CHARLES UNIVERSITY

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Institute of economic studies

Andrea Rákosníková

Determinants of residential real estate prices in the Baltic States

Bachelor thesis

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Author: Andrea Rákosníková

Supervisor: PhDr. Michal Hlaváček, Ph.D.

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Abstract

The burst of the housing bubble on the US market that contributed to the start of the Great Recession was a warning sign to many economists. Consequently, the last decade birthed important studies analysing the real estate market in the search for the driving determinants of the housing prices. This thesis continues these efforts by time series analysis of the residential real estate determinants in Estonia, Latvia, and Lithuania. The VECM analysis showed that the importance of classic housing determinants differs from country to country. The price persistence is a crucial determinant of Baltics housing prices in the short run, but only Estonia and Lithuania showed this persistence in the long run. Latvian house price index seems to be very affected by the construction cost index and therefore supply side of the housing market. The model also suggested an unexpected negative relationship between house and rent prices. The analysis was however done on relatively short time series, and that could cause some smaller discrepancies in the results as well. The author also used the P/I and P/R ratios and the Hodrick-Prescott filter to analyse the housing prices in search of possible overvaluation and concluded that these measures do not seem to indicate the existence of the housing bubble in Baltic countries.

Keywords

Housing prices determinants, residential housing, Baltic countries, time series analysis, housing bubble, endogenous model, VECM.

Range of thesis: 81 800 characters

Abstrakt

Splasknutí nemovitostní bubliny na americkém trhu, jež přispělo k začátku Velké recese, bylo varovným znamením pro mnoho ekonomů. V důsledku toho bylo v minulém desetiletí napsáno nespočet studií zabývajících se identifikací determinantů cen nemovitostí ve snaze najít důvod pro jejich fluktuaci. Tato práce na zmíněný výzkum navazuje a pokouší se jej rozšířit pomocí analýzy časových řad za účelem identifikace determinantů cen rezidenčních nemovitostí v Estonsku, Lotyšsku a Litvě. VECM analýza prokázala rozdílný vliv determinantů na jednotlivé země. Z krátkodobého hlediska jsou ceny nemovitostí v Baltských státech určeny především svými zpožděnými hodnotami, tento vztah byl ale v dlouhodobém horizontu potvrzen pouze v Estonsku a Litvě. Lotyšský nemovitostní cenový index je na druhou stranu signifikantně ovlivněný vývojem indexu cen výstavby, a tedy nabídkovou cenou trhu. Model také indikuje nečekaný negativní vliv nájmů na ceny nemovitostí, poukazující na možnou nutnost transformace nájemního trhu v Baltských státech. Je nutné poznamenat, že analýza byla provedena na relativně krátkých časových řadách, což může také vysvětlit drobné nesrovnalosti ve výsledcích. Dodatečně byla provedena P/I a P/R analýza a na data o nemovitostním cenovém indexu byl aplikován Hodrick-Prescott filtr. Žádná z těchto metod neprokázala existenci realitní bubliny na trhu Baltských států.

Klíčová slova

Determinanty cen nemovitostí, rezidenční nemovitosti, Baltské státy, analýza časových řad, realitní bublina, endogenní model, VECM.

Rozsah práce: 81 800 znaků

Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague, July 25, 2020 Andrea Rákosníková

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I would like to express my deepest gratitude to my supervisor, PhDr. Michal Hlaváček Ph.D., for his guidance, useful advice, and wiliness to help.

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Acronyms

(A)DF test	(Augmented) Dickey-Fuller Test
AIC	Akaike's Information Criterion
BIS	Bank for International Settlements
CCI	Construction Cost Index
CEE(C)	Central and Eastern European (Countries)
CIS	Commonwealth of Independent States
(D)OLS	(Dynamic) Ordinary Least Square
ECT	Error Correction Term
EU	European Union
FDEV	Forecast Error Variance Decomposition
FPE(C)	Final Prediction Error (Criterion)
HICP	Harmonized Index of Consumer Prices
HP filter	Hodrick–Prescott Filter
HPI	House Price Index
HQ	Hannah–Quinn Criterion
I(0/1/2)	Integrated of Order Zero/One/Two
IRF	Impulse Response Function
KPSS test	Kwiatkowski–Phillips–Schmidt–Shin Test
NATO	North Atlantic Treaty Organization
OECD	Organization for Economic Co–operation and Development
P/I (ratio)	Price to Income (ratio)
P/R (ratio)	Price to Rent (ratio)
PP test	Phillips–Perron test
RPI	Rent Price Index
RPPI	Residential Property Price Index
SC	Schwarz Criterion
USSR	Union of Soviet Socialist Republics
VAR	Vector Autoregression
VEC(M)	Vector Error Correction (Model)

Bachelor's Thesis Proposal

Institute of Economic Studies
Faculty of Social Sciences
Charles University in Prague

Author's name and surname: Andrea Rákosníková

E-mail: 40937665@fsv.cuni.cz

Phone: 775 268 293

Supervisor's name: PhDr. Michal Hlaváček, Ph.D.

Supervisor's email: michal.hlavacek@unrr.cz

Notes: Please enter the information from the proposal to the Student Information System (SIS) and submit the proposal signed by yourself and by the supervisor to the Academic Director ("garant") of the undergraduate program.

Proposed Topic:

Determinants of residential real estate prices in the Baltic States

Preliminary scope of work:

Research question and motivation

The aim of this thesis is to identify specific determinants that influence supply and demand for residential properties in the Baltic States, and subsequently to determine their impact on the real estate prices. I will also try to determine how similar the real estate markets in Latvia, Lithuania and Estonia are in order to find out if they differ in some essential factors. I will also try to highlight the most significant differences between determinants affecting Baltic prices compared to other European countries.

Both theoretical and empirical part of this thesis will mainly focus on the events of the last two decades, which is the time period when the prices of real estate significantly fluctuated. It was caused by both internal and external influences like the global financial crises, the entry of examined countries to the EU or the subsequent adoption of euro as the national currency. This thesis will also focus on the housing bubbles in Baltic States, whether the ones that appeared there in the past or possibly the one that is there in the present, if empirical part of this thesis will support its existence.

Contribution

It is necessary to constantly monitor how property prices change and what is main reason for it, as these changes affect not only individual economic entities but also the economy as a whole. This thesis will analyze this for Baltic States in order to show, if situation changed in comparation with older available academic work. For this purpose I will reference the paper by Laura Tupenaite, Loreta Kanapeckiene and Jurga Naimaviciene Determinants of Housing Market Fluctuations: Case Study of Lithuania from year 2017, which unfortunately relate only to situation in one of examined countries. For this reason, I will also compare my results to study Determinants of House Prices in Central and Eastern Europe, which was written by Balázs Égert and Dubravko Mihaljek.

This work will also compare the situations on the real estate markets in major cities of Baltic States for better comparation of the individual states.

Methodology

Practical part of this thesis will firstly introduce and describe the data sets. I will use data files from numerous sources, but mainly from Eurostat and Statistical office of Lithuania, Estonia and Latvia. Some additional data may also be found on the sites of central banks of examined countries and on the site of real estate agency Ober Haus.

Next, I will introduce econometrics method that will be used in my thesis. I will explain its main purpose and in which way it could be problematic.

Outline

1. Abstract
2. Introduction
3. Theoretical framework and literature overview
4. Empirical part – data and methodology
5. Results and their interpretation
6. Conclusion
7. References

List of academic literature:

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1 Introduction

The real estate market has always been the object of economists' interest, and not just because of its importance to the economy, but also because of its complicated nature and susceptibility to the housing market bubbles. The economic crisis in 2008, triggered by the burst of the US real estate market bubble, was good indicator of just how much trouble can imbalance on the housing market cause. The crisis spread from the US to the rest of the world at lightning speed, causing the worst recession since the 1930s, leaving the economy paralyzed (Aiginger, 2009).

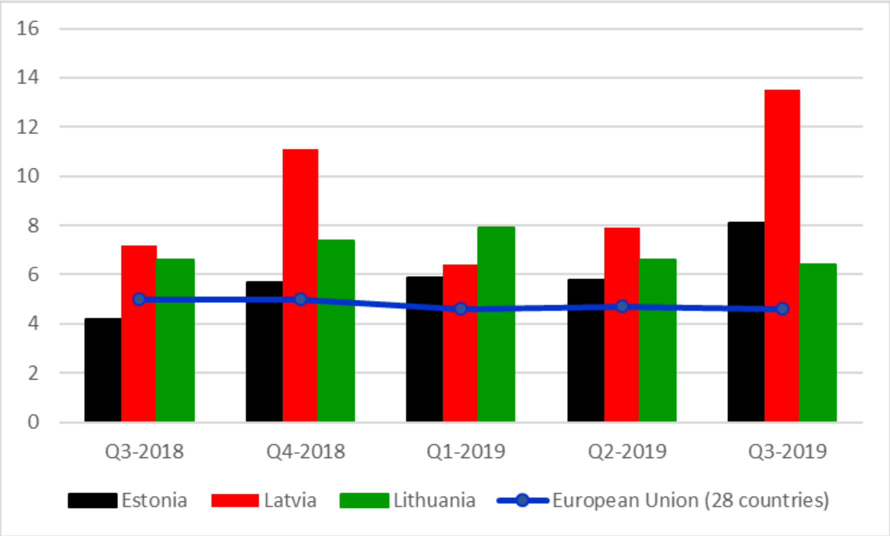
The risk surrounding the real estate market is always present; it needs to be monitored to eliminate potential threats. The burst of the housing bubble is worse than the burst of the stock market bubble in both reality and theory (O'Toole, 2012). This thesis aims to analyse the real estate market in the Baltic States, introduce its dynamic, and pinpoint the effect of individual determinants of the housing prices in each of the Baltic countries.

The Baltic States are tied by more than just geographic location. They share history, similar population, area, trade partners, and other resemblances that make them similar enough to compare while still being unique countries with independent and differently developed markets.

The residential property price index of the Baltic States from the third quarter of the year 2019 shows that the change on the same period for the previous year for Latvia equals 13.5%, which is the most significant change among all EU member states.[1] The average of all EU countries equals 4.6%, and both Estonia and Lithuania also exceed this average considerably, as their change in RPPI, in comparison to previous year, is 8.1% and 6.4%, respectively.

[1] The RPPI is calculated from sales of both existing and newly built dwellings, and data were taken from the OECD web page.

Figure 1: The change in RPPI of the Baltics in comparison to previous year (%)



Source: OECD

Figure 1 compares data for the RPPI index for the last five available quarters of the year, showing the fluctuation of property prices. This thesis aims to determine which factors are responsible for these changes in property prices, how big their effect is, and how significant they are. Countries will be analysed individually and then compared to show how the real estate markets of the Baltic States differ.

The theoretical part will be started by the literature review that will present existing studies and papers dealing with a similar topic as this thesis, and that will shortly summarize used methods and results. We will follow the literature overview by the brief introduction of essential terms and main properties of the housing market. Lastly, the dynamic of the real estate market of Baltics will be explained, and the possible determinants of the housing prices will be introduced in the context of the existing literature.

The empirical part of this thesis will focus on how the individual determinants affect housing prices. First we will introduce the collected data and their intended usage. We will explain the problems caused by the nature of the data and fix them if possible. Then we will introduce the endogenous models that we intend to use in this thesis, specifically the VAR and VEC models, and that will be followed by the actual analysis and interpretation of the results. We will also briefly touch on the issue of the housing bubbles and analyse the Estonian, Latvian, and Lithuanian markets using the P/I and P/R ratios, and the HP filter.

2 Literature review

After the burst of the housing bubble in 2008, economists tried to identify its exact cause and impacts on the real estate market. That gave rise to countless studies and papers whose primary purpose was to analyse the real estate market, identify its specific problems, and find ways to prevent similar situations. As a result, the literature related to the determinants of housing prices was extended as well. The Baltic countries were, however, always partially overlooked in both older and more recent studies, and literature that concentrates on the dynamic of the real estate markets of Estonia, Latvia, and Lithuania is therefore limited. This part of the thesis will introduce and shortly summarize crucial studies, starting with the most relevant ones.

Égert & Mihaljek (2007) examine the determinants of housing prices for the 8 transition countries of the Eastern and Central Europe and 19 developed non-transition member states of the OECD. Their study seems to be, to this day, the most relevant and extensive study of the real estate market of CEE countries. Authors use the panel analysis to pinpoint determinants specific to the chosen countries. That showed to be quite problematic as it was hard for them to collect comparable data, especially for the transition economies. That limits the possible approaches to the model, which can, due to the structure of the data, obtain only a few explanatory variables. Their analysis showed that the house prices in all examined countries, including Estonia and Lithuania[2], are strongly affected by interest rates, housing credit, and GDP per capita.

Bibolov & Poghosyan & Stepanyan (2010) followed this study with their paper, which focuses on identifying short and long term house price determinants in the countries of the former Soviet Union. Like Égert & Mihaljek (2007), the authors used the panel data analysis but chose a different approach, as they used the pooled mean group estimator method. Contrary to the previous studies, they also used the lagged variables and included the worker's remittances and foreign inflows in their model. The analysis revealed that the remittances, foreign inflows, and real GDP are significant determinants of the housing prices in all former Soviet Union countries, including the Baltic States.

Kanapeckiene & Naimaviciene & Tupenaite (2016) analysed the situation at the Lithuanian real estate market in the context of the financial crisis. They concentrate on

[2] Latvia was not included in the study.

the period of ten years (from 2005 to 2015) when the Lithuanian real estate market went from the extreme price growth to recession. Before the crisis hit, the flat prices in Lithuanian biggest cities rose at a record pace, accordingly by 50-120 percent a year. Interestingly, the country was one of the first to recover as in 2014 it already recorded the price growth in the real estate sector. To find the determinants behind this fast market recovery, the authors use the analytic hierarchy process. The study also splits the determinants of fluctuation into two groups – rational (economic and market indicators) and irrational (expectations of the customers and other hard to measure factors). The analysis showed that the rational economic indicators, primarily the interest rate and inflation, are the main drivers of the change in the housing prices. The rational market indicators are also significant; the irrational indicators, on the other hand, proved to be irrelevant. As we cannot include these irrational factors in our models, the findings of this study show us that it does not pose a big problem.

The same topic of the Lithuanian real estate market was also covered in study by Gaspareniene & Remeikiene & Skuka (2017). In this study, authors are examining the data for the average price of one square meter of a two-room apartment in big Lithuanian cities using the regression analysis to figure out the effect of major macroeconomics determinants on the price of housing. Regression analysis confirmed that the tested factors – interest rate, inflation, and availability of the debt financing – all significantly affect the price level of housing. However, the GDP showed up to be insignificant in the tested time period (2008-2015).

Kulikauskas (2016) decided to fill in the blanks in existing literature with his study, which focuses solely on the analysis of the housing prices in the Baltic countries. The author tries to determine whether there was any way to forecast the problems the real estate market faced before and during the crisis. He uses the P/I ratio, P/R ratio, and Hodrick-Prescott filter to explore if there were any significant changes in them before the crisis hit. He concluded that the market was showing signs of imbalances since 2005. While this thesis will not use the panel regression to analyse the determinants of housing prices as Kulikauskas did, it will expand on the overvaluation analysis that consists of the calculation of the P/I and P/R ratios, and their consequent evaluation, and of the usage of the HP filter. Therefore, if the housing prices in the Baltics are overvalued or undervalued, these methods should help uncover it.

Cohen & Karpavičiūtė (2017) used the multiple regression and the Granger causality test to analyse the Lithuanian housing market. Authors were motivated to write their study because existing literature seems not to be able to agree on which determinants of housing prices in Lithuania are significant. They pointed out that unemployment was examined in the context of its relationship with Lithuanian housing prices only twice before. The relationship between the interest rate and the average housing prices in Lithuania was also unclear. Some papers claimed that the interest rate is a significant determinant of housing prices, while others were not able to prove this. The Granger causality test yielded interesting results, as it has shown that the housing prices are a causal determinant of the interest rate and not the other way around. Their regression analysis has shown that unemployment, GDP, and the introduction of the means of the macroprudential policy are the only significant determinants of the average housing prices.

Vizek & Posedel (2009) wrote a study that compares two groups of European countries – the transition (Croatia, Estonia, and Poland) countries and developed EU-15[3] (Spain, United Kingdom, and Ireland) countries. Their paper aims to analyse these countries in an attempt to find the determinants that contributed to the extreme house price growth in transition countries using the Vector Autoregressive model. Similarly to this thesis, the results were then accessed by the variance decomposition and impulse response functions. The results for individual countries differed, and authors were unable to identify a single determinant that would significantly affect all analysed countries. However, the past values of housing prices and the volume of housing loans significantly affected the present value of housing prices in all the transition countries. Vizek (2010) expanded on this paper, using the Error Correction model to analyse the determinants of housing prices in Eastern and Western Europe. Author concluded that the housing prices are driven especially by their price resistance and also by income.

Difficulties that may occur when working with the housing data are explained by Hildebrandt & Martin & Steiner & Wagner (2012) in their study about real estate markets in ten countries of Central, Eastern, and South-eastern Europe. The paper focuses on the affordability, explaining the movement in housing prices after the crisis in 2008.

[3] OECD Glossary of Statistical Terms defines the EU-15 countries as "number of member countries in the European Union prior to the accession of ten candidate countries on 1 May 2004".

According to the authors, the extreme fall in housing prices that followed the burst of the housing bubble was disproportional to fall in other variables, including the real wages.

While the previously mentioned papers are influential in their field of study, we can see that the literature concerning the Baltic States mostly lacks individual time series analysis of specific countries. We will now briefly mention studies that do not specifically target Baltic countries but use the endogenous models to identify the determinants of housing prices in other countries. Sutton (2002) used the VAR model to analyse the determinants of housing prices – GNP, stock prices, and interest rate – in six advanced countries. While this study is not extensive and uses very short time series, the author showed that the effect of individual determinants differs among the countries. While the shock in GNP evokes a relatively large positively oriented response in housing prices in Ireland, the response to the same shock is in US small in comparison.

This paper was followed by a similar study by Tsatsaronis & Zhu (2004) that compared the importance of specific determinants of housing price among 17 countries, using the Structural Vector Autoregressive model. The authors used the panel version of this model and divided the 17 countries into groups. That was also necessary due to the small sample size of individual countries. As the authors used the nominal housing prices, inflation was an especially important determinant.

Lastly, the Marku & Lleshaj & Lleshaj (2020) did use the Vector Error Correction model to analyse the long run relationships between the house price index and numerous determinants (CCI, currency exchange rate, the interest rate of loans, and national mortgage loan) of housing prices. The authors were able to find four cointegrating vectors among the five endogenous variables in the model, showing that the housing prices and its determinants move together in the long run.

3 Theoretical Background

3.1 Introduction of the real estate market properties and terminology

The real estate market is, in many aspects, different from the other markets. For better understanding, Jowsey (2011) listed these differences as follows:

Durability – The housing may not last forever, but its lifespan is longer than that of the common good. Even though it is not possible to determine the exact lifespan of the house or flat, the Swiss Life page estimates it to be, on average, 70 to 100 years[4]. Because of this, the housing supply is made not only by the newly-built dwellings, but also by the existing dwellings that are resold.

Heterogeneity – The determination of housing prices is complicated because there are not two flats or houses that are in all regards identical. The property can differ in location, building material, or solely orientation of the windows in a specific cardinal direction.

High transaction costs – While the purchase of the housing is very costly, the transaction costs make the entire process even more expensive. These additional fees can be associated with searching for the housing (real estate agent), administration, or moving process. According to the Global Property Guide, the transaction costs in Tallinn (Estonia) are equal to 4,08%, in Riga (Latvia) to 6,11%, and in Vilnius (Lithuania) to 3,44% of the property value[5].

Speculation – The property speculation is defined by Collins dictionary as "the buying or selling of property in the hope of deriving capital gains" (Collins English Dictionary). This principle may seem straightforward, but it complicates the pricing process, as it makes the real estate not only consumption good consumed by the families, but possibly the investment good as well. While consumers prefer to buy the housing when the prices are low, which is in agreement with a typical supply-demand model (lower the price, higher the demand), investors sometimes continue to buy real estate even when the price increases. Gao & Sockin & Xiong (2019) explained that the investors drive

[4] Renato Pifferatti estimated these numbers.

[5] The Global Property Guide page considers four main costs while calculating the overall transaction costs: registration costs, real estate agent costs, legal fees, and sales and transfer taxes.

the housing prices higher and higher, often contributing to the creation of the housing bubble that would not form otherwise.

Time-lags – Both demand and supply are practically inelastic in the short run. The demand side of the market can adjust faster because, unlike the supply side, it is not limited by factors like the shortage of land, construction period, or the time it takes to get the building permit. However, that does not change the fact that the real estate market is prone to both demand and supply surpluses.

These specific properties make the identification of the real estate determinants a problematic process. They are also the giveaway of why the housing prices may be prone to fluctuation in prices even when prices of other consumption goods stay the same. Moreover, it is necessary to mention that the real estate market can cause severe economic problems for the economy. The world was lastly reminded of that in 2008 when the housing bubble on the US market contributed to the start of financial crisis.

The housing bubble[6] is caused by a large unsustainable increase in prices of the real estate. The causes vary, but the speculative nature of the real estate market is usually one of the main reasons, jointly with increased demand and low interest rates. The property bubbles are one of the most important concepts when talking about the residential real estate market. Due to this is a subsection of the empirical part dedicated specifically to this issue.

3.2 Market of the Baltic countries

This part of the thesis will shortly introduce the evolution and dynamic of the market of the Baltic countries to give this thesis a theoretical context, and to make it easier to understand the results of the empirical part. It will also answer essential questions in the process, such as how and why the markets in Lithuania, Latvia, and Estonia differ, and what difficulties they had to face in the past, compared to the other European countries.

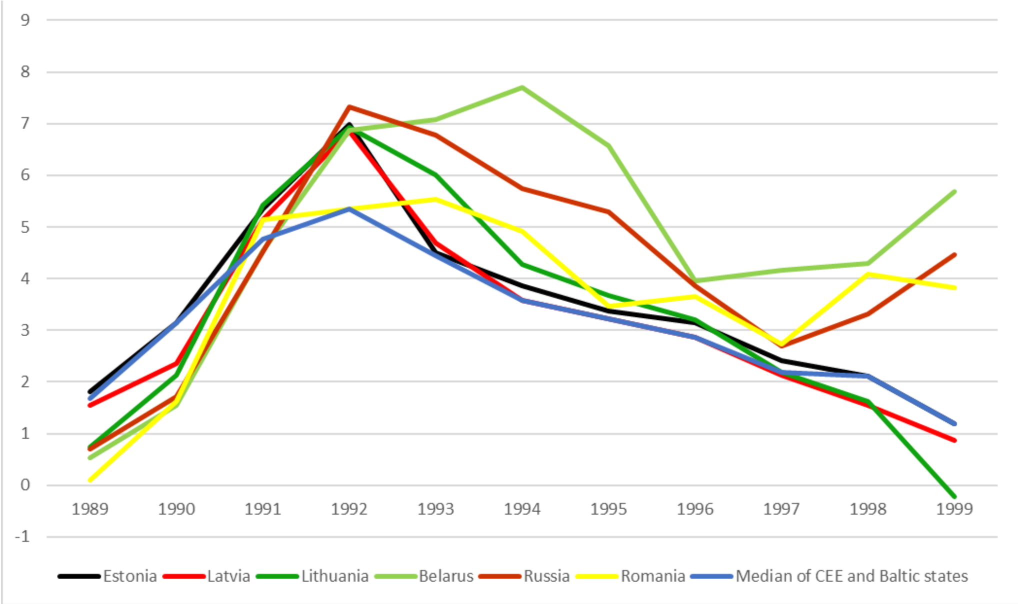
[6] The housing bubble and property bubble are also synonyms to the real estate market bubble.

3.2.1 Brief historical overview of the market of the Baltic countries

Even though Lithuania, Latvia, and Estonia are countries with many specific features and autonomous economies and politics, their history is in many aspects similar. Baltic countries went through 50 years of the Soviet occupation that was only shortly interrupted during the 1940's – this time by the German occupation. Being part of the Soviet Union was hard on the Baltics in general, and it was hard on their economy as well. The USSR economic situation was relatively good at first, and the Soviet Union went through a long period of steady economic growth. Unfortunately, tools used to achieve this – like industrialization, collectivization of the land, and full employment - were hurtful to the countries in the aftermath. However, the economic situation got worse long before the collapse of the Soviet Union as in the 1970s the economic growth and investments stagnated, possibly due to the Cold War and the internal labour politics (Allen, 2001).

Lithuania gained independence on 14 March 1990, soon followed by Estonia and Latvia in August 1991. The countries had to deal with the damage that the collapse of the Soviet Union caused, and according to Vaidere (2011), their economy went straight into recession. The situation was even more complicated since countries became ones of the so-called transition economies. The transformation from the planned economy to the market economy would not be easy even without other challenges that the Baltics had to face. They also had to build the government institution basically from scratch, face the problems with foreign trade, that were partly caused by their problematic past with Russia, and very high inflation.

Figure 2: The inflation in chosen former USSR countries between 1989 and 1999 (logarithmic form, %)



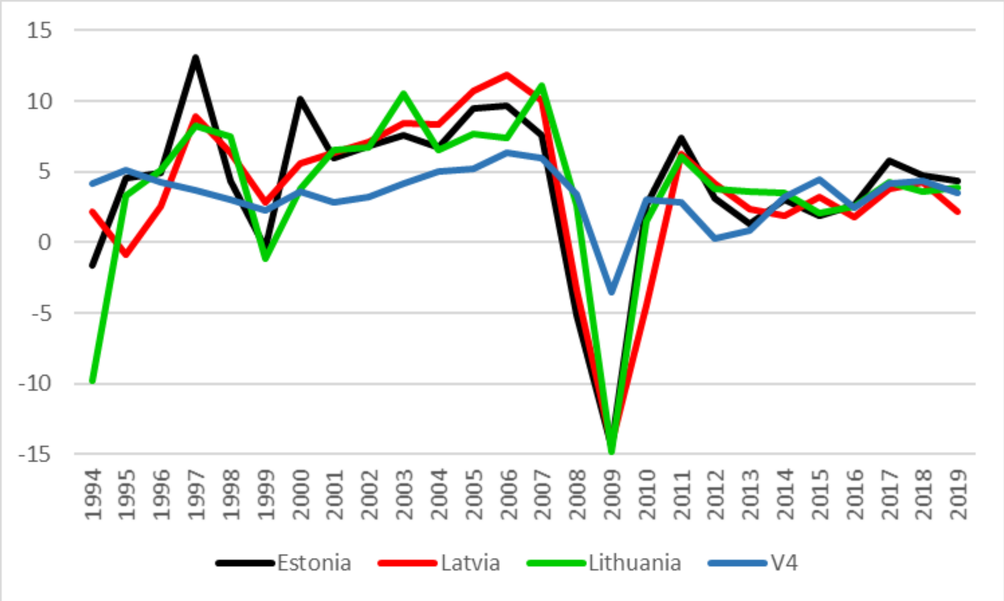
Source: EBRD Transition Report 2000

Figure 2 shows the extreme inflation that countries had to deal with after the collapse of USSR. Both Estonia and Lithuania exceeded the 1 000% mark in 1992 with 1076% and 1021%, respectively, and Latvia reported only a slightly better number of 951%.

Problems of the Baltics were severe and asked for stabilization policy. Estonia used the currency board[7] to deal with this problem in 1992, and was followed by Lithuania in 1994. Latvia set the floating exchange rate[8]. Even though the Baltics had to give up the possibility of using the exchange rate as a tool of independent monetary policy, the currency board helped the economy stabilize the inflation rate and establish economic growth. That started a period of prosperity and integration of the Baltic States. To this day, they are the only three former USSR countries that are members of the European Union and NATO[9].

[7] According the Cambridge Dictionary, the currency board is defined as "a government organization in some countries that controls the value of its country's currency, often by setting a fixed exchange rate with the currency of another country".
[8] The Cambridge Dictionary defines the floating Exchange rate as "an exchange rate that is allowed to change in relation to the value of other currencies".
[9] Baltics became members of the NATO on the 29 March 2004. That was followed by their entrance into the European Union on the 1 May 2004.

Figure 3: The GDP growth of the Baltic States and V4 (%)



Source: AMECO, author's calculations

Figure 3 shows the Baltic States' GDP growth compared to the countries of the Visegrád Group (Czech Republic, Hungary, Poland, and Slovakia). Both groups of countries had to deal with the consequences of communism and establish market economies. As the countries of the V4 are larger and their joint population is ten times the one of the Baltic countries, we can see that their GDP growth is stable in comparison to the Baltic States. Baltics went through a long period of significant economic growth, but they were hugely affected by the economic crisis. That shows that they are more vulnerable to exogenous shocks. However, Figure 3 also shows that the GDP growth of Baltics was stable in the last decade and similar to the one of V4. Poissonnier (2017) did explain the reasoning behind this. For one, the Baltic countries are structurally and economically changing, resembling the Western European countries. The GDP growth of Estonia, Latvia, and Lithuania also correlates with the GDP growth of other European countries.

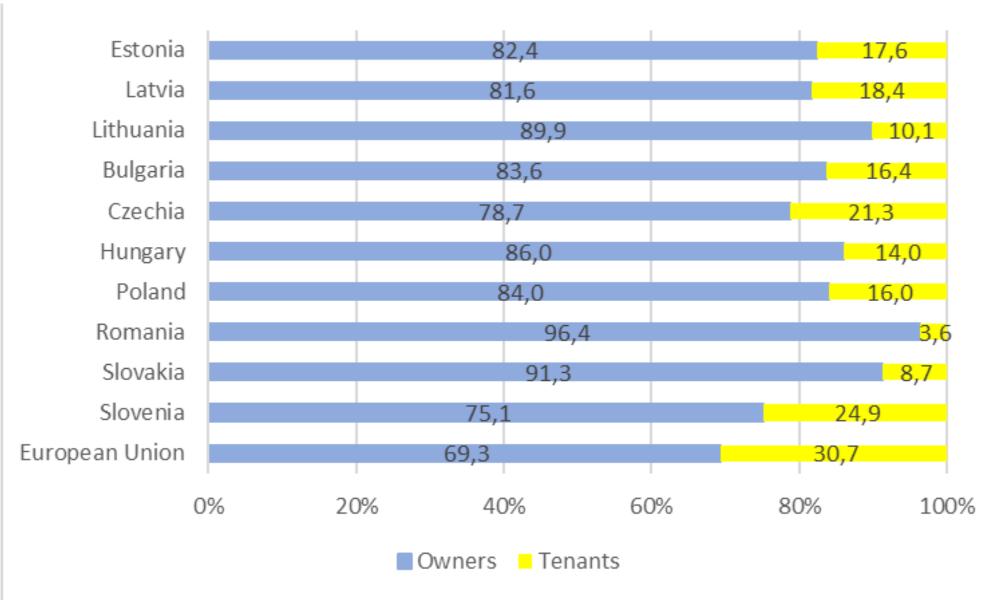
3.2.2 Overview of the Baltic countries' real estate markets

The real estate market in the Baltics has a few specific characteristics that are mostly given by their history. However, communism reached farther than just to the Soviet Union, and the Baltic countries, just as some other countries of the former Eastern

Bloc[10], had to transform their housing market significantly. During the Soviet occupation, the real estate market in Baltic countries looked different. It was caused by the fact that the Soviet Union did recognize the personal ownership principle on a limited scale.

According to Morton (1984), the USSR flats and houses were not seen as a commodity. They were financed from the government budget to meet the needs of people who then got the housing seemingly for free in order given by the waiting list, creating a completely different dynamic from the one we know today. The real estate was generally split into three categories. First were the real estate owned by the state, second the so-called housing cooperatives, that were also owned by the state, and last was the housing that was the personal property of the citizens. The private housing, however, had to meet restricting conditions about size and location[11]. Gentile & Sjöberg (2013) analysed the living conditions in the USSR through the years, and their calculations show that the people with Baltic surname had, on average, 6.07 square meters of living space in 1953.

Figure 4: The share of owned and rented housing in the Baltic States and in other CEE countries in 2018[12] (%)



Source: Eurostat

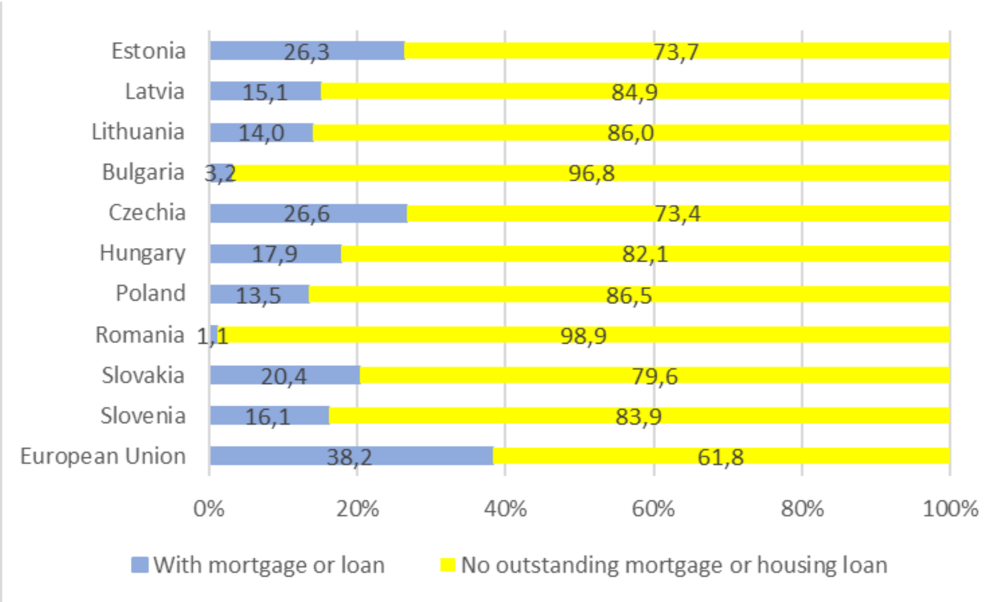
[10] Former communist countries in Eastern and Central Europe and East and Southeast Asia.

[11] The area of living space was restricted to less than 60 meters square, houses could have been built only in towns with the maximum population of 100 000 people. Surprisingly, it was also prohibited to have a garden (Morton 1984).

[12] The Eurostat is yet to release the comparable data for all countries for year 2019.

After the Baltics gained independence, the real estate market had to transform. Housing became the commodity and not the social tool, and the ownership rate in Baltic countries is to this day very high compared to the developed countries. As we can see in Figure 4, the ownership rate is exceptionally high in Lithuania (89.9%) and only two CEEC, specifically Romania and Slovakia, do exceed it. Estonia and Latvia are in this regard relatively average in comparison to CEE countries as their ownerships rates are close to 80%. For better understanding, the average of 28 EU countries[13] is also included. The main reason for the ownership rates this high is probably the underdeveloped rent market in transition countries. Kulikauskas (2016) also explains that the need for own housing is rooted in citizens of Baltic countries due to the massive privatization during the Soviet occupation.

Figure 5: Owners of the housing according to the type of financing in Baltic States and in other CEE countries in 2018 (%)



Source: Eurostat and own calculation

The Baltic States also stand out when it comes to the amount of the debt financing of housing, as it is unusually low in all three countries. As shown in Figure 5, 86% of the private housing owners in Lithuania have no outstanding mortgage or housing loan. Latvia is closely following with merely 85%, and Estonia, with 73.7%, is still high above the European Union average. However, looking at the numbers for the CEE countries, we

[13] The United Kingdom is included.

can see that only the Czech Republic has more owners with outstanding loan or mortgage than Estonia.

Lastly, there is a clear preference of the Baltic citizens for the type of housing. While more than 57% of citizens of EU member states live in houses, the flats are preferred in the Baltics. Even Estonia, which is usually closest to the EU averages given the previous measures, has 62% of its population living in the flats. In Latvia and Lithuania are these percentages equal to 66.1 and 58.2, respectively[14].

3.3 Determinants of the residential real estate prices

The *GDP* is a macroeconomic determinant that is included in a fair share of the studies. Its effect on the housing prices in Baltics was examined by Égert & Mihaljek (2007), Bibolov et al. (2010) and Kanapeckiene et al. (2016). The consensus among these studies is that the GDP is a significant determinant of housing prices. However, the Gaspareniene et al. (2017) contradicted this statement, as they found the GDP to be an insignificant determinant in big Lithuanian cities. Similarly, Posedel & Vizek (2009) found out that the GDP is not a significant determinant of housing prices in Estonia. The positive relationship between the GDP and prices of housing is easily explained. The GDP growth, resulting from a good economic situation, pushes the demand for properties up, and increases the price. However, sometimes are *real wages* just as good, or better, determinant, as they are the sign of how much money households have. However, as there is an established relationship between the increase in real GDP and an increase in real wages, both are viable options.

The factors related to *the change in population* can have a significant effect on the price of housing. In general, the increasing population relates to the fact that more people need housing. However, the reason behind the increase in the population is essential as it does not have to be necessarily caused by the increased *birth rate*. Another explanation for this change in population is the change in *net migration*[15].

[14] Source for the data is Eurostat, which divides the dwellings types to flats, houses and other dwellings. Less than 1% percent of the population of both EU and Baltics live in the dwelling other than flat and house.
[15] The net migration is defined as the difference in the number of immigrants (people that come to live in a country) and the number of emigrants (people that leave the country to live elsewhere).

The important demand determinant is the *unemployment rate*. Not only lower unemployment usually relates to the good economic situation and economic boost, but it also relates to the higher *income of households*. The increase in wages increases the household's purchasing power and, therefore, demand for goods and services, including the real estate. From the well-known correlation between unemployment and *inflation rate* given by the Philips curve, we could, in the same fashion, say that the inflation rate is also determinant of housing prices. Cohen & Karpavičiūtė (2017), however, contradicted this statement by using the Granger causality analysis that showed that the housing prices are the determinant of inflation and not the other way around.

However, not everyone can finance housing from the savings. The *interest rate of mortgages* is an essential factor that people consider when deciding whether to obtain a housing loan. The higher interest rate makes a loan more expensive for the borrower, and it is less likely that he will decide to go through with it. Therefore, the high interest rate drives the volume of outstanding and new business loans down and decreases the demand for housing. Consequently, the smaller *volume of loans* causes smaller demand for housing.

In general, the change in the price of the good positively affects the price of its substitute. The housing is no exception, and it is therefore important to consider the *rent prices* as a possible determinant. Baltic countries are known for their underdeveloped rent markets and high price to rent ratios. We would expect that the rent prices will influence the residential real estate prices, but the effect could be less significant than in other European countries. The dynamic behind the P/R ratio also shows if there are imbalances present at one or both markets, which could affect the way rent prices affect the housing prices.

While most of the determinants that we named affect the demand side of the real estate market, the supply side is just as important. The developers decide whether to build new real estate based on the *price of land and materials* because the more expensive these necessities are, the bigger are the costs. Moreover, sometimes there can be a shortage of essential factors (labour and land), slowing down the developing process,

Not every possible determinant is easy to measure. While we would expect that the irrational factors like *expectations* about the future and *uncertainty* would change both demand and supply for housing, it is not easy to include them in the model. The people's expectations are always hard to measure, and the collected data are not very informative, as they tend to be subjective. Kanapeckiene et al. (2016) included these factors in their study about Lithuania. The results showed that these irrational factors were not significant determinants in the tested period. For these reasons is the empirical part of this thesis focused only on the analysis of rational determinants.

4 Empirical part

4.1 Motivation

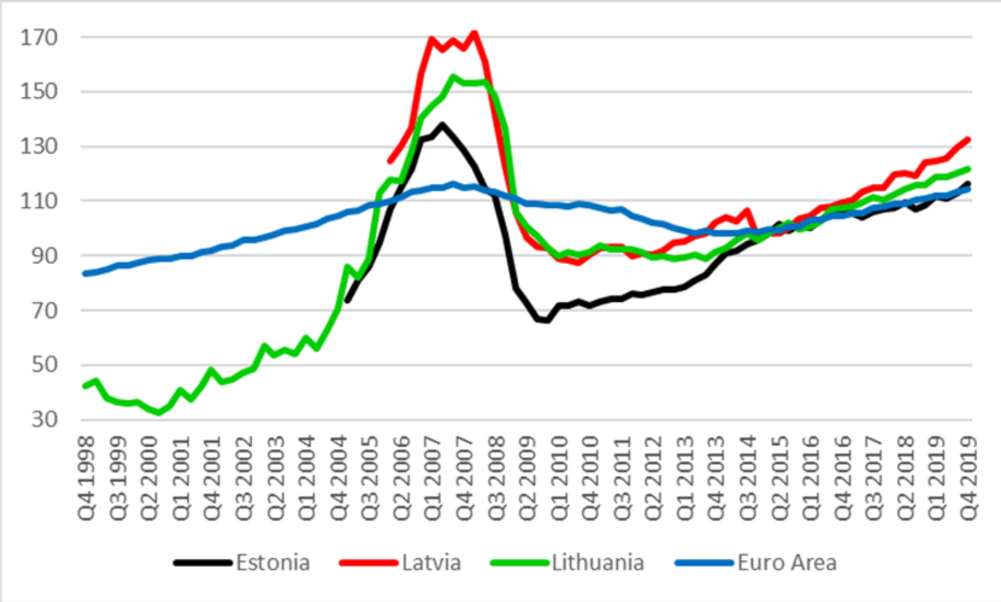
While there is the affluence of the literature focusing on identifying the determinants of the housing prices, the literature focusing specifically on the Baltic countries is limited. That could come out as a surprise, as the real estate prices in Estonia, Latvia, and Lithuania fluctuate significantly. The authors of the existing literature usually implemented the panel data analysis[16], and therefore examined all three countries as one unit. This choice was usually made due to the limited number of observations that could lead to less accurate results when doing the time series analysis. Sometimes were the Baltics included in a more extensive study that analysed many countries. The Baltic States were then included in one panel[17] based on their similarities to make the study transparent and easy to follow. We will try to expand the existing literature by the implementation of the time series analysis on the individual Baltic countries.

Figure 6 shows the change in the real house price index over the years. It is visible that the hypothesis that the individual determinants may affect the housing prices differently in each of the countries is not overreaching. The quarterly data will be used to increase the number of observations. The time series analysis will allow us to compare the individual housing markets and name their specifics, and it will be executed through the endogenous models (either the VAR or VEC model). The endogenous models let us use the variables that are tied together by causal relations. Also, while the Vector Autoregression is used for forecasting, it is a powerful tool for determination of the relationships between variables.

[16] The section 2, Literature review, summarized the most influential papers in this field of study. All of the mentioned studies either used the panel analysis (Kulikauskas (2016), Bibolov & Poghosyan & Stepanyan (2010), Égert & Mihaljek (2007)) or done the time series analysis only for one of the countries (Posedel & Vizek (2009) for Estonia, Kanapeckiene et al. (2017) and Gaspareniene (2017) for Lithuania).

[17] It is not unusual for Baltic countries to be included in even broader panels that include not only observations about Estonia, Latvia, and Lithuania, but also other countries of the former Soviet Union. That is the case for the study by Bibolov & Poghosyan & Stepanyan (2010). The authors included the Baltic States in the panel with Russia, Kazachstan, and Uzbekistan.

Figure 6: The real HPI of the Baltic States (units, 2015=100)[18]



Sources: Eurostat, BIS, OECD

In addition, the housing prices will be analysed in search for possible overvaluation. That will be done by calculation of the P/I and P/R ratio and application of the Hodrick-Prescott filter on the HPI data. This part of the thesis is to be seen as the extension of the Kulikauskas' (2016) paper in which he was trying to find out whether it was possible to detect the real estate bubble in the Baltic States before its burst. The pre-crisis situation analysis led to the conclusion that the burst of the property bubble that started the last economic crisis could have been predicted years before it actually happened, as both P/R and P/I ratios were unsustainably high since 2005. We will proceed similarly and apply some methods that he used on current data to determine whether there is some possible risk that arises from the current situation on the housing market.

4.2 Data

This part of the thesis will introduce the collected data and explain the necessary alterations that were done to them to create usable datasets. The data were, if not stated

[18] The individual countries have different sample sizes. While BIS provided data for Lithuania since the year 1998, the Estonian time series starts in 2005 and Latvian in 2006. Statistical Offices also do not provide additional observations. BIS does provide data for Estonia since Q3 2003, but they are not comparable with the rest of the time series as they capture only the prices of flats in Estonia excluding Tallinn.

otherwise, collected quarterly. This frequency of data was chosen to ensure the largest possible number of observations for the respective time series analyses.

4.2.1 Housing prices

The analysis of individual countries will be done using *the house price indices* data due to the unavailability of data on the average housing prices in the Baltic States. Estonia provides the price data, but they capture only prices of flats in the country, excluding Tallinn. The data for Latvia and Lithuania could be theoretically calculated from the provided information, but we would then limit the analysis to flat prices in only five biggest selected cities. As the collected data about the house price index consider the overall growth of prices for all residential housing (flats, detached houses, semi-detached houses, etc.), we find them to be more suitable.

The data for Lithuania are specifically calculated from both existing and new dwellings in the whole country. The index is calculated from the pure price of these dwellings, and the values are expressed in constant prices. Data for Estonia and Latvia were taken from the OECD web page, which claims that the data are calculated for existing and new dwellings in the whole country. The index is in real terms. The house price index for Estonia, Latvia and Lithuania is calculated from all types of dwellings. The Eurostat data used for the calculation of P/I and P/R ratios were collected at a yearly frequency and calculated from the sales of all types of residential dwellings, both new and existing. Note that the Statistical Offices of Lithuania and Latvia and the Land Board of Estonia were also searched for additional housing prices data. The Lithuanian time series was shorter than the one provided by BIS, and the Latvian time series was of the same length (starting in Q1 2005). Estonian Land Board provides the data on the prices of flats in either the capital or the whole country, excluding Tallinn. These data were not used as they are not comparable with the rest of the data that consider the whole country and all types of residential dwellings.

The empirical part of this thesis will use both nominal and real house price indices data. While the real HPI is to be used as the variable of interest in our model, the nominal data will be used for the overvaluation analysis, specifically for evaluation of the P/I and P/R ratios.

Table 1: Description of the housing data

Country	Data	Frequency	Time - period	Data source
Estonia	Real HPI (100 = 2015)	Quarterly	Q1 2005 – Q4 2019	OECD
	Nominal HPI (100 = 2015)	Yearly	2005 – 2019	Eurostat
Latvia	Real HPI (100 = 2015)	Quarterly	Q1 2006 – Q4 2019	OECD
	Nominal HPI (100 = 2015)	Yearly	2006 – 2019 (+est. for 2000 - 2005)	Eurostat
Lithuania	Real HPI (100 = 2010)	Quarterly	Q4 1998 – Q4 2019	BIS, OECD
	Nominal HPI (100 = 2015)	Yearly	2006 – 2019 (+est. for 2000 - 2005)	Eurostat

While HPI for Estonia and Latvia were collected from Eurostat and OECD web page, the values of real HPI for Lithuania were collected from the BIS, as their database provides data from Q4 1998 onward and other sources only cover the period from Q1 2006 to Q4 2019. The Lithuanian HPI was altered to change the base year to 2015.

4.2.2 Explanatory variables

Some of the data in this section were harder to obtain, and some required proper adjustments. Table 2, that can be found below, captures the individual variables and other variables used to adjust our data. The sources of the data and alterations done to the dataset are mentioned.

Table 2: Description of data

Data	Country	Frequency	Additional information	Availability	Data source
Unemployment rate	Estonia				
(% of the active population)	Latvia	Quarterly	Seasonally adjusted data (by Eurostat)	Q1 1997 – Q4 2019	Eurostat
	Lithuania				
Rent price index	Estonia			Q1 1998 – Q4 2019	
(units, 100 = 2015)	Latvia	Quarterly		Q2 1992 – Q4 2019	OECD
	Lithuania			Q1 1995 – Q4 2019	
Net income	Estonia		Net average monthly wages of employees per Q	Q1 2005 – Q4 2017	
(EUR)	Latvia	Quarterly	Net average monthly wages of employees per Q	Q1 1994 – Q4 2019	Statistical
	Lithuania		Net average monthly earnings per Q in public sector	Q4 2008 – Q4 2019	offices
			Seasonally adjusted using moving average method		
Construction cost index	Estonia			Q1 05 – Q4 19	
(units, 100 = 2015)	Latvia	Quarterly		Q1 06 – Q4 19	Eurostat
	Lithuania			Q4 1998 – Q4 2019	
Population	Estonia				
(thousands of persons)	Latvia	Quarterly		Q1 1995 – Q4 2019	Eurostat
	Lithuania				
Main GDP aggregates	Estonia		Chain linked volumes (2010), gross domestic product		
(EUR per capita)	Latvia	Quarterly	at market price, seasonally adjusted by the method of	Q1 1995 – Q4 2019	Eurostat
	Lithuania		the moving averages		
Interest rate on mortgages (%)	Estonia	Monthly	Averaged to quarterly values, converted to real (real interest rate = nominal interest rate – inflation)	Jan 05 – Dec 19	Central bank
Stock of mortgages granted to individuals (million EUR)	Estonia	Quarterly		Q1 2002 – Q4 2019	Central bank
+ HICP, all items	Estonia				
(units, 100 = 2015)	Latvia	Monthly		Jan 1996 – Dec 2019	Eurostat
	Lithuania				
+Exchange rate	Lithuania	Quarterly	ER between LTL and EUR	Q1 1992 – Q4 2014	ECB

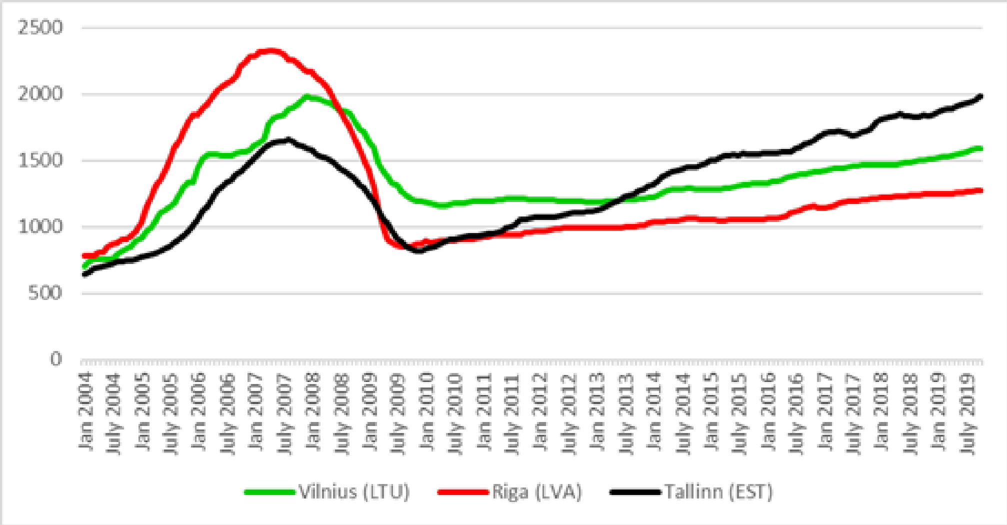
The collection of the real net wage data showed up to be complicated. Lithuanian official data cover only the years 2008 to 2019. That is inconvenient, as we are missing almost ten years' worth of data. Fortunately, we were able to find some of the missing values of the net earnings in the Monthly Bulletins and Quarterly Bulletins posted by the Bank of Lithuania. These publications obtain the data on the growth in the net earnings. We were subsequently able to calculate the actual values using the growth rates and the known values for net earnings in Euro that we already obtained from the Lithuanian Department of Statistics. This way we were able to get the additional data from Q2 2002 to Q4 2007. Estonia, on the other hand, generated missing values for years 2018 and 2019. The average net income for these years was calculated from the gross average income that was adjusted by the tax. The real wages were then calculated using the HICP. The real wages were then seasonally adjusted to get rid of the seasonal trend using the moving average method.

Also, because we have a high number of variables in our system, given the number of observations, we will test different combinations of variables to see which one yields the best model. The information from the theoretical part of this thesis will also be considered to choose the best country-specific determinants for the models. That means that our model will not obtain all mentioned variables as that would produce a system of equations with low number of degrees of freedom.

4.2.3 Housing prices in the capital

The Ober-Haus web page offers the data on the average prices of flats in the Baltics' capital cities. As we are interested in the dynamic of the real estate market in the whole country, these data are not too much of the use. However, that does not stop us from accessing the price dynamic in the capital cities.

Figure 7: Average apartment prices in Riga, Tallinn, and Vilnius (EUR, price per square meter)

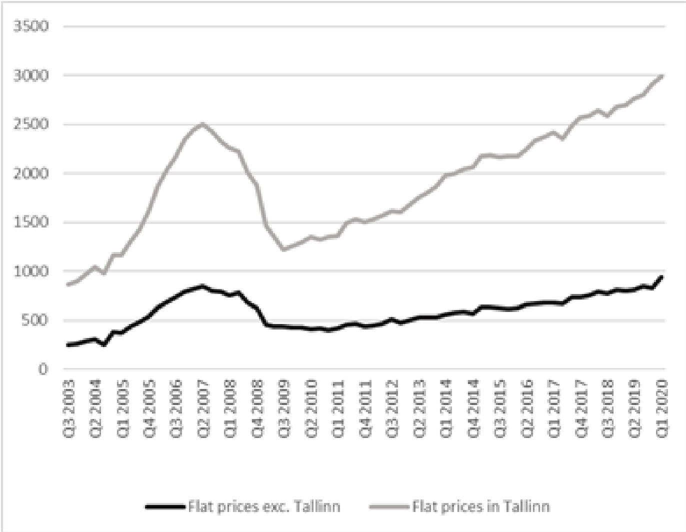


Source: Ober-Haus

Figure 7 shows that the flat prices in Tallinn do increase at a swift pace. While in 2009 were flat prices in Tallinn lowest out of the three capitals, in 2019 square meter of flat in this city on average cost 400 EUR more than in Vilnius. Prices in Riga and Vilnius are also increasing, but the change is much slower.

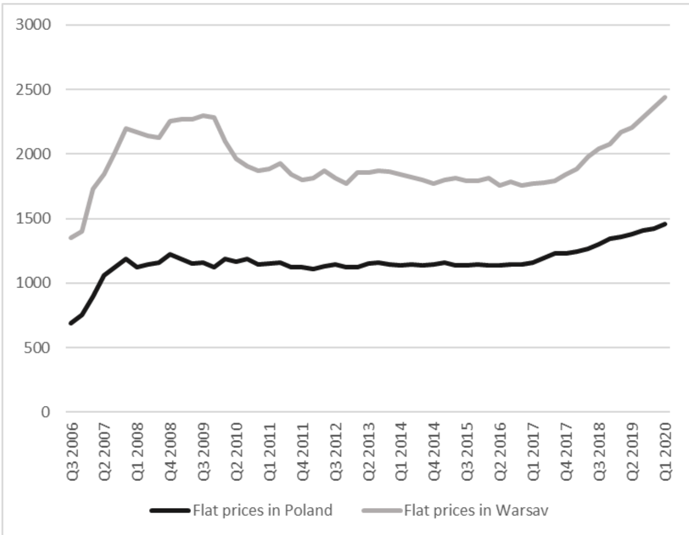
The housing prices in the whole country and capital usually mirror each other, but the increase in prices in the capital city tends to be more prominent. If this occurs, it is probably because the capital city is the price "leader" of the country's prices. We will now use the flat prices in Tallinn and the flat prices in the whole country, excluding Tallinn, to see whether this holds for Estonia and whether the Tallinn could be the price leader when it comes to housing prices. Unfortunately, we cannot do the same for the remaining two countries as the housing prices data for the whole country are not available for either Latvia or Lithuania, and price index data are not plausible for this analysis. We will, therefore, assume that the dynamic in those countries could be similar.

Figure 8: The average prices in Estonia and Tallinn (EUR)



Sources: BIS, Ober-Haus

Figure 9: The average prices in Poland and Warsav (EUR)



Sources: BIS

Figure 8 shows the comparison of flat prices in Estonia and its capital. The same graphic depiction was done for Poland for comparison (Figure 9). The prices in the capital and the rest of the country seem to move similarly, and how we expected, the price level in the capital is much higher. Both time series do move upwards, but the increase in prices in Tallinn is steeper and faster, and the gap between the two subsequently grows. If we compare it to Poland, the prices in both capital and the entire country are more stable, and the difference between the two is smaller. The price leader effect of the capital city in

Estonia, a small country, is more profound than in Poland, which is a considerably larger country.

4.3 Methodology

4.3.1 Vector autoregressive (VAR) model

The time series analysis of the housing determinants was in existing literature usually done by using either the Ordinary Least Square method (or possibly its variation, the DOLS) or the endogenous models (the Vector Autoregressive model or the Vector Error Correction model). This thesis will use the VAR model, or possibly the VEC model if the analysis shows it is the possibility. The VAR model was used by Sutton (2002), Tsatsaronis & Zhu (2004), Posedel & Vizek (2009), and by many other authors when dealing with similar themes and topics. This model is also often used in other fields of the economy as it is a useful method for forecasting and, in general, imposes relatively accomplishable assumptions.

The VAR model is used when dealing with multivariate time series, where each series y_t is not only linear equation of its past values, but also of past values of other time series in the model. The VAR(p) is the denomination for the vector autoregressive model of order p, which can, according to Wang & Zivot (2006) and Brooks (2014), be generally written as:

$$y_t = \nu + \mathrm{A}_1 y_{t-1} + \mathrm{A}_2 y_{t-2} + \cdots + \mathrm{A}_p y_{t-p} + \varepsilon_t,$$

where $t = 1, \dots, T,\ y_t = (y_{1t}, y_{2t}, \dots, y_{nt})'$ is an $(n \times 1)$ vector capturing the individual time series variables, ν is the $(n \times 1)$ vector of intercepts, A_i, $i = 1, \dots, p$, are the $(n \times n)$ coefficient matrices and ε_t is the $(n \times 1)$ vector of unobservable independent and identically distributed error terms (also known as white noise terms). Note that this model assumes that all of the variables are endogenous.

We will now introduce the simple bivariate model, VAR(1), that consists of the following two equations:

$$y_1 = \alpha_1 + \alpha_{11} y_{1t-1} + \alpha_{12} y_{2t-1} + \varepsilon_{1t}$$
$$y_2 = \alpha_2 + \alpha_{21} y_{1t-1} + \alpha_{22} y_{2t-1} + \varepsilon_{2t}.$$

We can see that the VAR(1) model consists of two linear equations, each of which has different left-side endogenous variable and the same right-side lagged variables. The $y_{it-1}, i = 1, 2,$ are called the lags, and we can see that the same number of lags is used for every variable.

The VAR(p) model that obtains not only the endogenous variables but also set of the exogenous variables is called the VARX(p,q) model and Ocampo & Rodriguez (2011) established the general form of the model as follows:

$$y_t = \nu + \mathrm{A}_1 y_{t-1} + \mathrm{A}_2 y_{t-2} + \cdots + \mathrm{A}_p y_{t-p} + \mathrm{B}_0 x_t + \mathrm{B}_1 x_{t-1} + \cdots + \mathrm{B}_q x_{t-q} + \varepsilon_t,$$

where B_j, $j = 0, \dots, q$, are $(n \times m)$ coefficient matrices and x_t is the exogenous variable.

4.3.2 Concept of stationarity and cointegration

The VAR model has less demanding assumptions than the OLS, and it allows for all of the chosen variables to be endogenous. To use the classic form of the VAR model, two key assumptions need to be fulfilled – the individual time series used in the model have to be stationary, and the variables cannot be cointegrated. In the case that the variables are cointegrated, the VECM is used instead. We will now introduce these assumptions and explain the alternative procedures in the case of their violation.

Firstly, to use the VAR model, we need to ensure the covariance stationarity of variables. Wooldridge (2013) defined the covariance stationary process as follows:

"A stochastic process $\{y_t, t = 1, 2, \dots\}$ *with a finite second moment* $[E(y_t^2) < \infty]$ *is covariance stationary if*

(1) $E(y_t)$ *is constant;*

(2) $Var(y_t)$ *is constant;*

(3) for any $t, h \geq 1, Cov(y_t, y_{t+h})$ *depends only on* h *and not on* t*."*

The covariance stationarity is a "weaker" form of stationarity, but it is a sufficient assumption for the endogenous models. Stationarity can be easily tested using the Dickey-Fuller (or the Augmented Dickey-Fuller test) or PP test. These tests are testing for the unit roots in the time series. If we reject the null hypothesis of the non-stationarity at the chosen significance level[19], we are saying that the time series is covariance stationary and that it is integrated of order zero. Time series integrated of order zero are therefore stationary without a need for further adjustments and without being differenced. The proper definition given by Wooldridge (2013) says that the process integrated of order zero is "*stationary, weakly dependent time series process that, when used in regression analysis, satisfies the law of large numbers and the central limit theorem*." Therefore, if we need to use the first difference method to ensure the stationarity of variables, we say that the series are integrated of order one.

We can now introduce the principle of cointegration. While the linear combination of two I(1) time series is usually I(1) as well (Brooks, 2014), we can find special cases when a combination of two non-stationary (but difference stationary) variables results in the I(0) combination. While the VAR model does not assume that the variables are cointegrated, the VEC model does. The next subpart of this thesis will introduce this model.

4.3.3 Vector error correction model (VECM)

The VECM is derived from the VAR model, and it assumes that the variables are cointegrated. Unlike the VAR model, the VECM obtains the error correction term, which is supposed to bring the time series to the long-run equilibrium. This model does not require the variables to be level stationary but assumes that they are I(1), as the model automatically uses time series in first-differences. General form of VECM is

$$\Delta y_t = v + \Pi y_{t-1} + \Gamma_1 Y_{t-1} + \Gamma_2 Y_{t-2} \ldots + \beta_{p-1} Y_{t-p+1} + \varepsilon_t,$$

where $\Pi = \left(\sum_{i=1}^{p} \mathrm{A}_i\right) - I$ and $\Gamma_i = \left(-\sum_{j=1+i}^{p} \mathrm{A}_i\right)$. Π is the long-run coefficient matrix and its rank is crucial for the interpretation of the Johansen's cointegration test. If the rank of matrix Π equals 0, we know that there is no cointegration in the model and all variables are I(1). From the properties of individual models we therefore know that we will use the VAR model, specifically the differenced VAR model. If the rank of matrix Π is greater than zero but less than n ($0 < r(\Pi) < n$), where n is the number of endogenous

[19] The significance level is usually set to 1%, 5% or 10%. The lower significance levels are preferred, as it is basically the probability of wrongfully rejecting the null hypothesis. However, the 1% mark is very strict and very often unachievable, and this thesis is therefore usually working with significance level of 5%, if not stated otherwise.

variables in the model, we know that there is cointegration present in the model between two or more variables. In general, the rank suggests the existence of r cointegrating vectors and the matrix Π can be written as a product of two matrices $n \times r, \alpha$ and β:

$$\Pi = \alpha\, \beta'.$$

If the rank of matrix Π is equal to n (therefore matrix has full rank), we will use the VAR model as all time series are I(0).

4.3.4 Testing the properties of the model

To choose the appropriate model for each of the countries, we need to test the nature of the collected data. If the individual time series are I(0), we will use the VAR model. If not, we will try to find the cointegration between the variables, and if we are successful, we can use the VEC model. If we are unable to detect the cointegration in our model, we will have to use the VAR model on differenced data.

It is also necessary to mention why we would prefer the VECM over the VAR model. As the VAR model requires the level stationarity of all variables, we will probably not be able to use the VAR model in its basic form. If we use its alternative – the differenced VAR – we will lose the long-term effects of the variables. The VECM, on the other hand, can be used in the case that there are one or more cointegrating vectors present in the model. If we can confirm the existence of these vectors, we can also say that the variables are moving together in the long run. Therefore, while the VAR used on the differenced data is still a powerful tool for the determination of the short term relationships, the VEC model would be preferred as we want to establish the long run determinants of housing prices.

The optimal number of lags

According to Wooldridge (2013), the maximum lag length for the quarterly data is usually set to either 4 or 8 lags for quarterly data, given the number of observations and other factors. We chose the lower number for numerous reasons. For one, if we include more lags, we lose more observations. The number of observations that we were able to collect is not low in comparison to similarly themed papers[20], the inclusion of 8 lags

[20] For comparison, Posedel & Vizek (2009), who used the VAR model to determine the effect of numerous variables on the housing prices, were able to collect from 37 to 52 observations for each of the six analysed countries. One of them was Estonia, with 44 observations.

would, however, decrease the number significantly and would also cause a decrease in degrees of freedom. The 4 lags benchmark should not cause these problems while still covering the entire year cycle of data and not causing the estimation bias.

We employed the information criteria, specifically the Akaike's Information Criterion, Final Prediction Error Criterion, Hannan-Quinn Criterion, and Schwarz Criterion, to help us decide the lag length. The multivariate versions of these criteria are used.

Table 3: Optimal number of lags

	AIC	HQ	SC	FPE
Estonia	4	4	1	4
Latvia	4	1	1	3
Lithuania	4	1	1	4

Source: Author's calculation

Liew (2004) compared the accuracy of the individual information criteria. While all criteria are equally valid, he pointed out that the Akaike's Information Criterion and Final Prediction Error Criterion are better than their counterparts when dealing with smaller sample sizes of around 60 observations. The number of lags suggested by information criteria can be seen in Table 3. These criteria have chosen 4 lags to be the optimal lag length for both Estonia and Lithuania. Results for Latvia suggest that 3 and 4 lags are both reasonable choices, and further testing showed that the model with the lag length of 4 seems to work better. Note that the number of lags n in the VAR model equals the lag length of $n - 1$ for the VECM model.

Stationarity

Firstly, we will use the Augmented Dickey-Fuller test and the PP test to determine whether the individual time series are stationary. The ADF test is searching for the unit roots in the time series. Its null hypothesis is that the time series has a unit root and is non-stationary. Note that the ADF test, in its basic form, assumes the existence of the intercept and time trend. The PP test is based on a similar principle, and its null hypothesis also assumes non-stationarity. Therefore, we can assume that the time series is stationary when both ADF and PP tests reject the null hypothesis. Tests on the original time series assume the existence of both drift and trend, while the tests on the differenced data work with drift only.

Table 4 and Table 5 show detailed results of ADF and PP tests. Except for unemployment and real interest rate are variables in the logarithmic forms. This decision was made because the logarithmic transformation helps with stationarity. We, however, need to consider that the logarithmic variables in first-differences are to be interpreted as elasticities.

Table 4: ADF and PP stationarity tests results (original time series) [21]

	Estonia		Latvia		Lithuania	
	ADF test (p-value)	**PP test (p-value)**	**ADF test (p-value)**	**PP test (p-value)**	**ADF test (p-value)**	**PP test (p-value)**
lHPI	0.236	0.386	0.409	0.910	0.561	0.766
unem	0.017	0.291	0.360	0.886	0.307	0.837
lrwage	0.351	0.732	0.243	0.694	0.612	0.873
lCCI	0.087	0.600	0.826	0.892	0.207	0.764
lRPI	0.010	0.424	0.387	0.649	0.189	0.719
rir	0.372	0.012	-	-	-	-
lstock	0.845	0.990	-	-	-	-
lGDP	0.041	0.243	0.183	0.734	0.196	0.781

Significance level: 0.05

Source: Author's calculation

Table 4 shows the results of unit root tests for the original data, where *lHPI* is the logarithm of house price index, *unem* is the unemployment rate, *lrwage* is the logarithm of real net wage, *lCCI* is the logarithm of construction cost index, *lRPI* is the logarithm of rent price index, *rir* is the real interest rate, *lstock* is the logarithm of the stock of mortgages granted to households and *lGDP* is the logarithm of gross domestic income. Note that the Estonian dataset was altered due to severe stationarity problems, even in first-difference. The sample size was reduced from 60 to 47 observations, and the analyses will be run only for the shortened period (Q2 2008 - Q4 2019).

Looking at the results, we can see that the variables are not stationary. While we were able to reject the null hypothesis of non-stationarity on four separate occasions[22],

[21] Some of the variables that were tested for individual countries were not included in the final model as they either did not produce informative results or were not chosen due to the previous research in the field.

[22] For the ADF test, we rejected the null hypothesis in the case of Estonian unemployment, rent price index and GDP. However, the PP was not able to reject the null hypothesis (at not only 5% but even 10% significance level) in any of the cases. Therefore, we have reason to believe that they are not stationary at levels. The PP test rejected the null hypothesis of non-stationarity for the real interest rate, which was once again not confirmed by the ADF test.

the ADF and PP test never came to the same conclusion of stationarity in any of the cases. Therefore, we will use the data in first-differences and rerun the tests.

Table 5: ADF and PP stationarity tests results (differenced time series)

	Estonia		Latvia		Lithuania	
	ADF test (p-value)	PP test (p-value)	ADF test (p-value)	PP test (p-value)	ADF test (p-value)	PP test (p-value)
lHPI	0.010	0.010	0.018	0.010	0.394	0.010
unem	0.025	0.010	0.101	0.010	0.252	0.012
lrwage	0.360	0.010	0.044	0.010	0.247	0.010
lCCI	0.037	0.010	0.078	0.010	0.402	0.010
lRPI	0.010	0.088	0.042	0.010	0.040	0.010
rir	0.010	0.010	-	-	-	-
lstock	0.010	0.033	-	-	-	-
lGDP	0.010	0.010	0.277	0.010	0.071	0.010
						Significance level: 0.05

Source: Author's calculations

Table 5 shows the results of stationarity tests for the differenced data. As we can see, the results are plausible, and there is no variable that both tests suggested to be non-stationary. The ADF test was, however, in numerous cases unable to reject the null hypothesis of non-stationarity in favor of the alternative hypothesis of stationarity. We decided to run the third test to decide whether these specific time series are I(1) or not.

The KPSS test is the unit root test with the null hypothesis of stationarity. If we are unable to reject the null hypothesis of the problematic time series, we will assume they are indeed I(1). We once again use the version of the test that assumes the existence of the drift.

Table 6: The KPSS test results (differenced time series)

	Estonia	Latvia	Lithuania
	KPSS test (statistics)	KPPS test (statistics)	KPSS test (statistics)
lHPI	0.197	0.208	0.331
unem	0.204	0.244	0.127
lrwage	0.565	0.157	0.192
lCCI	0.311	0.183	0.084
lRPI	0.152	0.067	0.079
rir	0.078	-	-
lstock	0.441	-	-
lGDP	0.321	0.091	0.196
			Critical value: 0.463

Source: Author's calculations

Table 6 shows results of KPSS test. The null hypothesis of stationarity is rejected when the LM statistics is greater than the critical value. We have done this only once, in the case of Estonian real wage. However, even though this time series is I(2), it should not impose a problem, as we still have at least two I(1) relations in the model, and we therefore still could be able to find the cointegration.

Cointegration

We will now put the time series to test to see whether there is a long run connection between them. If we can find at least one cointegrating vector, we will use the VECM. To do this, we will use the Johansen cointegration test. There are two versions of this test – the maximum eigenvalues test and the trace test.

It is also important to note that while both versions of the test have the same null hypothesis of no cointegrating vectors, the alternative hypotheses differ. If the trace test rejects the null hypothesis, the alternative hypothesis states that there are one or more cointegration vectors in the model. The maximum eigenvalue test has an alternative hypothesis of exactly one cointegrating vector. The Johansen test detected at least one cointegration vector in all cases.

Table 7: Results of the Johansen's maximum eigenvalue test

	Null hypothesis	Test statistics	Critical value (5%)
Estonia	r=0	35.94*	31.46
	r=1	28.15*	25.54
	r=2	19.04*	18.96
	r=3	7.94	12.25
Latvia	r=0	32.64*	31.46
	r=1	16.09	25.54
Lithuania	r=0	38.70*	37.52
	r=1	31.69*	31.46
	r=2	21.96	25.56

* rejection at 5%

Source: Author's calculation

Table 8: Results of the Johansen's trace test

	Null hypothesis	Test statistics	Critical value (5%)
Estonia	r=0	91.08*	62.99
	r=1	55.14*	42.44
	r=2	26.99*	25.32
	r=3	7.94	12.25
Latvia	r=0	68.28*	62.99
	r=1	35.64	42.44
Lithuania	r=0	111.90*	87.31
	r=1	73.20*	62.99
	r=2	41.51	42.44
			* rejection at 5%

Source: Author's calculation

Table 7 and Table 8 show that both tests suggest the existence of 3 cointegrating vectors for Estonia, 1 vector for Latvia, and 2 for Lithuania. That means that we will use the VECM for all three countries. The higher number of cointegrating vectors is relatively common when it comes to analysing the real estate prices. For example, Marku & Lleshaj & Lleshaj (2020) who have done similar VECM analyses for Tirana's case, found 4 cointegrating vectors among the 5 variables. Even though multiple vectors' existence does not cause any trouble, it complicates the interpretation of the results that will be subsequently done by the variance decomposition[23] and by interpretation of IRFs.

4.4 Identification of the housing bubbles

4.4.1 Price to income ratio

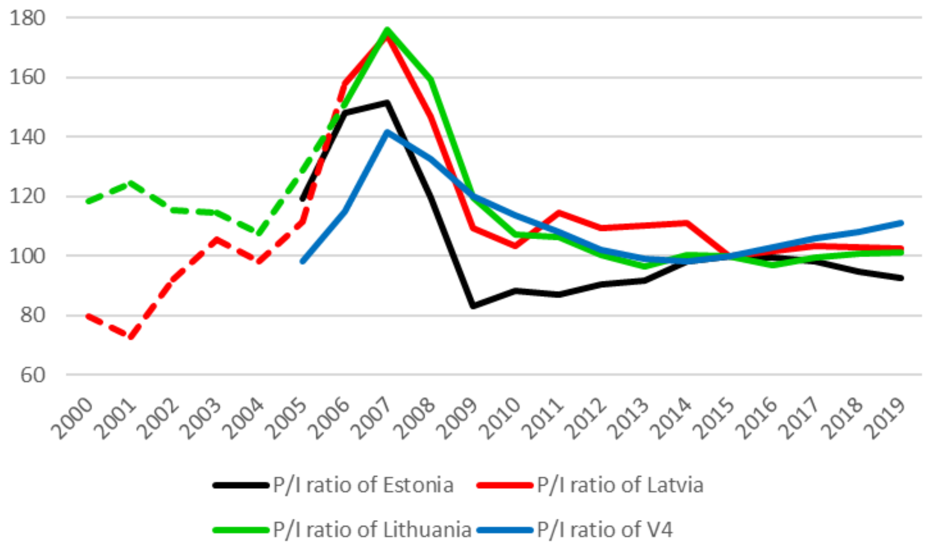
The price to income ratio measures the affordability of the housing. As the P/I ratio is the ratio between the price of the housing and average income of the individual or the household, the higher values signal the faster growth of the house prices compared to the growth of the income. That means two things – the average family is less likely to afford their housing, and the housing prices are overestimated.

The OECD web page offers the official data covering the evolution of the P/I ratio for all three analysed countries. However, these data start with the year 2005 for Estonia and a year later for Latvia and Lithuania. To recreate the possible development of the P/I ratio before the recorded time period, the Eurostat's estimated data of Lithuanian and Latvian HPI and the OECD's data on the gross disposable adjusted income of

[23] Variance decomposition is sometimes also called the forecast error variance decomposition (FEVD).

households[24] were used. The dashed line in the graph distinguishes these additional estimates of the P/I. These values were calculated using Eurostat's estimated HPI data and the adjusted disposable income of households that obtains information about both the families' monetary income and the additional income in the form of social transfers. Therefore, we can see the approximate progression of the measure, but the values themselves are presumed. Unfortunately, the Eurostat did not estimate the HPI for Estonia before the year 2005, and we were subsequently unable to imitate the movement of P/I ratio before that year.

Figure 10: The price to income ratio of Estonia, Latvia, and Lithuania (units, 2015=100)



Sources: Eurostat, OECD, own calculations

Figure 10 shows that Latvia and Lithuania experienced imbalances on the housing market long before the Great Recession. The ratio was increasing rapidly for all three countries since 2004. To better comprehend how extreme the increase in P/I ratio in these two countries was, we can compare it to the average P/I ratio of countries of V4, which was, for example, in 2007 equal to 141.6. In the same year were the P/I ratios in Estonia, Latvia, and Lithuania equal to 151.45, 174.4, and 176.11, respectively. The P/I ratios peaked in 2007 and then started to decline rapidly. However, if we look at the post-crisis development, we can see that there is no significant fluctuation that would point out the disproportionate rise of the housing prices to the rise of the disposable income. Therefore,

[24] The gross adjusted disposable income is the disposable income, therefore the income that people got left after they pay taxes and other necessary fees, plus the social transfers.

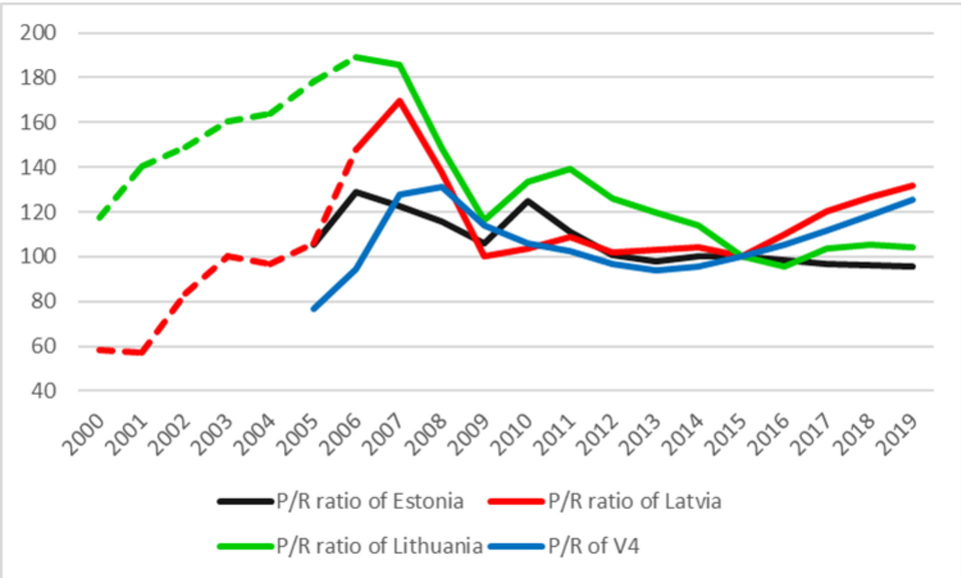
while the HPI grew significantly in the last few years, it does not create the problem as the income grew as well, and there is no sign of the imbalance.

4.4.2 Price to rent ratio

The price to rent ratio is the ratio between the average nominal price of the housing and the average rent prices. It is used as an easy way to determine whether the consumer should rent or buy housing. The higher the ratio gets, the more expensive it is to buy the property, and consumers will choose to rent instead.

Eurostat's data on the HPI in Estonia, Latvia, and Lithuania were used. The data on the rent index were obtained from the OECD page. The data cover the period from 2005 to 2019 for Estonia, and 2006 to 2019 for Latvia and Lithuania. We are also using the predictions of HPI in Latvia and Lithuania from 2000 to 2005. The dashed line in the graph distinguishes these additional predicted values.

Figure 11: The price to rent ratio of Estonia, Latvia, and Lithuania (units, 2015=100)



Sources: Eurostat, OECD, own calculations

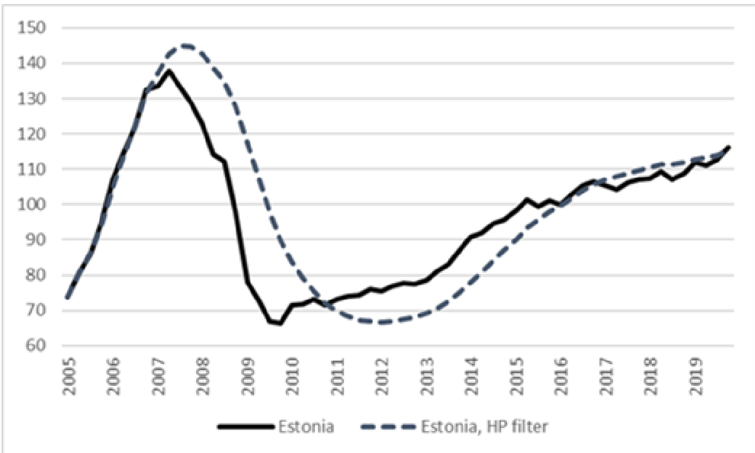
Figure 11 shows that the P/R ratio followed a similar pattern as the P/I ratio. All three countries reported high P/R ratios before the crisis in 2008. It seems, however, that Lithuania experienced imbalances on the real estate market long before the other Baltic countries. On the other hand, Latvia did not report high P/R at first, but that led to an even more extreme increase in this measure in the years before the crisis. Even though Estonia seems stable in comparison, its P/R of 122.7 was still relatively high. Unlike the P/I ratio, the P/R ratio fluctuated significantly during and after the crisis. Estonia even exceeded its 2007 pre-crisis value in 2010, but the P/R ratio then started to fall. The current values of both Estonia and Latvia do not seem to show any suspicious behavior. On the other hand, Latvia shows an unusually high increase in P/R ratio in the past four years. That is understandable as the Latvian HPI lately experienced huge growth in house prices.

4.4.3 The Hodrick-Prescott Filter

The least reliable method of the housing bubble recognition is the Hodrick-Prescott filter. As the HP filter works only with the housing prices, without considering the overall economic situation, the results are not always accurate. Therefore, it will be treated only as an additional measure that is to be compared with the results provided by the P/I and P/R ratios analysis.

The HP filter is used to deprive the data of the changes caused by the business cycle. By taking away the short term trend, the long term trend can be easily recognized. Based on the paper by Sakarya and De Jong (2016), the Hodrick-Prescott filter should be used on the data that are expressed in real terms. That lead to the choice to use the quarterly data on the real home price index provided by the OECD and BIS. To apply the one-sided HP filter, the add-in Excel function[25] created by Kurt Annen was used.

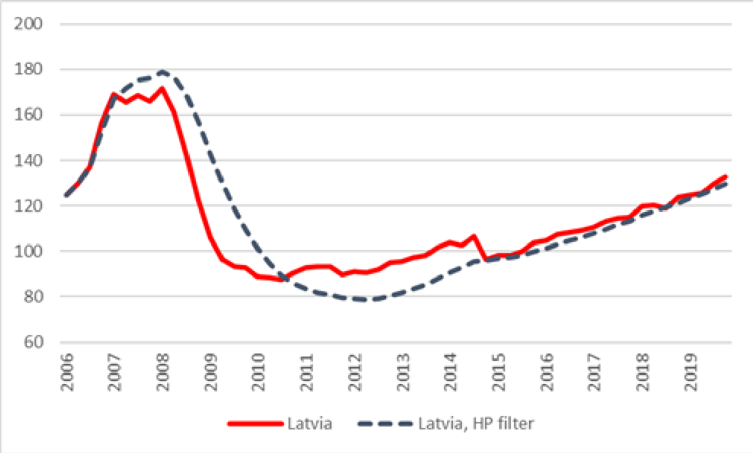
Figure 12: Estonian HPI and long term trend



Sources: BIS, OECD, author's calculations

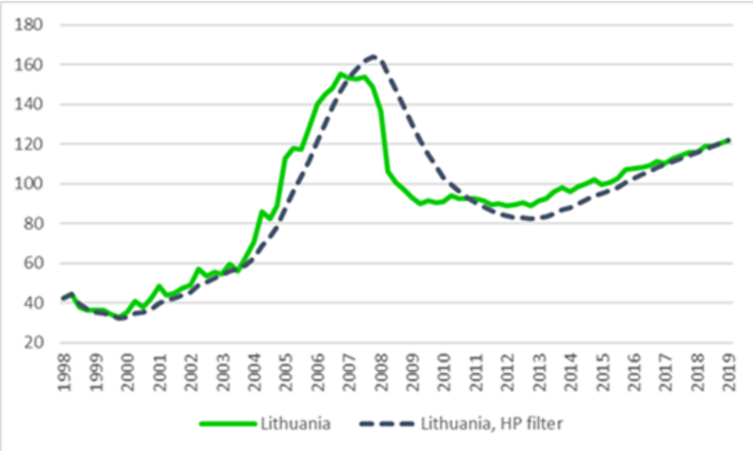
[25] We are using quaterly data and λ is therefore set to 1600.

Figure 13: Latvian HPI and long term trend



Sources: BIS, OECD, author's calculations

Figure 14: Lithuanian HPI and long term trend



Sources: BIS, OECD, author's calculations

Figure 12, Figure 13, and Figure 14 are the graphic depictions of the long term trends in the real HPI in the Baltic countries. We can see that, especially in the time during and after the Great Recession, the trend significantly deviates from the real HPI. Unfortunately, the time series of Estonia and Latvia do not give us much information about the actual pre-crisis situation, as they start in 2005 and 2006 respectively. We can only guess that there was similar development as in Lithuania, where we can see an overvaluation in the prices of residential real estate, especially in the year 2004 and onwards. The trend and actual values seem to almost coincide in last few years. Subsequently, there is no sign of the overvaluation or undervaluation of the housing prices.

4.5 Results

4.5.1 Estonia

The Estonian sample size is the smallest, with 47 observations. Thus, we decided to use a limited number of variables in the model to get the best possible results. The chosen variables are real net wage, construction cost index, stock of granted mortgages to households, and, of course the variable of interest, the house price index. We also created the alternative model with a real mortgage interest rate, that yielded similar results, but showed up not to be a great determinant in Estonia. Appendix B: Alternative Estonian model, however, shows detailed results of this model. Our final model obtains one dummy variable, popgrowth, equal to one if Estonia experienced population growth in the specific period and to zero otherwise. The population is used in this form out of necessity, as it is a non-stationary variable even at first differences.

We also faced the decision of whether to use the GDP per capita or real wages in our model. While Égert & Mihaljek (2007) analysed the effect of GDP on the house prices in Estonia and came to the classic conclusion of the significant positive relationship between the two, these results were challenged in 2009 by OECD, as they decided to use numerous methods to analyse the effect of the disposable income instead. In the same year, Vizek & Posedel (2009) published a paper that used the VAR model to analyse the effect of GDP on house prices, which showed no significant relation between Estonian GDP and housing prices. GDP also showed up to be insignificant in our model, and we, therefore, settled for the net real wage as it showed up to be a slightly better determinant.

Both versions of Johansen's cointegration test confirmed the existence of 2 cointegrating vectors at a 1% significance level and 3 cointegrating vectors at 5%. As it is very unusual to choose the 1% significance level, we decided to choose the more usual 5% mark. The cointegrating vectors have the following forms:

$$\Delta lHPI = -1.280\Delta lCCI - 0.008,$$

$$\Delta lrwage = 1.826\Delta lCCI - 0.002,$$

$$\Delta lstock = -1.199\Delta lCCI - 0.028.$$

The existence of multiple cointegrating vectors makes interpretation more complicated. We will now employ two methods – the variance decomposition and the impulse response function – that will help us to understand the dynamic between the variables.

Figure 15: Variance decomposition for the house price index (Estonia)

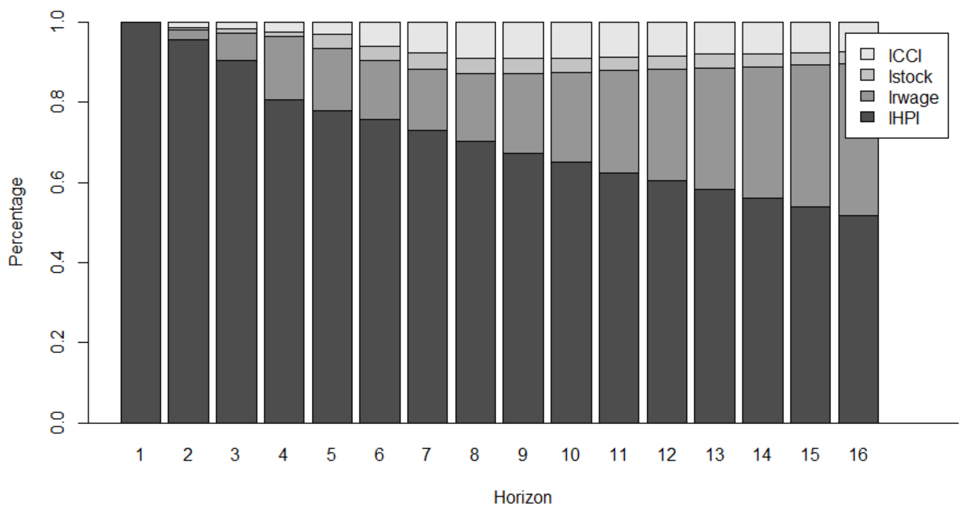
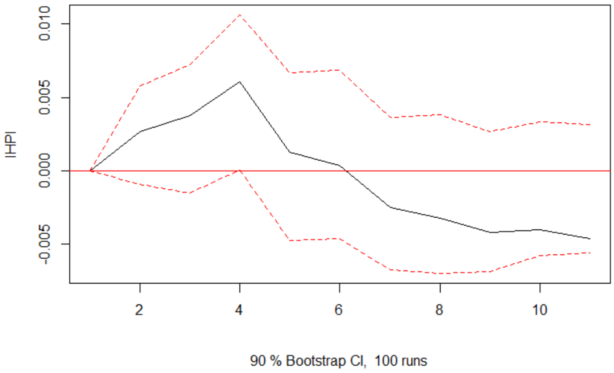


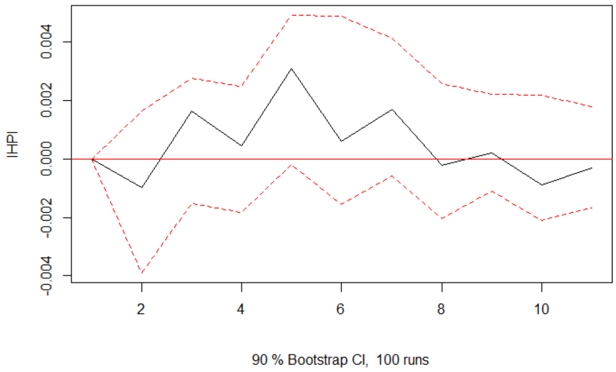
Figure 15 shows the variance decomposition of the house price index. The specific estimated values beyond the 16 graphed periods can be found in Appendix A, Table 12. As we can see, the shock in HPI strongly influences its future values, and there is a strong price persistence. Even after 5 years, HPI still explains over 40% percent of its own variations. The net real wages showed up to carry out a lot of information essential to forming the HPI as well. As we can see in Figure 15, it takes time before the shock in real wages significantly affect the housing prices. However, after circa 4 years, the real wage already explains almost 40% of information obtained in HPI. That can be explained by the fact that it takes time before consumers react to their increased income and start to demand better housing, increasing the house prices. The stock of the mortgages granted to households has a relatively moderate effect on the housing prices. In the semi-long run (circa 5th to 16th quarter), the change in mortgages explains on average 3.5% of the variance in HPI, which is not large in comparison to, for example, real wages, but is still bigger and more persistent than the effect of the real mortgage interest rate (see Appendix B for results of the alternative model with the real interest rate). That is mostly consistent with Kulikauskas' (2016) findings, even though he did find the real interest rate of mortgages to be a significant determinant in the panel setting. The construction cost index's effect also grows relatively slowly at first but reaches 9% after two years.

Figure 16: Impulse response functions for house price index (Estonia)

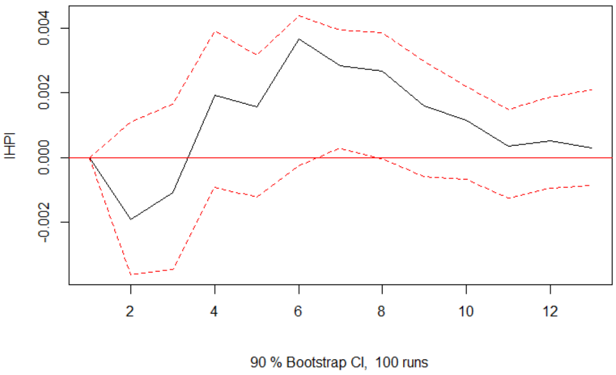
Real wage → House price index



Stock of morgages → House price index



Construction cost index → House price index



House price index → House price index

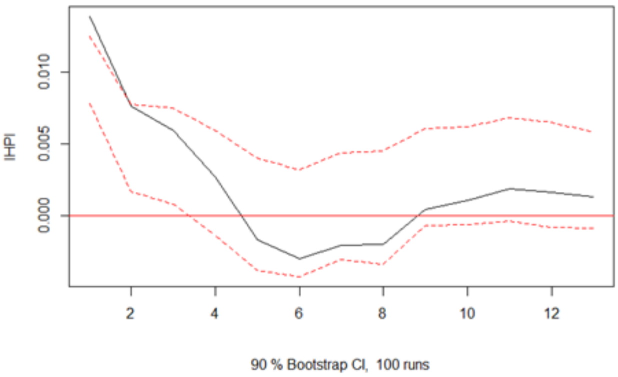


Figure 16 shows the response of HPI to the impulse (change) in other variables[26]. We can see that while the house price index responses to impulse in real wage and construction cost index are not significant at first, there are periods of significant responses later on. The stock of the mortgages granted seems not to affect house prices significantly, and we, therefore, have to interpret its effect with caution. The change in the stock of borrowed money seems to affect the prices expectedly – the more money people borrow for house purchases, the more they demand the housing, which increases the house price index. However, the effect is relatively volatile and small, and how was mentioned, insignificant.

Both real wages and construction cost index cause in some periods significant and relatively big positive effect. The shock in HPI causes significant positive change for 2 time periods following the shock. However, we can see that the curve afterward falls below the zero and response is not significant, showing that the change in HPI itself is significant and positive only in short run. Vizek (2010) came to a similar conclusion, as she claimed that the housing prices in analysed countries, including Estonia, are driven by price persistence in the short run, but not in the long run. Note, however, that the response of HPI to the exogenous shocks is permanent.

Now we need to comment on the properties of the model. The main problem of this model is the low number of observations. While the original dataset obtained 60 observations, there was a severe problem with the stationarity at even first-difference that would make analysis nearly impossible. Therefore, we sacrificed a few observations to fix this problem. The model is stable, and the Engle's ARCH test did not reject the null hypothesis of homoskedasticity of residuals. The Portmanteau test, however, rejected the null hypothesis of no serial correlation. That could, unfortunately, make the results less reliable. Note, however, that while the Durbin-Watson statistics may suggest a weak positive correlation, its test statistic of 1.75 is relatively close to the desired values.

Additionally, Figure 9 shows the short term coefficients. All error correction terms are negative, which suggests the converge of the variables to the equilibrium. Note, however, that the $ect2$ is not significant. The dummy variable did validate that there is a

[26] The impulse response functions for all countries are build with the 90% confidence bootstrap intervals. That means that we are 90% certan that the values obtain the population means.

significant positive relationship between an increase in population and an increase in house prices.

Table 9: Short term coefficients (Estonia)

Short term coefficient and std. errors of equation of interest (ΔHPI_t)	
$ect1$	-0.6750*** (0.1684)
$ect2$	-0.1128 (0.1507)
$ect3$	-0.1721* (0.1000)
$constant$	1.0768 (2.2730)
$popgrowth$	0.0211* (0.0108)
$\Delta lHPI_{t-1}$	-0.4112** (0.1608)
$\Delta lrwage_{t-1}$	0.2700 (0.2431)
$\Delta lstock_{t-1}$	-0.6407 (1.8276)
$\Delta lCCI_{t-1}$	-0.5316 (0.6755)
$\Delta lHPI_{t-2}$	-0.3710* (0.1818)
$\Delta lrwage_{t-2}$	0.2271 (0.2436)
$\Delta lstock_{t-2}$	1.4322 (1.8468)
$\Delta lCCI_{t-2}$	-0.3113 (0.6789)
$\Delta lHPI_{t-3}$	-0.5039*** (0.1534)
$\Delta lrwage_{t-3}$	0.4630* (0.2571)
$\Delta lstock_{t-3}$	0.9608 (1.3856)
$\Delta lCCI_{t-3}$	0.5528 (0.6965)
$Observations$	47
$Multiple\ R^2$ $(Adjusted\ R^2)$	0.7616 (0.6057)

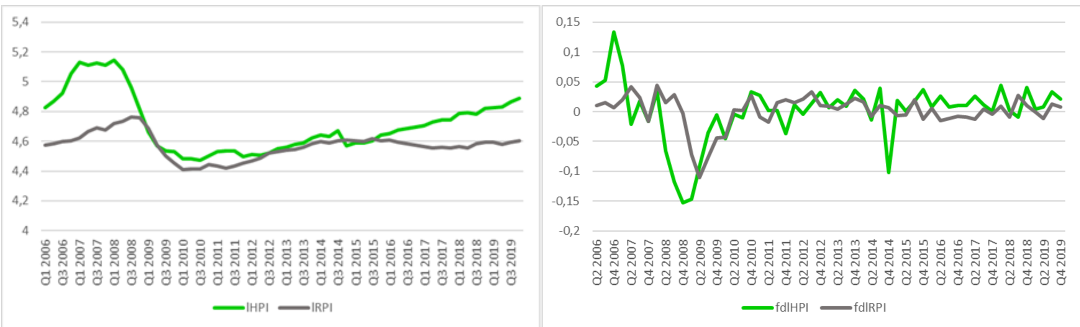
$*** \, means \, p-value \, < 0.01, ** \, p-value \, < 0.05, * \, p-value \, < 0.1$

4.5.2 Latvia

The Latvian model uses a similar set of variables as its Estonian counterpart. We once again tried to build the model with the GDP per capita, but the real wage was chosen as the usage of GDP resulted in lower multiple R-squared and adjusted R-squared. The model with GDP (with the same variables and same lag length) did not produce the desired negative significant error correction term while the alternative wage included model did. Also, we decided to include the country-specific variable – the rent price index. However, we also traded the RPI for the variable capturing the stock of mortgages granted to households in the model. These data are not available for Latvia, and we would also lose more degrees of freedom. The stock of mortgages is also a country-specific variable for Estonia as it is a country with the highest percentage of housing owners with outstanding loans out of the Baltic countries. Note, that the popgrowth dummy variable is not present. Latvia has decreasing population through the entire period and we would therefore obtain dummy variable with only zeroes.

Figure 4 showed that Latvia has the highest percentage of people renting instead of owning housing from all three Baltic countries. However, this percentage is still low compared to the EU average, and we expect its effect to be relatively moderate. Figure 17 shows the graphic depiction of both HPI and RPI that seems to support the hypothesis that the effect of rent prices on housing prices may not be significant, as the past value of rent price index do not seem to significantly influence the housing prices.

Figure 17: The comparison of rent and home price indices (original and differenced form)



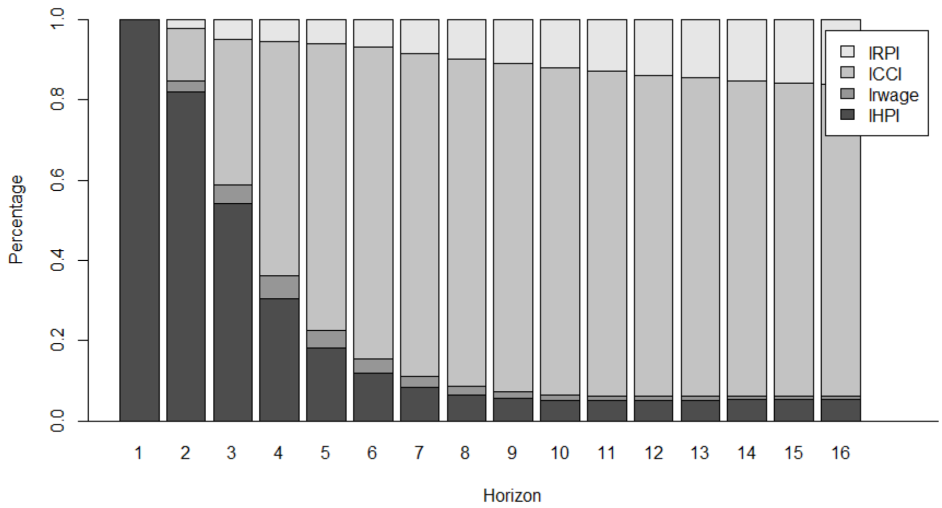
Source: OECD, own calculations

The model uses 4 lags. The Johansen's test indicates the existence of 1 cointegrating vector at a 5% significance level:

$$\Delta lHPI = 1.391\Delta lrwage - 3.626\Delta lCCI + 0.809\Delta lRPI - 0.012.$$

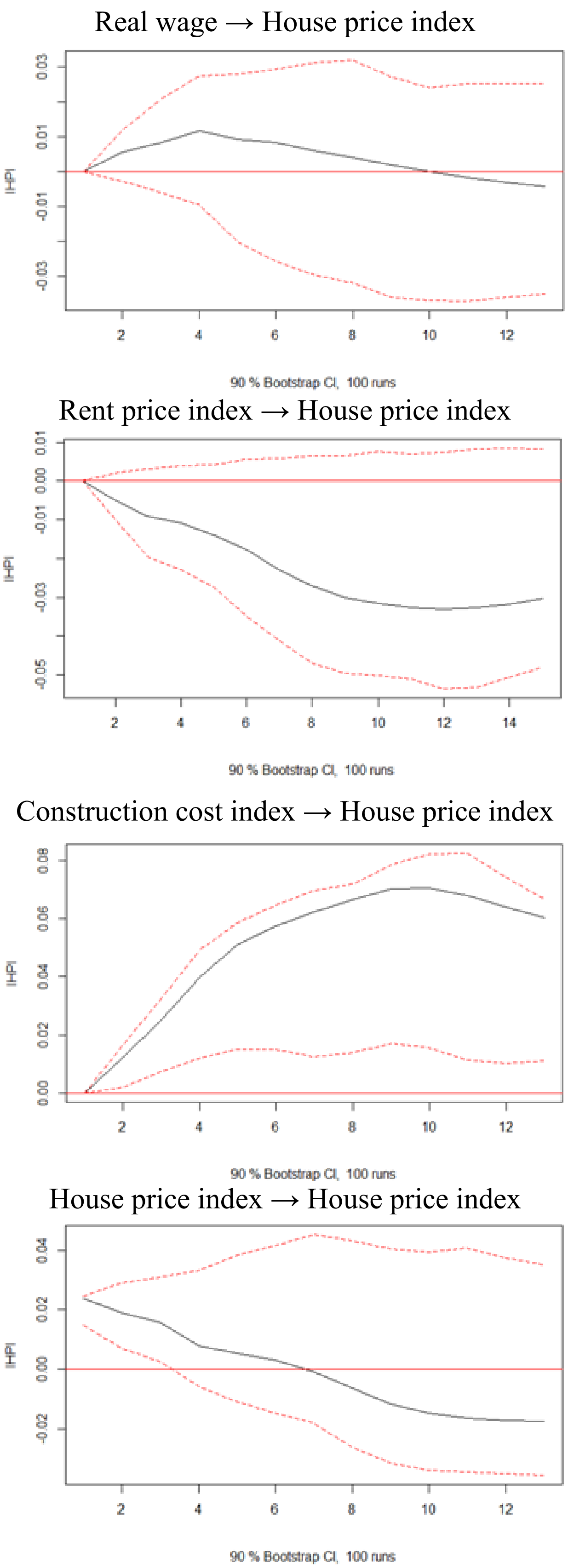
We can see that the estimated relationship between housing prices and real wages is positive in the long run. The positive relation with RPI was also expected, as we are dealing with substitutes. However, the negative sign of the logarithmic CCI suggests a negative relationship between the elasticity of HPI and elasticity of CPI. However, the results of our model of interest do not suggest this dynamic. We will now look closely at the long run effects of housing determinants using the variance decomposition (Figure 18) and impulse response functions (Figure 19).

Figure 18: Variance decomposition for the house price index (Latvia)



As expected, the housing prices themselves at first explain most of the variance in HPI. However, that changes rather quickly, and Latvian housing prices do not suggest the same price persistence as in Estonia. The most crucial determinant in the semi-long horizon seems to be the construction cost index. The CCI seems to explain most of the housing prices' variance around the 2 year mark, and then its effect starts to fade away very slowly. Around this time, the rent price index starts to show some importance in forming the HPI, and then its effect consistently grows. The most surprising result seems to give the real wage, as it seems to be relatively irrelevant over most of the graphed time period. After 3 to 4 periods, the real wage approaches the 6% mark, and its effect slowly diminishes.

Figure 19: Impulse response functions for house price index (Latvia)



As was already suggested by the variance decomposition, the response of HPI to shock in the construction cost index is relatively large, positive, and significant. The HPI also shows the price persistence as it responses in a positive manner to its own shock. The effect is also relatively large at first, but similarly to the Estonian case, it becomes insignificant after a few quarters. Neither the real wage nor rent price index cause a significant reaction in HPI. Note that the housing prices seem to decrease in response to the increase in rent prices. The real wage, on the other hand, seems to cause the expected positive change in housing prices. However, in the case of insignificance, the signs are not too informative, as the confidence interval lies in both positive and negative territories.

We once again ran the tests to find out whether the model is stable and well behaved. The model is stable as all inverse roots of the companion matrices lie inside the unit circle (Appendix A, Figure 23). The model has a relatively low number of observations. However, by restriction of the number of variables in the model, we managed to create a model with 38 degrees of freedom, which is a manageable number. The tests also showed that the residuals are homoscedastic, normally distributed, and not autocorrelated.

Table 10 shows specific short run coefficients, showing that lags of $\Delta lHPI$ and $\Delta lCCI$ are indeed significant determinants in the short run. The error correction term has a desired negative sign and is significant, which means that variables are moving towards the long run equilibrium, in our case with a specific speed of 43% over one period. Both R-squared and adjusted R-squared are high, meaning that even though our model obtains only 4 lagged variables, they can explain a large part of the variation in the house price index's present value.

Table 10: Short term coefficients (Latvia)

Short term coefficient and std. errors of equation of interest ($\boldsymbol{\Delta HPI_t}$)	
$ect1$	-0.4337*** (0.0797)
$constant$	0.0160** (0.0061)
$\Delta lHPI_{t-1}$	-0.2056 (0.1553)
$\Delta lrwage_{t-1}$	0.3916 (0.3010)
$\Delta lRPI_{t-1}$	-0.3411 (0.2513)
$\Delta lCCI_{t-1}$	0.6985*** (0.2144)
$\Delta lHPI_{t-2}$	-0.3184** (0.1568)
$\Delta lrwage_{t-2}$	0.3204 (0.2724)
$\Delta lRPI_{t-2}$	-0.2761 (0.2409)
$\Delta lCCI_{t-2}$	0.8533*** (0.2419)
$\Delta lHPI_{t-3}$	0.5172*** (0.1781)
$\Delta lrwage_{t-3}$	-0.1981 (0.2293)
$\Delta lRPI_{t-3}$	-0.1950 (0.2222)
$\Delta lCCI_{t-3}$	1.3181*** (0.2641)
$Observations$	56
$Multiple\ R^2$ $(Adjusted\ R^2)$	0.734 (0.636)

$***\ means\ p-value\ < 0.01, **\ p-value\ < 0.05, *\ p-value\ < 0.1$

4.5.3 Lithuania

Lithuania is the country with most observations (specifically 71). Our model obtains real wage, unemployment, rent price index, construction cost index, and house price index as the endogenous variables. We also included exogenous dummy variable, the popgrowth, which is equal to 1 in the case that the population increased compared to the previous period, and to 0 otherwise. The population is once again obtain in the model in the form of dummy variable due to problem with stationarity. As we can see, this model has an additional endogenous variable compared to Estonian and Latvian models. This decision was made based on the fact that Lithuania has a bigger sample size.

Both versions of the Johansen's cointegration test suggest the existence of 2 cointegrating vectors of the following forms:

$$\Delta lHPI = -0.144\Delta unem - 8.158\Delta lCCI + 2.530\Delta lRPI - 0.042,$$

$$\Delta lrwage = -0.003unem - 1.726\Delta lCCI - 0.127\Delta lRPI - 0.006.$$

The existence of multiple cointegrating vectors once again complicates the interpretation of the information obtained in them. We can see that there is more than one long run relationship between the variables, and they possibly converge to two different equilibriums. Therefore, we will again use the variance decomposition and the impulse response functions to explain the long run dynamic between the variables.

Figure 20: Variance decomposition for the house price index (Lithuania)

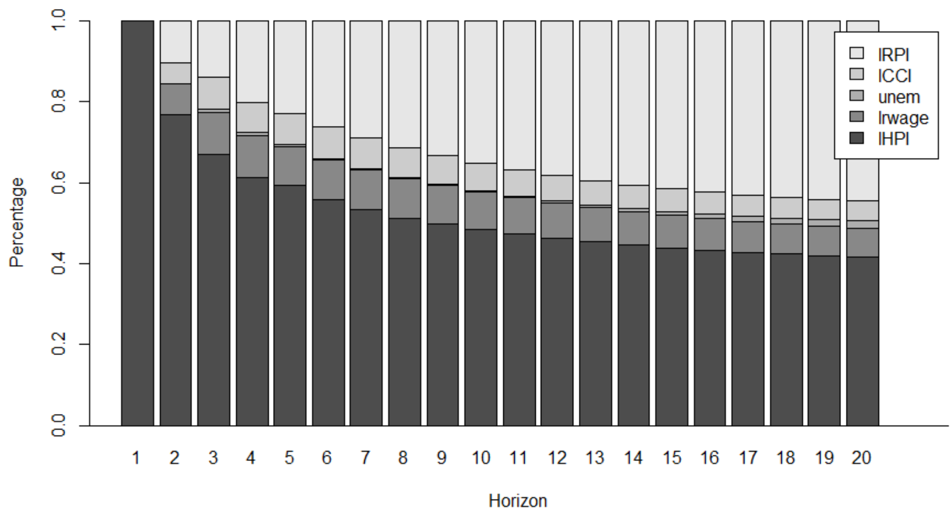
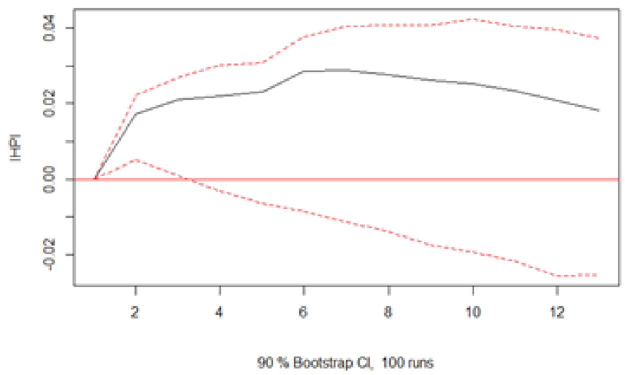


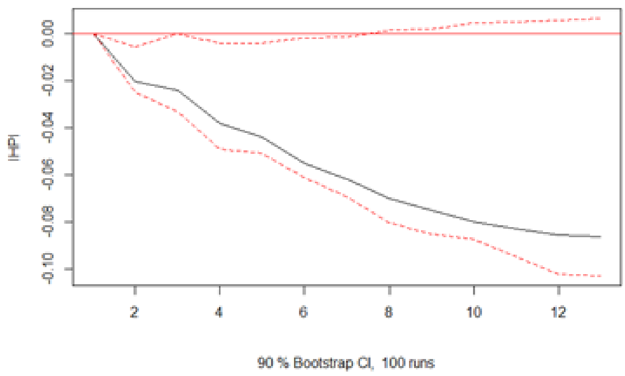
Figure 20 shows the variance decomposition for house price index in Lithuania. The price persistence is an essential tool for explaining the variations in the house price index, as even after 5 years, it still does explain around 35% of the information. However, its effect is still smaller than in Estonia, but more prominent than the one in Latvia. Therefore, even though the Baltic countries are similar, their individual analyses gave us useful information. The change in real wage and construction cost index seems to evoke a response of similar magnitude as they are both approaching the 10% mark at their peak. Unemployment, on the other hand, showed to be relatively unimportant. As unemployment seemed to fluctuate even before the crisis, often reporting two-digit numbers, it is surprising that this fact did not affect the HPI significantly in either the short or long run. The shock in rents seems to affect the housing prices in the long run horizon. Given that Lithuania has an extremely undeveloped rent market and, according to Figure 4, only a little over 10% of the Lithuanian population is renting the property that they live in, we can say that the effect of rent prices is large.

Figure 21: Impulse response functions for house price index (Lithuania)

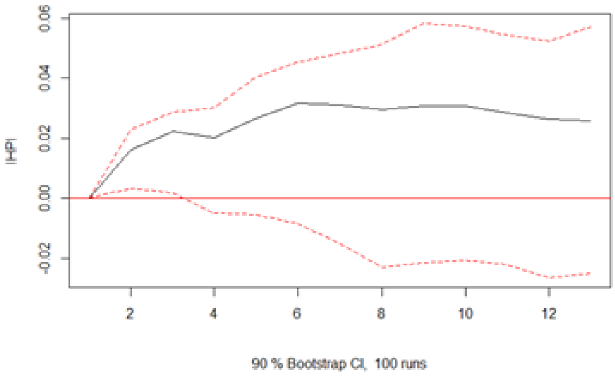
Real wage → House price index



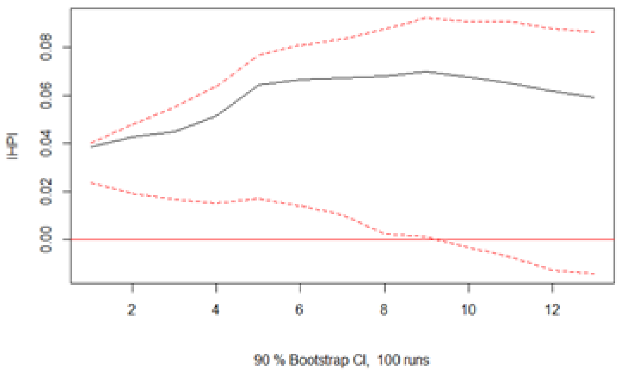
Rent price index → House price index



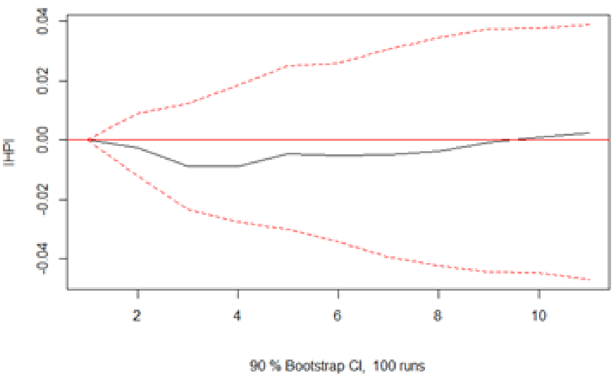
Construction cost index → House price index



House price index → House price index



Unemployment → House price index



House price index → Rent price index

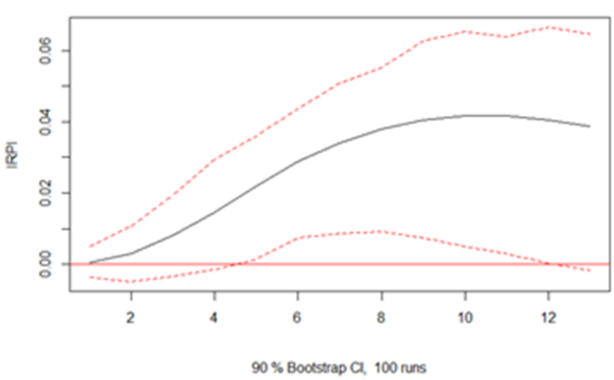


Figure 21 shows the IRFs. The reaction of house price index to shock in net real wage and construction cost index is significant for 3 time periods after the shock and has expected positive sign. The positive effect is permanent but insignificant after the mentioned 3rd quarter. The reaction of housing prices to impulse in the housing prices is positive and significant longer than in Estonia and Latvia – for circa two years. The IRF for unemployment shows what was already suggested by the variance decomposition. The response of HPI to shock in unemployment is insignificant and small in the short and long run. While it seems that the increase in unemployment causes a decrease in housing prices, we need to interpret this information with caution, as the confidence interval takes on both negative and positive values. Now we need to address the reaction of housing prices to increase in rent prices. Renting the property is the substitute for owning it, and we would expect the positive relation between these two variables. As we can see, the shock in rent prices seems to, however, cause a significant negative response of housing prices. In the previous part of the thesis (4.4.2), we calculated the so-called price to rent ratio, that can recognize the imbalances happening on either housing or renting market. The results showed that this ratio indeed yielded alarming results long before the crisis started. This imbalance is probably why the model cannot recognize the usual substitute effect between the two goods. Note, however, that Figure 21 also shows the reaction of RPI to impulse in HPI that suggests the usual positive dynamic. That is probably because the housing prices grew at an extreme rate during the pre-crisis period, while rent prices grew at a moderate rate. The substitution effect caused part of this increase. The housing prices were pushed down by the rent prices, but this effect was not enough to decrease the prices before the crisis in 2008. We also need to realise that the demand for renting is much smaller than the demand for owning the housing, and this may cause some disturbances as well.

The model is stable (for stability test see Appendix A, Figure 24) as all inverse roots lie inside the unit circle. We were not able to reject the null hypothesis of homoskedasticity of residuals, and the JB test did not reject the null hypothesis of a normal distribution of residuals. However, we were able to reject the null hypothesis of Portmanteau test of no serial correlation of residuals. On the other hand, the Durbin-Watson statistics gave us a result of 1.914, which suggests that if there is positive autocorrelation, it is weak and should not cause a problem, as the statistic is very close to the desired value of 2.0.

The short run coefficients can be seen in Table 11. As we are interested in the long run dynamic between the variables, these are not the primary concern of this thesis. The $ect1$ and $ect2$ are both negative and significant, and the variables, therefore, do restore into the equilibrium. The R-squared and adjusted R-squared are both reasonably high (with values of 0.6165 and 0.4746, respectively). However, it seems that the Lithuanian model is in this regard worse than the model for Estonia and Latvia, even though it obtains additional endogenous variable. Note that the dummy variable, $popgrowth$, indicates that the increased population causes larger housing prices, but its effect is not significant.

Table 11: Short term coefficients (Lithuania)

Short term coefficient and std. errors of equation of interest (ΔHPI_t)	
$ect1$	-0.1736*** (0.0454)
$ect2$	-0.8700*** (0.2154)
$constant$	-6.5058*** (1.5898)
$popgrowth$	0.0170 (0.0340)
$\Delta lHPI_{t-1}$	-0.2372* (0.1352)
$\Delta lrwage_{t-1}$	0.5374 (0.3281)
$\Delta unem_{t-1}$	0.0011 (0.0117)
$\Delta lCCI_{t-1}$	2.2081*** (0.5027)
$\Delta lRPI_{t-1}$	-1.0721*** (0.2938)
$\Delta lHPI_{t-2}$	-0.3982*** (0.1440)
$\Delta lrwage_{t-2}$	-0.2433 (0.3495)
$\Delta unem_{t-2}$	-0.0045 (0.0114)
$\Delta lCCI_{t-2}$	1.0890* (0.5748)
$\Delta lRPI_{t-2}$	-0.0577 (0.3289)
$\Delta lHPI_{t-3}$	-0.2880** (0.1353)
$\Delta lrwage_{t-3}$	0.5340* (0.3631)
$\Delta unem_{t-3}$	0.0179 (0.1138)
$\Delta lCCI_{t-3}$	2.6566*** (0.3082)
$\Delta lRPI_{t-3}$	-1.0828*** (0.3082)
$Observations$	71
$Multiple\ R^2$ $(Adjusted\ R^2)$	0.6165 (0.4746)

$***\ means\ p-value\ < 0.01, **\ p-value\ < 0.05, *\ p-value\ < 0.1$

4.5.4 Discussion of the results

The VECM analysis showed that the reaction of housing prices to exogenous shock differs for each of the analysed countries. While we did include country-specific variables for each of the countries, we also used the selected determinants for all three countries (housing prices, real wage, and construction cost index).

The past values of the HPI index are significant determinants for the first few periods in all Baltics countries, expectedly affecting the housing prices. The lags of HPI explain over 40% of the variance in Estonian HPI even five years after the shock. The number is similar for Lithuania, but Latvia showed minimal price persistence in the long run. These findings are consistent with the similarly themed papers. Posedel & Vizek (2009) found that price persistence is an essential determinant for all transition analysed countries, even though Estonia showed a smaller reaction than in our model. Note, however, that there is no time overlap of data between their and our analysis, which is probably why the results slightly differ. Vizek (2010) also stated that the price persistence is important determinant in the short run, but for many countries not in the long run, which is clearly case of Latvia.

To acknowledge the supply side of housing market, the construction cost index was included in the analysis. Unexpectedly, the Latvian house prices are very affected by the change in the CCI in the long run, and we can say that the changes on the supply side have a bigger effect on housing prices in Latvia than in the remaining countries. Estonian and Lithuanian results also showed that the construction cost index affects their housing prices in an expected way and that it is a significant determinant, even though not over the entire time horizon. Our results are once again consistent with previous studies by, for example, Kanapeckiene et al. (2016) or Kulikauskas (2016) that found the CCI to be a significant determinant that positively affects housing prices.

We were able to confirm that the real net wage is a significant determinant of housing prices in only Estonia and Lithuania. That is probably due to a slow increase in Latvia's real net wages over the observed period. It is not completely out of the ordinary for the income to show up to be insignificant in the model. For example, Belke & Keil (2017) came to similar conclusion, as they found income to be insignificant determinant of housing prices in German regions.

The country-specific variables yielded surprising results. The unemployment rate in Lithuania, which is over the observed period on average 10%, has small impact on housing prices. It is, however, worth mentioning that Kanapeckiene et al. (2016) were able to prove that the unemployment rate is a significant determinant in Lithuania at a 10% significance level. On the other hand, Égert & Mihaljek (2007) were also unable to prove that unemployment is a significant variable in their CEE panel analysis. For Estonia, we chose to test the effect of the availability of debt financing on housing prices. We found out that the volume of outstanding loans seems to be a better determinant than the real interest rate of mortgages, but the effect is not significant. Posedel & Vizek (2009) did found the volume of loans to be the most important determinant of housing prices in Estonia. However, they did use the VAR model, and that can possibly be part of the reason why our results differ. Also, Vizek (2010) was able to find only a significantly smaller connection between housing prices and a real interest rate of mortgages. Lastly, we also tested the effect of rent prices on the Lithuanian and Latvian housing prices. We obtained unexpected results, as the rent prices in Lithuania seem to negatively, and sometimes significantly, affect housing prices.

The VECM analysis, but also the analysis of the P/R ratio, showed that there could be problems concerning the rent market. The Latvian P/R, for example, is high, and rent prices do not significantly affect their housing prices. We also know from the theoretical properties that the rental market in the Baltics is underdeveloped, and the Baltic countries have high ownership rates. To solve these problems, renting should be incentivized. The government could impose the monetary subsidies, and, according to Rubaszek & Rubio (2020), the additional protection policies for both tenants and landlords could be imposed. These could, for example, avert the spurious increase in rent prices or destruction of the landlord's property.

5 Conclusion

In the light of the Great Recession, many authors tried to analyse the real estate market and find the driving determinants of housing prices. This thesis expands on these studies and uses the time series analysis to identify the determinants of residential real estate prices in Estonia, Latvia, and Lithuania.

The empirical part of this thesis firstly introduced the collected data, their sources, and availability. It was necessary to alter some of the used time series, for example by using the moving average method to seasonally adjust the data. This was followed by thorough introduction of the endogenous models – the Vector Autoregression model and the Vector Error Correction model.

To determine which of the endogenous models is suitable for our analysis, we tested for the stationarity and cointegration of the time series. We had severe problems with the stationarity of the Estonian data even at first differences, and we were, in search for stable model, forced to slightly reduce the number of observations for this specific country. The Johansen's cointegration test proved the existence of at least one cointegrating vector in all Baltic countries, and that lead to choice of VEC model. The information criteria were also employed to decide the optimal number of lags in the model.

The VEC models were constructed for all three countries and long run dynamics were studied. The interpretation of the results was done by introduction of the cointegrating vectors, impulse response functions, and variance decomposition. The quality of the models was estimated using the ARCH, Portmanteau, Jarque-Bera, and stability tests that mostly suggested that the models are well behaved, even though Estonia did show signs of possible autocorrelation of the residuals. Each of the model contains the three same variables – real wages, construction cost index, and of course the house price index. We then decided to test the country specific determinants that were chosen based on the specific properties of the countries. Our analysis lead to results that are mostly consistent with the findings of the existing literature. The price persistence of housing showed up to be the most important determinant, which is standard in both transition and developed countries, as was proved by Posedel & Vizek (2009). The price persistence is weakest for Latvian housing prices, that seems to be in the long run very influenced by the construction cost index. The variance decomposition suggested the real wage to be important determinant of housing prices in Estonia and Lithuania, but its effect on the Latvian housing prices seems moderate and insignificant in both short and long run. The rent price index, however, seems to affect countries in unexpected negative way. As this is probably the direct consequence of the countries high ownerships rates and underdeveloped rent markets, we did offer possible future solutions and policy implications.

The main analysis was accompanied by brief analysis of P/I ratio, P/R ratio, and by application of the Hodrick-Prescott filter on the housing prices data in the search for possible overvaluation and, subsequently, housing bubbles. All three indicators showed signs of imbalances long before the 2008 financial crisis, but they do not seem to indicate any danger as of today. The P/R ratio yielded relatively large current values in the case of Latvia, but P/I ratio and HP filter did not show any overvaluation.

The main shortcoming of this thesis is the limited number of observations, ranging from 47 to 71. Our sample size is, however, comparable with existing literature analysing the transition countries, and often even exceeds their number of observations. More observations would also allow us to use more variables in individual models. Of course, panel analysis would in theory solve this problem, but we ruled this possibility out, as it was used by many authors before, including Égert & Mihaljek (2007) and most recently also Kulikauskas (2016), and it would not allow us to compare the determinants among the countries. We would suggest that analysis similar to ours could therefore possibly be repeated in foreseeable future, when the longer time series are available. The future analysis could also expand this thesis by building the model for either CEE or former Soviet Union country, that would be used solely for comparison.

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7 Appendices

7.1 Appendix A: Additional model results

Table 12: The variance decomposition over 5 years (Estonia)

Time since shock	lHPI	lrwage	lstock	lCCI
Q1	1.000	0.000	0.000	0.000
Q2	0.956	0.027	0.004	0.0138
Q3	0.906	0.067	0.012	0.015
Q4	0.808	0.158	0.011	0.023
Q8	0.704	0.169	0.038	0.089
Q12	0.606	0.277	0.035	0.083
Q16	0.517	0.379	0.038	0.0737
Q20	0.4378	0.470	0.0269	0.065

Figure 22: Stability test (Estonia)

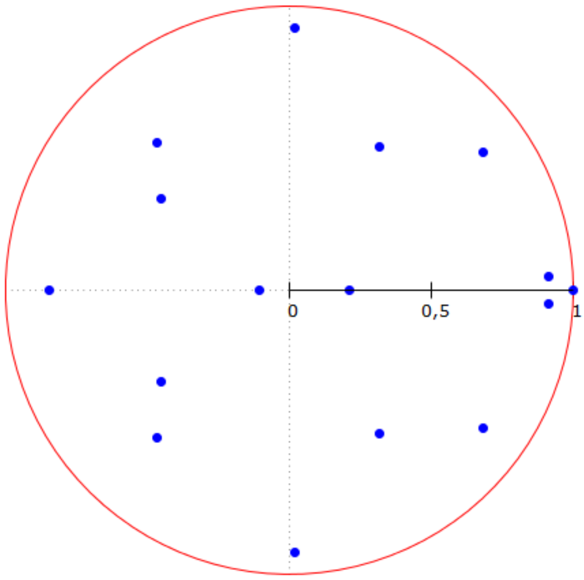


Table 13: Testing of residuals (normality, homoskedasticity, serial correlation)

	ARCH test (p-value)	Jarque-Bera test (p-value)	Portmanteau test (p-value)
Estonia	0.630	0.001*	0.001*
Latvia	0.376	0.948	0.847
Lithuania	0.395	0.198	0.001*

Note: The null hypothesis of ARCH test is homoskedasticity of residuals, the null hypothesis of Jarque-Bera test in the normality of residuals and the null-hypothesis of Portmanteau test is no serial correlation.

Table 14: The variance decomposition over 5 years (Latvia)

Time	lHPI	lrwage	lCCI	lRPI
Q1	1.000	0.000	0.000	0.000
Q2	0.821	0.0260	0.131	0.0225
Q3	0.542	0.046	0.363	0.050
Q4	0.304	0.058	0.583	0.0547
Q8	0.065	0.022	0.816	0.098
Q12	0.051	0.011	0.801	0.137
Q16	0.054	0.009	0.776	0.162
Q20	0.052	0.008	0.768	0.173

Figure 23: Stability test (Latvia)

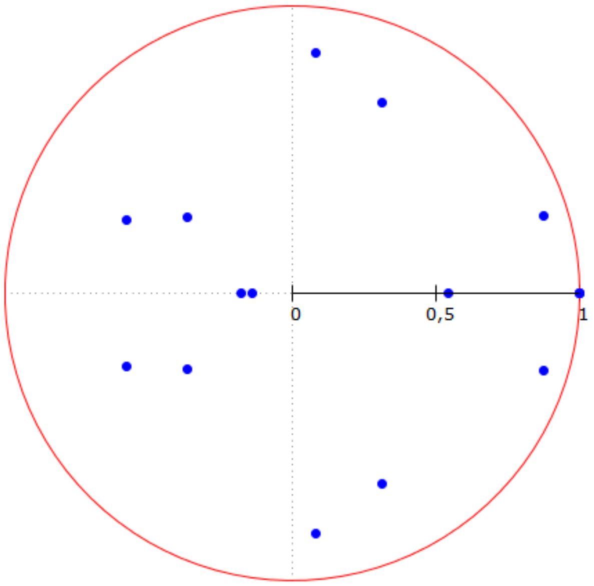
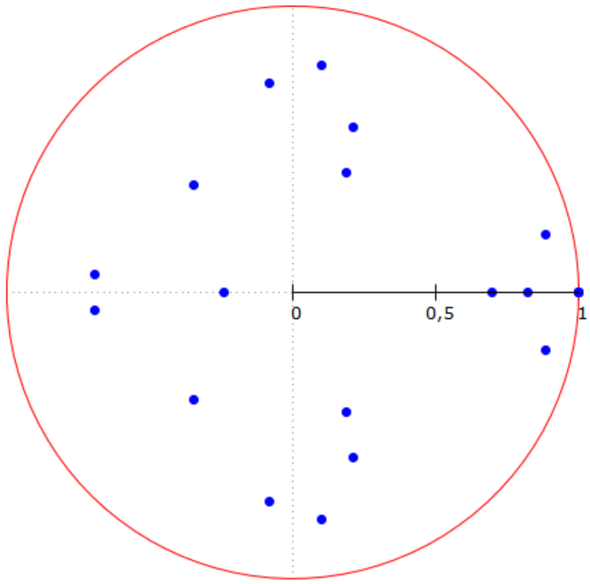


Table 15: The variance decomposition over 5 years (Lithuania)

Time	lHPI	lrwage	unem	lCCI	lRPI
Q1	1.000	0.000	0.000	0.000	0.000
Q2	0.773	0.071	0.001	0.060	0.095
Q3	0.675	0.0944	0.011	0.0953	0.125
Q4	0.615	0.095	0.013	0.090	0.197
Q8	0.504	0.082	0.005	0.092	0.316
Q12	0.430	0.065	0.003	0.081	0.422
Q16	0.379	0.051	0.004	0.071	0.495
Q20	0.345	0.042	0.006	0.066	0.541

Figure 24: Stability test (Lithuania)



7.2 Appendix B: Alternative Estonian model

Table 16: Johansen's cointegration test (alternative Estonian model)

	Null hypothesis	Test statistics	Critical value (5%)	Critical value (1%)
Estonia	r=0	113.81*	62.99	70.05
	r=1	59.92*	42.44	48.45
	r=2	19.56	25.32	30.45

$$\Delta lHPI = -0.007\Delta rir - 0.926\Delta lCCI - 0.014$$
$$\Delta lrwage = 0.028\Delta rir - 0.178\Delta lCCI - 0.009$$

Table 17: The variance decomposition over 5 years (alternative Estonian model)

Time since shock	lHPI	lrwage	rir	lCCI
Q1	1.000	0.000	0.000	0.000
Q2	0.927	0.023	0.049	0.001
Q3	0.884	0.061	0.041	0.014
Q4	0.856	0.083	0.040	0.0216
Q8	0.740	0.140	0.034	0.088
Q12	0.647	0.206	0.028	0.118
Q16	0.592	0.249	0.025	0.134
Q20	0.553	0.278	0.023	0.146

Figure 25: Impulse response functions (alternative Estonian model)

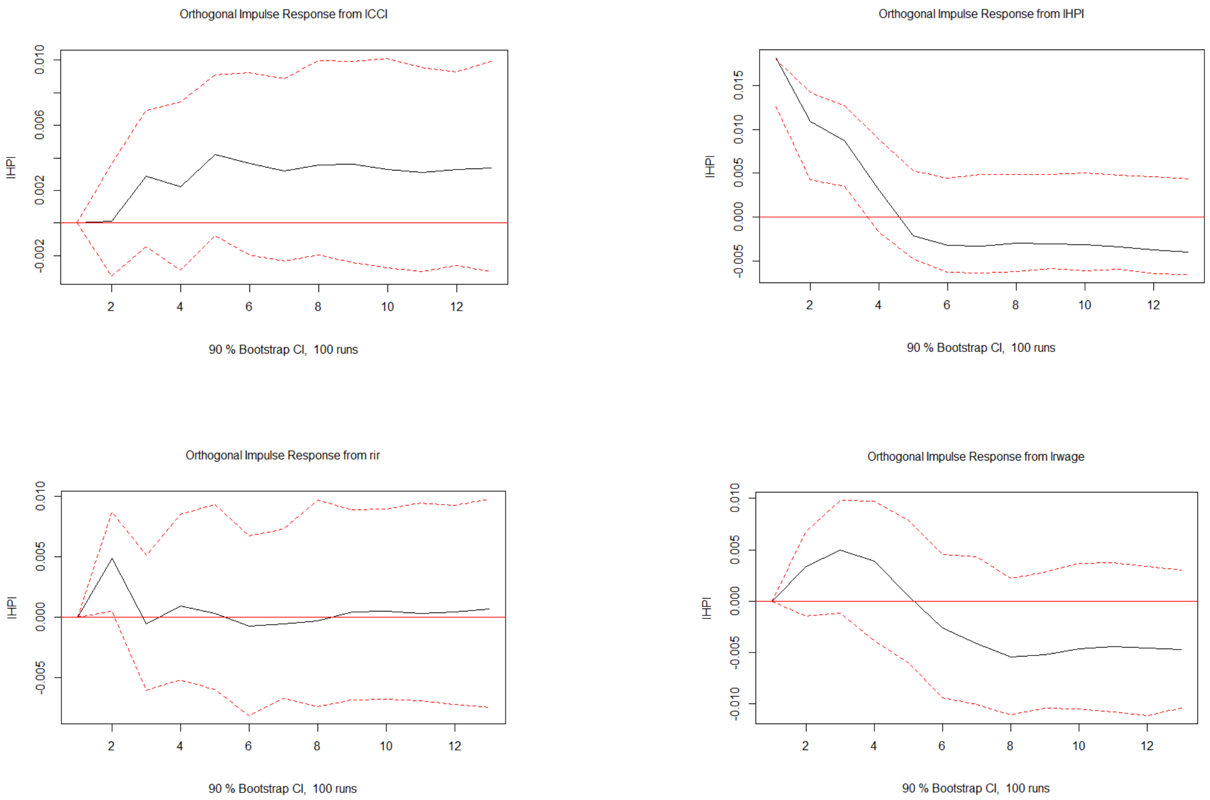


Figure 26: Stability test (alternative Estonian model)

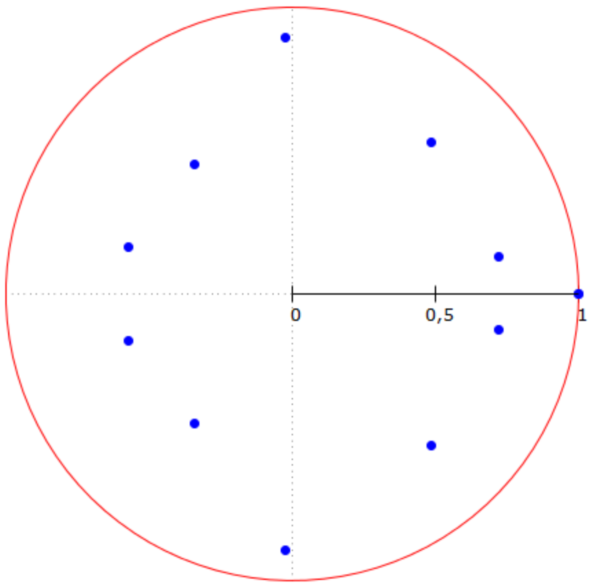


Table 18: Testing of the residuals (alternative Estonian model)

	ARCH test (p-value)	Jarque-Bera test (p-value)	Portmanteau test (p-value)
Estonia	0.235	0.110	0.010*

Table 19: Short term coefficients (alternative Estonian model)

Short term coefficient and std. errors of equation of interest (ΔHPI_t)	
$ect1$	-0.6237*** (0.0866)
$ect2$	0.0686 (0.1146)
$constant$	-0.4583 (0.6607)
$\Delta lHPI_{t-1}$	-0.4537*** (0.1406)
$\Delta lrwage_{t-1}$	0.2541 (0.2435)
Δrir_{t-1}	0.0082 (0.0056)
$\Delta lCCI_{t-1}$	0.0316 (0.6206)
$\Delta lHPI_{t-2}$	-0.4045*** (0.1049)
$\Delta lrwage_{t-2}$	0.4629* (0.2562)
Δrir_{t-2}	-0.0025 (0.0051)
$\Delta lCCI_{t-2}$	1.1107** (0.5328)
$Observations$	47
$Multiple\ R^2$ $(Adjusted\ R^2)$	0.831 (0.774)

$***\ means\ p-value\ < 0.01, **\ p-value\ < 0.05, *\ p-value\ < 0.1$