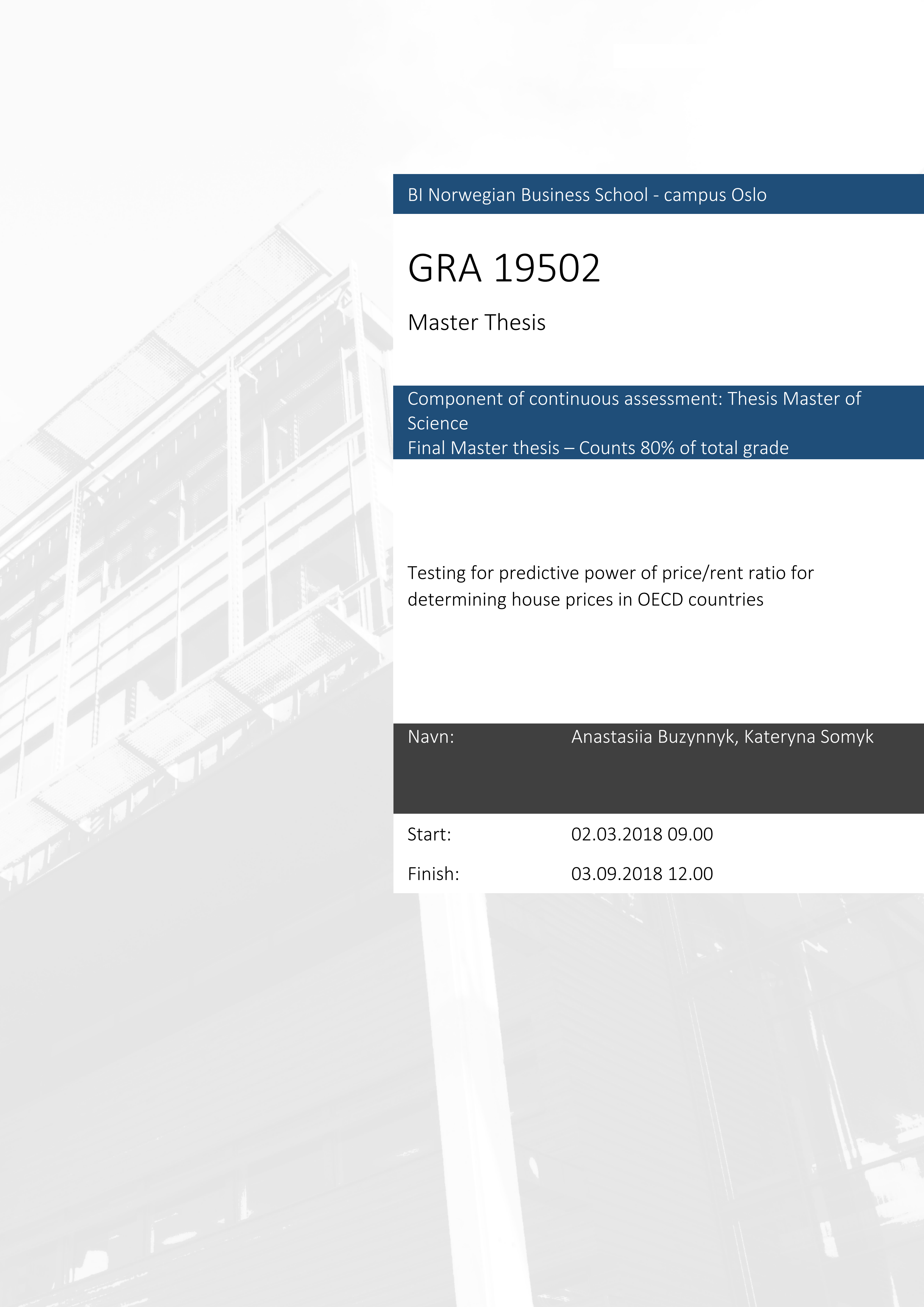

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Master Thesis

Testing for predictive power of price/rent ratio for determining house prices in OECD countries

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Content

Abstract

We study the predictability of price and rent changes by rent-to-price ratio for 20 OECD countries over the period 1970 to 2017. To investigate the relationship we used Vector Error-Correction Model (VECM) and long-horizon model. We constructed bootstrapping procedures to address the issues of biased estimates from the long-horizon model. First, we found that for most countries prices do all the correcting over the long-run time range. Second, there are significant cross-country differences in how rent-to-price ratio defines future rent growth. Third, both models showed completely different results. We concluded that rent-to-price ratio is not a complete predictor of price and rents formations on these markets.

1. Introduction

Real estate market is one of the biggest and most important sectors for the economy. Due to its huge size (the total value of world real estate market was around $217 trillion in 2015) (Hackett, 2016) and deep inter-linkages with other economic sectors, housing market can substantially influence the economic environment. Therefore, it also can be viewed as one of the indicators of economic stability for every country.

Because of strong connections to other economic areas, the distress on the real estate market can provoke macroeconomic vulnerabilities. The influential power of the housing market has become especially evident after the Financial Crisis of 2008 – the most severe economic downturn since the Great Depression (Havemann, n.d.). The housing bubble has burst on the US real estate market and provoked a serious recession in all major economies around the world. It is worth to notice that nowadays for many countries, housing price growth significantly outperforms rent growth rates showing the same disturbing patterns as before crisis 2008. The countries at risk include the USA, Canada, New Zealand, Norway, Sweden, Switzerland, UK, and Germany (see Figure 1 in the appendix). So, another price bubbles can be suspected on these markets.

Because of its importance, housing market is among the most popular research topics for scholars and practitioners. In particular, many scientists including Gallin (2008), Campbell (2009), and Pederson (2015), tried to find the way to predict the real estate market movements.

In this paper, we want to investigate the possibility to forecast changes in house prices and rents for OECD countries using rent-to-price ratio as the main predictive variable. It is widely believed that rent-to-price ratio on housing market is analogous to the dividend-to-price ratio on the stock market and can be implied to predict real estate market fundamentals such as rents and prices. The aim of this research is to check the credibility of this hypothesis.

In our study, we followed Gallin's (2008) methodological approach, where he conducted a similar study for the US real estate market. However, we extended the scope of our investigation to 20 OECD countries using the latest possible data.

We believe that the research performed on a bigger sample of countries will allow us to obtain more reliable results and draw a more precise conclusion about the forecasting power of the ratio.

The rest of the paper is structured as follows. The second part summarizes academic literature dedicated to our topic. Section three presents the relevant theoretical background while in section four we discuss the methodology to proceed with our research. In addition, section five contains the description of data used. In part six the main results and findings of our research are presented. Finally, section seven concludes this investigation and contains some suggestions for the future studies.

2. Literature review

This paper is built on a significant amount of previous researches that study housing returns relationships. The most related studies to ours by topic are by Campbell et al. (2009), Kishor and Morley (2014), Hill and Syed (2014), André et al. (2014), Sommer (Bureau of Labor Statistics, 2011), Engsted and Pedersen (2015), Jäger and Schmidt (2017), Shiller and Case (2003), Kivedal (2013) Plazzi et al. (2006), etc. Those related by model are by Gallin (2008), Mark (1995), Cochrane (2011), etc. Most researches are done for the US real estate market (e.g., Campbell et al. (2009), Gallin (2008), Ghysels (2012)). However, there are a few done for OECD countries (Andréa et al. (2014), Engsted and Pedersen (2015)) and other particular countries (e.g., research on Australian housing market by Hill and Syed (2014), Dutch market by Nijskens et al. (2017)).

Engsted and Pedersen (2015) use dynamic Gordon growth model derived by Campbell and Shiller (1988a), where the log rent-to-price ratio equals the present discounted value of expected future log housing returns and rent growth. They apply a restricted VAR model to test the given relationship in 18 OECD countries. It is restricted on the model coefficients to construct the more powerful test for null hypothesis rejection and to eliminate potential serial correlation in the residuals due to seasonality (as data used is on the quarterly basis). The main findings include the following. First, in most countries, the rent-to-price ratio is significant in predicting housing returns: “[a]n increase (decrease) in the ratio signals a future increase (decrease) in returns” (Engsted & Pedersen, 2015).

Second, there is a difference when taking nominal and real data. For example, in Japan, Germany, and Switzerland using nominal data, the rent-to-price ratio significantly impacts nominal returns with a negative sign, but when switching to the real data the sign transforms into a positive significant. For the USA nominal data does not show any significant relationship, but while turning to the real data this becomes significant with a positive sign.

Andréa et al. (2014) in addition to price-to-rent ratio uses price-to- income ratio to find their persistence in 16 OECD countries. The rationale is straightforward: if price changes are larger than income changes, households are not able to afford to buy the property; so the demand falls bringing prices down. To investigate these relationships, the authors use the framework of fractional integration. It is based on estimating the order of integration, from which one can say whether ratios are mean-reverting over time. They found that except some countries, overall there is no persistence in price-to-rent and price-to-income ratios over the period of 1970-2011, even after controlling for the structural breaks.

Campbell et al. (2009) use the same methodology as Engsted and Pedersen (2015), but for the US data, and decomposes rent-to-price ratio into the expected present value of risk-free interest rate, housing premia, and rent growth to examine its variance, but not the predictive power. The model also includes other variables, such as real per-capita income growth, employment growth, and population growth rates. The authors document that variation in risk premia and rent growth are the main sources of rent-to-price ratio variation on the national level. Surprisingly, the changes in risk-free interest rates did not account for changes in housing valuation during the period from 1975 to 2007. In addition, factors including real per-capita income growth, employment growth, and population growth rates do not seem to affect rent-to-price ratio variation.

Plazzi et al. (2006) use a version of Campbell and Shiller's (1988a) dynamic Gordon growth model for the commercial estate market to show that the 'cap rate' (as they call rent-to-price ratio) explains time variation in expected housing returns of apartments, retail and industrial properties in 53 US metropolitan areas during 1994:Q2 - 2003:Q1. However, it does not capture the same in expected rent growth rates. For offices, the opposite holds: rent-to-price ratio can capture the variation in housing returns, but not in rents growth. Unlike the regression for stock market, for housing market, authors use a pooled approach. Because of short time range (36 quarters), they combine each of 53 separate series into one-panel data. Another specific feature is that due to returns, rents and cap rates heterogeneity, tests based on the pooled approach might show higher predictive power, as relationships are modeled on the long-time perspective.

Overall, some researches could find a lot of similarities between housing and other financial markets. Ghysels et al. (2012) tell how these markets are different. Housing market is characterized by large transaction costs, carrying costs, illiquidity, tax considerations, and also large search costs due to the real estate’s heterogeneity, etc. All these lead to the point there might be issues with the reliability of any real estate price indices.

Cochrane (2011) briefly discusses what affects housing returns in his discount-rate variation research. He regresses log annual housing returns, log rent growth and log rent-to-price ratio on the current rent-to-price ratio for the USA market from 1960 till 2010. The author finds that high price-to-rent ratios lead to low returns, not growing rents or prices that rise forever. The research is done to investigate the effect of the discount rate on returns, and not to prove causality.

Then, Gallin (2008) finds the evidence that the rent-to-price ratio helps to predict changes in real prices over 4-year time-range, but not changes in real rents in the US during 1970-2005, using the error-correction model and long-horizon regression model with bootstrapping. The main result is that when prices are high relative to rents, in consecutive years rent changes are lower and price changes higher, but prices correct more than rents. This is in favor of the hypothesis that rent-to-price ratio can be used as an indicator of valuation on the US real estate market. Besides rent-to-price ratio, the factor called direct user cost of housing capital is added. It is the cost of housing excluding the risk premium and expected capital gains, but taking into consideration nominal interest rate, property tax rate, marginal income tax rate and combined maintenance and depreciation rate. He examines two versions of the model: the first has as independent variables both the log rent-to-price ratio and the log of the direct cost of capital, and the second uses only the log rent-to-price ratio. The findings are that including direct cost of housing capital do not seem to affect the relationship between the rent-to-price ratio and subsequent changes in rents and housing prices. The standard error-correction model does not provide significant results while more advanced long-horizon regression combined with bootstrap procedures suggested that house prices correct back to rents.

Mark (1995) also uses a long-horizon model with bootstrapping to account for the bias and size distortions, however, to find the evidence of predictability of current log spot exchange rates. He investigates the deviations of 1-, 4-, 8-, 16-quarter changes in the log exchange rates from theirs “fundamental values”, which are theoretically calculated based on the monetary policy, relative money stocks and relative real incomes. He presents the evidence that long-horizon changes in log exchange rates can be predictable, as opposed to the long time belief they are not. The main argument is that while we find the noise in short-horizon changes, it is averaged out if to use long-horizon changes of the log exchange rates, so there is a systematic pattern of movements defined by fundamentals. In our research, we will also use long-horizon changes (in particular, 16-quarter changes in prices and rents) following the same logic. “Fundamental value” in our case will be rent-to-price ratios throughout countries.

Our paper uses a similar approach to Gallin’s (2008). Since the housing and rent prices seem to be cointegrated for the US market, we can suggest that the same holds for OECD countries. Therefore, we believe the model proposed by Gallin will be suitable for our own investigation. Our research will be extended for the period after the Global Financial Crisis to find out whether rent-to-price ratios determine the housing returns in these countries and briefly discuss whether there are signs of new bubbles on the markets.

3. Theory

In order to better understand the logic behind the idea of using rent-to-price ratio to forecast housing market, the main theoretical concepts related to our topic should be revised.

This research is based on the assumption that rent-to-price ratio can be used to predict real estate market variables. Therefore, our study is concentrated around price-to-rent ratio, which is widely considered an indicator of under- or overvaluation in the market.

Similar to the stockowners receiving dividends, house owners also get rewarded in form of rent (Engsted et al., 2016). Therefore, rent-to-price ratio for the real estate market is assumed to be an equivalent to dividend-to-price ratio developed by Campbell and Shiller (1988a) for the stock market. As dividend-to-price ratio incorporates expectations for the future stock returns and dividend growth, so does rent-to-price ratio show the market expectations for the housing returns and rent changes (Campbell et al., 2009).

In their study, Campbell and Shiller (1988a) proved that the stock prices which are high relative to the dividends lead to the future decline in the stock growth rate. Hence, we can expect that the same relation holds for the rents and housing prices.

In addition, according to the classical theory (Gordon growth model), the intrinsic value of any asset (including the real estate property) is determined by its fundamentals, namely the sum of discounted cash flows (e.g., dividends for stock, rent for real estate property, etc.). The general formula for stock market can be written as follows:

$$P_0 = \frac{D_0}{k-g} \text{ , (1)}$$

where P is the price of the share, D is the current dividend, k accounts for the cost of equity or the required rate of return and g indicates the rate at which dividends are expected to grow (Gordon & Shapiro, 1956).

The original formula considers dividend growth rates and discount rates to be constant over time. Later Campbell and Shiller (1988a) developed a dynamic version of the Gordon growth model allowing dividend-to-price ratio to vary through time. To derive the new equation they assume that log dividends and discount rates constitute vector of variables that "…evolves through time as a multivariate linear stochastic process with constant coefficients" (Campbell & Shiller, 1988a).

Further, using the Campbell and Shiller (1988a) approach for stock market, Engsted and Pedersen (2015) derived the linear relation for the real estate market linking log returns to log rent and log price-to-rent ratio:

$$h_{t+1} = \Delta r_{t+1} + (r_t - p_t) - \rho(r_{t+1} - p_{t+1}) + c, \text{ (2)}$$

where h, r, and p define log return, log rent, and log house prices respectively, $\rho = e^{\mathrm{E}[\Delta r - h]}$, and c accounts for a linearization constant. After imposing a no-bubble transversality condition, where $\lim_{j \to \infty} \rho^j (r_{t+j} - p_{t+j}) = 0$, and taking conditional expectation, Engsted and Pedersen (2015) obtained the following relation:

$$r_t - p_t = E_t \sum_{j=0}^{\infty} \rho^j \left(h_{t+1+j} - \Delta r_{t+1+j}\right) - \frac{c}{1-\rho}, \quad (3)$$

According to the equation (3), rent-to-price ratio is appeared to be a predictor of future returns and/or rent growth.

It is also worth discussing some significant differences and particularities of housing market compared to stock market.

In contrast to the stock market, real estate market has lower liquidity, larger transaction costs, a high level of heterogeneity (e.g., houses differ significantly in terms of geographical location, size, construction characteristics), high carrying costs and tax rates, seasonality, unavailability of short-selling, etc. Besides, often real estate market is subject to strict governmental regulations, which can considerably distort its behavior. It leads to the conclusion that the real estate market is not as efficient as other financial markets (Ghysels et al., 2013). Such inefficiency further implies the theoretical possibility of forecasting the future changes in housing market.

However, the specificity of real estate market also imposes significant difficulties on our investigation. For instance, trying to include many different factors in the research can make it too complex and impossible to analyze. Besides, due to a high level of heterogeneity among different countries, it is extremely hard to gather reliable data for the study. Another distinguishable feature is the high level of seasonality (e.g. the increasing of demand for the housing in touristic locations during summer). Therefore, to obtain trustworthy results seasonality should be taken into consideration while building a dataset.

Besides rent-to-price ratio, there are other possible fundamental variables which might be useful in forecasting real estate market such as personal income, population growth, user cost, employment rate, mortgage interest rate, etc. (Case & Shiller, 2003). For example, mortgage rate theoretically can have an influence on the demand on housing market: lower interest rate makes the property more affordable to purchase and subsequently leads to an increase in demand. However, many scientists did not prove these variables to be significant predictors of housing prices and rents. For example, Gallin (2008) proved that inclusion of user cost in the model for the US market does not have any significant influence on the model’s coefficients. Because of this and also for the sake of simplicity we decided to limit our research to one fundamental variable, namely price-to-rent ratio. In addition, we believe the variables chosen for our research already incorporate to a great extent other factors such as geographical location, user cost, size, interest rate, etc.).

Taking into consideration the theoretical framework discussed above we can assume it is also possible to indicate the bubbles in the housing market using price-to-rent ratio.

Overall, the term ‘bubble’ refers to a sharp increase in the price of an asset, which is driven not by its fundamentals but rather by irrational expectations and overconfidence of market players. When expectations about asset value do not hold anymore, bubble bursts and the asset price falls down quickly (Stiglitz, 1990; Shiller, 2014; Brunnermeier, 2016). Bubbles can occur on different markets (e.g., tulip mania in the Netherlands in 1637 (Garber, 1990)).

The logic to identify the bubble is as follows: if the price-to-rent ratio increases significantly above its historical average (literally meaning that the housing prices grow faster than rents), we can suggest that the housing prices are driven by irrational expectations rather than by its fundamentals, namely, rents. Therefore, the presence of the price bubble on the market can be suspected.

Our research will also rely on the theory of cointegration The term ‘cointegration’ refers to the presence of a common stochastic trend between two or more time series (Stock & Watson, 2012). In fact, it means the presence of a long-run relationship between variables. Therefore, even if variables may diverge from equilibrium in a short-run, in a long run the equilibrium will be restored.

The concept of cointegration was introduced by Granger in 1983 and further discussed and developed by other scientists. The formal definition of cointegration can be formulated as follows:

If time series X_t and Y_t are integrated of order d and if for some coefficient θ, $Y_t - \theta X_t$ is integrated of order less then d (e.g., $(d - b)$, where $b > 0$) then X_t and Y_t are said to be cointegrated. The coefficient θ is called the cointegration coefficient (Stock & Watson, 2015; Engle & Granger, 1987).

Since the term $Y_t - \theta X_t$ is stationary and eliminates the stochastic trend, it can be applied for econometric analysis by including it to the regression.

For instance, let’s assume the following model for two variables, which can be further generalized:

$$\Delta Y_t = \beta_{10} + \beta_{11}\Delta Y_{t-1} + \cdots + \beta_{1\rho}\Delta Y_{t-\rho} + \gamma_{11}\Delta X_{t-1} + \cdots + \gamma_{1\rho}\Delta X_{t-\rho} + \alpha_1(Y_{t-1} - \theta X_{t-1}) + u_{1t} \text{ , } (4)$$

$$\Delta Y_t = \beta_{20} + \beta_{21}\Delta Y_{t-1} + \cdots + \beta_{2\rho}\Delta Y_{t-\rho} + \gamma_{21}\Delta X_{t-1} + \cdots + \gamma_{2\rho}\Delta X_{t-\rho} + \alpha_2(Y_{t-1} - \theta X_{t-1}) + u_{2t} \text{ . } (5)$$

(Stock & Watson, 2015)

The model above is the Vector Error Correction Model (VECM) and the term $(Y_t - \theta X_t)$ is an error correction term. The coefficients α_1 and α_2 show the speed with which the time series adjust to the long-run equilibrium.

Our study is based on the assumption that rents and prices are cointegrated and achieve the long-run equilibrium. Therefore, the VECM framework is applied to analyze their relationship. However, before using the VECM technique, the actual presence of cointegration must be confirmed. There are three possible methods to reveal cointegration: expert judgement, visual analysis, and statistical testing (Stock & Watson, 2015). Although we will apply all of them, we believe statistical testing to be the most reliable one and will use it to derive the final conclusion.

In the second part of our research, we also want to check the possibility to forecast real estate market using the long-horizon model. Since housing market appears to be less efficient than, for example, stock market, it is logical to assume that longer-horizon changes of variables are needed to restore the equilibrium. So, it is interesting to check if long-horizon forecasting will deliver superior results than those of VECM.

The practical implication of VECM and long-horizon model will be discussed in the next chapter.

4. Methodology

To study the housing market, authors mostly use either vector autoregression (VAR), vector error-correction model (VECM) or simple linear regression models.

This research is built on Gallin's approach and combines a vector error-correction model (VECM) and a long-horizon regression model to investigate whether rent-to-price ratio can predict changes in house prices and rents. We believe that using several models will allow us to obtain a more accurate result and to perform a deeper analysis of the topic.

We applied error-correction model to check the possibility to forecast house prices and rents using rent-to-price ratio, as in our opinion, these variables show cointegration relationship, meaning in the long-run house prices correct back to rents and rents correct back to prices. Both should move together in the long-run as renting the house is the alternative to buying it (Kivedal, 2013). For example, Meese and Wallace (1994) showed the cointegration of house and rent prices for Alameda and San Francisco counties, while Gallin (2008) did the same for the US at the national level during 1970-2005. Nielsen (2009) shows that cointegrated VAR (VECM) models are the perfect framework to analyze processes with a unit root and an explosive root. We prefer VECM over Engle and Granger two-step procedure as the latter one requires two-step estimation, so it is less reliable: any error possibly incurred in the first step will be transmitted to the second step (Boero, 2009).

To build the VECM model we went through the following steps. First, we checked the stationarity of our data using the Augmented Dickey-Fuller (ADF) test. If the data appeared to be non-stationary we applied Johansen test to investigate the presence of cointegration between variables. This was done since non-stationarity and the presence of cointegrating relations are two necessary conditions for utilizing VECM. The absence of cointegration means variables drift away from each other and show no long-run relationship. In case the required conditions did not hold, we employed a simple VAR model to investigate the presence of the short-term relationship.

Furthemore, the Chow breakpoint test was performed to check for the structural breaks in rent-to-price ratios. For the countries where we found the evidence of structural break, we ran additional VECM using short-range data before the breakpoint. In this way, we were able to eliminate possible inconsistency in the models' results caused by the presence of irrational factors such as financial crisis, policy changes, etc.

We studied the predictive power of price-to-rent ratio both for price and rent changes. The following equations were examined:

$$\Delta \log R_t = a_0(L)\Delta \log R_{t-1} + a_1 \log R_{t-1} + a_2(L) \log \left(\frac{R}{P}\right)_{t-1} + e_t, \quad (6)$$

$$\Delta \log P_t = b_0(L)\Delta \log P_{t-1} + b_1 \log R_{t-1} + b_2(L) \log \left(\frac{R}{P}\right)_{t-1} + u_t, \ (7)$$

where R is a real rent price, P is a real house price and $\frac{R}{P}$ is a rent-to-price ratio. Therefore, the hypothesis we will test is that rent-to-price ratio predicts the housing returns and house and rent prices tend to correct to each other in the long-run. To model the relationship we need to gather real house and rent prices for each of the countries under investigation. The correlations between variables used in the error-correction model are presented in Table 1 (see the appendix).

We will run the following tests to ensure the relationship can be modeled: Dickey-Fuller test to check for unit root and other tests to check for autocorrelation (Breusch–Godfrey) and heteroskedasticity (Breusch-Pagan & White). We will also correct for the unknown forms of heteroskedasticity and autocorrelation using Newey-West estimators. The number of relevant lags will be decided based on the Schwartz criterion.

Having built price and rent models, we would interpret the coefficients $a_1$and b_1 as usual for the error-correction model: whether and by how much rents correct back to prices and vice versa (Gallin, 2008).

Gallin (2008) shows the incompleteness of the error-correction model: in his analysis, the obtained coefficients are insignificant. To prove the predictability of rent-to-price ratio, he constructs a long-horizon regression approach and then the bootstrap distribution to address the issue of biased estimators. This method has been also used by Campbell (2001) to conduct similar research for the dividend-to-price ratio, and Mark (1995) to study the predictability of spot exchange rates.

Long-horizon model allows us to study the behavior of housing market fundamentals over a long-time range. In our research, we assume that if rents and prices are calculated over an interval of a few years instead of just one time period, they are better predictable (Campbell, 2001). Because of a small number of observations in our data sample, we decided to choose the relatively short 4-year horizons.

Therefore, similarly to Gallin (2008), we used the following equations:

$$r_{t+16} - r_t = a_0 + a_1(r_t - p_t) + u_t \ (8)$$

$$p_{t+16} - p_t = b_0 + b_1(r_t - p_t) + v_t \ (9)$$

In the equations presented above lowercase letters stand for the log values and the index ‘t+16’ represents the 4-year period (since we have quarterly data).

However, there is one statistical problem related to the absence of lags in the long-horizon model. It leads to the issues with model interpretation: since we do not have lags it is impossible: a) to say with certainty which variable (price or rent) does all the correction, and b) to define the significance of the coefficients. Following the logic Gallin (2008) used in his study, in VECM we said that if coefficients $a_1$and b_1 are statistically significant in both rent and price models, this means that prices do correct back to rents and rents do correct back to prices, and consequently tha,t rent-to-price ratio has the predictive power. Now, in the long horizon model, we cannot say this because of the issues mentioned above. For example, if b1 =0 in the long-horizon model, it does not mean necessarily that prices do not correct back and rents do all the correcting and we cannot conclude for sure whether rent-to-price ratio is significant.

Thus, we suppose that r_t and p_t are constructed in such way that:

$$r_t = p_t + \varepsilon_{r,t} \text{ , (10)}$$

$$\Delta p_t = \alpha \Delta p_t + \varepsilon_{p,t} \text{ , (11)}$$

where

$$\begin{pmatrix} \varepsilon_{r,t} \\ \varepsilon_{p,t} \end{pmatrix} = iid\ N \begin{pmatrix} 0, & \sigma_r^2 & \sigma_{rp} \\ & \sigma_{rp} & \sigma_p^2 \end{pmatrix} \text{, (12)}$$

meaning that residuals are normally distributed.

From the equations above, it can be seen that rent depends on price but price does not depend on rent and that past changes in price affect current changes in price. Let us assume that the long-horizon model contains s periods. Therefore, analogous to equations (8) and (9):

$$r_{t+s} - r_t = \alpha_0 + \alpha_1(r_t - p_t) + u_t \text{ , (13)}$$

$$p_{t+s} - p_t = \beta_0 + \beta_1(r_t - p_t) + v_t \text{ . (14).}$$

The equations (13) and (14) can be further rewritten using the terms from equations (10) and (11) changed for the s periods:

$$r_{t+s} - r_t = p_{t+s} + \varepsilon_{r+s,t} - (p_t + \varepsilon_{r,t}) = p_{t+s} - p_t + \varepsilon_{r+s,t} - \varepsilon_{r,t} \text{ , (15)}$$

$$p_{t+s} - p_t = \sum_{j=k}^{s} \sum_{k=1}^{\infty} \alpha^k \varepsilon_{p,t+j-k} \text{ . (16)}$$

After the estimation of the above equations with the OLS method, we are able to obtain coefficients α_1 and β_1 which can be represented as follows:

$$\hat{\alpha}_1 = \frac{\alpha(1-\alpha^s)}{1-\alpha}\sigma_{rp} - 1 \text{ , (17)}$$

$$\hat{\beta}_1 = \frac{\alpha(1-\alpha^s)}{1-\alpha}\sigma_{rp} \text{ . (18)}$$

From the preceding formulas we, see that $\hat{\alpha}_1 = \hat{\beta}_1 - 1$. Thus to say that $\hat{\beta}_1 = 0$, meaning price do not correct back and rent does all correcting, would mean that $\hat{\alpha}_1 = -1$, which is a constant.

However, in theory, $\hat{\alpha}_1$ should be affected by the value of the independent variable (in our case, rent-to-price ratio).

The term $\frac{\alpha(1-\alpha^s)}{1-\alpha}\sigma_{rp}$ implies that if there is an α shock influencing rent-to-price ratio through σ_{rp} it will correlate with shocks running to Δp_t through α.

The above derivation was made under the assumption that H_0: rents do all the correcting (so, price affects rent but rent does not affect price). Therefore, the shock running to H_0 will provoke shock in price changes. So, that H_0: rents do all the correcting does not mean $\beta = 0$ as Δp_t is also affected by the shock. Therefore, the autocorrelation in the price changes will cause correlation between rent-to-price ratio and long-horizon differences in prices (Gallin, 2008).

In order to address this issue, we applied bootstrapping. The idea behind the bootstrapping is that the sample is an estimate of the population. So, an estimate of the sampling distribution can be obtained by randomly drawing many samples (with replacement) from the observed sample. Such technique allows computing more reliable statistics (including mean, variance, confidence intervals, etc.) (Chen, 2017)

For the purpose of our study, we used bootstrapping technique to check two null hypotheses:

1) H_0: prices do all the correcting;
2) H_0: rents do all the correcting.

In order to check the first null hypothesis we generated 4000 log prices and rent-to-price ratios for each quarter and took their means by quarters. The following step was to construct the levels of rents as the sum of levels of rent-to-price ratios and prices. After that, the 4-year-period changes for rents and prices were created. Finally, we made sure that all the variables are stationary and run a regression applying an ordinary least square method using Newey-West estimators to account for the autocorrelation and heteroskedasticity of the data.

Similarly, for the second null hypothesis, 4000 log rents and rent-to-price ratios for each country and for each quarter were generated and their means were calculated. Using the same logic as for the rent model, we computed levels of rent-to-price ratios, the differences for the rents and prices, and estimated the regression using this data. In such a way we were able to resolve the issues described above and to obtain credible p-values. Overall, bootstrapping allowed us to simulate a larger sample of observations to downgrade the correlations between shocks to rents and shocks to rent-to-price ratios.

In chapter 6, the results obtained will be presented and discussed.

5. Data

We obtained quarterly data for real and nominal house prices and nominal rent prices indices for 20 OECD countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, South Korea, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK and the US. The dataset is provided by the OECD statistical database (OECD.Stats, n.d.) and starts from 1970:Q1 until 2017:Q4 (except for Australia (1972:Q3), Belgium (1976:Q2), Norway (1979:Q1), South Korea (1986:Q1), Sweden (1980:Q1), Portugal (1988:Q1) and Spain (1971:Q1)). The time-range is appropriate to conduct the research, as rent-to-price ratio makes at least two full cycles.

House price indices are index numbers that measure the prices of residential properties over time. The real house prices were taken instead of nominal as they are seasonally adjusted for consumers' expenditure deflator in each country (OECD.Stats, n.d.). There are a couple of reasons behind. First, seasonality in housing market influences demand, supply and corresponding house price fluctuations. Second, it affects macroeconomic indicators. Third, because of seasonality, pattern predictability in housing returns may lead to potential abnormal gains for buyers or sellers (Valadkhani, 2017). For further analysis, we use annual data.

The annual house price index is given by the fourth quarter of each year, and annual rent price is computed by adding the indices for each quarter. From nominal and real house price indices we extract annual inflation, which is used to transform nominal rent prices into real. We calculated price-to-rent ratio in real terms by dividing real house price by real rent for each corresponding period. The price-to-rent ratio is a measure of profitability of owning the house (OECD.Stats, n.d.; Engsted & Pederson, 2015). The rent growth is calculated as

$$\Delta R_{t+1} = \frac{R_{t+1} - R_t}{R_t} \ . \ (19)$$

For further analysis in this section, we need housing returns, which are obtained as

$$H_{t+1} = \frac{P_{t+1} + \frac{R_{t+1}}{4} - P_t}{P_t} \ . \ (20)$$

Further, we construct descriptive statistics for real housing returns and rent growth for each country under investigation (see Table 2 in the appendix). The scatterplots of real house price and real rent price indices, and the correlation between them are presented in Figure 1 and Table 1 respectively (see the appendix).

From Panel A in Table 2 (see the appendix), we spot quite a difference between real estate returns among OECD countries. Germany, Italy, Japan, Korea, Portugal, Switzerland and the United States show comparably small housing returns (average 5.5-7% annually) with relatively low volatility during these years. To compare, returns in Canada, New Zealand, and Norway were on average more than 9.5% per year with relatively high volatility. Real rent growth from Panel B (see Table 2 in the appendix) during 1970-2017 was relatively low for most of the countries (on average 0.5% per annum), except Spain and Portugal, where real rent growth rates constituted on average 2.9% and 3% respectively per annum (Engsted & Pederson, 2015). South Korea is the only country on the list having negative median real rent growth (average -0.1% annually). Negative rates were persistent in South Korea during 1991-2000 and from 2004 till 2010 except 2007.

Test for autocorrelation was made for real housing and rent prices, and rent-to-price ratio (see Table 3 in the appendix). It showed high positive autocorrelation, which is normal for such time series. Thus, in models we used t-statistics based on Newey-West standard errors (also helpful in presence of heteroskedasticity, which is our case). The positive autocorrelation is also persistent in real housing returns and rent growth (Engsted & Pedersen, 2015; Case and Shiller, 1988a). Engsted and Pedersen (2015) say the reason of autocorrelation of rent growth might be the regulation of rental markets in some countries.

Turning to real house prices and rent price graphs (see Figure 2 in the appendix), we normally see the upward movement both in real house and rent prices. Housing prices generally were rising from 1970’s till mid-1990’s, slowing the pace afterwards. However, Germany, South Korea, and Portugal are exceptions. In Germany real housing and rent prices almost did not change over time. Housing prices had relatively increased during the 1980's and mid-1990’s. However, since then, they were dropping with a small recovery just in recent years. Rent decreased in the 1980’s but came in line with housing prices in the mid 1990’s. In South Korea, both housing and rent prices peaked in the 1990’s but dropped ever since. Table 1 (see the appendix) also shows a correlation between both variables. In most cases, we see a strong positive relationship. Nevertheless, for Germany and Japan, it is weak and negative. For Denmark, Netherlands, Spain, Ireland and the US, we see that prior to the Financial Crisis of 2008 the increase in house prices is not followed by a correspondent growth in rent. This implies there are some other variables that explain the rise in prices: fundamentals or psychological factors causing the bubble. The numerous studies (Kivedal, 2013; Nijskens & Heeringa, 2017) show that for the case of the US, Spain, and Denmark it was indeed the overheating caused by irrational behavior.

Figure 2 (see the appendix) shows the time-series plot of the price-to-rent ratio. For most countries in the late 1980’s - 1990’s ratio demonstrated a build-up. One of the signs of overvaluation of the housing prices may be if price-to-rent ratio is above the long-term mean (OECD.Stats, n.d.). Following the logic, we can assume that today real estate market of Australia, Canada, Germany, New Zealand, Norway, Sweden, Switzerland, UK, and the US is overvalued, which may indicate the new bubble. In 2014 ratio in the United States was back to its historical mean, but now it starts to go up again (Engsted & Pedersen, 2015). Nevertheless, the additional research should be done to confirm the overheating on the markets.

For the further analysis, we use quarterly data for all the variables.

6. Empirical results

6.1 Graphic analysis

In order to further investigate the topic, we performed a scatterplot analysis comparing rent-to-price ratio with subsequent 4-year quarterly rent and price changes (see Figure 3 in the appendix). As can be seen from the graphs the data is very heteroskedastic, which can possibly indicate that rent-to-price ratio is not a good instrument to forecast real estate market fluctuations.

Overall, only three countries (Germany, Ireland and Japan) showed the behavior which is consistent with the theory. Both prices and rents in this countries seem to correct back to equilibrium meaning the high prices relative to rents (low rent-to-price ratio) now are followed by smaller price increases and higher rent increases in the consequent 4 years. Therefore, we can assume that rent-to-price ratio for these countries potentially can be an indicator of valuation on the real estate market.

For all other countries under investigation, except these three, rent scatterplots showed the different trend: the high prices relative to rents (low rent-to-price ratio) now usually meant smaller rent increases in the next 4 years which contradicts our assumptions. At the same time, prices behave in accordance with the theory. Thus, we can conclude that rent-to-price ratio could not be a trustworthy indicator of valuation on the housing market and that prices do all correcting in Australia, Belgium, Canada, Denmark, Finland, France, Italy, South Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, and the US.

It is also interesting to investigate the scatterplots for the presence of housing bubbles on the market. Theoretically, we can suspect them in countries where the subsequent 4-year price growth is too high compared to the long-term average (trend line on the graphs). These countries are Canada, Germany, Ireland, Japan, Netherlands, New Zealand, Portugal, Spain, and the US. It is worth mentioning that Norway, Sweden, Switzerland, and the UK (the countries believed to have the most overheated housing markets) have normal price levels according to this evaluation.

The scatterplot analysis allows us to assume that prices do most correcting for most of the countries, and in general rent-to-price ratio is not a reliable predictor on the real estate market (or at least, not a complete predictor).

However, there are several possible issues with the scatterplot analysis which can affect the reliability of our conclusions. First, the data used is very heteroskedastic. Second, the observations in the time series are not independent of each other (see Table 1 and Table 3 in the appendix) (Gallin, 2008). With the aim to address these issues and to further explore our research question, we developed VECM and long-horizon models.

6.2 VECM results

The detailed results for the VECM estimation are presented in Table 4 (see the appendix) and will be discussed in this subsection. From the outcome of the Augmented Dickey-Fuller (ADF) test, all time series in the dataset are non-stationary. However, only in 11 countries out of 20 (Belgium, Canada, France, Italy, Japan, South Korea, New Zealand, Norway, Portugal, Switzerland, and the US), there was an evidence of cointegrating relationship at least at 90% confidence level. Thus, for these countries, VECM was performed.

It is also interesting to notice that Germany and Ireland revealed no signs of cointegrated variables which contradicts the results of scatterplot analysis of 4-year ahead rent and price changes (Figure 3 in the appendix).

Besides, for the countries where variables do indeed cointegrate, we also ran price and rent models using the shorter data sample. The size of data sample for the short-range model was defined using Chow breakpoint test. In most countries, the structural break took place between 2005 and 2010. So, we might assume that the main reason for the break was the Financial Crisis of 2008. It is also worth noticing that some time series that appeared to be cointegrated in the full data range have shown no signs of cointegration while using the shorter time period (Japan, South Korea, New Zealand, Portugal). It can be due to the bigger influence of irrational factors (e.g. Financial Crisis of 2008) on the smaller date range.

In theory, the coefficient in the rent model should be negative and the coefficient near the price model – positive. It means that prices and rents correct toward each other and rent-to-price ratio can be viewed as a good predictor for the future prices and rents changes. In other words, low rents changes relative to price changes now mean higher rents afterwards, and low price changes relative to rent changes theoretically mean that in the future we should expect higher prices (Gallin, 2008).

However, in our models, we also received ‘incorrect’ (opposite to the theoretically assumed) signs for some of the countries.

For the most countries, the outcome of the short- and long-range models are consistent. Exceptions are rent model results for Belgium and South Korea, price and rent model results for the US. The possible reasons for this will be further discussed.

The VECM estimation results for each country are summarized below.

The long-range model results for Belgium are in accordance with the theory and imply correcting of price and rent series to equilibrium. The absolute value of coefficients near price appeared to be larger than those near rent. This, together with the fact that both coefficients near prices are significant means that prices do more corrections than rents (Gallin, 2008). However, the coefficient near rent in the short-range model is positive. The possible explanations for this inconsistency could be market irrationalities caused by Financial Crisis of 2008 and higher volatility of real prices. The later one enabled prices to better mirror the rent-to-price ratio in comparison with real rents. Indeed, in the course of 2000 – 2007, Belgium real house price index rose by 47,16%, while rents grew up only by 17.01% (OECD.Stats, n.d.).

Similarly to Belgium, for Portugal we obtained coefficients consistent with the theory, but only for the long-range model. So, both rents and prices converge to long-run equilibrium and define the long-term value of the ratio. However, in contrast to Belgium, here rents do more corrections (the absolute value of the rent coefficient is higher and significant).

Considering the absence of cointegration relationship for the shorter sample for Portugal, we did not estimate the short-range VECM. We believe that the absence of cointegration relationship before breakpoint (2012Q4) could be explained by a long period of Portuguese recession and slow economic growth compared to other OECD countries, which affected the country’s housing market (housing prices dropped significantly). According to the statistics, only after 2012, the Portuguese economy started to recover (Trading Economics, n.d.), bringing more stability to the real estate market. In addition, the factors such as declining interest rates, the extremely favorable for landlords lease laws (introduced in 2012 (Global Property Guide, n.d.), and growing demand for the housing (due to the bigger immigration inflow (OECD.Stats., n.d.) contributed to the rising of the housing prices.

The outcome obtained for New Zealand is also theoretically correct: prices do correct back to rents and vice versa in the long-run. However, only rent coefficient is significant. Moreover, the results suggest rents correct more than prices do (the absolute value of the coefficient near rent is larger than those near price).

Thus, statistically speaking, for Belgium, New Zealand and Portuguese markets ratio is an indicator of prices formations. However, this does not mean that results are consistent over time and replicable in the future.

In Italy price coefficients are significant and negative, meaning the divergence of prices from long-term equilibrium. The rent coefficients are insignificant and positive for the full-sample model and negative for the shorten model. These results suggest that the Italian housing market is still suffering from irrationalities possibly caused by the economic downturn. Indeed, the graph presented on Figure 1 (see the appendix) shows high volatility in rents and prices, including a few periods of undervaluation in late 90’s and on the market when prices dropped significantly compared to rents.

For Norway, Canada, France, and Switzerland all the coefficients near prices and rents are negative in both long and short range models, meaning that only rent corrects back to equilibrium. In Canada and Norway only rent coefficients are significant both for long and short sample estimations: rents alone converge to the long-run equilibrium and define the long-term value of the ratio. The fact that prices diverge from equilibrium according to the model together with graphic analysis results can suggest the presence of overvaluation on these markets in recent years. In France, the rent coefficient is significant only in the long-range model. In the shorter sample estimation results, rent loses its significance. But there is a significant and negative coefficient near prices for the short-range model, which contradicts the theory. The reason for this can be the impact of recession in late 2000’s.

However, in Switzerland all coefficients are significant but only rents correct back to equilibrium. Such an outcome can be explained by the fact that

Switzerland is perceived as a safe haven for the investors with unusually small rates and low risk. The big investment flow (especially during the crises in mid-80's and in late 00's when investors were searching for the safe assets to invest in) could have provoked the irrational housing prices' increases afterwards which were causing overvaluations on the market. Only in 2016 the prices on the real estate market began to slow down due to the active governmental policy (stricter lending criteria and abandoning the currency ceiling for euro) (Global Property Guide, n.d.).

In Japan, the estimation results are analogous to Norway, Canada, France, and Switzerland. The rent and price coefficients are negative and significant, implying the convergence of rents to and divergence of prices from the long-term equilibrium. In addition, due to the lack of cointegration relationship for the shorter sample, we did not estimate short range VECM.

Such results of the cointegration test for Japan can mean that only now Japanese real estate market starts to show the 'normal (expected) behavior'. There could be several explanations for this. The first reason for the deviation from theory can be unusual housing policy conducted till 2009, which coincides with the date of structural break in our data (2010 Q4). In accordance to these laws, real estate property had a relatively short lifespan compared to Europe or the US (around 30 years for the residential property) and lost their asset value quickly. This fact makes Japanese houses (especially on the second-hand market) quite an unattractive investment. However, in 2009 the Japanese Government endorsed Long Life Housing Law, which prolonged the life of Japanese real estate property and increases its adaptability over time (Minami, 2010). The other reason for the absence of cointegration for the short-range model could be market irrationalities caused by Oil Crisis and high inflation rates in the 1970s, Japanese asset price bubble (1986-1992), and Asian Financial Crisis of 1997.

South Korea also has revealed interesting results. The model showed no cointegration of prices to rents, therefore VECM was estimated only for the rent model. We obtained the negative sign using the full data sample, meaning, rent corrects back to prices. However, the sign changes while estimating the short-range model (1987Q1 – 2008Q4). It is also worth noticing that in both cases the coefficients are significant.

These results can be attributed to the fact that in general, the Korean real estate market is strictly regulated. Every time the presence of the housing bubble can be suspected the government interferes the market and tries to cool it down by raising taxes, tightening loan conditions, etc. It means that the rent-to-price ratio could have been influenced and shaped artificially – by the strict governmental policy rather than by market fundamentals. However, in the response to the Financial Crisis of 2008, the state tried to stimulate the market via deregulation and tax reductions (Kim & Park, 2016). Hence, the housing market started to behave in accordance with the theory and we can spot the 'correct' sign near the rent coefficient.

Besides, the peculiar results can be attributed to the unusual lease practice in South Korea called 'Jeonsei' (Lee & Parc, 2018). According to this system, the tenant pays a huge lump-sum deposit equal to two or three years' worth of monthly rent. This deposit can constitute around 50-60% of the property's market value. After paying the deposit the renter can live in the accommodation without paying monthly rent for the period equivalent to the settled deposit. However, recently the percentage of Jeonsei leases is falling rapidly compare to the usual monthly-rent contracts. For instance, in 2017 the share of Jeonsei leases dropped from 45 to 39.5% (Ya-Young, 2017). Therefore, we can assume that since the Jeonsei deposit historically was so large, the rent variable in the model was showing divergence from equilibrium. But considering that Jeonsei leases are losing their popularity quickly and most tenants pay for their accommodation monthly, the rents started to behave in accordance with the theory and we obtained the consistent sign near the rent coefficient.

The US model showed a positive price sign in the long-range model and the negative rent sign in the short-range model, meaning prices do all the correction in the full sample while rents do all the correction in the shorter sample. In addition, both coefficients were significant. However, rent coefficient in the long-range model and the price coefficient in the short range-model appeared to be inconsistent with the theory. Thus, it can be concluded that prices do all correction in the long period while rents did all the correction before mid-00's (when structural break occurred). Overall, prices define the long-term behavior of the ratio and converge to the equilibrium. Nevertheless, before the Financial Crisis of 2008, the irrational factors influenced prices, preventing them from being determined by rent-to-price ratio. Another possible explanation for the discrepancy Gallin's results could be a different type of data used in two studies. In his investigation, Gallin utilized real data while we used indexes.

Overall, from the results of VECM estimation, we can conclude rent-to-price ratio cannot be used as a general indicator of valuation on the real estate market. Only for Belgium, New Zealand, and Portugal we have obtained the signs which were more or less consistent with the theory. In other countries the outcomes vary significantly. It may imply the presence of other factors which influence the housing market and are not included in our model (f.e., interest and tax rates, transaction costs, etc.).

6.3 VAR model results

The data for countries, where no cointegrated relationships were found (Australia, Denmark, Finland, Germany, Ireland, Netherlands, Spain, Sweden, UK), was stationarized using first difference and a simple VAR (Vector autoregression) model was performed in order to investigate the presence of short-term dependence between prices and rents.

VAR is one of the most utilized models in economic research. It is easy to estimate and good for summarizing and forecasting data. Besides, in VAR there is no need to specify endogenous and exogenous variables. At the same time, VAR has some significant disadvantages such as a big number of parameters to estimate, which can become a problem in case of the limited data sample. VAR models are also a-theoretical and cannot produce structural estimates.

Despite the significant drawbacks mentioned above, VAR still seems to be a relevant method to check for the short-time dependence between housing market variables (Juselius, 2006). The number of lags for the model was chosen to be four based on Swartz criterion.

Generally, four countries (Australia, Denmark, Spain, and the UK) appeared to have no short-run dependence (no significant coefficients) in both price and rent models. Some of the countries have shown the signs of short-term relationships either in rent (Ireland, Netherlands) or price models (Germany, Sweden). Finally, only for Finland, the coefficients in both models were significant, implying the presence of a short-term causality between prices and rents (see Table 5 in the appendix). However, since VAR model is considered to be a ‘black box’ where all the variables are both dependent and independent, it is hard to give a concrete interpretation of the coefficients obtained.

Overall, results vary significantly from country to country. Therefore, the rent-to-price ratio cannot be used as a universal predictor of the real estate market fundamentals in the short-run period. Even considering that some countries have the signs of short-term relationships between rent-to-price ratio and price and/or rent, the further research must be conducted in order to prove the trustworthiness of these estimations. However, they are beyond the scope of this paper.

6.4 Long-horizon model and bootstrapping results

The coefficients obtained in the long-horizon model are presented in Table 6 (see the appendix) and described in this subsection. In general, they show how rent-to-price ratio affects the price and rents changes over a 4-year horizon. The findings of long-horizon model will be discussed below.

The obtained results suggest that only three countries delivered an outcome consistent with the theory. These are Germany, Ireland, and Japan. For Germany, each percentage-point discrepancy between rents and prices, on average leads to the 0.08 percentage point smaller changes in rents and 0.16 percentage point bigger change in real prices during the next four years. The corresponding coefficients for Ireland are 0.15 and 0.29, while for Japan - 0.11 and 0.13 respectively. It allows us to suggest that in these particular countries periods in which prices are high relative to rents are typically followed by periods of relatively larger changes in rents and relatively smaller changes in prices.

In all other countries under investigation a percentage-point difference between rents and prices is followed by larger changes in both prices and rents, meaning that periods in which prices are high relative to rents are typically followed by periods of relatively smaller changes in prices and rents.

As was mentioned previously, p-values estimated with long-horizon model are not reliable. Therefore, we used p-values obtained from bootstrapping procedure. Based on the results of bootstrapping, all countries under investigation can be broadly divided into three groups: the countries where all the coefficients were insignificant, the countries where only price does the correcting and, finally the countries where both rent and price correct back to equilibrium and ratio is a predictor of valuation on the market (see Table 7 in the appendix).

Most of the countries did not reveal any significant outcome. The group of countries with insignificant results in both models includes Australia, Denmark, Ireland, Italy, Japan, Finland, South Korea, Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, Switzerland, the UK, and the US. The outcomes received after the models' estimation for these countries signalize that neither rents nor prices correct back to equilibrium. Thus, rent-to-price ratio does not predict changes on housing markets in these countries.

According to the estimation results for Belgium, Canada, and France, only prices are significant at 10% level. In Belgium every percentage point difference between rents and prices leads to the 0.2 percentage point larger change in rents and 0.35 percentage point larger change in price over 4 years.

The estimation results for Canada imply that each percentage point difference between rents and prices leads to the 0.18 percentage point bigger changes in rents and 0.04 percentage point bigger changes in prices over the next 4 years. Therefore, the time periods in which prices are high relative to rents are usually followed by time periods of relatively smaller changes in prices than in rents.

For France, for each percentage-point difference between rents and prices, the real rents change by 0.06 percentage point more, and the change in real prices is on average 0.36 percentage points more over the next 4 years. It leads to the conclusion that periods in which prices are high relative to rents are usually followed by periods of comparably smaller changes in prices and rents.

Finally, Germany is the only country on our list where both rent and price correct back to equilibrium. Here, for each percentage-point difference between rents and prices, the 4-year change in real rents is 0.08 percentage point less, and the corresponding change in real prices is on average 0.16 percentage points more, during the following 4-year period. The point estimates suggest that periods in which prices are high relative to rents are typically followed by periods of relatively larger changes in rents and relatively smaller changes in prices which is in accordance with the theory and implies that rent-to-price ratio is a good predictor for the housing market fundamentals.

There were no countries where only rent was proven to do all the correcting.

However, it is worth noticing that the estimation results obtained from the long-horizon model and bootstrapping procedure differ significantly from VECM and VAR models. One of the reasons might be different estimation periods used. For the error-correction model we used rent and price changes over a quarter time-range, and for a long-horizon model with bootstrapping - 16-quarter time-range changes. Former studies showed that returns are better predictable when they are measured over several years' intervals, rather then 1 year or so (Campbell and Shiller, 1987). Thus, we might trust results of long horizon model with bootstrapping more than those of VECM. Moreover, different results of both models might be in favor of the general conclusion of this analysis that rent-to-price ratio is not a complete indicator of valuation on the real estate markets.

7. Conclusion

The aim of this research was to investigate whether rent-to-price ratio can predict changes in rent payments and housing prices in 20 OECD countries. The motivation of using ratio as a predictor and not lagged returns follows from the former investigations showing that explained variance in such cases is higher than if to use absolute values. Error-correction model and long-horizon model with bootstrapping procedure were used to find the relationships of interest. Overall, we found that ratio is not a complete indicator of prices and rents formations on the real estate markets, and thus can not be used for valuations. The reasons for this assumption are:

a) two models showed very different results;

b) in both models ratio explains the future behavior of price and rent changes only for 5-10% of analyzed countries.

Throughout the analysis we assumed markets maintain rational expectations regarding the future prices and rents formation. The real data was used, which allowed performing the analysis free from the predictability of inflation. For most countries results are based on the quarterly time-range between 1970Q1-2017Q4 (except few with shorter available time-series).

Vector error-correction model (VECM) showed the presence of cointegrated relationships between prices and rents movements only for approximately half of the investigated countries. Moreover, for only three countries (Belgium, New Zealand, and Portugal) model showed consistent with theory results: the rent-to-price ratio predicts price returns with positive coefficients and rents growth with negative coefficients, meaning convergence of prices and rents in the long-run period.

In the second analysis (long-horizon model), simple linear regressions of rent-to-price ratio on 4-years rent/price changes were performed. Previous investigations showed that measuring returns over several-year intervals are better predictable than using 1 year or so. The results were mixed. Most countries showed that periods in which prices are high relative to rents are typically followed by periods of relatively smaller changes in prices and rents. Results for only a few countries (Germany, Ireland, Japan) suggested that periods in which prices are high relative to rents are typically followed by periods of relatively larger changes in rents and relatively smaller changes in prices. However, due to the imperfections of the model, we could not support the hypotheses that rents alone or prices alone do all the correcting. Constructing the bootstrap procedures addressed the issues of biased results.

Bootstrapping results suggested that only in Germany prices and rents correct back over 4-years period so that rent-to-price ratio can be used as an indicator of valuation on the real estate market. Few countries (Belgium, Canada, France) showed that prices do all the correcting. For all other countries ratio was not significant or/and there was no correcting over specified time-range.

In general, we must say we cannot fully trust the outcomes obtained. First of all, statistical significance of results does not mean its reliability, consistency over time and, the most important, replicability. Second, for the analysis we used indices, and not the real data, which could have influenced the result. Third, housing market data (basically, as any financial market data) is very heteroskedastic, which complicates the possibility of prices prediction. Fourth, we used 4-year horizon changes to define the degree of correction due to the lack of data, which may be not enough to define the convergence of rents and prices.

To gain more complete results, the analysis can be further supplemented. Instead of using just rent-to-price ratio to find out the predictability of returns, other variables can be added: interest/mortgage rates, tax rates, income-to-price ratio, employment rates, etc. For example, recently interest rates in the US started to increase, which lowered the housing prices throughout the market, as demand is going down. The whole new investigation potentially can also be built on the influence of transaction costs on prices. One would assume they impact prices through brokerage fees, however, there are very few studies done as transaction costs are hard to measure. Another advancement can be developing similar models for other types of real estate property (e.g., commercial). In addition, longer horizon changes (f.e., 10 years instead of 4) can be used to define the degree and speed of correction of prices to rents and vice versa.

Appendix

Table 1: Correlations of variables for 20 OECD countries

Table 1 presents the correlations of variables for 20 OECD countries.

Countries	Price-to-rent vs Δln(price)	Price-to-rent vs Δln(rent)	Real house prices vs real rents
Australia	0,109	-0,146	0,921
Belgium	0,001	-0,281	0,865
Canada	0,197	-0,253	0,730
Denmark	0,032	-0,066	0,861
Finland	0,135	0,156	0,860
France	0,020	-0,081	0,858
Germany	0,037	-0,018	-0,113
Ireland	0,119	0,010	0,740
Italy	0,061	0,019	0,827
Japan	-0,046	-0,057	-0,348
Korea	0,159	0,092	0,914
Netherlands	-0,029	-0,125	0,886
New Zealand	0,105	-0,075	0,760
Norway	0,103	-0,165	0,893
Portugal	-0,021	0,031	0,162
Spain	0,015	0,032	0,907
Sweden	0,093	-0,197	0,749
Switzerland	0,075	0,052	0,598
United Kingdom	-0,004	-0,124	0,920
United States	0,047	-0,069	0,922

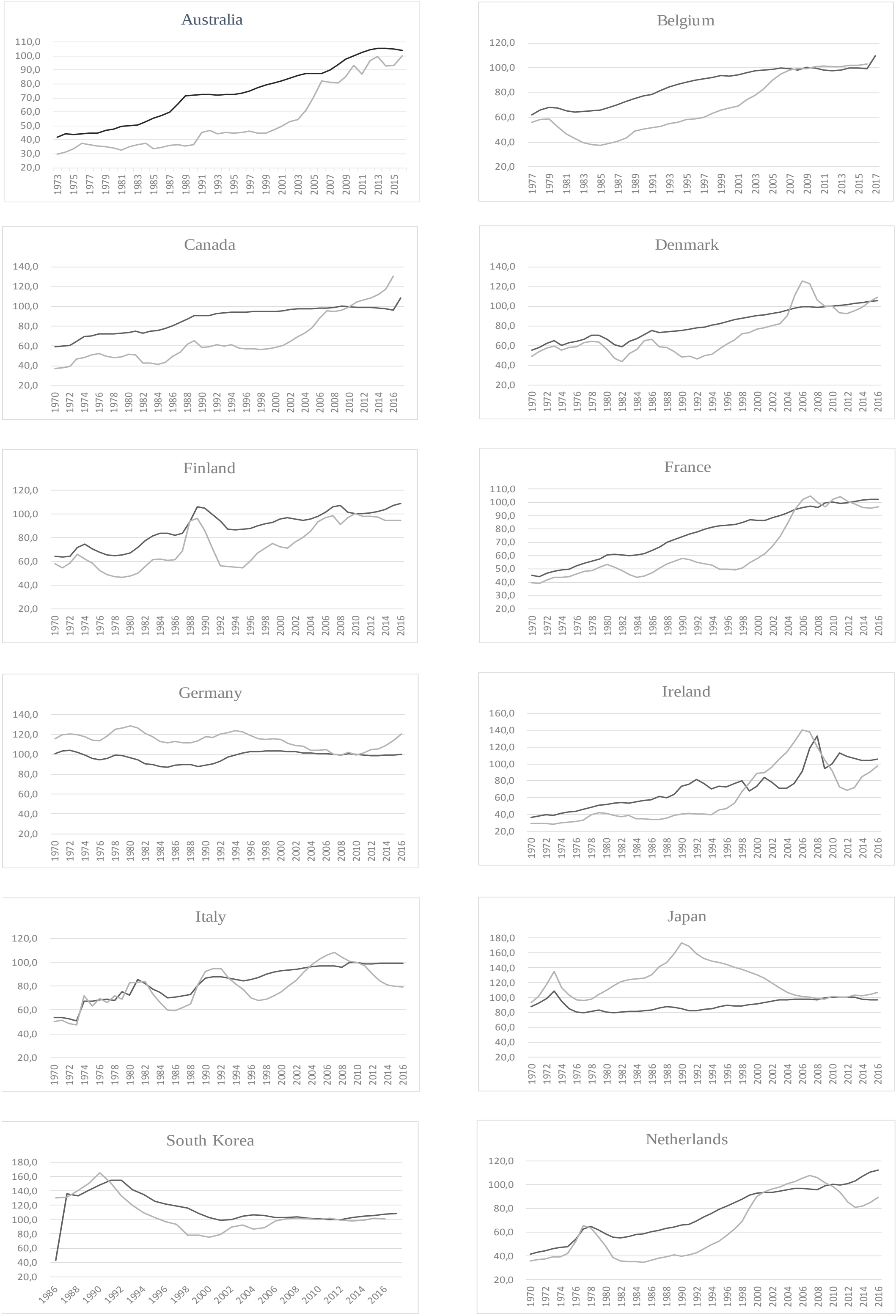
Table 2: Summary statistics for real returns and rent growth

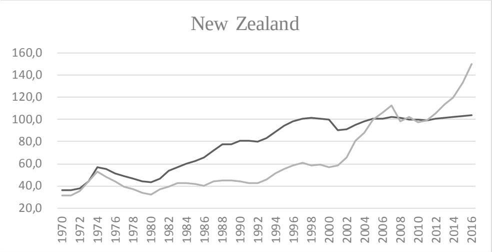
Table 1 presents the mean, median, standard deviation, kurtosis and skewness for the real returns and rent growth for 20 OECD countries chosen for the research.

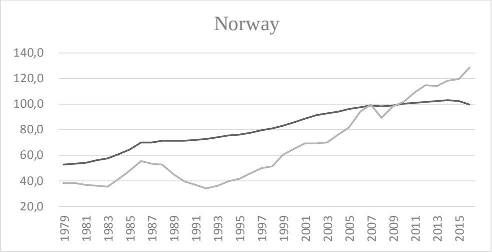
	Panel A. Real Returns					Panel B. Rent Growth				
Country	Mean	Median	SD	Kurtosis	Skewness	Mean	Median	SD	Kurtosis	Skewness
Australia	0,092	0,094	0,095	1,903	0,596	0,005	0,005	0,024	2,660	1,364
Belgium	0,089	0,095	0,092	-0,870	-0,027	0,004	0,003	0,024	3,848	1,234
Canada	0,097	0,100	0,094	0,188	0,231	0,003	0,001	0,025	8,201	2,446
Denmark	0,080	0,079	0,110	-0,143	-0,093	0,004	0,004	0,034	1,822	-0,568
Finland	0,083	0,083	0,110	1,835	0,659	0,004	0,003	0,046	1,038	0,770
France	0,084	0,084	0,079	-0,772	0,109	0,005	0,005	0,018	-0,547	0,069
Germany	0,054	0,053	0,036	-0,335	0,069	0,001	0,000	0,022	7,121	1,836
Ireland	0,092	0,094	0,132	-0,112	-0,298	0,007	0,008	0,089	4,025	-0,413
Italy	0,071	0,065	0,125	9,045	2,339	0,004	0,001	0,062	13,777	3,232
Japan	0,049	0,050	0,077	0,633	0,289	0,001	0,001	0,035	5,347	-1,191
Korea	0,067	0,066	0,079	0,186	0,098	0,016	-0,001	0,388	31,240	5,559
Netherlands	0,087	0,091	0,122	-0,882	-0,203	0,006	0,005	0,036	5,959	1,363
New Zealand	0,095	0,099	0,125	-0,571	-0,167	0,006	0,003	0,063	5,155	1,632
Norway	0,096	0,093	0,121	-0,659	0,278	0,006	0,004	0,033	15,907	3,480
Portugal	0,059	0,055	0,057	-0,547	0,521	0,030	0,006	0,417	42,859	6,419
Spain	0,089	0,092	0,129	1,116	0,378	0,029	0,005	0,604	46,511	6,804
Sweden	0,089	0,091	0,121	-0,706	0,053	0,004	0,003	0,031	2,546	0,892
Switzerland	0,062	0,064	0,068	0,565	-0,608	0,002	0,002	0,023	4,757	-1,044
United	0,088	0,087	0,134	-0,233	0,041	0,009	0,006	0,059	3,298	1,072
United States	0,067	0,070	0,049	2,448	-1,462	0,003	0,003	0,016	0,098	0,371

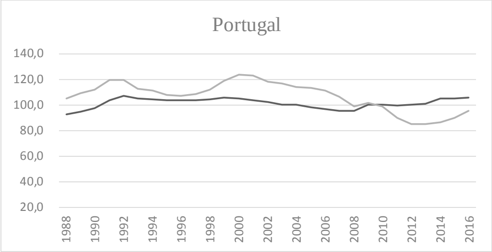
Figure 1: Historical changes in real house prices and rents

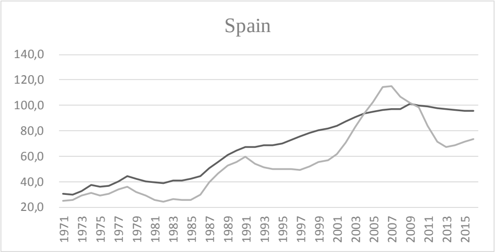
Figure 1 presents the historical changes in real house prices and rents over the studied period for 20 OECD countries chosen for the research (2010 is defined to be the base year).

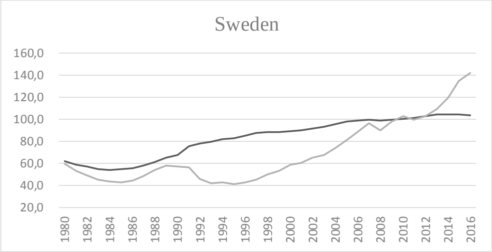


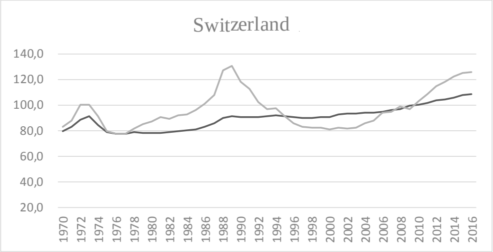


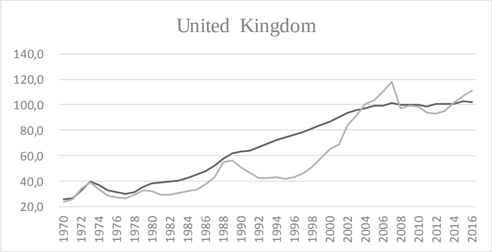


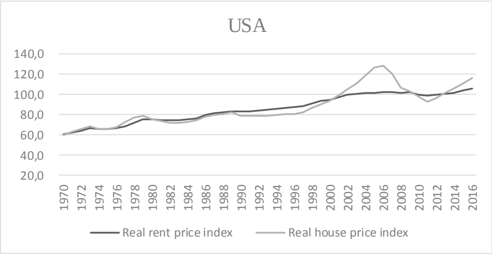








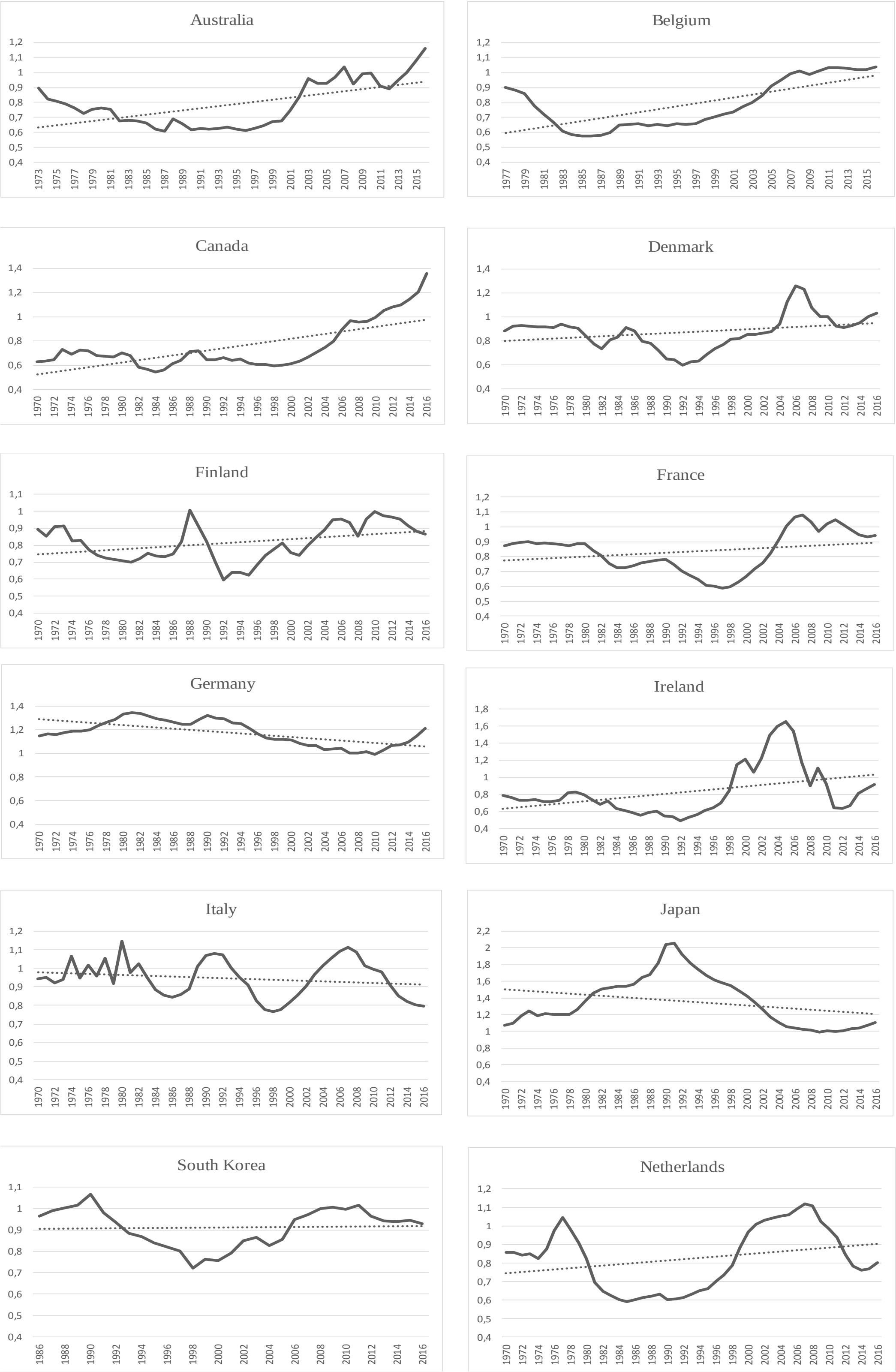


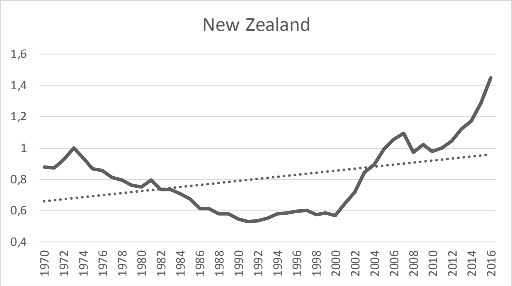


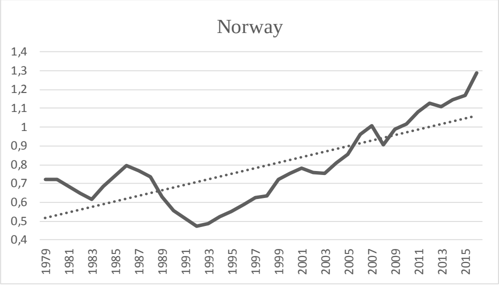
— Real rent price index
— Real house price index

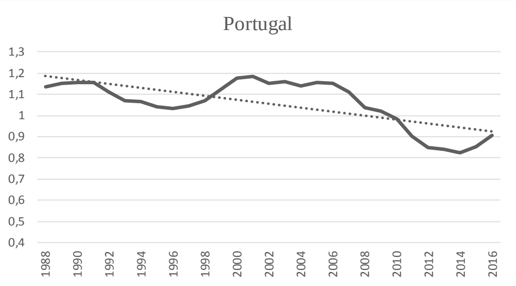
Figure 2: Historical changes in price-to-rent ratio

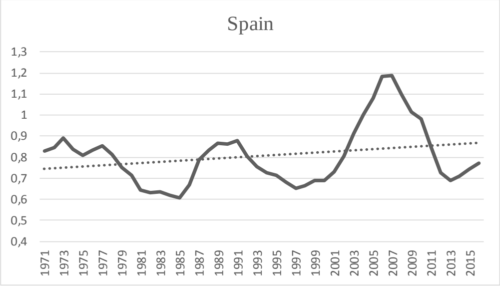
Figure 2 presents the historical changes in the price-to-rent ratio over the studied period for 20 OECD countries chosen for the research.

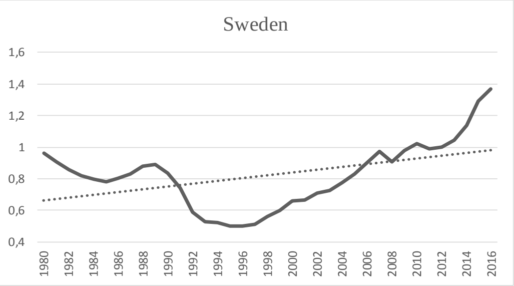


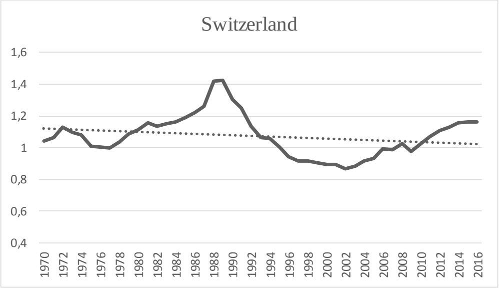


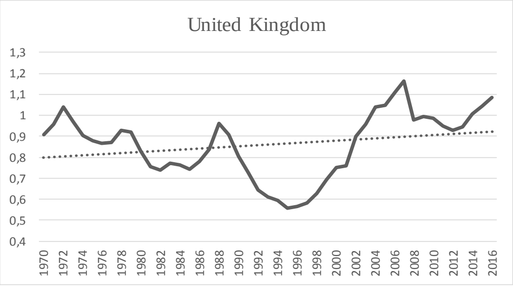


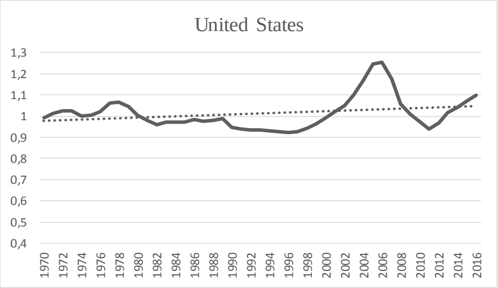












—— Price-to-rent ratio

······· Linear (Price-to-rent ratio)

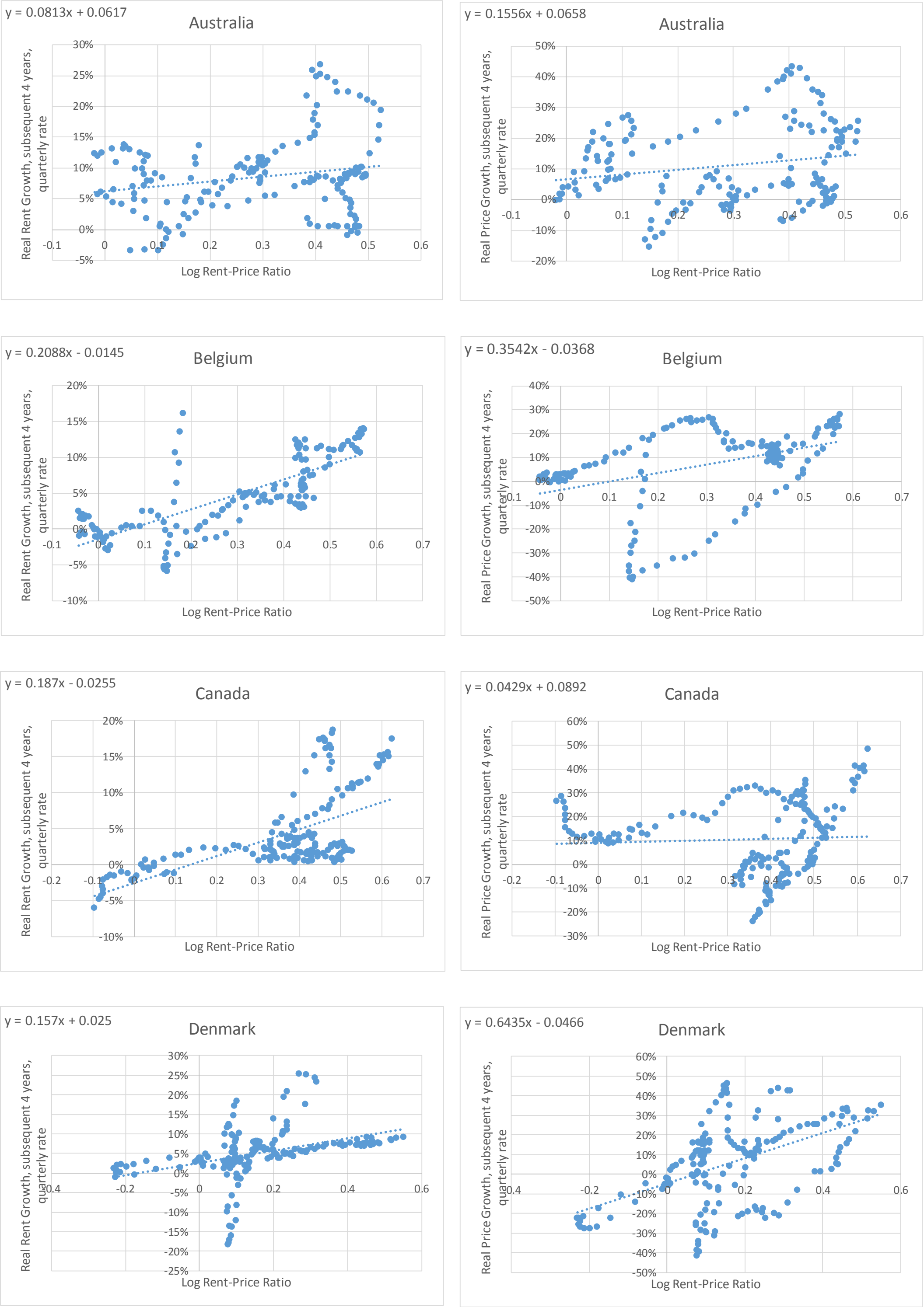
Table 3: Autocorrelation coefficients

This table contains first order autocorrelation coefficients (*Φ*(1)) for rent and price growth, rent-to-price ratio for 20 OECD countries.

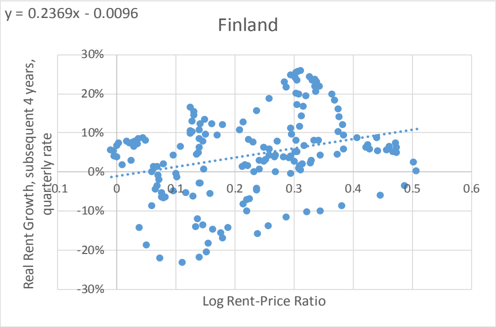
Country	Φ(1) (real house prices)	Φ(1) (real prices changes)	Φ(1) (real rents)	Φ(1) (real rent changes)	Φ(1) (rent-to-price ratio)
Australia	0.984	0.565	0.984	0.508	0.980
Belgium	0.990	0.409	0.983	0.458	0.990
Canada	0.976	0.337	0.982	0.454	0.972
Denmark	0.986	0.557	0.984	0.338	0.989
Finland	0.989	0.601	0.982	0.412	0.998
France	0.990	0.824	0.987	0.700	0.994
Germany	0.985	0.160	0.992	0.295	0.993
Ireland	0.989	0.338	0.979	0.497	0.989
Italy	0.977	0.713	0.974	0.584	0.980
Japan	0.986	0.758	0.987	0.648	0.993
Korea	0.989	0.640	0.820	0.004	0.989
Netherlands	0.990	0.621	0.983	0.493	0.996
New Zealand	0.981	0.811	0.984	0.684	0.981
Norway	0.986	0.501	0.983	0.158	0.985
Portugal	0.990	0.592	0.943	0.312	0.992
Spain	0.991	0.738	0.988	0.604	0.992
Sweden	0.984	0.740	0.992	0.515	0.980
Switzerland	0.983	0.348	0.979	0.267	0.992
UK	0.986	0.751	0.987	0.659	0.998
USA	0.982	0.673	0.981	0.289	0.989

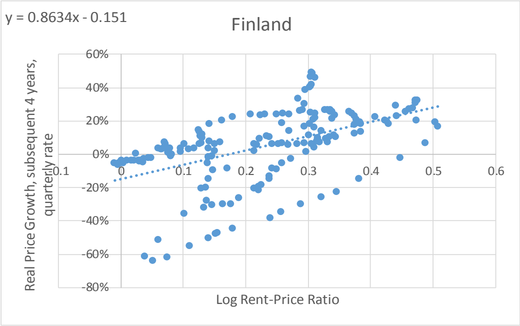
Figure 3: The log rent–price ratio and subsequent changes in rents and prices four years ahead

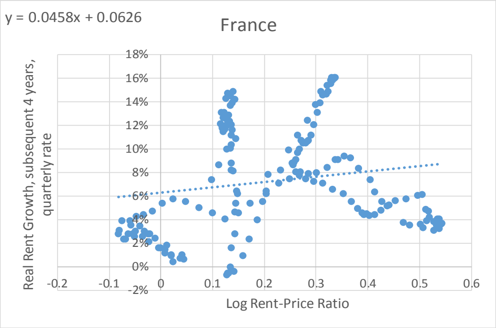
Figure 3 shows the scatterplot analysis of rent–price ratio and subsequent changes in rents and prices four years ahead (1970:Q1 to 2017:Q4).

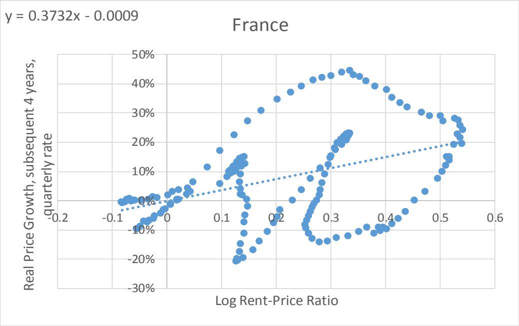


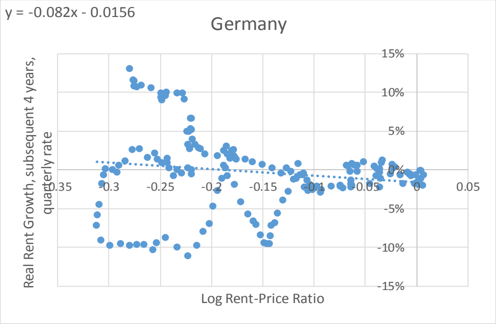
Notes: The equation for the trendline slope is given in the left corner of each graph.

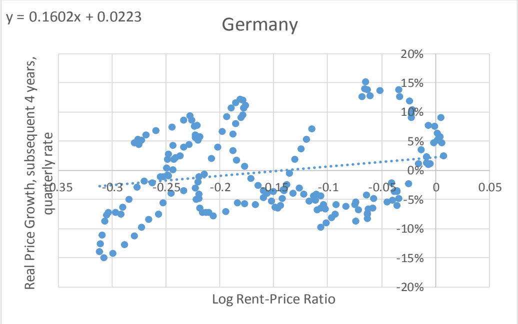


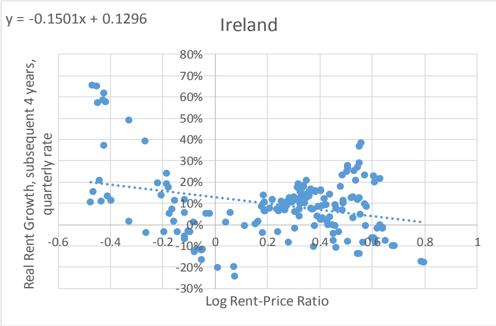


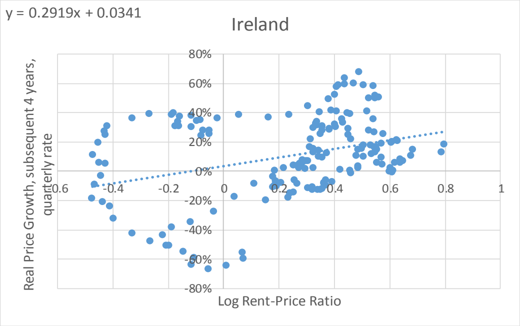


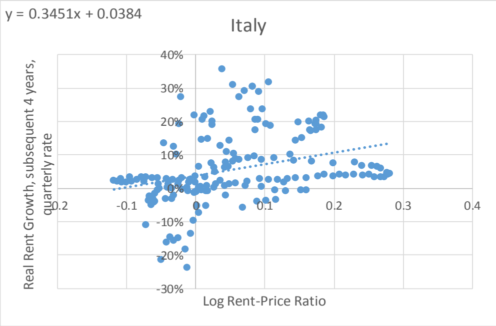


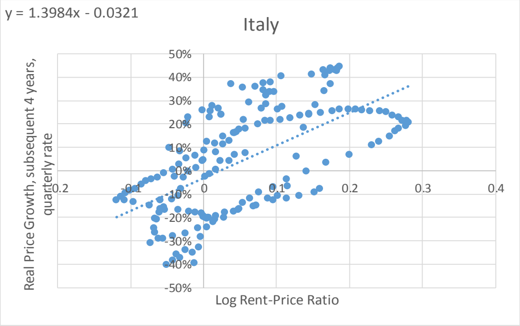




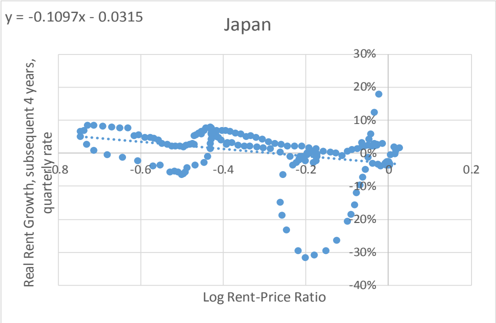


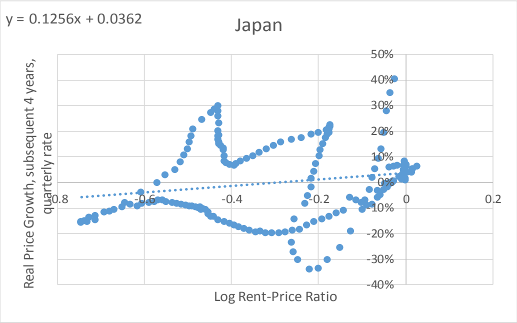


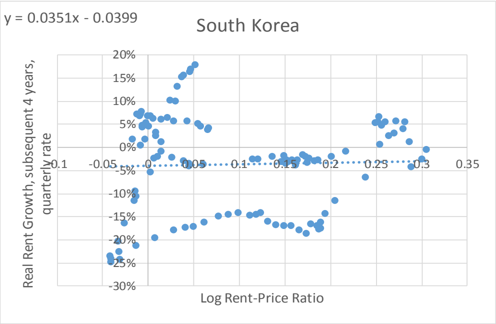


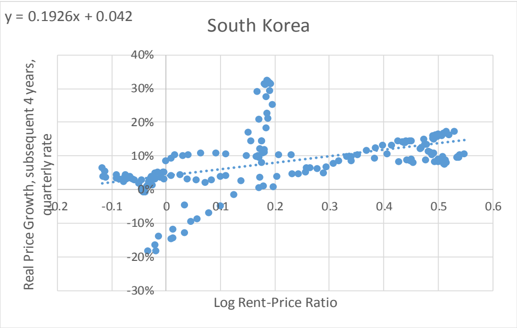


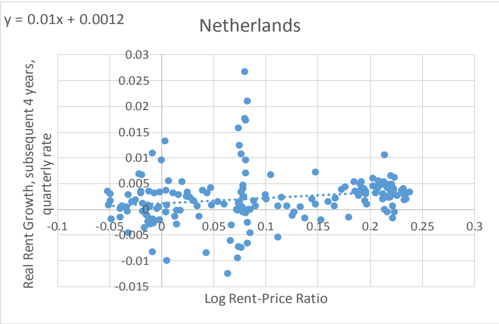
Notes: The equation for the trendline slope is given in the left corner of each graph.

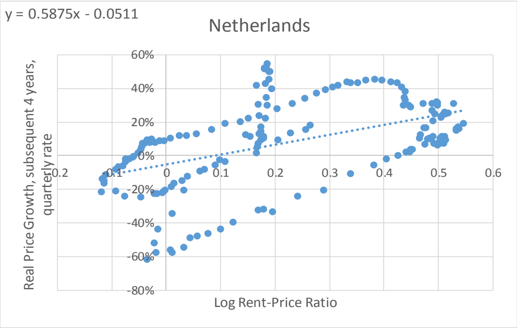


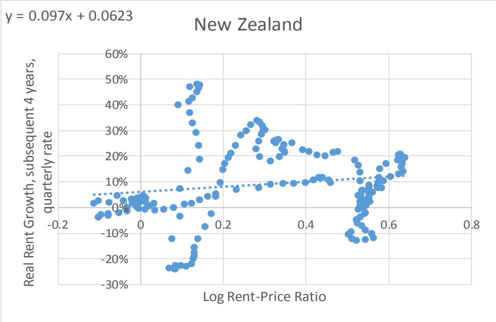


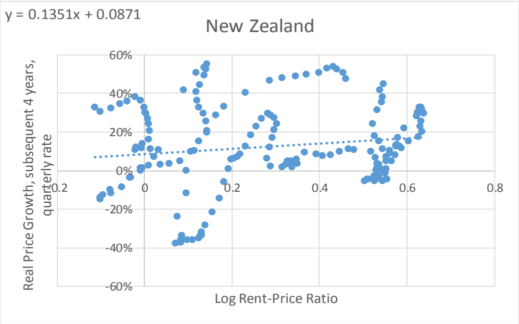


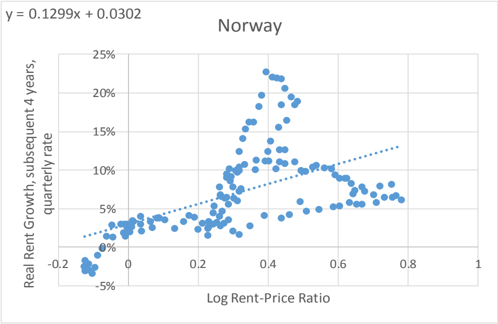


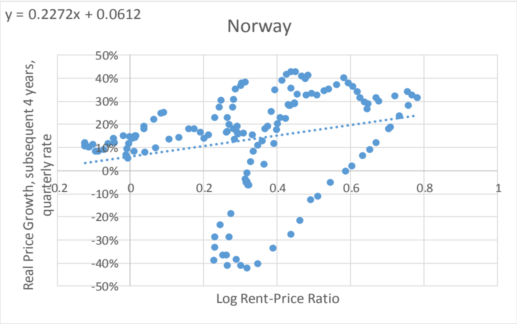




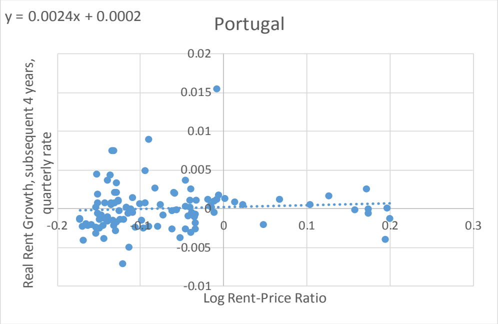


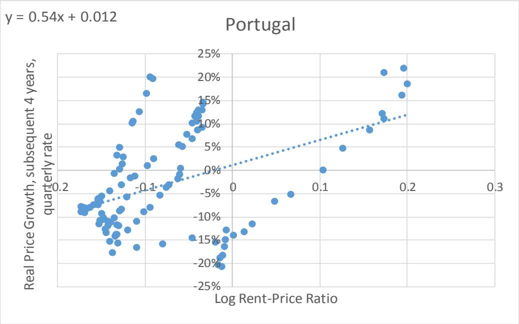


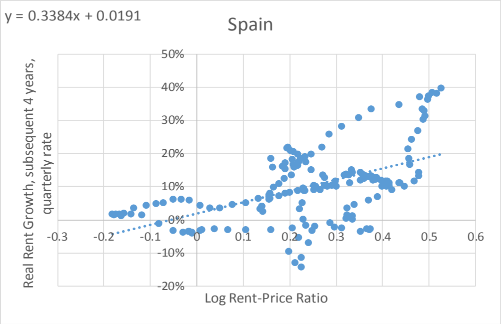


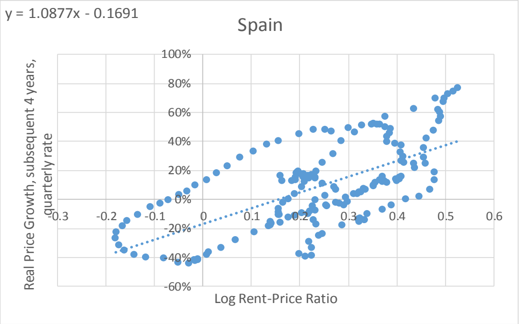


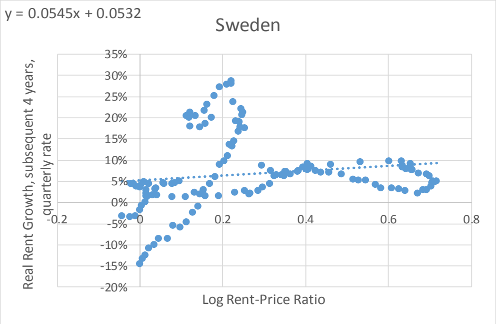
Notes: The equation for the trendline slope is given in the left corner of each graph.

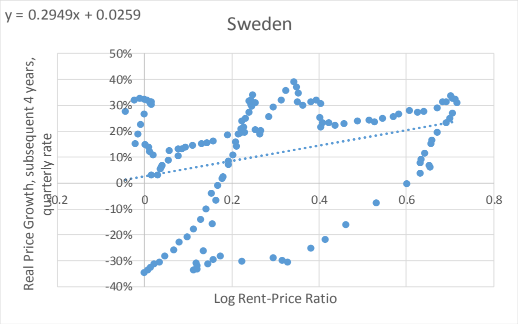


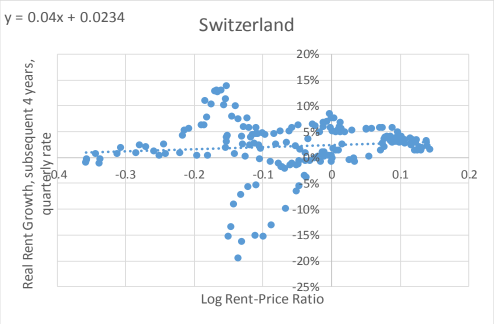


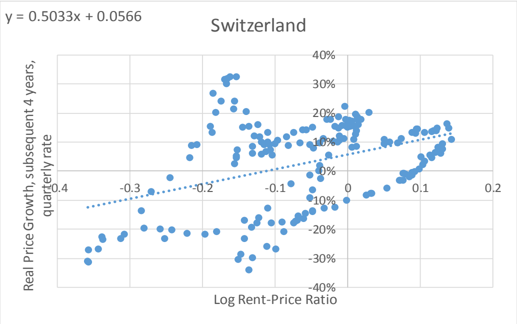


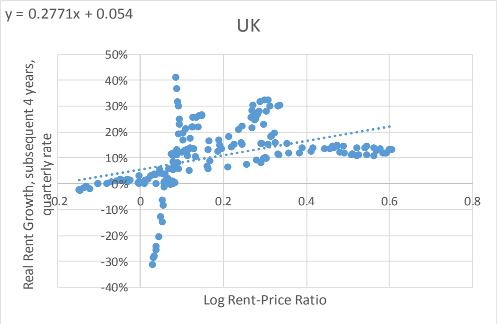


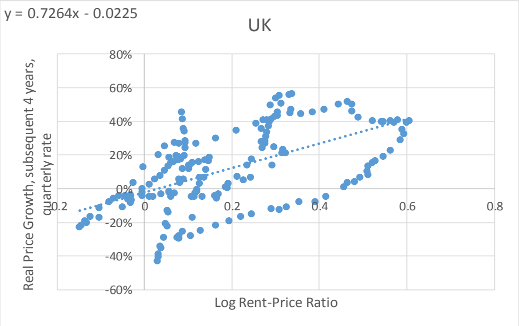




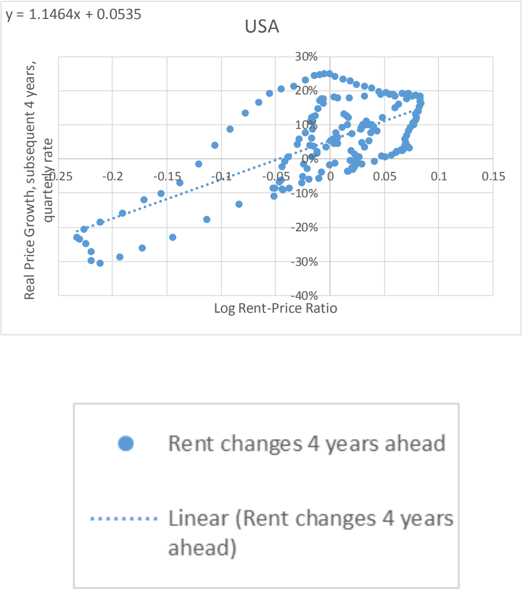








Notes: The equation for the trendline slope is given in the left corner of each graph.



Notes: The equation for the trendline slope is given in the left corner of each graph.

Table 4: Vector error correction model of housing market

Table 4 presents the results of vector error model for 20 OECD countries.

Belgium

	1977:Q3 - 2017Q4		1977:Q3 - 2007Q4	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	0.024*	-0.002	0.027*	0.002
Standard Error	(0.001)	(0.004)	(0.014)	(0.044)

Canada

	1971:Q2 - 2017Q4		1971:Q2 - 2010Q1	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-0.009	-0.009*	-0.013	-0.011*
Standard Error	(0.009)	(0.003)	(0.013)	(0.004)

France

	1971:Q2 - 2017Q4		1971:Q2 - 2008Q4	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-0.001	-0.004*	-0.013*	0.001
Standard Error	(0.002)	(0.001)	(0.001)	(0.001)

Italy

	1971:Q2 - 2017Q4		1971:Q2 - 2008Q1	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-0.008*	0.001	-0.014*	-0.003
Standard Error	(0.003)	(0.003)	(0.005)	(0.004)

Notes: * indicates a significance level of 0.1. Number of lags for each model chosen based on Schwartz criterion. Coefficients are expressed in quarterly rates.

Japan

	1971:Q2 - 2017Q4		1971:Q2 - 2010Q3	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-0.042*	-0.029*	-	-
Standard Error	(0.013)	(0.010)	-	-

South Korea

	1987:Q2 - 2017Q4		1987:Q2 - 2008Q4	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-	-0.001*	-	0.026*
Standard Error	-	(0.000)	-	(0.010)

Norway

	1980:Q2 - 2017Q4		1980:Q2 - 2007Q4	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-0.015	-0.017*	-0.010	-0.015*
Standard Error	(0.011)	(0.005)	(0.015)	(0.006)

Portugal

	1989:Q2 - 2017Q4		1989:Q2 - 2012Q4	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-0.004	-0.053*	-	-
Standard Error	(0.032)	(0.020)	-	-

Notes: * indicates a significance level of 0.1. Number of lags for each model chosen based on Schwartz criterion. Coefficients are expressed in quarterly rates.

Switzerland

	1981:Q2 - 2017Q4		1971:Q2 - 2002Q3	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	-0.063*	-0.018*	-0.094*	-0.031*
Standard Error	(0.019)	(0.009)	(0.026)	(0.013)

United States

	1981:Q2 - 2017Q4		1971:Q2 - 2002Q3	
	Price model	Rent Model	Price model	Rent Model
Lagged rent-to-price ratio	0.003*	0.001	-0.008	-0.012*
Standard Error	(0.001)	(0.001)	(0.005)	(0.004)

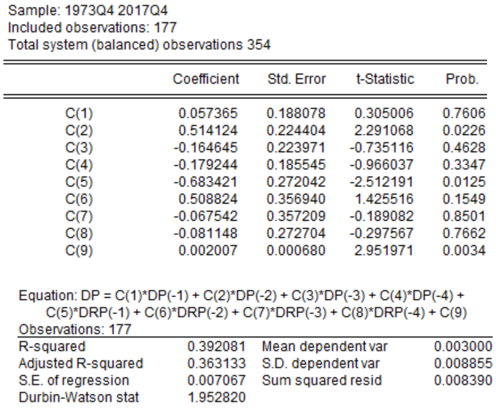
Notes: * indicates a significance level of 0.1. Number of lags for each model chosen based on Schwartz criterion. Coefficients are expressed in quarterly rates.

Table 5: Vector autocorrelation (VAR) models of housing prices and rents

Table 5 presents the results of VAR models' of housing prices and rents for 9 OECD countries

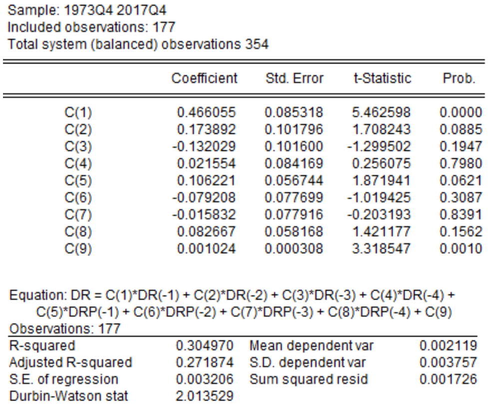
Australia

Price model



```
Sample: 1973Q4 2017Q4
Included observations: 177
Total system (balanced) observations 354
==========================================================================
                        Coefficient     Std. Error    t-Statistic    Prob.
==========================================================================
         C(1)             0.057365      0.188078      0.305006      0.7606
         C(2)             0.514124      0.224404      2.291068      0.0226
         C(3)            -0.164645      0.223971     -0.735116      0.4628
         C(4)            -0.179244      0.185545     -0.966037      0.3347
         C(5)            -0.683421      0.272042     -2.512191      0.0125
         C(6)             0.508824      0.356940      1.425516      0.1549
         C(7)            -0.067542      0.357209     -0.189082      0.8501
         C(8)            -0.081148      0.272704     -0.297567      0.7662
         C(9)             0.002007      0.000680      2.951971      0.0034

  Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
        C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
  Observations: 177
  ------------------------------------------------------------------------
  R-squared                0.392081   Mean dependent var         0.003000
  Adjusted R-squared       0.363133   S.D. dependent var         0.008855
  S.E. of regression       0.007067   Sum squared resid          0.008390
  Durbin-Watson stat       1.952820
```

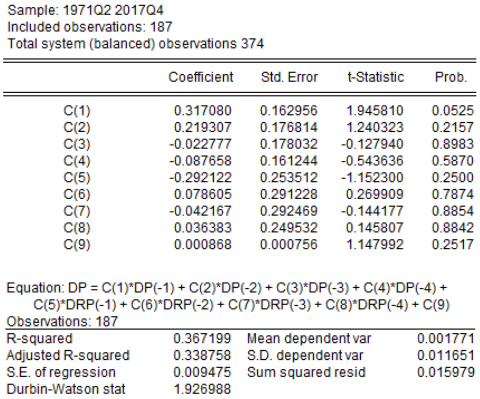
Rent Model



```
Sample: 1973Q4 2017Q4
Included observations: 177
Total system (balanced) observations 354
==========================================================================
                        Coefficient     Std. Error    t-Statistic    Prob.
==========================================================================
         C(1)             0.466055      0.085318      5.462598      0.0000
         C(2)             0.173892      0.101796      1.708243      0.0885
         C(3)            -0.132029      0.101600     -1.299502      0.1947
         C(4)             0.021554      0.084169      0.256075      0.7980
         C(5)             0.106221      0.056744      1.871941      0.0621
         C(6)            -0.079208      0.077699     -1.019425      0.3087
         C(7)            -0.015832      0.077916     -0.203193      0.8391
         C(8)             0.082667      0.058168      1.421177      0.1562
         C(9)             0.001024      0.000308      3.318547      0.0010

 Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
       C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
 Observations: 177
 -------------------------------------------------------------------------
 R-squared                0.304970   Mean dependent var         0.002119
 Adjusted R-squared       0.271874   S.D. dependent var         0.003757
 S.E. of regression       0.003206   Sum squared resid          0.001726
 Durbin-Watson stat       2.013529
```

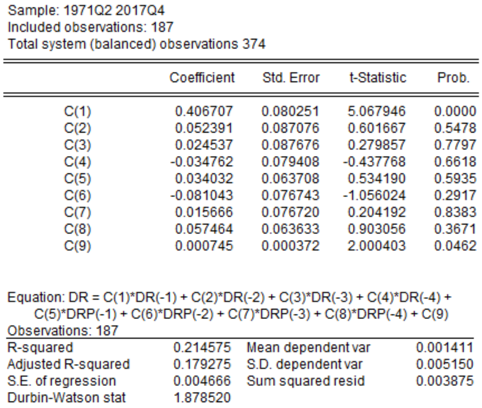
Denmark

Price model



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374
==========================================================================
                        Coefficient     Std. Error    t-Statistic    Prob.
==========================================================================
         C(1)             0.317080      0.162956      1.945810      0.0525
         C(2)             0.219307      0.176814      1.240323      0.2157
         C(3)            -0.022777      0.178032     -0.127940      0.8983
         C(4)            -0.087658      0.161244     -0.543636      0.5870
         C(5)            -0.292122      0.253512     -1.152300      0.2500
         C(6)             0.078605      0.291228      0.269909      0.7874
         C(7)            -0.042167      0.292469     -0.144177      0.8854
         C(8)             0.036383      0.249532      0.145807      0.8842
         C(9)             0.000868      0.000756      1.147992      0.2517

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
      C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
--------------------------------------------------------------------------
R-squared                0.367199   Mean dependent var         0.001771
Adjusted R-squared       0.338758   S.D. dependent var         0.011651
S.E. of regression       0.009475   Sum squared resid          0.015979
Durbin-Watson stat       1.926988
```

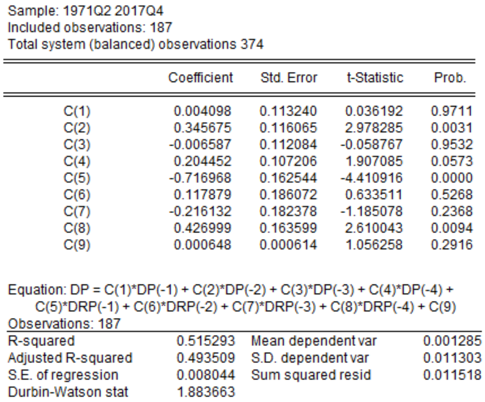
Rent model



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374
==========================================================================
                        Coefficient     Std. Error    t-Statistic    Prob.
==========================================================================
         C(1)             0.406707      0.080251      5.067946      0.0000
         C(2)             0.052391      0.087076      0.601667      0.5478
         C(3)             0.024537      0.087676      0.279857      0.7797
         C(4)            -0.034762      0.079408     -0.437768      0.6618
         C(5)             0.034032      0.063708      0.534190      0.5935
         C(6)            -0.081043      0.076743     -1.056024      0.2917
         C(7)             0.015666      0.076720      0.204192      0.8383
         C(8)             0.057464      0.063633      0.903056      0.3671
         C(9)             0.000745      0.000372      2.000403      0.0462

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
      C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
--------------------------------------------------------------------------
R-squared                0.214575   Mean dependent var         0.001411
Adjusted R-squared       0.179275   S.D. dependent var         0.005150
S.E. of regression       0.004666   Sum squared resid          0.003875
Durbin-Watson stat       1.878520
```

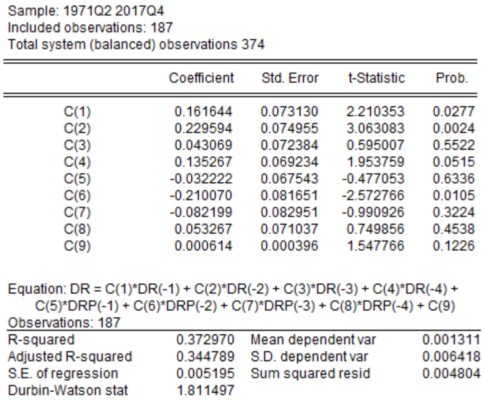
Finland

Price model



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374
==========================================================================
                        Coefficient     Std. Error    t-Statistic    Prob.
==========================================================================
         C(1)             0.004098      0.113240      0.036192      0.9711
         C(2)             0.345675      0.116065      2.978285      0.0031
         C(3)            -0.006587      0.112084     -0.058767      0.9532
         C(4)             0.204452      0.107206      1.907085      0.0573
         C(5)            -0.716968      0.162544     -4.410916      0.0000
         C(6)             0.117879      0.186072      0.633511      0.5268
         C(7)            -0.216132      0.182378     -1.185078      0.2368
         C(8)             0.426999      0.163599      2.610043      0.0094
         C(9)             0.000648      0.000614      1.056258      0.2916

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
      C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
--------------------------------------------------------------------------
R-squared                0.515293   Mean dependent var         0.001285
Adjusted R-squared       0.493509   S.D. dependent var         0.011303
S.E. of regression       0.008044   Sum squared resid          0.011518
Durbin-Watson stat       1.883663
```

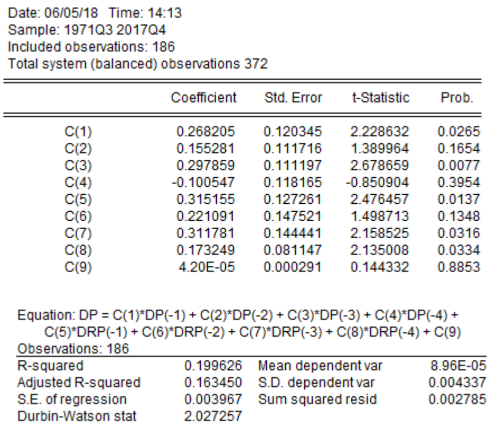
Rent mode



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374
==========================================================================
                        Coefficient     Std. Error    t-Statistic    Prob.
==========================================================================
         C(1)             0.161644      0.073130      2.210353      0.0277
         C(2)             0.229594      0.074955      3.063083      0.0024
         C(3)             0.043069      0.072384      0.595007      0.5522
         C(4)             0.135267      0.069234      1.953759      0.0515
         C(5)            -0.032222      0.067543     -0.477053      0.6336
         C(6)            -0.210070      0.081651     -2.572766      0.0105
         C(7)            -0.082199      0.082951     -0.990926      0.3224
         C(8)             0.053267      0.071037      0.749856      0.4538
         C(9)             0.000614      0.000396      1.547766      0.1226

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
      C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
--------------------------------------------------------------------------
R-squared                0.372970   Mean dependent var         0.001311
Adjusted R-squared       0.344789   S.D. dependent var         0.006418
S.E. of regression       0.005195   Sum squared resid          0.004804
Durbin-Watson stat       1.811497
```

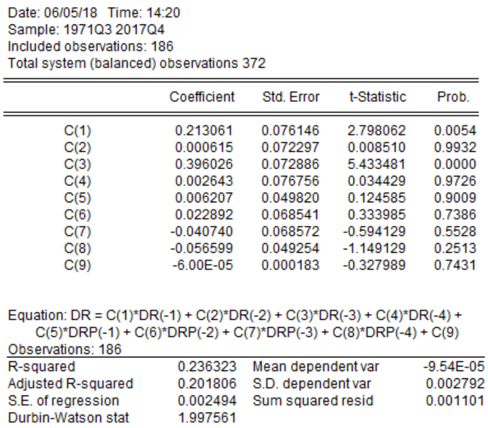
Germany

Price model



```
Date: 06/05/18   Time: 14:13
Sample: 1971Q3 2017Q4
Included observations: 186
Total system (balanced) observations 372

                     Coefficient   Std. Error   t-Statistic    Prob.

        C(1)           0.268205    0.120345     2.228632      0.0265
        C(2)           0.155281    0.111716     1.389964      0.1654
        C(3)           0.297859    0.111197     2.678659      0.0077
        C(4)          -0.100547    0.118165    -0.850904      0.3954
        C(5)           0.315155    0.127261     2.476457      0.0137
        C(6)           0.221091    0.147521     1.498713      0.1348
        C(7)           0.311781    0.144441     2.158525      0.0316
        C(8)           0.173249    0.081147     2.135008      0.0334
        C(9)           4.20E-05    0.000291     0.144332      0.8853

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
        C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 186
R-squared              0.199626   Mean dependent var      8.96E-05
Adjusted R-squared     0.163450   S.D. dependent var      0.004337
S.E. of regression     0.003967   Sum squared resid       0.002785
Durbin-Watson stat     2.027257
```

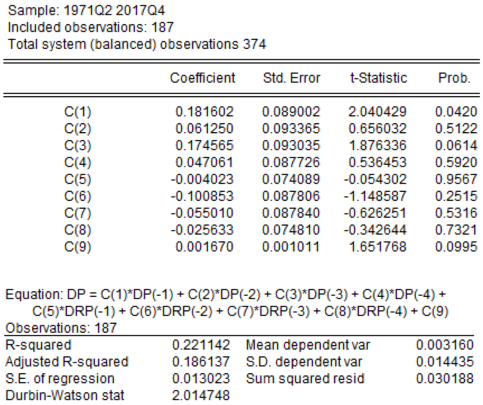
Rent model



```
Date: 06/05/18   Time: 14:20
Sample: 1971Q3 2017Q4
Included observations: 186
Total system (balanced) observations 372

                     Coefficient   Std. Error   t-Statistic    Prob.

        C(1)           0.213061    0.076146     2.798062      0.0054
        C(2)           0.000615    0.072297     0.008510      0.9932
        C(3)           0.396026    0.072886     5.433481      0.0000
        C(4)           0.002643    0.076756     0.034429      0.9726
        C(5)           0.006207    0.049820     0.124585      0.9009
        C(6)           0.022892    0.068541     0.333985      0.7386
        C(7)          -0.040740    0.068572    -0.594129      0.5528
        C(8)          -0.056599    0.049254    -1.149129      0.2513
        C(9)          -6.00E-05    0.000183    -0.327989      0.7431

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
        C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 186
R-squared              0.236323   Mean dependent var     -9.54E-05
Adjusted R-squared     0.201806   S.D. dependent var      0.002792
S.E. of regression     0.002494   Sum squared resid       0.001101
Durbin-Watson stat     1.997561
```

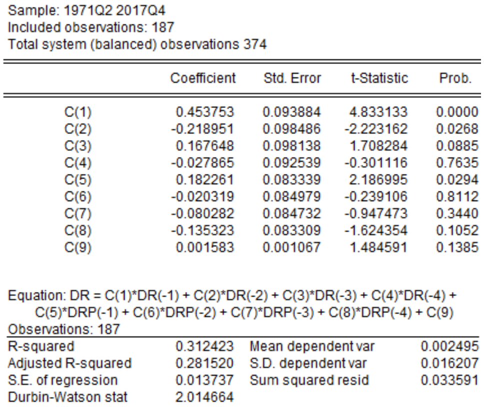
Ireland

Price model



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374

                     Coefficient   Std. Error   t-Statistic    Prob.

        C(1)           0.181602    0.089002     2.040429      0.0420
        C(2)           0.061250    0.093365     0.656032      0.5122
        C(3)           0.174565    0.093035     1.876336      0.0614
        C(4)           0.047061    0.087726     0.536453      0.5920
        C(5)          -0.004023    0.074089    -0.054302      0.9567
        C(6)          -0.100853    0.087806    -1.148587      0.2515
        C(7)          -0.055010    0.087840    -0.626251      0.5316
        C(8)          -0.025633    0.074810    -0.342644      0.7321
        C(9)           0.001670    0.001011     1.651768      0.0995

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
        C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
R-squared              0.221142   Mean dependent var      0.003160
Adjusted R-squared     0.186137   S.D. dependent var      0.014435
S.E. of regression     0.013023   Sum squared resid       0.030188
Durbin-Watson stat     2.014748
```

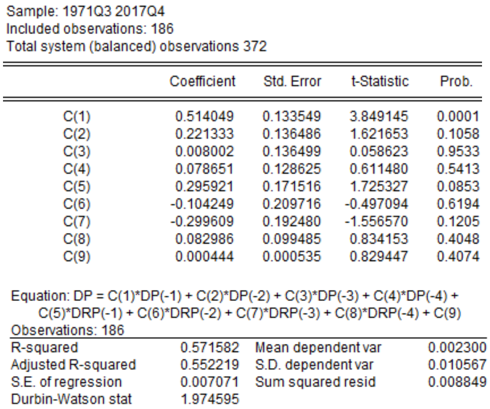
Rent model



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374

                     Coefficient   Std. Error   t-Statistic    Prob.

        C(1)           0.453753    0.093884     4.833133      0.0000
        C(2)          -0.218951    0.098486    -2.223162      0.0268
        C(3)           0.167648    0.098138     1.708284      0.0885
        C(4)          -0.027865    0.092539    -0.301116      0.7635
        C(5)           0.182261    0.083339     2.186995      0.0294
        C(6)          -0.020319    0.084979    -0.239106      0.8112
        C(7)          -0.080282    0.084732    -0.947473      0.3440
        C(8)          -0.135323    0.083309    -1.624354      0.1052
        C(9)           0.001583    0.001067     1.484591      0.1385

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
        C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
R-squared              0.312423   Mean dependent var      0.002495
Adjusted R-squared     0.281520   S.D. dependent var      0.016207
S.E. of regression     0.013737   Sum squared resid       0.033591
Durbin-Watson stat     2.014664
```

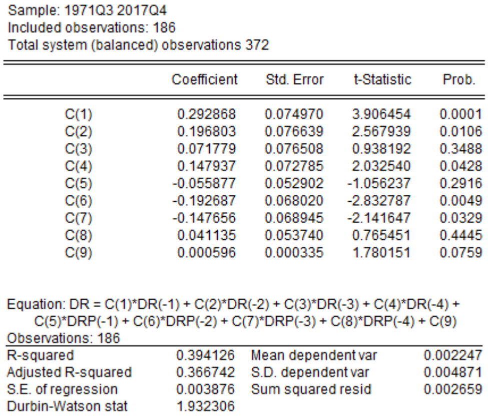
Netherlands

Price model



```
Sample: 1971Q3 2017Q4
Included observations: 186
Total system (balanced) observations 372

                     Coefficient   Std. Error   t-Statistic    Prob.

        C(1)           0.514049    0.133549     3.849145      0.0001
        C(2)           0.221333    0.136486     1.621653      0.1058
        C(3)           0.008002    0.136499     0.058623      0.9533
        C(4)           0.078651    0.128625     0.611480      0.5413
        C(5)           0.295921    0.171516     1.725327      0.0853
        C(6)          -0.104249    0.209716    -0.497094      0.6194
        C(7)          -0.299609    0.192480    -1.556570      0.1205
        C(8)           0.082986    0.099485     0.834153      0.4048
        C(9)           0.000444    0.000535     0.829447      0.4074

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
        C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 186
R-squared              0.571582   Mean dependent var      0.002300
Adjusted R-squared     0.552219   S.D. dependent var      0.010567
S.E. of regression     0.007071   Sum squared resid       0.008849
Durbin-Watson stat     1.974595
```

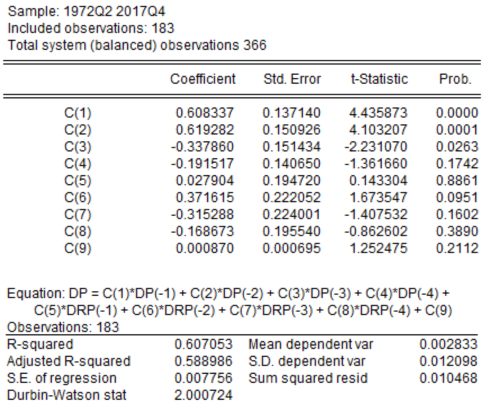
Rent model



```
Sample: 1971Q3 2017Q4
Included observations: 186
Total system (balanced) observations 372

                     Coefficient   Std. Error   t-Statistic    Prob.

        C(1)           0.292868    0.074970     3.906454      0.0001
        C(2)           0.196803    0.076639     2.567939      0.0106
        C(3)           0.071779    0.076508     0.938192      0.3488
        C(4)           0.147937    0.072785     2.032540      0.0428
        C(5)          -0.055877    0.052902    -1.056237      0.2916
        C(6)          -0.192687    0.068020    -2.832787      0.0049
        C(7)          -0.147656    0.068945    -2.141647      0.0329
        C(8)           0.041135    0.053740     0.765451      0.4445
        C(9)           0.000596    0.000335     1.780151      0.0759

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
        C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 186
R-squared              0.394126   Mean dependent var      0.002247
Adjusted R-squared     0.366742   S.D. dependent var      0.004871
S.E. of regression     0.003876   Sum squared resid       0.002659
Durbin-Watson stat     1.932306
```

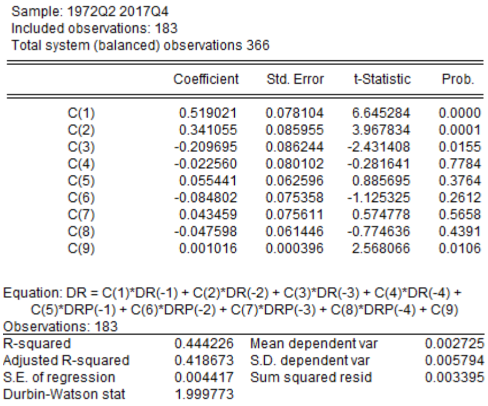
Spain

Price model



```
Sample: 1972Q2 2017Q4
Included observations: 183
Total system (balanced) observations 366

                 Coefficient   Std. Error   t-Statistic   Prob.

      C(1)        0.608337     0.137140     4.435873     0.0000
      C(2)        0.619282     0.150926     4.103207     0.0001
      C(3)       -0.337860     0.151434    -2.231070     0.0263
      C(4)       -0.191517     0.140650    -1.361660     0.1742
      C(5)        0.027904     0.194720     0.143304     0.8861
      C(6)        0.371615     0.222052     1.673547     0.0951
      C(7)       -0.315288     0.224001    -1.407532     0.1602
      C(8)       -0.168673     0.195540    -0.862602     0.3890
      C(9)        0.000870     0.000695     1.252475     0.2112

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
     C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 183
R-squared              0.607053   Mean dependent var     0.002833
Adjusted R-squared     0.588986   S.D. dependent var     0.012098
S.E. of regression     0.007756   Sum squared resid      0.010468
Durbin-Watson stat     2.000724
```

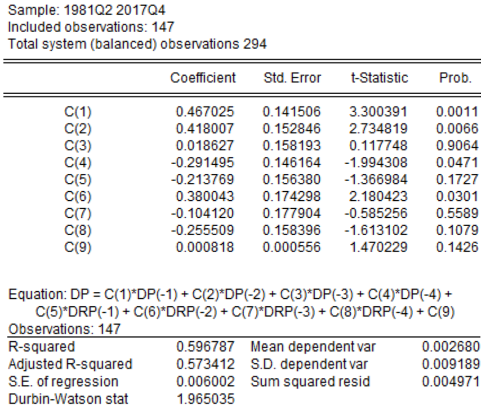
Rent model



```
Sample: 1972Q2 2017Q4
Included observations: 183
Total system (balanced) observations 366

                 Coefficient   Std. Error   t-Statistic   Prob.

      C(1)        0.519021     0.078104     6.645284     0.0000
      C(2)        0.341055     0.085955     3.967834     0.0001
      C(3)       -0.209695     0.086244    -2.431408     0.0155
      C(4)       -0.022560     0.080102    -0.281641     0.7784
      C(5)        0.055441     0.062596     0.885695     0.3764
      C(6)       -0.084802     0.075358    -1.125325     0.2612
      C(7)        0.043459     0.075611     0.574778     0.5658
      C(8)       -0.047598     0.061446    -0.774636     0.4391
      C(9)        0.001016     0.000396     2.568066     0.0106

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
     C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 183
R-squared              0.444226   Mean dependent var     0.002725
Adjusted R-squared     0.418673   S.D. dependent var     0.005794
S.E. of regression     0.004417   Sum squared resid      0.003395
Durbin-Watson stat     1.999773
```

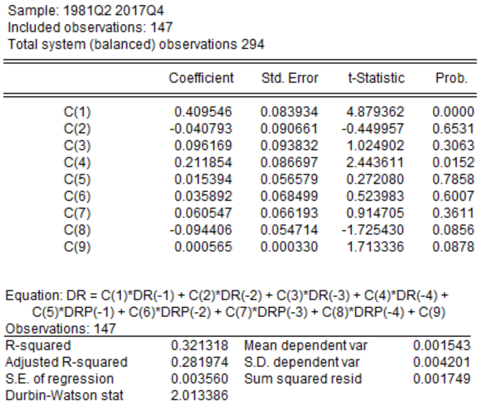
Sweden

Price model



```
Sample: 1981Q2 2017Q4
Included observations: 147
Total system (balanced) observations 294

                 Coefficient   Std. Error   t-Statistic   Prob.

      C(1)        0.467025     0.141506     3.300391     0.0011
      C(2)        0.418007     0.152846     2.734819     0.0066
      C(3)        0.018627     0.158193     0.117748     0.9064
      C(4)       -0.291495     0.146164    -1.994308     0.0471
      C(5)       -0.213769     0.156380    -1.366984     0.1727
      C(6)        0.380043     0.174298     2.180423     0.0301
      C(7)       -0.104120     0.177904    -0.585256     0.5589
      C(8)       -0.255509     0.158396    -1.613102     0.1079
      C(9)        0.000818     0.000556     1.470229     0.1426

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
     C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 147
R-squared              0.596787   Mean dependent var     0.002680
Adjusted R-squared     0.573412   S.D. dependent var     0.009189
S.E. of regression     0.006002   Sum squared resid      0.004971
Durbin-Watson stat     1.965035
```

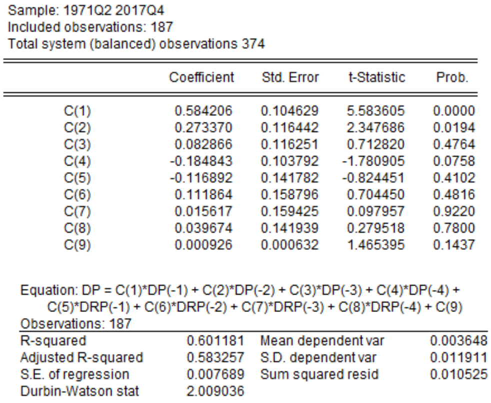
Rent model



```
Sample: 1981Q2 2017Q4
Included observations: 147
Total system (balanced) observations 294

                 Coefficient   Std. Error   t-Statistic   Prob.

      C(1)        0.409546     0.083934     4.879362     0.0000
      C(2)       -0.040793     0.090661    -0.449957     0.6531
      C(3)        0.096169     0.093832     1.024902     0.3063
      C(4)        0.211854     0.086697     2.443611     0.0152
      C(5)        0.015394     0.056579     0.272080     0.7858
      C(6)        0.035892     0.068499     0.523983     0.6007
      C(7)        0.060547     0.066193     0.914705     0.3611
      C(8)       -0.094406     0.054714    -1.725430     0.0856
      C(9)        0.000565     0.000330     1.713336     0.0878

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
     C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 147
R-squared              0.321318   Mean dependent var     0.001543
Adjusted R-squared     0.281974   S.D. dependent var     0.004201
S.E. of regression     0.003560   Sum squared resid      0.001749
Durbin-Watson stat     2.013386
```

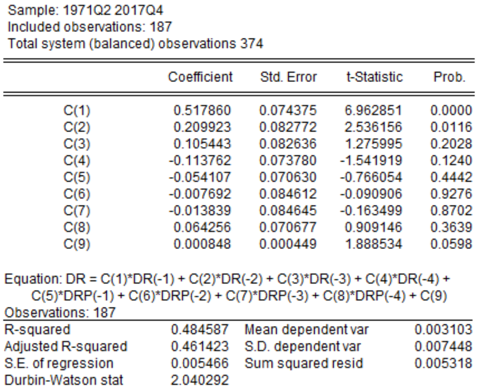
UK

Price model



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374

                 Coefficient   Std. Error   t-Statistic   Prob.

      C(1)        0.584206     0.104629     5.583605     0.0000
      C(2)        0.273370     0.116442     2.347686     0.0194
      C(3)        0.082866     0.116251     0.712820     0.4764
      C(4)       -0.184843     0.103792    -1.780905     0.0758
      C(5)       -0.116892     0.141782    -0.824451     0.4102
      C(6)        0.111864     0.158796     0.704450     0.4816
      C(7)        0.015617     0.159425     0.097957     0.9220
      C(8)        0.039674     0.141939     0.279518     0.7800
      C(9)        0.000926     0.000632     1.465395     0.1437

Equation: DP = C(1)*DP(-1) + C(2)*DP(-2) + C(3)*DP(-3) + C(4)*DP(-4) +
     C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
R-squared              0.601181   Mean dependent var     0.003648
Adjusted R-squared     0.583257   S.D. dependent var     0.011911
S.E. of regression     0.007689   Sum squared resid      0.010525
Durbin-Watson stat     2.009036
```

Rent model



```
Sample: 1971Q2 2017Q4
Included observations: 187
Total system (balanced) observations 374

                 Coefficient   Std. Error   t-Statistic   Prob.

      C(1)        0.517860     0.074375     6.962851     0.0000
      C(2)        0.209923     0.082772     2.536156     0.0116
      C(3)        0.105443     0.082636     1.275995     0.2028
      C(4)       -0.113762     0.073780    -1.541919     0.1240
      C(5)       -0.054107     0.070630    -0.766054     0.4442
      C(6)       -0.007692     0.084612    -0.090906     0.9276
      C(7)       -0.013839     0.084645    -0.163499     0.8702
      C(8)        0.064256     0.070677     0.909146     0.3639
      C(9)        0.000848     0.000449     1.888534     0.0598

Equation: DR = C(1)*DR(-1) + C(2)*DR(-2) + C(3)*DR(-3) + C(4)*DR(-4) +
     C(5)*DRP(-1) + C(6)*DRP(-2) + C(7)*DRP(-3) + C(8)*DRP(-4) + C(9)
Observations: 187
R-squared              0.484587   Mean dependent var     0.003103
Adjusted R-squared     0.461423   S.D. dependent var     0.007448
S.E. of regression     0.005466   Sum squared resid      0.005318
Durbin-Watson stat     2.040292
```

Table 6: Long-horizon model results

Table 6 reveals the results of long-horizon model estimated for 20 OECD countries.

Australia

	Price Model	Rent model
Rent-to-price ratio	0.156	0.081
Standard errors	0.211	0.119
R-squared	0.040	0.046

Belgium

	Price Model	Rent model
Rent-to-price ratio	0.354	0.209
Standard errors	0.087	0.058
R-squared	0.176	0.592

Canada

	Price Model	Rent model
Rent-to-price ratio	0.043	0.187
Standard errors	0.703	0.069
R-squared	0.003	0.383

Denmark

	Price Model	Rent model
Rent-to-price ratio	0.644	0.160
Standard errors	0.178	0.061
R-squared	0.261	0.152

Finland

	Price Model	Rent model
Rent-to-price ratio	1.689	1.000
Standard errors	0.221	1.48E-16
R-squared	0.667	0.562

France

	Price Model	Rent model
Rent-to-price ratio	0.373	0.046
Standard errors	0.143	0.142
R-squared	0.167	0.030

Germany

	Price Model	Rent model
Rent-to-price ratio	0.160	-0.082
Standard errors	3.081	0.167
R-squared	0.045	0.024

Ireland

	Price Model	Rent model
Rent-to-price ratio	0.292	-0.150
Standard errors	0.352	0.126
R-squared	0.108	0.093

Italy

	Price Model	Rent model
Rent-to-price ratio	1.398	0.345
Standard errors	0.577	0.361
R-squared	0.386	0.105

Japan

	Price Model	Rent model
Rent-to-price ratio	0.126	-0.110
Standard errors	0.103	0.052
R-squared	0.034	0.097

South Korea

	Price Model	Rent model
Rent-to-price ratio	0.645	0.035
Standard errors	0.435	0.311
R-squared	0.117	0.001

Netherlands

	Price Model	Rent model
Rent-to-price ratio	0.587	0.193
Standard errors	0.195	0.068
R-squared	0.241	0.200

New Zealand

	Price Model	Rent model
Rent-to-price ratio	0.135	0.097
Standard errors	0.235	0.128
R-squared	0.021	0.021

Norway

	Price Model	Rent model
Rent-to-price ratio	0.227	0.130
Standard errors	0.142	0.153
R-squared	0.063	0.284

Portugal

	Price Model	Rent model
Rent-to-price ratio	0.446	0.120
Standard errors	0.193	0.275
R-squared	0.249	0.124

Spain

	Price Model	Rent model
Rent-to-price ratio	1.088	0.338
Standard errors	0.259	0.109
R-squared	0.421	0.294

Sweden

	Price Model	Rent model
Rent-to-price ratio	0.295	0.055
Standard errors	0.233	0.091
R-squared	0.097	0.021

Switzerland

	Price Model	Rent model
Rent-to-price ratio	0.503	0.040
Standard errors	0.269	0.081
R-squared	0.154	0.008

UK

	Price Model	Rent model
Rent-to-price ratio	0.726	0.277
Standard errors	0.292	0.233
R-squared	0.331	0.183

USA

	Price Model	Rent model
Rent-to-price ratio	1.146	0.323
Standard errors	0.224	0.035
R-squared	0.476	0.357

H_0: rents do all the correcting suggests that prices follow a random walk with drift. H_0: prices do all the correcting suggests that rents follow a random walk with drift.

Table 7: Bootstrapping results

Table 7 shows the results of bootstrapping procedure performed for 20 OECD countries.

Australia

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.156	0.364
Rent model	0.081	0.000
H_0 : Prices do all correcting		
Price model	0.156	0.000
Rent model	0.081	0.326

Belgium

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.354	0.746
Rent model	0.209	0.000
H_0 : Prices do all correcting		
Price model	0.354	0.000
Rent model	0.209	0.081

Canada

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.043	0.694
Rent model	0.187	0.000
H_0 : Prices do all correcting		
Price model	0.043	0.000
Rent model	0.187	0.102

Denmark

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.644	0.112
Rent model	0.160	0.000
H_0 : Prices do all correcting		
Price model	0.644	0.000
Rent model	0.160	0.541

Finland

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	1.689	0.019
Rent model	1.000	0.000
H_0 : Prices do all correcting		
Price model	1.689	0.000
Rent model	1.000	0.172

France

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.373	0.996
Rent model	0.046	0.000
H_0 : Prices do all correcting		
Price model	0.373	0.000
Rent model	0.046	0.004

Germany

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.160	0.038
Rent model	-0.082	0.000
H_0 : Prices do all correcting		
Price model	0.160	0.000
Rent model	-0.082	0.067

Ireland

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.292	0.179
Rent model	-0.150	0.000
H_0 : Prices do all correcting		
Price model	0.292	0.000
Rent model	-0.150	0.509

Italy

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	1.398	0.310
Rent model	0.345	0.000
H_0 : Prices do all correcting		
Price model	1.398	0.000
Rent model	0.345	0.404

Japan

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.126	0.290
Rent model	-0.110	0.000
H_0 : Prices do all correcting		
Price model	0.126	0.000
Rent model	-0.110	0.324

South Korea

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.645	0.335
Rent model	0.035	0.012
H_0 : Prices do all correcting		
Price model	0.645	0.000
Rent model	0.035	0.883

Netherlands

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.587	0.681
Rent model	0.193	0.000
H_0 : Prices do all correcting		
Price model	0.587	0.000
Rent model	0.193	0.688

New Zealand

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.135	0.039
Rent model	0.097	0.000
H_0 : Prices do all correcting		
Price model	0.135	0.000
Rent model	0.097	0.442

Norway

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.227	0.062
Rent model	0.130	0.000
H_0 : Prices do all correcting		
Price model	0.227	0.000

Portugal

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.446	0.551
Rent model	0.120	0.210
H_0 : Prices do all correcting		
Price model	0.446	0.000
Rent model	0.120	0.733

Spain

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	1.088	0.743
Rent model	0.338	0.006
H_0 : Prices do all correcting		
Price model	1.088	0.224
Rent model	0.338	0.782

Sweden

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.295	0.035
Rent model	0.055	0.000
H_0 : Prices do all correcting		
Price model	0.295	0.003
Rent model	0.055	0.518

Switzerland

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.503	0.613
Rent model	0.040	0.000
H_0 : Prices do all correcting		
Price model	0.503	0.014
Rent model	0.040	0.314

UK

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	0.726	0.652
Rent model	0.277	0.000
H_0 : Prices do all correcting		
Price model	0.726	0.008
Rent model	0.277	0.793

USA

	Coefficient	p-value
H_0 : Rents do all correcting		
Price model	1.146	0.417
Rent model	0.323	0.001
H_0 : Prices do all correcting		
Price model	1.146	0.003
Rent model	0.323	0.217

Notes: H_0: rents do all the correcting suggests that prices follow a random walk with drift. H_0: prices do all the correcting suggests that rents follow a random walk with drift.

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Preliminary Master Thesis Report

Testing for predictive power of price-to-rent ratio for determining house prices in OECD countries

Hand-in date:
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Campus:
BI Oslo

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Programme:
Master of Science in Business – Major in Finance

Thesis supervisor:
Ilan Cooper

Table of contents

1. Introduction and motivation

As history shows, the real estate market is one of the main indicators of financial health of the economy. Due to its large size (the total value of world real estate market was roughly $217 trillion in 2015) (Fraser, 2016) and deep inter-linkages with other economic sectors, housing market can significantly influence the macroeconomic environment. For example, raising house prices usually bursts increase in household consumption, employment rate, and consequently, the real GDP growth.

Further, this sector can also cause economic vulnerabilities. Indeed, one of the most prominent consequences of the real estate market fluctuations is the housing bubbles phenomenon. Although not that frequent, they can be more severe than the stock market bubbles, leading to the times larger losses. For instance, the financial crisis in 2008 has started from the USA house market bust and led to recession in all major economies. It was declared to be the worst economic distress since the Great Depression (Havemann, n.d.). Moreover, nowadays for many countries, housing price growth significantly outperforms rent growth showing the same disturbing pattern as before crisis 2008. The countries which provoke the most anxiety include USA, Canada, New Zealand, Norway, Sweden, Switzerland, UK, and Germany (see Figure 1 in the appendix). So, another price bubble can be suspected on these markets. Therefore, the continuous researches of the housing market are essential in order to better understand this sector and to be able to prevent or mitigate similar crises in the future.

In our research, we aim to investigate the possibility to forecast changes in house prices and rents for OECD countries using price-to-rent ratio as the main predictive variable. The empirical part of the analysis will be based on the error-correction model which is a similar approach as Gallin (2008) did for the examination of the relationship between rent and house prices in the USA.

There are already many studies dedicated to this topic. However, most of the papers examine only one particular country such as the USA or use old statistics. In contrast, we will build our investigation using the latest possible data ranged from 1970:Q1 (in some cases from 1986:Q1) to 2017:Q3 for 20 OECD countries. We believe that these advancements will contribute to better understanding of the long-run relationship between housing and rent prices.

The rest of the paper will be organized as follows. The second section contains a comprehensive literature review. In section three the main theoretical concepts are revised and in section four the relevant methodology is presented. In addition, section five describes the data used in the study while section six outlines further steps in our research.

2. Literature review

This paper builds on the significant amount of the previous researches which study housing returns relationships. The studies related the most to ours by topic include Campbell et al. (2009), Kishor (2014), Hill (2014), Andréa (2014), Sommer (Bureau of Labor Statistics, 2011), Engsted and Pedersen (2015), Jäger (2017), Shiller and Case (2003), Kivedal (2013) Plazzi, Torous, Valkanov (2006), etc. Those related by model are by Gallin (2008), Cochrane (2011), etc. Most researches are done for the real estate market of the USA (e.g., Campbell et al. (2009), Gallin (2008), Ghysels (2012)). However, there are a few done for OECD countries (Andréa (2014), Pedersen (2012)) and other particular countries (e.g., research on Australian housing market by Hill (2014)).

Engsted and Pedersen (2015) use dynamic Gordon growth model derived by Campbell and Shiller (1988a), where the log rent-to-price ratio equals the present discounted value of expected future log housing returns and rent growth. They apply restricted VAR model to test the given relationship in 18 OECD countries. It is restricted on the model coefficients to construct the more powerful test for null hypothesis rejection and to eliminate potential serial correlation in the residuals due to seasonality (as data used is on the quarter basis). The main findings include the following. First, in most countries, the rent-to-price ratio is significant in predicting housing returns: “[a]n increase (decrease) in the ratio signals a future increase (decrease) in returns” (Engsted & Pedersen, 2015). Second, there is a difference when taking nominal and real data. For example, in Japan, Germany, and Switzerland using nominal data, the rent-to-price ratio significantly impacts nominal returns with a negative sign, but when switching to the real data the sign transforms into a positive significant. For the USA nominal data does not show any significant relationship, but while turning to the real data this becomes significant with a positive sign.

Campbell et al. (2009) uses the same methodology framework for the USA, and decomposes rent-to-price ratio into the expected present value of risk-free interest rate, housing premia, and rent growth to examine its variance, but not the predictive power. The model also includes other variables, such as real per-capita income growth, employment growth, and population growth. The authors document that variation in risk premia and rent growth are the main sources of rent-to-price ratio variation on the national level. Surprisingly, the changes in risk-free interest rates did not account for changes in housing valuation (1975-2007). In addition, factors including real per-capita income growth, employment growth, and population growth do not seem to affect rent-to-price ratio variation.

Plazzi, Torous, Valkanov (2006) use a version of Campbell and Shiller's (1988a) dynamic Gordon growth model for the commercial estate market to show that the 'cap rate' (as they call rent-to-price ratio) explains time variation in expected housing returns of apartments, retail and industrial properties in 53 US metropolitan areas during 1994:Q2 - 2003:Q1. However, it does not capture the same in expected rent growth rates. For offices, the opposite holds: cap rates can capture the variation in housing returns, but not in rents growth. Unlike the regression for stock market, for housing market authors use pooled approach. Because of short time range (36 quarters), they combine each of 53 separate series into one-panel data. Another advantage is that due to returns, rents and cap rates heterogeneity, tests based on the pooled approach might show higher predictive power, as relationships are modeled on the long-time perspective.

Overall, some researches could find a lot of similarities between housing and other financial markets. Ghysels (2012) tells how these markets are different. Housing market is characterized by large transaction costs, carrying costs, illiquidity, tax considerations, and also large search costs due to the real estate's heterogeneity, etc. All these lead to the point there might be issues with reliability of any real estate price indices.

Cochrane (2011) briefly discusses what affects housing returns in his discount-rate variation research. He regresses log annual housing returns, log rent growth and log rent-to-price ratio on the current rent-to-price ratio for the USA (1960-2010). The author finds that high price-to-rent ratios lead to low returns, not growing rents or prices that rise forever. The research is done to investigate the effect of the discount rate on returns, and not to prove causality.

Lastly, Gallin (2008) finds the evidence that the rent-to-price ratio helps to predict changes in real prices, but not changes in real rents in the USA during 1970-2005, using the error-correction and long-horizon regression models. Beside rent-to-price ratio, the factor called direct user cost of housing capital is added. It is the cost of housing excluding the risk premium and expected capital gains, but taking into consideration nominal interest rate, property tax rate, marginal income tax rate and combined maintenance and depreciation rate. He examines two versions of the model: the first has independent variables both the log rent-to-price ratio and the log of the direct cost of capital, and the second examines only the log rent-to-price ratio. The findings are that including direct cost of housing capital do not seem to affect the relationship between the rent-to-price ratio and subsequent changes in rents and housing prices. The standard error-correction model does not provide significant results while more advanced long-horizon regression using bootstrap procedures suggested that house prices correct back to rents.

Our paper uses the same approach as Gallin (2008). Since the housing and rent prices seem to be cointegrated for the USA market, we can suggest that the same holds for OECD countries. Therefore, we believe the model proposed by Gallin will be suitable for our own investigation. Our research will be extended for the period after the Global Financial Crisis to find out whether price-to-rent ratios determine the housing returns and whether there are signs of new bubbles on the markets.

3. Theory

As was stated above, in this paper we aim to investigate the possibility of the house and rent prices prediction using price-to-rent ratio. In order to proceed with the research, it is necessary to revise the main theoretical concepts.

One of the key variables used in our research is price-to-rent ratio which is widely considered to be an indicator of under- or overvaluation in the housing market. For house owners, the rent can be viewed as an equivalent of dividends which stock owner receives on the equity market (Engsted et al., 2016). Therefore, the price-to-rent ratio for the real estate market is assumed to be analogical to the price-to-dividend ratio developed by Campbell and Shiller (1988a) for the stock market. Similarly to the price-to-dividend ratio which incorporates expectations for the future stock returns and dividend growth, the price-to-rent ratio shows the market expectations for the housing returns and rent changes (Campbell et al., 2009). In their study, Campbell and Shiller (1988a) proved that the stock prices which are high relative to the dividends lead to the future decline in the stock growth. Hence, we can expect that the same relation holds for the rents and housing prices.

Further, according to the classical theory (Gordon growth model), the intrinsic value of any asset is determined by its fundamentals, namely the sum of discounted cash flows (e.g., dividends for stock, rent for real estate property). The general formula for stock market can be written as follows:

$$P_0 = \frac{D_0}{k-g} \text{ , } (1)$$

where P is the price of the share, D is current dividend, k accounts for the cost of equity or the required rate of profit and g indicates the rate at which dividends are expected to grow (Gordon & Shapiro, 1956).

The original formula considers dividend growth rates and discount rates to be constant. Later Campbell and Shiller (1988a) developed a dynamic version of Gordon growth model allowing dividend-to-price ratio to vary through time relative to predictable fluctuations in these rates. To derive the new equation they assume that log dividends and discount rates constitute vector of variables that "…evolves through time as a multivariate linear stochastic process with constant coefficients" (Campbell & Shiller, 1988a).

Further, using the Campbell and Shiller approach for stock market, Engsted and Pedersen (2015) derived the linear relation for the real estate market linking log returns to log rent and log price-to-rent ratio:

$$h_{t+1} = \Delta r_{t+1} + (r_t - p_t) - \rho(r_{t+1} - p_{t+1}) + c, \text{ } (2)$$

where h, r, and p define log return, log rent, and log house prices respectively, $\rho = e^{\mathrm{E}[\Delta r - h]}$, and c accounts for a linearization constant. After imposing a no-bubble transversality condition, where $\lim_{j\to\infty} \rho^j (r_{t+j} - p_{t+j}) = 0$, and taking conditional expectation, Engsted and Pedersen (2015) obtained the following relation:

$$r_t - p_t = E_t \sum_{j=0}^{\infty} \rho^j \left(h_{t+1+j} - \Delta r_{t+1+j}\right) - \frac{c}{1-\rho}, \text{ } (3)$$

According to the equation (3) the rent-to-price ratio is appeared to be a predictor of future returns and/or rent growth.

Other possible fundamental variables which might be useful in predicting bubbles include personal income, population growth, employment rate, mortgage interest rate etc. (Case & Shiller, 2003). However, the majority of scientists did not prove these variables to be significant predictors of housing prices and rents (e.g., Gallin (2008) for the US market). In addition, in our research, we will focus attention on rent since we believe that this fundamental incorporates to a great extent other variables.

Apart from this, we should consider some significant differences between stock and real estate markets. By comparison with the stock market, the real estate market has low liquidity, bigger transaction costs, a high level of heterogeneity (e.g., houses differ significantly in terms of geographical location, size, construction characteristics), high carrying costs and tax rates, the unavailability of short-selling, etc. It leads to the conclusion that real estate market is not as efficient as other financial markets (Ghysels et al., 2013). Such inefficiency further implies the theoretical possibility of forecasting the future changes in housing market.

At the same time, the real estate market inefficiency entail some significant difficulties for its analysis (e.g., reliability of statistical indicators, non-stationarity of the data, inability to model all factors that influence housing market), which will be discussed in more detail in the next sections.

As was mentioned before, one of the practical implications of our research is the theoretical possibility to predict bubbles on the real estate market by forecasting the housing prices and rents changes using price-to-rent ratio.

Theoretically, the asset price movements should be caused only by changes in its fundamental variables such as rents. If it is not the case, the asset price bubble may occur.

American economist Brunnermeier (2016) states that “[b]ubbles are typically associated with dramatic asset price increases followed by a collapse. Bubbles arise if the price exceeds the asset’s fundamental value”. Another well-known researcher and Nobel laureate Shiller (2014) especially emphasizes the emotional aspect of price bubble and defines it as “[a] situation in which news of price increases spurs investor enthusiasm which spreads by psychological contagion from person to person, in the process amplifying stories that might justify the price increase and bringing in a larger and larger class of investors, who, despite doubts about the real value of the investment, are drawn to it partly through envy of others’ successes and partly through a gambler’s excitement”. Stiglitz (1990) argues that “if the reason that the price is high today is only because investors believe that the selling price will be high tomorrow—when "fundamental" factors do not seem to justify such a price—then a bubble exists".

Summarizing all written above, the bubble refers to a sharp increase in the price of an asset which is driven not by its fundamentals but rather by irrational expectations and overconfidence of market players. When the expectations about asset do not hold anymore the bubble burst and asset price fall down quickly. The bubbles can occur in different markets (e.g., tulip mania in the Netherlands in 1637 (Garber, 1990)).

The bubbles on the real estate market are especially dangerous due to its large size and deep connections to other economic sectors. As was explained by Himmelberg, Mayer, and Sinai (2005), during the housing bubble people buy real estate property more actively because of anticipated further house prices growth which will compensate their purchase. Further, house buyers fear that if they do not buy a home now it will become unaffordable in the future due to the price growth. In addition, the investment demand for real estate property will increase because of its relatively low-risk versus high expected gains perception. However, at some point in time, houses become so expensive that demand starts to decrease leading to a rapid price fall. It was the case in 2008 when after years of fast growth the real estate market collapsed provoking a huge financial instability and economic distress both in the USA and other countries around the globe.

Taking into consideration the theoretical framework discussed above we can assume that it is possible to indicate the bubbles in the housing market using price-to-rent ratio. The logic is as follows: if the price-to-rent ratio increases significantly above its historical average (literally meaning that the housing prices grow faster than rents) we can suggest that the housing prices are driven by irrational expectations rather than by its fundamentals, namely, rents. Therefore, the presence of the price bubble on the market can be suspected.

4. Methodology

To determine the predictability of housing prices by rent-to-price ratio, most articles use dynamic Gordon growth model. Afterwards, the basic formula can be modified to add other variables.

The above model developed for stock market can be used for housing market due to similarities between two. An investor can consider buying the house as the alternative to buying a stock: he receives the rent price as would receive the dividend payments. Thus, the value of the house is the present value of future rents, as the value of any asset is the present value of cash flows associated with it (Kivedal, 2013).

Generally, most authors use either vector-autoregressive (VAR) model or cointegrated VAR model. We will follow the approach adopted by Gallin (2008) and apply error-correction model to forecast house prices using rent-to-price ratio, as we believe these show cointegrated relationship, meaning in the long run house prices correct back to rents. Both should move together in the long run because renting the house is the alternative to buying it (Kivedal, 2013). For example, Meese and Wallace (1994) showed the cointegration of house and rent prices for Alameda and San Francisco counties while Gallin (2008) did the same for the US at the national level during 1970-2005. Nielsen (2009) shows that cointegrated VAR models are the perfect framework to analyze processes with a unit root and an explosive root.

We will study the predictive power of price-to-rent ratio both for house price and rent changes. The following equations will be examined:

$$\Delta \log R_t = B_1(L)\Delta \log R_{t-1} + B_2 \log R_{t-1} + B_3(L) \log \frac{P}{R_{t-1}} + e_t, \ (4)$$

$$\Delta \log P_t = B_1(L)\Delta \log P_{t-1} + B_2 \log R_{t-1} + B_3(L) \log \frac{P}{R_{t-1}} + e_t, \ (5)$$

where R is the real rent price, P is the real house price and P/R is a price-to-rent ratio. Therefore, the hypothesis we will test is that price-to-rent ratio predicts the housing returns and house and rent prices tend to correct for each other in the long run. To model the relationship we need to gather nominal or real house and rent prices for each of the countries under investigation. The correlations between variables used in the error-correction model are presented in Table 1 (see the appendix).

We will run the following tests to ensure the relationship can be modeled: Dickey-Fuller test to check for unit root and other tests to check for autocorrelation (Breusch–Godfrey) and heteroscedasticity (Breusch-Pagan & White). We will also correct for the unknown forms of heteroskedasticity and autocorrelation using Newey-West estimators. The number of relevant lags will be decided based on the Schwartz criterion. To verify the results of error-correction model, the test for cointegration (Johansen test) will be conducted.

Having built price and rent models, we would interpret the coefficients B_3 as usual for the error-correction model: whether and by how much rents correct back to prices and vice versa (Gallin, 2008).

Gallin (2008) shows the incompleteness of the error-correction model: in his analysis, the obtained coefficients are insignificant. To prove the predictability of price-to-rent ratio, he constructs long-horizon regression approach and then the bootstrap distribution to address the issue of biased estimators. We will use the same methods for our research in case the error-correction model will not deliver significant results. The outcomes of Gallin's (2008) analysis for the USA during 1970:Q1 - 2005:Q4 are in favor of the hypothesis that price-to-rent ratio is the measure of valuation and that house prices correct back to rents. We expect to find a similar relationship for 20 OECD countries.

5. Data

We obtained quarterly data for real and nominal house prices and nominal rent prices indices for 20 OECD countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, South Korea, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK and US. The dataset is provided by OECD statistical database (OECD.Stats, n.d.) and starts from 1970:Q1 until 2017:Q3 (except for South Korea (1986:Q1), Portugal (1988:Q1) and Spain (1971:Q1)). House price indices are index numbers that measure the prices of residential properties over time. The real house prices were taken instead of nominal as they are seasonally adjusted for consumers' expenditure deflator in each country (OECD.Stats, n.d.). There are a couple of reasons behind. First, seasonality in housing market influences demand, supply and corresponding house price fluctuations. Second, it affects macroeconomic indicators. Third, because of seasonality, pattern predictability in housing returns may lead to potential abnormal gains for buyers or sellers (Valadkhani, 2017). For further analysis, we use annual data. The annual house price index is given by the fourth quarter of each year, and annual rent price is computed by adding the indices for each quarter. From nominal and real house price indices we extract annual inflation, which is used to transform nominal rent prices into real. We calculated price-to-rent ratio in real terms by dividing real house price by real rent for each corresponding period. The price-to-rent ratio is a measure of profitability of owning the house (OECD.Stats, n.d.; Engsted & Pederson, 2015). The rent growth is calculated as

$$\Delta R_{t+1} = \frac{R_{t+1} - R_t}{R_t}, (6)$$

For further analysis in this section, we need housing returns, which are obtained as

$$H_{t+1} = \frac{P_{t+1} + \frac{R_{t+1}}{4} - P_t}{P_t}. (7)$$

The rent price is measured as a total cost per year for each quarter, therefore we divide it by four to obtain quarterly data (Kivedal, 2013).

Further, we construct descriptive statistics for real housing returns and rent growth for each country under investigation (see Table 2 in the appendix). The scatterplots of real house price and real rent price indices, and the correlation between them are presented in Figure 1 and Table 1 respectively (see the appendix).

From Panel A in Table 2 (see the appendix), we see quite a difference between real estate returns among OECD countries. Germany, Italy, Japan, Korea, Portugal, Switzerland and United States show quite low housing returns (5.5-7% annually) with relatively low volatility. To compare, returns in Canada, New Zealand, and Norway were more than 9.5% per year with relatively high volatility. Real rent growth from Panel B (see Table 2 in the appendix) during 1970-2017 was relatively low for most of the countries (on average 0.5% per annum), except Spain and Portugal, where real rent growth rates constituted 2.9% and 3% respectively per annum (Engsted & Pederson, 2015). South Korea is the only country on the list having negative median real rent growth (-0.1% annually). Negative rates were persistent in South Korea during 1991-2000 and from 2004 till 2010 except 2007.

Test for autocorrelation was made for real housing and rent prices. It showed high positive autocorrelation, which is normal for such time series. Further, calculations will be done to address this issue for the modeling part. The high positive autocorrelation is also persistent in real housing returns and rent growth (Engsted & Pedersen, 2015; Case and Shiller, 1988a). Engsted and Pedersen (2015) say the reason of autocorrelation of rent growth might be the regulation of rental markets in many countries.

Turning to real house prices and rent price graphs (see Figure 2 in the appendix), we normally see the upward movement both in real house and rent prices. Housing prices generally were risen from 1970’s till mid-1990’s, slowing the pace afterward. However, Germany, South Korea, and Portugal are exceptions. In Germany real housing and rent prices almost did not change over time. Housing prices had relatively increased during 1980's and mid-1990’s. However, since then, they were dropping with a small recovery just in recent years. Rent decreased in 1980’s but came in line with housing prices in mid 1990’s. In South Korea, both housing and rent prices peaked in 1990’s but dropped ever since. Table 1 (see the appendix) also shows a correlation between both variables. In most cases, we see a strong positive relationship. Nevertheless, for Germany and Japan, it is weak and negative. For Denmark, Netherlands, Spain, Ireland and the USA, we see that prior to the financial crisis the increase in the house prices is not followed by a correspondent increase in rent. This implies there are some other variables that explain the rise of prices: fundamentals or psychological factors causing the bubble. The numerous studies (Kivedal, 2013; Nijskens & Heeringa, 2017) show that for the case of the USA, Spain, and Denmark it was indeed the overheating caused by irrational behavior.

Figure 2 (see the appendix) shows the time-series plot of the price-to-rent ratio. For most countries in late 1980’s - 1990’s ratio demonstrated the build-up. One of the signs of overvaluation of the housing prices may be if price-to-rent ratio is above the long-term mean (OECD.Stats, n.d.). Following the logic, we can say that today real estate market of Australia, Canada, Germany, New Zealand, Norway, Sweden, Switzerland, UK, and the USA is overvalued, which may indicate the new bubble. In 2014 ratio in the United States was back to its historical mean, but now it starts to go up again (Engsted & Pedersen, 2015).

6. Outline of further steps to finalize the thesis

After completing the preliminary report, we have a solid fundament to proceed with our research. Therefore, the next step to take is an empirical study using the data gathered and methodology discussed above. While setting a model specification further advancements can be used to improve the model. Based on the empirical results the hypotheses defined during the preliminary stage will be tested, and the main findings will be described and further analyzed. In regard to the analysis, conclusions will be discussed. Also, we will suggest the possible directions for further researches in this area. After concluding the thesis and providing the implications of the results the paper will be reviewed and handed in. The planned date of the thesis submission is August 31, 2018.

Appendix

Table 1: Correlations of variables for 20 OECD countries

Table 1 presents the correlations of variables for 20 OECD countries.

Countries	Price-to-rent vs Δln(price)	Price-to-rent vs Δln(rent)	Real house prices vs real rents
Australia	0,109	-0,146	0,921
Belgium	0,001	-0,281	0,865
Canada	0,197	-0,253	0,730
Denmark	0,032	-0,066	0,861
Finland	0,135	0,156	0,860
France	0,020	-0,081	0,858
Germany	0,037	-0,018	-0,113
Ireland	0,119	0,010	0,740
Italy	0,061	0,019	0,827
Japan	-0,046	-0,057	-0,348
Korea	0,159	0,092	0,914
Netherlands	-0,029	-0,125	0,886
New Zealand	0,105	-0,075	0,760
Norway	0,103	-0,165	0,893
Portugal	-0,021	0,031	0,162
Spain	0,015	0,032	0,907
Sweden	0,093	-0,197	0,749
Switzerland	0,075	0,052	0,598
United Kingdom	-0,004	-0,124	0,920
United States	0,047	-0,069	0,922

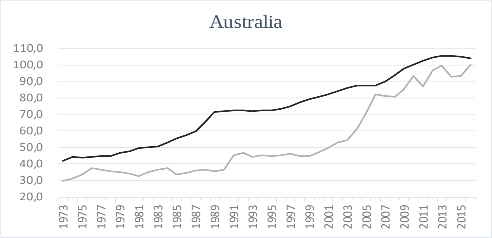
Table 2: Summary statistics for real returns and rent growth

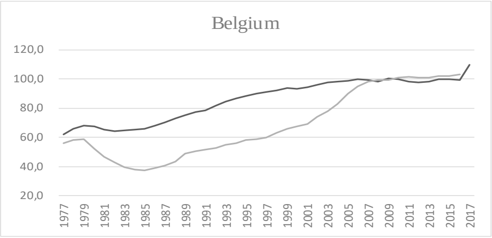
Table 1 presents the mean, median, standard deviation, kurtosis and skewness for the real returns and rent growth for 20 OECD countries chosen for the research.

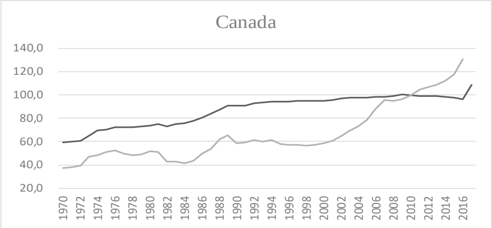
	Panel A. Real Returns					Panel B. Rent Growth				
Country	Mean	Median	SD	Kurtosis	Skewness	Mean	Median	SD	Kurtosis	Skewness
Australia	0,092	0,094	0,095	1,903	0,596	0,005	0,005	0,024	2,660	1,364
Belgium	0,089	0,095	0,092	-0,870	-0,027	0,004	0,003	0,024	3,848	1,234
Canada	0,097	0,100	0,094	0,188	0,231	0,003	0,001	0,025	8,201	2,446
Denmark	0,080	0,079	0,110	-0,143	-0,093	0,004	0,004	0,034	1,822	-0,568
Finland	0,083	0,083	0,110	1,835	0,659	0,004	0,003	0,046	1,038	0,770
France	0,084	0,084	0,079	-0,772	0,109	0,005	0,005	0,018	-0,547	0,069
Germany	0,054	0,053	0,036	-0,335	0,069	0,001	0,000	0,022	7,121	1,836
Ireland	0,092	0,094	0,132	-0,112	-0,298	0,007	0,008	0,089	4,025	-0,413
Italy	0,071	0,065	0,125	9,045	2,339	0,004	0,001	0,062	13,777	3,232
Japan	0,049	0,050	0,077	0,633	0,289	0,001	0,001	0,035	5,347	-1,191
Korea	0,067	0,066	0,079	0,186	0,098	0,016	-0,001	0,388	31,240	5,559
Netherlands	0,087	0,091	0,122	-0,882	-0,203	0,006	0,005	0,036	5,959	1,363
New Zealand	0,095	0,099	0,125	-0,571	-0,167	0,006	0,003	0,063	5,155	1,632
Norway	0,096	0,093	0,121	-0,659	0,278	0,006	0,004	0,033	15,907	3,480
Portugal	0,059	0,055	0,057	-0,547	0,521	0,030	0,006	0,417	42,859	6,419
Spain	0,089	0,092	0,129	1,116	0,378	0,029	0,005	0,604	46,511	6,804
Sweden	0,089	0,091	0,121	-0,706	0,053	0,004	0,003	0,031	2,546	0,892
Switzerland	0,062	0,064	0,068	0,565	-0,608	0,002	0,002	0,023	4,757	-1,044
United	0,088	0,087	0,134	-0,233	0,041	0,009	0,006	0,059	3,298	1,072
United States	0,067	0,070	0,049	2,448	-1,462	0,003	0,003	0,016	0,098	0,371

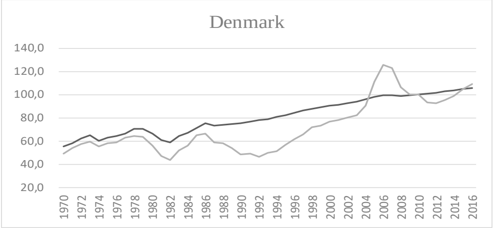
Figure 1: Historical changes in real house prices and rents

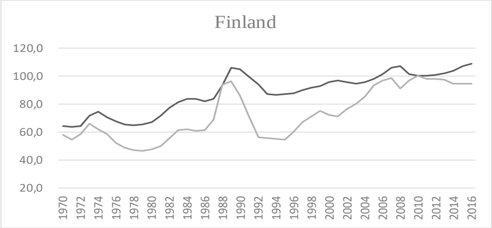
Figure 1 presents the historical changes in real house prices and rents over the studied period for 20 OECD countries chosen for the research (2010 is defined to be the base year).

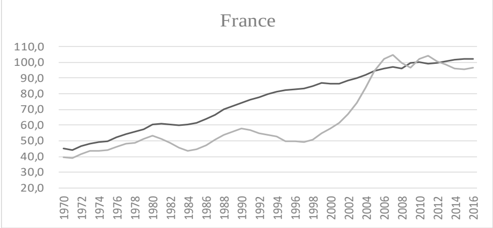


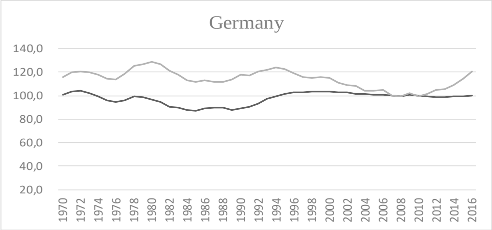


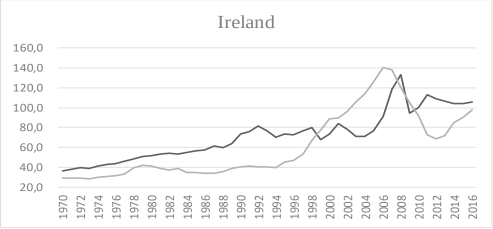


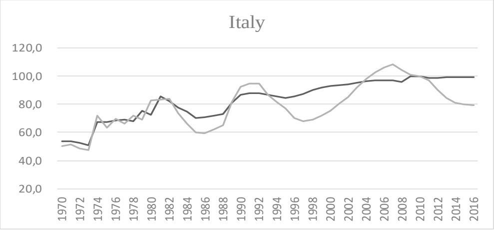


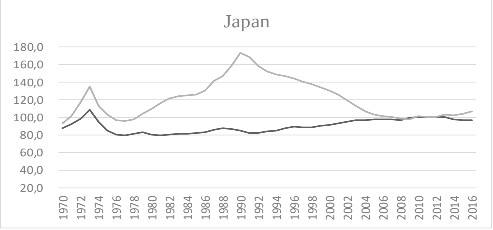


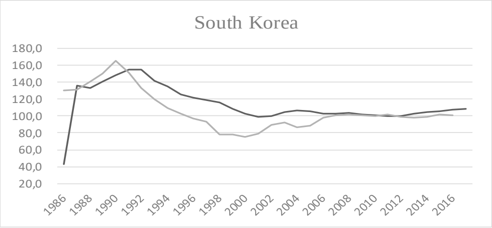


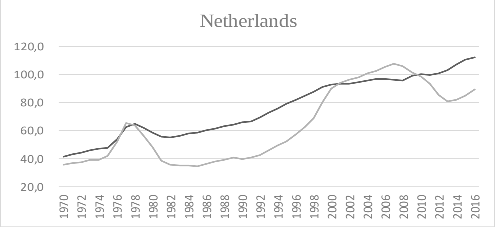


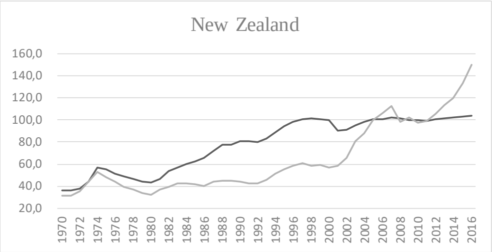


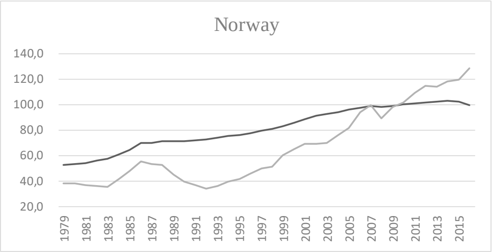


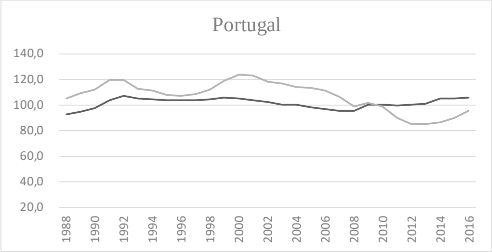


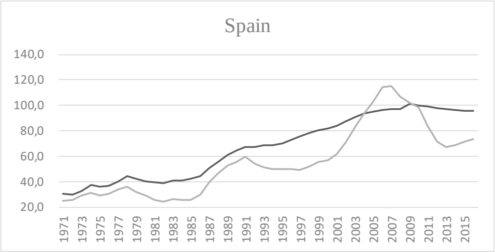


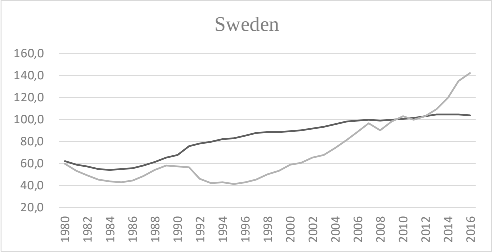


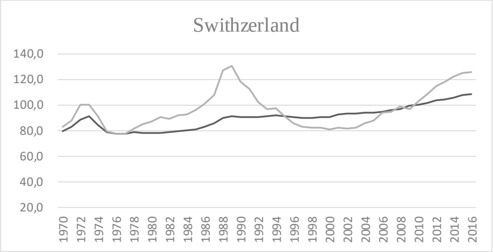


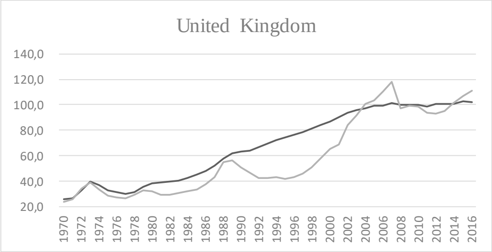


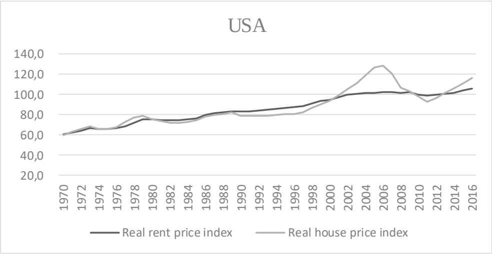








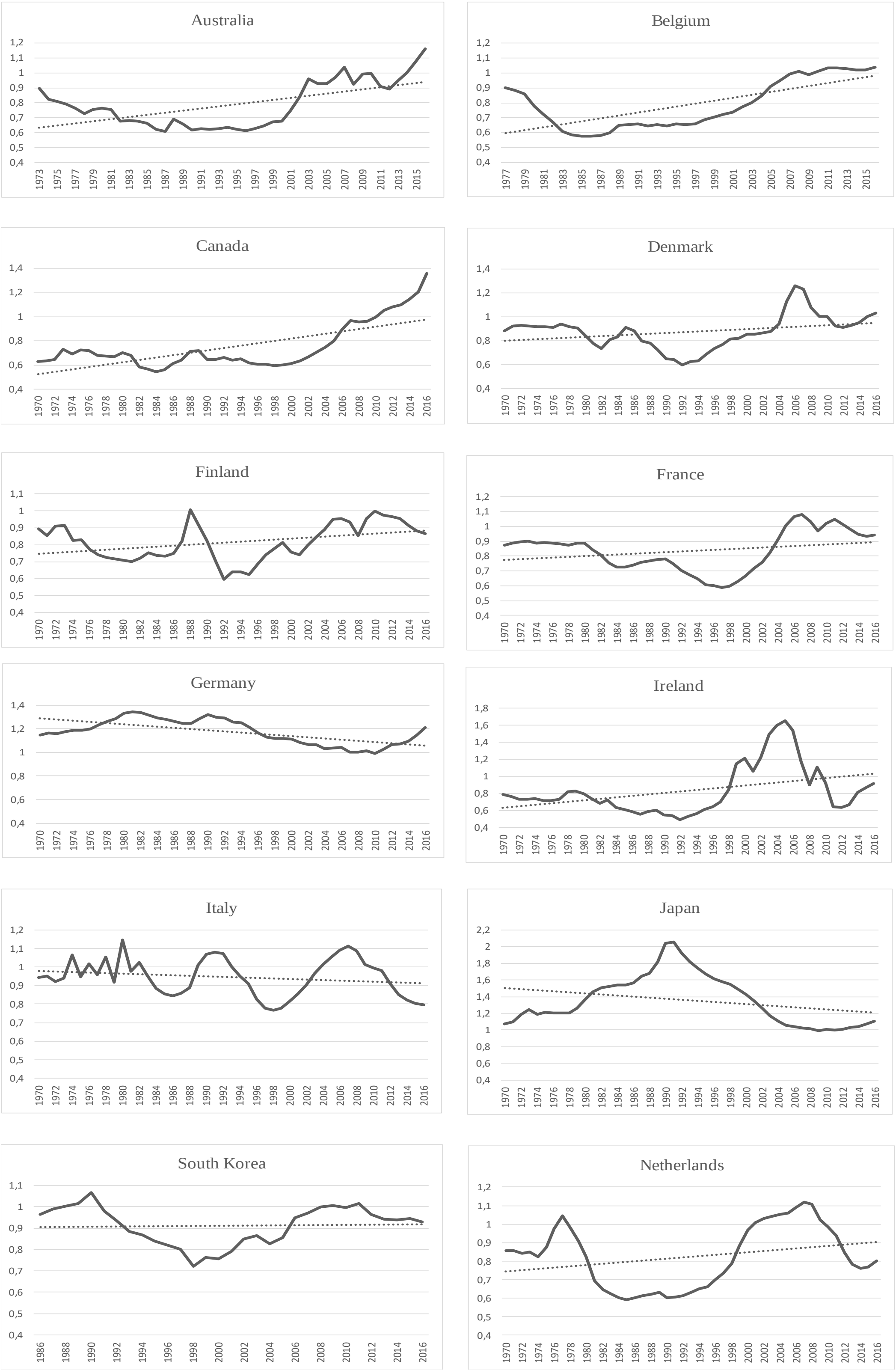


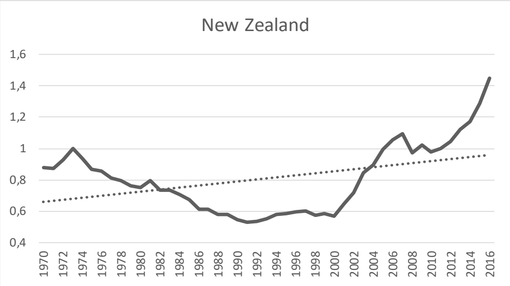


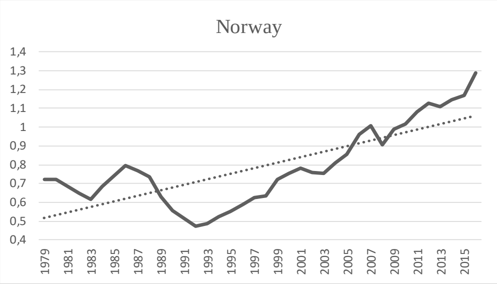
— Real rent price index
— Real house price index

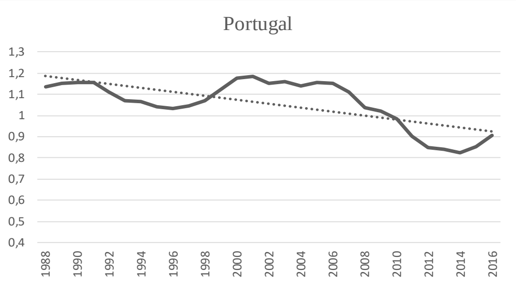
Figure 2: Historical changes in price-to-rent ratio

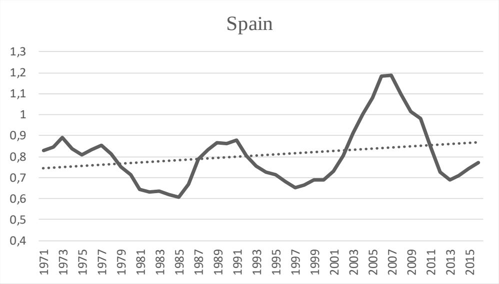
Figure 2 presents the historical changes in the price-to-rent ratio over the studied period for 20 OECD countries chosen for the research.

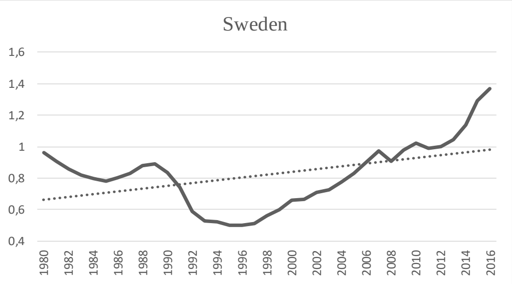


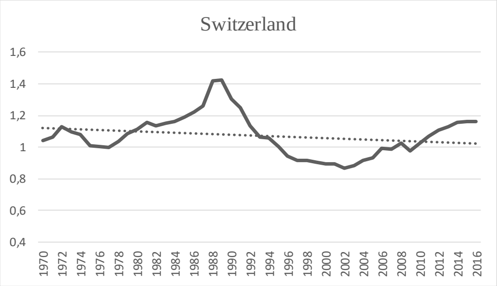


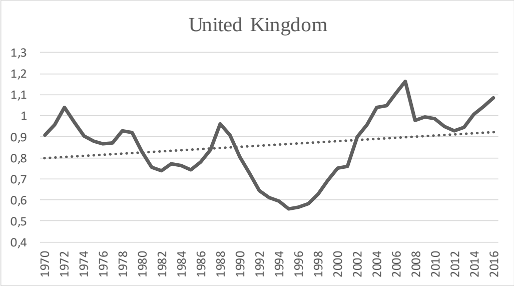


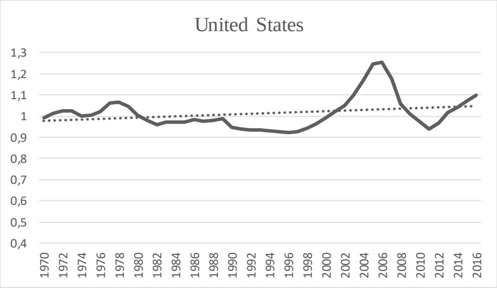












— Price-to-rent ratio

······ Linear (Price-to-rent ratio)

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