

Kulikauskas, Darius

**Article**

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# Fundamental housing prices in the Baltic States: empirical approach

Darius Kulikauskas<sup>a,b</sup> 

<sup>a</sup>Bank of Lithuania, Vilnius, Lithuania; <sup>b</sup>Faculty of Economics, Vilnius University, Vilnius, Lithuania

## ABSTRACT

This paper investigates if the imbalances in the Baltic residential real estate markets that were mounting up prior the crisis of 2008–2009 could have been detected in real time. It develops an empirical framework comprised of various empirical techniques for assessing housing price misalignments from their fundamental prices. For this purpose, several statistical indicators (price-to-rent ratio, price-to-income ratio, price deviations from Hodrick-Prescott filtered trend) together with the estimates from equilibrium equations are computed. The use of those indicators in a consistent graphical framework reduce the uncertainty associated with using only a single metric and allows to arrive to clearer conclusions about residential real estate price misalignments. It is shown that the framework would have been able to identify the overvaluation in the residential real estate markets in the Baltics as early as in 2005.

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R3; R30; R31

## 1. Introduction

After the accession to the EU the residential real estate markets of the Baltic States<sup>1</sup> experienced a very pronounced boom-bust cycle that greatly exacerbated the consequences of the Global Financial Crisis. Beginning with 2004 easily available credit started pouring in the Baltic economies and fuelled the demand for housing. Soon these developments transformed into unsustainable housing price increases that continued to accumulate until mid-2008. Imbalances unraveled with grave consequences on the real economy with prices falling by 40–50 percent from the peak to the trough.

A bit surprisingly, the literature focusing on residential real estate market valuation in the Baltics is rather scarce: the countries only tend to be included in studies as a part of larger panels with little attention to the features that might be relevant to those countries alone (see, e.g. Ciarlone, 2015). Therefore, evaluating whether residential real estate is under- or over-valued has to rest almost solely on expert judgement and *ad hoc* approaches. A robust analytical approach to the real estate market is crucial for the macroprudential oversight as this sector is closely linked with the financial sector (e.g. when one

**CONTACT** Darius Kulikauskas  [darius.kulikauskas@ef.vu.lt](mailto:darius.kulikauskas@ef.vu.lt)

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needs to identify if the systemic risk is building up). However, researchers, policymakers and practitioners in the Baltic States are forced to resort to the case by case analysis, which slows the process and, because of increased time inconsistency problem, is exposed to the higher probability of errors.

This paper investigates if the imbalances that were mounting up in the Baltic housing markets prior the crash of 2008–2009 could have been identified in real time. It proposes an empirical framework in which statistical measures together with the estimates from econometric models can be used for a consistent evaluation of housing price misalignments. Two of the statistical measures are the ‘rule of thumb’ price-to-rent and price-to-income ratios. The intuition behind them is simple: because their averages in the long-run should be constant, departure of one of the ratios from its mean might be a sign of housing price misalignments.

The ratios are complemented with housing price departures from their long-run trend which is obtained using one-sided Hodrick- Prescott filter. This method of deriving equilibrium housing prices rests on the observation that balanced price movements are not overly volatile and are supposed to follow a smooth trend. Departure from it (e.g. exponential growth episodes) can be considered a sign of price misalignments.

The three statistical measures are used in combination with the estimates of housing price deviations from the equilibrium obtained from equilibrium (error-correction) equations. The latter approach takes advantage of the fact that variables that are fundamental determinants of housing prices should show a lot of co-movement. In case they depart from such long-run relationship, it may be a sign of imbalances in the market.

This paper shows that the framework is able to identify whether housing prices in the Baltics are below, inline or above the levels justified by the fundamentals. Time series derived from the framework are able to tell a plausible story of the residential real estate developments in all three of the Baltic countries. Most importantly, restricting the sample at the end of 2005 shows that the framework would have signalled overvaluation in the housing markets of the Baltic States as early as in 2005 (caveats such as reduced certainty about the results due to limited data availability at the time do apply). Therefore, it shows promise to identify future imbalances in the housing market as they accrue (as the data becomes available).

The rest of the paper is structured as follows. The next section provides a literature review on modelling fundamental housing prices with a particular focus on studies that analyse the Baltic housing markets. The third section employs the statistical measures of price misalignment in order to show that a deeper analysis of the housing prices is warranted. After that, the modelling set-up used in this paper is presented. It is followed by the section that describes the estimation exercise and the section that discusses the results. The final section concludes.

## 2. Literature review

In the most basic form there are two ways of estimating fundamental housing prices. The first one relies more on theory and models pricing of housing assets in a similar fashion to pricing of financial assets (see Bolt, Demertzis, Diks, & Van der Leij, 2011, for an example). Basically it states that housing prices are justified by fundamentals if they are in line with the present value of the dividends that such assets provide (whereas such dividends are

usually understood as housing services proxied by imputed rents). The latter approach is often referred to as user costs of owning a house or imputed rents method.

The second one relies more on empirical estimation of fundamental housing prices. Simply put, this method tries to find reasonable relationships in the data that help determine the equilibrium level of housing prices. It potentially overcomes problems stemming from treating housing as an ordinary financial asset<sup>2</sup> and estimates price misalignments with greater accuracy: Fuster and Zafar (2014) show that user costs approach overestimates the importance of mortgage interest rates on housing demand while Hott and Monnin (2008) argue that fundamental price models significantly outperform models based only on the observed price dynamics. For this reason, this paper focuses on the panel error-correction framework.

Previous work on fundamental housing prices in the Baltics is rather limited: the countries have been analysed in this regard only as a part of larger panels in Stepanyan, Poghosyan, and Bibolov (2010); Égert and Mihaljek (2007); Huynh-Olesen, Steiner, Hildebrandt, and Wagner (2013) and Ciarlone (2015). Stepanyan et al. (2010) estimate an error correction model for the former Soviet Union countries. Because the countries included in their analysis are structurally very different<sup>3</sup>, they used pooled mean group estimator with the assumption of parameter homogeneity only in the equilibrium relationship. Their dataset ends with the third quarter of 2009 and, as far as the Baltics are concerned, housing prices in Latvia and Estonia are represented by the averages of housing prices in respective capitals (in addition, Latvian time series start only in the first quarter of 2005). While it can be argued that the capitals represent the housing price movements in those countries well enough, pooling them together with other former Soviet Union countries introduces a lot of uncertainty. Because the Baltics are the only members of the pool with the European Union institutional set up, the forces driving equilibrium housing prices might differ from those in other countries in the sample.

Égert and Mihaljek (2007) analyse 8 transitional European countries along with 19 OECD countries in a mean group dynamic OLS panel. They show that in the former group housing prices are determined to a large extent by the variables that are most commonly considered as fundamentals for the developed economies. However, the study does not cover all of the Baltic States: Latvia is not included in the sample.

Huynh-Olesen et al. (2013) using stock-flow model by Meen (2010) as a theoretical benchmark for fundamentals in an unbalanced panel cointegration setting estimate equilibrium housing prices in Central, Eastern and South-eastern EU countries covering the period from 1999 to 2011. They show that prior the financial crisis of 2007 in the region residential real estate prices rose above the levels warranted by macroeconomic fundamentals and undershot their equilibrium values after the correction that followed. Nevertheless, because of the unbalanced panel approach, the Baltic States dataset has a few gaps and the countries are not analysed in detail.

Ciarlone (2015) investigates the characteristics of house price dynamics in 16 emerging economies from Asia and East Europe. All three of the Baltic States are included in the panel estimation that covers the period from 1995 to 2011 (the panel is not balanced and the Baltics have a few data gaps in the earlier periods). The author shows that housing markets rarely displayed dramatic signs of overvaluation: according to the results only in Latvia overvaluation reached 40 percent. Such finding is rather surprising

at least from the perspective of the Baltic countries: one would expect that the situation was similar in Lithuania and Estonia.

Papers by Égert and Mihaljek (2007); Huynh-Olesen et al. (2013) and Ciarlone (2015) all found transition specific factors to be significant drivers of housing prices in emerging European economies. The examples of such factors include institutional development and remittances. While as of 2015 it could be argued that the institutions were fairly well developed in the Baltic countries, the income levels were still lagging behind those of higher-income OECD member, thus, remittances were still an important way to fund housing purchases.

With a different focus than fundamental housing price, developments in the Baltics (as well as in the Central and Eastern European countries) were also analysed by Leika and Valentinaitė (2007). They argued that large housing price increases in the region during 2004–2006 were a result of rapid credit expansion. While Leika and Valentinaitė (2007) did not estimate fundamental housing prices, they used simple panel regression to show that in the short-term changes in lending for house purchase, interest rates and income can explain almost half of the variation of housing prices.

### 3. Indications of unsustainable housing price movements

Before turning to modelling, statistical ratios such as price-to-income or price-to-rent can be computed to learn if there was indeed something out of ordinary going on in the housing markets in the Baltic States. These ratios, similarly as the price-earnings ratio for equity stocks, could signal imbalances in the residential real estate market. The intuition is very simple: if the housing prices become too steep as compared to the rent prices, market participants will favour renting instead of buying, thus, decreasing the demand for house purchases and increasing the demand for rental apartments. This should cause an increase in the rental prices and a decrease in the selling prices that should put the market back in balance (see Krainer & Wei, 2004).

A similar mechanism operates with the price-to-income ratio. If the ratio is getting higher, housing is becoming less affordable, i.e. it shows that the income cannot keep up with the increasing property prices. If the prices get too steep, the demand for housing falls and puts pressure on the housing prices to decrease. Thus, this self-correcting mechanism should put the prices back in balance (see McCarthy & Peach, 2004).

One has to keep in mind, that the results from such ratios must be interpreted with care as they suffer from various limitations. Himmelberg, Mayer, and Sinai (2005) argue that price-to-rent and price-to-income ratios generally fail to reflect the state of housing costs (e.g. due to changing interest rates), thus their deviations from historical averages might not be a sign of price misalignments. André (2010) suggests that highly regulated rental markets, and the fact that such ratios can be greatly affected by income distribution among households and even the changes in average size of a household, distorts the interpretation of the ratios.

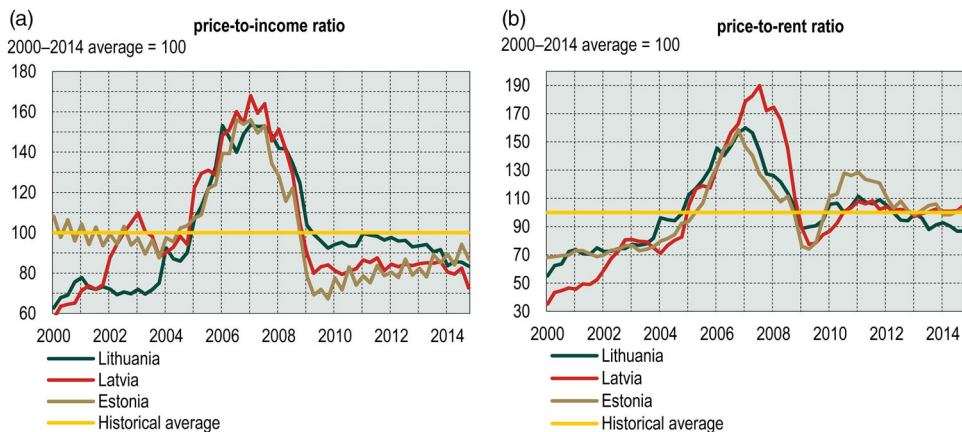
In addition, the indices available are comprised of different objects each quarter, thus cannot control for changes in quality. For example, if the popularity of higher quality housing increases in some quarter, such an index would show an increase in prices even though the prices for the types of dwellings that were sold in the previous quarter might not have changed. Furthermore, the price and the rent indices used in calculations

(see Appendix 1) are calculated based on different samples, therefore, e.g. an increase in price-to-rent ratio might simply reflect that owners choose higher quality housing as opposed to renters who opt for cheaper apartments and not an actual divergence between the rental and sale prices of homogenous dwellings. However, the ratios still carry useful information, especially, when they are used alongside other measures of price misalignments.

Figure 1 plots price-to-income and price-to-rent ratios for the Baltic countries. These simple measures seem to signal overvaluation of the residential real estate during the years prior the financial crisis of 2008, i.e. the ratios were well above their historical averages<sup>4</sup>. According to these indicators housing prices plummeted below their equilibrium values after the price bubble burst and more or less stayed undervalued to the extent of 10–20%.

The deviations from the long-term average that the price-to-rent and price-to-income ratios register in the Baltic countries are very pronounced. The price-to-rent ratios were about 60–90%, while price-to-income ratios were some 40–150%, higher than their long-term averages in the years prior the crisis of 2008–2009. The deviations of price-to-rent and price-to-income ratios from their long-term averages in other countries that also experienced boom and bust patterns in their property markets were lower (with a few exceptions such as Spain and Ireland). For example, data gathered by The Economist (2015) show that such countries as the US, Japan (in the 90s), Belgium and Netherlands at the peak of the boom saw their price-to-rent ratios 40–45% above the long-term average.

So the developments in the Baltic countries' price-to-rent and price-to-income ratios raises a natural question whether those misalignments were justified. It must be noted that the ratios can be good determinants of the residential real estate over- or undervaluation only if these ratios are stationary. However, Caporale and Gil-Alana (2010) show that traditional unit root tests for such ratios suggest non-stationarity. This can occur because of the factors that affect equilibrium housing prices but are not included in the calculation of the ratios (e.g. changes in borrowing conditions), as well as various structural breaks (e.g. changes in rental market regulation). Visually time series in Figure 1 seem to be non-stationary, formal ADF tests support this insight (see Table A7 in Appendix 2). The reason for this is



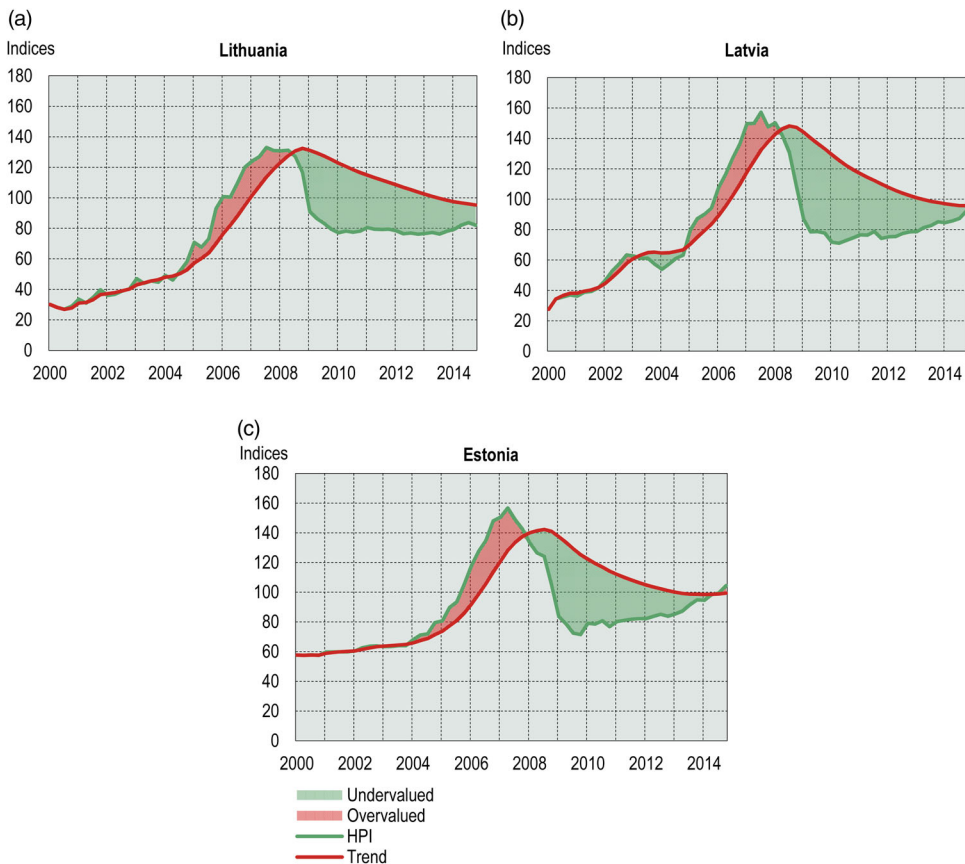
**Figure 1.** Price-to-income and price-to-rent ratio indices in the Baltics. Source: author's calculations based on Eurostat and national statistics agencies data.



twofold: the time series are rather short and the deviations from the average seem to be relatively long-lasting; however, asymptotically the time series might still be mean-reverting.

It is also possible to evaluate the housing price developments without taking into account any additional information. A fairly common approach is just to compare price levels with their trends that are usually obtained using Hodrick-Prescott filter with large  $\lambda$  values (see, e.g. Agnello & Schuknecht, 2011; and European Commission, 2012). To address the end-point problem of the Hodrick-Prescott filter a one-sided Hodrick-Prescott filter is used. Since this method does not take into account any additional information, analysing housing prices in nominal terms might be misleading (e.g. nominal price changes that are in line with the changes in the general price level might seem as unjustified appreciation). For this reason, housing price indices used here are deflated by the consumer price indices of respective countries.

As can be seen from Figure 2, according to this procedure housing assets at the end of the sample were undervalued in Lithuania but in line with fundamentals in Latvia and Estonia. However, results from Hodrick-Prescott filter should be treated only as complementary to other evidence as this procedure is the most atheoretical and the deviations from smooth trend may not necessary be a sign of imbalances in the market. This method



**Figure 2.** Real housing price deviations from Hodrick-Prescott filter (one-sided) trend ( $\lambda = 100\,000$ )<sup>5</sup>. Source: author's calculations based on Eurostat and national statistics agencies data.



incorporates even less information than the ratios discussed above, hence, it is even more prone to misjudge structural shifts.

Simple statistical ratios seem to be able to capture possible housing price imbalances in the Baltic States. However, their signalling performances were worse when it mattered<sup>6</sup>: the variation available for the calculation of such ratios only covered the pre-boom years and was rather short. Hence, while they are good first estimates and benchmarks for further analysis, they are unable to convincingly tell if the housing price developments were sustainable. Thus, there is need for a deeper analysis of the matter.

#### 4. Modelling set-up

Reviewing literature is a good start for narrowing down possible variables for a regression. While a fixed list of variables that determine the equilibrium housing prices does not exist, literature analysis reveals what variables are most commonly referred as housing price fundamentals. Borowiecki (2008) provides a review of such variables, while the following paragraphs discuss several studies that are relevant to this paper.

To obtain reasonable results the fundamental variables have to be theoretically linked to the housing prices. Otherwise, it is hard to expect that the findings would not be coincidental. McQuinn and O'Reilly (2007) and Girouard, Kennedy, Noord, and André (2006) propose different theoretical DSGE models where housing prices are driven by increases in income. In addition to income, population dynamics, mortgage interest rates, activity in construction sector are also often used as fundamental housing price determinants. For example, Hott (2009), in his imputed rents model employs income, population, mortgage interest rates and construction sector activity variables, while Muellbauer (2012) in his supply and demand approach uses the stock of housing, income and after-tax interest rate for borrowing as factors driving equilibrium housing prices.

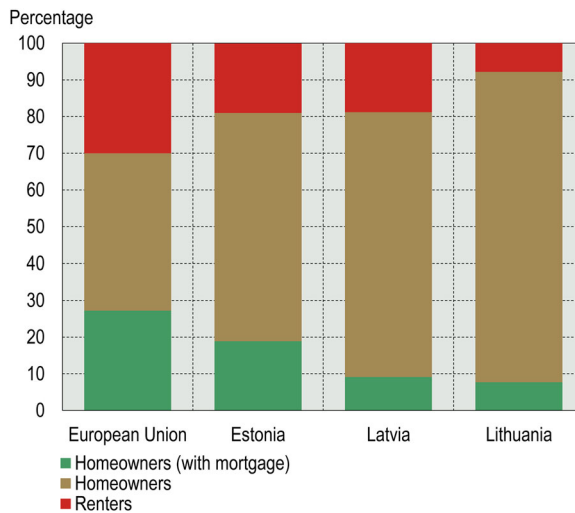
Leung (2014) shows how a simple DSGE framework used for housing price analysis can produce reduced-form dynamics consistent with error-correction models, thus, the later are natural candidates for equilibrium housing price estimation. Such studies where the Baltic countries are included in larger panels use rather similar variables to those outlined above. Égert and Mihaljek (2007) include GDP per capita (as a proxy for income and wealth) and interest rates on the right-hand side with one of the following as an additional variable: credit, stock market, unemployment, population, labour force and wages. They also include some additional variables for transitional economies that represent institutional housing market improvements. Stepanyan et al. (2010) include real GDP, remittances (as an additional proxy for income) and foreign direct investment (as a proxy for lending conditions in transitional economies because FDI in those countries mostly reflected bank borrowing abroad) as fundamentals in the long-term equation.

Empirical studies that do not analyse developments in the Baltics tend to also choose similar variables to those discussed above. Gattini and Hiebert (2010) build a VECM model for euro area using housing investment, real disposable income per capita and interest rates as fundamentals. A similar approach is employed by European Commission (2012) and ECB (2011). Corradin and Fontana (2013) estimate a Markov-switching error correction model for thirteen European countries to examine house price deviations from their fundamentals. They use disposable income, long-term interest rates and unemployment as price determinants.

In short, income, some measure of housing supply (e.g. housing stock or construction costs), population, mortgage interest rates and mortgage credit are the variables that are most commonly referred as fundamentals in the literature. However, it is also important to note that fundamental housing values are greatly affected by other features of a residential real estate market that are harder to represent as quantified fundamental indicators. The elasticity of housing supply can contribute greatly to the price dynamics as documented by Micheli, Rouwendal, and Dekkers (2014): the abler supply is to react to demand changes, the lesser is the probability that in the short-run prices will increase above their fundamental values. The quality of rental markets also affects the housing price dynamics: if the rental market is underdeveloped (or restricted), renting a house is a poor substitute for owning a house.

It is reasonable to expect that the housing market features outlined above are similar in the Baltics. All of these countries started their transition to market economies basically at the same time and transformed their institutions in a similar manner (e.g. all three of them joined EU and adopted the euro). While all of the Baltic States had some form of partial mortgage interest tax deductibility prior the crisis, it has been phased out in Latvia and Lithuania and reduced by 40 percent in Estonia from 2012 onwards. Real estate taxation in these countries remains one of the lowest in the EU (Bukevičiūtė & Kosicki, 2012). In addition, ECB (2005) documents that the institutional characteristics of the Baltic banking sectors are very homogenous, i.e. the banking systems are concentrated and dominated by the Nordic banking groups.

Housing market structures in terms of the occupier type and rental market seem to also share common features in the Baltics. As can be seen in Figure 3, all three Baltic States had higher than 80 percent homeownership rate in 2013. Though Lithuania stood out with the homeownership rate exceeding 90 percent, it is rather clear that households prefer owning a house to renting in the Baltics more than on average in the EU. The Baltic States also have significantly larger shares of homeowners without mortgage as compared



**Figure 3.** Home occupiers in the Baltics and EU by ownership type in 2013. Source: compiled by the author using Eurostat data.

to the average of the EU. It can be argued that such structure is the evidence of underdeveloped renting market but in case of the Baltics a more plausible explanation is that it is the result of large privatization that followed the break-up of the Soviet Union as well as the general preference of owning to renting a residence.

Housing market similarities across the Baltic States suggest that modelling price dynamics is reasonable in a panel setting. Homogenous institutional arrangements and market structures warrant the assumption of parameter homogeneity. In addition, in case of small ( $i = 3$ ) and fairly homogenous cross-section with relatively large time dimension ( $t = 58$ ) estimating panel regressions in terms of technique is not that different from estimating country-specific time series models. Consequently, a lot of possible problems that occur in large panels will not be relevant here (e.g. incidental parameter problem, see Neyman & Scott, 1948), but usual time series issues have to be accounted for.

Based on the literature review, in this paper equilibrium housing prices in the Baltics are estimated using household income, population dynamics, mortgage credit, mortgage interest rates and construction prices as fundamentals. To account consistently for the developments in the market and avoid possible estimation biases both, the supply and the demand side of the market, have to be considered simultaneously. However, the structural demand and supply equations can be reduced to a single equation (see Wooldridge, 2002) that can be consistently estimated using even ordinary least squares<sup>7</sup>:

$$\begin{aligned}
 HPI_{it} = & \text{const} + \text{fixed}_i + \underset{(+)}{\gamma_1} CCPI_{it} + \underset{(+)}{\gamma_2} INC_{it} + \underset{(+)}{\gamma_3} POP_{it} + \underset{(+)}{\gamma_4} CRED_{it} + \underset{(-)}{\gamma_5} R_{it} \\
 & + \underset{(+)}{\gamma_6} REMIT_{it} + \varepsilon_{it}
 \end{aligned} \tag{1}$$

The variables in Equation (1) are coded as follows. *HPI* denotes the indices of housing prices, *CCPI* – construction input price indices, *INC* – GDP per capita (income), *POP* – population, *CRED* – mortgage loan stock, *R* – real mortgage interest rates and *REMIT* – remittances. All the time series except for the interest rates in the modelling exercise are used in logs. The thorough description of the data is provided in Appendix 1.

Pluses and minuses under parameters denote expected signs in the long-term relationship. Higher construction prices increase the costs of producing new residences, thus the demand for existing structures increases and pushes the prices up. Increases in income makes owning a house accessible for a bigger share of population, consequently increasing the demand and prices (the effect of remittances manifests through the same channel). Population increases also push the demand for housing up, thus, positively affect the prices. Credit growth also increases demand for housing, thus, is positively associated with the changes in prices. Higher interest rates mean that credit accessibility deteriorates and dampens the demand for housing putting a negative pressure on residential real estate prices.

## 5. Estimation exercise

This section turns to estimating the equilibrium housing prices using a panel error-correction approach. Visually all of the variables seem to have unit-roots (see Appendix 1). Formal unit-root tests show that the times-series used in this paper are integrated of order 1 (see Appendix 2). Hence, in the equilibrium regressions they are used in log

levels (except for interest rates which are used just in levels) and tested for cointegration: the results show that the series are indeed cointegrated (see Appendix 2). The full sample is used for the calculation, i.e. from the period of 2000–2014. The tests show that the cointegration rank is at least of order 3, thus, the interplay between variables at the equilibrium is somewhat complicated. However, since this paper is mainly concerned with the equilibrium of housing prices and their adjustment process, it focuses only on the error-correction equations that has housing prices on the left-hand side. Several regressions are estimated using panel dynamic least squares estimator that accounts for possible endogeneity between variables (e.g. some of the explanatory variables, such as credit, may be endogenous, see Hofmann, 2004) and serial correlation in the residuals that could occur in the ordinary least squares set-up. The equations are summarized in the Table 1 below (variable coding is provided in Section 3).

All the parameters get expected signs but the ones near real interest rates and remittances turn out to be statistically insignificant. The parameter near interest rates is most probably statistically insignificant because interest rate effects are captured by the changes in the stock of mortgage credit. Parameter near remittances turns out to be insignificant most likely because it represents only transitional effects that are in principal temporary, i.e. remittances contribute to the short-term developments in the real estate market but do not affect the long-term equilibrium.

The error correction terms that are obtained from the equations reported in Table 1 can only be relevant if they are statistically significant in the short-term dynamics equation. This is essential for the equilibrium adjustment to happen: if the parameter near the error correction term is not statistically different from zero (or is positive), the adjustment does not happen. In other words, housing prices would not show a tendency to revert back to the equilibrium.

The row 'SoA' reports the parameter values and their p values in the error-correction equations. The parameters are statistically significant at 95 percent confidence level in all analysed cases. Because they all have a negative sign, the correction does happen, thus there is a long-term cointegrating relationship between the house prices and the

**Table 1.** Long-term relationships.

	EC1 HPI	EC2 HPI	EC3 HPI	EC4 HPI
CCPI	0.425289* (0.179951)	0.451050** (0.173850)	0.418507** (0.175688)	0.575814** (0.185899)
INC	1.486337** (0.312695)	1.450032** (0.305929)	1.679478** (0.266879)	2.340452** (0.205139)
R	-0.011269 (0.007494)	-0.010824 (0.007461)	- (-)	- (-)
POP	2.870274** (0.782591)	2.871443** (0.783770)	3.514667** (0.658660)	3.373430** (0.719890)
CRED	0.139225** (0.043505)	0.128342** (0.038674)	0.135824** (0.039060)	- (-)
REMIT	-0.038258 (0.070439)	- (-)	- (-)	- (-)
SoA	-0.090549* (0.043371)	-0.086816* (0.043294)	-0.103705* (0.042188)	-0.108312* (0.037971)

Source: author's calculations. Notes: standard errors of the parameters are presented in parenthesis. Stars indicate statistical significance as follows: \*\*\* – 99%, \*\* – 95%. 'SoA' is the speed of adjustment parameter (the parameter near the error correction term).

**Table 2.** Long-term specifications with alternative time series.

	Alternative income HPI	Alternative population HPI	Alternative population and income HPI
<i>CCPI</i>	1.467700** (0.305864)	2.071763** (0.302269)	– (–)
<i>INC</i>	–0.761005** (0.223690)	–1.195139** (0.207553)	1.764212** (0.281319)
<i>R</i>	–0.024620** (0.006822)	– (–)	– (–)
<i>POP</i>	– (–)	0.979229* (0.395040)	1.760796** (0.438313)
<i>CRED</i>	0.304499** (0.043337)	0.341449** (0.043054)	0.161660** (0.041881)
<i>REMIT</i>	– (–)	0.240683** (0.073141)	– (–)
<i>SoA</i>	–0.021054 (0.6068)	–0.051090 (0.041294)	–0.133189** (0.037982)

Source: author's calculations. Notes: standard errors of the parameters are presented in parenthesis. Stars indicate statistical significance as follows: \*\*\* – 99%, \*\* – 95%.

selected explanatory variables (in addition to the evidence from tests in Appendix 2). Thus, if the prices are above their long-term equilibrium values and if the other factors stay constant, the prices will readjust.

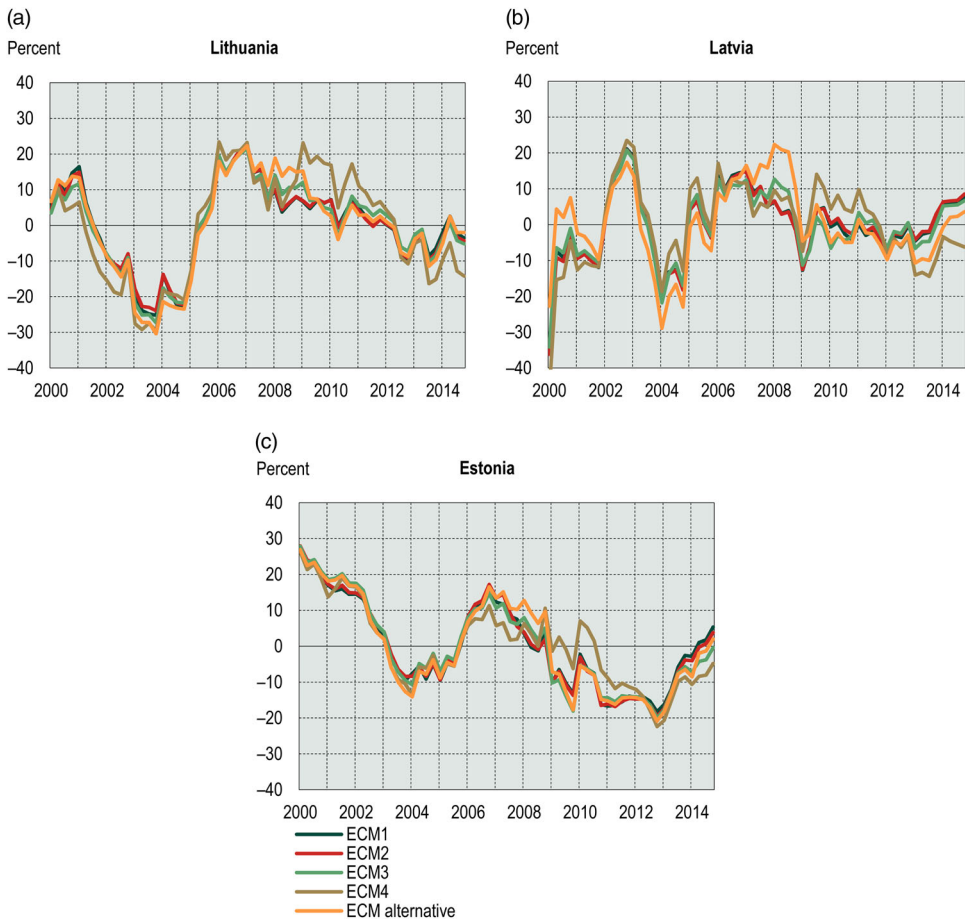
The strongest adjustment would happen in the model with the error correction term obtained from the equilibrium regression that includes the least variables on the right-hand side ('EC4'). All else equal, the prices would revert back to the equilibrium values in approximately 9 quarters in this case. However, it has statistically insignificant parameters, therefore, 'EC3' should be preferred. In the latter case, all else equal, the prices adjust back to equilibrium in over 9 and a half quarters.

For additional robustness checks some of the specifications of long-term equilibrium are re-estimated using alternative time series. In particular, average monthly net wages are used instead of real GDP per capita as the income variable and population aged between 25 and 44 years old is used instead of total population as the demographic variable (individuals in this age group are the most common home buyers, see, e.g. National Association of Realtors, 2015). The alternative specifications are reported only with the statistically significant parameters. The results are reported in the Table 2 below.

The equation with the alternative income series gets an unexpected sign near the income parameter. Thus, the real GDP per capita series might be better able to capture income effects than the net wages (e.g. due to income from informal sector). In addition, the error correction does not occur in 'Alternative income' and 'Alternative population' models. On the other hand, in the model with both of the alternative time series, the error correction does happen. However, the values of the parameters in this model changes little as compared to the models from Table 1. As can be seen in Section 6, however, the messages that the models convey does not change when using alternative time series.

## 6. Results

Next the estimated misalignments from the equilibrium housing prices from panel regressions are visually inspected. The series expressed as percentage deviations from the equilibrium values are plotted in Figure 4. In each case the long-term equilibrium value is considered to be the fitted value of a respective model's long-term equation



**Figure 4.** The estimated housing price deviations from equilibrium in the Baltics. Source: author's calculation.

(see Table 1). 'ECM alternative' refers to the model with alternative income and population time series (see Table 2).

There are several things that are immediately visible from the figure. While the estimates of the long-term equilibrium values of housing prices from different equation disagree on the extent to which prices are above or below equilibrium, they all follow similar pattern. For all three countries the models were able to identify housing overvaluation before the subsequent market crashes in 2008–2009.

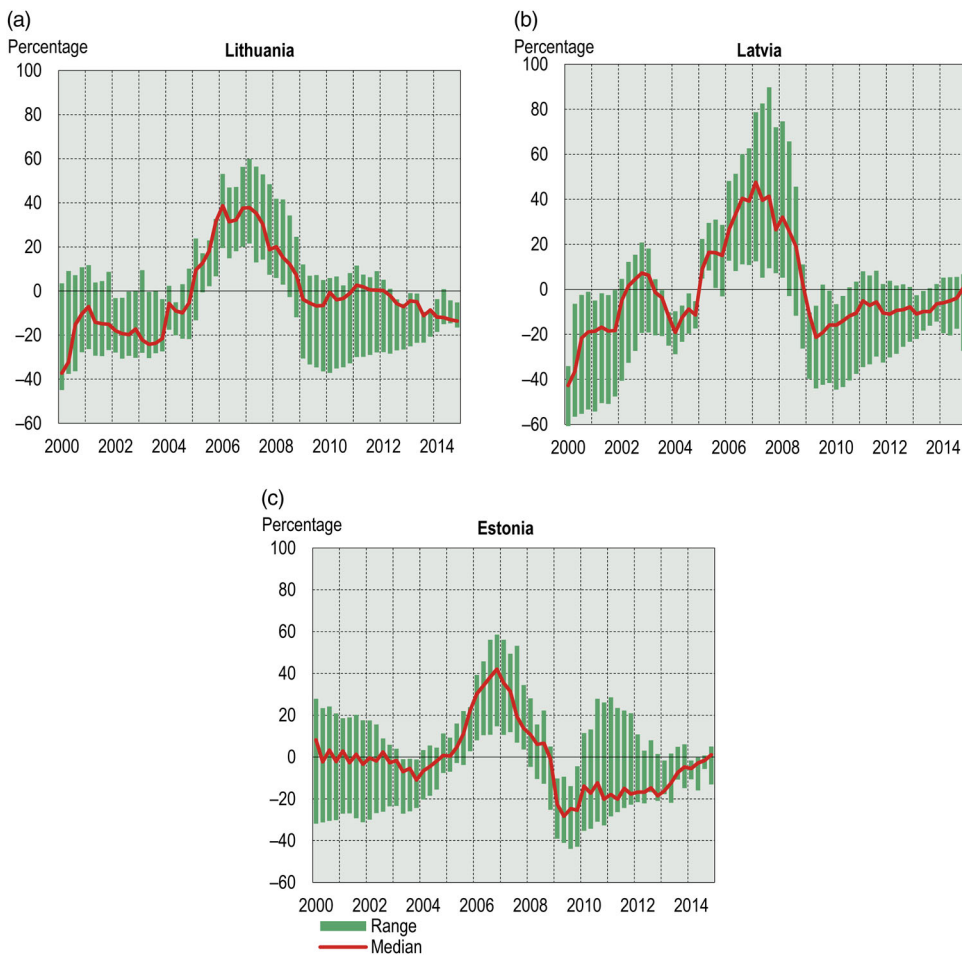
The models signal housing prices wandering above their long-term equilibrium values sometime in 2005 or 2006. Residential real estate was overvalued in Lithuania, Latvia and Estonia to the extent of about 10–20% at the peak of the boom. The largest price correction seems to have occurred in Estonia where housing prices briefly found themselves over 20% below fundamentally justified values. A somewhat milder correction occurred in Lithuania and Latvia with housing prices slipping about 10–15% below their long-term equilibrium values.

After 2009 the residential real estate prices recovered from being undervalued and there is some evidence that they overshoot the equilibrium in Latvia<sup>8</sup>. At the end of the

sample the prices in Estonia were at their equilibrium values according to long-term equations from Table 1. In Lithuania the residential real estate was slightly undervalued.

Though the estimates from all the models follow similar patterns, contradictions do occur. Therefore, it would be difficult to call which of them has the most desirable properties based purely on a visual inspection. To make the task of arriving to clear conclusions easier, the information obtained from the long-term equation is combined with the indicators discussed in Section 3. This information is synthesized graphically in Figure 5. Since 'EC3' in Table 1 is without statistically insignificant parameters, it is used in the figure to represent the estimates from long-term equations.

The bars in the figure cover the range from the minimum to the maximum out of all the indicators used in this paper for measuring housing price misalignments. All measures were included as percentage deviations from equilibrium (e.g. percentage difference



**Figure 5.** Residential real estate price deviations from fundamental values in the Baltics. Source: author's calculations. Note: 'Range' covers the minimum and the maximum values of housing price over- or under-valuation from the price-to-rent and price-to-income ratios, the deviations from Hodrick-Prescott trend and the estimates from the error-correction models. 'Median' represents the median value of those indicators.



between price-to-rent ratio and the long-term average of the price-to-rent ratio at every point in time). Thus, the lowest point of each bar correspond to the minimum value out of measures obtained from price-to-rent ratio, price-to-income ratio, Hodrick-Prescott filter procedure and the error correction model. Similarly, the highest point of each bar correspond to the maximum value out of the same indicators. The line represents the median for the same estimates at each point in time.

For all three Baltic States [Figure 5](#) is able to tell a plausible story of housing price developments. The overheating that took place in the period of 2005–2008 is clearly visible for all the countries under consideration. Although the ranges tend to get wide, in all cases even the minimum values leave no doubt of housing assets being traded considerably above their long-term equilibrium prices.

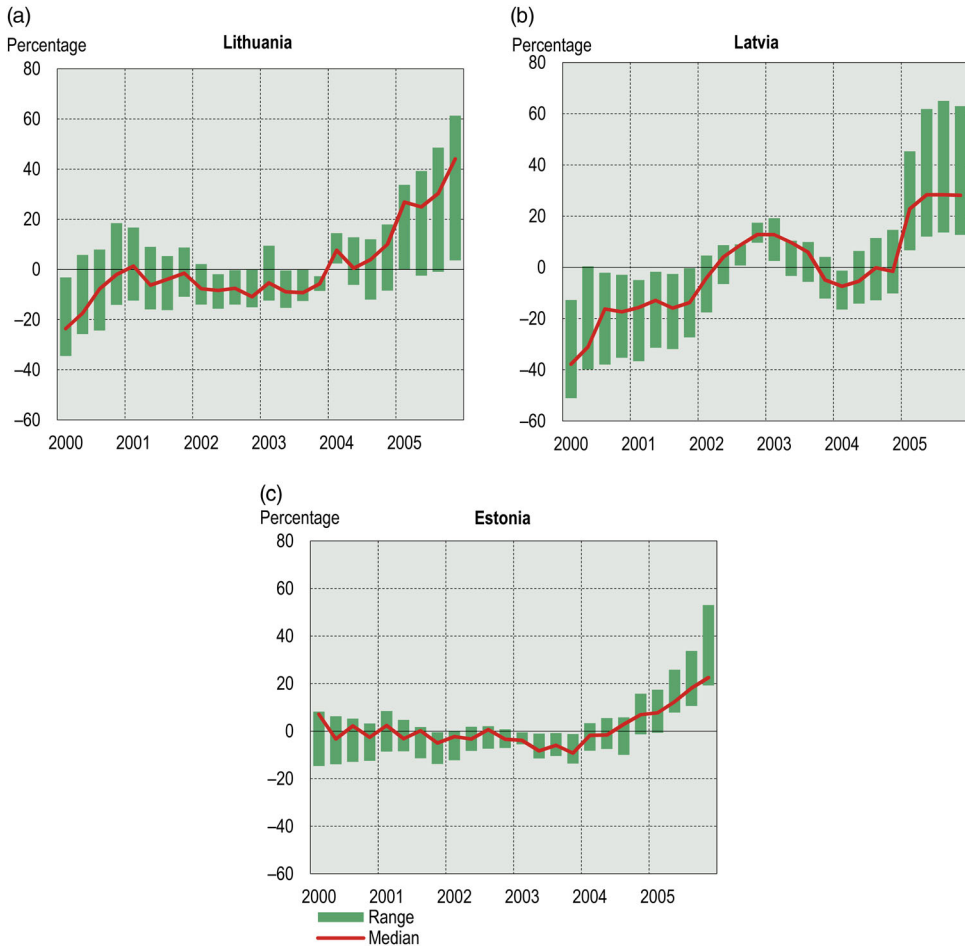
Residential real estate prices overreacted in correcting accumulated imbalances after 2009. They slipped under their long-term equilibrium values in all three Baltic States. After the correction ended, the prices started converging to their equilibrium levels. The largest progress had been made in Estonia and Latvia, where prices were more or less balanced in the fourth quarter of 2014. At the same time, residential property prices were still undervalued in Lithuania (13%).

The real question is, whether the same framework would have signalled housing price misalignments in real time, i.e. as data was becoming available before the crisis. For this purpose, the calculations described in this paper were repeated with a restricted sample (time series end with the fourth quarter of 2005) in [Appendix 3](#). The results are plotted in [Figure 6](#).

As evident from [Figure 6](#), at the end of 2005 one would have been able to conclude that the housing prices have departed from their fundamental values in all three Baltic States. In cases of Latvia and Estonia, the framework is able to give a rather clear message of housing price overvaluation. In case of Lithuania the uncertainty is still high as error-correction model estimates were inconclusive<sup>9</sup>; however, the median of the measures would have still convincingly signalled overvaluation. Of course, given the short time series available in 2006, relying on this framework alone would have been careless at the time. Only with the benefit of hindsight, we now know that the signals the framework would have sent would have been correct. Currently as well as in the future, data limitations problems, arguably, are not going to be as bad as they were in 2006, thus, the framework could be useful for detecting over valuation in real time, i.e. as the data becomes available and could empower policymakers to act against the risk build-up.

It must be noted, that the actual prices being above or below their equilibrium values does not necessary translate to price correction. The equilibrium prices can move in response to various developments in fundamental factors<sup>10</sup> (e.g. due to changes in population) and close the under- or overvaluation gap without any apparent movement in the actual prices. For example, the actual housing prices in Lithuania did not change much after the correction in 2009–2010 but the misalignment widened because the levels of equilibrium prices adjusted responding to the developments of the fundamentals.

Judging by the performance of [Figure 5](#) and [Figure 6](#), this framework could be used for making judgements about price misalignments rather successfully. Although in the fourth quarter of 2014 the estimates did not signal any immediate dangers stemming from the housing markets, the situation might change in the future as the prices have more or less converged to their equilibrium. There is no reason to believe that in the future if the actual



**Figure 6.** Residential real estate price deviations from fundamental values in the Baltics (restricted sample to 2000–2005, see Appendix 3). Source: author's calculations. Note: 'Range' covers the minimum and the maximum values of housing price over- or under-valuation from the price-to-rent and price-to-income ratios, the deviations from Hodrick-Prescott trend and the estimates from the error-correction models. 'Median' represents the median value of those indicators.

housing prices depart from their equilibrium values it will not be able to detect the decoupling.

## 7. Concluding remarks

This paper showed that the imbalances in the Baltic residential real estate markets that were accruing prior the crisis of 2008–2009 could have been detected in real time, i.e. as the data became available. In order to make inferences about housing price misalignments it developed an empirical framework that combines the price-to-rent, price-to-income ratios, deviations from Hodrick-Prescott trend and estimates from error-correction models. The results show that with the sample restricted to the end of 2005 this framework could have successfully identified the overheating in the housing markets in real time (as

data became available). The estimates also capture the price correction overshooting that happened in the Baltic States after the recession of 2009. Since then, housing prices have been converging to their equilibrium values.

The result implies that there are no immediate systemic risks arising from the residential real estate markets in the Baltic countries. Looking further, the framework developed here can be used to supplement macroprudential oversight, risk identification and analysis. While the framework is not designed to calibrate policy instruments or identify if such instruments are needed, it can still be useful in policymaking process to answer questions of whether imbalances in the housing market are mounting up.

Modelling the equilibrium housing prices revealed that price misalignments in the Baltic States may not necessary lead to corrections in the actual housing prices. Even if the residential real estate is over- or undervalued in one of the Baltic countries, prices might not actually fall or rise. In turn, the actual adjustment may happen through movements in the equilibrium housing price which can change in response to variation in fundamental determinants.

## Notes

1. In this paper the Baltics, the Baltic States and the Baltic countries are used as synonyms to refer to Lithuania, Latvia and Estonia together.
2. See, e.g., Davis and Nieuwerburgh (2014) and Glaeser and Nathanson (2014) for reviews on the differences between housing and ordinary financial assets.
3. For example, some are members of the EU and are considered advanced economies by the IMF (2015), others have made little progress transforming their economies after the collapse of the Soviet Union.
4. It has to be kept in mind, that taking a smaller sample for the long-term average could potentially produce different conclusions. For countries that were undergoing large transitions such as the Baltic States it might be a problem, but Figure 1 does not indicate that this is the case (i.e. the ratios are indeed fluctuating around the average).
5. The  $\lambda$  value is set following Goodhart and Hofmann (2008) and Agnello and Schuknecht (2011).
6. One can easily see why by simply restricting calculations not to include data that became available after the end of 2005. While most of the time the indicators would still signal overvaluation, it would arguably be too small to look alarming. See Appendix 3 for the measures calculated on the restricted sample.
7. It is possible that the error correction could occur not only through the housing prices, i.e. one or some of the right-hand side variables may not be exogenous. In order to avoid parameter biases associated with endogeneity in the explanatory variables, panel dynamic ordinary least squares are used in Section 5.
8. The estimates from "EC3" model showed overvaluation of 7% in Latvia, undervaluation of 5% in Lithuania and prices being equal to their equilibrium values in Estonia at the end of the sample (the fourth quarter of 2014).
9. It must be noted, that due to short time series the error correction models discussed in this paper would have been near impossible to come by in 2006, see Appendix 3.
10. The fundamental variables are treated as exogenous in this paper. It has to be kept in mind that the developments of those variables might be unsustainable. However, gauging the exact effect of fundamentals overshooting their equilibrium (sustainable) values falls out of the scope of this paper.
11. The correlation of nominal GDP and net average wages in Latvia for the period from the first quarter of 2001 to the second quarter of 2014 equals 0.95, therefore it is reasonable to use GDP series to extend time series on net wages.

12. The correlation of mortgage interest rates and average weighted interest rates on total credit is equal to 0.61 for the period from the first quarter of 2004 to the second quarter of 2014.

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## Disclaimer

The views expressed in this paper are those of the author and may not necessary represent the position of the Bank of Lithuania or its staff.

## ORCID

Darius Kulikauskas  <http://orcid.org/0000-0003-0021-5960>

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## Appendix 1. Data

Data used in writing this paper covers the period from the first quarter of 2000 to the fourth quarter of 2014. Time series of housing prices, construction input costs, loans for house purchase, income, remittances, inflation, interest rates on credit for house purchase and population were collected for this exercise (see Table A1). However, data availability in different countries varied and had to be in some cases interpolated or extrapolated.

House price indices were taken from Eurostat database. Since it is available for Estonia starting only from 2005 and for Lithuania and Latvia – from 2006, time series had to be extended using supplementary time-series. For Estonia the data was extrapolated backwards to 2003 by mimicking housing price movements obtained from Estonian Land Board transactions database. The data for the period of 2000–2003 was constructed using housing group time series from harmonized index of consumer prices. For Latvia

**Table A1.** Long-term relationships.

Time series	Data description	Data source	Reference code in the source
House price index	Quarterly levels of housing prices indexed to equal 100 in 2010	Eurostat	prc_hpi_q
Construction input costs	Monthly levels of construction costs indexed to equal 100 in 2010 (averaged for every quarter)	National statistics agencies	Lithuania: Construction input price indices (2010 – 100) Latvia: RC08 Estonia: XO10
Loans for house purchase	Stocks of loans to households for house purchases in euros at the end of a quarter	Baltic central banks	Lithuania: 2.5.2.5. Latvia: 16.b Estonia: 3.3.3
Mortgage interest rates	Mortgage interest rates (in annual terms), calculated as a weighted average (with amounts in respective currency as weights) for the periods when the countries were not part of Euro zone	Baltic central banks	Lithuania: 3.3.3. Latvia: Table 21 Estonia: 3.7.3
Population and alternative population	Population levels at the beginning of a quarter	National statistics agencies	Lithuania: Resident population at the beginning of the month Latvia: IE02 Estonia: PO021
Net monthly average wages	Quarterly data of average net monthly wages in euros	National statistics agencies	Lithuania: Average earnings Latvia: DS01 Estonia: WS041
Real GDP per capita	Quarterly series of real GDP per capita in euros	Eurostat	namq_10_pc
Harmonized consumer price index	Monthly harmonized consumer price index (levels averaged for every quarter)	Eurostat	prc_hicp_midx CP00
Rent prices	Monthly actual rentals for housing index (levels averaged for every quarter)	Eurostat	prc_hicp_midx CP041
Real house prices	House price indices deflated by harmonized consumer price indices	Eurostat	Detailed above
Real mortgage interest rates	An average of mortgage interest rates over quarter minus annual consumer price change during the respective quarter	Eurostat and national central banks	Detailed above
Remittances	Current transfers (secondary income) to other sectors than general government from the Balance of Payments in euros over a quarter	Baltic central banks	Lithuania: BOP 1.C.2 Latvia: BOP C 14200 Estonia: BOP 1.13.2

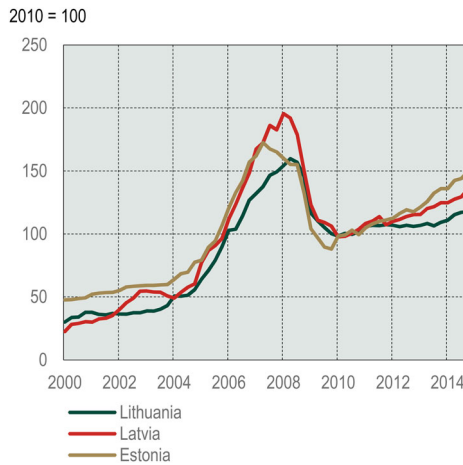
Source: compiled by the author.

Notes: Statistics Lithuania can be accessed at <http://osp.stat.gov.lt/en/>, Statistics Latvia – at <http://www.csb.gov.lv/en>, Statistics Estonia – at <http://www.stat.ee/en>. Eurostat database is available at <http://ec.europa.eu/eurostat>. The databases of the Baltic central banks are available at the following addresses: Lithuania – [http://www.lb.lt/en\\_index.htm](http://www.lb.lt/en_index.htm), Latvia – <http://www.bank.lv/en/>, Estonia – <http://www.eestipank.ee/en>.

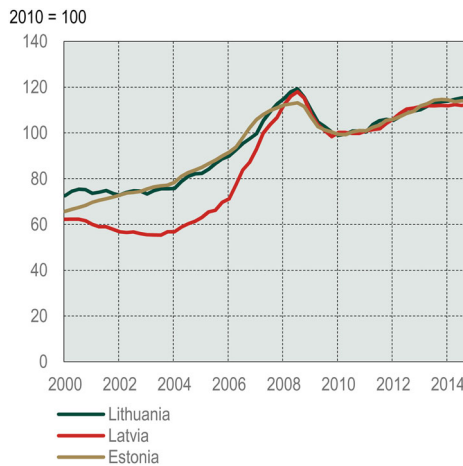
the data was extrapolated backwards to 2000 using average housing prices registered by Latio (a private real estate company). These time series are plotted in [Figure A1](#).

Time series on costs of construction inputs were available for all three countries at their respective national statistics agencies (see [Figure A2](#)). For income data average net monthly wages were used (see [Figure A3](#)). Lithuanian and Estonian data was available from respective national statistics agencies for the whole timeframe covered in this paper. Data on Latvian net average monthly wages was missing for the year 2000 so it had to be interpolated backwards by mimicking nominal GDP dynamics<sup>11</sup>.

Data on mortgage interest rates were obtained from central banks (see [Figure A4](#)). For the periods when the Baltic countries were not part of the euro area, the interest rate was calculated as a weighted average of the interest rates of loans issued in the national currency (at the time) and in euro. The data was not fully available only for Latvia; therefore, it had to be extrapolated backwards from 2004 to 2000 proportionally to the average weighted interest rates on all loans<sup>12</sup>.

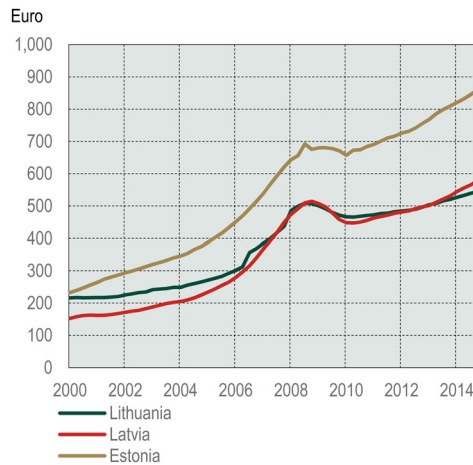


**Figure A1.** Housing price indices. Source: author's calculations.

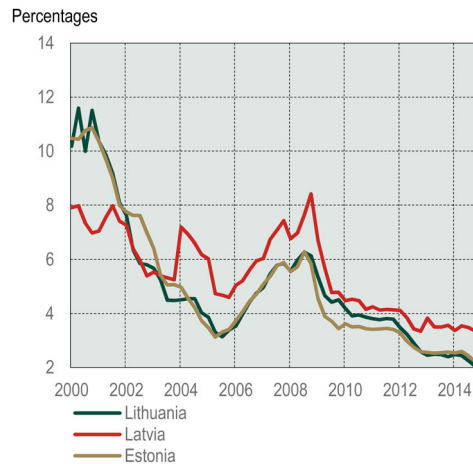


**Figure A2.** Construction input cost indices. Source: author's calculations.





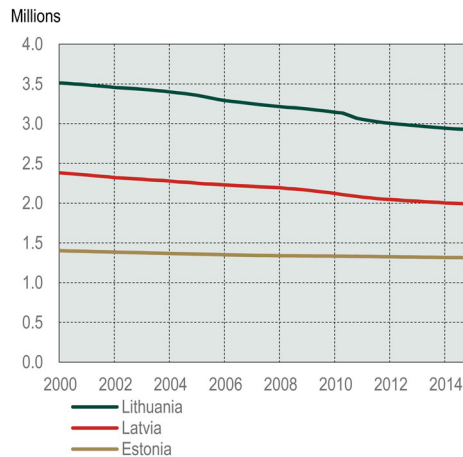
**Figure A3.** Average monthly net wages (seasonally adjusted). Source: author's calculations.



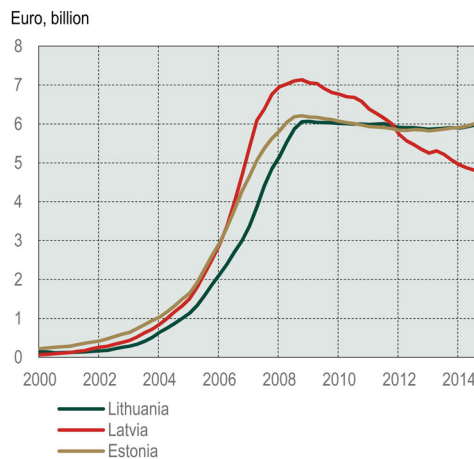
**Figure A4.** Mortgage interest rates. Source: author's calculations.

Population time series were available fully for all three Baltic States at the respective national statistics agencies (see [Figure A5](#)). However, for Estonia the data is provided only at annual frequency and had to be interpolated. Under assumption that changes in population can be described as a smooth process, blanks were filled by connecting adjacent data points linearly.

Stocks of credit issued for house purchase were also obtained from central banks but it was available from the first quarter of 2000 only for Estonia. Lithuanian data on mortgage portfolio is available starting from 2004, Latvian – from 2003. For Lithuania it was extrapolated backwards proportionally to the outstanding amounts of total credit issued to households. For Latvia the same procedure was applied but instead of all credit issued to households archived mortgage loan data was used (which is not directly



**Figure A5.** Population. Source: author's calculations.

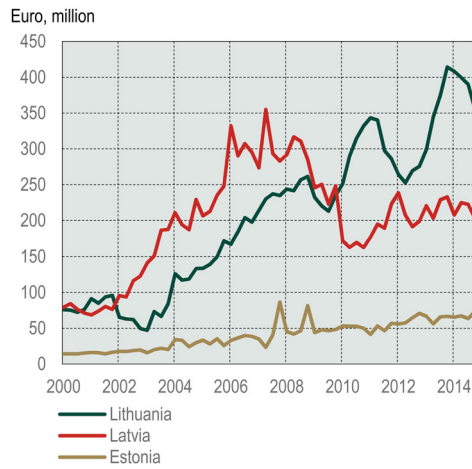


**Figure A6.** Stocks of mortgage loans. Source: author's calculations.

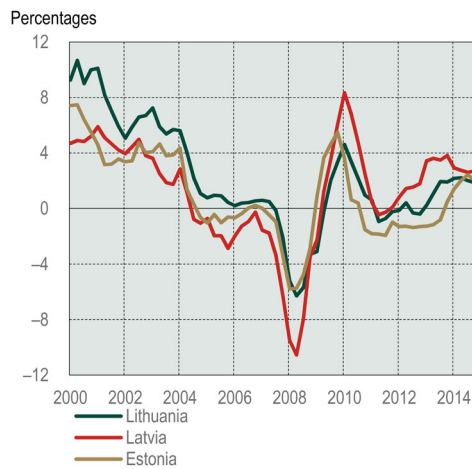
comparable because of changes in methodology). These time series are plotted in [Figure A6](#).

For price-to-rent calculations monthly data from consumer price indices was used. Actual rentals for housing index that is a part of harmonized consumer price index compiled by Eurostat were used as a proxy for rental prices. These time series were not extrapolated in any way.

Data on remittances ([Figure A7](#)) was obtained from respective central banks' databases. The time series on current transfers (secondary income) to other sectors than general government from Balance of Payments statistics were used. Real mortgage interest rates ([Figure A8](#)) were calculated as the difference between nominal mortgage interest rates ([Figure A4](#)) and the price inflation as measured by the annual change in harmonized consumer price indices taken from Eurostat.



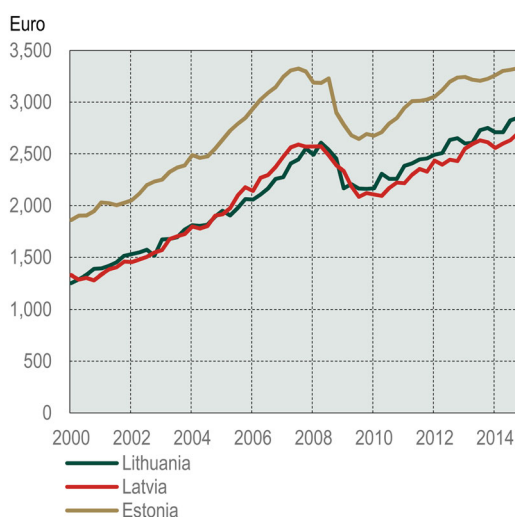
**Figure A7.** Remittances. Source: author's calculations.



**Figure A8.** Real interest rates. Source: author's calculations.

Real GDP per capita time series were taken from Eurostat. ESA 2010 national accounts classification was used. The data is available for all three Baltic countries beginning with 1995. Therefore, no extrapolation had to be done.

It is clearly visible from the charts above that there are indeed a lot of homogeneity among the Baltic countries in terms of housing price movements. In general, time series of all three countries show a lot of co-movement. These synchronized movements suggest that the real estate markets have developed in similar fashion in all three Baltic States and, therefore, respond to shocks of the same kind in a similar way. This makes the case for treating the Baltics as a panel in estimation exercise.



**Figure A9.** Real GDP per capita. Source: author's calculations.

## Appendix 2. Unit-root and cointegration tests

This appendix provides the results of unit-root tests for the variables (see Tables A2 and A3) and the results of cointegration tests (see Tables A4, A5 and A6). All the calculations in this appendix were done with the full sample, i.e. from 2000 to 2014.

**Table A2.** Panel unit-root tests for the levels of time series: individual intercepts, automatic lag selection based on modified Schwartz criterion (Zhang & Siegmund, 2007).

	HPI	CCPI	INC	POP	CRED	R	REMIT
Levin, Lin, and Chu (2002)	-1.108 (0.134)	-1.293 (0.098)	-2.458 (0.007)	-1.415 (0.079)	-3.569 (0.000)	-0.432 (0.333)	-0.998 (0.159)
Im, Pesaran, and Shin (2003)	0.121 (0.548)	0.438 (0.669)	-0.646 (0.259)	1.519 (0.936)	-1.630 (0.051)	-1.328 (0.092)	0.228 (0.590)
Maddala and Wu (1999)	3.635 (0.726)	2.961 (0.814)	6.257 (0.395)	3.606 (0.730)	10.907 (0.091)	9.958 (0.126)	3.777 (0.707)
Choi (2001)	6.470 (0.373)	2.458 (0.873)	5.454 (0.487)	20.578 (0.002)	21.765 (0.001)	10.425 (0.108)	4.471 (0.613)

Source: author's calculations.

Notes: values were rounded to three digits after decimal point. Null hypothesis is unit root in all cases, p values are presented in parenthesis.

**Table A3.** Panel unit-root tests for the first differences of time series: automatic lag selection based on modified Schwartz criterion (Zhang & Siegmund, 2007).

	dHPI	dCCPI	dINC	dPOP	dCRED	dR	dREMIT
Levin et al. (2002)	-4.078 (0.000)	-3.490 (0.000)	-2.348 (0.009)	-1.737 (0.041)	-2.787 (0.003)	-7.411 (0.000)	-9.648 (0.000)
Maddala and Wu (1999)	23.356 (0.001)	18.786 (0.005)	-4.843 (0.000)	8.068 (0.233)	14.911 (0.021)	60.167 (0.000)	241.484 (0.000)
Choi (2001)	52.331 (0.000)	30.858 (0.000)	82.813 (0.000)	9.4890 (0.148)	10.397 (0.109)	60.993 (0.000)	430.334 (0.000)

Source: author's calculations.

Notes: values were rounded to three digits after decimal point. Null hypothesis is unit root in all cases, p values are presented in parenthesis.

**Table A4.** Johansen cointegration test (trace).

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.294553	166.1710	95.75366	0.0000
At most 1 *	0.281484	108.5987	69.81889	0.0000
At most 2 *	0.202125	54.05510	47.85613	0.0117
At most 3	0.060127	16.79765	29.79707	0.6549
At most 4	0.029534	6.565977	15.49471	0.6286
At most 5	0.009767	1.619516	3.841466	0.2032

Source: author's calculations.

Notes: trace test indicates 3 cointegrating equations at the 0.05 level. \*\* denotes rejection of the hypothesis at the 0.05 level. \*\*\* MacKinnon, Haug, and Michelis (1999) p values.

**Table A5.** Johansen cointegration test (maximum eigenvalue).

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigenvalue Statistic	0.05 Critical Value	Prob.**
None *	0.294553	57.57231	40.07757	0.0002
At most 1 *	0.281484	54.54360	33.87687	0.0001
At most 2 *	0.202125	37.25745	27.58434	0.0021
At most 3	0.060127	10.23168	21.13162	0.7226
At most 4	0.029534	4.946461	14.26460	0.7486
At most 5	0.009767	1.619516	3.841466	0.2032

Source: author's calculations.

Notes: max-eigenvalue test indicates 3 cointegrating equations at the 0.05 level. \*\* denotes rejection of the hypothesis at the 0.05 level. \*\*\* MacKinnon et al. (1999) p values. Population time-series were used as exogenous variable since they were not Granger caused by other variables.

**Table A6.** Kao (1999) cointegration test (cross-section specific intercepts, no deterministic trend).

	EC1	EC2	EC3	EC4	Alt. income	Alt. population	Alt. pop and inc.
ADF t statistic	-3.949	-3.974	-4.094	-4.280	-3.138	-2.989	-3.145
p value	0.000	0.000	0.000	0.000	0.001	0.001	0.001

Source: author's calculations.

Notes: values were rounded to three digits after decimal point. Null hypothesis is no cointegration. ADF test equation lag was selected based on modified Schwartz criterion.

**Table A7.** ADF test results for price-to-income and price-to-rent time series.

	Price-to-income	Price-to-rent
Lithuania	0.5573	0.3312
Latvia	0.1536	0.3854
Estonia	0.0320	0.3162

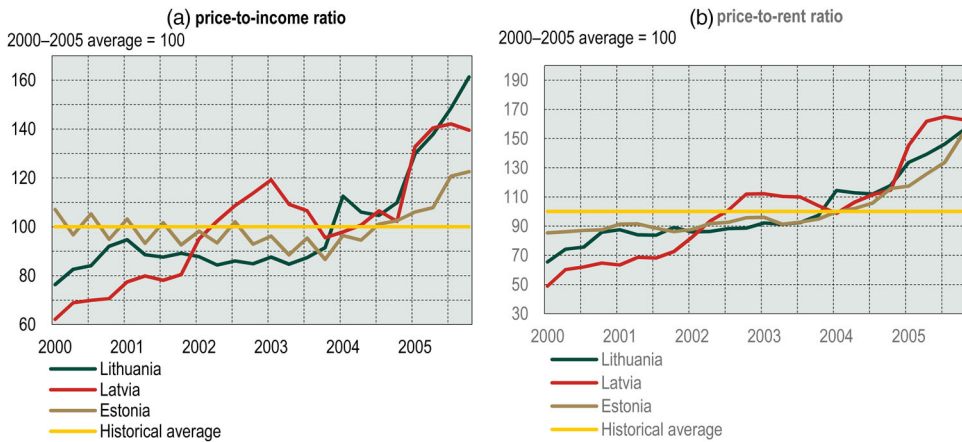
Source: authors calculations.

Note: table reports p values for ADF test with a constant and automatically selected lags (BIC criterion).

### Appendix 3. Fundamental price measurements with restricted data sample

The framework employed in this paper could only be useful if it is able to detect mounting imbalances as they occur, i.e. as data becomes available. This appendix investigates if the approach proposed in Section 6 would have been able to detect housing price imbalances in real time during the 2005–2008 episode of market overheating. For this purpose, all the calculations that were done in this paper are repeated with the sample restricted to end at the beginning of 2006.

This means, that the last available data point for calculations is the fourth quarter of 2005. This particular date for restricting the sample was chosen on the grounds that at



**Figure A10.** Price-to-income and price-to-rent ratios in the Baltics restricted to data available until the end of 2005. Source: author's calculations based on Eurostat and national statistics agencies data.

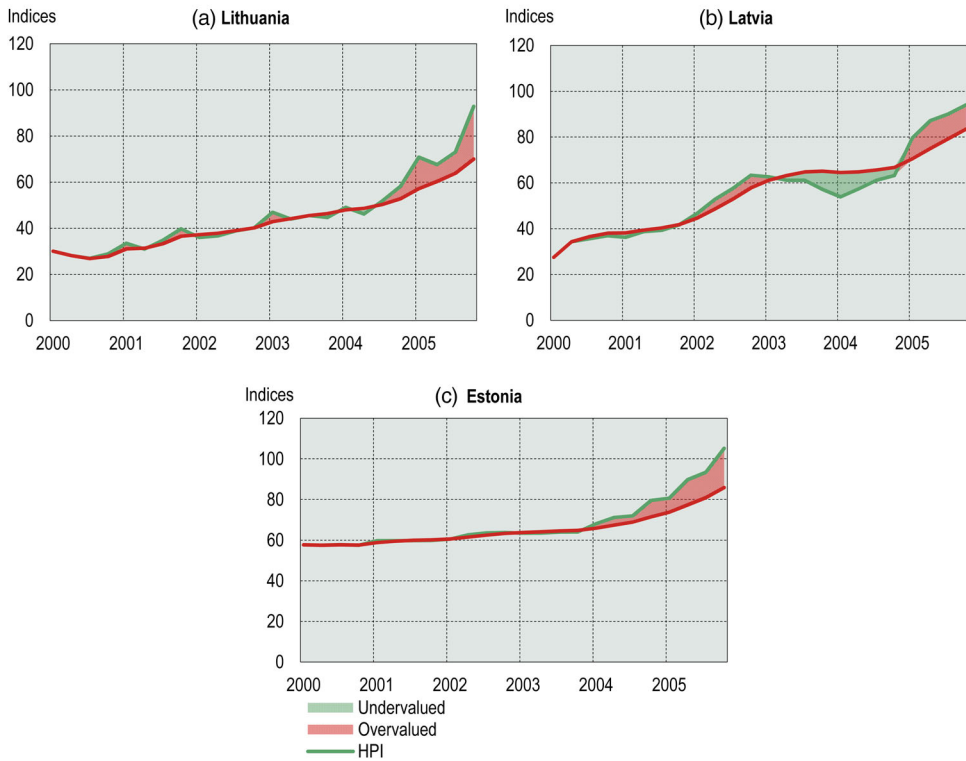
that date there had been a full year of data available to signal mounting imbalances in the Baltic residential real estate sectors. If the framework is able to identify the beginning of the overheating with this restriction, it, arguably, could be used in practice for monitoring housing valuations in the Baltic States and making judgements if the price developments signal mounting imbalances.

First of all, the price-to-income and price-to-rent ratios were recalculated. The results are plotted in Figure A10. The calculation procedure is identical to the one in Section 3.

As can be seen from the figure, both the price-to-income and price-to-rent ratios did deviate from their long-term averages in late 2004 or early 2005. This means that at those dates these fairly simplistic measures were signalling that the properties in the Baltic residential real estate markets were being traded above their equilibrium values. According to the price-to-income ratios, houses were above their equilibrium values to the tune of around 60 percent in Lithuania, 40 percent in Latvia and 20 percent in Estonia at the end of 2005. At the same time, the price-to-rent ratios signalled overvaluation of around 60 percent in Latvia and 50 percent in Estonia and Lithuania.

Of course, it would be naïve to expect policymakers acting on this information alone, thus, other measures should also be investigated. Hodrick-Prescott exercise (one-sided) described in Section 3 was repeated in Figure A11 but with the restricted sample. Just as before, the housing prices used for the calculation here were deflated by harmonized consumer price indices.

Figure A11 shows that the estimates derived from Hodrick-Prescott filter would have also signalled imbalances in the Baltic countries' housing markets. In Estonia and Lithuania the estimates started signalling overheating in 2004, in Latvia – in 2005. At the end of the restricted sample, the estimates obtained from the Hodrick-Prescott filter exercise suggested that the housing prices were approximately 32 percent above their equilibrium value in Lithuania. The corresponding figure for Latvia stood at around 13 percent. Finally, according to Hodrick-Prescott estimates, in Estonia housing prices seemed around 23 percent above their long-term average.



**Figure A11.** Housing price deviations from Hodrick-Prescott filter (one-sided) trend ( $\lambda = 100\,000$ ) restricted sample. Source: author's calculations based on Eurostat and national statistics agencies data.

So the Hodrick-Prescott filter would have also ringed some alarms in early 2006 if it had been used for measuring housing price misalignments. Next, the error-correction models are re-estimated with the same specifications as outlined in Table 1 in Section 5. Since in

**Table A8.** Long-term relationships (restricted sample).

	EC1.res HPI	EC2.res HPI	EC3.res HPI	EC4.res HPI
CCPI	0.547933 (0.400671)	0.545932 (0.421305)	0.446651 (0.350794)	0.529214 (0.347045)
INC	-0.729487 (0.555506)	-0.737708 (0.584090)	-0.764621 (0.574544)	-0.580807 (0.554816)
R	-18.39406 (7.329736)	0.007441 (0.017048)	-	-
POP	0.008105* (0.016218)	-17.20539* (7.663185)	-15.94287* (7.019578)	-21.52780* (4.494945)
CRED	0.053112 (0.130892)	0.118685 (0.129930)	0.129328 (0.126242)	-
REMIT	0.130915 (0.086201)	-	-	-
SoA	-0.146231 (0.083450)	-0.153703 (0.079929)	-0.158752* (0.079501)	-0.140001 (0.078518)

Source: author's calculations.

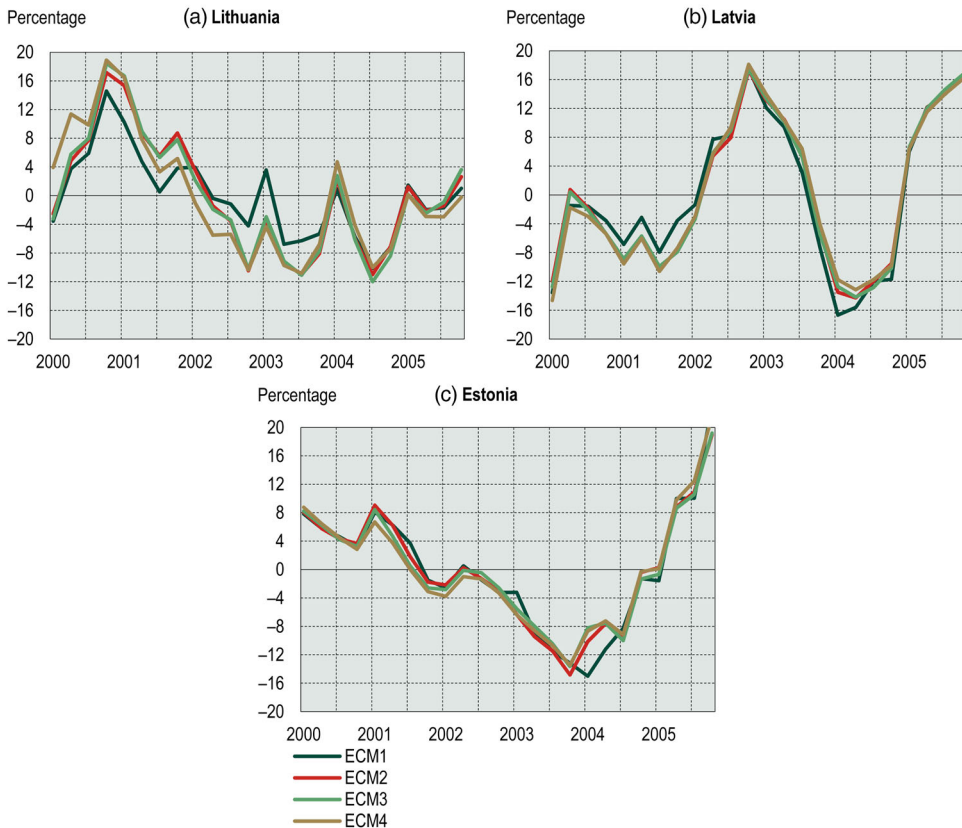
Notes: standard errors of the parameters are presented in parenthesis. Stars indicate statistical significance as follows: \*\*\* – 99%, \*\* – 95%. 'SoA' is the speed of adjustment parameter (the parameter near the error correction term).



order to be accurate econometric models usually require rather long time series, this technique will probably suffer the most from sample restriction as compared to other methods used in this paper. Short time series reduce the power of statistical tests such as those used to test for parameter significance and become unreliable. Table A8 below reports the estimation results with the restricted sample.

As can be seen from the table, it would have been near impossible to come up with the same equation specifications in 2006 as almost all equations would have been plagued by statistically insignificant parameters. In addition, there would have been evidence of error correction only in EC3.res case. It is, therefore, safe to assume, that such models would have been impossible to construct due to data limitations. Anyway, for the sake of comparison to the full sample results, the results from the restricted sample error-correction equations are plotted in Figure A12.

The figure shows that in case of Lithuania the estimates from error-correction model provided little guidance on how well aligned housing prices were with their fundamentals. It should not come as surprise, given poor statistical properties of the models. However, in case of Latvia and Estonia, the models were able to signal overheating in the housing market starting with early 2005. However, such models would have been near impossible to come by at the time, thus, these results should only be viewed as indicative.



**Figure A12.** The estimated housing price deviations from equilibrium in the Baltics (restricted sample). Source: author's calculation.