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# Essays on Housing, Monetary Policy and Consumption

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**Declaration:**
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for doctoral or equivalent academic degree.
Signe Rosenberg

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# Uurimused kinnisvarast, rahapoliitikast ja tarbimisest

SIGNE ROSENBERG

TALTECH KIRJASTUS

# Contents

## List of Publications

The list of author's publications, on the basis of which the thesis has been prepared:

I Rosenberg, S. (2019). The Effects of Conventional and Unconventional Monetary Policy on House Prices in the Scandinavian Countries. *Journal of Housing Economics,* Vol. 46, pp. 1-17. DOI: doi.org/10.1016/j.jhe.2019.101659. (ETIS 1.1)

II Rosenberg, S. (2020). Conventional and Unconventional Monetary Policies: Effects on the Finnish Housing Market. *Baltic Journal of Economics,* Vol. 20, No. 2, pp. 170-186. DOI: doi.org/10.1080/1406099X.2020.1792085. (ETIS 1.1)

III Rosenberg, S. (2015). The Impact of a Change in Real Estate Value on Private Consumption in Estonia. *Research in Economics and Business: Central and Eastern Europe*, Vol. 7, No. 2, pp. 5-26. (ETIS 1.2)

## Author's Contribution to the Publications

I The author of the thesis is the sole author of the article.

II The author of the thesis is the sole author of the article.

III The author of the thesis is the sole author of the article.

# Introduction

During the financial crisis at the end of the 2000s, house prices fell dramatically in many countries after a preceding steep rise. There is no doubt that house prices were an important channel to amplify the consequences of the crisis, as shown in the studies by Duca et al. (2010), Igan et al. (2011) and Mian and Sufi (2011) among others. Hence, there is empirical evidence that developments in the housing market can affect financial stability and the economy through various channels, thereby making it essential to understand how house prices can influence the economy as well as how house prices can themselves be impacted through different policies such as monetary policy.

The aim of the thesis is to investigate the impact of different types of monetary policy on house prices and to study the effect that the dynamics of the housing market in turn have on the real economy, and more specifically on private consumption. This choice of topics for the thesis is predicated by the importance of the housing sector in the economy as underscored by the experiences during the global financial crisis.

There has been a growing interest in the effect of monetary policy on house prices since the start of the global financial crisis in 2008. As the monetary policy interest rate reached the zero lower bound in around 2009 in several countries, the central banks could no longer use conventional monetary policy measures and had to turn to unconventional monetary policy tools. How monetary policy interest rates affect macroeconomic variables and house prices has been studied extensively in the literature, but the effects of unconventional monetary policy have been investigated much less, especially its effects on house prices.

Changes in interest rates affect asset prices, creating wealth effects that have an impact on the consumption decisions of households (Kuttner, 2018). Housing has an important position among the assets held by households, as housing wealth makes up a large share of household wealth. An important channel that links the housing market to the real economy is the wealth effect on consumption. Studying this link gives a better understanding of how potential changes in the housing market could affect the economy. The value of housing influences the ability of agents to borrow and spend and so the dynamics of housing markets can trigger movements in aggregate economic activity (Kanik and Xiao, 2014).

The thesis consists of three published articles. Publications I and II study the impact of different types of monetary policy on house prices and Publication III investigates the effect of housing wealth on private consumption.

The publications of the thesis focus on the three Scandinavian countries Sweden, Norway and Denmark, and on Finland and Estonia. The housing sectors in all these countries have played an important role in the economy, and all five countries have experienced large booms and busts in the housing market.

The motivation for choosing these sample countries was different for each of the different publications of the current thesis. The Scandinavian countries were chosen as the object of study because of their similar economic backgrounds but yet differences in monetary policies, housing loan systems and owner-occupancy rates, which makes comparison of the effects of different types of monetary policy shock across the countries appealing. Finland is a small open economy that is part of the euro area and studying the impact of monetary policy shocks using Finnish data and comparing the results with those of the whole euro area is especially interesting. This is because doing so gives a picture of whether and how the house prices of a small individual country in a monetary union respond differently to the shocks compared to the house prices of the whole monetary union. Estonia is a country in Central and Eastern Europe (CEE) that experienced a large upsurge and a steep downturn in house prices in the 2000s and has a remarkably high owner-occupancy rate. Studying how the dynamics of housing wealth might influence private consumption in Estonia constitutes an example that could be used in case of other CEE countries for example, or more generally in countries with volatile housing markets.

The publications of the thesis employ the Bayesian structural vector autoregressive method (Publications I and II) and the vector error correction model approach (Publication III). Different types of identification are used: in Publications I and II the monetary policy shocks are identified using a combination of zero and sign restrictions, while in Publication III the impacts of innovations in housing value are studied using Cholesky identification. Impulse response functions are used in all three papers to show the effects of the innovations on impact and in the subsequent quarters.

The thesis contributes to the academic literature by extending the literature on the impact of monetary policy on house prices by analysing how unconventional policy affects house prices and whether and how the effects of different types of monetary policy differ. Moreover, the thesis presents a comparison of the effects across the three Scandinavian countries, where there are similarities as well as differences. The thesis also analyses how different types of monetary policy affect house prices in an individual euro area country and whether and how these impacts are different from those in the whole euro area. Finally, the thesis also provides new insights on how the housing market affects private consumption in a CEE country that has a notably high owner-occupancy rate and that has seen large rises and falls in house prices.

The thesis is organised as follows. Section 1 discusses the link between monetary policy and house prices, introduces different types of monetary policy and gives an overview of Publications I and II. Section 2 explains the relationship between housing wealth and private consumption and gives an overview of Publication III. Section 3 contains the final comments summarising the contributions of the paper and presenting the directions for future research. Appendices I-III contain the three publications.

# 1 Monetary Policy and House Prices

The primary objective of the monetary policy of central banks is to maintain price stability, which means meeting a target year-on-year growth in the consumer price index. In order to keep the rise in the general price level at its target level, the central bank can adjust the money supply or policy interest rates.

If money is neutral, the central bank cannot impact the real economy in the long run through monetary policy. However, the New Keynesian theory states that in the short run monetary policy can influence economic activity through its effect on consumption and investment. An important part of the transmission mechanism of monetary policy are asset prices. The volatility of asset prices may have a considerable effect on output and the price level (Bjørnland and Jacobsen, 2010).

House prices are an important category within asset prices. They can play a large role in a financial crisis, as was witnessed, for example, during the Global Financial Crisis of 2008-2010 (see for example Duca et al., 2010; Igan et al., 2011; Mian and Sufi, 2011). Rapid increases in house prices allowed households to use the additional value to borrow for consumption through household equity withdrawal, and this in consequence boosted the economy. When the prices plummeted during the crisis, the fall in the value of collateral had a severe impact on the financial position of households as most housing was financed by loans. Negative housing equity and a rise in mortgage defaults amplified the recession (Diamond and Rahan, 2009; Rötheli, 2010; Mian and Sufi, 2011). This makes it essential to study thoroughly the relationship between monetary policy and house prices, as house prices represent one important channel through which monetary policy can affect financial stability and the economy (Aoki et al., 2004; Mian and Sufi, 2011; Cesa-Bianchi et al., 2015; Jordà et al., 2015; Williams, 2016).

How monetary policy measures affect macroeconomic variables has been studied widely. However, most of the literature on the impact of monetary policy focuses on the effect of the monetary policy interest rate, which is also referred to as conventional monetary policy; see the reviews of that strand of the literature in Uhlig (2005) and Gertler and Karadi (2011) for example. However, there are times when this kind of monetary policy cannot be implemented, because interest rates cannot be lowered any further to stimulate the economy. In those situations Taylor rules would suggest the nominal interest rates to be negative, but market interest rates are effectively bounded by zero as agents can always hold non-interest bearing cash (Joyce et al., 2012). Around 2009 the zero lower bound was reached by the monetary policy interest rates of several central banks, including the European Central Bank (ECB), the Federal Reserve, the Bank of England and the Bank of Japan.

In those unusual circumstances other kinds of monetary policy measures have to be used by the central banks. Measures other than steering the key interest rates are often referred to as unconventional monetary policy. Examples of those measures are large-scale asset purchases, forward guidance and credit easing. The ECB has, for example, conducted outright purchases of government bonds, asset-backed securities and covered bonds starting from 2009 (Boeckx et al., 2017). The ECB has run three covered bond purchase programmes, launched in 2009, 2011 and 2014, while outright monetary transactions were started in 2012 and the asset-backed securities purchase programme began in 2014. The Federal Reserve has carried out large-scale asset purchases, a maturity extension programme and forward guidance since 2008 (Kuttner, 2018). It has had three large-scale asset purchase rounds started in 2008, 2010 and 2012, and it launched a maturity extension programme in 2011. The unconventional monetary policies have led to substantial increases in the balance sheets of the central banks (Joyce et al., 2012).

The transmission channels from conventional monetary policy and unconventional monetary policy to house prices may be different. With conventional monetary policy, a cut in the monetary policy interest rate would lead to a decline in banks' lending rates and a rise in the interest rate spreads as the fall in banks' lending rates is less than proportional (Peersman, 2011). With unconventional monetary policy, the injection of liquidity would result in an increase in the amount of credit supplied by the banks, so reducing the lending rates of the banks and their interest rate spreads (Peersman, 2011; Huber and Punzi, 2020). For example Walentin (2014) argues that if unconventional monetary policy succeeds in influencing the mortgage spread, then it may have large effects on property prices.

As unconventional monetary policy would reduce the long-term interest rates on, say, government bonds, other long-term interest rates like housing loan interest rates would also decrease. A fall in interest rates on housing loans would imply a reduction in the user cost of housing that would in turn increase the demand for housing (Kanik and Xiao, 2014; Walentin, 2014; Rahal, 2016) and hence, house prices would start to rise.

The upshot is that for both types of monetary policy an effect on the lending rates of banks, including those for housing loans, would be expected, but the magnitudes of the effect would be different. This difference would in turn lead to differences in the effects on house prices.

The literature on the effects of unconventional monetary policies on the economy has been expanding fast and includes the academic studies by Baumeister and Benati (2013), Schenkelberg and Watzka (2013), Gambacorta et al. (2014), Boeckx et al. (2017), Gupta and Jooste (2018), and Elbourne et al. (2018). However, relatively few studies have focused on how unconventional monetary policy affects house prices. This topic has been studied by Smith (2014), Rahal (2016), Gabriel and Lutz (2017), Renzhi (2018), and Huber and Punzi (2020), while Publications I and II of the current thesis also contribute to that literature. Moreover, to the best of the knowledge of the author of this thesis, Publication I of the current thesis is the first to compare the effects of the two types of monetary policy shock on house prices in one empirical model. The effects of the two types of monetary policy shock have earlier been studied in one model in, for example, Peersman (2011), but that paper does not include house prices in the model.

To study the effects of different types of monetary policy on house prices, two types of monetary policy shock are identified in the current thesis in Publications I and II. An innovation in the central bank's policy interest rate is used as a proxy for a conventional monetary policy shock, and that shock is labelled as a policy rate shock. An innovation in the central bank's total assets that leaves the policy interest rate unchanged is used as a proxy for an unconventional monetary policy shock, and that shock is labelled as a balance sheet shock. Both shocks are expansionary shocks referring to a decrease in the monetary policy rate and an increase in the central bank's balance sheet.

The central bank's balance sheet innovations are used as a proxy for unconventional monetary policy shocks, following, for example, Peersman (2011), Gambacorta et al. (2014), Rahal (2016), Boeckx et al. (2017), and Gupta and Jooste (2018). Another possibility used in the literature studying unconventional monetary policy is to use the shadow interest rate. Such an approach is employed in Elbourne et al. (2018) for example, and also in Huber and Punzi (2020). The shadow interest rate could not have been used in case of Publications I and II, because it would then not have been possible to distinguish between and compare conventional and unconventional monetary policy shocks in one model, which was a main aim of the two studies. Furthermore, Çekin et al. (2020) mention in their paper for example that a shadow interest rate is a common metric for conventional and unconventional monetary policies, meaning the effects of the two types of monetary policy cannot be separated if the shadow interest rate is used.

Following most of the studies that identify shocks using sign restrictions, Publications I and II employ the Bayesian approach for estimation and inference because in case of inequality restrictions the models are set identified, not point identified. Using the frequentist approach with sign restrictions would tend to give confidence intervals that are wide and not informative about the shape of the impulse responses, making it difficult to interpret the results economically (Kilian and Lütkepohl, 2017).

In Publications I and II the monetary policy shocks are identified using a combination of sign and zero restrictions, following an increasing strand of VAR literature that employs this kind of identification (for example Baumeister and Benati, 2013; Gambacorta et al., 2014; Rahal, 2016; Boeckx et al., 2017). The algorithm of Arias et al. (2018) is followed for the identification in Publications I and II. The use of sign restrictions on the responses of monetary policy shocks has grown since the seminal paper of Uhlig (2005), which proposed the new agnostic method of imposing sign restrictions on impulse responses. Sign restrictions make it possible to make the a priori theorising explicit and at the same time to use it as little as possible (Uhlig, 2005). Adding zero restrictions to the identification scheme in addition to sign restrictions sharpens the identification of the structural shocks by narrowing down the set of admissible impulse responses so that the shocks can be distinguished from each other better. If a combination of sign and zero restrictions is used, the identification generally comes from fewer restrictions than with the Cholesky identification scheme for example (Arias et al., 2018).

The shocks in Publications I and II are of the size of one standard deviation as is common in the structural VAR literature, for example in Uhlig (2005), Christiano and Eichenbaum (2005), Cesa-Bianchi (2013), and Boeckx et al. (2017).

To achieve orthogonality of the two shocks identified in Publications I and II it is assumed that a balance sheet shock has no contemporaneous impact on the monetary policy rate, as in Baumeister and Benati (2013) and Boeckx et al. (2017) for example. In Publication II, which models the euro area and Finland, the assumption of block exogeneity is added to the identification scheme, following Mumtaz and Surico (2009) and Kilian and Lütkepohl (2017). The assumption is necessary because there is a euro area block and a Finnish block in the identification scheme of Publication II and it can be assumed that the variables of Finland cannot contemporaneously affect the variables of the euro area.

Next, subsections 1.1 and 1.2 give overviews of Publications I and II.

## 1.1 Overview of Publication I

Publication I, *The Effects of Conventional and Unconventional Monetary Policy on House Prices in the Scandinavian Countries*, explores the impacts of two types of monetary policy shock on house prices in Sweden, Norway and Denmark. The impacts are studied separately for each of the three countries so the effects can be compared also across the countries. The main focus is on the impact of the identified shocks on house prices, but the responses of the other variables of the model, which are GDP, building permits, the mortgage interest rate, the monetary policy interest rate, and the total assets of the central bank, are considered as well.

Publication I employs quarterly data with the sample period lengths based on data availability. The data period for Sweden is 1989Q1-2017Q1, for Norway the data run from 1988Q4 to 2017Q1, and the data for Denmark are from 1990Q1 to 2017Q1. The data are in levels, allowing for implicit cointegration proposed by Sims et al. (1990) and followed by many authors (for example Gambacorta et al., 2014; Boeckx et al., 2017; Cesa-Bianchi et al., 2020). For the estimation, Publication I uses the Bayesian structural vector autoregressive approach with two shocks identified, which are a policy rate shock and a balance sheet shock. A policy rate shock is an exogenous innovation in the monetary policy interest rate proxied by the repo rate for Sweden and Denmark and by the overnight lending rate for Norway. A balance sheet shock is an exogenous innovation in the central bank's total assets. The balance sheet of the Swedish central bank is proxied by M3 for reasons of data availability. The Normal-Wishart prior is used, following for example Uhlig (2005), Peersman (2011), Schenkelberg and Watzka (2013), and Boeckx et al. (2017).

The results presenting the impact of the identified shocks on house prices show that there are similarities as well as differences in the three Scandinavian countries in the responses of house prices to the two types of monetary policy shock. In Sweden, Norway and Denmark both a policy rate shock and a balance sheet shock have a positive impact on house prices. Moreover, in all the three countries a balance sheet shock results in a response with a higher peak than that of the response of a policy rate shock. Also, the effect of a balance sheet shock on house prices is more persistent in all the countries, which is consistent with Peersman (2011) for example, who also finds that non-standard monetary policy has a more persistent impact than interest rate shocks do. One possible explanation for why the balance sheet shock has a larger and more persistent effect than the policy rate shock is that the results show that the impact of a balance sheet shock on the mortgage interest rate is larger and more persistent.

The effect of a balance sheet shock is more sluggish than the effect of a policy rate shock in Sweden and Denmark, whereas in Norway the speed of impact is similar for both types of monetary policy shock. It is fascinating that the responses of each type of monetary shock are so similar across the three countries, despite of the differences in the monetary policy regimes and mortgage market structures.

Before being published in the *Journal of Housing Economics*, an earlier version of this paper was issued in the TUTECON Working Paper series (No. WP-2018/2). The paper was accepted for publication in the *Journal of Housing Economics* in November 2019. The paper was presented at the 10th *Economic Challenges in Enlarged Europe* conference in June 2018, at the 2nd Baltic Economic Conference in June 2019, and in doctoral seminars at Tallinn University of Technology.

## 1.2 Overview of Publication II

Publication II, *Conventional and Unconventional Monetary Policies: Effects on the Finnish Housing Market*, investigates the topic of Publication I further by concentrating on a small open economy that is part of a monetary union. The paper focuses its study on how different types of monetary policy have influenced house prices in Finland, a small euro area country. It extends this by also looking at how house prices in the euro area as a whole are affected so that the effects in an individual country and in the monetary union as a whole can be compared. It also presents the effects on other variables of the model, which are GDPs, HICPs, building permits, mortgage interest rates in Finland and the euro area, EONIA, and the ECB's total assets.

Publication II uses quarterly data from 2009Q1 to 2018Q2. As in Publication I, implicit cointegration is also assumed in Publication II. Similar to Publication I the Bayesian structural vector autoregressive approach is employed with two shocks identified, which are a policy rate shock and a balance sheet shock. A policy rate shock is identified as an exogenous innovation in the monetary policy interest rate, which is proxied by EONIA in the paper. A balance sheet shock is an exogenous innovation in the ECB's total assets. Sign and zero restrictions are used in the identification scheme and, as mentioned above, in order to account for the fact that a small euro area member country cannot contemporaneously affect the variables of the whole euro area, the block exogeneity assumption is included in the identification scheme in Publication II. The independent Normal-Wishart prior is used in Publication II.

The main results of Publication II that present the effect of the identified shocks on house prices show that both types of expansionary monetary policy shock have a positive and temporary effect on house prices in Finland as well as in the euro area as a whole. In both Finland and the euro area the policy rate shock seems to have a greater and more persistent effect on house prices than the balance sheet shock does. The impact of a policy rate shock on house prices peaks faster in Finland than in the euro area. The peak effect is a little larger in Finland than it is in the euro area, but the magnitudes are still quite similar. The effect of a policy rate shock on house prices may have peaked faster and been more persistent in Finland because the response of the mortgage interest rate in Finland was larger and more persistent than that in the euro area as a whole. The smaller and less persistent response of the mortgage interest rate of the euro area as a whole would in turn be consistent with the euro area variables containing the indicators of all the euro area countries, where there are various different systems for financing housing.

A balance sheet shock has quite a small impact on house prices in Finland and the euro area and again, as was the case with a policy rate shock, the effects are of a similar magnitude. The findings of the paper indicate that policy rate shocks have a larger and more persistent effect on house prices than balance sheet shocks do. The conclusion is the same both in Finland and in the whole euro area. That balance sheet shocks have a very small impact on house prices in the euro area is in line with the results of Rahal (2016) and Huber and Punzi (2020); the effect in Finland has not been studied before. The results of Publication II could indicate that conventional monetary policy measures are more effective in a monetary union at affecting house prices than unconventional monetary policy measures are.

The paper has been presented in doctoral seminars at Tallinn University of Technology. The paper was accepted for publication in the *Baltic Journal of Economics* in June 2020.

# 2 Housing Wealth and Private Consumption

The literature on the impact of wealth on private consumption is vast. The wealth effect on consumption is usually studied using the life-cycle model developed by Ando and Modigliani (1963), who modified the standard Keynesian consumption function, the grounds of which were introduced in Keynes (1936). The life-cycle model is based on the assumption that consumers maximise their utility under a lifetime resource constraint (Altissimo et al., 2005), while lifetime resources consist of both income and wealth. In the life-cycle model households smooth their consumption over their lifetime, taking account of the current and future expected flows of income and wealth. Households alter their consumption in response to any unexpected changes in income or wealth.

Although many studies investigate the effect of wealth on consumption with a focus on wealth as a whole, wealth is not actually homogenous but consists of different components. Consumption can vary in its response to the different wealth components as those components exhibit different degrees of persistence and uncertainty. Wealth is typically divided into housing wealth and financial wealth. There are also papers that divide wealth into housing wealth and non-housing wealth, for example Iacoviello (2011), but in its essence non-housing wealth still refers to financial wealth; the examples of non-housing wealth given by Iacoviello (2011) are shares in firms or holdings in government debt. Financial wealth is in some cases grouped into equity and non-equity financial wealth, depending on whether or not it represents ownership in, for example, a company.

Housing wealth makes up a large share of household wealth. Data from national accounts show that housing wealth increased as a share of total household wealth in the whole euro area from 50% in 1999 to about 62% in 2008, then declined as the result of the financial crisis and began to increase again in around 2016 (Bondt et al., 2020). The study by Meriküll and Rõõm (2019), who use household level data from the Household Finance and Consumption Survey, puts the share of housing in total assets at about 67% in 2013-2014 in the euro area, while in Estonia it was about 68% in 2013 and around 63% in 2017.

The different transmission channels through which changes in the value of housing feed into the economy are the wealth channel, the credit channel, and the private investment channel (Goodhart and Hoffman, 2008). The wealth channel is consumers feeling wealthier if the value of their assets increases, leading them to reduce their savings and increase their consumption. Thus, an unexpected change in wealth induces revisions in the optimal consumption plan of consumers (Paiella and Pistaferri, 2017). The credit channel works through changes in the value of collateral, as the value of the collateral increases, it improves the availability of credit to households, which may encourage them to borrow more (Aoki et al., 2004; Bjørnland and Jacobsen, 2010; Jordà et al., 2015). The private investment channel is connected to Tobin's q effect on investment, with the value of housing increasing relative to construction costs (Goodhart and Hoffman, 2008; Altissimo et al., 2005; Bjørnland and Jacobsen, 2010; Huber and Punzi, 2020).

The literature on how the different components of the total wealth of households affects consumption has produced different findings for which component affects consumer spending the most, financial wealth or housing wealth. Most authors find that housing wealth has a larger effect (for example Benjamin et al., 2004; Case et al., 2005; Pachebo and Barata, 2005; Muellbauer, 2008; Bostic et al., 2009; Iacoviello, 2011; Paiella and Pistaferri, 2017; Caceres, 2019; May et al., 2020). However, there are other papers where it is argued that financial wealth has a larger effect than housing wealth. This conclusion is reached for example in Altissimo et al. (2005), Skudelny (2009), Sousa (2009), and Ludwig and Sløk (2004). In any case, the importance of disaggregating wealth into components in order to study the effect of wealth on consumption is emphasised in the literature.

Many studies use micro level data to estimate the wealth effect on consumption as using micro level data allow the consumption response to be heterogeneous across socio-economic groups. However, using macro level data makes it possible to link the wealth effect explicitly to the dynamics of aggregate consumption and to find long-term relationships. Publication III uses aggregate data to investigate at the aggregate level how changes in housing wealth affect private consumption.

The conventional approach to measuring the wealth effect on private consumption does not, however, take into account that the variables of the model, which are consumption, labour income and wealth, are likely to share a trend and may be cointegrated (Lettau and Ludvingson, 2004). Publication III relates to the strand of literature that takes possible cointegration into account and performs a cointegration analysis to allow for the possibility that the non-stationary time series of the variables in the model could have a stationary linear combination. Cointegration techniques combined with error correction models also make it possible to find empirical evidence for the long-run relationships as well as to explain the short-term linkages between the variables (Pachebo and Barata, 2005).

Next, an overview of Publication III is presented.

## 2.1 Overview of Publication III

Publication III, *The Impact of a Change in Real Estate Value on Private Consumption in Estonia*, studies the link between the value of residential housing stock and private consumption in Estonia, allowing the effect that changes in housing wealth have on private consumption to be estimated for a CEE country that has a very high rate of owner-occupancy and has experienced large rises and falls in house prices. The paper focuses on the impact of housing value on private consumption, while also noting the effects on the other variables of the model, which are GDP and household debt. Hereinafter instead of the term “real estate” the term “housing” is used as is more common in the literature on macroeconomics.

Publication III estimates a VECM model, as in for example Lettau and Ludvingson (2004), in order to capture the long-term equilibrium and short-term relationships between the variables of the model. Before the VECM method is applied, the order of integration of the time series of the variables of the model is tested. As all the time series appear to be non-stationary and the order of integration is the same for all of them, the possible existence of cointegrating relationships is tested using the Johansen cointegration test. As cointegration between the time series is found, a VECM model is estimated. Weak exogeneity is also tested for each variable in the process of estimation, and for the variables that appear to be weakly exogenous, the restriction is kept in the model. Also the normalisation restriction is imposed on the private consumption variable. Cholesky identification is used and the ordering of variables, based on decreasing exogeneity, is housing stock value, GDP, household debt and private consumption. For example it is assumed that an innovation in the value of the housing stock affects all the variables in the same period and so it is ordered first, while the value of the housing stock is not contemporaneously impacted by the other variables of the model.

Publication III uses quarterly data from Estonia from the first quarter of 1997 to the first quarter of 2015. The sample period is chosen due to the availability of the data, as the real estate transaction register of the Estonian Land Board was established in 1997. The value of the housing stock that is used as the variable for housing wealth in Publication III is derived using data on the level of house prices and data on housing space. Many studies use house prices as a proxy for housing wealth, but the value of the housing stock is a more precise measure because it also takes account of the changing housing stock. Total aggregate consumption is used for private consumption, as in Ludwig and Sløk (2004) for example. It may also be worth distinguishing between durable and non-durable consumption to detect explicitly whether the flow of consumption is affected by the wealth effect, but this remains for future research.

Publication III presents both the long-term equilibrium relationship and the short-term dynamics. All the coefficients of the long-term equation are statistically significant and the results indicate that housing value exhibits a positive long-term relationship with private consumption. As some results could have been explained more thoroughly in the article, the author of the thesis uses the opportunity to add the explanation in this section. More particularly, the positive long-term relationship between household debt and consumption might be surprising given that it is a negative component of wealth, but it can be explained by the use of housing equity withdrawal and financial deepening for example. In the literature on financial deepening, the credit stock is often used as a proxy for financial intermediary development, in for example Beck et al. (2000), Beck et al (2014). A positive relationship between housing debt and private consumption has also been found by Martínez-Carrascal and del Rio (2004), who use the VECM approach like is used in Publication III in the current thesis, and in Chucherd 2006.

The short-term responses to changes in housing wealth, which are the responses to a 1% innovation in housing value, confirm the positive and long-lasting effect on the variables. The impulse response function indicates that the effect on private consumption is initially small after the moment of impact, but it increases after that until it settles at a level of around 0.4%. The impulse response function indicates that an increase in the value of the housing stock has a permanent effect on private consumption. The estimates of that impulse response function are used to calculate the elasticity[1], and the elasticity of private consumption with respect to the value of the housing stock converges to 0.217%. In order to be able to compare the results better to the existing literature, the elasticity is transformed into the marginal propensity to consume (MPC). The MPC shows how the effect of a unit change in housing value on private consumption has changed during the sample period.

The main conclusion of Publication III is that an innovation in the value of the housing stock leads to a positive and long-lasting increase in private consumption. The impact is larger than in most of the academic literature on the topic, but this may at least to some extent be induced by the high rate of owner-occupancy in Estonia. The increase in the value of housing may also encourage households to take more consumer loans, which can also boost consumption.

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[1] The elasticity presented in Figure 3 of Publication III is calculated by dividing the impulse responses of an innovation in housing value on private consumption by the impulse responses of an innovation in housing value on the housing value variable itself.

The paper was presented at the 7th *Economic Challenges in Enlarged Europe* conference in June 2015, at the doctoral summer school in August 2015 and in doctoral seminars at Tallinn University of Technology. The paper was accepted for publication in the journal *Research in Economics and Business in Central and Eastern Europe* in May 2016, though the year of the journal volume is 2015.

# 3 Final Comments

House prices are of key importance for household finances, macroeconomic dynamics and financial stability, and this makes it important to study the factors that drive house prices as well as how house prices affect the key macroeconomic variables. This thesis investigates selected issues pertaining to the complex interactions between house prices and macroeconomic developments.

Although there is a large academic literature on the impact of conventional monetary policy on house prices, the literature on the effect of unconventional monetary policy on house prices is as yet quite limited. One contribution that Publications I and II make is that they add to this strand of the literature. Another contribution of those papers is the comparison of the effects of the two types of monetary policy on house prices. This comparison is essential because unconventional monetary policy measures might need to be considered also in the future and it is helpful for planning monetary policy to have a view of how their potential impact compares to that of conventional policy measures. To the best of the knowledge of the author of the current thesis, she is the first to compare the effects of the two types of monetary policy shock in the Scandinavian countries (Publication I) and in an individual euro area country (Publication II). Publication I also contributes by being the first to compare the impacts of each type of monetary policy shock on house prices across the three Scandinavian countries, which are countries with very similar economic backgrounds, but different monetary policy regimes.

Another contribution to the literature is the unique identification scheme applied in Publication I, which allows the impact of both types of monetary policy shocks on house prices to be studied in one model using a combination of zero and sign restrictions. In Publication II the identification scheme is developed further by adding the block exogeneity assumption in order to adapt a model with variables of the whole euro area and an individual euro area country in one model.

Given the complexity of the issues involved it is inevitable that many issues are left for future studies. One possible avenue of research could be to study the effects of the two types of monetary policy shock using a larger sample of euro area countries to reveal whether there are differences in the results across different countries within a single monetary union. Another alternative direction for further research would be to use the narrative sign restrictions approach proposed by Antolín-Díaz and Rubio-Ramírez (2018) and implemented also in Zhou (2019), Afanasyeva et al. (2020) and Cross et al. (2020) for example. Moreover, a time-varying VAR framework could be used as in Baumeister and Benati (2013) and Huber and Punzi (2020) to bring out some examples. Another route for future research in the area studied by Publications I and II is to use high-frequency data for identification, as in Gertler and Karadi (2015) and Cesa-Bianchi et al. (2020) for example.

The contribution of Publication III lies in adding to the literature that examines how housing wealth affects private consumption. There is a large amount of academic literature that studies the wealth effect on private consumption, but there is much less literature that focuses particularly on housing wealth. Moreover, the literature within that field using a post-Socialist transition country is relatively scarce and the results of Publication III also contribute to the literature on CEE countries. The results may be applicable to other transition countries that have witnessed large changes in the value of the housing stock.

Future studies on the relationship between housing wealth and consumption could, for example, focus on the three Baltic countries and the Nordic countries to see if the transmission of housing wealth into the real economy differs across the countries, and if there are any differences then what might cause the heterogeneity. Further studies could also implement the Bayesian structural VAR method, as in Publications I and II of this thesis. Furthermore, it could also be worth studying whether and how much the owner-occupancy rate influences the impact of housing wealth on private consumption. An additional possibility for future studies could be to investigate whether the impact of changes in housing wealth is different in different phases of the economic cycle as in, for example, de Roiste et al. (2020). Also, micro level data could be used instead of macro level data, as in the papers of Campbell and Cocco (2007) and Bostic et al. (2009) for example.

## References

Afanasyeva, E., Jerow, S., Lee, S. J. and M. Modugno. (2020). Sowing the Seeds of Financial Imbalances: the Role of Macroeconomic Performance. Federal Reserve System Finance and Economics Discussion Series, No. 2020-28.

Altissimo, F., Georgiou, E., Sastre, T., Valderrama, M.T., Sterne, G., Stocker, M., Weth, M., Whelan, K. and A. Willman. (2005). Wealth and Asset Prices Effects on Economic Activity. ECB Occasional Paper Series, No. 29.

Ando, A. and F. Modigliani. (1963). The "Life-Cycle" Hypothesis of Saving: Aggregate Implications and Tests. *American Economic Review*, Vol. 53, No. 1, pp. 55-84.

Antolín-Díaz, J. and J. F. Rubio-Ramírez. (2018). Narrative Sign Restrictions for SVARs. *American Economic Review*, Vol. 108, No. 10, pp. 2802-2829.

Arias, J. E., Rubio-Ramirez, J. F. and D. F. Waggoner. (2018). Inference Based on Structural Vector Autoregressions Identified With Sign and Zero Restrictions: Theory and Applications. *Econometrica*, Vol. 86, No. 2, pp. 685-720.

Aoki, K., Proudman, J. and G. Vlieghe. (2004). House Prices, Consumption, and Monetary Policy: a Financial Accelerator Approach. *Journal of Financial Intermediation*, Vol. 13, No. 4, pp. 414-435.

Baumeister, C. and L. Benati. (2013). Unconventional Monetary Policy and the Great Recession. Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound. *International Journal of Central Banking*, Vol. 9, No. 2, pp. 165-212.

Beck, T., Levine, R. and N. Loayza. (2000). Finance and the Sources of Growth. *Journal of Financial Economics*, Vol. 58, No. 1-2, pp. 261-300.

Beck, T. Georgiadis, G. and R. Straub. (2014). The Finance and Growth Nexus Revisited. *Economics Letters*, Vol. 124, No. 3, pp. 382-385.

Benjamin, J. D., Chinloy, P. and G. D. Jud. (2004). Real Estate versus Financial Wealth in Consumption. *Journal of Real Estate Finance and Economics*, Vol. 29, No. 3, pp. 341-354.

Bjørnland, H. C. and D. H. Jacobsen. (2010). The Role of House Prices in the Monetary Policy Transmission Mechanism in Small Open Economies. *Journal of Financial Stability*, Vol. 6, No. 4, pp. 218-229.

Boeckx, J., Dossche, M. and G. Peersman. (2017). Effectiveness and Transmission of the ECB's Balance Sheet Policies, *International Journal of Central Banking*, Vol. 13, No. 1, pp. 297-333.

de Bondt, G., Gieseck, A. and M. Tujula. (2020). Household Wealth and Consumption in the Euro Area. ECB Economic Bulletin, No. 1.

Bostic, R., Gabriel, S. and G. Painter. (2009). Housing Wealth, Financial Wealth, and Consumption: New Evidence from Micro Data. *Regional Science and Urban Economics*. Vol. 39, No. 1, pp. 79-89.

Caceres, C. (2019). Analyzing the Effects of Financial and Housing Wealth on Consumption Using Micro Data. IMF Working Paper, No. WP/19/115.

Campbell, J. Y. and J. F. Cocco. (2007). How Do House Prices Affect Consumption. *Journal of Monetary Economics*, Vol. 54, No. 3, pp. 591-621.

Case, K. E., Quigley, J. M., and R. J. Shiller. (2005). Comparing Wealth Effects: the Stock Market vs. the Housing Market. *Advances in Macroeconomics*, Vol. 5, No. 1, pp. 1-32.

Çekin, S. E., Gupta, R. and E. Olson. (2020). The Taylor Curve: International Evidence. University of Pretoria Working Papers, No 202034.

Cesa-Bianchi, A. (2013). Housing Cycles and Macroeconomic Fluctuations: a Global Perspective. *Journal of International Money and Finance*, Vol. 37, pp. 215-238.

Cesa-Bianchi, A., Cespedes, L. F. and A. Rebucci. (2015). Global Liquidity, House Prices and the Macroeconomy: Evidence from Advanced and Emerging Economies. *Journal of Money, Credit and Banking*, Vol. 47, No. 1, pp. 301-335.

Cesa-Bianchi, A., Thwaites, G. and A. Vicondoa. (2020). Monetary Policy Transmission in the United Kingdom. *European Economic Review*, Vol. 123, pp. 1-19.

Christiano, L. J. and M. Eichenbaum. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy*, Vol. 113, No. 1, pp.1-45.

Chucherd, T. (2006). The Effect of Household Debt on Consumption in Thailand. Bank of Thailand Discussion Paper, No. DP/01/2006.

Cross, J. L., Nguyen, B. H. and T. D. Tran. (2020). The Role of Precautionary and Speculative Demand in the Global Market for Crude Oil. CAMA Working Paper, No. 34.

Diamond, D. W. and R. G. Rajan. (2009). The Credit Crisis: Conjectures about Causes and Remedies. *American Economic Review: Papers & Proceedings*, Vol. 99, No. 2, pp. 606-610.

Duca, J. V., Muellbauer, J. and A. Murphy. (2010). Housing Markets and the Financial Crisis of 2007-2009: Lessons for the Future. *Journal of Financial Stability*, Vol. 6, No. 4, pp. 203-217.

Elbourne, A, Ji, K. and S. Duijndam. (2018). The Effects of Unconventional Monetary Policy in the Euro Area. CPB Discussion Paper, No. 371.

Gabriel, S. and C. Lutz. (2017). The Impact of Unconventional Monetary Policy on Real Estate Markets. Mimeo, available at SSRN: https://ssrn.com/abstract=2493873.

Gambacorta, L., Hofmann, B. and G. Peersman. (2014). The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis. *Journal of Money, Credit and Banking*, Vol. 46, No. 4, pp. 615-642.

Gertler, M. and P. Karadi (2011). A Model of Unconventional Monetary Policy. *Journal of Monetary Economics*, Vol. 58, No. 1, pp. 17-34.

Gertler, M. and P. Karadi (2015). Monetary Policy Surprises, Credit Costs, and Economic Activity. *American Economic Journal: Macroeconomics*, Vol. 7, No. 1, pp. 44-76.

Goodhart, C. and B. Hoffman. (2008). House Prices, Money, Credit and the Macroeconomy. *Oxford Review of Economic Policy*, Vol. 24, No. 1, pp. 180-205.

Gupta, R. and C. Jooste. (2018). Unconventional Monetary Policy Shocks in OECD Countries: How Important is the Extent of Policy Uncertainty. *International Economics and Economic Policy*, Vol. 15, No. 3, pp. 683-703.

Huber, F. and M. T. Punzi. (2020). International Housing Markets, Unconventional Monetary Policy and the Zero Lower Bound. *Macroeconomic Dynamics*, Vol. 24, No. 4, pp. 774-806.

Iacoviello, M. (2011). Housing Wealth and Consumption. FRB International Finance Discussion Paper, No. 1027.

Igan, D., Kabundi, A., de Simone, F. N. and M. Pinheiro. (2011). Housing, Credit and Real Activity Cycles: Characteristics and Comovement. *Journal of Housing Economics*, Vol. 20, No. 3, pp. 210-231.

Jordà, Ò., Schularick, M. and A. M. Taylor. (2015). Betting the House. *Journal of International Economics*, Vol. 96, No. S1, pp. 2-18.

Joyce, M., Miles, D., Scott, A. and D. Vayanos. (2012). Quantitative Easing and Unconventional Monetary Policy – an Introduction. *The Economic Journal,* Vol. 122, No. 564, pp. 271-288.

Kanik, B. and W. Xiao. (2014). News, Housing Boom-Bust Cycles, and Monetary Policy. *International Journal of Central Banking*, Vol. 10, No. 4, pp. 249-298.

Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. London: MacMillan.

Kilian, L. and H. Lütkepohl. (2017). *Structural Vector Autoregressive Analysis*. Cambridge University Press, 782 pp.

Kuttner, K. N. (2018). Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond. *Journal of Economic Perspectives*, Vol. 32, No. 4, pp. 121-146.

Lettau, M. and S. C. Ludvigson. (2004). Understanding Trend and Cycle in Asset Values: Reevaluating the Wealth Effect on Consumption. *American Economic Review,* Vol. 94, No. 1, pp. 276-299.

Ludwig, A. and T. Sløk. (2004). The Impact of Changes in Stock Prices and House Prices on Consumption in OECD Countries. *The BE Journal of Macroeconomics*, Vol. 4, No. 1, pp. 1-26.

Martínez-Carrascal, C. and A. del Rio. (2004). Household Borrowing and Consumption. Banco de España Working Paper Series, No. 0421.

May, D., Nodari, G. and D. M. Rees, (2020). Wealth and Consumption in Australia. *The Australian Economic Review*, Vol. 53, No. 1, pp. 105-117.

Meriküll, J. and T. Rõõm. (2019). Estonian Household and Consumption Survey: Results from the 2017 Wave. Eesti Pank Occasional Paper Series, No. 1/2019.

Mian, A. and A. Sufi. (2011). House Prices, Home Equity-Based Borrowing, and the US Household Leverage Crisis. *American Economic Review*, Vol. 101, No. 5, pp. 2132-2156.

Muellbauer, J. N. (2008). Housing, Credit and Consumer Expenditure. CEPR Discussion Paper, No. 6782.

Mumtaz, H. and P. Surico. (2009). The Transmission of International Shocks: A Factor-augmented VAR Approach. *Journal of Money, Credit and Banking*, Vol. 41, No. S1, pp. 71-100.

Pachebo, L. M. and J. M. Barata. (2005). Residential and Stock Market Effects on Consumption across Europe. *European Journal of Housing Policy*, Vol. 5, No. 3, pp. 255-278.

Paiella, M. and L. Pistaferri. (2017). Decomposing the Wealth Effect on Consumption. *The Review of Economics and Statiscics*, Vol. 99, No. 4, pp. 710-721.

Peersman, G. (2011). Macroeconomic Effects of Unconventional Monetary Policy in the Euro Area. ECB Working Paper, No. 1397.

Rahal, C. (2016). Housing Markets and Unconventional Monetary Policy. *The Journal of Housing Economics*, Vol. 32, No. C, pp. 67-80.

Renzhi, N. (2018). House Prices, Inflation and Unconventional Monetary Policy. Mimeo, available at SSRN: https://ssrn.com/abstract=3174289.

de Roiste, M., Fasianos, A., Kirkby, R. and F. Yao. (2020). Are Housing Wealth Effects Assymetrical in Booms and Busts? *Journal of Real Estate Finance & Economics*, available online, https://doi.org/10.1007/s11146-020-09757-6.

Rötheli, T. F. (2010). Causes of the Financial Crisis: Risk Misperception, Policy Mistakes, and Banks' Bounded Rationality. *The Journal of Socio-Economics*, Vol. 39, No. 2, pp. 119-126.

Schenkelberg, H. and S. Watzka. (2013). Real Effects of Quantitative Easing at the Zero Lower Bound: Structural VAR-based Evidence from Japan. *Journal of International Money and Finance*, Vol. 33, pp. 327-357.

Sims, C. A., Stock, J. H. and M. W. Watson. (1990). Inference in Linear Models with Some Unit Roots. *Econometrica*, Vol. 58, No. 1, pp. 113-144.

Skudelny, F. (2009). Euro Area Private Consumption: Is There a Role for Housing Wealth Effects? ECB Working Paper Series, No. 1057.

Smith, A. L. (2014). House Prices, Heterogeneous Banks and Unconventional Monetary Policy Options. The Federal Reserve Bank of Kansas City Research Working Papers, No 14-12.

Sousa, R. M. (2009). Wealth Effects of Consumption – Evidence from the Euro Area. ECB Working Paper, No. 1050.

Uhlig, H. (2005). What Are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure. *Journal of Monetary Economics*, Vol. 52, No. 2, pp. 381-419.

Walentin, K. (2014). Business Cycle Implications of Mortgage Spreads. *Journal of Monetary Economics*. Vol. 67, pp. 62-77.

Williams, J. C. (2016). Measuring the Effects of Monetary Policy on House Prices and the Economy. BIS Paper, No. 88b.

Zhou, X. (2019). Refining the Workhorse Oil Market Model. *Journal of Applied Econometrics*, Vol. 35, No 4, pp. 130-140.

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# Abstract
# Essays on Housing, Monetary Policy and Consumption

The aim of the thesis is to investigate the impact of different types of monetary policy on house prices and to study the effect that house prices in turn have on the real economy, focusing on the effect on private consumption. The thesis is based on three publications. The first and second publications investigate the effect of different types of monetary policy on house prices. The third publication explores the impact of the value of the housing stock on private consumption.

House prices are an important part of the economy. As was witnessed during the financial crisis at the end of the 2000s for example, house prices can have an amplifying impact on the consequences of crises. This makes it of crucial importance to investigate the impact that house prices can have on macroeconomic variables, like private consumption for example, and to study the effect that different monetary policy instruments can have on house prices, which can in turn have an impact on macroeconomic variables.

The first and second publications employ the Bayesian structural vector autoregressive approach and the third publication uses the vector error correction model approach. In the first and second papers the monetary policy shocks are identified using a combination of zero and sign restrictions, while the third paper uses Cholesky identification. In all the three publications impulse response functions are reported and discussed

The first publication, *The Effects of Conventional and Unconventional Monetary Policy on House Prices in the Scandinavian Countries*, studies how different types of monetary policy affect house prices in Sweden, Norway and Denmark. The results show that expansionary policy rate and balance sheet shocks have a positive effect on house prices in all three countries and that the effect of balance sheet shocks on house prices peaks at a higher level and is more persistent than the effect of policy rate shocks. The impacts of each type of monetary policy shock are quite similar across the three countries. There is little literature on the impact of unconventional monetary policy on house prices and this paper contributes to that literature. Moreover, a unique identification scheme is developed in this paper for studying the impact of two types of monetary policy shock on house prices in one model that makes it possible to compare the impacts of the two types of monetary policy shock.

The second publication, *Conventional and Unconventional Monetary Policies: Effects on the Finnish Housing Market*, explores the impact of different types of monetary policy on house prices in Finland, a euro area country. The study reveals that the policy rate shock and the balance sheet shock both have a positive and temporary impact on house prices in Finland and also in the euro area as a whole. Policy rate shocks appear to have a larger and more persistent impact on house prices than balance sheet shocks do, both in Finland and in the euro area as a whole. Like the first publication of this thesis, the second publication also contributes to the relatively scarce literature studying the effect of unconventional monetary policy on house prices. Moreover, to the best of the knowledge of the author of the current thesis the impact of unconventional monetary policy on the house prices of an individual euro area country has not been studied before.

The third publication, *The Impact of a Change in Real Estate Value on Private Consumption in Estonia*, investigates the relation between the value of residential real estate stock and private consumption using data from Estonia, a country that has seen

large rises and falls in house prices and has a high owner-occupancy rate. The results indicate that a change in housing wealth has a positive effect on private consumption in the long run. One of the contributions of this paper to the literature is that a good database of real estate transactions in a post-transition country that has experienced a large housing market boom and bust is used. Also, the topic of the paper has not previously been studied extensively in post-Socialist countries and the results may be applicable to other CEE countries that have witnessed large changes in the value of the housing stock.

The publications of the current doctoral thesis provide new insights about the relationship between monetary policy, the housing market and the real economy. Publications I and II contribute to the relatively scarce academic literature in the field of the impact of unconventional monetary policy on house prices and provide novelty by comparing the effects of different types of monetary policy on house prices. Publication III, in turn, investigates the effect of changes in the value of the housing stock on private consumption, using a good database from a CEE country, which represents a region where the effect has not been studied extensively.

# Lühikokkuvõte
# Uurimused kinnisvarast, rahapoliitikast ja tarbimisest

Käesoleva doktoritöö eesmärk on uurida, milline on eri tüüpi rahapoliitikate mõju kinnisvarahindadele ja milline efekt on kinnisvaral omakorda reaalmajandusele, täpsemalt eratarbimisele. Doktoritöö põhineb kolmel publitseeritud artiklil. Esimene ja teine artikkel uurivad eri tüüpi rahapoliitikate mõju kinnisvarahindadele ja kolmas artikkel analüüsib kinnisvara väärtuse mõju eratarbimisele.

Kinnisvarahindadel on majanduses oluline roll. Nagu näiteks 2000. aastate lõpu finantskriisi kogemus näitab, võivad kinnisvarahinnad kriisi tagajärgi võimendada, mistõttu on äärmiselt oluline uurida, milline võib olla kinnisvarahindade mõju makroökonoomilistele näitajatele nagu näiteks eratarbimine. Samuti on tähtis uurida, milline efekt võib olla erinevatel rahapoliitilistel instrumentidel kinnisvarahindadele, mis omakorda võivad mõjutada teisi makroökonoomilisi näitajaid.

Esimeses ja teises artiklis kasutatakse Bayesi struktuurset vektorautoregressiivset meetodit ja kolmandas artiklis vektorveakorrektsiooni meetodit. Esimeses ja teises artiklis identifitseeritakse rahapoliitilised šokid, kasutades null- ja märgipiirangute kombinatsiooni ja kolmandas artiklis kasutatakse Cholesky identifitseerimist. Kõigis kolmes artiklis on välja toodud ja kommenteeritud impulsi reaktsioonifunktsioonid.

Esimene artikkel *Konventsionaalse ja mittekonventsionaalse rahapoliitika efektid kinnisvarahindadele Skandinaaviamaades* uurib, kuidas eri tüüpi rahapoliitikad mõjutavad kinnisvarahindu Rootsis, Norras ja Taanis. Tulemused näitavad, et kõigis kolmes riigis on ekspansiivsel rahapoliitika intressimäära šokil ja ekspansiivsel keskpanga bilansi šokil positiivne mõju kinnisvarahindadele ning et bilansišokkide puhul on efekti haripunkt kõrgemal tasemel ning mõju on püsivam kui rahapoliitika intressimäärade šokkide efekt. Võrreldes riikide tulemusi rahapoliitikate tüüpide lõikes, selgub, et kummagi rahapoliitika šoki mõju on kõigis kolmes riigis küllaltki sarnane. Mittekonventsionaalse rahapoliitika mõju kohta kinnisvarahindadele leidub küllaltki vähe akadeemilist kirjandust ja doktoritöö esimene artikkel annab panuse sellealase kirjanduse täiendamisse. Samuti arendatakse antud artiklis välja unikaalne identifitseerimisskeem, uurimaks kahte tüüpi rahapoliitiliste šokkide mõju kinnisvarahindadele ühes mudelis, mis võimaldab šokkide efekte omavahel võrrelda.

Teine artikkel *Konventsionaalne ja mittekonventsionaalne rahapoliitika: efekt Soome kinnisvaraturule* keskendub eri tüüpi rahapoliitikate mõjule Soomes: riigis, mis kuulub euroalasse. Uurimuses leitakse, et nii rahapoliitilise intressimäära šokil kui ka bilansišokil on positiivne ja ajutine mõju kinnisvarahindadele Soomes ja ka kogu euroalas kui tervikus. Ilmneb, et rahapoliitika intressimäära šokkidel on suurem ja püsivam mõju kinnisvarahindadele kui bilansišokkidel, seda nii Soome puhul kui ka kogu euroalas. Sarnaselt doktoritöö esimesele artiklile on ka teise artikli üheks panuseks täiendada mittekonventsionaalse rahapoliitika mõju kinnisvarahindadele uurivat akadeemilisele kirjandust. Lisaks sellele ei ole doktoritöö autorile teadaolevalt varem uuritud mittekonventsionaalse rahapoliitika mõju euroala ühe liikmesriigi kinnisvarahindadele.

Kolmas artikkel *Kinnisvara väärtuse muutumise mõju eratarbimisele Eestis* uurib seost elukondliku kinnisvarafondi väärtuse ja eratarbimise vahel, kasutades Eesti andmeid: riigi, mis on kogenud märkimisväärseid tõuse ja langusi kinnisvarahindades ja kus on kõrge koduomanike poolt pinna hõivatuse määr. Tulemused näitavad, et kinnisvara väärtuse muutumisel on positiivne mõju eratarbimisele pikal perioodil. Üks kolmanda artikli panustest akadeemilisse kirjandusse on see, et kasutatud on head kinnisvaratehingute andmebaasi üleminekujärgses riigis, mis on kogenud märkimisväärset kinnisvarabuumi ja -langust. Samuti on panuseks asjaolu, et antud teemat ei ole kuigi palju uuritud postsotsialistlikes riikides ja tulemusi võib saada rakendada ka teiste Kesk- ja Ida-Euroopa riikide puhul, mille puhul on samuti olnud täheldada suuri muutuseid kinnisvarafondi väärtuses.

Käesoleva doktoritöö kolm publikatsiooni annavad uusi teadmisi rahapoliitika, kinnisvaraturu ja reaalmajanduse seose kohta. Esimene ja teine artikkel panustavad mittekonventsionaalse rahapoliitika mõjusid kinnisvarahindadele uurivasse akadeemilisse kirjandusse, mida doktoritöö kirjutamise hetkel on veel üsna vähe, ja uudsusena võrdlevad eri tüüpi rahapoliitikate mõju kinnisvarahindadele. Kolmas artikkel omakorda uurib kinnisvarafondi väärtuse muutuste mõju eratarbimisele, kasutades head andmestikku riigi kohta Kesk- ja Ida-Euroopas: regioonis, mille osas ei ole antud efekti palju uuritud.

# Appendix 1. Publication I

**THE EFFECTS OF CONVENTIONAL AND UNCONVENTIONAL MONETARY POLICY ON HOUSE PRICES IN THE SCANDINAVIAN COUNTRIES**

**Publication I**

Rosenberg, S. (2019). The Effects of Conventional and Unconventional Monetary Policy on House Prices in the Scandinavian Countries. *Journal of Housing Economics,* Vol. 46, pp. 1-17. DOI: doi.org/10.1016/j.jhe.2019.101659. (ETIS 1.1)

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# The effects of conventional and unconventional monetary policy on house prices in the Scandinavian countries

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ABSTRACT

This paper studies the impact of conventional and unconventional monetary policy on house prices in the Scandinavian countries, using sign and zero restrictions in a Bayesian structural vector autoregressive model, covering the policy rate and balance sheet policies of the central banks over a period of nearly 30 years. Expansionary shocks to the policy rate and the balance sheet both have a positive impact on house prices in the Scandinavian countries, but the effects vary greatly within each country. In all three countries the effect of balance sheet shocks on house prices peaks higher and is more persistent than the response of policy rate shocks. In Sweden and Denmark the impact is more sluggish in case of balance sheet shocks while in Norway the speed of the reaction is similar in case of both types of monetary policy shock.

## 1. Introduction

After the Great Financial Crisis erupted in 2008, there has been growing interest in how monetary policy affects macroeconomic variables. After interest rates reached the zero lower bound (ZLB), unconventional monetary policy became the primary monetary policy tool in many countries. Theoretical and empirical studies suggest that unconventional monetary policy measures can be effective tools if short-term interest rates cannot be changed (Paavola, 2016). Unconventional monetary policy may also affect the prices of long-term assets (Gagnon et al., 2011). One area where unconventional monetary policy may have an effect is house prices. From the existing literature it may be expected that in case of both conventional and unconventional expansionary monetary policy shocks the demand for house purchases would increase and hence the house prices would start to rise, but the transmission mechanisms would be different. The rise in liquidity caused by unconventional monetary policy measures would increase the credit supplied by the banks, and this in turn would reduce the lending rates and the interest rate spreads of the banks (Peersman, 2011). With an expansionary conventional monetary policy shock, there would be a decline in the banks' lending rates and a rise in the interest rate spreads.

Housing wealth comprises a large share of the wealth of households. It is relevant to study the role of monetary policy in house price dynamics, since interest rates have been historically low since the beginning of the financial crisis, and this could raise the risk of a housing market bubble occurring that could impact economic and financial stability. As unconventional monetary policy measures may also be needed in the future, it is important to study how shocks from such policies affect house prices and to compare their effects with those of conventional monetary policy shocks. This will reveal whether unconventional monetary policy measures taken in an environment where the policy rate is constrained by the ZLB could influence house prices. It is also important to examine whether there are differences in the impacts across countries that share many economic characteristics but have different monetary policy regimes, like the Scandinavian countries for instance.

House prices rose and fell a long way in many European countries, including the Scandinavian countries. In this paper I focus on the three Scandinavian countries, Sweden, Norway and Denmark. The housing sector has played an important part in the dynamics of the economic cycle in these countries. Not only were they severely affected by the

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Great Financial Crisis of 2008–2010, but those countries had also seen another cycle of real estate bubbles and busts in the early 1990s. The dynamics of house prices have been quite similar in the three countries, especially until 2008. All three Scandinavian countries experienced a housing boom before the Great Financial Crisis, but the subsequent falls in house prices that they experienced were of different magnitudes. The largest fall was in Denmark and the smallest in Sweden. Owner-occupancy rates[1] are also different across the countries.

There are both similarities and differences in the housing loan systems of the Scandinavian countries. The three countries have quite similar average loan-to-value ratios and mortgage interest payments are tax deductible in all three countries. There are still some differences in the mortgage market structure that could lead to differences in how house prices react. Firstly, in Denmark the bulk of the housing loans are provided by mortgage credit institutions which fund themselves by issuing covered bonds, while in Sweden and Norway housing loans are given by commercial banks. Secondly, the mortgage debt-to-GDP ratio is higher in Denmark than in the other two countries. The mortgage market in all three of the Scandinavian countries can be considered highly developed, but according to the IMF mortgage market index[2] the mortgage market in Denmark has the highest degree of development and completeness.

These three advanced small open economies, which have had two house price booms and busts and have similar economic backgrounds but different monetary policy systems, different owner-occupancy rates, and mortgage market structures with similarities and differences, provide a good case for exploring how different monetary policy measures impact house prices. Sweden announced purchases of government bonds in 2015. Although there has been no official unconventional monetary policy in Norway or Denmark, the effects of balance sheet policies in Norway have been studied earlier by Gambacorta et al. (2014) and Rahal (2016) for example, and those in Denmark by e.g. Behrendt (2013). The results of the current paper may be seen as benchmarks for understanding and forecasting how different monetary policy measures impact house prices in other small open welfare economies.

The aim of this paper is to study the impact of conventional and unconventional monetary policy on house prices in the Scandinavian countries, covering the policy rate and balance sheet policies of the central banks over a period of nearly 30 years. I address three questions in this paper. First, I study how conventional and unconventional monetary policy affect house prices within each of the three Scandinavian countries. Second, I investigate whether there are differences in the timing and the magnitude of the effects of the two types of monetary policy shock. Third, I explore whether the effects are different across the three countries.

I use Bayesian structural vector autoregressive (SVAR) models identified with a combination of sign and zero restrictions, following for example Baumeister and Benati (2013), Peersman (2011), Schenkelberg and Watzka (2013), Boeckx et al. (2017), Rahal (2016), and Weale and Wieladek (2016). This approach enables to sharpen the identification of the structural shocks and hence, by using additional economic information it can interpret the impulse response functions better.

The estimation results show that expansionary shocks to the policy rate and to the central bank's balance sheet both have a positive effect on house prices in all the Scandinavian countries. Following the previous literature I expected that the impact of a balance sheet shock on house prices would be more sluggish than that of a policy rate shock, and this was indeed the case for Sweden and Denmark. In Norway however, the speed of the reaction is similar for both types of monetary policy shock. In all the Scandinavian countries the effect of a balance sheet shock peaks higher and is more persistent than the effect of a policy rate shock. The results are robust to different model specifications. It is striking how different the responses to each type of monetary policy shock are within each country, whereas the responses of each variable to each monetary policy shock are very similar across the countries.

There is an extensive empirical literature suggesting that house price dynamics are closely interrelated with macroeconomic variables. Englund and Ioannides (1997), Tsatsaronis and Zhu (2004), Égert and Mihaljek (2007) and Goodhart and Hoffmann (2008) for example study the determinants of house prices in a range of industrialised countries, including the three Scandinavian countries. Capozza et al. (2002) and Case and Shiller (2003) explore the relationship between US house prices and other key variables. Kasparova and White (2001) examine the degree of similarity in housing market responses to changes in macroeconomic forces in four countries, including Sweden. Iacoviello (2000) identifies the main macroeconomic factors behind house price fluctuations in six countries, including Sweden.

The impact of monetary policy rate shocks on house prices has also been studied in a number of papers such as Iacoviello (2000), Iacoviello and Minetti (2003), Goodhart and Hoffmann (2008), Musso et al. (2011), and Aspachs-Bracons and Rabanal (2011). These papers find that monetary policy rate shocks are important determinants of house price dynamics; a change in the monetary policy rate changes house prices in the opposite direction. The effect is temporary in Iacoviello (2000) and Iacoviello and Minetti (2003) but it is permanent or very persistent in Goodhart and Hoffmann (2008), Musso et al. (2011) and Aspachs-Bracons and Rabanal (2011).

A growing number of studies explore the effect of unconventional monetary policy on macroeconomic variables, and interest in this field has increased markedly since the global financial crisis. How an unconventional monetary policy shock affects output and consumer prices has been explored using a combination of zero and sign restrictions in VAR models in papers like Schenkelberg and Watzka (2013) and Gambacorta et al. (2014). Gambacorta et al. (2014) study the macroeconomic effects of unconventional monetary policies in eight advanced economies, including Norway and Sweden. Their panel VAR results show that the effects on output and prices are statistically significant but temporary. Individual country results show there to be a temporary effect on output and a temporary but quite persistent effect on prices in case of Sweden. In Norway the effects on output and prices are not statistically significant. Schenkelberg and Watzka (2013) explore the effects of quantitative easing in Japan and find that the effects on output and prices are statistically significant but temporary. The effect of unconventional monetary policy on consumer prices and stock market indexes in nine countries, including Sweden and Denmark, is explored by Behrendt (2013), using the Cholesky decomposition for identification. The effects on consumer prices are statistically insignificant in Denmark and are initially negative in Sweden until they become statistically insignificant after a few months.

Peersman (2011) and Baumeister and Benati (2013) use zero and sign restrictions and include conventional and unconventional shocks in one VAR model as I do in this paper, but they do not include house prices as a variable. They have the consumer prices/GDP deflator in the model instead. According to Peersman (2011), conventional monetary policy shocks are innovations to the credit supply that result from a shift in the monetary policy rate, and unconventional monetary policy shocks are innovations to the credit supply caused by monetary policy actions that are orthogonal to the policy rate. The results of Peersman (2011) indicate that both conventional and unconventional monetary policy shocks have statistically significant temporary effects on output and permanent effects on the level of prices. The effect of the unconventional monetary policy shock is more sluggish, as the increases in output and prices only become statistically significant after

[1] According to Eurostat the owner-occupancy rate in 2016 was 65.2% in Sweden, 82.7% in Norway and 62.0% in Denmark.

[2] The IMF mortgage market indices as given in Calza et al. (2013) are: Denmark 0.81, Sweden 0.66 and Norway 0.59.

approximately one year and the peak effect occurs at least six months later than it does following a conventional monetary policy shock. Baumeister and Benati (2013) use a time-varying VAR model and find statistically significant temporary effects on output and price.

There is only a little literature on the impact that unconventional monetary policy shocks have on the housing market. It has been studied by Rahal (2016), Gabriel and Lutz (2017), Smith (2014) and Huber and Punzi (2016). Rahal (2016) uses zero and sign restrictions as I do in this paper, and he explores the impact in eight OECD countries, including Sweden and Norway, in panel VAR and also separately for each country. His results (only medians are displayed) show a temporary effect on house prices in Sweden and a hump-shaped but eventually permanent effect in Norway. Gabriel and Lutz (2017) do not include house prices as a variable and they identify the monetary policy shock with the assumption that the variance of the shock is heteroskedastic across event and non-event days. Smith (2014) concentrates mainly on developing a financial mechanism connecting housing and real economics using US data. He also compares the impacts of announcements of alternative unconventional monetary policy measures on output and house prices, simulating different scenarios and using the Cholesky decomposition for identification. Rahal (2016), Gabriel and Lutz (2017), and Smith (2014) analyse only unconventional monetary policy shocks in the model. I will include both types of monetary policy shock in my model and use longer time series. Huber and Punzi (2016) apply time-varying VAR, use the shadow interest rate for the unconventional monetary policy variable, and identify the unconventional monetary policy shock using only sign restrictions in their main analysis. In the robustness check, which is only presented for the USA, they label the spread shock as the unconventional monetary policy shock, and use zero and sign restrictions. They also have the conventional monetary policy shock in the identification scheme of their robustness check, but they do not show or comment on the results or compare them with the impact of the unconventional monetary policy shock.

My paper contributes to the literature in two ways. First, I develop a unique identification scheme in which I study the impact of two types of monetary policy shock on house prices in one model, using zero and sign restrictions. Second, to the best of my knowledge, I am the first to compare the impacts of the two types of monetary policy shock on house prices in each of the Scandinavian countries and the differences in the impacts across the three countries, which have very similar economic backgrounds and different monetary policy regimes.

The remainder of the paper is organised as follows. Section 2 introduces the model and describes the data. Section 3 discusses the details of the identification scheme. Section 4 presents the results and Section 5 concludes.

## 2. Model specification and data

I use as a proxy for conventional monetary policy shocks the innovations in the monetary policy rate, hereinafter labelled as policy rate shocks, and I use as a proxy for unconventional monetary policy shocks the innovations in the central bank's total assets, leaving the policy rate unchanged, hereinafter labelling these as balance sheet shocks.

As is common for sign-identified VAR models, I employ the Bayesian SVAR approach (e.g. Kilian and Lütkepohl, 2017) to study the dynamic effects of the policy rate and balance sheet shocks on house prices. First, the following benchmark reduced-form VAR model is estimated:

$$Y_t = c + \sum_{i=1}^{n} b_i Y_{t-i} + u_t \tag{1}$$

where $c$ is a vector of intercepts, $Y_t$ is a vector of endogenous variables, $b_i$ s are matrices of autoregressive coefficients of the lagged values of $Y_t$, $i$ is the number of lags in the model and $u_t$ is a vector of residuals.

In order to identify the monetary policy shocks I transform the reduced-form VAR model into the structural form:

$$A_0 Y_t = B_0 + \sum_{i=1}^{n} B_i Y_{t-i} + \varepsilon_t \tag{2}$$

where $A_0$ is the structural matrix of contemporaneous impact effects, $B_i$s are matrices of structural coefficients of the lagged values of $Y_t$ and the reduced-form error terms are related to the mutually uncorrelated structural errors (shocks) $\varepsilon_t$:

$$u_t = A_0^{-1} \varepsilon_t \tag{3}$$

I assume that the VAR is of finite order as in most of the sign restriction literature (Fry and Pagan, 2007).

The vector of the six endogenous variables of the VAR model is:

$$Y_t = [GDP_t,\ HP_t,\ BP_t,\ M_t,\ R_t,\ T_t]' \tag{4}$$

where $GDP_t$ denotes the real GDP per capita, $HP_t$ denotes the real house price index of residential real estate, $BP_t$ is the variable of building permits granted, $M_t$ is the nominal mortgage interest rate, $R_t$ indicates the nominal overnight/repo interest rate, and $T_t$ is the real total assets of the central bank (M3 for Sweden).

GDP is used as a variable in most papers that study monetary policy shocks. The house price is the variable the dynamics of which I am interested in. Housing starts, following Case and Shiller (2003) for example, represent the supply side of the housing market in the model.[3] I use the mortgage interest rate as the long-term interest rate, following Rahal (2016), Case and Shiller (2003), and Musso et al. (2011) among others. Peersman (2011) uses the bank lending interest rate.[4] I use the overnight/repo rate, following several authors who use the federal funds rate for the USA such as Jarociński and Smets (2008), Stock and Watson (2001), Ravn and Simonelli (2007), Uhlig (2005), Christiano et al. (2005), Sims and Zha (2006), Guerrieri and Iacoviello (2017), Peneva (2013), and Uusküla (2016), and I also follow Peersman (2011) and Boeckx et al. (2017), who use the main refinancing operations (MRO) policy rate.

There are two connected interest rates in the VAR, because it is necessary to distinguish between the two types of monetary policy shock (see detailed information on the identification scheme in the next subsection). Among the papers that identify both the conventional and unconventional monetary policy shocks, Baumeister and Benati (2013) use the short-term interest rate and the 10-year government bond yield spread, while Peersman (2011) uses the MRO policy rate and the bank lending interest rate. Among the papers that identify only the unconventional monetary policy shock, Boeckx et al. (2017) use the MRO policy rate and the EONIA-MRO spread, Schenkelberg and Watzka (2013) use only the 10-year government bond yield, and Rahal (2016) and Case and Shiller (2003) use only the mortgage interest rate. Musso et al. (2011) identify the conventional monetary policy shock and they use the three-month interbank interest rate and the mortgage interest rate.

I use the central bank's total assets as the balance sheet variable following for example Gambacorta et al. (2014), Boeckx et al. (2017), Rahal (2016), Gupta and Jooste (2018) and Peersman (2011). Schenkelberg and Watzka (2013) use the average outstanding current account balances held by financial institutions at the Bank of Japan.

Since I could find quarterly data for the total assets of the Riksbank starting from 2004Q1 only, I use M3 as the balance sheet policy variable for Sweden, following e.g. Peersman (2011). To check whether changing the variable affects the results I also estimated the impulse responses for the same length of time series as with total assets. The

[3] Jarociński and Smets (2008), Musso et al. (2011) and Aspachs-Bracons and Rabanal (2011) use residential investment, Rahal (2016) uses (in case of Norway) gross fixed capital formation for construction.

[4] A weighted average of the interest rates of MFIs to households, non-financial corporations and non-MFI financial intermediaries.

IRFs using total assets (available upon request) are very similar to those using M3 and hence there is an argument for using M3 as a variable in the model.

For Denmark I use the Danish certificates of deposit rate and the central bank's total assets, though the Danish krone is pegged to the euro. However, in ordinary times the fixed exchange rate is credible and if the ECB changes its interest rates, then the Danish central bank will follow, but differences still remain in the interest rates. If there were uncertainty or speculative attacks, the differences would be large. Furthermore, using the ECB versions of the variables would have made the sample period much shorter, so it would not have been comparable to the other Scandinavian countries. Moreover, if ECB variables had been used then the identification scheme of the shocks would not have been appropriate for Denmark as block exogeneity should have been used.

The data are in levels, which allows for implicit cointegrating relationships (Sims et al., 1990). Using first differences of the data instead of using data in levels may result in valuable information being lost. The assumption that a VAR using data in levels implicitly takes into account the cointegrated relationships is used quite extensively in the literature. For example implicit cointegration is assumed in Gambacorta et al. (2014), Rahal (2016), Boeckx et al. (2017), Cesa-Bianchi et al. (2015) and Cesa-Bianchi et al. (2018). Data in log levels instead of, say, logged first differences have been also used in the VAR by Uhlig (2005) and Vargas-Silva (2008) for example. Moreover, the seminal paper by Sims et al. (1990) points out that as the Bayesian approach is entirely based on the likelihood function, which also has the same Gaussian shape in case of nonstationarity, the Bayesian inference does not need to take special account of nonstationarity.

The estimated VAR model satisfies the stability condition (no root outside the unit circle) for all the three countries. For robustness I still estimated the model using first differences in case of the logged level variables. The results (available upon request) did not change notably.

All the variables are quarterly and are seasonally adjusted using the multiplicative X12-ARIMA method. GDP per capita, the house price index and the central bank's total assets are deflated by the CPI. See Appendix A for a detailed description of the data and the data sources and Appendix B for the descriptive statistics. All the variables except the interest rates are transformed using natural logarithms, and multiplied by 100 to display the results better. Two lags are used, following the usual lag order selection criteria.[5] The sample periods are based on data availability and are 1989Q1-2017Q1 for Sweden, 1988Q4-2017Q1 for Norway and 1990Q1-2017Q1 for Denmark,[6] so both the Nordic Banking Crisis and the Global Financial Crisis are included. Gertler and Karadi (2015) show that the results of their VAR models are not dependent on including the crisis period in the sample, nor on using other sample periods.

Although there was no official unconventional monetary policy before 2008, there was clearly volatility in the balance sheets of central banks. At the beginning of the 1990s for example, the central bank of Sweden helped to ease the burden on the stricken institutions through unconditional lending (Moe et al., 2004). Similar events also occurred in other Scandinavian countries, for instance the large increase in reserves in Denmark starting from 1992 (Behrendt, 2013). Unconventional monetary policy, using the period before 2008, has been studied by Peersman (2011) and Behrendt (2013) for example. Moreover, Gertler and Karadi (2015) show that a VAR model can be estimated for a long period using shocks from a shorter sub-period.

The estimations are done in Matlab, using the BEAR toolbox (Dieppe et al., 2016). I use the Normal-Wishart (sigma as univariate AR) prior, following e.g. Uhlig (2005), Peersman (2011), Schenkelberg and Watzka (2013), and Boeckx et al. (2017). The toolbox's default values for the hyperparameters to compute the mean and variance of the prior distribution for the VAR coefficients are used, where autoregressive coefficient = 0.8, overall tightness = 0.1, lag decay = 1, and exogenous variable tightness = 100, which are also the typical values found in the literature. A total of 10,000 successful draws from the posterior are used for the impulse response functions, following Boeckx et al. (2017) among others. The 16th and 84th percentiles (i.e. the 68% credible set) of the IRFs are reported as standard in the sign restriction literature, reflecting model uncertainty and sampling uncertainty (Gambacorta et al., 2014). The median is also shown, as in e.g. Uhlig (2005).

## 3. Identification scheme

I use a combination of sign and zero restrictions on the contemporaneous impact matrix as in Baumeister and Benati (2013), Peersman (2011), Schenkelberg and Watzka (2013), Gambacorta et al. (2014), Boeckx et al. (2017), Rahal (2016), and Weale and Wieladek (2016) for example, in order to sharpen the identification of the structural shocks and hence, by using additional economic information, to better interpret the impulse response functions.

As a proxy for conventional monetary policy shocks I use the innovations in the monetary policy rate, which are labelled as policy rate shocks in the current paper, and I use as a proxy for unconventional monetary policy shocks the innovations in the total assets of the central bank, leaving the policy rate unchanged, labelling this as balance sheet shocks in the current paper. Hence, to distinguish between the two monetary policy shocks I assume that the balance sheet shock has zero contemporaneous effect on the monetary policy rate, following for example Baumeister and Benati (2013), Peersman (2011), and Boeckx et al. (2017). A balance sheet shock is identified as an orthogonal innovation to the central bank's total assets (M3 in case of Sweden), following the studies of Gambacorta et al. (2014), Rahal (2016), Boeckx et al. (2017), Gupta and Jooste (2018), Peersman (2011) and others. The central bank's balance sheet has been mentioned as the most concrete measure of the Federal Reserve's credit market innovations in the theoretical paper of Gertler and Karadi (2011). Using the innovations in the central bank's balance sheet could be justified by the transmission mechanism of balance sheet policies into the real economy. An increase in the central bank's balance sheet would lead to an increase in liquidity, which in turn would lead to an increase in the volume of loans of the commercial banks (e.g. Boeckx et al., 2017 and Peersman, 2011). That would reduce lending rates and hence the user cost of housing, and house prices would rise (e.g. Rahal, 2016).

The effect of an unconventional monetary policy shock on real estate markets has been studied by Rahal (2016), Gabriel and Lutz (2017), Smith (2014), and Huber and Punzi (2016). Gabriel and Lutz (2017) and Smith (2014) do not use sign restrictions for identification. Rahal (2016) and Huber and Punzi (2016) use a combination of zero and sign restrictions, as I do in my paper, but Huber and Punzi (2016) use only sign restrictions in the identification scheme of their main analysis and add a zero restriction in the robustness check.

I have used the papers of Peersman (2011) and Rahal (2016) as a basis for developing the identification scheme for my paper. Rahal (2016) identifies only the unconventional monetary policy shock and he does not include the monetary policy rate. In order to sharpen the distinction between the two types of monetary policy shock, I add the monetary policy interest rate to the Rahal (2016) model, with a zero restriction on the contemporaneous impact matrix. Unlike the model in Rahal (2016) I also have the policy rate shock in the model as in Peersman (2011). Peersman (2011) has both the conventional and unconventional monetary policy shocks in the model; however, he does

[5] Using two lags was proposed by HQ criterion for Sweden, for Denmark by the AIC, SC and HQ criteria and for Norway by AIC and HQ. The results are robust to various lag lengths.

[6] I also estimated the impulse responses for identical period lengths across countries, but it did not make any notable difference.

**Table 1**
Identification of monetary policy shocks.

| | GDP | HP | BP | M | R | T |
|---|---|---|---|---|---|---|
| Policy rate shock | 0 | 0 | 0 | < 0 | < 0 | ? |
| Balance sheet shock | 0 | 0 | 0 | < 0 | 0 | > 0 |

Note: "?" indicates that the impact of the shock on the variable was left unrestricted.

not include house prices or the housing supply.

Table 1 presents the identification scheme of my paper. Two types of monetary policy shock are identified: a monetary policy rate shock and a balance sheet shock. The zero restrictions are binding on impact and the sign restrictions are imposed on impact and the following two quarters after the shock, following e.g. Rahal (2016).

For both shocks I assume that there is only a lagged impact of the monetary policy shocks on GDP and house prices following for example Schenkelberg and Watzka (2013), Peersman (2011), Gambacorta et al. (2014), and Boeckx et al. (2017). They have consumer prices in their models, but the characteristics of housing markets suggest that the responses of house prices may be even slower. A lagged impact on the variables for GDP, house prices and housing supply is assumed in e.g. Rahal (2016) and Jarociński and Smets (2008), and the contemporaneous impact of a policy rate shock on house prices and GDP being not significantly different from zero in e.g. Iacoviello (2005). Hence, I restrict the contemporaneous impact on those three variables to zero.

I restrict the mortgage interest rate to decrease in case of both types of monetary policy shock, following for example Peersman (2011), Rahal (2016), and Weale and Wieladek (2016). Since a restriction on the monetary policy rate variable is needed for a distinction to be made between the two types of monetary policy shock, I restrict that variable to decrease[7] in case of a policy rate shock and to have only a lagged impact in case of a balance sheet shock. I restrict the central bank's total assets to increase contemporaneously following the balance sheet shock, following for example Schenkelberg and Watzka (2013), Gambacorta et al. (2014), and Rahal (2016).

## 4. Results

Figs. 1–3 show the impulse responses to the policy rate and balance sheet shocks. For better comparability the effects of both types of monetary policy shock are displayed on the same figure. Areas bordered by lines represent the 68% credible sets of the responses to expansionary policy rate shocks, while the shadowed areas show the 68% credible sets of the effects of the expansionary balance sheet shocks. The lines within the credible sets represent the median impulse responses.

### *4.1. Sweden*

Fig. 1 shows the IRFs of the monetary policy shocks of Sweden. The impulse responses indicate that an expansionary policy rate shock of the size of one standard deviation, meaning a decrease in the repo rate of about 1 percentage point, is followed by a temporary rise in house prices that peaks in the 14th quarter. A positive balance sheet shock of the size of one standard deviation, meaning an increase in M3 of about 1.5%, is followed by a permanent rise in house prices that peaks at the end of the 7th year. By the 15th quarter, a 2% increase in M3 has an impact on house prices that is similar in magnitude to the effect of a 150-basis-point cut in the repo rate. These results suggest that in times when unconventional monetary policy measures are used, the effect on house prices may be a prolonged or permanent increase. One reason that the response of house prices to a balance sheet shock is more persistent than that to a policy rate shock may be that the households in Scandinavia have a very high level of debt relative to income.[8] This means that they are very sensitive to changes in mortgage interest rates and as the balance sheet shock results in a more persistent decline in mortgage interest rates, then the rise in house prices is also more persistent.

The responses of house prices and GDP to balance sheet shocks are more sluggish, are very persistent, and peak at higher levels than the responses to policy rate shocks. The result that the responses of output and prices are more sluggish in case of balance sheet shocks is consistent with the findings in e.g. Peersman (2011) and could possibly be ascribed to differences in the transmission mechanisms of the two types of monetary policy shock, as described in the introduction.

It is striking how different the responses of house prices are to the two types of monetary policy shock. Looking at earlier studies, Peersman (2011) finds the response of consumer prices to be temporary in case of interest rate shocks and permanent in case of non-standard policy shocks. The results of my paper indicate that this kind of pattern also applies to the response of house prices.

The response of housing starts is restricted to zero on impact and there is a positive response to a policy rate shock after the impact period, but the value zero is within the credible interval until the 10th quarter. The subdued effect could potentially be explained by the low housing supply in relation to demand, a feature that has been characteristic of the Swedish housing market for decades (Emanuelsson, 2015). At first a balance sheet shock has a negative impact on housing starts, then zero is inside the credible interval from the 10th quarter until the 24th, after which the impact becomes positive. The upper band of the credible set is very close to zero during the first quarters and in case of a larger credible set zero would have been inside the credible interval.

In line with the imposed sign restrictions, the mortgage interest rate falls on impact and stays negative for the two following quarters in case of both types of monetary policy shock; the response remains negative until it dies out, which is consistent with the response to unconventional monetary policy shocks in for example Rahal (2016). The effect fades out sooner in case of conventional monetary policy shocks, as the value zero is already included in the credible set in the 7th quarter. The effect is much more persistent in case of balance sheet shocks.

### *4.2. Norway*

The IRFs of the two types of monetary policy shock for Norway are reported in Fig. 2. An expansionary policy rate shock of one standard deviation, which is a cut of about 0.3 percentage points in the overnight lending rate, is followed by a rise in house prices, which peaks in around the 14th quarter, like in Sweden. After that, the impact slowly starts to diminish. A positive balance sheet shock of the size of one standard deviation, which equates to an increase in the central bank's total assets of about 3%, is also followed by a rise in house prices that peaks by the 14th quarter just as it did after the policy rate shock. Comparing the responses of house prices to different types of monetary policy shock shows that house prices feel an equivalent effect in, say, the seventh quarter from a cut of around 50 basis points in the overnight lending rate and from a 1% increase in the central bank's total assets. The response of house prices to balance sheet shocks peaks at a similar time but at a higher level than the response to policy rate shocks. The effect of policy rate shocks fades out much sooner than the

[7] Peersman (2011) imposes this restriction on the interest rate in case of the conventional monetary policy as a non-strict inequality; however, I believe that imposing a strict inequality improves the orthogonality of the shocks.

[8] According to OECD Data the Scandinavian countries have some of the highest levels of household debt to disposable income; in 2016 it was 290% in Denmark, 230% in Norway, and 183% in Sweden.

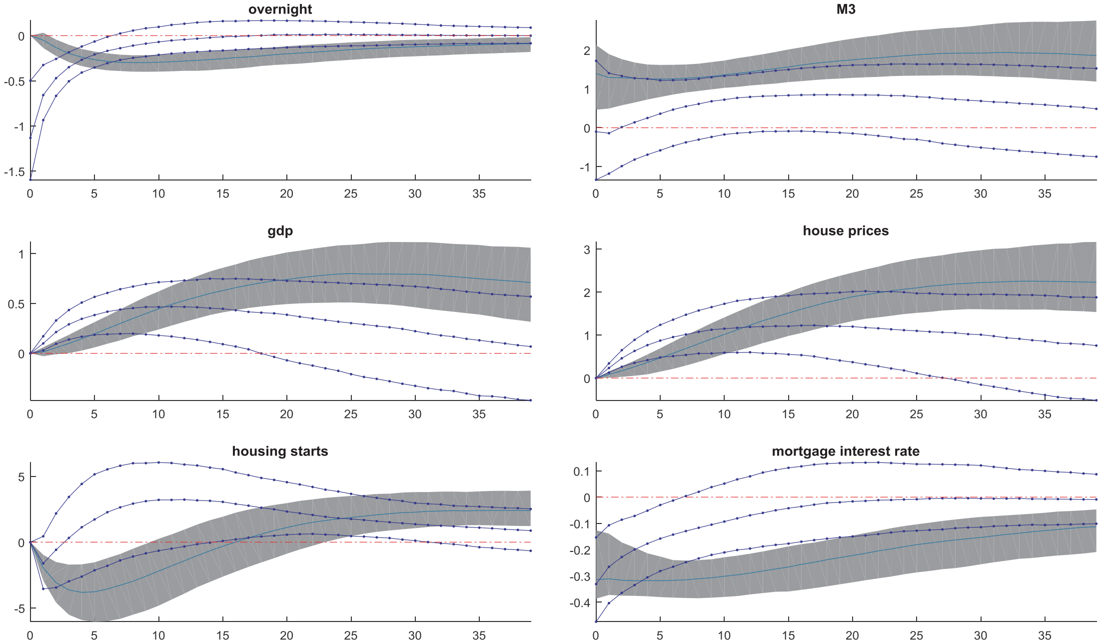


**Fig. 1.** Impulse responses to policy rate and balance sheet shocks in Sweden
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of the balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

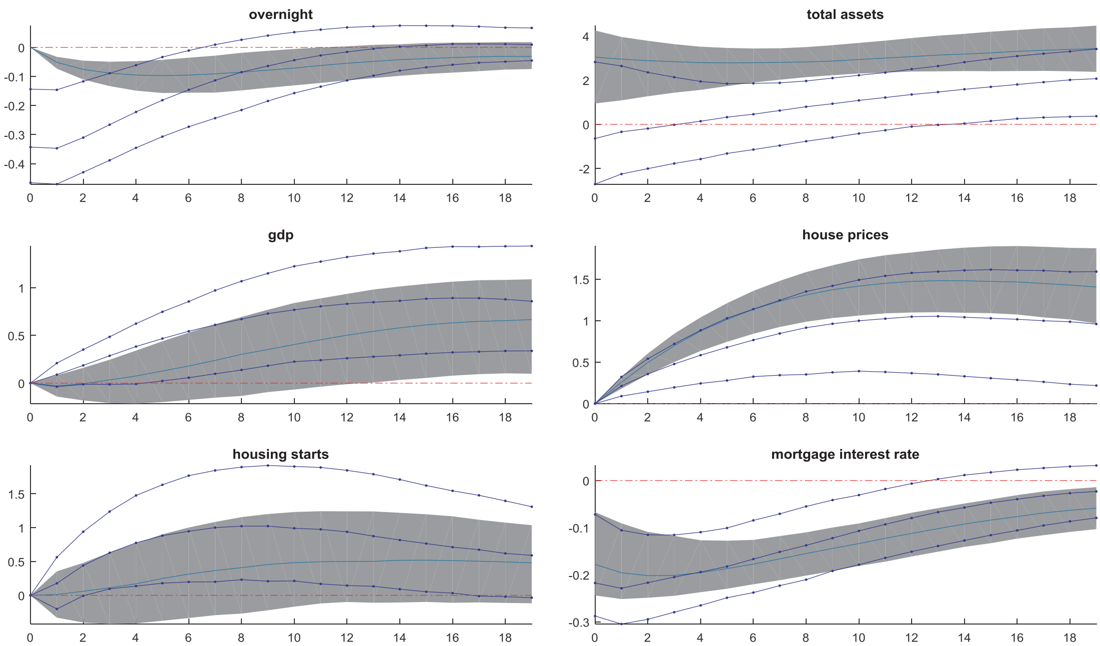


**Fig. 2.** Impulse responses to policy rate and balance sheet shocks in Norway
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

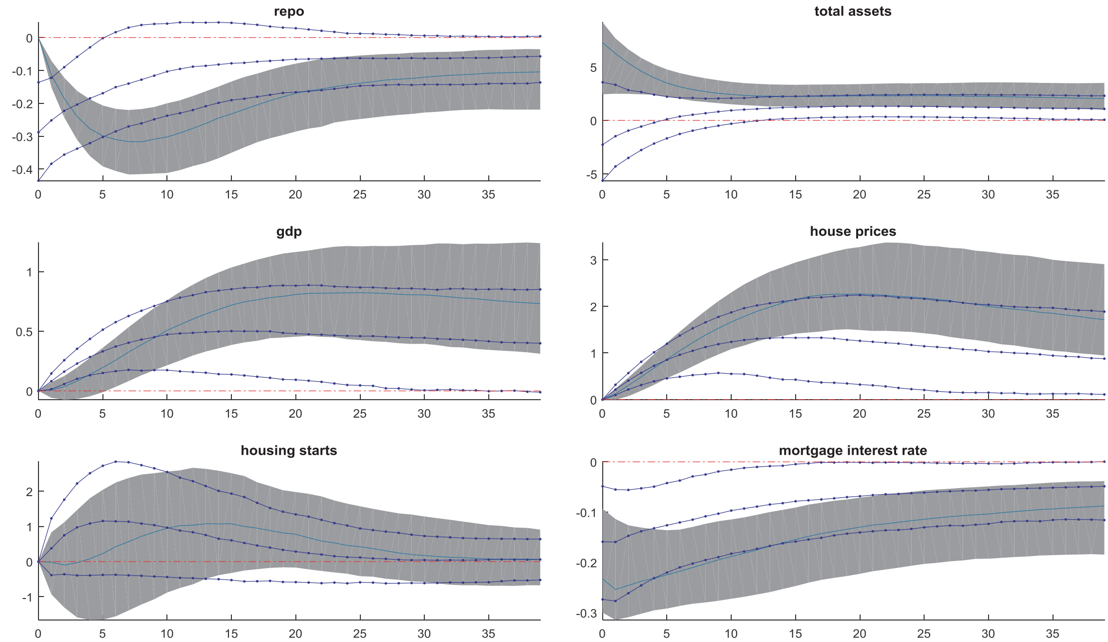


**Fig. 3.** Impulse responses to policy rate and balance sheet shocks in Denmark
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

effect of balance sheet shocks. The response of house prices in Norway to a balance sheet shock is very similar to the results of Rahal (2016). He, however, does not study the effect of conventional monetary policy shocks and thus no comparison is available for the differences between the impacts of the two types of shock.

The effect on GDP is positive in case of both types of monetary policy shock, but it is more sluggish, peaks at a lower level, and the value zero is later outside the credible interval in case of the balance sheet shock. The persistence of the response of GDP is arguably quite surprising.

Turning to housing starts Fig. 2 shows a positive response of this variable to a policy rate shock after the impact period but zero is in the credible set until the second quarter. Zero is within the credible set of the response of housing starts to a balance sheet shock in all quarters. This may be because the supply of housing relative to demand is low in Norway, like in Sweden. Possible causes of that could be rapid population growth, a lack of suitable land in urban areas and planning delays at the municipality level.

The response of the mortgage interest rate is initially negative due to the restrictions imposed and it stays negative until the effect dies out. The effect fades out sooner in case of a policy rate shock, but the responses to the two types of monetary policy shock are broadly quite similar.

### 4.3. Denmark

Fig. 3 plots the IRFs of the policy rate and balance sheet shocks of Denmark. An expansionary policy rate shock of the size of one standard deviation, or a cut of about 0.3 percentage points in the repo rate, is followed by a temporary rise in house prices that peaks by the 14th quarter. A positive balance sheet shock of the size of one standard deviation, or a rise of about 7% in the central bank's total assets, is followed by a temporary rise in house prices that peaks by the 20th quarter. By the 7th quarter, the response of house prices to a cut of 45 basis points in the repo rate is equivalent to an increase of around 7% in the central bank's total assets. Like in the results for Sweden, the response of house prices to balance sheet shocks is more sluggish and peaks higher than the response to the policy rate shocks.

Looking at how the monetary policy shocks affect other variables reveals that there is a positive effect on GDP after the period of impact in case of both types of monetary policy shock, and the response is more sluggish and peaks at a higher level after a balance sheet shock. Zero is within the credible interval of the IRFs of GDP until the beginning of the second year. The credible set of the response of housing starts to both types of monetary policy shock includes zero and, like in the two other Scandinavian countries, this could perhaps be explained by the low supply of housing relative to demand (Pedersen and Isaksen, 2015). The response of the mortgage interest rate is initially negative by identification restrictions and it stays negative until the effect dies out. The effect fades out sooner in case of a policy rate shock.

### 4.4. Comparison of the responses across the countries

Fig. 4 displays the impulse responses of all six variables to the expansionary policy rate and balance sheet shocks in the Scandinavian countries. For each variable the scales of the figures are the same across countries to give better comparability of the magnitudes of the responses across countries. The shocks are the size of one standard deviation, which makes it easier to compare the responses as the balance sheet policy measures vary across the countries.

The effect of policy rate shocks on house prices is positive in case of all three countries, which coincides with the findings of the earlier

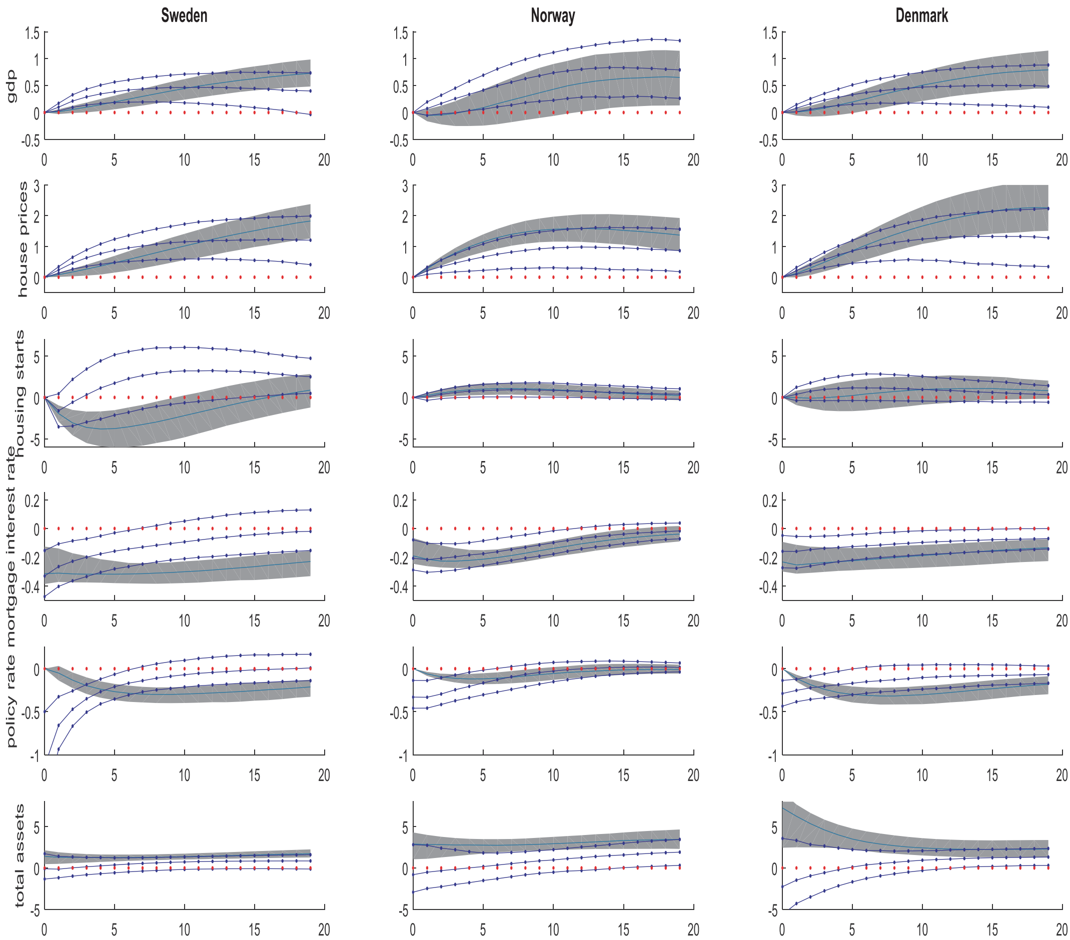


**Fig. 4.** Impulse responses of variables to policy rate and balance sheet shocks: comparison across countries
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

literature. The magnitudes of the responses and the timings of the peaks are very similar across the three countries, which suggests that the differences in the monetary policy regimes and the housing market characteristics do not seem to play an important role. The response of house prices to balance sheet shocks, however, is not as similar across the countries as is the response to policy rate shocks, although the magnitudes of the impacts are broadly the same for all the Scandinavian countries. The effect of the balance sheet shocks is more persistent and peaks higher than the response of the policy rate shocks in all the Scandinavian countries. The response of house prices to the balance sheet shocks is more sluggish than the response of policy rate shocks for Sweden and Denmark. All the Scandinavian countries have very high of household debt to disposable income ratios that could also account for a proportion of the similarity in the impact responses across countries.

It is surprising how different the effects of the two different types of monetary policy shocks are within each country, but the effects of each type of monetary policy shock are quite similar across the countries. The small differences in the magnitudes of the effects of the shocks could possibly be explained at least partly by the mortgage market characteristics. As shown in Calza et al., 2013, house prices are usually more responsive to policy shocks in countries with more developed mortgage markets. The effect of the shocks on house prices is the largest in Denmark. The mortgage market in all of the Scandinavian countries can be considered highly developed, but according to the IMF mortgage market index the degree of development and completeness of the mortgage market is highest in Denmark. Also the mortgage debt-to-GDP ratio is much higher in Denmark than in Sweden or Norway.

For the other variables, it can be seen from Fig. 4 that the effect of both types of monetary policy shock on GDP is positive in case of all three countries, which is consistent with the results of earlier studies (e.g. Peersman, 2011). The response to balance sheet shocks is more sluggish than the response to policy rate shocks in all three countries. The peak of the response to balance sheet shocks is very similar in magnitude, possibly showing that the choice of balance sheet policy measures does not play an important role in the response of GDP. In case of Norway, zero falls outside the credible set of the response much later. The effect of the balance sheet shocks is more persistent in Sweden and Denmark than the effect of the policy rate shocks is. For Norway the responses to both types of shock are similar in persistence.

The response of housing starts to policy rate shocks is similarly shaped in all the Scandinavian countries. The magnitudes of the responses are, however, different, as the effect is largest for Sweden and smallest for Norway, while zero is within the credible set for Denmark. The response of housing starts to balance sheet shocks has zero barely outside the credible set at first in case of Sweden and zero within the credible set in case of Norway and Denmark. In all three countries the housing supply is quite inelastic, as the population is growing in the more popular areas faster than the housing supply is. This could be one explanation for the small impact that the monetary policy shocks have on the housing supply variable.

The response of the mortgage interest rate to either type of monetary policy shock is negative in all three countries. The responses are similar in magnitude in case of Norway and Denmark and a bit larger in case of Sweden. The responses to balance sheet shocks are similar in shape for all three countries. The responses of Norway and Denmark are similar across the two types of monetary policy shock despite the differences in for example mortgage interest rate systems.[9]

The responses of the overnight/repo rate to both types of monetary policy shock are negative and similar in shape in all three countries. The responses to a policy rate shock are similar in magnitude in case of Norway and Denmark and largest in case of Sweden. The responses of the monetary policy rate to balance sheet shocks are similar in magnitude in case of Sweden and Denmark and smallest in case of Norway.

The responses of the central bank's total assets (M3 in case of Sweden) to a balance sheet shock are permanent or very persistent in all three countries. The effect is smallest in Sweden, although it is the only country among the three that has had “official” unconventional monetary policy measures. The responses to a policy rate shock initially have zero outside the credible set for a number of periods in all the countries. The response has zero within the credible set in case of Sweden, while zero is outside the credible set in case of Norway and Denmark starting from around the 14th quarter.

### *4.5. Robustness analysis*

For robustness I have also estimated the model for the period before the Great Financial Crisis and the results are very similar to the benchmark model (Appendix C).

I also ran the regressions for a period starting from 2007 to see if using only the period since the start of the financial crisis would make a difference to the impact of the shocks on house prices. The impulse responses for the shorter period are plotted in Appendix D. The response of house prices to unconventional monetary policy shocks is more sluggish than the response to conventional monetary policy shocks in case of all the Scandinavian countries. This was the same in case of Sweden and Denmark when the longer period was used. In case of the shorter period, the effect of conventional monetary policy shocks peaks at higher levels than does the effect of unconventional monetary policy shocks in case of Norway and Denmark.

I have also produced an extended model with CPI as an additional variable to check whether the very persistent impact on GDP and house prices could partly be explained by containing also the response of consumer prices. The main results of the analysis do not, however, change notably with CPI added to the model (Appendix E).

## 5. Conclusion

In this paper, I have analysed the impact of conventional and unconventional monetary policy on house prices in the three Scandinavian countries, Sweden, Norway and Denmark. Within a Bayesian structural VAR framework, I have identified, using a mixture of zero and sign restrictions, two types of monetary policy shock, which are a policy rate shock and a balance sheet shock, and I have computed the impulse response functions for the variables of the model using a data period of nearly 30 years.

The empirical analysis of this paper yields the following main findings. I find that there is a positive effect from both an expansionary policy rate shock and an expansionary balance sheet shock on house prices in all the Scandinavian countries. The effect of a balance sheet shock on house prices is more sluggish than the effect of a policy rate shock in Sweden and Denmark while in Norway the speed of the reaction is similar in case of both types of monetary policy shock. The effect of a balance sheet shock on house prices peaks higher and is more persistent than the effect of a policy rate shock in all the Scandinavian countries.

The effects of each type of monetary policy shock are quite similar across the three countries, which is an interesting result given the differences in their monetary policy regimes. This could indicate that the differences in the monetary policy regimes in those countries do not appear to play an important role for the effects of monetary policy shocks in these countries. Moreover, it could also suggest that the unconventional monetary measures chosen do not change the impact notably. Among the Scandinavian countries, only Sweden has implemented official unconventional monetary policy measures, but interestingly the responses to changes in balance sheet variables are nevertheless very similar across the countries.

The upshot would be that if it is not possible to implement conventional monetary policy measures and so unconventional monetary policy measures that influence the central bank's balance sheet are used instead, house prices could also be affected.

A number of important venues of research remain. First, it has to be borne in mind that the estimations of the paper are based on a period that contains normal times as well as crisis times. Further research could study the impact of the two types of monetary policy shock in those countries using a time-varying VAR framework. Second, the current paper focuses on the domestic responses to domestic monetary policy shocks. This suggests that the spill-over effects of the monetary policy shocks in one Scandinavian country to house prices in the other Scandinavian countries could possibly be studied in the future.

## Declaration of Competing Interest

None.

## Appendix A. Description and Sources of the Data

Table A1, Table A2, Table A3.

[9] For example, in Denmark mortgage credit bonds are used. The market price of the bonds determines the mortgage loan interest rates.

**Table A1**
Description and Sources of the Data, Sweden.

| Variable | Description | Source |
|---|---|---|
| GDP per capita | GDP in market values (SEK) divided by total population. The population figure is monthly, quarterly averages are calculated. | GDP from Statistics Sweden, monthly population from Eikon/Statistics Sweden |
| House prices | House price index (1995 = 100); up to 2004Q4 residential property prices, from 2005Q1 all types of dwellings | BIS Residential Property Base database |
| Housing starts | Number of building permits (the available data series about the m2 is much shorter). | Thomson Reuters Eikon / Statistics Sweden. |
| Mortgage interest rate | Interest rate on outstanding loans (up to 2005Q2 there are data just about the fixed rate, from 2005Q3 there are data on fixed and floated interest rates; to have consistency in the data fixed interest rate was used for the whole time series) to households (loans secured on dwellings). The series for new loans is a lot shorter, because of that the interest rates of outstanding loans are used. | Statistics Sweden |
| Short term interest rate | The repo rate is used in this paper as the Swedish monetary policy rate. The data are monthly, quarterly averages are calculated. The dynamics of the repo and overnight rates are historically very similar. The repo rate is used because the available time series of repo rate are much longer. | Thomson Reuters Eikon / Sveriges Riksbank |
| M3 | Since no data are available about total assets for earlier periods than 2004, M3 is used as the balance sheet variable. | International Financial Statistics |

**Table A2**
Description and Sources of the Data, Norway.

| Variable | Description | Source |
|---|---|---|
| GDP per capita | GDP in market values (NOK) divided by total population. | GDP from Statistics Norway, total population 1978–1997 from Eurostat, 1997Q4-2016Q3 from Statistics Norway. |
| House prices | House price index (1995 = 100); up to 1991Q4 house prices, from 1992Q1 onwards residential property prices | BIS Residential Property Base database |
| Housing starts | Building permits – m2 of utility area of dwellings | Thomson Reuters Eikon / Statistics Norway |
| Mortgage interest rate | Interest rate on outstanding loans (weighted average of fixed and floated interest rates) to households (loans secured on dwellings) by mortgage companies. The series for new loans is a lot shorter, because of that the interest rates of outstanding loans are used. | Statistics Norway |
| Short term interest rate | The overnight lending rate is used as the Norwegian monetary policy rate in this paper. Quarterly averages are calculated. | Thomson Reuters Eikon / Norges Bank |
| Central bank's total assets | Total assets of the central bank's balance sheet | Norges Bank |

**Table A3**
Description and Sources of the Data, Denmark.

| Variable | Description | Source |
|---|---|---|
| GDP per capita | GDP per capita at current prices (DKK) | Statistics Denmark |
| House prices | House price index (1995 = 100); up to 2001Q4 residential property prices (single family houses), from 2002Q1 all types of dwellings | BIS Residential Property Base database |
| Housing starts | The number of residential buildings started are available for a longer period than the data about the residential building permits total floor area | Eikon/Statistics Denmark |
| Mortgage interest rate | The mortgage credit bonds' rate with the maturity of 30 years for 1990Q1-2012Q4 and for 2013Q1-2017Q1 the mortgage credit bonds' rate (long-term) are used as a proxy of housing loan interest rate The 30-year bonds rate is the closest to the long-term credit bonds' rate of FinansDanmark. Danmarks Nationalbank's data are monthly and quarterly averages are calculated. FinansDanmark's data are weekly and quarterly averages are calculated. | Danmarks Nationalbank, FinansDanmark |
| Short term interest rate | The repo rate on Certificates of Deposit is used in this paper as the Danish monetary policy rate. Data are monthly, quarterly averages are calculated. | IMF, Statistics Denmark |
| Central bank's total assets | Total assets of the central bank's balance sheet | Danmarks Nationalbank |

## Appendix B. Descriptive Statistics of the Data

Table B1, Table B2, Table B3.

**Table B1**
Descriptive Statistics, Sweden.

| | Ln Real GDP | Ln House Prices | Ln Housing Starts | Mortgage Interest Rate | Repo Interest Rate | Ln M3 |
|---|---|---|---|---|---|---|
| Mean | 1078.17 | 481.47 | 874.44 | 7.17 | 4.49 | 1368.60 |
| Median | 1079.66 | 473.36 | 873.00 | 6.13 | 3.59 | 1363.97 |
| Maximum | 1108.61 | 557.24 | 978.82 | 17.17 | 28.88 | 1440.69 |
| Minimum | 1045.93 | 426.26 | 756.36 | 1.95 | −0.51 | 1309.38 |
| Std. Dev. | 18.43 | 39.20 | 57.78 | 4.25 | 4.47 | 41.93 |
| Probability | 0.01 | 0.02 | 0.13 | 0.001 | 0 | 0.007 |
| Observations | 113 | 113 | 113 | 113 | 113 | 113 |

Note: All data in natural logarithms have been multiplied by 100 for better display of IRFs.

**Table B2**
Descriptive Statistics, Norway.

| | Ln Real GDP | Ln House Prices | Ln Housing Starts | Mortgage Interest Rate | Overnight Interest Rate | Ln Total assets |
|---|---|---|---|---|---|---|
| Mean | 1104.79 | 493.83 | 1359.86 | 6.80 | 6.01 | 1342.87 |
| Median | 1106.26 | 494.64 | 1361.54 | 6.57 | 5.96 | 1346.03 |
| Maximum | 1143.36 | 565.65 | 1406.32 | 14.74 | 12.37 | 1539.58 |
| Minimum | 1056.53 | 416.54 | 1293.17 | 2.41 | 1.49 | 1181.32 |
| Std. Dev. | 31.39 | 45.40 | 22.33 | 3.37 | 2.98 | 120.60 |
| Probability | 0.003 | 0.01 | 0.04 | 0.001 | 0.03 | 0.01 |
| Observations | 114 | 114 | 114 | 114 | 114 | 114 |

Note: All data in natural logarithms have been multiplied by 100 for better display of IRFs.

**Table B3**
Descriptive Statistics, Denmark.

| | Ln Real GDP | Ln House Prices | Ln Housing Starts | Mortgage Interest Rate | Repo Interest Rate | Ln Total assets |
|---|---|---|---|---|---|---|
| Mean | 1077.37 | 482.92 | 840.29 | 6.24 | 3.65 | 1230.88 |
| Median | 1079.18 | 483.54 | 837.94 | 5.88 | 3.47 | 1243.22 |
| Maximum | 1096.10 | 532.64 | 922.11 | 11.15 | 12.84 | 1312.26 |
| Minimum | 1050.64 | 418.23 | 775.29 | 2.30 | −0.77 | 1121.60 |
| Std. Dev. | 14.62 | 34.92 | 33.50 | 2.34 | 3.36 | 44.45 |
| Probability | 0.004 | 0.01 | 0.30 | 0.12 | 0.001 | 0.03 |
| Observations | 109 | 109 | 109 | 109 | 109 | 109 |

Note: All data in natural logarithms have been multiplied by 100 for better display of IRFs.

## Appendix C. Impulse response functions for the period before the Great Financial Crisis

Fig. C1, Fig. C2, Fig. C3.

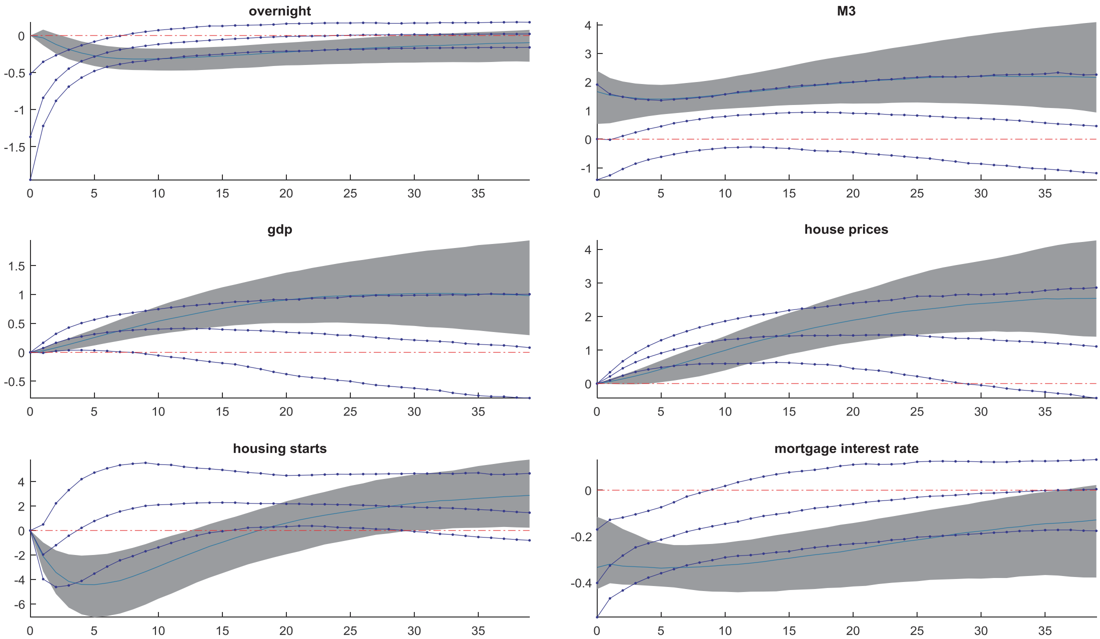


**Fig. C1.** Impulse responses to policy rate and balance sheet shocks in Sweden (1989Q1-2007Q4)
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

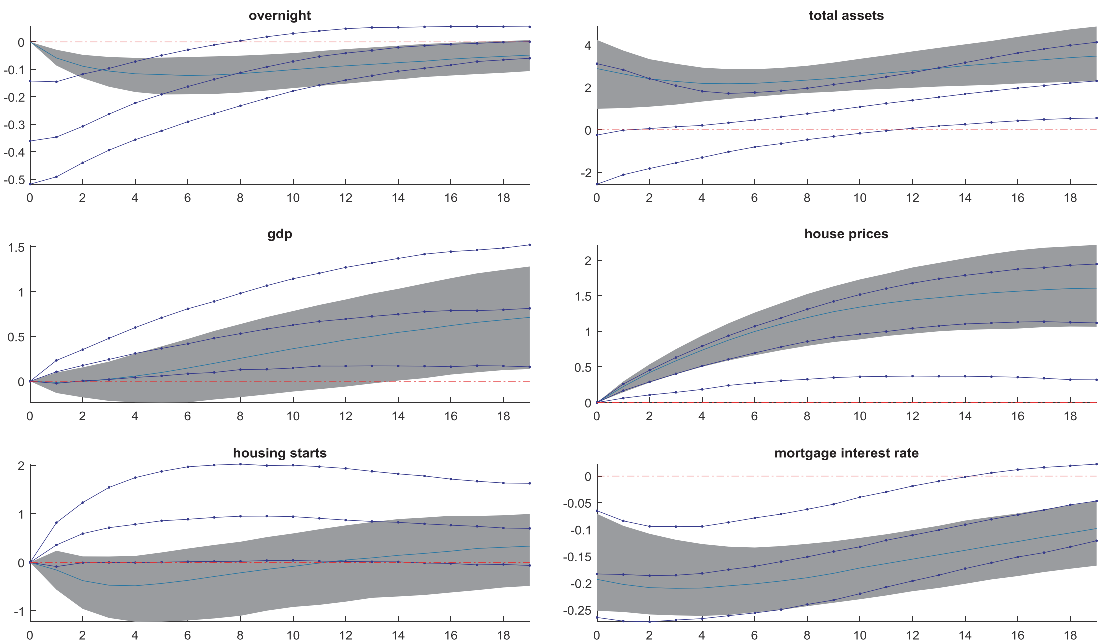


**Fig. C2.** Impulse responses to policy rate and balance sheet shocks in Norway (1988Q4-2007Q4)
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

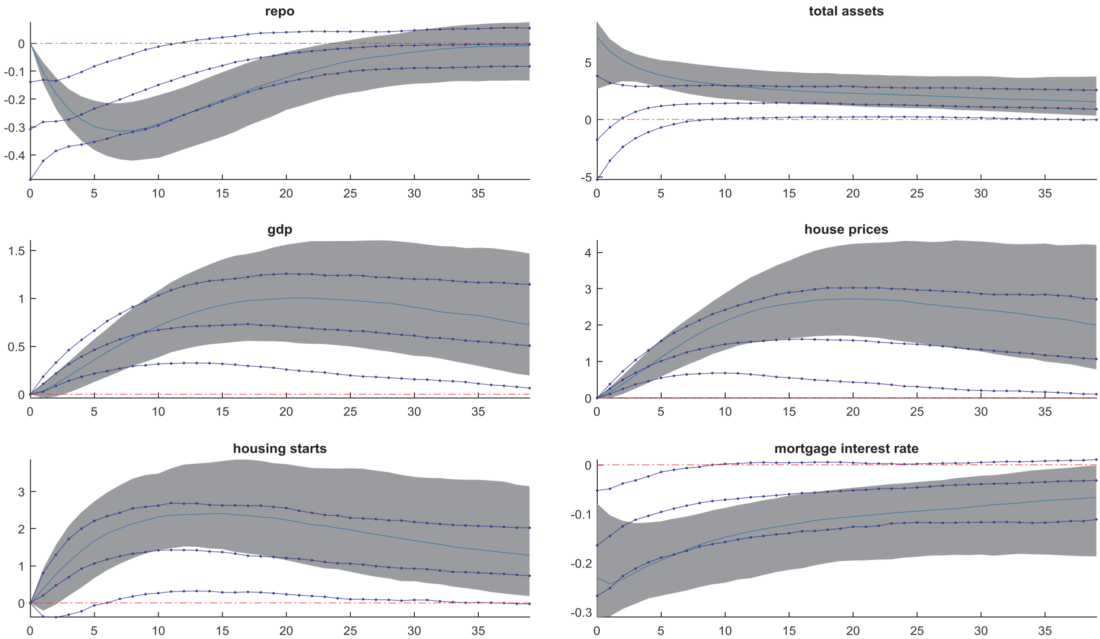


**Fig. C3.** Impulse responses to policy rate and balance sheet shocks in Denmark (1990Q1-2007Q4)
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

## Appendix D. Impulse response functions for 2007Q1-2017Q1

Fig. D1, Fig. D2, Fig. D3.

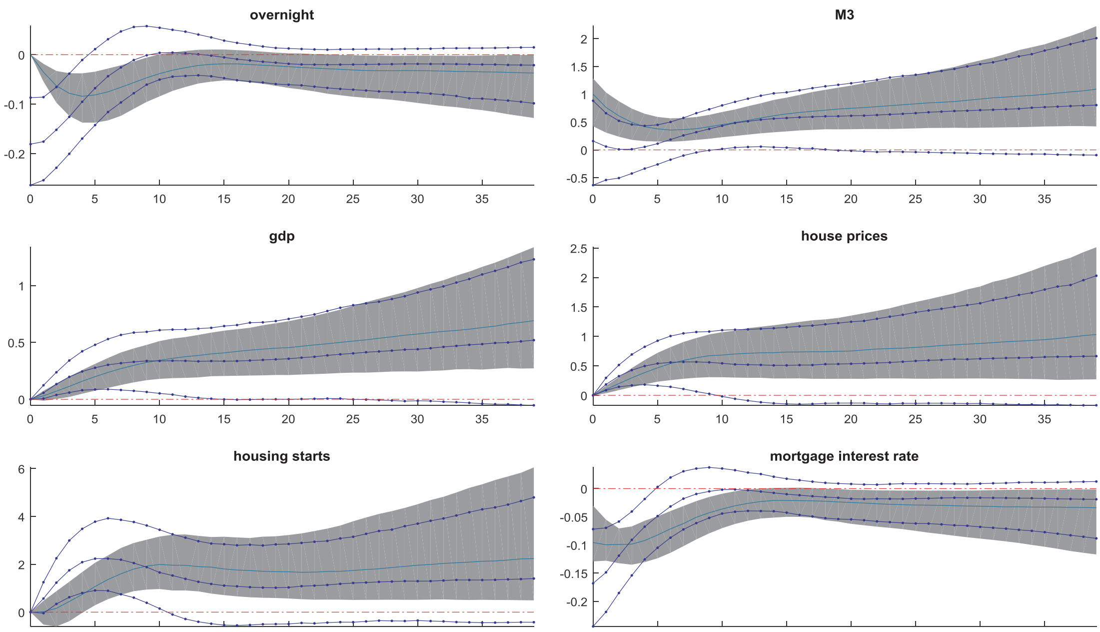


**Fig. D1.** Impulse responses to policy rate and balance sheet shocks in Sweden (2007Q1-2017Q1)
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

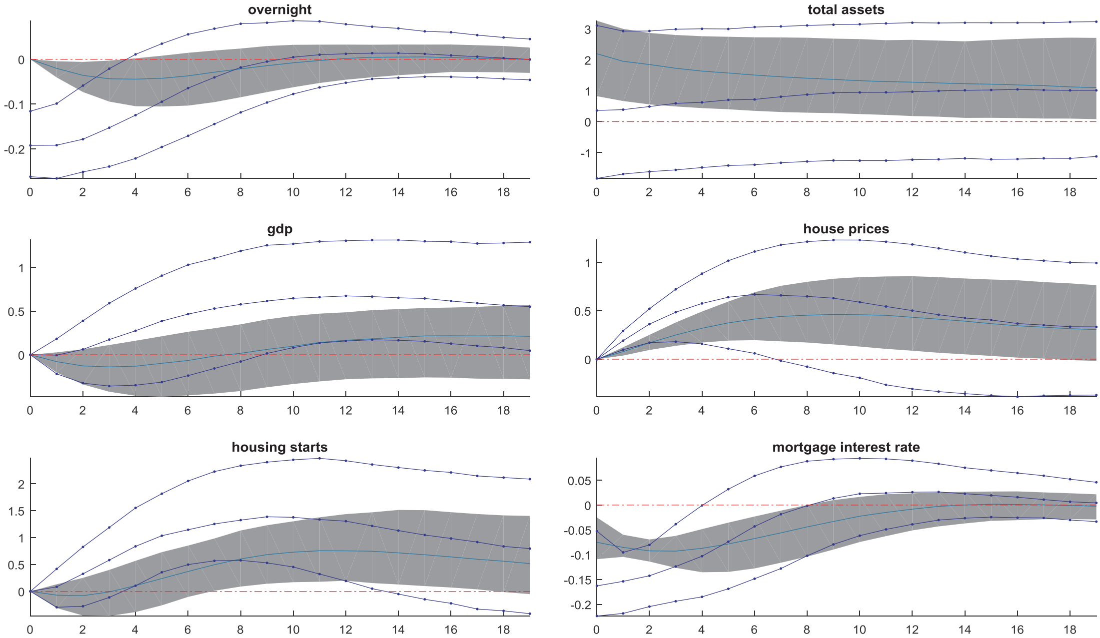


**Fig. D2.** Impulse responses to policy rate and balance sheet shocks in Norway (2007Q1-2017Q1)
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

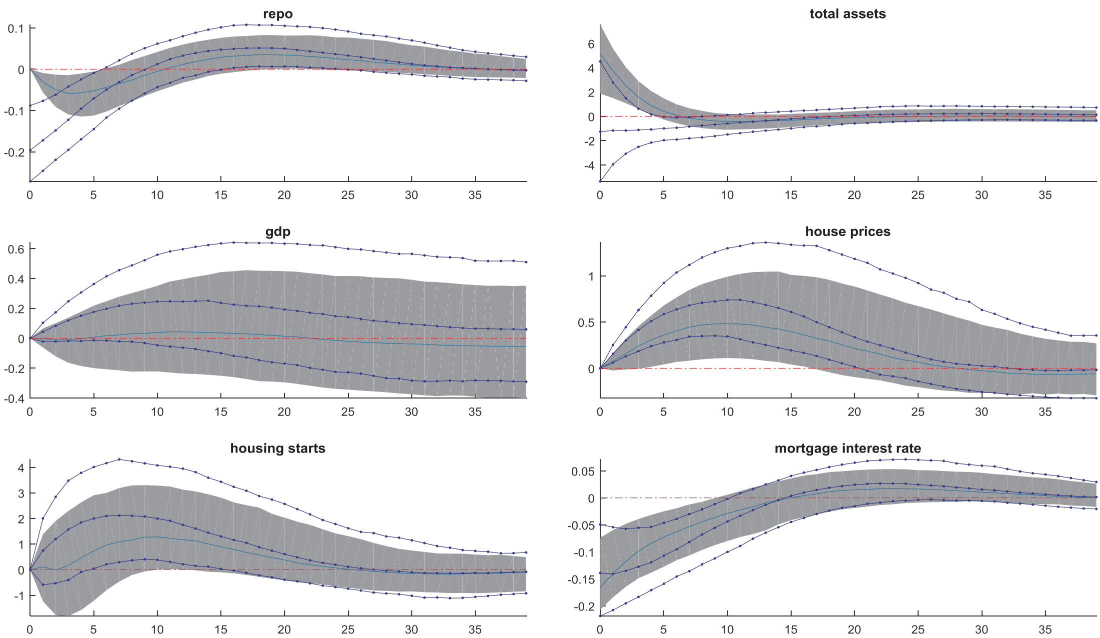


**Fig. D3.** Impulse responses to policy rate and balance sheet shocks in Denmark (2007Q1-2017Q1)
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

## Appendix E. Impulse response functions with CPI as an additional variable

Fig. E1, Fig. E2, Fig. E3.

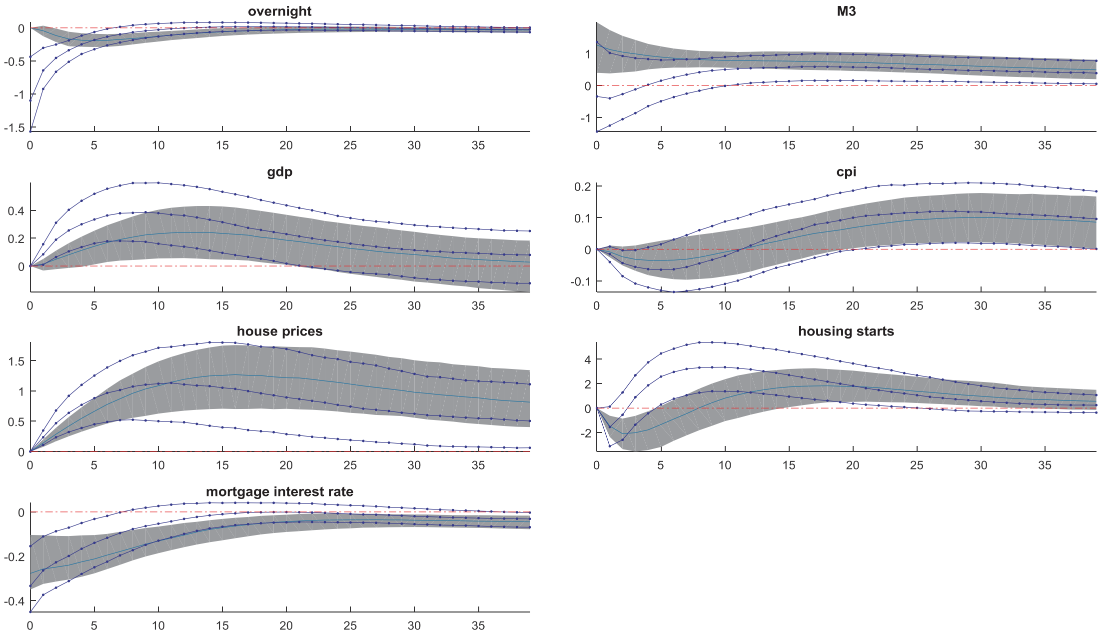


**Fig. E1.** Impulse responses to policy rate and balance sheet shocks in Sweden with CPI as an additional variable
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

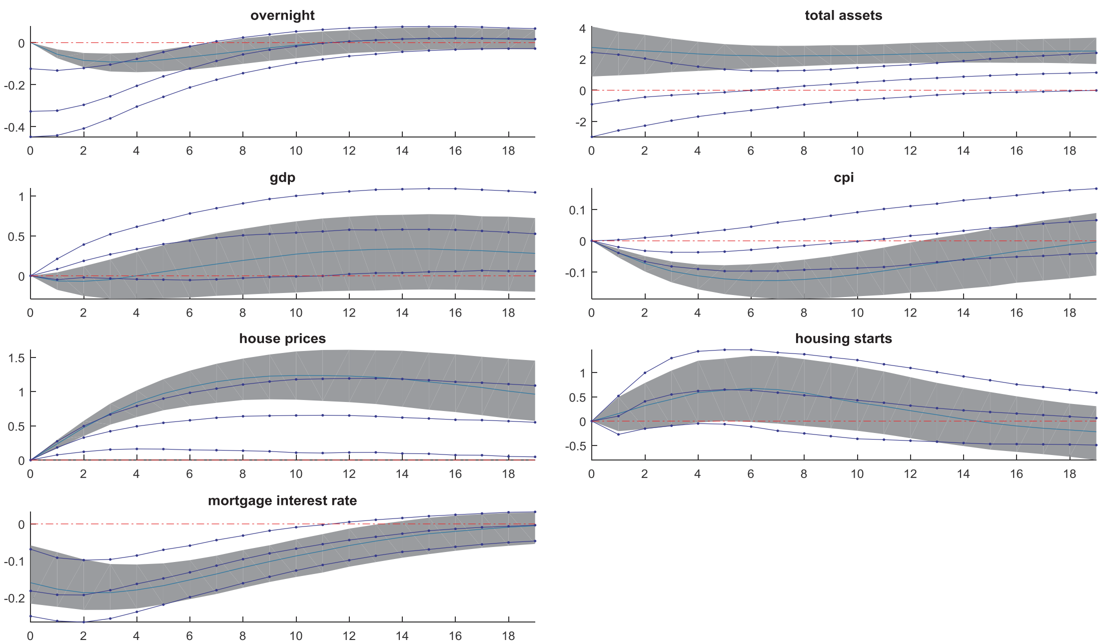


**Fig. E2.** Impulse responses to policy rate and balance sheet shocks in Norway with CPI as an additional variable
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

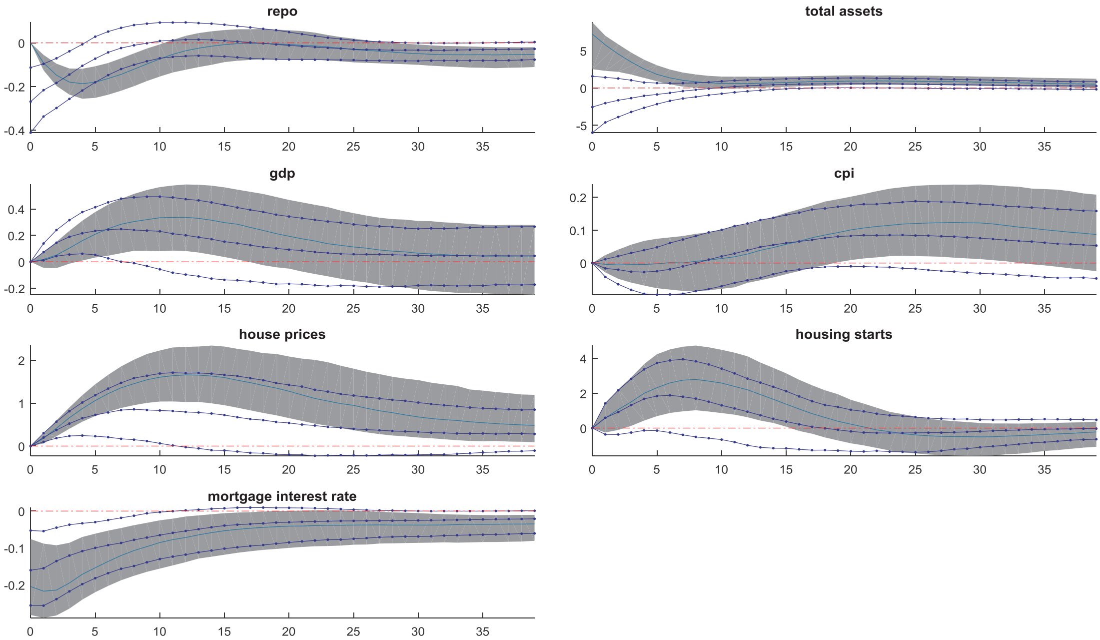


**Fig. E3.** Impulse responses to policy rate and balance sheet shocks in Denmark with CPI as an additional variable
*Note:* The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median impulse response.

## References

Aspachs-Bracons, O., Rabanal, P., 2011. The effects of housing prices and monetary policy in a currency union. Int. J. Cent. Bank. 7 (1), 225–274.
Baumeister, C., Benati, L., 2013. Unconventional monetary policy and the great recession. estimating the macroeconomic effects of a spread compression at the zero lower bound. Int. J. Cent. Bank 9 (2), 165–212.
Behrendt, S., 2013. Monetary transmission via the central bank balance sheet. In: University of Jena and University of Halle.
Boeckx, J., Dossche, M., Peersman, G., 2017. Effectiveness and transmission of the ECB's balance sheet policies. Int. J. Cent. Bank 13 (1), 297–333.
Capozza, D.R., Hendershott, P.H., Mack, C. and C.J. Mayer. (2002). "Determinants of real house price dynamics", NBER Working Paper Series, No. 9262.
Case, K.E., Shiller, R.J., 2003. Is there a bubble in the housing market? Brookings Pap. Econ. Activity 2, 299–362.
Calza, A., Monacelli, T., Stracca, L., 2013. Housing finance and monetary policy. J. Eur. Econ. Assoc. 11 (S1), 101–122.
Cesa-Bianchi, A., Cespedes, L.F., Rebucci, A., 2015. Global liquidity, house prices, and the macroeconomy: evidence from advanced and emerging economies. J. Money Credit Bank. 1 (S1), 301–335.
Cesa-Bianchi, A., Ferrero, A., Rebucci, A., 2018. International credit supply shocks. J. Int. Econ. 112, 219–237 No. C.
Christiano, L.J., Eichenbaum, M., Evans, C.L., 2005. Nominal rigidities and the dynamic effects of a shock to monetary policy. J. Polit. Econ. 113 (1), 1–45.
Dieppe, A., Legrand, R., van Roye, B., 2016. The Bayesian Estimation, Analysis and Regression (BEAR) Toolbox: Version 3.0. ECB External Developments Division.
Égert, B., Mihaljek, D., 2007. Determinants of house prices in central and Eastern Europe. Comp. Econ. Stud. 49 (3), 367–388.
Emanuelsson, R., 2015. "Supply of housing in sweden. Sveriges Riksbank Econ. Rev. 2015 (2), 47–75.
Englund, P., Ioannides, Y.M., 1997. House price dynamics: an international empirical perspective. J. Hous. Econ. 6 (2), 119–136.
Fry, R. and A. Pagan. (2007). "Some issues in using sign restrictions for identifying structural VARs", NCER Working Paper Series, No. 14.
Gabriel, S. and C. Lutz. (2017). "The impact of unconventional monetary policy on real estate markets", mimeo, available at SSRN: https://ssrn.com/abstract=2493873.
Gagnon, J., Raskin, M., Remache, J., Sack, B., 2011. Large-scale asset purchases by the federal reserve: did they work? FRBNY Econ. Policy Rev. 41–59 May.
Gambacorta, L., Hofmann, B., Peersman, G., 2014. The effectiveness of unconventional monetary policy at the zero lower bound: a cross-country analysis. J. Money Credit Bank. 46 (4), 615–642.
Gertler, M., Karadi, P., 2011. A model of unconventional policy. J. Monet. Econ. 58 (1), 17–34.
Gertler, M., Karadi, P., 2015. Monetary policy surprises, credit costs, and economic activity. Am. Econ. J. Macroecon. 7 (1), 44–76.
Goodhart, C., Hoffmann, B., 2008. House prices, money, credit and the macroeconomy. Oxf. Rev. Econ. Policy 24 (1), 180–205.
Guerrieri, L., Iacoviello, M., 2017. Collateral constraints and macroeconomic assymmetries. J. Monet. Econ. (90), 28–49.
Gupta, R., Jooste, C., 2018. Unconventional monetary policy shocks in OECD countries: how important is the extent of policy uncertainty. Int. Econ. Econ. Policy 15 (3), 683–703.
Huber, F. and M.T. Punzi. (2016). "International housing markets, unconventional monetary policy and the zero lower bound", FinMaP Working Paper, No. 58.
Iacoviello, M., 2000. "House prices and the macroeconomy in europe: results from a structural VAR analysis. In: .
Iacoviello, M., Minetti, R., 2003. Financial liberalization and the sensitivity of house prices to monetary policy: theory and evidence. Manch. Sch. 71 (1), 20–34.
Iacoviello, M., 2005. House prices, borrowing constraints, and monetary policy in the business cycle. Am. Econ. Rev. 95 (3), 739–764.
Jarociński, M., Smets, F., 2008. House prices and the stance of monetary policy. In: .
Kasparova, D., White, M., 2001. The responsiveness of house prices to macroeconomic forces: a cross-country comparison. Eur. J. Hous. Policy 1 (3), 385–416.
Kilian, L., Lütkepohl, H., 2017. Structural Vector Autoregressive Analysis. Cambridge University Press 782 pp.
Moe, T.G., Solheim, J.A. and B. Vale. (2004). "The norwegian banking crisis", Norges Banks Occasional Papers, No. 33.
Musso, A., Neri, S., Stracca, L., 2011. Housing, consumption and monetary policy. How different are the US and the Euro area? J. Bank. Financ. 35 (11), 3019–3041.
Paavola, A., 2016. What Is the Effect of Unconventional Monetary Policy on Asset Prices? – A Literature Review. Bank of Finland Bulletin. http://www.bofbulletin.fi/en/2016/what-is-the-effect-of-unconventional-monetary-policy-on-asset-prices-a-literature-review-2/ (17.11.16).
Pedersen, E.H., Isaksen, J., 2015. Recent housing market trends", Danmarks Nationalbank. Monet. Rev. 3, 51–61.
Peersman, G., 2011. Macroeconomic effects of unconventional monetary policy in the euro area. In: .
Rahal, C., 2016. Housing markets and unconventional monetary policy. J. Hous. Econ. 32, 67–80 No. C.
Ravn, M.O., Simonelli, S., 2007. Labor Market Dynamics and the Business Cycle: Structural Evidence for the United States. Scand. J. Econ. 109 (4), 743–777.
Schenkelberg, H., Watzka, S., 2013. Real effects of quantitative easing at the zero lower bound: structural VAR-based evidence from Japan. J. Int. Money Financ. 33, 327–357.
Sims, C.A., Stock, J.H., Watson, M.W., 1990. Inference in linear models with some unit

roots. Econometrica 58 (1), 113–144.
Smith, A.L. (2014). “House prices, heterogeneous banks and unconventional monetary policy options”, The Federal Reserve Bank of Kansas City Research Working Papers, No 14-12.
Sims, C.A., Zha, T., 2006. Were There Regime Switches in U.S. Monetary Policy? Am. Econ. Rev. 96 (1), 54–81.
Stock, J.H., Watson, M.W., 2001. Vector Autoregressions. J. Econ. Perspect. 15 (4), 101–115.
Tsatsaronis, K., Zhu, H., 2004. What drives housing price dynamics: cross-country evidence. BIS Q. Rev March 2004.
Uhlig, H., 2005. What are the effects of monetary policy on output? Results from an agnostic identification procedure. J. Monet. Econ. 52 (2), 381–419.
Uusküla, L., 2016. Monetary transmission mechanism with firm turnover. J. Macroecon. 50, 1–18.
Vargas-Silva, C., 2008. Monetary policy and the US housing market: a VAR analysis imposing sign restrictions. J. Macroecon. 30 (3), 977–990.
Weale, M., Wieladek, T., 2016. What are the macroeconomic effects of asset purchases? J. Monet. Econ. 79, 81–93.
Peneva, E. V. (2013). Effects of monetary shocks across time and across sectors, FEDS Working Paper No. 2013-70.

# Appendix 2. Publication II

**CONVENTIONAL AND UNCONVENTIONAL MONETARY POLICIES: EFFECTS ON THE FINNISH HOUSING MARKET**

**Publication II**

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# Conventional and unconventional monetary policies: effects on the Finnish housing market

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**ABSTRACT**

This paper investigates how different types of monetary policy have affected house prices in Finland, a small euro area economy that has experienced pronounced business cycles over time. The analyses are carried out using the Bayesian structural vector autoregressive approach. Monetary policy interest rate shocks and balance sheet shocks are identified using zero and sign restrictions. The results reveal that both a policy interest rate shock and a balance sheet shock have a positive and temporary impact on house prices in Finland, with the response to a balance sheet shock being smaller and fading out faster. The peak of the effect of a policy rate shock on house prices in Finland arrives faster than in the whole euro area but the magnitudes of the peak impact are similar. The effect of a balance sheet shock on house prices is not notably different in Finland to what it is in the whole euro area.

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## 1. Introduction

House prices played an important role in the global financial crisis of 2008–2010. The collapse of house prices led to a deleveraging process so that outstanding household debt suddenly exceeded property prices (Huber & Punzi, 2020). The economic boom of the 2000s was accompanied by an upsurge of house prices, and it also brought with it an increase in housing equity withdrawal and consumption. Even if house prices did not cause the crisis, they were important amplifiers of its consequences. Developments in house prices may strengthen and possibly even create macroeconomic cycles as housing wealth affects household consumption, construction activity and the financial sector (Oikarinen, 2007). As developments in the housing market are also likely to be of key importance for economic developments in the future, it is important to learn from the past about the impact they have.

In response to the global financial crisis, major central banks, including the European Central Bank (ECB), lowered their policy rates in order to ease liquidity conditions and stimulate economic growth. As the policy rates approached or reached the zero lower bound, other expansionary monetary policy measures were implemented in addition to the traditional steering of policy interest rates. These alternative measures are referred

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to as unconventional monetary policy, and include measures like large-scale asset purchases and forward guidance. As the use of conventional monetary policy measures was limited, unconventional monetary policy became the centre of the debate about the monetary toolkit. The aim of large-scale asset purchases was to lower long-term bond yields and long-term interest rates, including the interest rates on housing loans. This could cause changes in housing wealth. As housing wealth makes up a large share of total household wealth, it is important to study how unconventional monetary policy impacts house prices.

There is a rapidly growing literature on how unconventional monetary policy affects macroeconomic variables, but there are only a handful of studies about the effects on house prices, among them being Rahal (2016), Huber and Punzi (2020), Gabriel and Lutz (2017), Smith (2014), Renzhi (2018), and Rosenberg (2019). Only a couple of papers have explored the effect of unconventional monetary policy on house prices in the euro area, such as Rahal (2016) and Huber and Punzi (2020), and to the best of my knowledge there has not yet been any study of the impact of unconventional monetary policy on house prices in an individual euro area country. As there may be heterogeneity in the effects across the countries of the euro area and pooling the data may lead to biased inference (Nocera and Roma, 2017; and Pesaran and Smith, 1995), it would be relevant to learn about the effects in an individual euro area country.

The analysis in the current paper focuses on Finland. It is intriguing to study an advanced welfare monetary union member country that over time has witnessed notably large rises and falls in house prices, and different monetary policy regimes. Finland is a small country but its GDP per capita is similar to that of the United Kingdom, Japan and Canada. What makes Finland also interesting is that it is in a monetary union, making it possible to investigate whether the response to different kinds of monetary policy shock is different in a small member country to what it is in the monetary union as a whole.

This paper studies the effects of conventional and unconventional monetary policy on house prices in Finland, a small open economy in the euro area. The emphasis is on Finland, but as the shocks are identified using also the variables of the whole euro area, the paper also discusses the effects on euro area variables. I first study how policy rate and balance sheet shocks affect house prices in Finland and the whole euro area, estimating the impulse response functions. Then I investigate how the impacts of the two kinds of monetary policy shock differ within Finland and within the euro area. Third, I evaluate whether there are differences between the responses in Finland and those in the whole euro area.

The impact of unconventional monetary policy on house prices in Finland has not yet been studied. There are some papers that study the influence of conventional monetary policy on house prices in Finland, such as Giuliodori (2005), who explores the impact of interest rate shocks on house prices in nine European countries, including Finland, using data for the period 1979Q3-1998Q4 in VAR models identified by Choleski decomposition. He finds that a contractionary monetary policy shock of 100 basis points is followed by a negative response of house prices, with the impact peaking at 1.8%. The results are, however, not statistically significant. Oikarinen (2009) uses quarterly data from 1975 to 1987 in a VECM model and finds that a positive interest rate shock of 100 basis points has a small, positive temporary impact of a bit less than 1% on real house prices. Using a sample from a later period even gives a negative effect.

The effect of unconventional monetary policy on macroeconomic variables in the euro area and in individual euro area countries including Finland has been studied in Elbourne et al. (2018). They use SVAR and VARX models and the unconventional monetary policy shock is identified using zero and sign restrictions. House prices are not included in the model. The empirical study of Elbourne et al. (2018) is carried out using monthly data for the period 2009M1-2016M11. The results indicate that an unconventional monetary policy shock has a very small and not statistically significant effect on output and prices, both in the euro area and in Finland individually.

I use the Bayesian structural vector autoregressive approach with an identification that uses a combination of zero and sign restrictions. This kind of identification of shocks is increasingly used in the literature, and Baumeister and Benati (2013), Peersman (2011), Schenkelberg and Watzka (2013), Boeckx et al. (2017), Rahal (2016), Weale and Wieladek (2016), and Nocera and Roma (2017) are all examples.

To quantify the effects of unconventional monetary policy I follow the strand of literature that uses innovations in the central bank's balance sheet as a measure of unconventional monetary policy. Examples of this approach can be found in Peersman (2011), Gambacorta et al. (2014), Rahal (2016), Boeckx et al. (2017), Gupta and Jooste (2018), and Renzhi (2018). Another approach to identification found in the literature is the shadow interest rate, which is used for example by Huber and Punzi (2020) to investigate the effects of unconventional monetary policies on house prices in the United States, the United Kingdom, Japan and the euro area. However, using the shadow interest rate does not allow the effects of conventional and unconventional monetary policy to be distinguished separately. As an important objective of the current paper is to compare the effects of the two types of monetary policy shock on house prices, shadow interest rate cannot be employed and so balance sheet innovations are used. To identify a conventional monetary policy shock I use innovations in the overnight interest rate EONIA. Using a money market interest rate as a proxy for a monetary policy shock is quite common in the literature.

The results indicate that an exogenous decrease in the monetary policy interest rate has a small positive and temporary impact on house prices, both in Finland and in the whole euro area. The balance sheet shock has an even smaller effect on house prices in Finland and the euro area, and in both cases the effect of a balance sheet shock fades out faster than the effect of a policy rate shock.

The paper contributes to the literature in a number of ways. First, it contributes to the relatively scarce literature studying the effect of unconventional monetary policy on house prices. Second, this paper contrasts with the previous literature by being the first to explore the effect of unconventional monetary policy on house prices in an individual euro area country. Third, the paper is the first to compare the effects of conventional and unconventional monetary policy on house prices in a single euro area country.

The rest of the paper proceeds as follows. The next section introduces the benchmark VAR model and describes the data. Section 3 presents and discusses the identification scheme of the monetary policy shocks. Section 4 contains the results of the estimation, showing and commenting on the impulse response functions of the identified shocks. Section 5 describes the robustness checks. Section 6 concludes.

## 2. Model specification and data

To explore the responses of house prices to monetary policy shocks I set up a structural vector autoregressive (SVAR) model. Like most studies that use sign restrictions in the identification scheme, I employ the Bayesian approach for estimation and inference, since in case of inequality restrictions the models are set identified, not point identified. Frequentist confidence intervals in models identified with sign restrictions tend to be wide and not informative about the shape of the impulse response function, making it difficult to interpret the results economically (Kilian & Lütkepohl, 2017). For this reason, most of the studies that use sign restrictions follow the Bayesian approach.

First, I estimate the following reduced-form VAR model:

$$Y_t = c + \sum_{i=1}^{n} b_i Y_{t-i} + u_t \tag{1}$$

where $Y_t$ is a vector of endogenous variables, $c$ is a vector of constants, $b_i$s are matrices of the autoregressive coefficients of the lagged values of $Y_t$, $i$ is the number of lags in the model, and $u_t$ is a vector of residuals. To obtain orthogonal disturbances and to give economic meaning to the shocks, I transform the reduced-form VAR model into a structural form:

$$A_0 Y_t = B_0 + \sum_{i=1}^{n} B_i Y_{t-i} + \varepsilon_t \tag{2}$$

where $A_0$ is the contemporaneous impact matrix of structural disturbances, $B_i$s are matrices of the structural coefficients of the lagged values of $Y_t$ and the reduced-form error terms $u_t$ are related to the mutually orthogonal structural errors (shocks) $\varepsilon_t$ in the following way:

$$u_t = A_0^{-1} \varepsilon_t \tag{3}$$

The vector of endogenous variables is:

$$Y_t = [GDP_t^*, HICP_t^*, HP_t^*, BP_t^*,\ M_t^*,\ R^*,\ T^*,\ GDP_t,\ HICP_t, HP_t,\ BP_t,\ M_t]' \tag{4}$$

The model contains seven euro area variables, each marked with *, and five Finnish variables. Gross domestic product per capita[1] ($GDP_t^*,\ GDP_t$), harmonized indexes of consumer prices ($HICP_t^*, HICP_t$), house prices ($HP_t^*, HP_t$), building permits per capita ($BP_t^*,\ BP_t$) and mortgage interest rates ($M_t^*,\ M_t$) are included for both the euro area and Finland, and the monetary policy rate ($R^*$) and the central bank's total assets per capita ($T^*$) only for the euro area, as the monetary policy shocks of individual euro area countries have to be identified through euro area variables. All the variables except the interest rates are in natural logarithms and have been multiplied by 100 for a better presentation of results. GDP, house prices and the central bank's total assets were deflated by the HICP to obtain real variables. For robustness I also estimated the model using the GDP deflator instead of the HICP, and the results were very similar.

An interbank rate is used instead of the policy rate itself in the model, as the policy rate moves in discrete steps but the interbank rate reflects all the information currently available about the future direction of the policy rate (Elbourne et al., 2018). Money market rates are used a lot in the literature as the monetary policy interest rate variable. I have used the nominal euro overnight index average (EONIA), following Elbourne et al. (2018) among others. For robustness I also did the analysis using EURIBOR and MLF instead of EONIA and the results appeared to be quite similar (see Appendix B).

The dataset is of quarterly frequency. The period runs from 2009Q1 to 2018Q2. An overview of the data used in the paper is given in Appendix A. All the data time series except population were seasonally adjusted by using the X12-ARIMA method in Eviews. The population data are only available annually, and quarterly values were obtained by interpolation using the cubic spline approach. In the process of seasonal adjustments, the multiplicative approach was used, except for time series that contained negative numbers, in which case the additive approach was used.

The data are in levels, allowing for implicit cointegrating relationships (Sims et al., 1990), as widely used in the literature of VAR models such as Gambacorta et al. (2014), Rahal (2016), Boeckx et al. (2017), Cesa-Bianchi et al. (2015), and Cesa-Bianchi et al. (2018). The basic assumption of this approach is that a VAR using data in levels implicitly takes cointegrated relationships into account. As I am using the Bayesian approach for estimation and inference, the use of data in levels is also supported by the argument in Sims et al. (1990) that the Bayesian inference does not need to take non-stationarity into account as the likelihood function retains its Gaussian shape also in case of non-stationarity.

Two lags are used, following a large amount of literature employing quarterly data such as Baumeister and Benati (2013), Calza et al. (2013), Aspachs-Bracons and Rabanal (2011), and others. The Schwarz information criterion and the Hannah-Quinn information criterion suggested that one lag should be used. However, I still include two lags as is typical in the literature, because adding an additional unnecessary lag results only in a loss of estimation efficiency, but excluding a necessary lag is a misspecification (Elbourne et al., 2018).

The estimations are carried out in the BEAR Toolbox of MATLAB (Dieppe et al., 2016). I use the independent Normal-Wishart prior, as the Normal-Wishart prior cannot be used in case of block exogeneity. Unlike, say, the Minnesota prior, the Normal-Wishart priors do not assume that the variance-covariance matrix of the reduced-form residuals is known. The toolbox uses the model estimation algorithm of Arias et al. (2018) in case of structural identification with sign restrictions. The algorithm draws a posterior distribution over the orthogonal reduced-form parametrization and transforms the draws into structural parametrization (Arias et al., 2018). The draws that satisfy the restrictions are kept, while the other draws are rejected. Successful draws are used to generate the impulse response functions, displaying the credible sets derived from the posterior distributions.

The BEAR Toolbox's default values for the hyperparameters, that are the standard values of the literature for computing the mean and variance of the prior distribution for the VAR coefficients, are used. The autoregressive coefficient is 0.8, overall tightness is 0.1, cross-variable weighting is 0.5, lag decay is 2, exogenous variable tightness has the value 100, and block exogeneity shrinkage is 0.001. A total of 1000 successful draws from the posterior are used to generate the impulse response functions, following for example Peersman (2011) and Rahal (2016).

## 3. Identification scheme

In this paper I employ a partially identified model. To investigate the effects of different types of monetary policy shock on house prices, two shocks are identified. To sharpen the identification, the identification scheme combines zero and sign restrictions, using the algorithm of Arias et al. (2018). A combination of zero and sign restrictions in the identification scheme is increasingly used in the literature, for example in Baumeister and Benati (2013), Peersman (2011), Schenkelberg and Watzka (2013), Gambacorta et al. (2014), Boeckx et al. (2017), Weale and Wieladek (2016), Rahal (2016), and Nocera and Roma (2017).

The identification scheme of monetary policy shocks (see Table 1) is built on Rosenberg (2019). As Finland is in a monetary union, monetary policy shocks first have to be identified through their impact on the euro area variables and only then can the influence on Finnish domestic variables be studied. The assumption of block exogeneity, which is that the variables of a small member country do not contemporaneously affect the euro area variables, is added to the identification scheme of Rosenberg (2019), following Kilian and Lütkepohl (2017) and Mumtaz and Surico (2009). Also, compared to Rosenberg (2019) I have added the HICPs of the euro area and Finland as additional variables. HICP is used in models investigating the effect of monetary policy shocks on house prices in, for example, Nocera and Roma (2017) and Huber and Punzi (2020).

Two shocks are identified, a policy rate shock and a balance sheet shock. The zeros in Table 1 indicate no contemporaneous response of the shock on the variable. Inequalities show the sign of the effect on that variable on impact and in the two following quarters (following e.g. Rahal, 2016).

I assume that the house prices in the euro area and in Finland would contemporaneously increase in response to both types of monetary policy shocks. In other words, I allow for the possibility that the house prices could respond to the change in the cost of borrowing already in the quarter of the shock. By placing a sign restriction on the response of house prices in the euro area and in Finland to a monetary policy shock the current paper follows the empirical literature that argues that house prices react almost instantaneously to a monetary policy innovation (e.g. Bjørnland & Jacobsen, 2010; Huber & Punzi, 2020; Nocera & Roma, 2017; and Ume, 2018). This assumption is grounded by macroeconomic theory as house prices being asset prices are forward-looking and will respond fast to monetary policy shocks (Bjørnland & Jacobsen, 2010). The immediate effect of changes in monetary policy on asset prices is assumed in a large amount of literature, including for example Rigobon and Sack (2004), Bernanke and Kuttner (2005), Bohl et al. (2008) and Alessi and Kerssenfischer (2019).

The contemporaneous impacts of both types of monetary policy shock on GDP, consumer prices and the housing supply are restricted to zero. Most of the literature on monetary policy shocks assumes that these shocks have only a lagged impact on GDP and

**Table 1.** Identification of monetary policy shocks.

| | GDP* | HICP* | HP* | BP* | M* | R* | T* | GDP | HICP | HP | BP | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Policy rate shock | 0 | 0 | >0 | 0 | <0 | <0 | 0 | 0 | 0 | >0 | 0 | <0 |
| Balance sheet shock | 0 | 0 | >0 | 0 | <0 | 0 | >0 | 0 | 0 | >0 | 0 | <0 |

Note: * marks the euro area variables, the other variables are the domestic variables of Finland.

consumer prices, as in Peersman (2011), Gambacorta et al. (2014), Boeckx et al. (2017), and Nocera and Roma (2017). It can be assumed that the housing supply is quite inelastic in the short run, as new construction takes time to plan and build. The housing supply variable in this paper is the number of square metres of building permits and although building time is not reflected in that variable, it can be assumed that building permits are not obtained instantly and hence the one-period lag can be considered justified.

Following, for example, Peersman (2011), Rahal (2016), Weale and Wieladek (2016) and Nocera and Roma (2017), the mortgage interest rate is restricted to decrease on impact in case of both identified shocks. A cut in the policy rate would induce a fall in the money market interest rates that in turn would be passed through to lower bank lending rates, including mortgage rates. A rise in liquidity due to balance sheet policies would increase the credit supplied by the banks, and that in turn would reduce lending rates (Peersman, 2011).

As a policy rate shock is identified as an exogenous innovation in the monetary policy rate (proxied by EONIA in this paper), I restrict that variable to decrease in case of an expansionary policy rate shock. Since I define a balance sheet shock as a monetary policy shock that leaves the policy rate unchanged, I restrict the policy rate variable to have only a lagged impact in case of a balance sheet shock. As the central bank's total assets are the variable for the balance sheet innovations in my paper, I restrict the central bank's total assets to increase contemporaneously after an expansionary balance sheet shock, following, for example, Schenkelberg and Watzka (2013), Gambacorta et al. (2014), and Rahal (2016). I also assume that the policy rate shock can impact the central bank's total assets only with a lag.

The times series for the shocks identified are shown in Appendix C. The econometrically identified shocks are reasonable and broadly are in line with information on the monetary policy decisions of the ECB. The identified monetary policy rate shocks capture, for example, the decrease of the key interest rates in 2009 and also the decrease of the policy interest rates in the second half of 2011 after a period of them being unchanged or even slightly increasing for some quarters. Since the year 2013 there are no notably large shocks. However, in 2014 a small negative shock is observed, that could be tied to the introduction of a negative policy interest rate.

The identified balance sheet shocks seem to reflect, for example, the ECB decision to continue its main refinancing operation with full allotment in 2010 and the announcement of outright monetary transactions programme in 2012. Also, for example, the monetary policy decision of the expansion of the monthly purchases under the asset purchase programme, and the announcement of a new series of targeted longer-term refinancing operations in 2016 can be seen to be captured by the shocks.

## 4. Results

This section presents the responses to the policy rate and balance sheet shocks of house prices and other variables in the model. The 68% credible sets (the 16th and 84th percentiles) of the impulse response functions (IRFs) are reported, following the standard in the sign restrictions literature. The credible set reflects model uncertainty as well as sampling uncertainty (Gambacorta et al., 2014). Model uncertainty comes from the model being set identified, not point identified. Hence the data are potentially consistent with a number of structural models that are all admissible (Kilian & Lütkepohl, 2017). The median is also displayed in the figures, following for example Uhlig (2005).

The medians are commented in the interpretation of the impulse response functions, as in Uhlig (2005). I use the term 'significant' to refer to the credible set excluding zero as in Dieppe et al. (2016) and Nocera and Roma (2017), and so the term 'not significant' is used in this paper for a credible set containing zero.

The shock size in Figure 1 is one standard deviation as common in the literature using structural VAR models (e.g. Boeckx et al., 2017; Cesa-Bianchi, 2013; Christiano & Eichenbaum, 2005; Gambacorta et al., 2014; Peersman, 2011; Uhlig, 2005). I have followed the paper of Peersman (2011) in using shocks of the size of one standard deviation in case of comparing the effects of two types of monetary policy shocks. Also, Gambacorta et al. (2014) have compared the effects of different types on monetary policy shock, based on the impulse responses of shocks of the size of one standard deviation. This makes it possible to compare the impacts of shocks to different variables as one standard deviation shock represents a typical shock to the respective variable.

Exogenous innovations to the interest rate bring a decrease in EONIA of around 3.5 basis points, and exogenous innovations to the total assets of the ECB correspond to an increase of about 0.4%.

The results displayed in Figure 1 with the area bordered with lines indicate that a cut of 3.5 basis points in the euro area policy interest rate is followed in Finland by a rise in house prices that peaks at 0.07% two quarters after the shock. The price level is still 0.02% higher five years after the shock. The small impact of a policy rate shock on house prices in Finland is consistent with earlier studies such as Giuliodori (2005) and Oikarinen (2009).

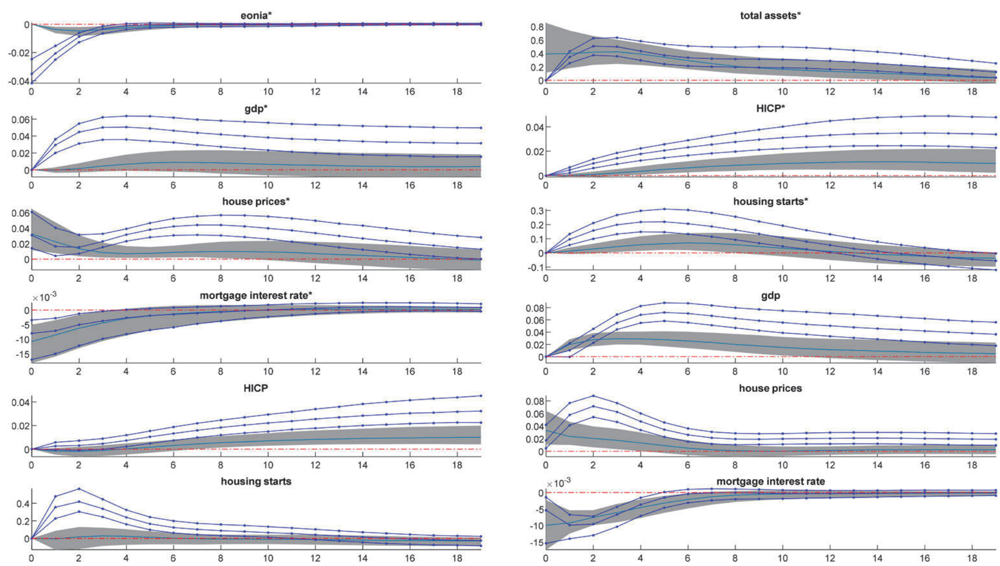


**Figure 1.** Impulse responses to policy rate and balance sheet shocks in Finland and the euro area (2009Q1-2018Q2). Notes: The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of the balance sheet shocks (68% credible set). The line within a credible set represents the median of the impulse responses. * is used to mark the euro area variables, the other variables are the domestic variables of Finland.

The policy rate shock has a positive impact on house prices also in the whole euro area like it does in Finland. The impact peaks around the 8th quarter at about 0.05%. The peak impact is reached later than in Finland. The effect dies out in about 4.5 years, and hence is also quite persistent as in case of Finland. The persistent effect of a policy rate shock on house prices in the euro area has also been found by, for example, Nocera and Roma (2017).

An expansionary balance sheet shock amounting to an increase of about 0.4% in the total assets of the ECB, also presented in Figure 1 (depicted with shadowed area) has a small, positive and temporary effect on house prices in Finland. The median response peaks at the magnitude of 0.035% and is reached in the period of the impact of the shock. The effect dies out in a year. The impact of a balance sheet shock in the euro area is of the same magnitude as in Finland. It peaks at around 0.035% also in the impact period of the shock as in case of Finland. The effect is more persistent than in Finland, fading out in the 9th quarter. As indicated in the introduction to this paper the literature on the effect of unconventional monetary policies on house prices is as yet very limited, but comparing the results of the current paper with those of the few papers that have studied the impact of unconventional monetary policy on house prices in the euro area shows that the results of this paper are in line with the earlier literature. There is a very small impact in case of most models in Rahal (2016) as well as in Huber and Punzi (2020). Huber and Punzi (2020) suggest that a possible explanation of the weaker response of housing variables in the euro area than in the US and the UK is that the individual members of the euro area tend to be less integrated.

A policy rate shock appears to have a larger and more persistent impact on house prices than a balance sheet shock does in Finland and in the euro area as a whole. In Finland though, the peak of the effect of a policy rate shock on house prices arrives faster than it does in the whole euro area. The impact peaks at roughly the same magnitude in Finland and the euro area. The effect of a balance sheet shock on house prices dies out much faster in Finland and in the total euro area compared to the effect of the policy rate. The peak magnitudes of the effects are smaller in case of a balance sheet shock than in case of a policy rate shock. These results would indicate that a standard deviation sized policy rate innovation would influence the house prices more strongly than a standard deviation sized balance sheet shock.

Turning briefly to the impact that the two types of monetary policy shock have on other variables of the model, it can be seen from Figure 1 that the impact on GDP is quite similar to the impact on house prices in magnitude of the peak effect in case of the effect of a policy rate shock in both areas and in case of the effect of a balance sheet shock in Finland. The impact of a policy rate shock on Finnish GDP peaks at around 0.07%; the effect is smaller for euro area GDP, being around 0.05%. A similarly small impact of a policy rate shock on GDP in Finland and in the euro area has also been found in earlier literature such as Giuliodori (2005) for Finland and Peersman (2011), or Errit and Uusküla (2014) for the euro area. The impact of a balance sheet shock on the GDP of Finland is very similar to the impact on house prices: it is positive and temporary, and peaks at the magnitude of about 0.03%. In the euro area a balance sheet shock does not appear to have a significant effect on GDP.

The small response of house prices and output to a balance sheet shock can be considered to be consistent with earlier studies. The effect of an unconventional monetary policy shock on house prices has only been studied in a few papers and a very small response in the euro area can be seen in those studies as well. The response of output can be compared to that in Elbourne et al. (2018), where the effect is also very small and not significant in both the euro area and Finland as an individual country. Elbourne et al. (2018) also study the impact on consumer prices in the euro area and individual euro area countries and the effect on that variable also appears to be notably small and not significant, again both at the level of the whole monetary union and in Finland. The latter conclusion is also consistent with the findings of the current paper as the response of the HICP of the euro area and the HICP of Finland to a balance sheet shock is very small and initially not significant for several quarters.

The impact of a policy rate shock on housing starts is faster and peaks at a higher magnitude in Finland than in the whole euro area. The effect dies out in the 11th quarter in case of Finland and in the 12th quarter in case of the euro area. In Finland there is no effect of a balance sheet shock on housing starts. In the euro area the effect is not significant until around the second quarter and after that there is a small positive effect on housing starts until the end of the second year. The effect of a policy rate shock on housing starts is much larger than the effect of a balance sheet shock on housing starts in case of Finland and the euro area.

The response of ECB total assets to a policy rate shock is restricted to be zero on impact by the identifying assumptions. After the period of impact the effect of the shock is positive and temporary. The impact of a policy rate shock on EONIA, which was used as the monetary policy rate variable in the model, and on the mortgage interest rate in both areas is quite similar. This is an expected result as loans with a variable interest rate are usually tied to EURIBOR in the euro area, and that rate is highly correlated with EONIA. The decline in mortgage interest rates is ca 0.01 percentage points in both areas.

In Appendix D the impulse responses are presented in a rescaled format, making it possible to study the impact of the two types of monetary policy shock on house prices relative to the impact of euro area GDP. The rescaled impulse responses are normalized by the peak median impact on euro area GDP with the peak impact being 1 in case of both types of monetary policy shock. The results show that the relative impact on house prices in Finland is initially higher in case of a balance sheet shock than in case of a policy rate shock. Later the relative impact of a balance sheet shock gets smaller and the relative impact of a policy rate shock increases until the effects of both types of monetary policy shock reach approximately the same magnitude around the time of the peak effect on euro area GDP. Similarly to the results of the benchmark model the relative impact on house prices dies out faster in case of a balance sheet shock. Turning now to the relative impact of both types of monetary policy shock on house prices in the whole euro area, the results show that the effect is initially larger in case of a balance sheet shock as was also the result in case of Finland. Moreover, like in Finland, the relative impact of house prices in the euro area is of the same magnitude relative to euro area GDP at the time of the peak effect on euro area GDP in case of both types of monetary policy shock. Also, as in the results of the benchmark model, the relative impact of a balance sheet shock on house prices fades out sooner than the relative effect of a policy rate shock.

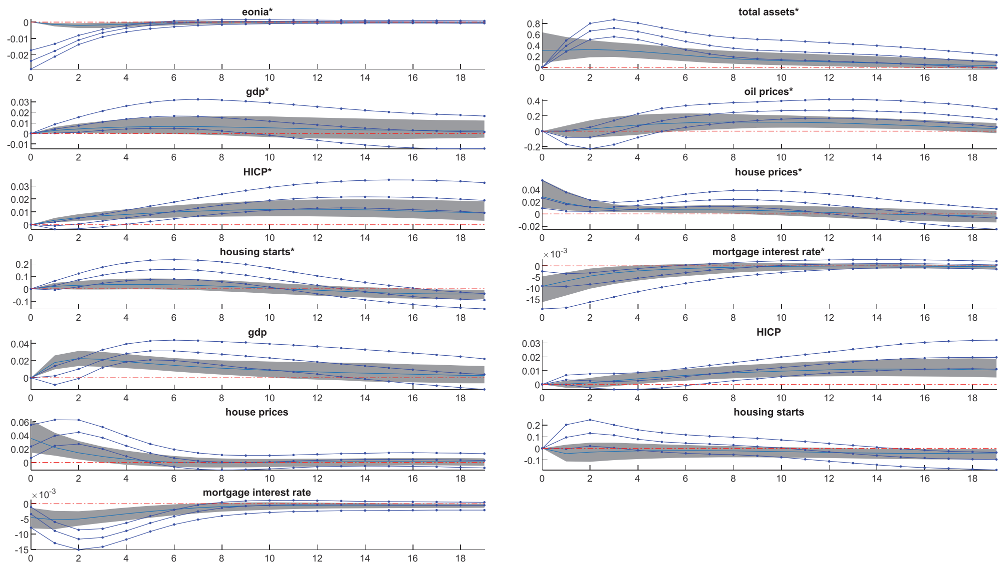


**Figure 2.** Impulse responses to policy rate and balance sheet shocks in Finland and the euro area with oil prices in the model (2009Q1-2018Q2). Notes: The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of the balance sheet shocks (68% credible set). The line within a credible set represents the median of the impulse responses. * is used to mark the euro area variables, the other variables are the domestic variables of Finland.

## 5. Robustness checks

To assess the robustness of the results of the paper, I also carry out estimations using different short-term interest rate variables and deflators as well as adding an additional variable to the model.

I estimate the model using alternative short-term interest rate variables and deflators in order to see if choosing another policy rate variable instead of EONIA would influence the results. I estimate the model using EURIBOR and MLF instead of EONIA as the monetary policy rate variables. In neither case is there any notable difference in the results (shown in Appendix B) from those obtained using EONIA.

For robustness of the results I also estimate the results using the GDP deflator instead of the HICP in deflating GDP, house prices and the central bank's total assets. The results do not differ notably from those presented in Section 4.

As studies have indicated that oil prices variable could possibly influence the results then in order to check for a possible omitted variables bias, I also try to specify a model with oil prices included, as in, for example, Baek and Miljkovic (2018). The results are presented in Figure 2 and they are very similar to the results of the benchmark model.

## 6. Conclusion

As witnessed during the financial crises, the housing market can have an amplifying effect in the transmission of financial market disruptions into the real economy. This makes it important to see how different types of monetary policy would influence house prices.

In this paper, I study the effects of monetary policy shocks on house prices in Finland, a small open economy that is part of the euro area. Using a combination of zero and sign restrictions within the Bayesian SVAR framework, I identify two types of monetary policy shock, which are a policy rate shock and a balance sheet shock. A policy rate shock is identified as an exogenous innovation to the central bank's policy interest rate and a balance sheet shock as an exogenous innovation to the central bank's balance sheet that leaves the policy rate unchanged.

The results of the paper indicate that an expansionary policy rate shock has a small and positive impact on house prices in Finland and the whole euro area. In Finland the peak of the effect of a policy rate shock on house prices arrives faster than in the whole euro area and the effect is more persistent than in the euro area. However, the impacts peak at quite similar magnitude in both Finland and the euro area with the impact being a bit larger in case of Finland.

The impact of the balance sheet policies on house prices is very small in Finland, as is the impact on house prices in the euro area. The impacts are of the same magnitude. To the best of my knowledge, the impact of unconventional monetary policy on the house prices of an individual euro area country has not studied before. As there are a couple of papers that investigate the effect of unconventional monetary policy on house prices in the euro area (Huber & Punzi, 2020; Rahal, 2016), we can say that the results for the whole euro area obtained in my paper are similar to those of the few existing earlier studies.

The findings of the paper indicate that policy rate shocks have a larger and more persistent impact on house prices than balance sheet shocks do, both in the small euro area economy of Finland and in the euro area as a whole. In Finland though, the peak of the effect of a policy rate shock on house prices and on housing starts is reached faster than it is in the whole euro area, showing that the response of the housing market is faster in a small open economy than in the whole monetary union. The results of the paper may indicate that the impact of a conventional monetary policy shock on main economic indicators could be stronger and more persistent than the effect of an unconventional monetary policy shock in a monetary union.

In future studies, the impact of the two types of monetary policy shock on house prices could be studied in a larger set of individual euro area countries, with a focus on the sources of possible differences in the results across countries. It would also be pertinent to study in greater detail why conventional monetary policy tends to have a larger effect on macroeconomic variables than unconventional monetary policy does in the euro area. Another powerful alternative for future research is using narrative sign restrictions for the identification of shocks.

## Note

1. GDP, building permits and the central bank's total assets are expressed per capita in order to ensure that changes in those variables are not affected by changes in population and to overcome the differences in scale between the euro area and Finland.

## Acknowledgements

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## References

Alessi, L., & Kerssenfischer, M. (2019). The response of asset prices to monetary policy shocks. *Journal of Applied Econometrics*, *34*(5), 661–672. https://doi.org/10.1002/jae.2706

Arias, J. E., Rubio-Ramirez, J. F., & Waggoner, D. F. (2018). Inference based on structural vector autoregressions identified with sign and zero restrictions: Theory and applications. *Econometrica*, *86*(2), 685–720. https://doi.org/10.3982/ECTA14468

Aspachs-Bracons, O., & Rabanal, P. (2011). The effects of housing prices and monetary policy in a Currency union. *International Journal of Central Banking*, *7*(1), 225–274.

Baek, J., & Miljkovic, D. (2018). Monetary policy and overshooting of oil prices in an open economy. *The Quarterly Review of Economics and Finance*, *70*, 1–5. https://doi.org/10.1016/j.qref.2018.04.015

Baumeister, C., & Benati, L. (2013). Unconventional monetary policy and the great recession: Estimating the macroeconomic effects of a spread compression at the zero lower bound. *International Journal of Central Banking*, *9*(2), 165–212.

Bernanke, B. S., & Kuttner, K. N. (2005). What explains the stock market's reaction to Federal Reserve policy? *The Journal of Finance*, *60*(3), 1221–1257. https://doi.org/10.1111/j.1540-6261.2005.00760.x

Bjørnland, H. C., & Jacobsen, D. H. (2010). The role of house prices in the monetary policy transmission mechanism in small open economies. *Journal of Financial Stability*, *6*(4), 218–229. https://doi.org/10.1016/j.jfs.2010.02.001

Boeckx, J., Dossche, M., & Peersman, G. (2017). Effectiveness and transmission of the ECB's balance sheet policies. *International Journal of Central Banking*, *13*(1), 297–333.

Bohl, M. T., Siklos, P. L., & Sondermann, D. (2008). European stock markets and the ECB's monetary policy surprises. *International Finance*, *11*(2), 117–130. https://doi.org/10.1111/j.1468-2362.2008.00219.x

Calza, A., Monacelli, T., & Stracca, L. (2013). Housing finance and monetary policy. *Journal of the European Economic Association*, *11*(S1), 101–122. https://doi.org/10.1111/j.1542-4774.2012.01095.x

Cesa-Bianchi, A. (2013). Housing cycles and macroeconomic fluctuations: A global perspective. *Journal of International Money and Finance*, *37*, 215–238. https://doi.org/10.1016/j.jimonfin.2013.06.004

Cesa-Bianchi, A., Cespedes, L. F., & Rebucci, A. (2015). Global liquidity, house prices and the macroeconomy: Evidence from advanced and emerging economies. *Journal of Money, Credit and Banking*, *47*(S1), 301–335. https://doi.org/10.1111/jmcb.12204

Cesa-Bianchi, A., Ferrero, A., & Rebucci, A. (2018). International credit supply shocks. *Journal of International Economics*, *112*, 219–237. https://doi.org/10.1016/j.jinteco.2017.11.006

Christiano, L. J., & Eichenbaum, M. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, *113*(1), 1–45. https://doi.org/10.1086/426038
Dieppe, A., Legrand, R., & van Roye, D. (2016). *The BEAR Toolbox*, ECB Working Paper Series, No. 1934.
Elbourne, A., Ji, K., & Duijndam, S. (2018). *The effects of unconventional monetary policy in the Euro Area*, CPB Discussion Paper, No. 371.
Errit, G., & Uusküla, L. (2014). Euro area monetary policy transmission in Estonia. *Baltic Journal of Economics*, *14*(1–2), 55–77. https://doi.org/10.1080/1406099X.2014.980113
Gabriel, S., & Lutz, C. (2017). *The Impact of unconventional monetary policy on real estate market*. mimeo. https://ssrn.com/abstract=2493873
Gambacorta, L., Hofmann, B., & Peersman, G. (2014). The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis. *Journal of Money, Credit and Banking*, *46* (4), 615–642. https://doi.org/10.1111/jmcb.12119
Giuliodori, M. (2005). The role of house prices in the monetary transmission mechanism across European countries. *Scottish Journal of Political Economy*, *52*(4), 519–543. https://doi.org/10.1111/j.1467-9485.2005.00354.x
Gupta, R., & Jooste, C. (2018). Unconventional monetary policy shocks in OECD countries: How important is the extent of policy uncertainty. *International Economics and Economic Policy*, *15*(3), 683–703. https://doi.org/10.1007/s10368-017-0380-8
Huber, F., & Punzi, M. T. (2020). International housing markets, unconventional monetary policy and the zero lower bound. *Macroeconomic Dynamics*, *24*(4), 774–806. https://doi.org/10.1017/S1365100518000494
Kilian, L., & Lütkepohl, H. (2017). *Structural vector autoregressive analysis*, p. 782. Cambridge University Press.
Mumtaz, H., & Surico, P. (2009). The transmission of international shocks: A factor-augmented VAR approach. *Journal of Money, Credit and Banking*, *41*(S1), 71–100. https://doi.org/10.1111/j.1538-4616.2008.00199.x
Nocera, A., & Roma, M. (2017). *House prices and monetary policy in the euro area: Evidence from structural VARs*, ECB Working Paper Series, No. 2073.
Oikarinen, E. (2007). *Studies on house price dynamics*, Turku School of Economics, Series A-9: 2007.
Oikarinen, E. (2009). Interaction between housing prices and household borrowing: The Finnish case. *Journal of Banking & Finance*, *33*(4), 747–756. https://doi.org/10.1016/j.jbankfin.2008.11.004
Peersman, G. (2011). *Macroeconomic effects of unconventional monetary policy in the Euro Area*, ECB Working Paper, No. 1397.
Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogenous panels. *Journal of Econometrics*, *68*(1), 79–113. https://doi.org/10.1016/0304-4076(94)01644-F
Rahal, C. (2016). Housing markets and unconventional monetary policy. *Journal of Housing Economics*, *32*(C), 67–80. https://doi.org/10.1016/j.jhe.2016.04.005
Renzhi, N. (2018). House prices, inflation and unconventional monetary policy, Mimeo, available at SSRN: https://ssrn.com/abstract=3174289</objidref.
Rigobon, R., & Sack, B. (2004). The impact of monetary policy on asset prices. *Journal of Monetary Economics*, *51*(8), 1553–1575. https://doi.org/10.1016/j.jmoneco.2004.02.004
Rosenberg, S. (2019). The effects of conventional and unconventional monetary policy on house prices in the Scandinavian countries. *Journal of Housing Economics*, *46*, 1–17. https://doi.org/10.1016/j.jhe.2019.101659
Schenkelberg, H., & Watzka, S. (2013). Real effects of quantitative easing at the zero lower bound: Structural VAR-based evidence from Japan. *Journal of International Money and Finance*, *33*, 327–357. https://doi.org/10.1016/j.jimonfin.2012.11.020
Sims, C. A., Stock, J. H., & Watson, M. W. (1990). Inference in linear models with some unit roots. *Econometrica*, *58*(1), 113–144.
Smith, A.L. (2014). *House prices, heterogeneous banks and unconventional monetary policy options*. The Federal Reserve Bank of Kansas City Research Working Papers, No. 14–12.
Uhlig, H. (2005). What are the effects of monetary policy on output? Results from an agnostic identification procedure. *Journal of Monetary Economics*, *52*(2), 381–419. https://doi.org/10.1016/j.jmoneco.2004.05.007

Ume, E. (2018). The impact of monetary policy on housing market activity: An assessment using sign restrictions. *Economic Modelling*, *68*, 23–31. https://doi.org/10.1016/j.econmod.2017.04.013

Weale, M., & Wieladek, T. (2016). What are the macroeconomic effects of asset purchases? *Journal of Monetary Economics*, *79*, 81–93. https://doi.org/10.1016/j.jmoneco.2016.03.010

## Appendices

### *Appendix A Description and Sources of the Data*

| Variable | Description | Source |
|---|---|---|
| **GDP*** | GDP of the euro area at current prices divided by the population of the euro area. | Statistical Data Warehouse |
| **HICP*** | Harmonized index of consumer prices of the euro area. | Eurostat |
| **House prices*** | Residential property price index of the euro area. | National sources, BIS Residential Property Price database |
| **Housing starts*** | Building permits index of the euro area, square metres of useful floor area of all residential buildings excluding residences for communities divided by the population of the euro area. | Statistical Data Warehouse |
| **Mortgage interest rate*** | Loans to households for house purchases, over 10 years, new business coverage. Data were monthly, I calculated the quarterly averages. | Statistical Data Warehouse |
| **Short term interest rate*** | Euro overnight index average (EONIA). Data were monthly, I calculated the quarterly averages. | Eikon/ECB |
| **Central bank's total assets*** | ECB total assets divided by the population of the euro area. | Eikon/ECB |
| **GDP** | GDP of Finland at current prices divided by the population of Finland. | Statistics Finland |
| **HICP** | Harmonized index of consumer prices of Finland. | Eurostat |
| **House prices** | House price index of Finland. | National sources, BIS Residential Property Price database |
| **Housing starts** | Building permits of residential buildings, square metres of floor area divided by the population of Finland. Data were monthly, I calculated the quarterly sums. | Statistics Finland |
| **Mortgage interest rate** | Loans to households for house purchases, over 5 years, outstanding loans. Data were monthly, I calculated the quarterly averages. | Statistical Data Warehouse |
| **Oil prices*** | Brent crude oil prices, converted into euros. Data were monthly, I calculated the quarterly averages. | Federal Reserve Bank of St. Louis |

Note: The euro area variables are marked with *.

## Appendix B Impulse responses with alternative measures for the short-term interest rate

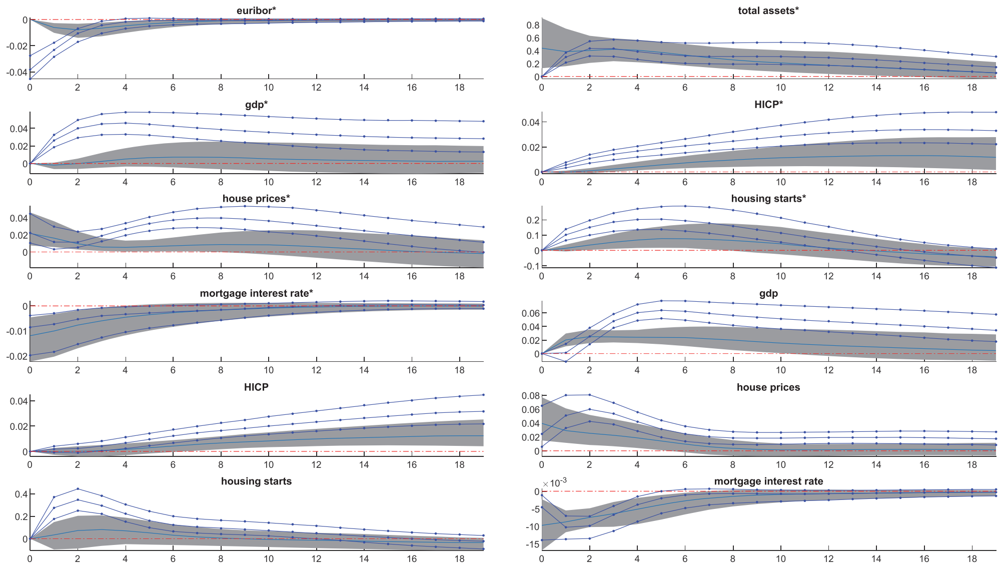


**Figure B1** Impulse responses to policy rate and balance sheet shocks using EURIBOR as a measure for the short-term interest rate. Notes: The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median of impulse responses. * is used to mark the euro area variables, the other variables are the domestic variables of Finland.

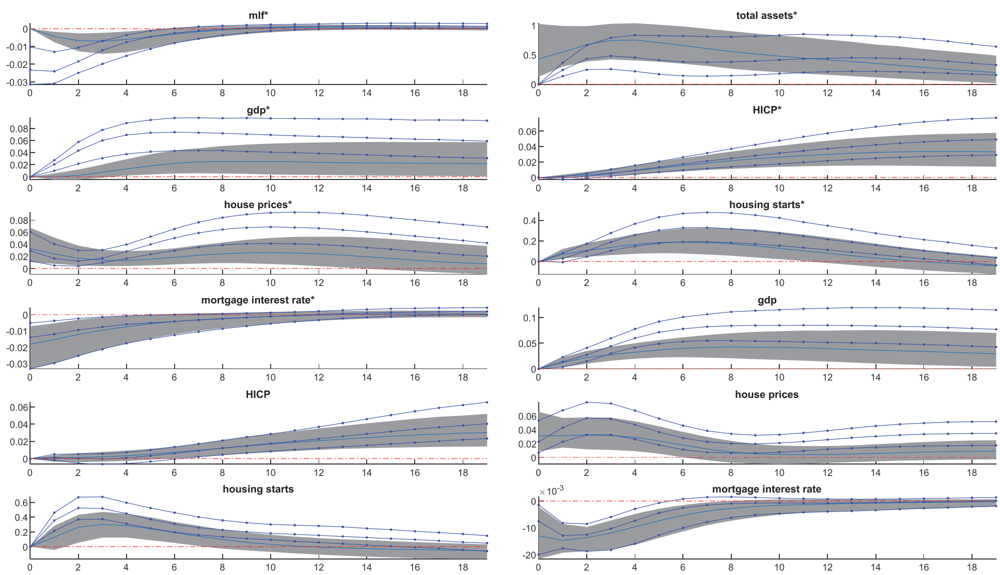


**Figure B2** Impulse responses to policy rate and balance sheet shocks using MLF as a measure for the short-term interest rate. Notes: The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median of impulse responses. * is used to mark the euro area variables, the other variables are the domestic variables of Finland.

## Appendix C Time series for the identified shocks

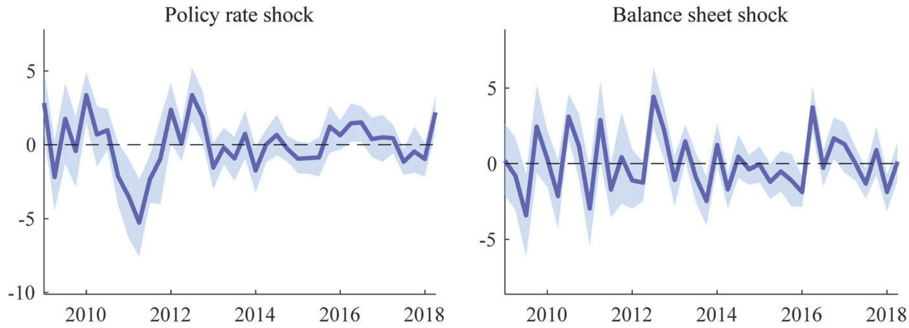


**Figure C1.** Time series for a policy rate shock and a balance sheet shock.

## Appendix D Impulse responses rescaled by the peak impact on euro area GDP

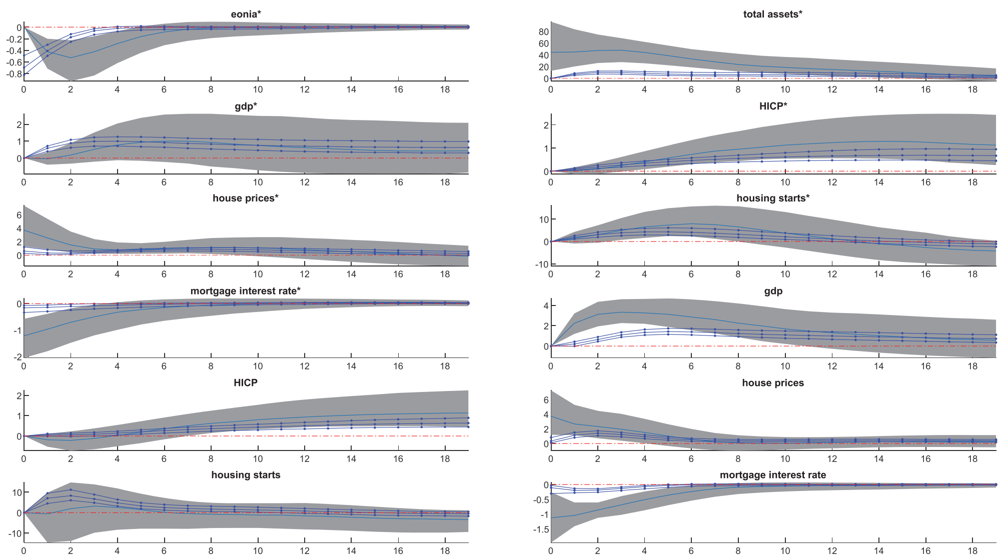


**Figure D1** Impulse responses to policy rate and balance sheet shocks rescaled to yield the same impact on euro area GDP. Notes: The area bordered by lines displays the impact of policy rate shocks, the shadowed area shows the impact of balance sheet shocks (68% credible set). The line within a credible set represents the median of impulse responses. * is used to mark the euro area variables, the other variables are the domestic variables of Finland.

# Appendix 3. Publication III

**THE IMPACT OF A CHANGE IN REAL ESTATE VALUE ON PRIVATE CONSUMPTION IN ESTONIA**

**Publication III**

Rosenberg, S. (2015). The Impact of a Change in Real Estate Value on Private Consumption in Estonia. *Research in Economics and Business: Central and Eastern Europe*, Vol. 7, No. 2, pp. 5-26. (ETIS 1.2)

# The Impact of a Change in Real Estate Value on Private Consumption in Estonia

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## Abstract

This paper examines the link between the value of residential real estate stock and private consumption using data from Estonia. Estonia has a high share of owner-occupancy due to the property reform that was begun after regaining independence in 1991, and has also seen large changes in real estate prices. A vector error correction model was constructed with private consumption, real estate stock value, GDP and household debt as the variables. The results suggest the presence of a long-run relationship, showing that changes in the value of residential real estate stock positively affect private consumption in the long run, i.e. the effect is permanent and has the expected positive sign.

JEL classification codes: E2, E3
Keywords: house prices, real estate wealth effect, owner-occupancy, cointegration, vector error correction model

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## 1. Introduction

The value of real estate changes over time. Europe, North and Central America and parts of Asia witnessed a rapid increase in house prices before 2007 and subsequently large declines during the global financial crisis (GFC) of 2008–2010. An example of a very large drop in real estate prices is in the post-Soviet country Estonia, where house prices declined severely during the GFC: the fall compared to the boom price was 60–70%, which is much higher than it was in most other EU countries except Latvia and Lithuania. In 2004–2006 the Estonian real estate price index tripled and future prospects for the market were optimistic. In 2007, the number and value of real estate transactions started to decrease slowly as the global economy headed towards crisis. There was a slowdown in economic growth and a soft landing was predicted for Estonia, but the GFC of 2008–2010 was much more severe. The peak of the GFC for the real estate market was in July 2009. By the end of the period of the data sample in this paper, real estate prices had almost doubled.

Since housing influences the business cycle, the boom in house prices in many developed countries before the GFC and the following sharp price declines have attracted the attention of policymakers and researchers. It is important to study the topic because, if there is a significant impact of a change in real estate value on economic activity, then this would indicate that policymakers should keep a close eye on the dynamics of the housing market to identify and possibly prevent large booms and busts. The problem is that shocks to house prices have not been studied extensively in the case of post-Soviet countries, including the periods during and after the GFC.



According to theory, there are four channels through which asset prices can be considered to affect economic activity: 1) the wealth effect on consumption; 2) Tobin's Q effect on investment; 3) the balance sheet effect on private spending (via the credit channel); and 4) the confidence effect on private spending (Altissimo et al., 2005). Ludwig and Slok (2002) divide the first channel (the wealth effect on consumption) into five sub-channels: the realized wealth effect, the unrealized wealth effect, the budget constraint effect, the liquidity constraint effect and the substitution effect. The realized and unrealized wealth effects cause an increase in house prices and so increase private consumption. The budget constraint and substitution effects work in the opposite direction. The liquidity constraint effect depends on how well the financial market is functioning.

Total wealth is not homogenous, but consists of several components. The three main components of household wealth are tangible wealth (mainly housing), non-equity financial wealth and equity wealth. This paper focuses on housing wealth, specifically residential real estate wealth. Most of the literature has not divided wealth into these components for calculating elasticity or marginal propensity to consume (MPC). The current paper focuses on housing wealth, as in, for example, Case et al. (2005), Pachebo and Barata (2005) and Campbell and Cocco (2007). Housing wealth is an important component of household wealth. As shown below, Estonia has a remarkably high rate of owner-occupied residential real estate, while only approximately 1.5% of the population has an account in the stock market.[1]

Estonia is unique for its large share of owner-occupied residential real estate, largely because of the housing and property reform that was begun in 1991. During this reform,

[1] According to Talpsepp (2010), from 1 January 2004 to 30 June 2008, transactions from 20,758 different individual accounts were made on the Nasdaq OMX Tallinn.

much of the property that had been unlawfully expropriated during the first years of the Soviet occupation in Estonia (1940) and after World War II was returned to its former owners or their successors. In addition to this restitution, state-owned residential real property was privatized – government tenants had the chance to buy their homes using privatization vouchers (every permanent resident of Estonia was entitled to a privatization voucher according to their length of employment). This led to a very high share of owner-occupied homes[2]; nearly 90% of the housing stock was in private ownership in Estonia by 2012. According to Eurostat, more than half of the population in each EU member state lived in owner-occupied dwellings in 2012, ranging from 53.2% in Germany up to 96.6% in Romania. It appears that it is characteristic of the new member states to have high owner-occupancy rates. The owner-occupancy rate has been slightly declining in recent years in Estonia. Estonia was chosen as the subject of this research because of its uniqueness due to its historical background and also due to the existence of a good transaction register (described in the data section of this paper).

This paper seeks to ascertain the impact of a change in real estate value on aggregate private consumption. The aim of the paper is to investigate empirically how private consumption is affected by changes in real estate value. The research questions that this paper aims to answer are as follows: Will a change in the value of property lead to a change in consumer spending? How much will it change consumption?

Essentially, wealth is not exogenous with respect to consumption but, rather, jointly endogenously determined. Most existing literature, however, implicitly assumes that a large proportion of the fluctuations in housing wealth are exogenous and that the dynamics are not substantially affected by decisions on consumption and other macroeconomic variables (Slacalek, 2009). In this paper I use four variables (private consumption, real estate stock value, GDP and household debt) in a vector error correction model (VECM) approach and hence all the variables are first considered endogenous and are subsequently tested for weak exogeneity. Based on the impulse response functions, I estimate the long-term elasticity of private consumption with respect to a 1% change in real estate stock value. The results show that the estimated elasticity is higher than in most previous studies referred to in the literature review, but it is in agreement with the upper end of the range in the results of, for instance, Pachebo and Barata (2005).



This paper contributes to the literature in the following way. Using a good database of real estate transactions in a transition country which has experienced a large boom and bust, I examine how the developments in the housing market may have affected consumption behaviour. The topic has not been studied widely in post-Socialist transition countries and the results may be applicable to other CEE countries that have witnessed dramatic changes in the value of housing stock, serving as an example of the impact of a change in real estate value on consumers in post-Socialist transition countries. The topic of the present paper has been studied by Paabut and Kattai (2007) and Šonje et al. (2012), but their time series are shorter and the methods used are different in my paper. Impulse response functions make it easier to see the effect of different shocks on the adjustment path of the variables.

The remainder of the paper is organised as follows: in the next section, a brief literature review is presented. In section 3 the econometric methods used are described, in section 4

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[2] In 1994, around 71% of all housing stock was owned by the state or local municipalities in Estonia, while at the beginning of 2002 the percentage was only 4.2%.

an overview of the data sources is given, and in section 5 the results are presented and discussed. The last section concludes.

## 2. Literature review

The effect of wealth on private consumption has traditionally been analyzed within the framework of the permanent income hypothesis or the life-cycle model (Ando and Modigliani, 1963; Friedman, 1957; Modigliani, 1971). Pachebo and Barata (2005) depart from the life-cycle theory of Modigliani, explaining consumption as a variable depending on wealth, beyond income. They argue that the traditional life-cycle model given in Ando and Modigliani (1963) implies that aggregate consumption is linearly related to labour income and wealth, but says nothing about the cointegration properties of the variables. Pachebo and Barata (2005) also argue that in the long run, trends in consumption are closely related to trends in income and wealth; in the short run, household consumption can deviate from this long-run equilibrium but will tend gradually to revert to equilibrium over time.

The life-cycle model of Gali (1990) implies that consumption, income and wealth variables may share a common trend, showing through the life-cycle factors that consumption changes should be predictable and smoother than in the infinite-horizon model. Modigliani (1971) advocates the significance of wealth effects on consumption. As indicated by Boone et al. (1998), subsequent evidence has presented some criticism of life-cycle theory. It is argued that this model takes no account of uncertainty in the future stream of revenue, as well as that the strength of any wealth effect should be linked to the distribution of wealth and the existence of liquidity constraints. The conventional analysis does not take into account the possibility that the variables are non-stationary or that there is reverse causality between, for instance, wealth and consumption (Pachebo & Barata, 2005). In the current paper, the order of the integration of the variables is tested and, since the variables are found to be I(1), cointegration analysis is performed.



Consumer intertemporal utility maximization under the lifetime resource constraint states that current consumption is proportional to total wealth (Altissimo et al., 2005):

$$C = MPC_W[A+H(Y)] \approx MPC_W A + MPC_Y Y \qquad (1)$$

where $C$ is consumption, $A$ is real non-human wealth, $H$ is real human wealth (the present value of expected labour income (net taxes)), $MPC_W$ is marginal propensity to consume wealth and $MPC_Y$ is marginal propensity to consume income. As can be seen in equation (1), within the framework of the life-cycle theory of permanent income, consumption is a function of human and non-human capital wealth (including labour income, transfer income, property income and financial wealth). Additionally, lags are put into the model. Equation (1) also shows that the weighted averages of non-human wealth and labour income can be presented as related to consumption in the long run because, by definition, labour income and human wealth are cointegrated (Altissimo et al., 2005).

Typically, the behaviour of utility-maximizing consumers is analyzed assuming rationality, perfect capital markets and the absence of distorting taxes or rigidities. In these ideal circumstances, where the composition of wealth can be changed without friction or cost, MPCs of different wealth components should be equal. In imperfect capital markets, the properties associated with different wealth components may well affect their respective MPCs; the MPC of each wealth component depends positively on the liquidity of the asset. For example, if the only way for a homeowner to increase consumption, as a response to a rise in housing value, is first to sell the house, then it is clear that most homeowners will not react to the increase in the market value of housing (Altissimo et al., 2005). The possibility of taking out a new mortgage on the house affects MPC positively. A rise in house prices increases the value of the collateral available to households, stimulating consumption and housing investment by making it easier and less expensive to borrow against the value of a house (Aoki et al., 2002).

The negative effect comes from renters. When housing value rises, the value of potential future homes for renters to buy also rises, and so they must save more, and hence consume less, in order to buy a house someday. In addition, the rental payments for their current home may rise, which will also decrease the tenant's private consumption. It goes the opposite way in the case of a decrease in house prices. Muellhauer (1994), Altissimo et al. (2005) and Ludwig and Slok (2002) suggest that differences between assets based on liquidity and the distribution of homeownership could imply different aggregate MPCs – the higher the proportion of homeowners and the lower the proportion of households in the rental market, the larger the consumption response to a rise in house prices. This means that an increase in the homeownership rate could increase the probability that a positive wealth effect will outweigh negative income and substitution effects on consumption – the greater the share of homeowners, the greater the MPC of wealth. Therefore, Estonia should have quite a large MPC of real estate wealth, due to the large proportion of owner-occupancy.

Altissimo et al. (2005) argue that the MPC of non-equity financial wealth is likely to be the highest, compared to other types of wealth. Since equity prices are more volatile than house prices, households may find it more difficult to assess whether a change in their equity wealth is permanent or temporary. They are likely to be more cautious in adapting consumption plans to changes in equity wealth than to changes in housing wealth. In most countries, housing wealth is more evenly distributed than equity holdings, which are concentrated at the upper end of income distribution, meaning that, at the aggregate level, the wealth effect from housing may be expected to be more important than the effect from equity wealth. Case et al. (2005) argue that research to quantify the effect of changes in wealth on changes in consumption has largely used aggregate measures of wealth that emphasize the stock market, and does not attempt to measure housing wealth with any accuracy. House purchases are generally largely financed with a mortgage loan, but financial asset purchases are not. As a result, increases in house prices will give a greater investment return to households than an equal percentage change in, for example, equity prices (Tang, 2006). Since only a very small share of the population is active in the stock market in Estonia, it is not justified to use stock wealth to measure MPC of wealth and hence, in this paper, residential real estate market data is used.

Some theories imply that an increase in housing wealth due to higher real estate prices leads to increased consumption, while other theories suggest that this is not the case (Aben et al., 2012). Ludwig and Slok (2002) say that there is no a priori reason to expect a positive impact from changes in housing prices on consumption but, due to the deregulation of financial markets, it should be expected that the positive influence of housing prices on consumption has become stronger over time. Pachebo and Barata (2005) and Muellbauer and Lattimore (1995) state that an increase in house prices may or may not make households better off because the positive effect for homeowners could be offset by the negative impact on renters. This means that when the value of residential real estate, for example, rises, the change in private consumption depends on how easily a property could be sold. If liquidity is high, private consumption rises more (since the homeowner can sell the house easily and hence cash out the increased value). Gan (2010) concludes that the main effect of housing wealth on consumption appears to stem from a reduction in precautionary saving.

It has been argued in the literature that the length of planning horizon is also important in calculating MPC of wealth. Following Poterba (2000), Altissimo et al. (2005) show that the shorter the horizon, the higher the MPC of wealth. On the other hand, a strong bequest motive affects the MPC of wealth in the same way as the lengthening of the planning horizon (Altissimo et al., 2005). Campbell and Cocco (2007), using data on individual households, also find evidence that the housing wealth effect is higher for older households.

There are alternative views regarding the effect of house prices on consumption – for example, Cristini and Sevilla (2014) discuss and compare the wealth effect hypothesis and the common factor hypothesis. They compare the results of two influential papers, Campbell and Cocco (2007) and Attanasio, Blow, Hamilton and Leicester (2009), which use the same data set but reach opposite conclusions as to the impact of changes in house prices on consumption. Browning et al. (2013) find, using Danish data, little evidence of a housing wealth effect on consumption. They suggest that house prices affect total expenditure through improved collateral, rather than directly through wealth. However, they also find that housing prices are stationary, which is not the case for Estonian data.



The central issue in analyzing wealth effects is timing. If the lag between a favourable shock to the household balance sheet and an increase in consumption spending takes many years to develop, then market fluctuations may have a limited impact on aggregate spending. If the link from net worth to consumption is powerful and immediate, then sharp changes in asset values may translate into sharp changes in consumer spending (Altissimo et al., 2005). Pachebo and Barata (2005) state that if consumption expenditures do not fully react immediately to changes in asset prices, then the wealth effect in the first periods will be smaller than the long-run effects. The error correction process will eventually bring actual spending into line with the long-run prediction of the life-cycle model. The paper by Aoki et al. (2002) shows that there is a strong co-movement between housing prices and consumption, and particularly between housing prices and consumer durables expenditure, and that house prices are not a source of fundamental shocks but are part of the transmission mechanism by which changes in short-term interest rates affect consumption, the output gap and inflation.

To give an overview of some studies that assess empirically the impact of housing wealth on consumption, I start with the study by Benjamin et al. (2004), which relies on US aggregate consumption and wealth data. The variables in their model are consumption, income other than from transfer payments, real estate wealth and financial wealth. Their results suggest that the MPC from housing wealth (0.08) is four times the size of that from financial assets (0.02). Case et al. (2005) rely on a panel of 14 countries observed annually and a panel of US states observed quarterly. The variables in their model are consumption, housing market wealth, stock market wealth and income. They find a statistically significant and rather large effect of housing wealth on household consumption. The housing wealth effect may be especially important in the preceding decades of the study of Case et al. (2005), as institutional innovations like second mortgages have made it simpler to extract cash from housing equity.

Altissimo et al. (2005) state that the variation in MPC of wealth estimates across studies, countries and estimation methods is disconcertingly large. It is quite difficult to compare different countries because their cultural and historical backgrounds may also have a significant influence on MPC.

Pachebo and Barata (2005) include in their model for nine EU countries the quarterly aggregate data for household consumption, disposable income, an equity price index, a residential price index, the unemployment rate, the short-term interest rate and the inflation rate. The selected time period differed across countries and the authors faced a serious lack of data and a short range of the time series for some of the smaller EU countries. In relation to residential prices, their results are significant for all the countries considered, with long-run consumption elasticity of residential prices between 6 and 21 per cent.

Gradner and Gstach (2006) study different papers on the effect of real estate wealth on consumption and find that in a series of recent papers, the real wealth effect on consumption from changes in housing prices has been found to be statistically significant and, for European countries, to exceed the stock market wealth effect considerably. Pachebo and Barata (2005) also state that the housing market appears to be more important than the stock market in influencing consumption. They report corresponding consumption elasticity of between 0.1 and 0.2 for various European countries, roughly the range of figures reported by Case et al. (2005). Greenspan (1999) gives a figure of roughly 0.05 for the USA and similar figures are reported for the G7 countries by Girouard and Blöndal (2001). Gan (2014) calculates the elasticity of consumption with respect to a change in housing value to be 0.17, based on data from Hong Kong. In some studies, self-reported housing values are used as a proxy for housing value, while in others only some areas of a country are covered, which makes it difficult to compare the results of different studies.



Muellbauer and Murphy (1994), using UK regional consumption data, find a negative effect from house prices. Girouard and Blöndal (2001) examine the impact of housing wealth on household consumption for France, Italy and the UK. Their results show that housing wealth exerts a positive influence on household consumption in France and in the UK in the short and long run, while Italy presents a negative relationship between those variables. Considering seven countries (Finland, Germany, Ireland, Italy, the Netherlands, Sweden and the UK), Henley and Morley (2001) suggest a significant degree of diversity in consumption functions and impacts from housing wealth. Ludwig and Slok (2004) evidence a significant long-run impact from stock market and housing market wealth to consumption. Aoki et al. (2002) say that house prices matter because houses can be used as loan collateral against which households borrow to finance housing investment or consumption (Pachebo and Barata, 2005).

The paper by Carroll et al. (2010) presents a simple new method for measuring wealth effects on aggregate consumption. This method exploits the stickiness of consumption growth to distinguish between immediate and eventual wealth effects. Using US data, they estimate that the immediate (next-quarter) MPC from a change in housing wealth is about 0.02, with a final eventual effect of around 0.09.

Altissimo et al. (2005) show estimates of MPC and elasticities of wealth components for different countries and by different authors. Their results concerning the topic of the current paper are shown in Table A1 in Appendix A. Unfortunately, these results cannot be directly compared because their data is based on a different foundation and the essence of the calculation of MPC and/or elasticity also differs across studies. For example, Ludwig and

Slok (2002) use panel data for 16 OECD countries and use a pooled estimation technique, which fixes the elasticity of wealth components to be equal within groups (countries have been divided into two groups: market-based economies and bank-based economies). Ludwig and Slok (2002) have not calculated MPC of housing wealth. Altissimo et al. (2005), however, have calculated MPC of housing wealth based on Ludwig and Slok (2002) and data on total household wealth decomposition into financial and housing wealth, and reach the conclusion that the corresponding MPCs of housing wealth would be around 0.075 euro cents for Germany and around 0.05 euro cents for France and Italy. In market-based economies, the estimates would be smaller; for example, 0.013 cents per euro for the Netherlands, 0.117 for the UK and 0.02 for the USA.

Sierminska and Tahktamanova (2007) have also gathered several authors' estimates of MPC and elasticities of different wealth components (see Table A2 in Appendix A). As can be seen, some authors have calculated MPCs of housing wealth, others have calculated elasticities. Some have used aggregate data, others household level data. The elasticities of consumption with respect to changes in housing wealth range from 0.017 up to 0.17. The MPCs of housing wealth are in the range of 0.015 up to 0.14. The elasticities and MPCs calculated for the same country differ also from author to author.



The relationship between real estate value and private consumption in Estonia has been previously investigated in three papers. Paabut and Kattai (2007) use a consumption function similar to the consumption function in the macro model EMMA of the Bank of Estonia. They use data up to 2006 and, using the Granger-Engle two-step methodology, find that the elasticity of private consumption with respect to a change in real estate value is 0.011. The present paper includes the years of the GFC and some years after that, having a much longer time series (73 quarters). Also, the method, used in the current paper is different. In 2012, Šonje et al. used data for four European post-transition countries, including Estonia. They use three variables (private consumption, residential real estate value and net wages) and the elasticity of private consumption with respect to a change in real estate value is found to be 0.04. They use data up to the first quarter of 2010 and two methods are applied: threshold error correction and vector error correction models. In my paper, GDP is used as a proxy for income and household debt is used as an additional variable. Although it is not customary for Estonians to take, for example, a second mortgage on their residential space, we can expect that there is a relationship between housing value and private consumption in Estonia. When the market value of their property rises, the homeowner may reduce precautionary savings. Estonian banks also offer a mortgage loan that does not necessarily need to be used to buy real estate. According to Aben et al. (2012), whose paper focuses on housing equity withdrawal in Estonia, the secured loan stock rose far more than the household net investment in housing during the years 2004–2008.

## 3. Methodology

The methodology of this paper follows the vector autoregression modelling approach (Sims, 1980). First, tests for the order of the integration of the variables are carried out to describe the characteristics of the data. If all the time series appear to be I(1), cointegration techniques are used. In the current paper, the Ng–Perron unit root test and Kwiatkowski–Phillips–Schmidt–Shin (hereinafter KPSS) stationarity test are used. A maximum of two lags is used. The Ng–

Perron test takes account of the fact that the bias in the autoregressive coefficients is highly dependent on the lag and adapts to the type of deterministic components present (Ng and Perron, 2001). This test uses a modified information criterion which selects the lag length according to the sample size (as opposed to the Akaike information criterion and Scwartz or Bayesian information criterion, which tend to choose lag values that are generally too small for unit root tests to have good size). Kwiatowski et al. (1992) argue that the way in which classical hypothesis testing is carried out makes it more likely that the null hypothesis is not rejected unless there is strong evidence against it. They propose that an alternative explanation for the common failure to reject a unit root is simply that most economic time series are not very informative about whether or not there is a unit root. Kwiatowski et al. (1992) provide a test of the null hypothesis of stationarity against the alternative of a unit root.

As will be shown, the variables are I(1), hence the Johansen cointegration approach (trace and maximum eigenvalue tests) is used. The choice of lag length is based on the Akaike information criterion. If the results of the trace and maximum eigenvalue tests show that there is cointegration between the series of the model, cointegration relation is highlighted using a VECM, which is used because it allows the capture of the long-term equilibrium and short-term relationships between variables and study of how deviations from the long-run equilibrium are corrected. Also, the multicollinearity effect is reduced in the error-correction form of the VAR model, because the first differences of the variables tend to be less correlated than levels.

Since this paper is focused on how the real estate variable affects the private consumption variable, it is useful to normalize the cointegration relationship to private consumption by setting the coefficient to unity. First a long-run relationship is shown and then short-run adjustments are calculated (private consumption adjusts to its long-run relationship with lags). The equation for the VECM (following e.g. Lütkepohl and Krätzig, 2004) is as follows (matrix notation in bold):



$$\Delta X_t = \Phi X_{t-1} + \mu + \sum_{j=1}^{k} \alpha_{t-j} \, \Delta X_{t-j} + \varepsilon_t \qquad (2)$$

where $X_t$ is the vector of variables in the VECM ($\ln PC_t$, $\ln H_t$, $\ln GDP_t$, $\ln HD_t$) $\Phi$ is the vector of the adjustment coefficients of the long-term equilibrium equation, $\mu$ is the vector of intercepts of the short-run error correction model and $\alpha_{t-j}$ are the shortrun coefficients ($j$ is the number of lagged periods). The variable *PC* is seasonally adjusted private consumption, *H* is seasonally adjusted residential real estate stock value, *GDP* is seasonally adjusted *GDP* and *HD* is seasonally adjusted household debt. I expect the signs of the long-term coefficients of all these variables to be positive. The variables are characterized in more detail in the data section of the paper.

Weak exogeneity of each variable for the long-run parameters is also tested using VECM restrictions on adjustment coefficients. If an adjustment coefficient appears not to be significant, the respective restriction is kept in the model and the variable is considered to be a pushing force in the system but not being pushed by the system. In order to see how responsive each variable in the VECM is to shocks to each of the variables, impulse responses are calculated and shown graphically. Based on the impulse response functions, the long-term elasticity of private consumption with respect to a change in real estate stock value is estimated.

The MPCs of real estate value, based on the elasticity from the long-term relationship, are calculated, varying each period with the variables $PC_t$ and $H_t$. The MPCs show by how many euros private consumption changes if the real estate stock value index changes by one unit.

## 4. Data

Based on equation (1) shown in the literature review section, I construct a model with four quarterly variables: private consumption, residential real estate stock value, GDP and household debt. The data for private consumption and GDP is from Statistics Estonia and the data for household debt (the balance of housing loans and consumer loans) is taken from the statistics of the Bank of Estonia. The data for real estate value per square metre is from the Estonian Land Board and the number of square metres of existing residential real estate is calculated based on the population censuses of 2000 and 2011. All of the time series are in real values (nominal data is deflated, using the consumer price index from Statistics Estonia) and in natural logarithms, since using elasticities makes it easier to include households with real property of different value levels in the variable. As the main variable of interest of this paper is real estate stock value, this variable is explained more thoroughly below.

In order to do any calculations based on the value of real estate, it is necessary to specify how the value is estimated. Value is an estimation showing how much a property is worth. Real estate value in everyday appraisal practice (for residential real estate) is usually estimated using the sales comparison approach, meaning that the market value of residential real estate is based on the (historical) sales prices of comparable real properties; that is, value is estimated based on the magnitude of transactions. There is a full database of the sales transactions of real estate in Estonia: the transaction register of the Estonian Land Board. The data for the total value of residential real estate transactions is taken from that register, which is a database of all real property transactions in Estonia, including, for example, the address, the land size and the percentage of built area, but not including information about the condition of housing. The data is electronically sent to the Land Board by notaries. The transaction register was founded in 1997 and is part of the land cadastre. Only real estate appraisers who have a special licence issued by the Land Board can apply for data from the transaction register. Most of the larger real estate companies have a licenced appraiser and therefore they can buy data from the transaction register and in practice use it in their everyday real estate appraisal work. For this paper, public aggregated and systemized data has been used, while data for transactions has not been used. Quarterly data from 1997Q1 to 2015Q1 was available, so 73 periods are used in the analysis of this paper for all the time series, based on the availability of the transaction data starting from 1997.



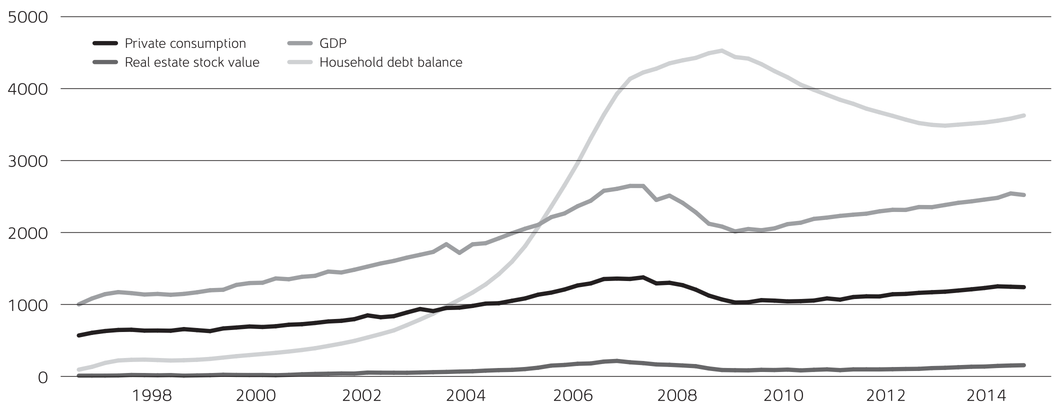
From 1 January 2002 until 19 July 2003, only data for transactions with the state's pre-emptive purchase right of real properties situated or reaching the building prohibition zone or reserve area was collected. For that reason, the number of transactions in the years 2002 and 2003 is very low and cannot be used in the analysis in its original form. Starting from the second half of 2003, data on transactions of apartment properties was also included in the transaction register. Only apartment properties marked as residential space are included in the apartment properties data (not all apartment properties are actually residential space). Data about apartment properties where the seller was the municipal government was also excluded.

In order to calculate estimates of the value of residential real estate, first the residential housing space (in square metres) in Estonia had to be found, and to that end the results of the population censuses of 2000 and 2011 were used. To obtain data for the other years, the number of square metres was linearly interpolated and extrapolated. It appears that from 1997 approximately 33–41% of the residential housing space has been in Harju County (including Tallinn). So the proportion was one-third but it has been growing steadily by around 3% a year. This is not surprising, since most of the new residential space has been built around Tallinn. In Tartu (the second-largest city in Estonia) and surroundings, the growth has been a bit less than 3% a year, being approximately 10% in 1997 and approximately 11.5% in 2014. The proportion of the total value of real estate transactions involving apartment properties is approximately 75% in Harju County (including Tallinn). The average proportion from all time periods of the value of other residential housing transactions is approximately 64% in Harju County (including Tallinn). So I make the assumption that 70% of the value of residential real estate housing stock is in Harju County (including Tallinn).

Based on the total value of residential real estate transactions, the transaction value per square metre was calculated for each county, separately for apartment properties and other residential housing properties. Unfortunately, the data for each county for the whole period was not available as there have been less than five transactions. For Harju County, data for total value of transactions and value of transactions per square meter were available from 2003Q3 until 2014Q4. From 1997Q1 until 2001Q4, information about transactions in regard to apartments was not available (because apartment properties were only included in the register from 2003), but it was available for other residential housing for that period. The values per square metre for the latter are available through the public search engine of the Land Board. It must be noted that the value of other residential housing besides apartment properties in the transaction register data reflects the value per square metre of the land on which the house is situated, not the number of square metres of the building. Therefore, the value per square metre is likely to be heavily underestimated.

In order to obtain the value of residential real estate (housing) stock, the respective index was multiplied by the respective type of space (in square metres). The seasonally adjusted value of the stock of residential real estate (value per square metre indexed, 1997=1, and multiplied by total number of square metres of residential real estate) is shown in Figure 1.

**Figure 1.** Seasonally adjusted data (EUR in millions, index for real estate stock value)




Note: All the variables, except real estate stock value, are in millions of euros; real estate value per square metre is indexed and multiplied by the number of square metres of existing residential real estate stock.

Since, as mentioned above, the data for total real estate value from 2002Q1 to 2003Q2 was not comparable with that of other periods, linear interpolation was used to recalculate the data for those six periods. Because of the nature and frequency of the data, seasonality was an issue; therefore, adjustments for seasonality were made using the X12 approach in Eviews.

To find the order of integration of the time series, I carried out unit root tests. The results of Ng–Perron unit root tests show that with the intercept as the deterministic component (Table 1), the null hypothesis of a unit root for all the time series cannot be rejected. I did the test also in first differences and, since in that case the null hypothesis of a unit root was rejected, I concluded that the time series are I(1). For robustness, I also tested for unit roots with the intercept and trend as the deterministic components, and these results (see Appendix B, Table B1) also suggest that all the time series are non-stationary.

**Table 1.** Ng–Perron unit root tests

| | MZa | MZt | MSB | MPT |
|---|---|---|---|---|
| ln*PC* | 0.284 | 0.231 | 0.814 | 41.981 |
| ln*H* | 2.696 | 1.639 | 0.608 | 38.750 |
| ln*GDP* | 0.459 | 0.392 | 0.853 | 47.200 |
| ln*HD* | 0.710 | 1.272 | 1.791 | 195.574 |



Notes: Intercept is taken as the deterministic component. The asymptotic critical values for 1%, 5% and 10% levels for MZa are −13.800, −8.100 and −5.700 respectively, for MZt are −2.580, −1.980 and −1.620 respectively, for MSB 0.174, 0.233 and 0.275 respectively and for MPT 1.780, 3.170 and 4.450 respectively (Ng and Perron, 2001).

For robustness analysis, an alternative test, the KPSS stationarity test, was also used. The results are shown in Table 2. The null hypothesis of the KPSS test is that the observable time series is stationary around a deterministic trend (Kwiatowski et al., 1992). The null hypothesis is rejected for all the time series with the intercept as the deterministic component, which means that all the time series are non-stationary. For robustness, the KPSS test was done also with the intercept and trend as the deterministic components (see Appendix B, Table B2), and these results also suggest that the time series are non-stationary.

**Table 2.** KPSS stationarity tests

| | LM-statistic |
|---|---|
| ln*PC* | 0.921 |
| ln*H* | 0.881 |
| ln*GDP* | 0.993 |
| ln*HD* | 1.040 |

Notes: Intercept is set as the deterministic component. The asymptotic critical values for 1%, 5% and 10% levels are with intercept and trend 0.216, 0.146 and 0.119 respectively and with intercept 0.739, 0.463 and 0.347 respectively (Kwiatowski et al., 1992).

Since the null hypothesis of a unit root was not rejected according to the Ng–Perron tests and the null hypothesis of stationarity was rejected according to the KPSS tests, and the time series appeared not to be of an order higher than one, then the time series can be considered to be integrated on the order one. Hence it is justified to test for cointegration and use the VECM to find the long-term equilibrium relation and the short-term adjustment.

## 5. Results

After finding unit roots for all the time series, cointegration was tested in order to find whether a VECM could be used and hence the long-term and short-term relationships between the variables could be modelled. The number of lags was chosen according to the lag length that minimizes the Akaike information criterion in the VAR model in levels minus one, because since VECM is in differences, the number of lags is smaller by one than in VAR in levels. The criterion suggested two lags; a lag length of two is in many cases sufficient to describe a rich dynamic structure (Juselius, 2006). According to the trace test and maximum eigenvalue test of the Johansen cointegration approach, one cointegration relationship with two lags is found using the intercept and no trend in the cointegration equation (Appendix B, Table B3). This means that, although all the time series appear to be non-stationary, there is a linear combination of the variables that is stationary, i.e. the residuals of this relationship are stationary.



After detecting cointegration between the time series, the relation between the four variables was modelled using a VECM. First the long-term estimates are presented and then short-term error correction estimates are shown. Earlier work on the relationship between residential real estate and private consumption in Estonia (Paabut and Kattai, 2007) has found cointegration in the long-term relationship; that particular paper was written before the GFC.

Equation (3) shows the long-term equilibrium relationship of the cointegrating variables. The coefficients of all the variables are statistically significant and the signs are positive, as expected based on theory and the results of most former studies on the topic. The positive coefficients of real estate stock value and GDP could already be expected based on the life-cycle model, which assumes a positive relationship between wealth, income and consumption. The positive coefficient of household debt can be explained by the increasing importance of consumer loans and, to some extent, also housing equity withdrawal.

$$\ln PC_{t-1} = 5.755 + \underset{(0.032)}{0.068}\ln H_{t-1} + \underset{(0.092)}{0.602}\ln GDP_{t-1} + \underset{(0.014)}{0.041}\ln HD_{t-1} \quad (3)$$

The short-term VECM estimates are shown in Table 3. According to the row of adjustment coefficients, 30.8% of the disequilibrium is corrected each quarter by changes in private consumption, 13.3% of the disequilibrium is corrected each quarter by changes in real estate stock value, 18.5% is corrected by changes in GDP and 45.6% by changes in household debt. The adjustment coefficients for real estate value and GDP are not statistically significant.

Table 3. VECM short-term estimates

| | $\Delta \ln H$ | $\Delta \ln GDP$ | $\Delta \ln HD$ | $\Delta \ln PC$ |
|---|---|---|---|---|
| Adjustment coefficient | −0.133<br>(0.902) | −0.185<br>(0.142) | 0.456<br>(0.106) | −0.308<br>(0.141) |
| $\Delta \ln PC_{t-1}$ | −0.271<br>(1.121) | 0.139<br>(0.176) | −0.363<br>(0.132) | −0.083<br>(0.175) |
| $\Delta \ln PC_{t-2}$ | 0.354<br>(0.996) | 0.421<br>(0.157) | −0.175<br>(0.117) | −0.072<br>(0.155) |
| $\Delta \ln H_{t-1}$ | 0.031<br>(0.271) | 0.054<br>(0.043) | 0.115<br>(0.032) | 0.046<br>(0.042) |
| $\Delta \ln H_{t-2}$ | 0.046<br>(0.260) | 0.034<br>(0.041) | 0.039<br>(0.031) | 0.091<br>(0.041) |
| $\Delta \ln GDP_{t-1}$ | 1.661<br>(1.044) | −0.284<br>(0.164) | 0.237<br>(0.123) | 0.179<br>(0.163) |
| $\Delta \ln GDP_{t-2}$ | 0.344<br>(1.000) | 0.041<br>(0.157) | 0.179<br>(0.117) | 0.130<br>(0.156) |
| $\Delta \ln HD_{t-1}$ | −0.060<br>(0.851) | 0.402<br>(0.134) | 1.050<br>(0.100) | 0.314<br>(0.133) |
| $\Delta \ln HD_{t-2}$ | −0.073<br>(0.703) | −0.309<br>(0.111) | −0.463<br>(0.083) | −0.158<br>(0.110 |
| Constant | 0.016<br>(0.024) | 0.003<br>(0.004) | 0.013<br>(0.003) | −0.002<br>(0.004) |

Notes: Intercept is set as the deterministic component, no VEC restrictions. Standard errors in parentheses.



Tests for weak exogeneity were performed next. If the null hypothesis for an adjustment coefficient being zero is not rejected, the variable in question can be considered a driving variable in the system: it pushes the system, but is not being pushed by it (Juselius & MacDonald, 2000). The results of the exogeneity test are shown in Table 4. As the null hypothesis of the adjustment coefficients for real estate stock value and GDP being zero together cannot be rejected, these adjustment coefficients are not significant at the 0.05 confidence level (together as well as separately). This means that, according to the test, those two variables influence the long-term stochastic paths of other variables in the system, but they are not influenced by the other variables. These restrictions are kept in the model, and real estate stock value and GDP are considered weakly exogenous for the long-term parameter. It could be argued that in an actual economy GDP depends, among other things, also on private consumption, but in this paper I consider GDP weakly exogenous, based on the statistical reasoning.

Table 4. Results for the weak exogeneity test of VECM variables

| Restriction | Chi-square | Probability |
|---|---|---|
| $A(\Delta \ln PC) = 0$ | 4.475 | 0.034 |
| $A(\Delta \ln H) = 0$ | 0.021 | 0.885 |
| $A(\Delta \ln GDP) = 0$ | 1.514 | 0.218 |
| $A(\Delta \ln HD) = 0$ | 15.186 | 0.000 |
| $A(\Delta \ln H) = 0$, $A(\Delta \ln GDP) = 0$ | 1.633 | 0.442 |

*Note*: A is the adjustment coefficient of the respective variable.

After putting the restrictions of the adjustment coefficients into the model, the long-term equation becomes:

$$\ln PC_{t-1} = 5.000 + \underset{(0.030)}{0.061}\ln H_{t-1} + \underset{(0.092)}{0.652}\ln GDP_{t-1} + \underset{(0014)}{0.033}\ln HD_{t-1} \quad (4)$$

The coefficients' magnitudes and signs have not changed much compared to the model with restrictions of adjustment coefficients and the coefficients are still statistically significant. The short-term VECM estimates of the adjusted model are shown in Table 5, where it can be seen that the adjustment coefficients of real estate stock value and GDP are set to zero, as the previous test suggested that they are weakly exogenous.

Table 5. VECM short-term estimates

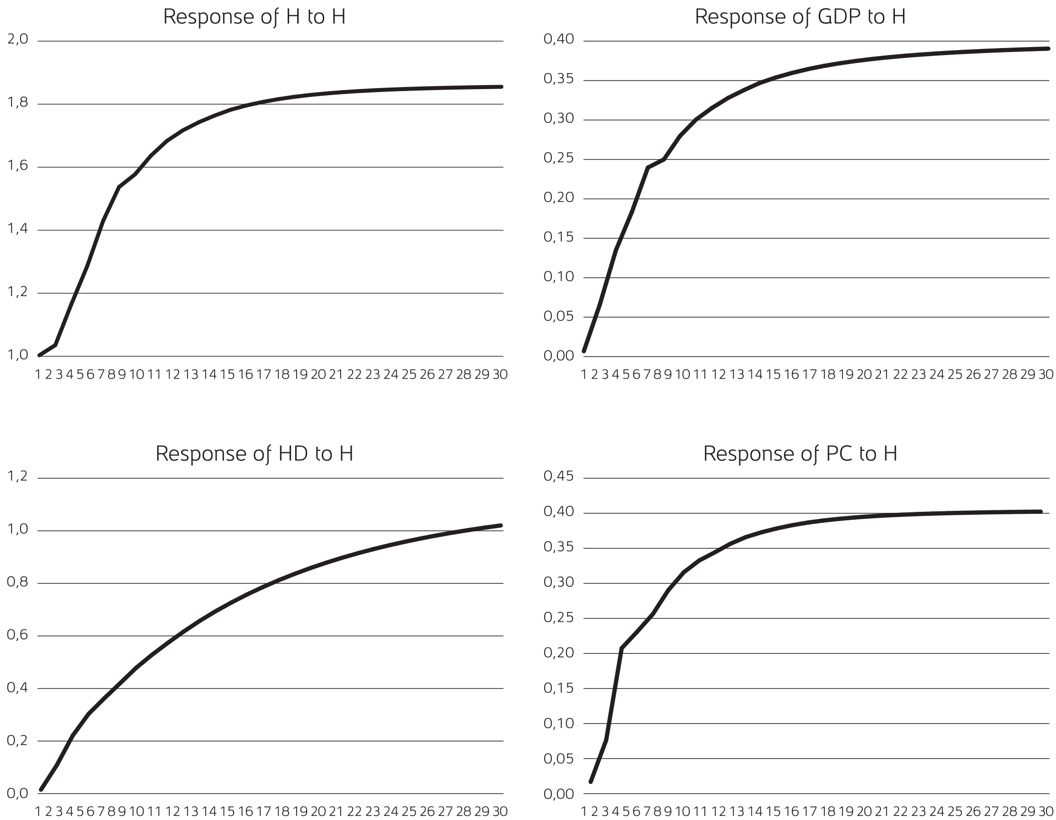
| | $\Delta\ln H$ | $\Delta\ln GDP$ | $\Delta\ln HD$ | $\Delta\ln PC$ |
|---|---|---|---|---|
| Adjustment coefficient | 0<br>– | 0<br>– | 0.504<br>(0.102) | −0.225<br>(0.114) |
| $\Delta\ln PC_{t-1}$ | −0.169<br>(1.122) | 0.119<br>(0.177) | −0.361<br>(0.132) | −0.078<br>(0.175) |
| $\Delta\ln PC_{t-2}$ | 0.410<br>(0.992) | 0.407<br>(0.157) | −0.168<br>(0.117) | −0.074<br>(0.155) |
| $\Delta\ln H_{t-1}$ | 0.026<br>(0.271) | 0.055<br>(0.043) | 0.113<br>(0.032) | 0.046<br>(0.042) |
| $\Delta\ln H_{t-2}$ | 0.042<br>(0.260) | 0.035<br>(0.041) | 0.039<br>(0.031) | 0.090<br>(0.041) |
| $\Delta\ln GDP_{t-1}$ | 1.542<br>(1.065) | −0.270<br>(0.168) | 0.254<br>(0.125) | 0.162<br>(0.166) |
| $\Delta\ln GDP_{t-2}$ | 0.266<br>(1.007) | 0.052<br>(0.159) | 0.187<br>(0.119) | 0.120<br>(0.157) |
| $\Delta\ln HD_{t-1}$ | −0.011<br>(0.851) | 0.393<br>(0.135) | 1.051<br>(0.100) | 0.316<br>(0.133) |
| $\Delta\ln HD_{t-2}$ | −0.056<br>(0.704) | −0.309<br>(0.111) | −0.468<br>(0.083) | −0.153<br>(0.110) |
| Constant | 0.014<br>(0.024) | 0.003<br>(0.004) | 0.013<br>(0.003) | −0.002<br>(0.004) |

*Notes*: Intercept is set as the deterministic component. VEC restrictions: the adjustment coefficients of real estate stock value and GDP are set to zero. Standard errors in parentheses.

In order to distinguish between permanent and transitory shocks to the system and to see the estimated responses of all the variables to an unexpected 1% increase in real estate stock value, impulse response functions were calculated. I ordered the variables according to decreasing exogeneity, starting with real estate stock value, since I assume that in the first period real estate stock value is affected only by its own shock, not by shocks in other variables. The next variables are GDP, household debt and private consumption. I assume that if real estate value grows, people feel that they are wealthier and immediately start consuming more. They take out, for example, a consumer loan. Additionally, if their income grows, they also immediately start consuming more. For robustness, I also tried other orders (placing real estate stock value as the second, third or fourth variable), but the results do not change very much. Hence the model is not very sensitive to the ordering of variables.

The impulse responses in Figure 2 show that a 1% shock in real estate stock value leads to a permanent increase in private consumption (see the bottom right graph), GDP and household debt (and on itself).

Figure 2. VECM impulse responses to 1% shock in real estate stock value



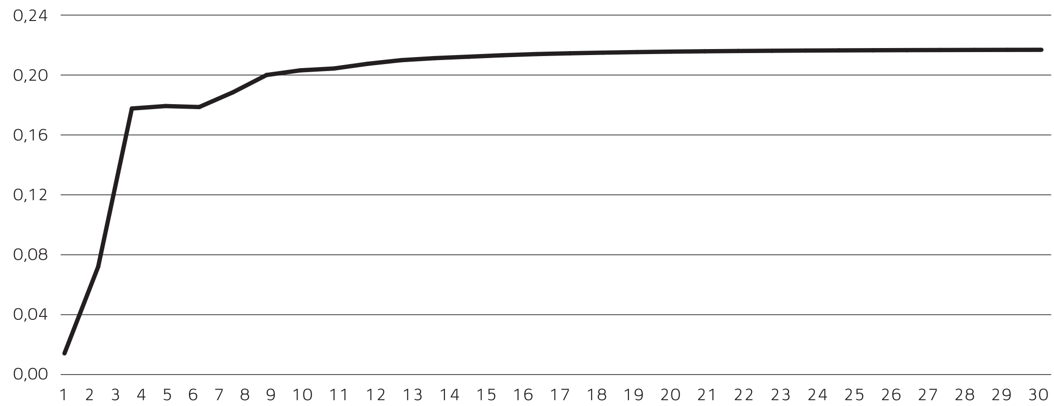

*Notes*: Intercept is set as the deterministic component. VEC restrictions: the adjustment coefficients of real estate stock value and GDP are set to zero.



The top left graph shows the response of real estate stock value and the other three graphs depict the responses of GDP, household debt and private consumption to an autoregressive shock in real estate stock value. The bottom right graph shows the response of private consumption to a 1% shock in real estate stock value. There is a small immediate response and a large response in the second half of the first year. After that the effect becomes smaller, until from the end of the fourth year it remains at the attained level. Hence, the effect of a shock in real estate stock value on private consumption is permanent.

The long-term elasticity of private consumption with respect to a change in real estate stock value was also calculated based on the IRFs and is plotted on Figure 3. It appears that a 1% change in real estate stock value leads to a 0.217% increase in private consumption in the long run. The initial effect is small, but it builds up in two years.

Figure 3. Long-term elasticity of private consumption with respect to real estate stock value

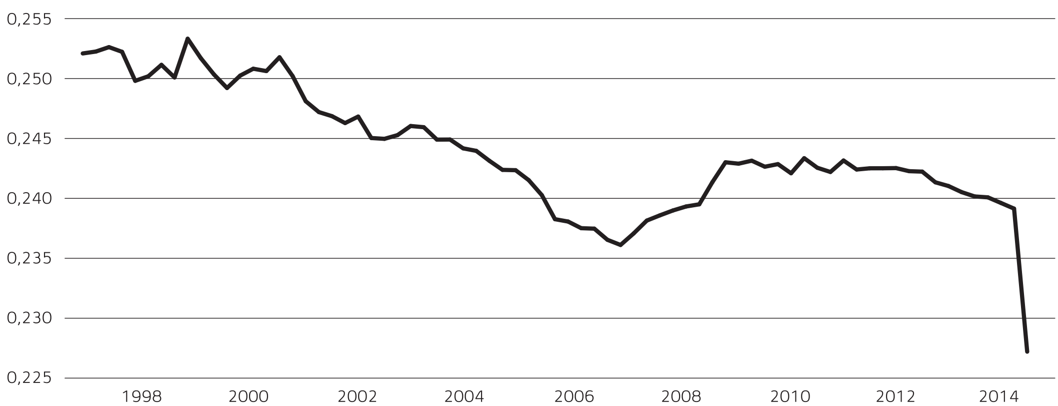



The estimated elasticity is large, compared to the findings of most previous authors. It may be assumed that one reason for this could be the high homeownership rate in Estonia. Another reason is likely the popularity of consumer loans in Estonia.

Quarterly MPCs were also calculated and they show how much private consumption changes when real estate stock value changes by one unit. The results are shown in Figure 4. It can be seen that the MPC fell remarkably during the GFC. This could show that people in Estonia were very cautious about spending money during the GFC – private consumption decreased more than the value of real estate stock.



Figure 4. The long-term marginal propensity to consume




For a robustness check, I replaced GDP with net personal wages as a proxy for income. Cointegration was detected between the variables of that alternative model also, but the long-term elasticities of private consumption with respect to a change in real estate stock value were not statistically significant when the trend and intercept were used as deterministic components. When only the intercept was used as a deterministic component, the elasticity was larger than one and hence is not economically reasonable; an elasticity of private consumption with respect to a change in real estate stock value larger than one would mean that if real estate value rose by 1%, then private consumption would rise by more than that. This would mean that a change in housing value would have an enormous effect on consumption and also that the MPC would be larger than one. This is not supported by theory, nor has it been detected by previous authors. The results of the robustness check are available from the author upon request.

## 6. Conclusions

This paper has focused on the effect on private consumption of changes in residential real estate stock value in Estonia, a post-Soviet country with a very high rate of homeownership. Four variables have been used: private consumption, real estate stock value, GDP and household debt; as VECM has been used, all these variables were considered to be endogenous. One cointegration relationship was found and hence there is a linear combination of the time series that is stationary.

Long-term and short-term cointegrating equations were estimated simultaneously and weak exogeneity tests were run to see which variables were pushing the system but were not pushed by it. Impulse responses were also studied to distinguish between permanent and transitory shocks, to examine the response of each variable to shocks in other variables and to show the long-term elasticity of private consumption with respect to a change in real estate stock value.



According to the impulse response functions, a shock in the real estate stock value has a positive and permanent impact on private consumption; the long-term elasticity, based on impulse response functions, appeared to be 0.217. This high value of elasticity may be at least partly due to the high homeownership rate and the popularity of consumer loans in Estonia. Research in Estonia conducted before the GFC concluded that the elasticity was 0.010 (Paabut and Kattai, 2007). By comparison, the period under observation in this study is much longer and the GFC and the years following it included. In the current paper, all variables were assumed to be endogenous, as opposed to Paabut and Kattai (2007), who used the Granger-Engle two-step methodology, which assumes one variable is endogenous and the others are exogenous. Another innovation of this paper is the estimation and presentation of impulse response functions, which allows distinguishing between and showing the persistence of the impact of a shock to housing stock value in relation to other variables.

A broader implication of the current paper is that, in a country where housing wealth is a very important part of household wealth, it is important to follow developments in the real estate market, since it has a significant impact on consumption. Also, the analysis is based on data from a country which witnessed a very large price increase before the GFC and a marked price fall during the GFC. This means that policymakers should keep a close eye on the dynamics of the housing market to identify and possibly prevent large booms and busts. The results of this paper could also be applicable to other Central and Eastern European countries that have experienced large booms and busts.

Further research could include a similar study for the three Baltic countries (separately as well as a panel regression) and possibly for other post-Socialist countries as well. There could also be a quantitative study on the influence of the owner-occupancy rate on private consumption.

## References

Aben, M., Kukk, M. and Staehr, K. 2012. Housing Equity Withdrawal and Consumption Dynamics in Estonia 2002-2011. *Research in Economics and Business: Central and Eastern Europe*, Vol. 4, No. 1, pp. 19-40.

Altissimo et al. 2005. Wealth and Asset Price Effects on Economic Activity. *ECB Occasional Paper Series*, No. 29.

Boone, L., Giorno, C. and Richardson, P. 1998. Stock Market Fluctuations and Consumption Behaviour: Some Recent Evidence. *OECD Economics Department Working Papers*, No. 208.

Brooks, C. 2011. *Introductory Econometrics for Finance* (2nd ed.), Cambridge University Press.

Browning, M., Gørtz, M. and Leth-Petersen, S. 2013. Housing Wealth and Consumption: a Micro Panel Study. *The Economic Journal*, Vol. 123, No. 568, pp. 401-428.

Campbell, J. Y. and Cocco, J. F. 2007. How Do Prices Affect Consumption? Evidence from Micro Data. *Journal of Monetary Economics*, Vol. 54, Iss. 3, pp. 591-621.

Carroll, C. D., Otsuka, M. and Slacalek, J. 2010. How Large are Housing and Financial Wealth Effects? *ECB Working Paper Series*, No 1283.

Case, K.E., Quigley, J.M. and Shiller, R.J. 2005. Comparing Wealth Effects: The Stock Market versus the Housing Market. *Advances in Macroeconomics*, Vol. 5, No. 1, pp. 1-32.

Cristini, A. and Sevilla, A. 2014. Do House Prices Affect Consumption? A Re-assessment of the Wealth Hypothesis. *Economica*, Vol. 81, No. 324, pp. 601-625.

Engle, R.F. and Granger, C.W.J. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, Vol. 55, No. 2, pp. 251-276.

Gali, J. 1990. Finite Horizons, Life Cycle Savings and Time Series Evidence on Consumption. *Journal of Monetary Economics*, Vol. 26, No. 3, pp. 433-452.

Gan, J. 2010. Housing Wealth and Consumption Growth: Evidence from a Large Panel of Households. *The Review of Financial Studies*, Oxford University Press.

Girouard, N. and Blöndal, D. 2001. House Prices and Economic Activity. *OECD Economics Department Working Papers*, No. 308.

Johansen, S. 1991. Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*, Vol. 59, No. 6, pp. 1551-1580.

Johansen, S., Mosconi, R. and Nielsen, B. 2000. Cointegration Analysis in the Presence of Structural Breaks in the Deterministic Trend. *Econometrics Journal*, Vol. 3, No. 2, pp. 216-249.

Juselius, K. and MacDonald, R. 2000. Interest Rate and Price Linkages between the USA and Japan: Evidence from the Post-Bretton Woods Period. *Discussion Papers: Department of Economics*, University of Copenhagen.

Juselius, K. 2006. *The Cointegrated VAR Model: Methodology and Applications*. Oxford University Press.

Kwiatowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. 1992. Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root. How Sure are we that Economic Time Series Have a Unit Root? *Journal of Econometrics*, Vol. 54, pp. 159-178.

Ludwig, A. and Slok, T. 2002. The Impact of Changes in Stock Prices and House Prices on Consumption in OECD countries. *IMF Working Paper*, No. WP/02/1.

Lütkepohl, H. and Krätzig, M. 2004. *Applied Time Series Econometrics*. Cambridge University Press.

MacKinnon, J.G. 2010. Critical Values for Cointegration Tests. *Queen's Economics Department Working Paper*, Queen's University, No. 1227.

Modigliani, F. 1966. The Life Cycle Hypothesis of Saving, the Demand for Wealth and the Supply of Capital. *Social Research*, Vol. 33, No. 2, pp. 160-217.

Muellbauer, J. and Lattimore, R. 1995. The Consumption Function: a Theoretical and Empirical Overview. *Handbook of Applied Econometrics: Macroeconomics*. Blackwell Publishing, Oxford, pp. 221-311.

Ng, S. and Perron, P. 2001. Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power. *Econometrica*, Vol. 69, No. 6, pp. 1519-1554.

Paabut, A. and Kattai, R. 2007. Kinnisvara väärtuse kasvu mõju eratarbimisele Eestis. [The Growth of Real Estate Value on Private Consumption in Estonia]. *Eesti Pank Working Papers*, No. 5/2007.

Pachebo, L.M. and Barata, J.M. 2005. Residential and Stock Market Effects on Consumption across Europe. *European Journal of Housing Policy*, Vol. 5, No. 3, pp. 255-278.

Phillips, P.C.B. and Ouliaris, S. 1990. Asymptotic Properties of Residual Based Tests for Cointegration. *Econometrica*, Vol. 58, No. 1, pp. 165-193.

Poterba, J. 2000. Stock Market Wealth and Consumption. *Journal of Economic Perspectives*, Vol. 14, No. 2, pp. 99-119.

Rao, B. B. 2007. Estimating Short and Long Run Relationships: A Guide for the Applied Economists. *Applied Economics*, Vol. 39, No. 13, pp. 1613-1625.



Sierminska, E. and Tahktamanova, Y. 2007. Wealth Effects out of Financial and Housing Wealth: Cross Country and Age Group Comparisons. *Federal Reserve Bank of San Francisco Working Paper*, No. 2007-01.

Sims, C. A. 1980. Macroeconomics and Reality. *Econometrica*, Vol. 48, No. 1, pp. 1-48.

Slacalek, J. 2009. What Drives Personal Consumption? The Role of Housing and Financial Wealth. *ECB Working Paper Series*, No. 1117.

Šonje, A. A., Časni, A. Č. and Vizek, M. 2012. Does Housing Wealth Affect Private Consumption in European Post-Transition Countries? Evidence from Linear and Threshold Models. *Post-Communist Economies*, Vol. 24, No. 1, pp. 73-85.

Talpsepp, T. 2010. Does Gender and Age Affect Investor Performance and the Disposition Effect? *Research in Economics and Business: Central and Eastern Europe,* Vol. 2, No. 1, pp. 76-93.

Tang. K.-K. 2006. The Wealth Effect of Housing on Aggregate Consumption. *Applied Economics Letters*, Vol. 13, No. 3, pp. 189-193.

Vizek, M. 2010. Short and Long Run Behaviour of House Price in Eastern European Countries: a Comparative Approach. *Privredna Kretanja I Ekonomska Politika*, Vol. 10, No. 125, pp. 27-60.

Zhou, J. 2010. Testing for Cointegration between House Prices and Economic Fundamentals. *Real Estate Economics*, Vol. 38, No. 4, pp. 599-632.

Eurostat Statistics Explained 2015, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Housing_statistics (22.01.15)

# Appendix A
## Estimates of MPCs and Elasticities in Different Countries

**Table A1.** Estimates collected by Altissimo et al. (2005)

| | BE | FR | DE | IT | NL | PT | SP | SE | UK | US | CA | JP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ludwig and Slok (2002) | | | | | | | | | | | | |
| $MPC_W$ | | 1.4 | 2.0 | 3.0 | | | | | 4.9 | 4.0 | 4.0 | 4.0 |
| $e_H$ | | 0.11 | 0.11 | 0.11 | 0.03 | | | 0.03 | 0.03 | 0.03 | 0.03 | 0.11 |
| Bertraut (2002) | | | | | | | | | | | | |
| $MPC_W$ | | | | | | | | | 4.3 | 5.4 | 8.3 | |
| $MPC_H$ | | | | | | | | | | 9.7 | | |
| $e_H$ | | | | | | | | | 0.09 | 0.14 | 0.16 | |
| Labhard, Sterne and Young (2005) | | | | | | | | | | | | |
| $MPC_W$ | 0.7 | 0.8 | 7.8 | 2.8 | 1.3 | -1.0 | 3.6 | | 5.6 | 3.7 | 7.8 | 4.2 |
| $e_W$ | 0.03 | 0.10 | 0.13 | 0.08 | 0.06 | -0.02 | 0.07 | | 0.16 | 0.12 | 0.19 | 0.16 |

*Source*: Altissimo et al. (2005).
*Note*: If the author(s) have calculated MPC and/or elasticity of housing wealth separately from total wealth, the indicator has been shown here. Otherwise MPC/elasticity of total wealth has been shown.



**Table A2.** Estimates collected by Sierminska and Takhtamanova (2007)

| | $MPC_H$ | $e_H$ | Country |
|---|---|---|---|
| Davis & Palumbo (2001) | 0.08 | | U.S.A. |
| Pichette & Tremblay (2003) | 0.06 | | Canada |
| Carroll (2004) | 0.09 | | U.S.A. |
| Case, Quigley & Schiller (2005) (aggregate data) | | 0.11–0.17 | Panel of 14 developed countries |
| Dvornak & Kohler (2003) | 0.03 | | Australia |
| Case, Quigley & Schiller (2005) (state-level data) | | 0.05–0.09 | U.S.A. |
| Disney, Henley & Jevons (2003) | 0.09–0.14 | | U.K. |
| Campbell & Cocco (2005) | | 0.017 | U.K. |
| Grant & Pelton (2005) | 0.014 | | Italy |
| Lehnert (2004) | | 0.04–0.05 | U.S.A. |
| Bostic, Gabriel & Painter (2005) | | 0.06 | U.S.A. |
| Bover (2005) | 0.015 | | Spain |

*Source*: Sierminska and Takhtamanova (2007).

# Appendix B

**Table B1.** Ng–Perron unit root tests (intercept and trend)

| | MZa | MZt | MSB | MPT |
|---|---|---|---|---|
| ln*PC* | −2.393 | −1.007 | 0.421 | 34.468 |
| ln*H* | −4.229 | −1.265 | 0.299 | 19.786 |
| ln*PW* | −5.360 | −1.571 | 0.293 | 16.787 |
| ln*GDP* | −5.123 | −1.523 | 0.297 | 17.457 |
| ln*HD* | 0.148 | 0.088 | 0.592 | 79.693 |

*Note*: The asymptotic critical values for 1%, 5% and 10% levels for MZa are −23.800, −17.300 and −14.200 respectively, for MZt are −3.420, −2.910 and −2.620 respectively, for MSB are 0.143, 0.168 and 0.185 respectively and for MPT 4.030, 5.480 and 6.670 respectively (Ng and Perron, 2001).

**Table B2.** KPSS stationarity tests

| | LM-statistic (intercept & trend) |
|---|---|
| ln*PC* | 0.221 |
| ln*H* | 0.192 |
| ln*PW* | 0.225 |
| ln*GDP* | 0.227 |
| ln*HD* | 0.247 |

*Note*: The asymptotic critical values for 1%, 5% and 10% levels are with intercept and trend 0.216, 0.146 and 0.119 respectively and with intercept 0.739, 0.463 and 0.347 respectively (Kwiatowski et al., 1992).

**Table B3.** Johansen test

**Trace test**

| Hypothesized no. of cointegrating equations | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.416 | 64.359 | 47.856 | 0.001 |
| At most 1 | 0.243 | 26.681 | 29.797 | 0.110 |
| At most 2 | 0.091 | 7.192 | 15.495 | 0.555 |

**Maximum eigenvalue test**

| Hypothesised no. of cointegrating equations | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.416 | 37.678 | 27.584 | 0.002 |
| At most 1 | 0.243 | 19.488 | 21.132 | 0.084 |
| At most 2 | 0.091 | 6.666 | 14.265 | 0.529 |

* denotes rejection of the hypothesis at the 0.05 level ** MacKinnon-Haug-Michelis (1999) p-values

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