1 percent leads to a maximum increase of *house price index* of 0.06 percent while explaining 12 percent of the variance of *house price index*. *Share other ECB balance sheet items* also has interpretable results. If *share other ECB balance sheet items* goes up with 1 percent, *house price index* increases by a maximum of 0.05 percent within the chosen timeframe. Results of the variable *housing scarcity* are displayed in Figure 25 and 26 because of its significant result in the VAR model. When *housing scarcity* increases by 1 percent, *house price index* has a maximum change of 0.2 percent while an insignificant small portion of *house price index* is explained by *housing scarcity.*

Due to all the conditions surrounding the VECM, it can only be significantly established in which direction the *variable house price index* is influenced by the other variables in the model during the chosen period. So positive or negative. From the results it becomes clear that *lending balance sheet* and *share other ECB balance items* significantly positively contributed to the *housing price index* variable, although it is not possible to say to what extent this happens. The variable *housing scarcity* too significantly influences the price, but that was expected because lower supply usually leads to a higher price keeping everything else constant. The variable *securities balance sheet* showed no significant positive or negative relationship.

6. Conclusion and recommendations

The paper focused on the following research question: *Is the Dutch increase in housing real estate prices partly due to European monetary policy in the period 2014-2021?* From the results it becomes clear that *lending balance sheet* and *share other ECB balance items* significantly positively contributed to the *housing price index* variable, although it is not possible to say to what extent this happens. To be able to answer this question, the available literature was first studied. This resulted in the ascertainment that there is a relationship between monetary policy and house prices with Del Negro and Otrok (2005) even concluding that 13 percent of the price variance could be explained by monetary policy. Literature suggested that the price of Dutch residential property is mainly determined by the inelastic supply (Vermeulen & Rouwendal, 2007), an existing demand surplus (Rijksoverheid, 2021) and institutional policy adjustments (Boelhouwer, 2017). All in all do ECB monetary policy measures impact the Dutch real estate market via banks that provide mortgages more easily when there is easing in monetary policy. Foreign monetary policy significantly affects banks mortgage lending in the Netherlands, so real estate prices (Everett et al, 2021).

The social relevance mainly concerns being able to answer the question if ECB monetary policy has an influence on Dutch housing prices and suggesting possible policy changes to ease the Dutch housing market. The scientific relevance is addressed by contributing to the current literature, which often focuses on the pre-financial crisis period and is also not specifically on the Netherlands.

Now moving on to the empirical research. When collecting the variables it became clear that three nominal variables need to be transformed from nominal to real cost by dividing them with *CPI.* In order to eventually use all variables in the time series analysis, they had to be stationary. To make them stationary, returns were calculated for equity variables, the first difference taken or detrended for other variables. A start has been made with the VAR model in which all conditions with regard to normal distribution, heteroscedasticity and serial correlation were met. Almost all variables were jointly significant in the model, but when performing the Granger causality test, it became clear that it was not possible for the VAR model to perform impulse response analysis. After establishing the correlation between the variables, a switch was made to the VECM model in order to be able to make a statement about the research question. The Johansen's method also had to be used for the co-integration. Now it was possible to do an orthogonalized impulse response analysis together with the orthogonalized variance decomposition. From the results it becomes clear that *lending balance sheet* significantly positively contributed to the *housing price index* variable while explaining 12 percent of the variance of *house price index*. Although it is not possible to say to what extent this happens. *Share other ECB balance items* also had a significant positive impact on *house price index.* The variable *housing scarcity* too significantly influences the price positively. With higher scarcity leading to higher prices.

The three hypotheses on the sub-questions from Chapter 2 can be treated on the basis of the research. The first was about: what is the relationship between monetary policy and house prices? The conducted empirical research stated that there is a significant positive relationship between monetary expansion and house prices. Although the empirical results are much more nuanced than the published literature, there are similarities. The positive relationship between monetary expansion and house prices emerged from the research and has been confirmed by Detken and Smets (2004), Goodhart and Hofmann (2008) and Demary (2010) in the past.

The second sub-question stated: what are the most important determinants of residential property prices in the Netherlands on a macroeconomic level? The most significant result was found for the variable *housing scarcity*, which focused on the tightness in the housing market. This tightening was the result of inelastic supply (Polinsky, 1977) and a surplus in demand (Rijksoverheid, 2021). *Housing scarcity* significantly affects the housing price in the Netherlands during the research period. The third sub-question focuses on the role and impact of the ECB's policy in the Dutch housing market. The answer to this question has been discussed in the answer to the general research question.

Research is often accompanied by limitations. These will be discussed in this paragraph. A disadvantage of the chosen model is that it had to work with quite a few assumptions. As a result, it could only be established in the conclusion that there is a significant positive relationship between ECB monetary policy and Dutch residential property prices. The scope of this relationship could not be quantified. These limitations were reinforced by the number of variables used and possible collinearity between variables. For example, more variables in a VAR model lead to more limitations in the assumptions of the order of the Choleski decomposition. This also made performing IRF more difficult. There is also the chance that a variable has been included that is strongly correlated with the *(Dutch) house price index* and one of the independent variables. This can cause the coefficient to be inconsistent and lead to less interpretable results. Furthermore, the chosen research period of 7 years with monthly data is relatively short compared to other literature. Influences of, for example, a SARS-CoV-2 pandemic during the chosen timeframe could too influence the results. The last limitation is that when choosing the optimal lag length in the statistical software, a maximum of 12 was chosen while data points were available over more than 7 years. This choice was made because of crashing software at a higher lag number.

A follow-up study could be that a distinction is made between the Randstad consisting of The Hague, Rotterdam, Utrecht and Amsterdam and the rest of the Netherlands in terms of house prices. It could be that monetary policy has a different impact between the largest cities in the country and the whole of the Netherlands. The SARS-CoV-2 pandemic has already passed in the limitations, but this also offers a research opportunity in the future. For example, the data can be adjusted so that there is a break before the pandemic and afterwards, so that SARS-CoV-2 specific effects can be filtered. Finally, future research can focus on other monetary instruments. This paper mainly focused on the nine balance sheet items, but the interest rates of *deposit facility, marginal lending facility* and *main refinancing operations* can be further investigated.

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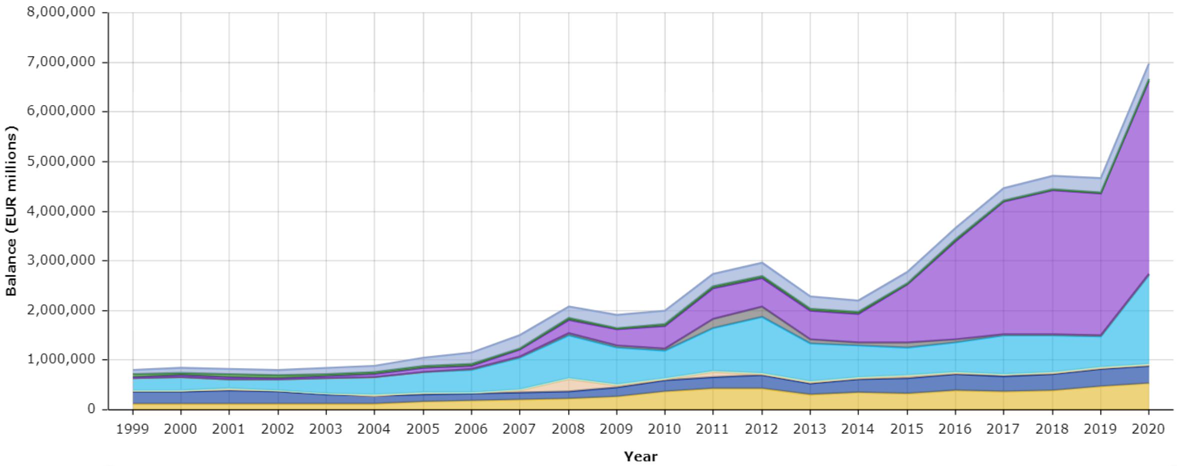
Appendix

A: ECB monetary policy

Figure 1A: overview of the total balance sheet value ECB assets side



Notes: Balance item specifications are shown in Figure 1B

Figure 1B: clarification of balance sheet items

A1 Gold and gold receivables

A2 Claims on non-euro area residents denominated in foreign currency

A3 Claims on euro area residents denominated in foreign currency

A4 Claims on non-euro area residents denominated in euro

A5 Lending to euro area credit institutions related to monetary policy operations denominate

A6 Other claims on euro area credit institutions denominated in euro

A7 Securities of euro area residents denominated in euro

A8 General government debt denominated in euro

A9 Other assets

B: Descriptive statistics

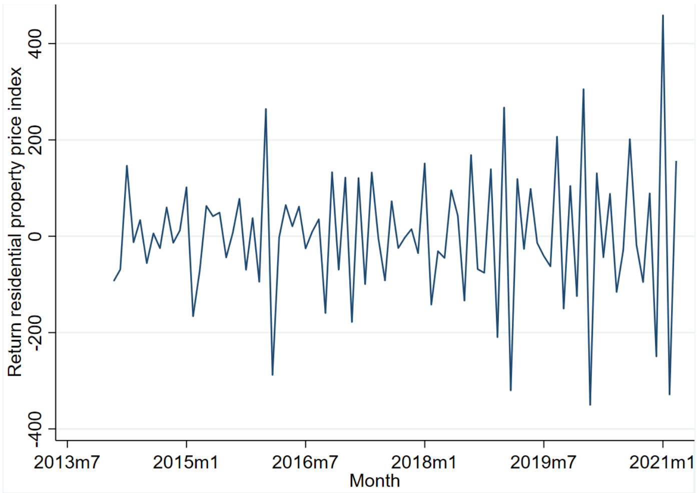
Table 3: Descriptive statistics untransformed variables vector autoregressive model

Variable	Mean	Minimum	Maximum
residential property price index	113.108 (12.637)	96.690	139.449
consumer price index	102.723 (3.142)	98.15	108.69
Securities balance sheet	2,089,817 (1,051,513.000)	556,809.000	4,042,081.000
Bitcoin	5,188.584 (7,816.369)	193.500	50,008.300
deposit facility	-0.345 (0.144)	-0.500	0.000
Share other balance items	0.309 (0.097)	0.180	0.489
index of housing rent prices	107.157 (2.213)	101.619	110.729
housing scarcity	0.002 (0.001)	0.0001	0.003
total mortgage costs	1,812,303.000 (342,784.800)	1,264,167.000	2,424,290.000
property tax	0.020 (0.001)	0.010	0.020
AEX	502.686 (63.635)	386.850	651.260
marginal lending facility	0.300 (0.127)	0.250	0.750
main refinancing operations	0.033 (0.068)	0.000	0.250
Lending balance sheet	760,411.500 (338,373.900)	488,659.000	1,793,194.000

Notes: Each variable has 87 observations. The standard deviations are between brackets. *Residential property price index* and *consumer price index* are indices with 2015 having the value 100. *Index of housing rent prices* is an index with 2014 having the value 100. *Main refinancing operations, marginal lending facility, deposit facility* and *property tax* are measured in percentage points. *Lending balance sheet* and *Securities balance sheet* are in millions of euros. *Housing scarcity* is a number between 0 and 1 coming from a deviation of house for sale to total homes in the Netherlands. *Share other balance items* is calculated by dividing 7 out of 9 balance items with the total balance sheet ECB. *AEX* is an index filled with the 25 largest and most traded Dutch listed companies. *Bitcoin* is measured in euros per unit. *Total mortgage costs* is in thousands of euros and *property tax* is a percentage resulting in a number between 0 and 1. All variables in the table have not yet undergone any transformations.

C: Stationarity

Figure 2: Return (Dutch) residential property price index



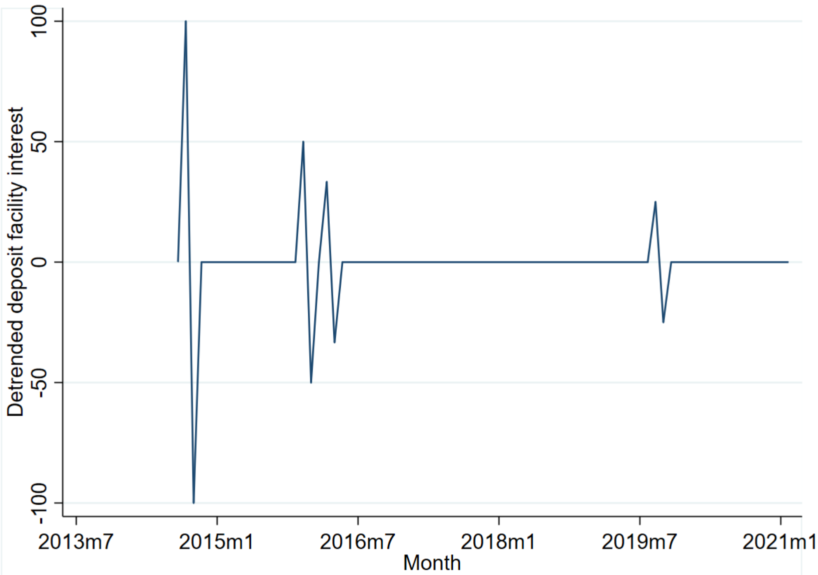
(Dutch) residential property price index MacKinnon approximate p-value for Z(t) = 0.000

Table 4: Augmented Dickey-Fuller test for (Dutch) residential property price index

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-4.344	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0.05.

Figure 3: Detrended deposit facility



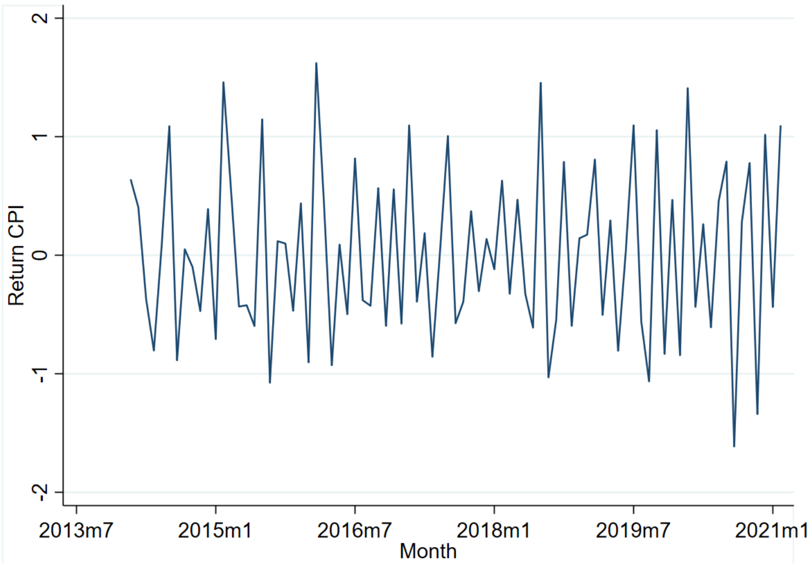
MacKinnon approximate p-value for Z(t) = 0.037

Table 5: Augmented Dickey-Fuller test for detrended deposit facility

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-2.979	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 4: Return (Dutch) consumer price index (CPI)



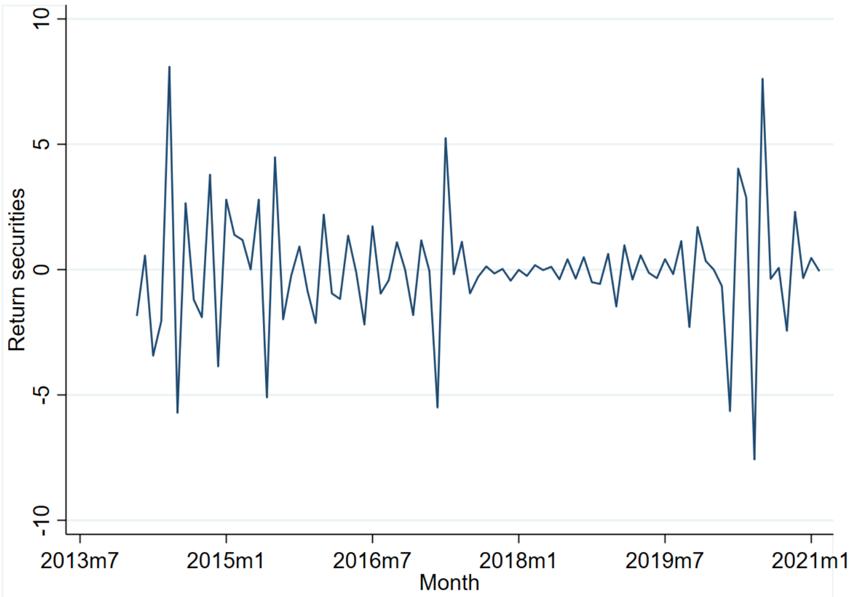
MacKinnon approximate p-value for Z(t) = 0.0000

Table 6: Augmented Dickey-Fuller test for return (Dutch) consumer price index (CPI)

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-5.077	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 5: Return securities balance sheet



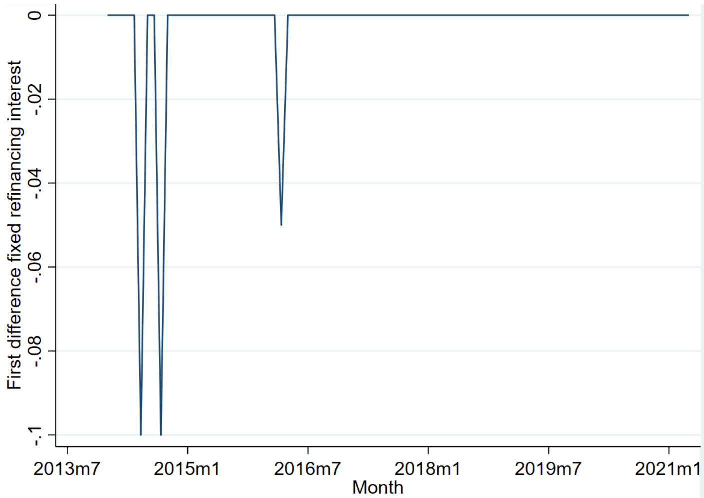
MacKinnon approximate p-value for Z(t) = 0.037

Table 7: Augmented Dickey-Fuller test for return securities balance sheet

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-2.980	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 6: First difference refinancing operations



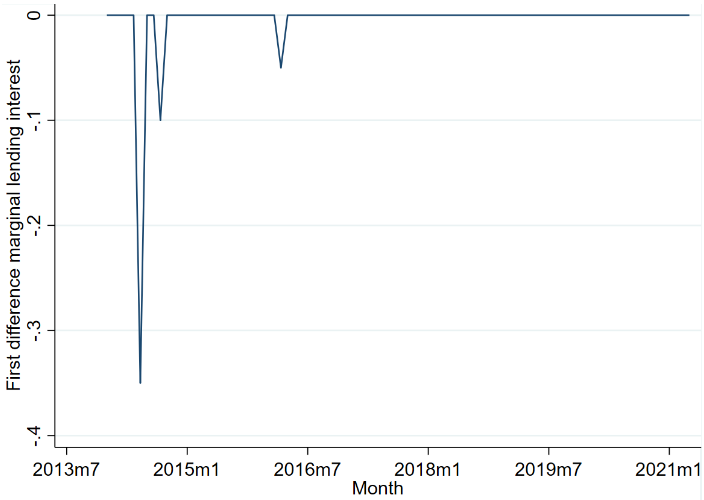
MacKinnon approximate p-value for Z(t) = 0.006

Table 8: Augmented Dickey-Fuller test for first difference refinancing operations

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-3.598	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 7: First difference marginal lending facility



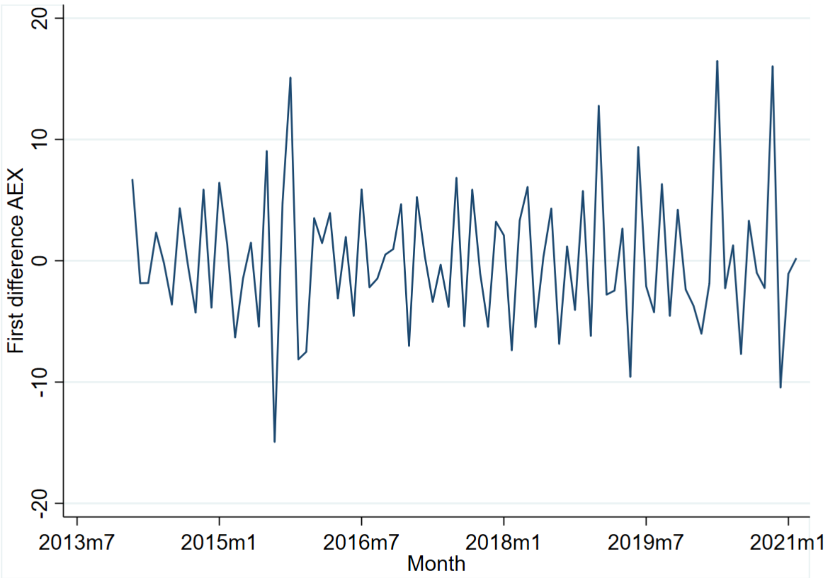
MacKinnon approximate p-value for Z(t) = 0.012

Table 9: Augmented Dickey-Fuller test for first difference marginal lending facility

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-3.372	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 8: Return AEX



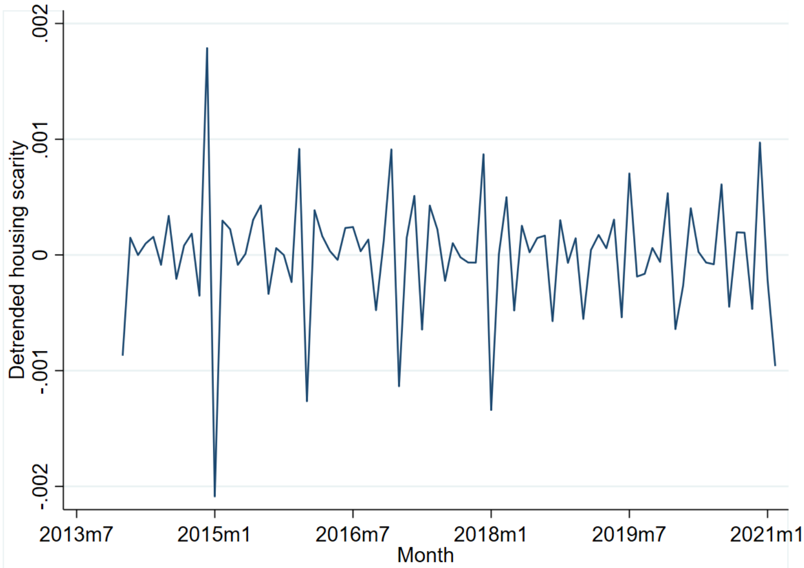
MacKinnon approximate p-value for Z(t) = 0.002

Table 10: Augmented Dickey-Fuller test for return AEX

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-3.873	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 9: Detrended housing scarcity



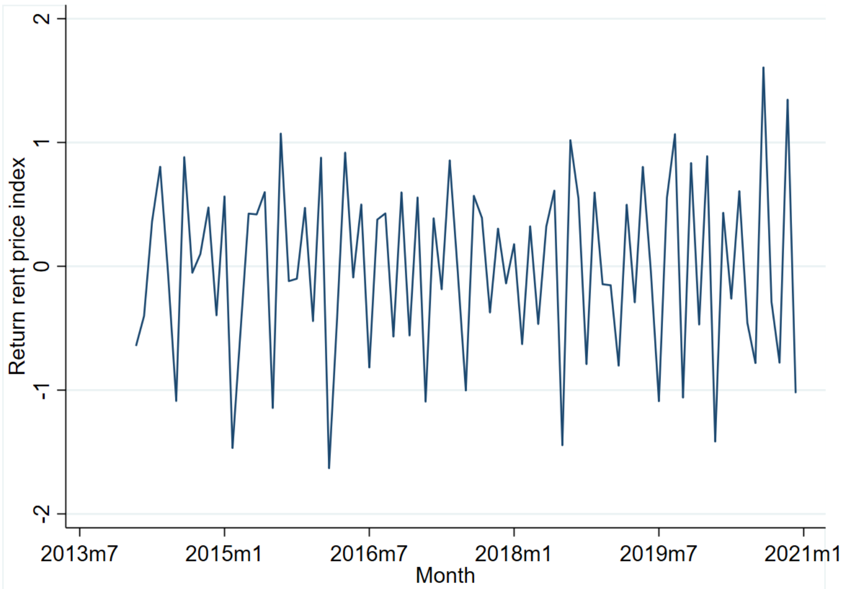
MacKinnon approximate p-value for Z(t) = 0.000

Table 11: Augmented Dickey-Fuller test for detrended housing scarcity

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-4.604	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 10: Return index housing rent prices



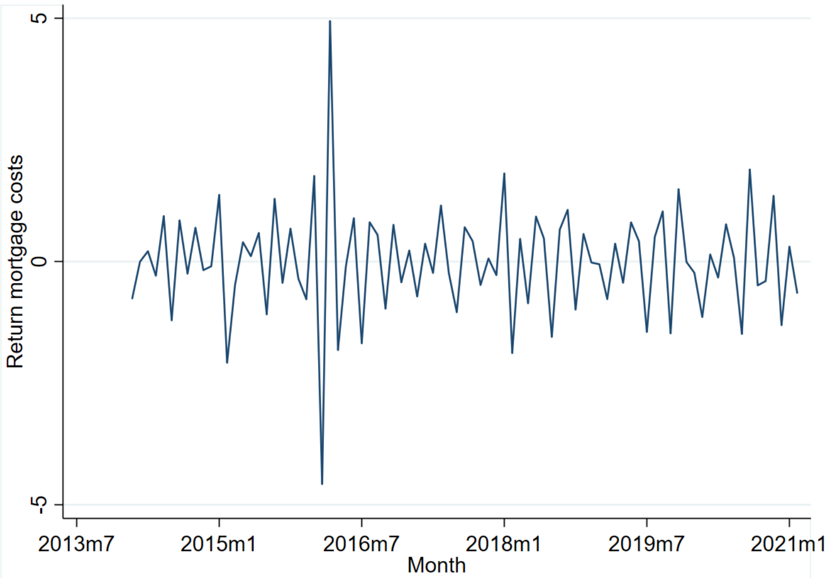
MacKinnon approximate p-value for Z(t) = 0.000

Table 12: Augmented Dickey-Fuller test for return index housing rent prices

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-4.569	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 11: Return total mortgage costs



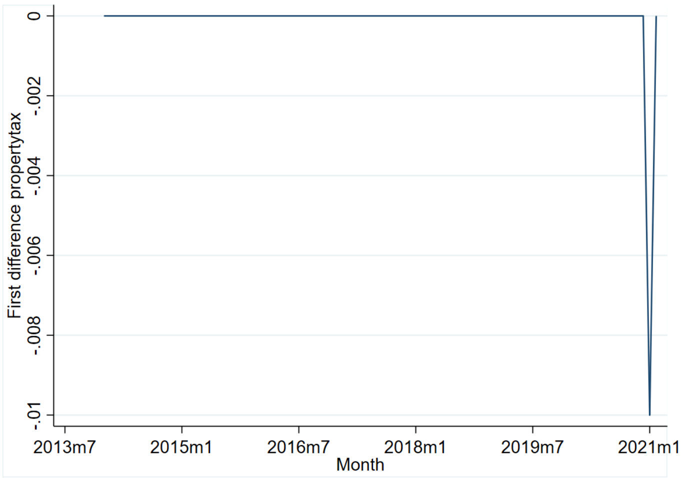
MacKinnon approximate p-value for Z(t) = 0.000

Table 13: Augmented Dickey-Fuller test for return total mortgage costs

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-5.130	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 12: First difference property tax



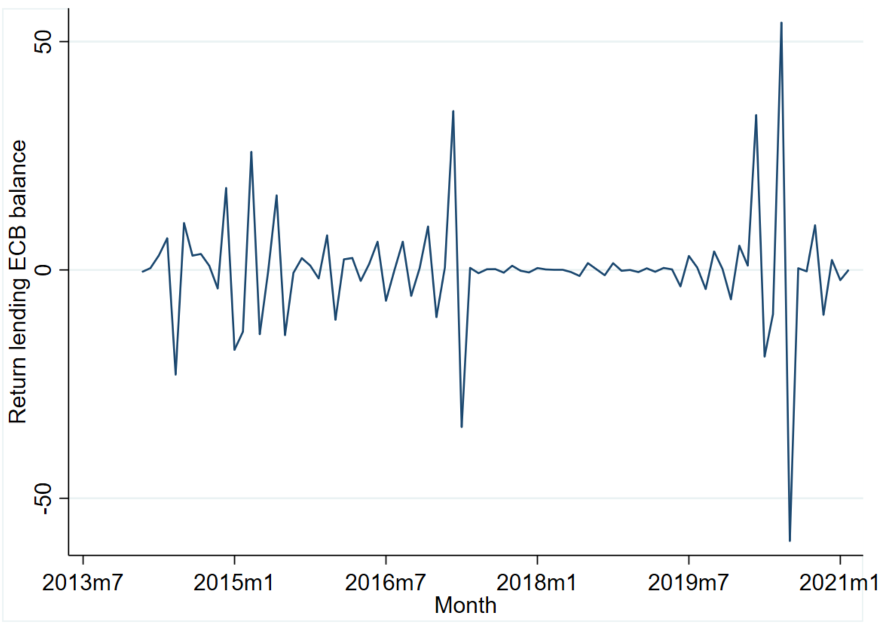
MacKinnon approximate p-value for Z(t) = 0.000

Table 14: Augmented Dickey-Fuller test for first difference property tax

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-8.544	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 13: Return lending balance sheet



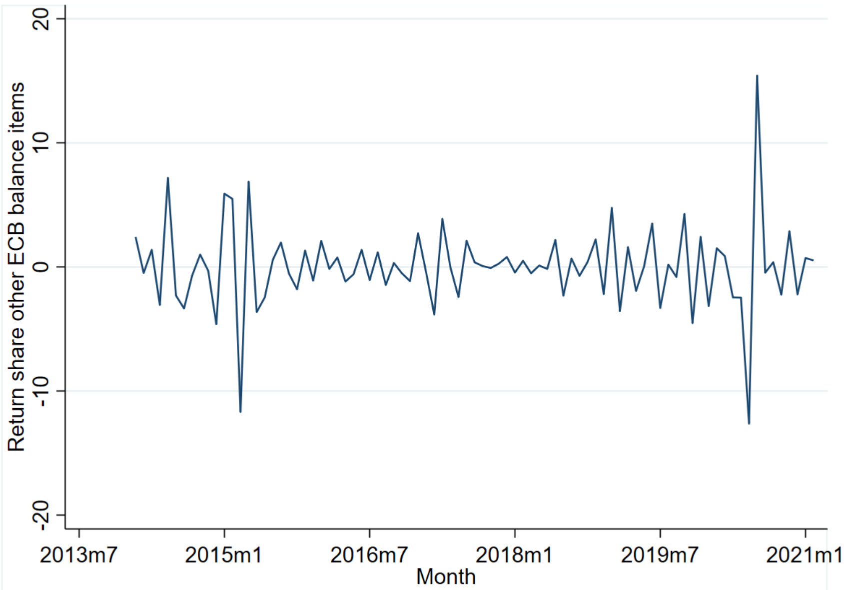
MacKinnon approximate p-value for Z(t) = 0.007

Table 15: Augmented Dickey-Fuller test for return lending balance sheet

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-3.564	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 14: Return share other ECB assets



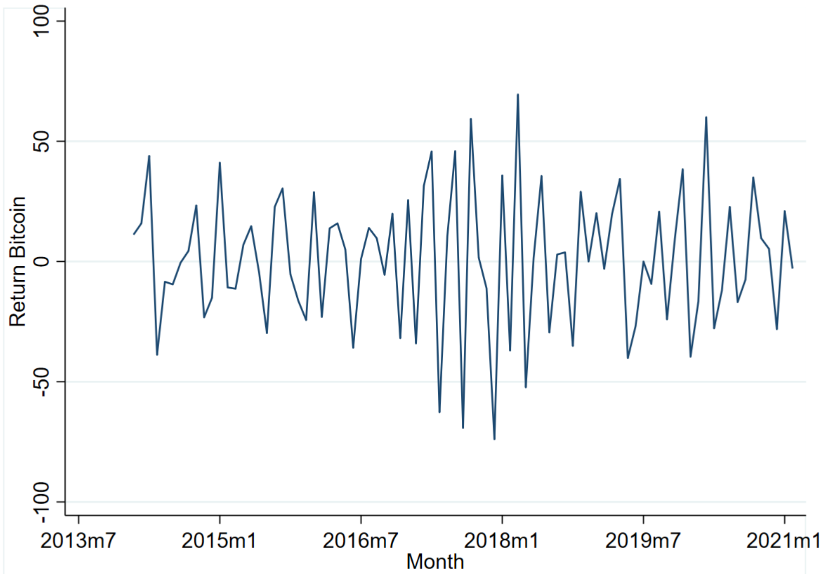
MacKinnon approximate p-value for Z(t) = 0.041

Table 16: Augmented Dickey-Fuller test for return share other ECB assets

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-2.935	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

Figure 15: Return Bitcoin



MacKinnon approximate p-value for Z(t) = 0.002

Table 17: Augmented Dickey-Fuller test for return Bitcoin

Augment Dickey Fuller Test Statistic	1% critical value	5% critical value	10% critical value
-3.855	-3.549	-2.912	-2.591

Notes: The Augmented Dickey-Fuller test was preformed on 12 lags in total because monthly data is used. The null hypotheses of non stationarity can only be rejected if the absolute value of Augment Dickey Fuller Test Statistic is lager than the 5% critical value and the MacKinnon approximate p-value for Z(t) is smaller than 0,05.

D: Serial correlation, normality and heteroscedasticity

Table 18: Breusch-Godfrey LM test for autocorrelation

Lag(p)	chi2	Degrees of freedom	Probability > chi2
12	19.613	12	0.075

Notes: The null hypothesis of no serial correlation can be rejected if the Probability > chi2 statistic is smaller than 0.05. In this case can't the null hypothesis be rejected, so there is no serial correlation. Chi2 stands for chi-squared with 2 degrees of freedom.

Table 19: Skewness Kurtosis test for normality

Variable	Observations	Pr(Skweness)	Pr(Kurtosis)	adjusted chi2(2)	Probability>chi2
Residual	83	0.997	0.972	0.00	0.999

Notes: The Skewness Kurtosis test, tests for different forms of normality. The probability of skewness having the null hypothesis that the skewness is asymptomatically distributed. The Kurtosis also has a null hypothesis of an alternative distribution. The statistic Probability>chi2 look at the overall normal distribution. If this value is below 0.05, the null hypothesis of an overall normal distribution should be rejected. Chi2 stands for chi-squared with 2 degrees of freedom.

Figure 16: Histogram distribution residuals

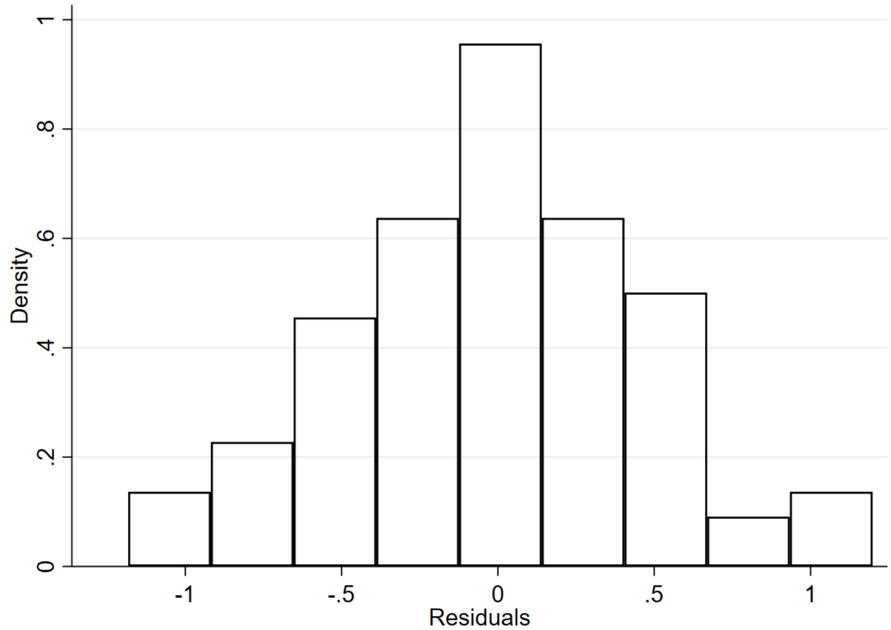


Table 20: White's test for heteroscedasticity

Source	chi2	degrees of freedom	p-value
Heteroscedasticity	65.940	59	0.250

Notes: The White's test for heteroscedasticity has the null hypothesis that there is homoscedasticity. The null hypothesis is rejected if the resulting p-value is less than 0.05. Then the alternative hypothesis of the presence of unrestricted heteroscedasticity is accepted. Chi2 stands for chi-squared with 2 degrees of freedom.

E: Optimal lag length

Table 21: Selection order criteria optimal lag lengths

Lag	HQIC	BIC	AIC	Final prediction error
0	24.364	24.595	24.212	0.000
1	24.618	27.613	22.641	0.000
2	24.530	30.289	20.728	0.000
3	24.153	32.676	18.526	0.000
4	21.9517	33.2387	14.500	0.000
5	-37.423	-23.3719	-46.700	0.000
6	-281.135	-264.780	-291.932	0.000
7	-279.200	-262.846	-289.998	0.000
8	-308.602	-292.248	-319.400	0.000
9	-307.560	-291.206	-319.400	0.000
10	-311.199	-294.764	-318.358	0.000*
11	-309.151	-292.797	-319.949	0.000
12	-316.170*	-299.816*	-326.968	0.000

Notes: The test for selection order criteria were preformed with a maximum length of 12 lags. * indicates that for that specific test it is the optimal number of lags. HQIC stands for the Hannan-Quinn Information Criterion. AIC and BIC stand for Akaike information criteria and Bayesian information criterion as discussed in Chapter 4. The final prediction error measures the quality of the model if it is tested on a different dataset.

F: Results vector autoregressive model estimates

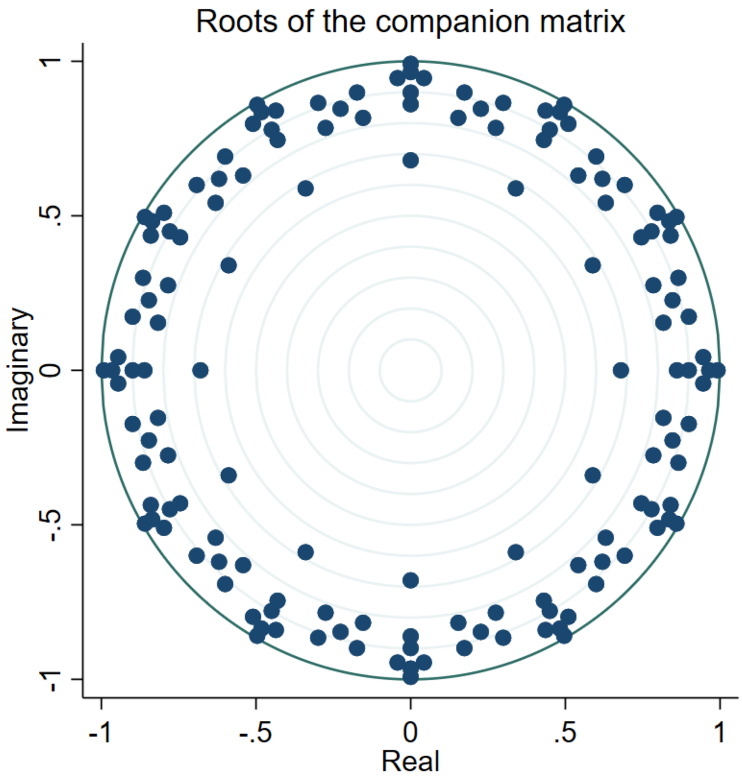
Table 22: Estimates VAR model all variables

Equation	Parameters	Root mean square deviation	R-squared	Chi2	P > chi2
Return property price index	13	0.818	0.572	95.037	0.0000
Return lending balance sheet	13	13.000	0.238	22.207	0.035
Return securities balance sheet	13	2.059	0.297	29.980	0.003
Return share other balance items	13	3.535	0.176	15.170	0.252
Return housing rent index	13	0.479	0.660	137.983	0.000
First difference mortgage costs	13	10987.500	0.468	62.477	0.000
Return AEX	13	6.038	0.208	18.666	0.097
Return CPI	13	0.478	0.661	138.669	0.000
Detrended housing scarcity	13	0.000	0.717	179.876	0.000
Detrended deposit facility	13	0.019	0.235	21.759	0.040
First difference refinancing	13	0.005	0.447	57.436	0.000
Return Bitcoin	13	29.249	0.229	21.023	0.050

Notes: The VAR model has a joint significant effect for a variable if the statistic P > chi2 is less than 0.05. Chi2 stands for chi-squared with 2 degrees of freedom.

G: Stability check VAR

Figure 17: Inverse roots of autoregressive characteristic polynomial VAR



Notes: From Figure 17 can be seen that all the eigenvalues lie inside the unit circle. This means that the vector autoregressive model's stability condition is satisfied. So the model is stable.

H: Granger causality check

Table 23: Granger causality Wald test all intended variables included

Equation	Excluded	chi2	Degrees of freedom	P > chi2
Return property price index	Return lending balance sheet	0.047	1	0.829
Return property price index	Return securities balance sheet	0.488	1	0.485
Return property price index	Return share other items	1.027	1	0.311
Return property price index	Return housing rent index	0.009	1	0.923
Return property price index	First difference mortgage costs	0.083	1	0.773
Return property price index	Return AEX	0.163	1	0.686
Return property price index	Return CPI	0.017	1	0.898
Return property price index	Detrended housing scarcity	14.969	1	0.000
Return property price index	First difference deposit facility	0.078	1	0.780
Return property price index	First difference refinancing	3.099	1	0.078
Return property price index	Return Bitcoin	0.465	1	0.495
Return property price index	All	22.632	11	0.020

Notes: The VAR model is Granger causal for a variable if the statistic P > chi2 is less than 0.05. Chi2 stands for chi-squared with 2 degrees of freedom.

I: VECM model

Table 24: Johansen test trace statistic

Maximum rank	Parameters	LL	eigenvalue	trace statistic	5% critical value
0	110	-642.649	none	419.934	233.130
1	129	-593.969	0.695	322.576	192.890
2	146	-516.794	0.544	258.225	156.000
3	161	-530.953	0.529	196.544	124.240
4	174	-504.772	0.472	144.180	94.150
5	185	-481.545	0.432	97.728	68.520
6	194	-462.540	0.371	59.617	47.210
7	201	-449.268	0.277	33.174	29.680
8	206	-439.475	0.212	13.587*	15.410
9	209	-434.621	0.112	3.879	3.760
10	210	-432.681	0.046	none	none

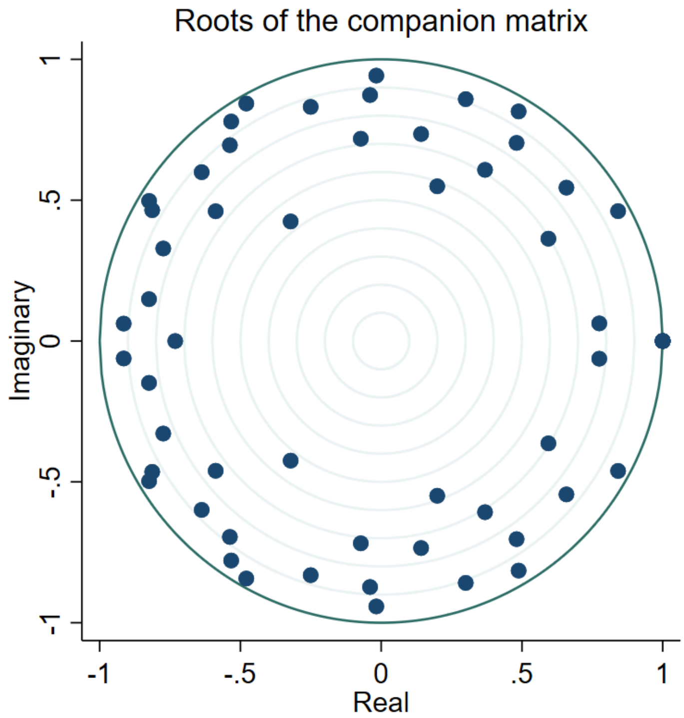
Notes: The maximum rank is chosen by comparing the trace statistic with the 5% critical value statistic. The optimal maximum rank is the rank where the trace statistic is lower than the 5% critical value statistic.

Table 25: Johansen test max statistic

Maximum rank	Parameters	LL	eigenvalue	max statistic	5% critical value
0	110	-642.649	none	97.359	62.810
1	129	-593.969	0.695	64.351	57.120
2	146	-516.794	0.544	61.681	51.420
3	161	-530.953	0.529	52.364	45.280
4	174	-504.772	0.472	46.453	39.370
5	185	-481.545	0.432	38.011	33.460
6	194	-462.540	0.371	26.542*	27.070
7	201	-449.268	0.277	19.587*	20.970
8	206	-439.475	0.212	9.708*	14.07
9	209	-434.621	0.112	3.879	3.760
10	210	-432.681	0.046	none	none

Notes: The maximum rank is chosen by comparing the max statistic with the 5% critical value statistic. The optimal maximum rank is the rank where the max statistic is lower than the 5% critical value statistic.

Figure 18: Inverse roots of autoregressive characteristic polynomial VECM



Notes: From Figure 18 can be seen that all the eigenvalues lie inside the unit circle. This means that the vector error correction model's stability condition is satisfied. So the model is stable.

Table 26: Lagrange-multiplier test

Lag	chi2	degrees of freedom	p > chi2
1	109.680	100	0.239
2	90.467	100	0.742
3	123.225	100	0.057
4	110.826	100	0.216
5	110.134	100	0.230
6	89.995	100	0.753
7	111.380	100	0.205
8	111.590	100	0.201

Notes: The null hypothesis of no autocorrelation at lag order is rejected is p > chi2 is lower than 0.05. Chi2 stands for chi-squared with 2 degrees of freedom.

Table 27: VECM model

Equation	Parameters	RMSE	R-squared	chi2	p > chi2
House price index	62	0.367	0.979	665.921	0.000
Securities balance	62	1.727	0.888	118.663	0.000
Lending balance	62	10.531	0.877	106.958	0.000
Share other items	62	2.452	0.905	142.844	0.000
CPI	62	0.212	0.984	896.628	0.000
Bitcoin	62	28.025	0.825	70.729	0.209
AEX	62	3.843	0.920	174.417	0.000
Mortgage costs	62	0.549	0.959	350.900	0.000
Rent price index	62	0.211	0.984	900.228	0.000
Housing scarcity	62	0.000	0.937	222.265	0.000

Notes: The VECM model has a joint significant effect for a variable if the statistic P > chi2 is less than 0.05. Chi2 stands for chi-squared with 2 degrees of freedom. The RMSE indicates the Root Mean Square Error.

Table 28: Long run equilibrium VECM

Beta of	Coefficient
House price index	1
Securities balance	0.336*** (0.031)
Lending balance	0.115*** (0.010)
Share other items	0.294*** (0.027)
CPI	2.238** (1.137)
Bitcoin	0.004*** (0.001)
AEX	0.010 (0.0149)
Mortgage costs	-0.884*** (0.166)
Rent price index	1.421 (1.062)
Housing scarcity	-0.372 (242.437)

Notes: The coefficients of the variables are given in the second column. *** is significant at 0.01, ** significant at 0.05 and * at 0.10. The standard errors are in parentheses.

J: Correlation between variables

Table 29A: Correlation between variables

	House price index	Lending balance	Securities balance	Share other balance items	Mortgage costs	Rent price index	CPI
House price index	1.000						
Lending balance	0.701	1.000					
Securities balance	0.960	0.670	1.000				
Share other balance items	-0.888	-0.585	-0.975	1.000			
Mortgage costs	-0.977	-0.626	-0.982	0.930	1.000		
Rent price index	0.800	0.480	0.862	-0.838	-0.866	1.000	
CPI	0.960	0.675	0.892	-0.793	-0.941	0.680	1.000

Notes: Table 29A is a correlation matrix with in column (1) the indicated variable and in row (1) the variable to which the indicated variable is correlated.

Table 29B: Correlation between variables

	House price index	Lending balance	Securities balance	Share other balance items	Mortgage costs	Rent price index	CPI
Bitcoin	0.828	0.808	0.795	-0.711	-0.778	0.679	0.791
AEX	0.849	0.510	0.873	-0.826	-0.882	0.756	0.819
Marginal lending	-0.481	-0.142	-0.555	0.515	0.614	-0.787	-0.443
Refinancing	-0.581	-0.211	-0.673	0.647	0.706	-0.869	-0.526
Deposit facility	-0.821	-0.455	-0.881	0.851	0.902	-0.945	-0.758
Property tax	none	none	none	none	none	none	none
Housing scarcity	0.471	0.358	0.584	-0.603	-0.565	0.603	0.440

Notes: Table 29B is a correlation matrix with in column (1) the indicated variable and in row (1) the variable to which the indicated variable is correlated.

Table 29C: Correlation between variables

	Bitcoin	AEX	Marginal lending	Refinancing	Deposit facility	Property tax	Scarcity
Bitcoin	1.000						
AEX	0.730	1.000					
Marginal lending	-0.310	-0.583	1.000				
Refinancing	-0.385	-0.667	0.971	1.000			
Deposit facility	-0.6049	-0.777	0.803	0.890	1.000		
Property tax	none	none	none	none	none		
Housing scarcity	0.446	0.511	-0.547	-0.611	-0.647	none	1.000

Notes: Table 29C is a correlation matrix with in column (1) the indicated variable and in row (1) the variable to which the indicated variable is correlated.

K: Variable sources

Table 30: Information sources of used variables

Variable	Sub-variable	Data period	Selected period	Organization
residential property price index		January 1995 to March 2021	January 1st 2014 to February 28th 2021	Centraal Bureau Statistiek
consumer price index		January 1995 to March 2021	January 1st 2014 to February 28th 2021	Centraal Bureau Statistiek
Securities balance sheet		Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
Bitcoin		November 2015 to April 2021	January 1st 2014 to February 28th 2021	Investing.com
share other balance items		Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
	gold and gold receivables	Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
	claims on non-euro area residents in foreign currency	Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
	claims on euro area residents in foreign currency	Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
	claims on non-euro area residents in euro	Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse

Variable	Sub-variable	Data period	Selected period	Organization
	general government debt	Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
	other claims on euro area credit institutions in euro	Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
	other assets	Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
index of housing rent prices		2014 to 2020	January 1st 2014 to December 31th 2020	Centraal Bureau Statistiek
housing scarcity		2012 to 2020	January 1st 2014 to December 2021	Centraal Bureau Statistiek
total mortgage costs		January 2003 to March 2021	January 1st 2014 to February 28th 2021	De Nederlandse Bank
property tax		March 1995 to April 2021	January 1st 2014 to February 28th 2021	Centraal Bureau Statistiek
AEX		November 1999 to April 2021	January 1st 2014 to February 28th 2021	Investing.com
marginal lending facility		Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse

Variable	Sub-variable	Data period	Selected period	Organization
main refinancing operations		Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
Lending balance sheet		Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse
deposit facility		Week 53 1998 to week 19 2021	January 1st 2014 to February 28th 2021	Statistical Data Warehouse

Notes: Table 30 contains information about the data sources for all variables included in the model. The column sub-variable is mainly for *share other balance items* as this variable is an aggregate of other variables. Column (3) indicates the total period for which a certain variable has data available and with column (4) indicating the selected period.