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economic growth in Europe

Economics Department

Juan Carlos Cuestas
Merike Kukk
Natalia Levenko

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Juan Carlos Cuestas
UJI & Tallinn University of Technology
IEI & Department of Economics
cuestas@uji.es

Merike Kukk
Tallinn University of Technology
Department of Economics and Finance
Merike.kukk@taltech.ee

Natalia Levenko
Tallinn University of Technology
Department of Economics and Finance
Natalia.levenko@taltech.ee

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Abstract

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Misalignments in house prices and economic growth in Europe[*]

JUAN CARLOS CUESTAS[b,c], MERIKE KUKK[a,b], NATALIA LEVENKO[a,b]

[a]Eesti Pank, Estonia

[b]Tallinn University of Technology, Estonia

[c]Jaume I University, Spain

Abstract

In this paper we investigate house price misalignments and how they affect the real economy. We estimate the long-term relationship between house prices and the fundamentals that determine long-term house prices for a panel of European countries with dynamic OLS, using data from 2005-2018. We find that income has been the main driver of fundamental house prices in all countries, while the supply of dwellings has calmed the rise in house prices in some of them. We calculate house price misalignments, which are deviations of house prices from the fundamental value, and we employ them in the growth model. The results of the growth regression indicate that house price imbalances amplify business cycles in the short term, but in the long term house price overvaluations slow economic growth down. The findings imply that it is crucial to take measures to stabilise housing cycles.

Keywords: housing markets, fundamental house price, misalignments, imbalances, overvaluation, economic growth

JEL codes: E21, E44, R21, R31, G01

1. Introduction

Ever since the crisis of 2008-2009, the discussion about the linkages between financial markets and the real economy has become increasingly relevant for both academics and policy makers alike. There is strong evidence that developments in financial markets are closely linked to those in the real economy; see the overview by Cochrane (2005). Policy makers monitor both business cycles and financial cycles, including housing market cycles, when they design policies to achieve economic stability. This paper focuses on the cycles in the housing market and how they are linked to the real economy.

The housing market has direct links with the real economy through various channels. First, housing is an important component of household wealth, and changes in the value of housing impact the consumption choices of households; for evidence see Case et al. (2005) and Carroll et al. (2011) among others. Likewise, housing is used as collateral, meaning that borrowing by households depends on the value of their housing, as found by Aoki et al. (2002) and Aron et al. (2012). Moreover, the state of the housing market affects developments in the construction industry and the real estate sector. Rising house prices attract more investment to construction (Girouard et al. 2006), which boosts employment and causes spill-over effects to consumption (Caldera & Johansson 2013, Byun 2010).

It is possible to distinguish between long-term house price movements that derive from how their fundamental determinants evolve, which is called in the literature long-term equilibrium house prices or fundamental house prices, and short-term fluctuations that are mostly induced by cyclical factors. Gao et al. (2009) find that house prices are very volatile and exhibit serial correlation and mean reversion. They find that house prices may deviate markedly from their fundamental values, and that they are more persistent when the trend movement is upwards than when it is downwards, suggesting that overvaluation lasts longer and is of larger magnitude than undervaluation.

House price misalignments have several implications for the economy.[1] First, the imbalances feed into the real economy and may amplify business cycles through household choices and through the construction industry, as already noted. The imbalances lead to economic resources being allocated inefficiently, which concerns both physical and human capital. Additionally, the larger the boom in prices has been, the more the sharp downward correction of the imbalances tends to overshoot, leading to more severe recessions. Case et al. (2008) show that the imbalances may feed into losses in the banking sector, affecting the supply of credit to households and companies. The mechanism is also explained by Girouard et al. (2006), who point out that the feedback effect from the financial markets to the real economy may have long-term consequences.

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[1] House price misalignments, imbalances and deviations from fundamental prices are used here interchangeably.

To understand how house price imbalances feed into the real economy in European countries, we investigate how house price misalignments affect economic growth. First, we estimate the house price misalignments for a panel of European countries by looking at the fundamental factors that determine the supply and demand of housing. The residuals of the model are the deviations of actual house prices from their fundamental values. We then use the estimated misalignments in the growth model to study how the house price imbalances affect GDP growth.

The paper contributes to the literature in several ways. First, we estimate fundamental house prices and misalignments for a large panel of European economies covering 20 countries. Second, we identify the main drivers of the fundamental house prices, finding that income has been the main driver of house price growth, while the role of low interest rate has been marginal and supply side has mostly calmed the rise in house prices. Third, we examine how house price imbalances affect economic growth. We find that house price misalignments have a positive short-term effect on GDP growth but a negative long-term effect.

The remainder of the paper is organised as follows. The next section provides a brief literature review, then the methodology for estimating fundamental house prices and the data are presented in Section 3. In Section 4 we discuss fundamental house prices and misalignments. In Section 5 we present the methodology and the results for estimating the impact of house price imbalances on economic growth. In the final section, Section 6, we summarise the findings.

2. Related literature

2.1. Literature on the long-term determinants of house prices

There are two main approaches within the framework of time-series econometrics to investigating the determinants of house prices. One approach is to investigate the effects of various shocks on the short-term dynamics of house prices and other economic variables. The standard method is to use vector autoregressive (VAR) models and estimate the impulse response functions of the variables of interest; see among others the factor VAR model of Beltratti & Morana (2010) for the G7 and some additional euro area countries, the structural VAR model of Musso et al. (2011) for the US and euro area countries, the panel VAR model of Goodhart & Hofmann (2008), or the structural VAR model of Tsatsaronis & Zhu (2004) for 17 industrial countries. These studies explain the short-term fluctuations of house prices using mainly economic and financial variables such as GDP, bank credit, money and inflation. Aastveit and Anundsen (2018) use data on US metropolitan areas and the local projection

method and find that the effects of a monetary policy shock on house prices are asymmetric and depend on the elasticities of the housing supply.

Another strand of literature investigates the determinants of the long-term movements of house prices, focusing on the fundamental economic factors that co-move with house prices. This approach estimates cointegrating models to identify the long-term relationship between house prices and their determinants. A comprehensive overview of the studies that cover the period before the 2008-2009 recession is provided by Girouard et al. (2006). They present the results for studies on different countries, most of which focus on one country and use vector error correction models (VECM). Three main fundamental factors that determine long-term equilibrium house prices are the housing stock, real disposable income, and the real interest rate. A rise in income increases demand from households for housing, pushing house prices up. The real interest rate is used as a proxy for the user cost of housing, where a higher interest rate lowers the demand for housing. The housing stock is used to account for the supply side, where a larger stock puts downward pressure on prices. Girouard et al. (2006) present the estimated elasticities of the three fundamental factors in different studies. The elasticities vary substantially across the studies; the elasticity of real disposable income is found to be in the range of 1% to 3%, the elasticity of the housing stock is between -1% and -4%, and the elasticity of the real interest rate is mostly in the range of -2% to -6%.

A more recent work by Anundsen (2019) assesses whether the housing market experienced a boom in the US, Norway and Finland in the 2000s, and uses four different approaches, one of which is the deviation of house prices from the fundamental prices. Anundsen (2019) obtains similar results when using the different approaches, finding that the US experienced the boom while Norway and Finland did not. He estimates the fundamental value of housing separately for each country with a recursive cointegrated VAR, using data for the US for 1975Q1-2014Q4, for Norway for 1986Q1-2014Q4 and for Finland for 1986Q1-2011Q4. Interestingly, Anundsen (2019) finds a much stronger long-term relationship between house prices and fundamental factors for Finland and Norway than for the US, and the estimated coefficients of the fundamental factors for Finland and Norway are in a higher range than those from the studies provided by Girouard et al. (2006). However, similar conclusions from different models suggest that the findings about over or undervaluation are robust to the choice of model.

Among the studies that use a panel of countries, Gattini & Hiebert (2010) estimate long-term equilibrium house prices for the euro area countries using data from 1970-2009. They use a VECM model to analyse the response of house prices to shocks that originate from changes in the fundamental factors. They estimate the elasticity of real house prices to real disposable income to be 3.1%, to the real mixed interest rate, which is the weighted average interest rate of government bonds and the short-term interest rate, to be -6.9%, and to real residential investment to be -2.2%.

A recent paper by Geng (2018) estimates house price imbalances for OECD countries in 1990Q3-2016Q4. The author estimates cointegrating relationships using a panel model with country fixed effects. The main long-run determinants of real house prices are disposable income, the real mortgage interest rate, housing stock per capita, and real household net financial wealth per capita. Geng (2018) also investigates institutional and structural factors, such as the long-run price elasticity of the housing supply, tax incentives for mortgage financing and home ownership, and rent controls. Geng (2018) estimates the elasticity of real disposable income to be 1.5-1.7%, the semi-elasticity of the real mortgage rate to be between -1.8% and -2.8%, and the elasticity of the housing stock to be -1.3%. Net financial wealth exhibits a marginal impact on house prices.

Estimated house price misalignments have been used for several purposes in the literature. Gao et al. (2009) investigate the properties of the house price misalignments in the US states in 1979-2006 using an autoregressive mean reversion model. They find downward price rigidity in the housing market and find that house prices in cyclical markets tend to have larger price cycles. Zhu et al. (2017) focus on the determinants of non-fundamental house price movements, more specifically on the effect of monetary policy and the structure of the mortgage market on the deviations of house prices from their fundamentals. They first estimate the fundamental values for each country separately using ordinary least squares (OLS) for the period 1992Q1-2012Q4, and they use the residual of the first-step equation to assess how different policy measures affect house prices with a panel VAR model. We use the estimated misalignments to investigate how the imbalances impact economic growth.

2.2. Literature on the linkages between house prices and economic growth

There are several ways that the dynamics of the housing market may be linked to the real economy. The literature points mainly to channels that are related to household consumption choices. The channel most commonly identified in the literature is the wealth effect channel, implying that a rise in house prices increases the wealth of households, and that in turn increases household consumption (Case et al. 2005, Carroll et al. 2011). Additionally, a rise in house prices increases the collateral value of credit constrained households, allowing them to borrow for consumption. This channel is called the collateral effect (Aoki et al. 2002, Aron et al. 2012). There is also evidence that rising house prices stimulate the construction industry and the real estate sector, and Girouard et al. (2006) point to the positive relationship between housing investment and profitability during periods of growth. Increasing employment and wages in construction cause an income effect and feed positively into the economy (Caldera & Johansson 2013, Byun 2010). Case and Quigley (2008) find that the largest direct effect on economic activity comes from the construction sector.

Empirical evidence confirms overall that house prices impact the economy positively through all three channels. The co-movement of house prices and economic activity is well established in the literature, see Igan et al. (2011) among others. Nyakabawo et al (2015) use US data from 1963-2012 to show that the causality mainly runs from real house prices to output.

Many papers focus on the determinants of house price dynamics, and they also show how shocks to house prices feed into real activity. Goodhart and Hofmann (2008) use data for 17 industrial countries from 1970-2006 and a fixed effects panel VAR. They find a positive GDP response to house price shocks and the effect is stronger during a more recent sample period. Beltratti and Morana (2010) focus on the US and the euro area and explore the relationship between house prices and economic activity using data from 1980-2007 and an F-VAR model. Like Goodhart and Hofmann (2008), one of the results they get is a positive response of GDP to a global house price shock. Elbourne (2007) investigates how changes in house prices affect output through consumption in the UK and Giuliodori (2005) does the same for eight European countries, and they both find that a decline in house prices leads to a decline in consumption. Gustafsson et al. (2016) show that a drop of 20% in house prices in Sweden would cause a decline in consumption and employment.

The literature has investigated the short-term effects of house prices on economic activity, confirming that they have a positive effect on real activity. However, there are two research gaps that can be identified. First, changes in fundamental house prices and misalignments in house prices may affect the economy in different ways. The over or undervaluation of house prices can cause economic resources to be allocated inefficiently. House price booms attract investment and labour into real estate at above the long-term optimal level.

Second, the long-term effects of imbalances are different from the short-term effects. Gao et al (2009) use house price data for US cities, metropolitan statistical areas, and divisions from 1980-2006, and they find that it is common that house prices deviate from the fundamental price but then tend to overshoot when they revert to it, so that actual house prices cross the fundamental price. Cerutty et al. (2017) analyse more than 50 countries from the 1970s to 2012, and find that two-thirds of housing booms ended with an economic recession.

One channel for this works through the financial sector. If housing is overvalued, the decline in house prices may leave households with negative net wealth, one consequence of which is a default that then feeds into the real economy. Mian et al. (2015) show that foreclosures are related to a fall in residential investment and consumer demand.

Another channel works through the inefficient allocation of resources. The cost of capital and the allocation of labour after the bursting of house price booms lowers the prospects for the economy. A further side-effect of the increased employment in the construction industry that comes in a construction boom is a higher rate of drop-outs from school (Aparacio & Fenoll 2010) and lower college enrolment (Charles et al. 2015). Lower levels of education reduce the

productivity of employees and may be a longer-term negative effect from housing booms on the economy.

To the best of our knowledge, there is only one paper that distinguishes between fundamental house prices and house price imbalances when investigating the effect on economic growth. Miller et al. (2009) explore the effect of house prices on the US metropolitan statistical areas in 1980Q1-2008Q2, distinguishing between predictable and unpredictable house prices. The predictable house prices are the fundamental prices predicted by the dynamics of the fundamental factors. They estimate a panel model with fixed effects and common correlated effects (CCE) estimators to draw inferences on the changes in per capita gross metropolitan product (GMP) caused by contemporaneous changes in predictable and unpredictable house prices, while controlling for median household income, population, the unemployment rate, and permits for family houses. Miller et al. (2009) explain the effect of predictable house prices on GMP as a collateral effect and the effect of the unpredictable component of house prices on GMP as a wealth effect. They find that both price components have a positive effect, but the effect of the changes in the predictable house price is three times stronger than the effect of the changes in the unpredictable house price.

There are no studies focusing on European countries that distinguish between fundamental house prices and house price imbalances when investigating their impact on real economy. Miller et al. (2009) estimate the contemporaneous effect, and to the best of our knowledge there is no literature that explores the long-term effects.

3. House price misalignments

3.1. Methodology

We are interested in the long-run relationship between real house prices and the fundamental determinants and in finding the gap between the actual house price and the house prices justified by fundamentals. We have to bear in mind that data are available for a large set of European countries for only quite a short time period. For the sample estimated in this study, the residential property price index, a proxy for housing prices, and the mortgage interest rate are available from 2005Q1. As the data are limited, we use a single equation panel model to estimate the long-term relationships between the variables, as the short-term deviations are beyond the scope of this exercise.

A parsimonious set of the determinants of real residential property prices is used in the long-term equation, as in Anundsen (2019) and Gattini & Hiebert (2010). We use the variables conventionally employed in the literature as the main fundamental factors of the house prices, as was described in Section 2. Compensation of employees captures the disposable income of

households, the mortgage interest rate is a proxy for the user cost of housing, and the number of dwellings is used to quantify the housing supply.

As the baseline model, we use the weighted dynamic OLS (DOLS) extended to a panel setting of Chiang (2000), Mark & Sul (1999, 2003), and Pedroni (2000). The model consists of a single cointegrating regression equation:

$$\tilde{y}_{it} = c_i + \tilde{X}'_{it}\beta + \sum_{j=-q_i}^{r_i} \Delta\tilde{X}'_{it+j}\,\delta_i + \tilde{v}_{it} \tag{1}$$

where the dependent variable $\tilde{y}_{it}$ is a housing price index and the vector of explanatory variables $\tilde{X}'_{it}$ contains the detrended data for income, the interest rate and the housing stock. Lags and leads of the explanatory variables ΔX_{it} eliminate the asymptotic endogeneity and serial correlation. The coefficients δ_i of the short-term dynamics are allowed to be cross-section specific, while the model allows for heterogeneity in the long-run variances. A country-specific constant term, c_i, captures the time invariant country-specific characteristics that explain the different levels of house prices across the countries. We assume that the long-term relationship between house prices and income, the interest rate and the housing stock is similar for all the European countries, while the short-term dynamics may be different. The assumption is reasonable given that the European countries are operating in a similar economic and financial framework in the EU, and that the markets of the EU countries are integrated.

The estimations are carried out in the following steps. First, the model is estimated for the panel of European countries with weighted DOLS. The estimation provides the long-term relationship of the residential property price index and the fundamentals. Second, the fitted values related to the long-term dynamics are calculated for each country using the estimated coefficients of $\tilde{X}'_{it}$ from the DOLS model and the country-specific constant. The fitted values of the house prices are based on the underlying economic fundamentals. Third, the gaps between the actual prices and the fitted values are the misalignment of residential property prices from the estimated fundamental values. Misalignments can be related to other non-economic factors such as the credit supply, household expectations or demand shocks, but the response of house prices to the changes in these variables is expected to be short-term and the prices will eventually tend to converge towards the fundamental value.

We also use fully-modified OLS (FMOLS), which is a non-parametric alternative to DOLS. The literature suggests that DOLS is superior to FMOLS (Kao & Chiang 2001), especially in small samples (Pedroni 2001), although asymptotically they are shown to provide similar results.

3.2. The data

We use data for twenty EU countries for the period 2005Q1-2018Q4. In the baseline model we use data on the real residential property price index, compensation of employees[2], the real mortgage interest rate, and the housing stock per thousand inhabitants. The main constraining variables are the mortgage interest rate and the housing stock, as these are not available before 2005Q1 for around half of the countries in the sample. The mortgage interest rate is not publicly available for Czechia, Denmark, Great Britain, Croatia, Lithuania or Sweden and we use instead the long-term interest rate from the 10-year government bond yield. The interest rate is measured in per cent.

There are twenty countries in the baseline sample: Austria (AT), Belgium (BE), Cyprus (CY), Czechia (CZ), Germany (DE), Denmark (DK), Estonia (EE), Spain (ES), Finland (FI), France (FR), Great Britain (GB), Greece (GR), Croatia (HR), Ireland (IR), Italy (IT), Lithuania (LT), Malta (MT), the Netherlands (NL), Sweden (SE), and Slovenia (SI). All the variables are in real terms. Quarterly variables are seasonally adjusted with X13 ARIMA-SEATS, while the annual data for the stock of dwellings and population are converted into quarterly data using cubic spline interpolation. The full list of the variables used in the model, the sources of the data and the data transformation are provided in Table A.1 in Appendix A and summary statistics are provided in Table A.2.

Figure 1 shows the dynamics of the residential property prices of the countries in the sample. The dynamics of the housing prices in the European countries observed vary quite widely. While housing prices were growing in a stable way in some countries, like Austria, Belgium, Germany, Finland or Sweden, other countries had pronounced booms and busts in the housing market. This pattern can be seen in Cyprus, Denmark, Spain, Ireland, Estonia, and Lithuania. In Italy, Croatia, and Slovenia housing prices have declined from the beginning of the sample period.

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[22] The standard variable to use in the literature is household disposable income. As disposable income is not publicly available for all the sample countries, like Cuestas (2017) we use instead compensation of employees, which is available from Eurostat. The variable includes taxes and social contributions on wages. Additionally, we use total compensation of employees rather than per capita. Given that income is not distributed equally, the role of the upper tail of wage earners in total compensation of employees is larger, and the demand for housing usually originates from the upper tail of wage earners, total compensation of employees captures better the purchasing power of the segment that determines housing demand
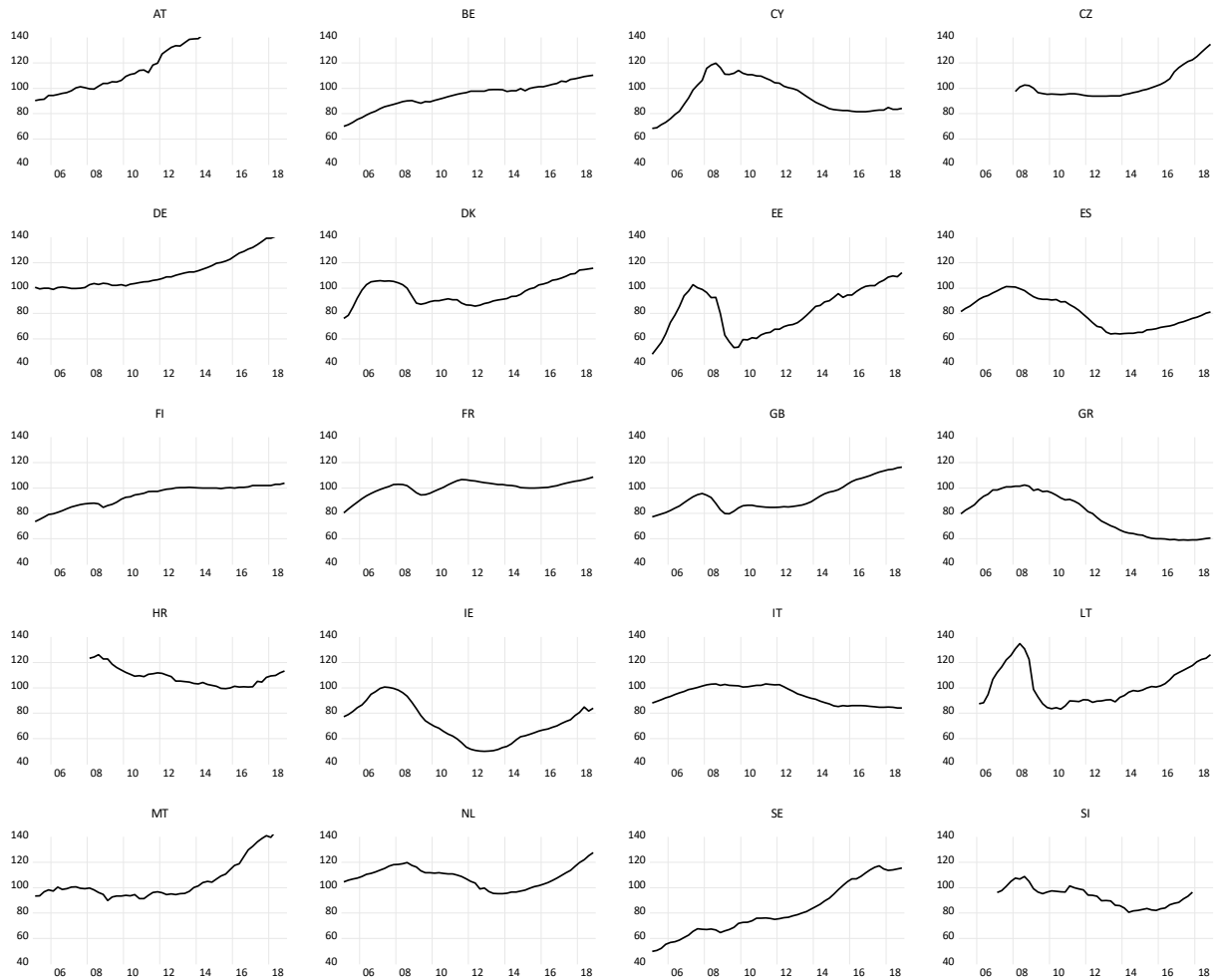
Figure 1. The dynamics of real property price index for 20 European countries

We have confirmed the existence of cointegrated relationships using the Kao (1999) panel cointegration test. We have shown that the p-value of the test is 0.0106, which rejects the null of no cointegration.

4. The estimations of the house price model

4.1. Model estimations

Table 1 provides the estimated coefficients for the long-term equation in the baseline model in Column (1) and alternative model specifications in Columns (2) – (6).

Table 1. Estimated long-term coefficients from the panel DOLS model.

Variable	(1) DOLS (baseline)	(2) DOLS (MIR)	(3) DOLS (LTIR)	(4) DOLS (core)	(5) DOLS (pooled)	(6) FMOLS (pooled)
Compensation	1.180***	1.339***	1.113***	1.219***	1.141***	1.198***
	(0.041)	(0.051)	(0.048)	(0.071)	(0.073)	(0.077)
Interest rate	-0.005***	-0.007***	-0.006***	-0.008**	-0.003	-0.012***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)
Dwellings	-1.724***	-2.018***	-1.647***	-2.002***	-1.797***	-1.688***
	(0.079)	(0.163)	(0.078)	(0.213)	(0.139)	(0.169)
Adj. R^2	0.86	0.90	0.87	0.84	0.86	0.73
No of groups	20	15	19	9	20	20
No of obs.	790	549	737	386	790	819

Notes: Dependent variable is the log of the Real Property Price Index. Baseline model in Column (1) and models in columns (2), (3), and (4) are estimated with pooled weighted Dynamic OLS (DOLS). Compensation is compensation of employees, and dwellings is the number of dwellings per capita. In the baseline model, the real mortgage interest rate is used (MIR), or if it is not available, the real long-term interest rate (LTIR) is used. In columns (2) and (3), the MIR and LTIR are used respectively; the sample varies because of data availability. In Column (4), only nine core European countries are included in the sample. The estimations in Column (5) are done with pooled DOLS, and in Column (6) with Fully-Modified OLS (FMOLS). The number of leads and lags in the models estimated with DOLS is detected endogenously with the Akaike criterion. Robust standard errors (Newey-West fixed) are reported in round parentheses below the coefficient estimates. Superscripts ***, ** and * indicate that the coefficient is statistically different from 0 at the 1%, 5% and 10% level respectively.

According to the baseline model, when compensation to employees increases by 1%, residential property prices rise by 1.18%. An increase of one percentage point in the real interest rate lowers house prices by 0.5% and an increase of 1% in the number of dwellings lowers house prices by 1.72%. The standard errors reflect the uncertainty around the point estimates. The results we obtain are in the lower part of the range from other studies; see the discussion in subsection 2.1. The estimated coefficient for the real interest rate is smaller than it is in the previous literature, and this apparently comes from including the period of low interest rates in the sample, which has resulted in house prices showing low sensitivity to the interest rate.

In columns (2) and (3) in Table 1 we provide the results for the estimations with only the mortgage interest rate and with only the long-term interest rate. Although the sample varies in response to the availability of the data on interest rates, the estimated coefficients are comparable. The estimated coefficients are slightly larger in the model with the mortgage interest rate, but on the whole they are the same as in the baseline model.

Our results are similar to those of Anundsen (2019) for the US. Adams & Füss (2010) and Zhu et al. (2017) estimate the fundamental house prices for each euro area country separately, the first study for the period 1975Q1-2007Q2 and the second study for the period 1992Q1-2012Q4. The estimated coefficients in both studies vary substantially across countries, and in some cases have different signs for different countries. Adams & Füss (2010) estimated DOLS for a longer

time period than we do in our study, but their sample ends before the 2008-2009 recession. Zhu et al. (2017) also use observations from after the recession but their methodology is different to ours as they estimate OLS with four lags of the fundamentals and they report the accumulated effect of each fundamental factor. This means that the results are not one-to-one comparable with the long-term relationship between house prices and fundamentals found in this paper.

Kiss et al. (2006) point out that the convergence process in the Eastern European countries makes it more difficult to calculate misalignments of credit growth. A similar argument may hold for house prices, which have experienced long-term convergence to the steady-state level of European countries. Hence for robustness purposes we use the same approach as in Kiss et al. (2006), who estimate the coefficients of long-term determinants from a model that includes advanced European countries. The estimated coefficients from the model with only European core countries in column (4) are similar for the compensation of employees in the baseline model but slightly larger for the interest rate and for dwellings. However, the differences are not statistically significant. We have also run estimations for various sub-samples of countries and the results are largely similar (not reported), indicating that the results are not sensitive to the inclusion of converging countries.

For robustness analysis we also test other model specifications. We replace the explanatory variables one-by-one with alternative ones. We use real GDP as a proxy for disposable income, the nominal mortgage interest rate instead of the real interest rate, and the replacement cost of dwellings instead of the number of dwellings. All the models provide relatively similar coefficients with the expected signs (not reported). We ran additional estimations with pooled DOLS instead of weighted DOLS and pooled FMOLS (see Columns (5) and (6) respectively), confirming that the estimated coefficients are robust to different model specifications.

4.2. Fundamental house prices

The contribution of each fundamental factor to the change in the long-term fitted value is shown in Figure 2. The line shows the annual growth rate of the fitted value based on the estimated baseline model, as seen in Table 3 Column (1), while the bars provide the contributions of each fundamental variable to the annual growth in the fitted value.

The decomposition of the fitted values reveals that the main driver of the fundamental house prices is income. This has a pronounced effect on the changes in the fitted values in all the countries in the sample, driving the fundamental house prices up when income increases and driving them down when income drops.
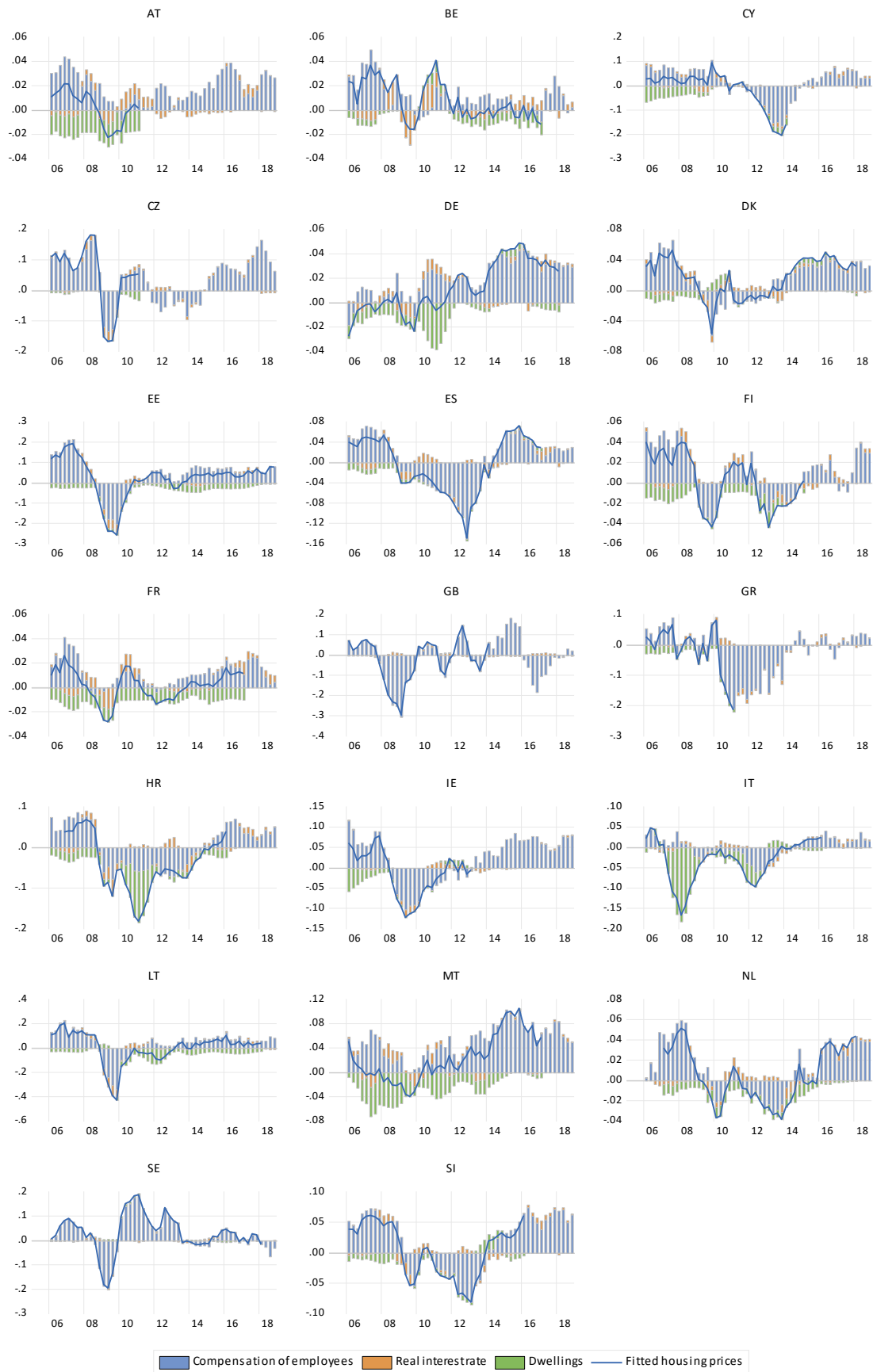
Figure 2. Contribution of the compensation of employees, the real interest rate and the housing stock to the annual growth rate of fundamental house prices (in per cent). Estimations from the baseline model in Table 1 Column (1).

In Austria and France, the changes in the supply of dwellings have contributed considerably to the movements of housing prices, holding back a rise in house prices that would otherwise have been larger. In Germany, Italy, and Malta the supply of dwellings has also contributed considerably to house prices but only during the period before the 2008-2009 crisis. The supply of dwellings contributed in Croatia to the drop in housing prices at the time of the crisis. An abrupt drop in the housing stock per capita in Lithuania in 2011-2012 drove house prices up somewhat.

The interest rate fluctuated much more than the supply of housing during the sample period, but the interest rate plays only a marginal role in the dynamics of fundamental house prices. The only period when the contribution of the interest rate to house prices is visible in almost all the countries in the sample is 2008-2009, when the real interest rate rose because of the falling inflation. During 2008-2009 the interest rate contributed to the decline in house prices. However, the decline in real interest rates in recent years has made a negligible contribution to the rise in house prices.

4.3. House price misalignments

Figure 3 shows the dynamics of the actual price movements for residential property and the fitted values from the baseline model for the long-term relationship between house prices and fundamentals; for the difference between actual prices and fundamental prices see Figure A.1 in Appendix A. A positive gap reflects an overvaluation of residential property prices given the movement of the fundamental variables, and a negative gap suggests prices are undervalued from the fundamental house price value.

As with the housing prices in Figure 1, the dynamics of the overvaluations are quite different to those of the undervaluations in our sample. The actual prices and fitted values in Belgium, Germany, Greece, Croatia, and Lithuania move very close together throughout the sample period, which suggests that the developments in the housing markets in those countries are balanced, and the growth of real property prices is supported by the fundamental factors. A similar pattern can be seen in two Scandinavian countries, Sweden and Finland, with the only difference that housing prices there are more volatile than in the countries in the first group.

In Denmark, Estonia, Spain, France, Ireland, and the Netherlands, the housing prices were considerably overvalued before the financial crisis and are undervalued or fairly valued at the end of the sample period. House price booms occurring before the 2008-2009 recession have been noted in several studies; see Gimeno and Martinez-Carrascal (2010) and Cuestas & Kukk (2020b) for Spain, Drudy and Collins (2011) and Norris and Coates (2014) for Ireland, and

Cuestas & Kukk (2020a) for Estonia. A negative gap in housing prices in 2014-18 can be also seen in Italy and Slovenia.
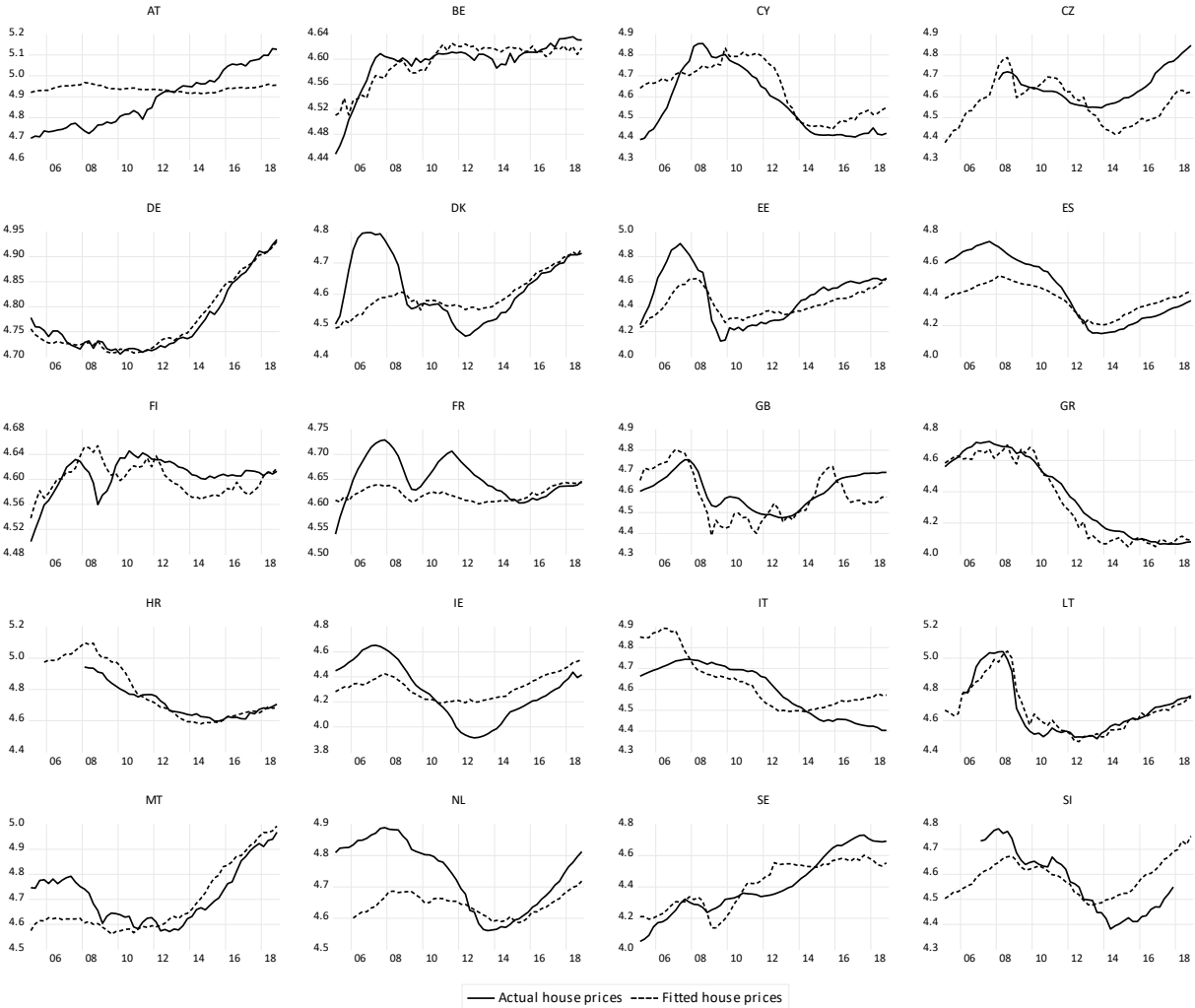

Figure 3. Actual RPP index versus fitted values from the baseline model (Table 1, Column 1) with extrapolated time series for dwellings.
Notes: The model is estimated using available data on dwellings; when computing fitted values, extrapolated data on dwellings are used.

The largest positive misalignments are observed in 2006-2007 in Estonia, where they vary between 6% and 7% of the house price index, while they are a little smaller in magnitude in Ireland and Spain. The average positive gap between house prices and fundamental value in Spain before the financial crisis is around 5.5% of the house price index, while in Ireland it is almost 6%. The largest negative gaps are detected in Ireland in 2012-2014, at around -7%, and in Cyprus in 2005 at around -5%. The largest average positive gaps over the whole sample period are in the Netherlands at 1.9% and in Czechia at 1.5%; the largest average negative gaps are in Cyprus at -1.4% and Austria at -1.1%. House prices in Finland, Sweden, Lithuania, Belgium, and Germany are on average neither overvalued nor undervalued.

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The misalignments follow the business cycle to a large extent, being positive when economic conditions are good and negative during economic slowdowns; see Figures A.2 and A.3 in Appendix A. The link between misalignments and business cycles is more pronounced when the fluctuations in the economy are large in magnitude, as they were in the Baltic states and Ireland, and to some extent in Spain.

5. House price misalignments and economic growth

5.1. Empirical model

In order to analyse both the short-term effect of house price misalignments on economic growth and their long-term relationship, we estimate a growth equation using an autoregressive distributed lag (ARDL) model with the pool mean group (PMG) estimator, proposed by Pesaran, Shin and Smith (1999) (PSS). The equation, which is estimated using quarterly data, can be expressed as follows:

$$\Delta y_{i,t} = EC_{i,t}\phi_i + \sum_{j=0}^{q-1} \Delta X_{i,t-j}{}'\beta_{i,j} + \sum_{j=1}^{p-1} \Delta y_{i,t-j}\lambda_{i,j} + \epsilon_{i,t}, \qquad (2)$$

where

$$EC_{i,t} = y_{i,t-1} - X_{i,t}{}'\theta \qquad (3)$$

This implies that the dynamics $\beta_{i,j}$ and $\lambda_{i,j}$ and the adjustment coefficients ϕ_i are idiosyncratic, while the long-run parameters θ are common. This is a valid assumption given the integrated economic and financial framework in the EU.

The PMG estimator is obtained from maximising a log-likelihood function with respect to the long-run coefficients and the adjustment coefficients. From this, PSS derive the following log-likelihood function:

$$l_t(\varphi) = -\frac{T_i}{2}\sum_{i=1}^{N} \log(2\pi\sigma_i^2) - \frac{1}{2}\sum_{i=1}^{N}\frac{1}{\sigma_i^2}(\Delta Y_i - \phi_i EC_i)'H_i(\Delta Y_i - \phi_i EC_i), \qquad (4)$$

where

$$H_i = (I_{T_i} - W_i(W_i{}'W_i)^{-1}W_i{}')^{-1} \text{ and } W_i = (\Delta Y_{i,-1}, \dots, \Delta Y_{i,-p+1}, \Delta X_{i,-1}, \dots, \Delta X_{i,-q+1}) \qquad (5)$$

As local policies may induce different short-term dynamics, it is reasonable to allow more flexibility in the short-term estimations in the model.

The ARDL model allows us to distinguish between the short-term effect and the long-term relationship of the variables, while also taking account of the endogeneity of the variables by including leads and lags of the first differences of the regressors (see PSS for more details on the issue of endogeneity in ARDL models). Moreover, the advantage of the ARDL model is its

flexibility in using stationary and non-stationary variables in the same model. This means that a mixture of the I(1) and I(0) variables may be included in the model and doing so does not compromise the testing, and PSS provide the corrected critical values for different combinations of the I(1)/I(0) variables.

We use the growth model in the spirit of King & Levine (1993) that has been used extensively in the literature on finance and economic growth; see among others Beck et al. (2000), Beck et al. (2014), Hasan et al. (2009), and Rousseau & Wachtel (2011). We use the following variables in the growth model: real GDP per capita, *gdppc*, as the dependant variable; tertiary education, *edut*, to capture the human capital; gross fixed capital formation as a proxy for investment, *gfcf*; openness from the sum of exports and imports as a share of GDP, *opn*; and house price misalignments defined as the difference between the actual house prices and the fundamental value estimated in the previous section for each country, *misal*.

The data are quarterly. All the variables are in logs. See the names of the variables and the data sources in Table A.3 and summary statistics in Table A.4 in Appendix A.

5.2. Results

The PMG equation is estimated using a model with a maximum of four lags for each variable and the optimal model is chosen by means of the Akaike information criterion. The final model is presented in Table 2.

Table 2. PMG estimates for economic growth

(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Short-run		
Long-run		Lag	t	$t-1$	$t-2$	$t-3$
edut	0.729***	Δ *edut*	-1.002*	2.242**	-1.775***	
	(0.081)		(0.616)	(1.076)	(0.697)	
gfcf	0.168***	Δ *gfcf*	0.054***	0.047**	0.043**	
	(0.046)		(0.020)	(0.019)	(0.020)	
misal	-0.124**	Δ *misal*	-0.020	0.070*	0.110**	
	(0.058)		(0.023)	(0.037)	(0.051)	
opn	-0.393***	Δ*opn*	0.109***	0.089***	0.045**	
	(0.093)		(0.041)	(0.026)	(0.020)	
		Δ *gdppc*		-0.053	-0.034	0.062
				(0.066)	(0.053)	(0.039)
		EC		-0.076**		
				(0.030)		

Note: Dependent variable is real output per capita. Superscripts ***, ** and * indicate that the coefficient is statistically different from 0 at the 1%, 5% and 10% level respectively. The values in parentheses are standard errors. Since the coefficients for the short-run are country-specific, in columns 4-7 we present the average coefficients.

We have tested the order of integration of the residuals of the ARDL-PMG model in Table 2 and found that they are stationary; we have estimated the roots of the companion matrix and found that they satisfy the stability condition; and we have run standard panel unit root tests and found that there is cointegration between the variables. These tests would satisfy the main assumptions in Pesaran et al. (1999, 2001) and guarantee that there is a long-run condition relationship between the variables.[3]

We observe that the error correction term is negative and significant, which is a sign that the variables are cointegrated. The coefficient -0.076 means that on average about 7.6% of the deviation is corrected in every quarter, which means that the effect of the shock vanishes in about three years.

We find from the long-term estimates that education has a positive sign as does investment, which is expected, whereas misalignments and openness have a negative sign. The size of the long-term coefficients imply that education has a primary effect on growth in these countries. The negative sign of the misalignments implies that the more misaligned the house price is with fundamental house prices, the more harmful it will be for GDP in the long run.

As discussed in subsection 2.2, there are several mechanisms through which house price misalignments hamper economic growth. Housing prices being higher than fundamentals would imply there is an excess of indebtedness, which can trigger a Fisher deflation effect. This means that as the amount of debt becomes unbearable, more home owners and banks with repossessed properties are forced to sell those properties, pushing housing prices downwards.

The negative sign for openness may be caused by an excess of imports over exports, which can affect the current account in the long term. This result is compatible with other works such as Cuestas et al. (2020).

When we look at the dynamics, we observe that education has a high marginal effect on economic growth that is not surprising, given that human capital is built gradually. We also find that the overall short-run effect of investment and openness is positive. This means overall that although openness may overshoot economic growth in the short run giving a positive sign to the dynamic coefficients, in the long run the effect on GDP is negative because of the high dependence on imports. Finally, house price misalignments have a positive effect on economic growth through the wealth effect and the collateral effect, and through the construction sector, as described in subsection 2.2.

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[3] Results available on request.

5.3. Robustness: results from the local projection method

We use an alternative model to estimate the response of GDP growth to the changes in house price misalignment. We use the local projection method (LPM) introduced by Jordà (2005) to estimate the cumulative response of GDP growth to house price misalignments. LPM has been used as an alternative to VAR models in the literature when yearly data are used and the focus is on one specific response; see the studies by Jordà et al. (2013) and Jordà et al. (2015) that investigate the effect of credit on economic growth using LPM.

To capture not only the short-term dynamics but also the longer-term response after several years, we use yearly data in the following equation[4]:

$$\Delta_h GDP_{it+h} = \alpha_i + \sum_{l=1}^{L} P_{h,l} \Delta GDP_{it-l} + \sum_{l=0}^{L} \Gamma_{h,l} \Delta X_{it-l} + \sum_{l=0}^{L} \Pi_{h,l} misal_{it-l} + u_{h,it} \, , \quad (6)$$

where $\Delta_h GDP_{it+h} = GDP_{it+h} - GDP_{it}$, the vector X contains the same explanatory variables as the model in subsection 5.1, and α_i is a country i specific effect. We use the projection horizon $h = 0, 1, .., H$ up to six years and two year lags $l = 1, 2$. As we are using yearly data, we assume that GDP responds immediately to the change in misalignment in the concurrent period. We use two lags that cover two years as the results are similar with a larger number of lags, but having more lags shortens the time dimension of the panel. As the yearly time span is quite short, we keep the number of lags as small as is reasonable.

Impulse response functions (IRF) show the cumulative response of GDP growth to the changes in house price misalignments after controlling for other regressors. We use stationary variables in the model and allow for the contemporaneous effects.

Equation (6) estimates the conditional path for the accumulated response of GDP growth, meaning that we estimate the response that is related to the changes observed in house price misalignments in the previous quarters, while controlling for GDP changes in previous periods and for investment, education level and openness.

Panel (a) of Figure 4 exhibits the impulse response functions to a change of 1sd in misalignment[5]. It shows that GDP responds marginally positively to the increase in misalignment. Although the positive response is statistically not significant, it mirrors the short-term results from the ARDL model. After two years the response turns negative and, like in the results for the long-term equation of the ARDL model, the negative response is significant. Four years after the rise of 1sd in misalignment, GDP growth is 0.3% lower.

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[4] To capture the long-term response using quarterly data we need to use a very long time horizon estimating the response after 24 periods, which results in imprecise estimations. Therefore we convert the quarterly data into annual data, as that allows us to estimate the response after only six periods.

[5] We use within standard deviation, excluding between standard deviation, as this reflects how the misalignment can move over time in the sample countries.

When more explanatory variables are included, such as government spending to control for policy measures or fundamental house prices to control for the co-movement of the two house price components, the results are even more clear, as seen in panel (b) of Figure 4.

The LPM method shows that the long-term negative response of GDP growth is larger than the short-term positive response to house price misalignments, suggesting that the long-term negative impact outweighs the short-term positive one.

The long-term effect of house prices on output can be expected to be non-linear, with larger misalignments having more severe negative consequences. We tested this hypothesis by adding the second term of misalignment in eq. (6) and estimating the responses at different levels of misalignment, with house prices overvalued by 10%, 20% and 30%. The subsequent decline in GDP after four years is more substantial at higher levels of misalignment, but as the standard errors become larger with this model specification, the negative response of GDP is imprecisely estimated (not reported). Longer time periods are needed to investigate non-linearities between house price misalignments and output growth.

Figure 4. Accumulated impulse responses of GDP growth to the 1sd innovation in house price misalignments from the Local Projection Method

Notes: 90% confidence intervals are presented, the intervals are calculated from heteroscedasticity robust standard errors. Tertiary education, investments and openness are included in the model in panel (a) and government expenditure and fundamental house prices are added in the model in panel (b).

The upshot of the ARDL and LPM estimations is that house price misalignments and GDP growth exhibit co-movement in the short-term, suggesting that the misalignments amplify the business cycle, while in the long-term larger imbalances seem to hamper economic growth. As discussed in sub-section 2.2, several papers have pointed out the short-term effect. However, it

is worth emphasising the importance of the long-term effects that are more substantial and ultimately play a bigger role for the economy than the short-term fluctuations. This makes it important to pay attention to the warning indicators of imbalances in housing markets and to take policy measures to avoid large house price misalignments from the fundamental values, as these seem to be a threat to long-term economic growth.

6. Conclusions

The importance of housing markets for the business cycle and the role of the fall in house prices in affecting the severity of the Great Recession have been widely acknowledged in the literature. Monitoring how housing prices evolve has become of paramount importance for both academics and policy makers alike.

The paper contributes to the literature on how house prices affect economic growth. We first estimate misalignments in house prices as deviations from the fundamental value that is obtained from long-term equations based on the fundamental factors of house prices. These factors include income measured as the compensation of employees, the real interest rate, and the number of dwellings per thousand inhabitants. We estimate the misalignments for 20 European countries using data from 2005Q1-2018Q4. Second, we analyse how the misalignments affect economic growth for the same group of countries using panel ARDL estimations.

Our results show that the demand-side factors like income have been the main driver of the dynamics of fundamental house prices, while the supply-side factors such as the supply of dwellings have alleviated the rise in fundamental house prices in the countries and the period analysed. The interest rate plays only a marginal role in the dynamics of fundamental house prices. We also find that the countries in Europe known to have been affected most by the housing bubble, which were Estonia, Ireland and Spain, are the ones that show the largest misalignments in the years before the 2008-2009 recession.

The growth regression reveals that misalignments in housing prices have both short-term and long-term effects. In the short-term, misalignment seems to have a positive effect on GDP by amplifying the business cycle, which confirms the findings of previous literature, while in the long-term it tends to have a negative impact on economic growth. The long-term negative implications of house price misalignments deserve more investigation to understand the mechanisms involved. Our overall results have important policy implications, suggesting that the authorities should use measures to stabilise the evolution of housing prices in order to promote long-term economic growth.

Literature

Aastveit, K. A., & Anundsen, A. K. (2017). Asymmetric effects of monetary policy in regional housing markets. Norges Bank research paper No. 25.

Adams, Z., & Füss, R. (2010). Macroeconomic determinants of international housing markets. *Journal of Housing Economics*, 19(1), 38-50.

Anundsen, A. K. (2019). Detecting imbalances in house prices: What goes up must come down?. *The Scandinavian Journal of Economics*, 121(4), 1587-1619.

Aparicio Fenoll, A. (2010). High-school dropouts and transitory labor market shocks: The case of the Spanish housing boom. IZA Discussion Paper No. 5139.

Beck, R., Georgiadis, G., & Straub, R. (2014). The finance and growth nexus revisited. *Economics Letters*, 124(3), 382-385.

Beck, T., Levine, R., & Loayza, N. (2000). Finance and the Sources of Growth. *Journal of financial economics*, 58(1-2), 261-300.

Beltratti, A., & Morana, C. (2010). International house prices and macroeconomic fluctuations. *Journal of Banking & Finance*, 34(3), 533-545.

Bond, S., Hoeffler, A. & Temple, J., (2001). GMM Estimation of Empirical Growth Models. CEPR Discussion Paper No. 3048.

Byun, K. J. (2010). The US housing bubble and bust: impacts on employment. *Monthly Labor Review*, 133(12).

Caldera, A., & Johansson, Å. (2013). The price responsiveness of housing supply in OECD countries. *Journal of Housing Economics*, 22(3), 231-249.

Carroll, C. D., Otsuka, M., & Slacalek, J. (2011). How large are housing and financial wealth effects? A new approach. *Journal of Money, Credit and Banking*, 43(1), 55-79.

Case, K. E., Quigley, J. M., & Shiller, R. J. (2005). Comparing wealth effects: the stock market versus the housing market. *Advances in macroeconomics*, 5(1).

Case, K. E., & Quigley, J. M. (2008). How housing booms unwind: income effects, wealth effects, and feedbacks through financial markets. *European Journal of Housing Policy*, 8(2), 161-180.

Charles, K. K., Hurst, E., & Notowidigdo, M. J. (2015). Housing booms and busts, labor market opportunities, and college attendance (No. w21587). National Bureau of Economic Research.

Cerutti, E., Dagher, J., & Dell'Ariccia, G. (2017). Housing finance and real-estate booms: A cross-country perspective. *Journal of Housing Economics*, 38, 1-13.

Cochrane, J. H. (2005). Financial markets and the real economy. Foundations and Trends® in Finance, 1(1), 1-101. Publishers Inc.: Hanover, USA

Cuestas, J. C. (2017). House prices and capital inflows in Spain during the boom: Evidence from a cointegrated VAR and a structural Bayesian VAR. *Journal of Housing Economics*, 37, 22-28.

Cuestas, J. C., & Kukk, M. (2020a). The Spanish housing market: is it fundamentally broken?. *Applied Economics Letters*, 27(15), 1295-1299.

Cuestas, J. C., & Kukk, M. (2020b). The interaction between housing prices and housing credit: evidence from a country with rapid credit accumulation. *Journal of Economic Studies*, forthcoming, available at https://doi.org/10.1108/JES-11-2019-0519

Cuestas, J.C., Mourelle, E. and Regis, P. J. (2020). Real exchange rate misalignments in CEECs: Have they hindered growth?. *Empirica,* 47, 733–756

Drudy, P. J., & Collins, M. L. (2011). Ireland: from boom to austerity. *Cambridge Journal of Regions, Economy and Society*, 4(3), 339-354.

Elbourne, A. (2008). The UK housing market and the monetary policy transmission mechanism: An SVAR approach. *Journal of Housing Economics*, 17(1), 65-87.

Hasan, I., Wachtel, P., & Zhou, M. (2009). Institutional development, financial deepening and economic growth: Evidence from China. *Journal of Banking & Finance*, 33(1), 157-170.

Gao, A., Lin, Z., & Na, C. F. (2009). Housing market dynamics: Evidence of mean reversion and downward rigidity. *Journal of Housing Economics*, 18(3), 256-266.

Gattini, L., & Hiebert, P. (2010). Forecasting and assessing Euro area house prices through the lens of key fundamentals. European Central Bank Working Paper No. 1249.

Geng, N. (2018). Fundamental Drivers of House Prices in Advanced Economies. IMF Working Paper WP/18/164

Gimeno, R., & Martinez-Carrascal, C. (2010). The relationship between house prices and house purchase loans: The Spanish case. *Journal of Banking & Finance*, 34(8), 1849-1855.

Girouard, N., Kennedy, M., Van Den Noord, P., & André, C. (2006). Recent house price developments: the role of fundamentals. OECD Economics Department Working Papers, No. 475.

Giuliodori, M., 2005. Monetary Policy Shocks and the Role of House Prices Across European Countries. *Scot. J. Polit. Economy* 52 (4), 519–543

Goodhart, C., & Hofmann, B. (2008). House prices, money, credit, and the macroeconomy. *Oxford Review of Economic Policy*, 24(1), 180-205.

Gustafsson, P., Stockhammar, P., & Österholm, P. (2016). Macroeconomic effects of a decline in housing prices in Sweden. *Journal of Policy Modeling*, 38(2), 242-255.

Igan, D., Kabundi, A., De Simone, F. N., Pinheiro, M., & Tamirisa, N. (2011). Housing, credit, and real activity cycles: Characteristics and comovement. *Journal of Housing Economics*, 20(3), 210-231.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American economic review*, 95(1), 161-182.

Jordà, Ò., Schularick, M., & Taylor, A. M. (2013). When credit bites back. *Journal of Money, Credit and Banking*, 45(s2), 3-28.

Jordà, Ò., Schularick, M., & Taylor, A. M. (2015). Leveraged bubbles. *Journal of Monetary Economics*, 76, S1-S20.

Kao, Chinwa D. (1999). "Spurious Regression and Residual-Based Tests for Cointegration in Panel Data," *Journal of Econometrics*, 90, 1–44.

Kao, C., & Chiang, M. H. (2001). On the estimation and inference of a cointegrated regression in panel data. In Nonstationary panels, panel cointegration, and dynamic panels (pp. 179-222). Emerald Group Publishing Limited.

King, R. G., & Levine, R. (1993). Finance and growth: Schumpeter might be right. *The quarterly journal of economics*, 108(3), 717-737.

Kiss, G., Nagy, M., & Vonnák, B. (2006). Credit growth in Central and Eastern Europe: convergence or boom? (No. 2006/10). MNB working papers.

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and statistics*, 61 (S1), 631-652.

Mian, A., Sufi, A., & Trebbi, F. (2015). Foreclosures, house prices, and the real economy. *The Journal of Finance*, 70(6), 2587-2634.

Musso, A., Neri, S., & Stracca, L. (2011). Housing, consumption and monetary policy: How different are the US and the euro area?. *Journal of Banking & Finance*, 35(11), 3019-3041.

Norris, M., & Coates, D. (2014). How housing killed the Celtic tiger: Anatomy and consequences of Ireland's housing boom and bust. *Journal of Housing and the Built Environment*, 29(2), 299-315.

Pedroni, P. (2001). Fully modified OLS for heterogeneous cointegrated panels. In Nonstationary panels, panel cointegration, and dynamic panels (pp. 93-130). Emerald Group Publishing Limited.

Pesaran, M. H., Shin, Y. and Smith, R. P. 1999. Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, 94: 621–34.

Pesaran, M. H., Shin, Y. and Smith, R. P. 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics,* 16: 289-326

Rousseau, P. L., & Wachtel, P. (2011). What is happening to the impact of financial deepening on economic growth?. *Economic inquiry*, 49(1), 276-28

Tsatsaronis, K., & Zhu, H. (2004). What drives housing price dynamics: cross-country evidence. *BIS Quarterly Review*, March.

Zhu, B., Betzinger, M., & Sebastian, S. (2017). Housing market stability, mortgage market structure, and monetary policy: Evidence from the euro area. *Journal of Housing Economics*, 37, 1-21.
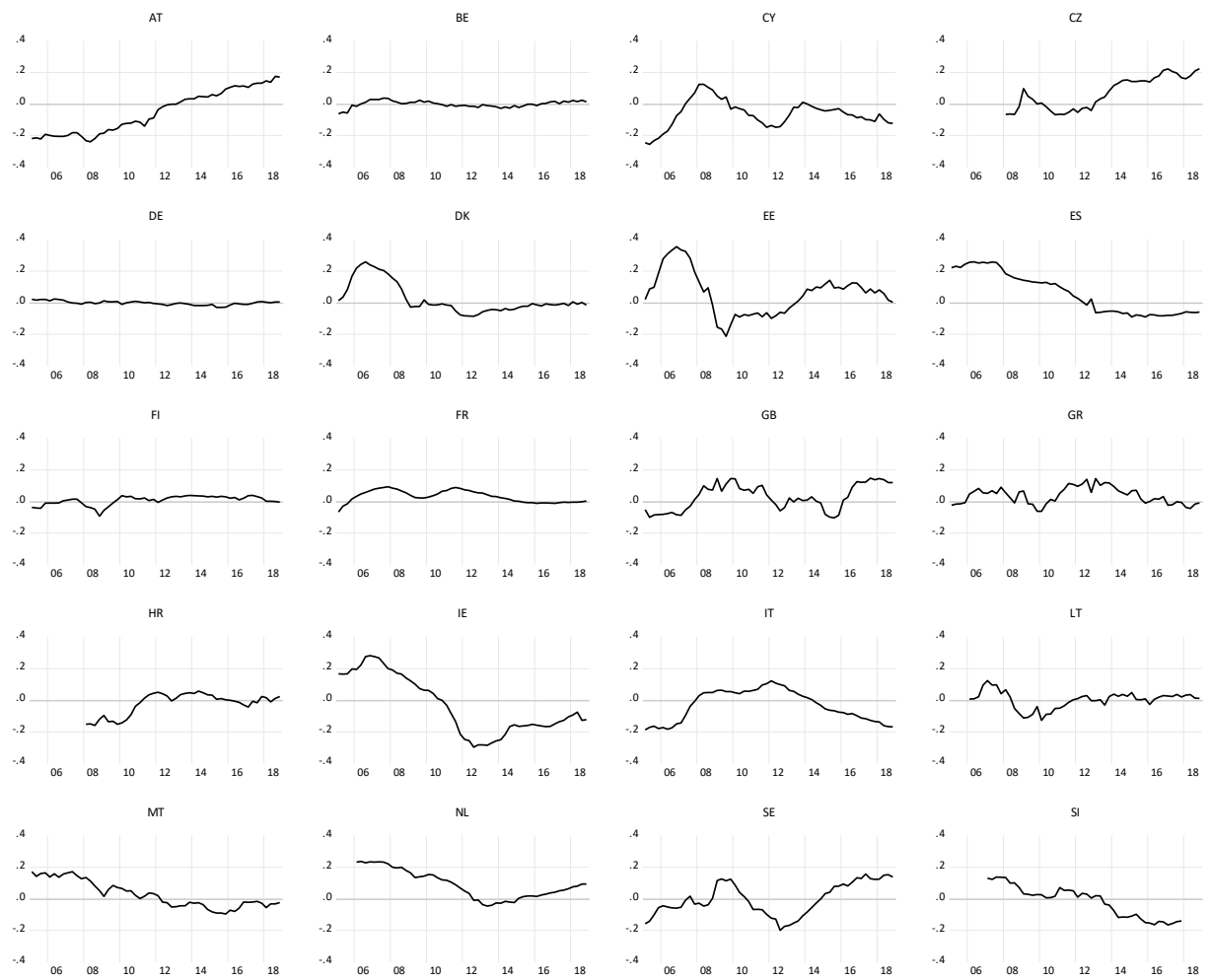
Appendix A

Figure A.1. Misalignments of house prices from the baseline model (Table 1, Column 1)
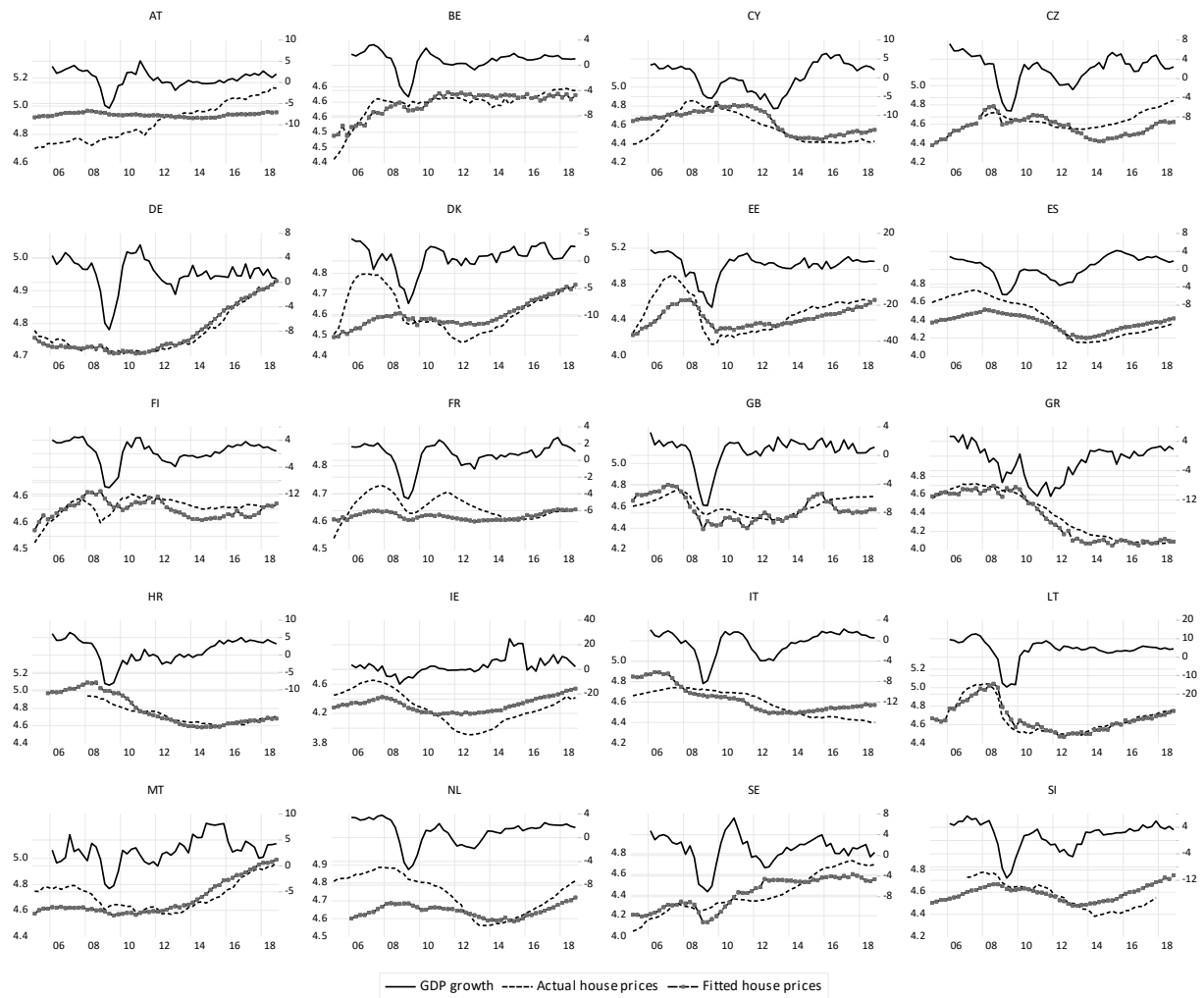
Figure A.2. GDP growth in per cent (right scale) versus the actual RPP index and fitted values from the baseline model (Table 1, Column 1)
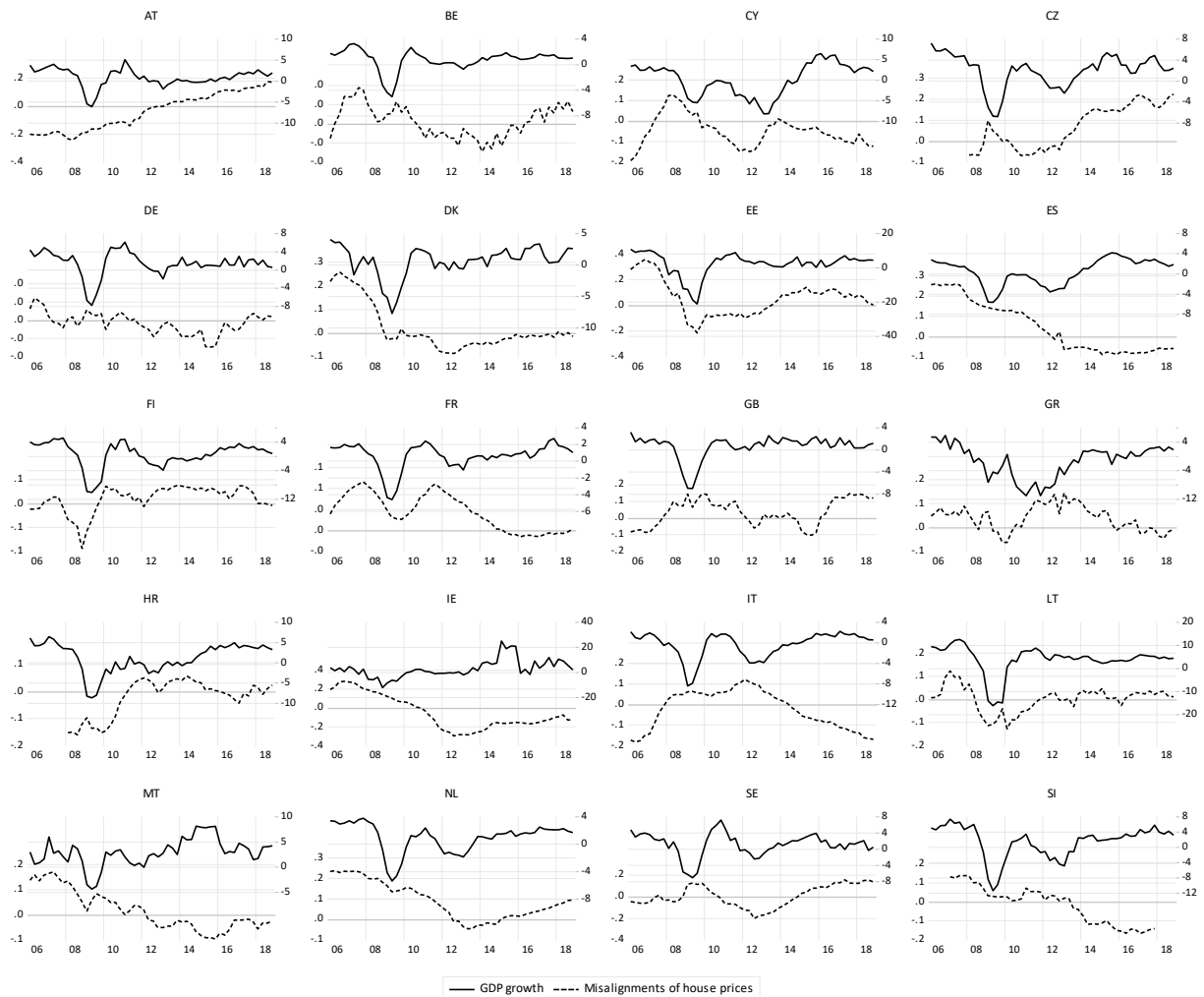
Figure A.3. GDP growth in per cent (right scale) versus misalignments of house prices from the baseline model (Table 1, Column 1)

Table A.1. Variables in the housing prices model

Variable	Variable code	Source
Residential property price index	RPP	ECB, [RPP.Q.CC.N.TD.00.*.00]
Compensation of employees	COMP	Eurostat, [namq_10_gdp]
Mortgage interest rate	RMIR	ECB, [MIR.M.CC.B.A2C.AM.R.A.2250.EUR.N]
Long-term interest rate	RLTIR	OECD (2018), doi: 10.1787/662d712c-ne [CCC.LTINT.TOT.PC_PA.Q]
Housing stock	DWEQP	ECB, [SHI.A.CC.DWEL.A]

Notes: All variables are seasonally adjusted and are in logs excluding interest rates, which are in per cent. Nominal variables are adjusted by year-on-year inflation rate calculated on the basis of the harmonised index of consumer prices, which is seasonally adjusted before being used to transform nominal values into real ones. Monthly interest rates are converted from monthly data to quarterly by simple averaging. Housing stock is adjusted by population (number of dwellings per thousand people) and converted from annual data to quarterly by cubic spline interpolation.

Table A.2. Summary statistics for housing price model variables

Variable	Mean	Median	Max	Min	Std.dev.	Obs.
RPP	4.596	4.621	5.130	3.913	0.202	1080
COMP	10.137	10.275	12.959	6.503	1.738	1120
RMIR	1.623	1.605	6.583	-5.228	1.547	776
RLTIR	1.599	1.275	23.826	-6.690	2.592	1061
DWEQP	6.184	6.195	6.383	5.969	0.096	871

Table A.3. Variables in the growth model

Variable	Variable code	Source
Real GDP per capita	GDPPC	Eurostat, [namq_10_pc]
Misalignments of house prices	MISAL	Authors calculated
Tertiary education (levels 5-8), %population	EDUT	Eurostat, [edat_lfse_03]
Gross fixed capital formation, %GDP	GFCF	Eurostat, [namq_10_gdp]
Export and imports of goods and services, %GDP	OPN	Eurostat, [namq_10_exi]

Notes: All data are in logs. GDP series are seasonally adjusted using X13 ARIMA-SEATS method.
Educational data are transformed into quarterly using cubic spline interpolation.

Table A.4. Summary statistics for the growth model variables

Variable	Mean	Median	Max	Min	Std.dev.	Obs.
GDPPC	8.731	8.890	9.596	7.555	0.459	1120
MISAL	0.010	0.005	0.357	-0.299	0.102	1076
EDUT	3.165	3.261	3.702	2.320	0.336	1400
GFCF	3.054	3.076	4.271	1.962	0.198	1120
OPN	4.629	4.616	5.793	3.833	0.457	1120