BANCA D'ITALIA
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# Questioni di Economia e Finanza

(Occasional Papers)


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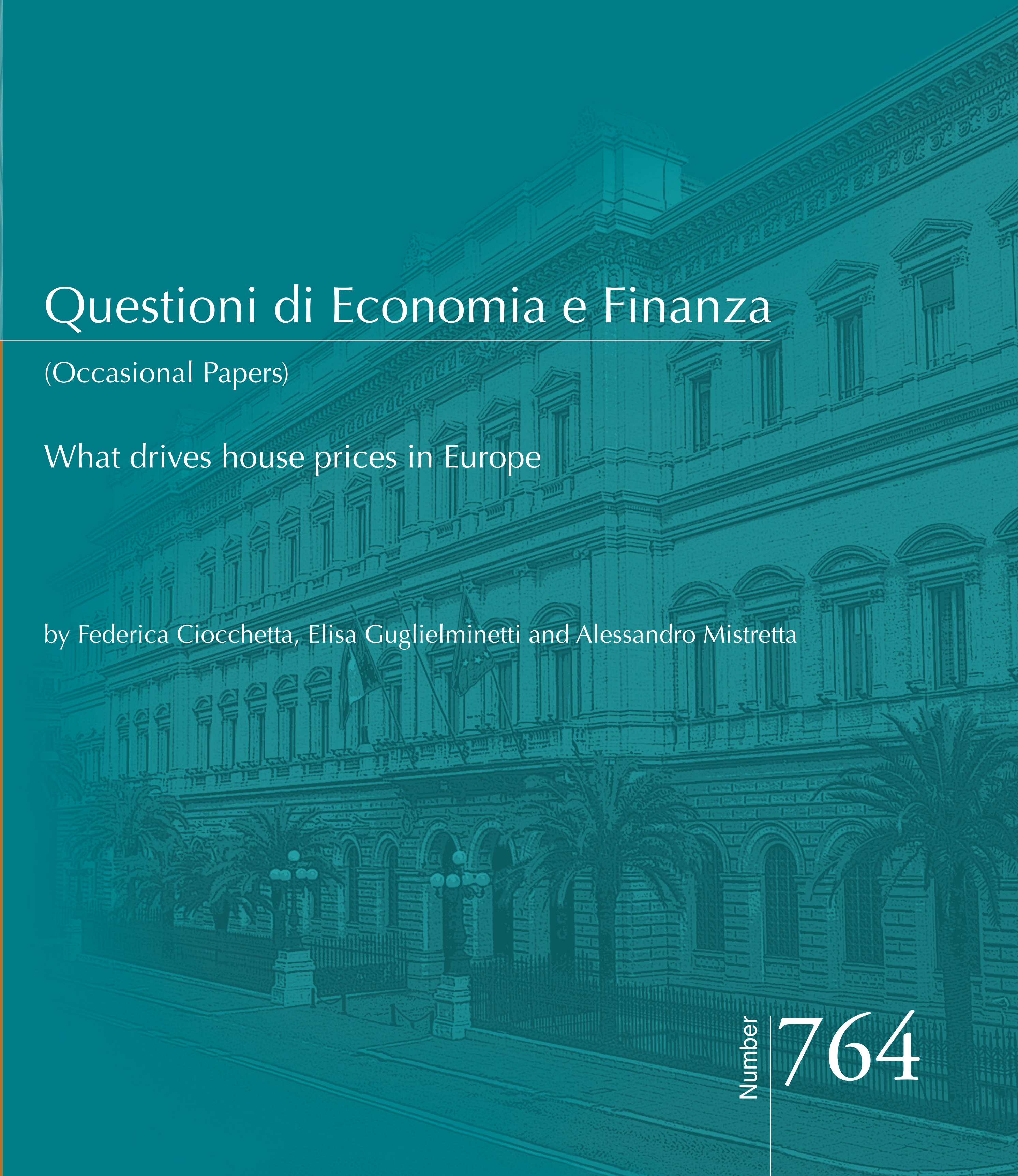
by Federica Ciocchetta, Elisa Guglielminetti and Alessandro Mistretta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# WHAT DRIVES HOUSE PRICES IN EUROPE?

by Federica Ciocchetta*, Elisa Guglielminetti* and Alessandro Mistretta*


## Abstract

Boom-and-bust cycles in the housing market pose a threat to macroeconomic and financial stability, thus calling for a timely assessment of imbalances. This work sheds light on the drivers of house price dynamics in some euro area economies, investigating whether the increases in house prices underway since 2015 signal a risk of overheating. We show that an Error-Correction-Model (ECM) featuring a long-run relationship between house prices and income and short-run effects of interest rates and housing supply fits the data well in most cases. We then propose a novel model-based misalignment indicator that consists in the difference between actual and predicted house prices once we have removed the component relating to extrapolative house price expectations (bubble-builder component). We find that, in 2021 (the last year in our analysis), prices were slightly undervalued in Italy and Ireland, moderately overvalued in France and Belgium, and significantly overvalued in Spain and Germany. Despite some quantitative differences, our results are broadly in line with the assessment of the European Central Bank.


**JEL Classification**: C22, C51, C52, R21, R31.
**Keywords**: house prices, Error Correction Model (ECM), over-valuation, housing bubbles.
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## Contents



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# 1 Introduction[1]

In most developed economies housing makes up the lion's share of households' wealth and banks' lending volumes (Jordà et al., 2016). Therefore, vulnerabilities arising in the residential real estate market represent a threat for macroeconomic and financial stability (Agnello and Schuknecht, 2011). In particular, volatile house prices together with high mortgage debt may trigger or amplify downturns, as it happened in the US during the Great Recession (Mian and Sufi, 2015). Moreover, activity downturns associated with credit crunches and boom-and-bust cycles in real estate prices are usually deeper and more prolonged and may have severe repercussions on banks' asset quality, banks' failure and economic growth (Claessens et al., 2009; Cerutti et al., 2017). This evidence suggests that monitoring the housing sector is paramount to prevent the build-up of financial fragility and its economic consequences. In this paper we focus on some euro area countries, studying the evolution of house prices and identifying their main drivers. Moreover, we propose a new indicator of house price imbalances, which allows us to assess potential risks of overvaluation in recent years.

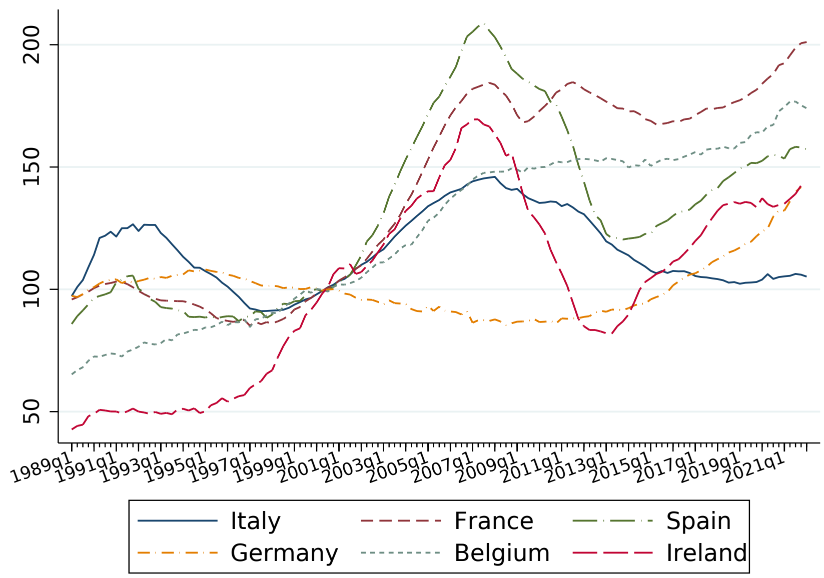
In the euro area a long expansionary housing cycle was interrupted by the double-dip recession. House prices gained again momentum from 2015 onwards, with significant cross-country heterogeneity (Figure 1). After the Great Recession, Spain and Ireland experienced sharp downward corrections; then, house prices recovered, but in 2021 they had not yet reached the respective pre-crisis peaks. In France the correction was much milder and short-lived, with house prices getting back to 2008 levels already two years later and growing at a more sustained pace from 2016 onward. In Italy the economy was deeply affected by the Sovereign Debt Crisis: in line with the uncertain economic outlook[2], house prices initially fell and then stagnated from 2015 until 2020, when they turned to moderate growth. On the other side of the spectrum, Belgium and Germany's real estate markets appeared to have been scarcely affected by the recessions around the 2010s. In Germany house values stagnated for almost two decades from the beginning of the '90s and began to accelerate in 2012. In all countries the expansion that was underway did not come to a halt with the outbreak of the Covid-19 pandemic: housing demand remained resilient thanks to fiscal support, high saving rates and favorable financing conditions (Igan et al., 2022);

[1]We thank Alessio Anzuini, Wanda Cornacchia, Ivan Faiella, Roberta Zizza, Giordano Zevi and Francesco Zollino for helpful comments and suggestions. The views expressed herein do not necessarily reflect those of the Bank of Italy.

[2]Italian GDP recovered the 2011 levels only in 2019 and so far has not yet got back to the levels preceding the outbreak of the Great Recession.

supply-side constraints exerted upward pressures on house prices as well. Moreover, the spread of remote working spurred interest in home purchases and may imply structural changes in the housing market that require careful monitoring (Gupta et al., 2021; Bricongne et al., 2021; Guglielminetti et al., 2021).

Figure 1: House prices in the euro area and main countries




*Notes:* Data are taken from the OECD. Index 2000 = 100.

The strong growth of house prices in recent years has created concern among policymakers and regulators about a possible overheating of European real estate markets. In February 2022, the European Systemic Risk Board (ESRB) carried out an EU-wide assessment of the Residential Real Estate (RRE) sector and issued five warnings and two Recommendations. For a number of countries a main source of vulnerability has been identified in the house price overvaluation, that may particularly harmful when coupled with strong credit expansion. This work contributes to shedding light on the drivers of house price dynamics in the main European countries, adopting a unifying methodology. This is a necessary step to determine if and to what extent market prices are increasing above their fundamental value, that is above what the evolution of fundamental drivers (such as household income and credit conditions) would imply.

To perform the analysis we face several challenges. First, housing markets are segmented and may respond differently to supply and demand factors depending on country-specific institutional and cultural factors.[3] At the same time, adopting country-specific models would make any cross-country comparison hardly possible. Second, common approaches to identify over(under)-valuation risks in real estate markets consider simple statistics like the price-to-rent ratio or the price-to-income ratio: deviations from their long-run trends signal a possible misalignment of property prices from their fundamental value. Although useful and easy to compute, these approaches do not provide any information about the underlying drivers and may entail false signals about the building-up of vulnerabilities.

We address these issues and contribute to the literature in two ways. First, we adopt a flexible econometric framework that allows testing for the existence of a long-run relationship between house prices and the selected drivers. Most applied works in the field do not consider that such a relationship may be rejected by the data, potentially leading to model misspecification. Among the countries under consideration, this issue is particularly relevant for Germany. We then estimate the model country by country, thus allowing for heterogeneous price elasticities to demand and supply factors. Second, we propose a new indicator of house price misalignment which combines appealing features of existing measures. In particular, we improve upon statistical indicators by adopting a model-based approach, which yields more robust and interpretable results. Compared to other model-based indicators, our proposal is easily applicable to a wide set of empirical frameworks and takes explicitly into account extrapolative house price expectations.

Our approach sets out from a relatively simple model of inverse demand that captures the main factors underlying real house price dynamics: demographics, household disposable income, housing supply and financing conditions. Although other drivers could potentially be included, these are widely recognized as the most relevant (Duca et al., 2021) and their time series are available for a relatively long time span. To bring the model to the data we use quarterly time series from the beginning of the '90s. The choice of the econometric strategy requires to strike a balance between flexibility – needed to account for cross-country heterogeneity – and a unifying framework – needed for interpreting and comparing the results. Therefore, we adopt an Auto-Regressive Distributed Lag (ARDL) approach that we estimate country by country. House price elasticities can potentially differ across economies, both in the short and in the long-run. The ARDL model can be easily recast in error-correction form to test for the existence of cointegrating relationships. We find that

[3]For instance the homeownership rate – which exhibits modest time variation – is much lower in Germany (around 50%) than in other euro area countries (in France it is above 60%, in Italy and Spain above 70%). Annual data on homeownership rates are taken from the EU-SILC survey (the latest data refer to 2021).

in all countries except Germany there exists a positive long-run relationship between house prices and household disposable income.[4] This indicates that for Germany it is instead more appropriate to estimate an OLS model in the growth rates.

Equipped with the model, we perform several analyses. First, we compare price elasticities to demand and supply factors and we interpret them in light of country-specific features of the mortgage market and adjustments of the housing supply. Second, we estimate the contributions of the different factors to house price dynamics: unsurprisingly, we show that they vary substantially across countries and over time. Over the considered period, in Spain actual house prices have been persistently above their estimated fundamental value, thus determining downward pressures on house price dynamics. The opposite occurred in Belgium, while in the other countries the contribution of this factor has changed over time. The decreasing trend in interest rates made mortgages increasingly affordable over time, thus pushing up house prices. Finally, extrapolative expectations played a large role in the run-ups preceding the Great Recession and in recent years, especially in Germany.

Third, we propose a new misalignment indicator. In the same spirit as Anundsen (2019), our measure compares actual price dynamics with the model-based predicted values. We innovate with respect to existing approaches by deducting from the latter the autoregressive component of house price growth. In fact there is abundant empirical evidence that agents form expectations by extrapolating from past house price dynamics (Kuchler et al., 2022). Therefore the autoregressive component of the model can be interpreted as a *bubble builder* term (Abraham and Hendershott, 1996). By considering multiple drivers, our measure is less sensitive than other simple indicators – such as the price-to-income ratio – to large fluctuations in income, like those occurred during the Covid crisis. According to our measure, in 2021 prices were slightly undervalued in Italy and Ireland, slightly overvalued in France and Belgium and significantly overvalued in Spain e, above all, in Germany. These indications are broadly consistent with the estimates of the European Central Bank (ECB) (European Central Bank, 2021).

Lastly, we run rolling regression to study whether the coefficients of interests have changed over time. For Germany, we find evidence of a loss of equilibrium correction as of 2012, further indicating a speculative run-up of the housing market henceforth. In some countries interest rates lost significance in the last decade, plausibly because they were less informative about the monetary policy stance and financing conditions due to the attainment of the zero lower bound and the adoption of unconventional monetary policies by the ECB.

[4] Although we allow all variables to be included in the cointegrating relationship, the more robust specification across countries includes only income.

This paper contributes to a long-standing literature that analyses the drivers of house price dynamics and devises tools to detect imbalances arising in real estate markets (see Duca et al., 2021 for a recent survey). The inverse demand approach, which provides the foundations of our multivariate regression model, has a long tradition, dating back to Kearl (1979) and later popularized by Di Pasquale and Wheaton (1994). This model has motivated numerous empirical studies estimating house prices as a function of income and other factors. Country panel studies such as Glindro et al. (2011), Igan and Loungani (2012), Geng (2018) and Cuestas et al. (2022) identify the elasticity of house prices to selected drivers exploiting both cross-sectional and time-series variation. Because the model parameters can vary depending on country-specific structural and institutional factors, we instead prefer to estimate single-country regressions, though using a unified framework to ease comparability. Studies that focus on single economies may instead use richer specifications that adapt to country-specific features (see Muellbauer et al., 2016 for Germany and Chauvin and Muellbauer, 2018 for France). Few papers estimate fully-fledged structural systems for the housing market, taking into account the multi-fold link with bank lending to both households and construction firms (for Italy, Loberto and Zollino, 2016; Nobili and Zollino, 2017). This approach allows for an in-depth and robust investigation of the drivers and potential imbalances of house prices, but it is not easily applicable to a cross-country analysis due to data limitation and country-specific features that advise against the use of standardized structural models. In terms of methodology, we are close to Anundsen (2019), but we use a single-equation ECM rather than a vector ECM. Moreover, we apply the method proposed by Pesaran et al. (2001) to formally test the existence of a long-term relationship and choose the specification which fits better for most countries. Other works exploit historical data over more than a hundred years adopting local projection methods or focusing on long-run trends (Jordà et al., 2015; Knoll et al., 2017). A major limitation of all the above-mentioned literature, to which this paper makes no exception, is not taking into account the within country heterogeneity, that in some cases may be substantial.

On the theory side, recent contributions highlight the role of households' expectations in driving house price dynamics and generating boom-bust cycles (Burnside et al., 2016; Glaeser and Nathanson, 2017; Kaplan et al., 2020). Although our work adopts an empirical perspective, the proposed misalignment indicator builds on the insights of these models – coupled with survey evidence – by considering extrapolative house price expectations as an important *bubble builder* component.

The rest of the paper is organized as follows. Section 2 describes the data and the methodology, Section 3 presents the results and Section 4 concludes.

# 2 Data and methodology

## 2.1 The theoretical framework

Early analyses of the housing sector are based on the stock-flow model, which posits an equilibrium relationship between housing demand and supply (Kearl, 1979; Di Pasquale and Wheaton, 1994).[5] Households' demand for housing depends on the real price level of housing $P$, the user cost of financing the house purchase $U$, the alternative cost of renting $R$ and other possible demand shifters – such as disposable income – $X_1$:[6]

$$D(P, U, R, X_1) = S \tag{1}$$

The housing demand function described by equation (1) can be derived from a multi-period optimization problem in which households trade-off the consumption of housing services with other goods (Dougherty and Order, 1982). Through the lens of these models, the user cost $U$ is the marginal rate of substitution between housing and alternative consumption goods. Empirically, it is usually measured by the after-tax inflation-adjusted mortgage interest rate:

$$U = (i + t_p)(1 - t_y) - \pi + \delta - \mathbb{E}(\Delta P/P) \tag{2}$$

where $i$ is the nominal interest rate on mortgages for house purchases, $t_p$ and $t_y$ are the marginal tax rates on property and income, respectively, $\pi$ is price inflation, $\delta$ is the depreciation rate and $\mathbb{E}(\Delta P/P)$ captures expected capital gains. In what follows we neglect interest rate deductability and property taxes (hence we assume $t_p = t_y = 0$), as well as housing depreciation ($\delta = 0$), as this would complicate cross-country comparisons.[7] Furthermore, tax policies and housing depreciation change

[5] We follow the notation in Di Pasquale and Wheaton (1994).

[6] Here we consider the supply of housing $S$ as exogenous. Stock-flow models often take into account the endogenous evolution of the housing stock. The housing stock depreciates at a given rate $\delta$ and expands thanks to residential investment, which may endogenously depend on housing prices and other supply factors.

[7] Fiscal systems can have a significant impact on house prices, mainly through the demand-side (see Geng, 2018 and ESRB, 2020). A certain heterogeneity in housing taxes and incentives for mortgages and homeownership can be observed across countries. France and Spain have generally a high level of housing taxation, in particular recurrent ones are higher than in other countries in the sample. The transfer tax is present in all the countries considered (low in Ireland and Germany high in Belgium and Italy, at intermediate levels in Spain and France). For what concerns the tax relief on mortgage interest rates, it is present in Italy and Belgium, whereas other countries have implemented reforms to gradually phase it out: Spain has removed it since 2012, Ireland since 2018. Finally, rent controls, which tend to raise house prices, are particularly stringent in Germany and, to a less extent, in France and Belgium.

infrequently and hence do not help identifying the parameters of interest (Barrios et al., 2019).[8] By defining the real interest rate as $r = i - \pi$, we thus obtain $U = r - \mathbb{E}(\Delta P/P)$.

Because the no-arbitrage condition between owner-occupied and rental housing implies that the rent-to-price ratio equals the user cost of housing, by substituting the expression of the user cost into (1) and inverting the demand function, we obtain[9]

$$P = D^{-1}(y, S, r, \mathbb{E}(\Delta P/P)) \tag{3}$$

where for simplicity we have assumed that the only demand shifter is household disposable income ($X_1 = y$). The inverted demand equation (3) shows that housing prices are a function of household disposable income, the housing stock, the real interest rate and expected variation in housing prices. Notice that all variables are expressed in real terms, so that inflation does not show up in equation (3). Moreover, the model describes the evolution of the housing sector in a representative agent framework with constant population. To take into account demographics, in the econometric implementation we express both household disposable income and the stock of housing in per capita terms.

To complete the model we need a theory on the formation of expectations of housing prices to measure $\mathbb{E}(\Delta P/P)$. Evidence abounds on extrapolative expectations of house price appreciation (see Armona et al., 2018; DeFusco et al., 2022, for recent evidence), which implies that expected capital gains are positively correlated with lagged price growth. In the econometric application we thus include several lags of house price growth.

## 2.2 The data

Here we describe the data we use to implement empirically the model described by equation (3). We focus on the four main euro area economies (Germany, France, Italy and Spain) plus Belgium and Ireland, which represent interesting case studies.

[8]The database described by Barrios et al. (2019) is an important source of information on housing taxation in European countries. However it can offer a simplifed version of the housing tax system, as it focuses on the standard transaction, without taking into account possible relevant differences in taxation applied to different categories of properties or households. Further (more qualitative) information on housing taxation can be drawn from the OECD tax database.

[9]By inverting equation (1), we obtain: $P = D^{-1}(S, U, R, X_1)$. Given that the no-arbitrage condition implies that the rental price depends on the user cost of housing and the latter depends on the real interest rate and expected capital gains, we obtain: $P = D^{-1}(S, r, \mathbb{E}(\Delta P/P), X_1)$. By assuming that the only factor included in $X_1$ is disposable income $y$, we obtain equation (3).

Similar to Germany, the Belgian economy was little affected by the double-dip recession that hit Europe from 2008 until 2012 and housing values have been growing at a fast pace in the last years. The Irish housing sector exhibited instead boom and bust dynamics akin to the Spanish ones: against the renewed momentum in house prices, in 2015 the country adopted macroprudential measures to cool down the market.[10]

To exploit effectively the time-series variation, we need the longest available time series for the variables of interest. As far as house prices are concerned, the OECD provides long series of nominal house prices since 1970.[11] National account data on household disposable income are instead available only from 1999. However we can leverage data from the Federal Reserve of Dallas: Mack and Martinez-Garcia (2011) collected a database of house prices and personal disposable income, both in nominal and real terms, as of 1975.[12] By taking the ratio between real and nominal disposable income we also obtain a long series for the consumption deflator, which we use to express in real terms house prices and interest rates as well. Data on the housing stock, which measure the number of residential real estate properties, are available on the statistical datawarehouse of the ECB. Unfortunately, for Germany and Belgium these series are available only from 1990q1 and 1991q1, respectively. We consider both household income and the housing stock in per capita terms, using population series from the census. This allows us to take into account demographic developments in a parsimonious way.[13][14] Finally, the inverse-demand model requires including the real user cost of housing. As is customary in the literature, we use as a proxy the real interest rate charged by banks on mortgages to households for house

[10] On February 9, 2015, the Central Bank of Ireland introduced macroprudential Regulations on the loan-to-value (LTV) and loan-to-income (LTI) ratios applying to new residential mortgage lending, with the aim of strengthening the resilience of households and banks to financial shock. Different caps have been defined in terms of borrower categories: first-time buyers, second-time and consequent buyers and buy-to-let segment. These measures have been extended and are still active.

[11] The OECD collects the data from different national sources. For Italy, long time series for house prices have been reconstructed by Muzzicato et al. (2008).

[12] Other historical time series are available through the AMECO database maintained by the European Commission, but at annual frequency.

[13] As is customary in the literature we take into account demographic trends using data on total population. However we acknowledge that housing demand may depend not only on the total number of residents, but also on the age structure of the population and the number of households.

[14] Since population and housing stock data are annual, we use linear interpolation to obtain them at quarterly frequency. Population in Germany between 1999 and 2011 is also interpolated to avoid a discontinuity that took place in 2011, when new census data became available and led to a sharp downward correction of previous population estimates.

purchases, provided by the ECB.[15] We take logs of all variables except the interest rate and we consider moving averages of four components, which smooth out one-off variations and allow focusing on relevant and clear tendencies.

To ease comparison of the results we consider for all countries the same time span: being constrained by data availability on the housing stock for Germany and Belgium, our estimation period runs from 1990q1 until 2016q4. We leave the last 5 years of data (2017q1–2021q4) as out-of-sample period to compare the prediction of the model to actual house price dynamics, similar to Anundsen (2019).

## 2.3 The econometric strategy

According to the inverted demand approach expressed by equation (3), the level of house prices should be positively related to household disposable income and expected housing appreciation (captured by past house price growth) and negatively related to the housing stock and the interest rate. As noted by Di Pasquale and Wheaton (1994), however, the housing market unlikely adjusts instantaneously, so that (3) can be regarded as long-run relationship rather than an equilibrium condition holding in every period. In the short-run house prices adjust to converge to their equilibrium value and respond to temporary changes in their drivers.

These dynamics can be well represented by an Auto-Regressive Distributed Lag (ARDL) model. The ARDL is a single equation regression that relates a given variable $y$ to past values of itself and to current and lagged values of control variables $x$. More formally, an ARDL$(p, q)$ reads as:

$$\begin{aligned} y_t &= c_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=0}^{q} \beta_j^{'} x_{t-j} + \epsilon_t, \\ \epsilon_t &\sim N\left(0, \sigma^2\right) \end{aligned} \tag{4}$$

where we have assumed that the independent variables share the same lag structure for simplicity. In our case, the dependent variable $y$ is the log of real house prices and $x$ is a vector including the log of real disposable income per capita, the log of housing stock per capita and the real interest rate on mortgages. The ARDL model

[15] Long time series (starting in the '80s) are available only to the members of the System of European Central Banks.

described by equation (4) can be recast in Error-Correction-Form (ECM):

$$\begin{aligned}\Delta y_t = \mu - \alpha\left(y_{t-1} - \theta \mathbf{x}_t\right) \\ + \sum_{i=1}^{p-1} \psi_{yi} \Delta y_{t-i} + \sum_{i=0}^{q-1} \psi'_{xi} \Delta \mathbf{x}_{t-i} + \epsilon_t\end{aligned} \tag{5}$$

where $\alpha = 1 - \sum_{i=1}^{p} \phi_i$ is the speed of adjustment and $\boldsymbol{\theta} = \frac{\sum_{j=0}^{q} \beta_j}{\alpha}$ represents the long-run coefficients.[16] The speed of adjustment $\alpha$ (with a negative sign) describes how fast house prices converge to their long-run relationship in case of imbalances. If $\alpha = 1$ any deviation from the equilibrium is fully corrected at any point in time, whereas $\alpha = 0$ implies that the process never reverts to its equilibrium path. Values between these two boundaries reflect a partial-adjustment process, where the gap to the equilibrium is gradually closed over time. For a long-run level relationship to exist, we need both $\theta \neq 0$ and $\alpha \in (0, 1)$. The first differences of the control variables capture their short-term impact on house prices and the sum of past values of house price is the expected housing appreciation.

The model described by equation (5) is very flexible, admitting the possibility that $x$ impacts $y$ both in the short- and in the long-run. Even if the theoretical framework posits the existence of a long-term level relationship between house prices and the other variables, this should be verified empirically. Indeed, the data may fail to detect such a long-term relationship for a variety of reasons, including lack of statistical power due to short time-series, measurement issues, structural breaks and explosive house prices dynamics. To test for the existence of a long-term relationship, we apply the bounds-testing procedure proposed by Pesaran et al. (2001) (PSS), which does not require prior knowledge of the order of integration of $x$, provided that $y$ is I(1). This is particularly important in our context, as we intend estimating the model on data from different countries with potentially different statistical properties.

To ensure the maximum degree of cross-country comparability, we compare several specifications and select the one which appears suited to fit the data for all or the majority of the countries in our sample.

We thus proceed as follows:

1. For each country, we estimate an ARDL where all the control variables are included in the long-term relationship. To ensure cross-country comparability we select a relatively high number of lags (6) for all the variables, instead of finding the optimal lag structure for each variable and each country. Prior

[16] We apply the specification defined as the second case in Pesaran et al. (2001), with restricted intercept and no time trend. In this case the intercept is included in the long-run relationship.

analysis on the optimal lag structure according to AIC and BIC criteria indicate that optimal number of lags is never greater than 6.

2. Apply the PSS procedure to test for the joint significance of $\alpha$ and $\theta$, where the null hypothesis is the absence of a long-term relationship between $y$ and $x$ $(H_0 : (\alpha = 0) \cap \left(\sum_{j=0}^{q} \beta_j = 0\right))$. The test statistic is a conventional F-statistic for joint validity imposed under the null hypothesis. However, the non-standard distribution requires using different critical values, defined in Kripfganz and Schneider (2020).[17]

   (a) If the test fails to reject $H_0$ because the test statistic is closer to zero than the lower bound of the critical values, the existence of a long-term relationship is not supported and the model should be specified in a different way. We thus proceed to step 3.

   (b) If the test rejects $H_0$ because the test statistic is more extreme than the upper bound of the critical values, there is evidence in favor of the existence of a long-term relationship, which should be confirmed by a single t-test on the significance of $\alpha$. In this case the model is well specified.

   (c) If the test is inconclusive because the test statistics fall within the boundaries of the critical values, one should take a stance on the order of integration of $x$, which implies what critical value should be considered (the upper or the lower bound). We avoid taking a stance on this issue and select instead the more robust specification across countries.

3. If the existence of a long-term relationship is not supported by the PSS test (cases 2a or 2c) we consider a partition of $x \equiv \{x', z\}$, where only $x'$ enter the long-term relationship, while $z$ is allowed to impact house prices only in the short-term. We consider three cases: i) $x'$ includes income and the housing stock; ii) $x'$ includes income and the interest rate, and iii) $x'$ includes only income.

In order to select the appropriate specification, we start by estimating four different ARDL models for each country, including a specification where all possible drivers are considered as long-term components and other three where we remove some variables from the long-term component (corresponding to three cases described at item 3 above). The results are reported in the Annex (Tables A.1-A.6).

[17] Kripfganz and Schneider (2020) improve upon and substantially extend the set of available critical values previously tabulated by Pesaran et al. (2001) and Narayan (2005).

For each country and specification, we report the coefficients of the model in the ECM form - including the (negative) speed-of-adjustment coefficient $-\alpha$ (ADJ section), the coefficients of the long-term relationship (LR section) and those capturing the short-term impact (SR section). We also report the results of the PSS bounds test for different significance levels, a goodness-of-fit measure such as the $R^2$ and the period of estimation.

The results vary across countries. In the case of Italy and Spain all the specifications confirm the existence of a long-term relationship between house prices and one or more factors. This is supported by the result of the bounds test (including both the F-test for the joint significance of $\alpha$ and $\theta$ and t-test for $\alpha$, as described at item 2 of the above-mentioned procedure) at least at the 10% significance level. In the case of France, Belgium and Ireland the bounds test supports the existence of a long-term relationship when it does not include the housing stock: the evidence is stronger for the latter specification, where only disposable income is considered in the cointegrating relationship. Regarding Germany, all models considered do not support the existence of a long-term relationship. As we show in Section 3.3, this finding may be related to the build-up of a speculative housing bubble in the last years of our sample period.

Overall the best model valid for all the countries with the exception of Germany is the ARDL(6,6) specification where the long-term relationship involves only house prices and income and the other demand factor (real interest rate for mortgages) and the supply factor (per-capita housing stock) are included in the short term component.[18] Our reference equation can be specified as:

$$\begin{aligned}\Delta \log(p)_t = \mu - \alpha\left(\log(p)_{t-1} - \theta \log(inc)_{t-1}\right) + \\ \sum_{i=1}^{5} \psi_{yi} \Delta \log(p)_{t-i} + \sum_{i=0}^{5} \psi'_{xi} \Delta \log(inc)_{t-i} + \\ \gamma'_1 \Delta \log(stock)_{t-1} + \gamma'_2 r_{t-1} + \epsilon_t\end{aligned} \tag{6}$$

where $\alpha\left(\log(p)_{t-1} - \theta \log(inc)_{t-1}\right)$ is the adjustment to the long-term relationship, $\sum_{i=1}^{5} \psi_{yi} \Delta \log(p)_{t-i}$ represents lagged house price appreciation and the other terms

[18]When considering the optimal lag structure according to the AIC criterion, that may differ across coutries, we obtain that: i) in Italy, France and Ireland the elasticity of house prices to their drivers is broadly unchanged and the fit stays the same or worsens; ii) in Belgium the long-run positive impact of income and the short-run negative impact of housing supply gain significance, with the R2 slightly improving; iii) in Spain the PSS test does not support any more the existence of a long-term relationhsip between house prices and income; iv) like in the benchmark specification, in Germany the PSS test fails to detect any cointegrating relationship, irrespective of the number of lags.

include the short-term drivers and the residual term. In what follows we consider model (6) as our main specification.

# 3 Results

## 3.1 Drivers of house price dynamics

Table 1 reports the main results for the selected benchmark model (6). As already highlighted in the previous Section, for most countries the bounds test rejects the null hypothesis of the absence of the long-term relationship at least at the 5% significance level, with the exception of Belgium, for which the null hypothesis is rejected only at a 10% level, and Germany. For Germany, we will thus consider an alternative OLS specification estimated in first differences.

For the countries for which a long-term relationship exists the fit of the model is relatively good, with the $R^2$ exceeding 60% in all cases except Belgium. The (negative) speed-of-adjustment coefficient is highly significant and varies between -0.03 and -0.06, reflecting a slow partial-adjustment process, where the gap to the equilibrium is gradually closed by a factor (between 3% and 6%) within a quarter. The long-term coefficient for income is positive and varies across countries between 1.21 (Belgium) and 4.21 (Spain). Interestingly, the long-run impact of demand is higher in Spain and France, where mortgage markets are relatively more liberalized (Zhu et al., 2017), consistent with the important role of mortgage market structures in house price booms (Cerutti et al., 2017). In Ireland – another country with a highly liberalized mortgage market – the impact of demand pressures was moderated by the strong increase in housing supply per capita (more than 50% between 1990 and 2016). Indeed, the price effect of demand tends to be lower when housing supply is elastic (Duca et al., 2021).

For what concerns the short-term components, the results are heterogeneous across countries. In Italy the housing stock has a negative significant impact on house prices, consistent with the theory; in the other countries the coefficient is not significant. The lack of significance may be due to the slow-moving nature of this variable, that makes it hard to estimate its impact on higher-frequency variations in house prices, and for the relative long auto-regressive component used in the benchmark specification.[19] The coefficient on the real interest rate has a negative and significant impact in Italy, Belgium and Ireland: a rise of 1% in the financing cost

[19] In France and Belgium the elasticity of house prices to housing supply gains significance when reducing the number of lags in house prices and income.

of mortgages reduces the q-o-q growth rate of house prices between 0.2 and 0.4 percentage points.[20] Note that in the case of France and Spain the coefficient on the interest rate is positive: it is possible that in these countries the average interest rate offers only limited indications about actual financing conditions due to the higher degree of mortgage markets liberalization which may determine variations in other aspects of the financing contracts.[21]

Table 1: ARDL model for log(real house prices): cross-country comparison

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | -0.04*** | -0.03*** | -0.06*** | -0.05*** | -0.05*** | 0.04 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.14) |
| LR | | | | | | |
| income | 2.59*** | 3.82*** | 4.21*** | 1.21 | 1.54*** | 0.10 |
| | (0.00) | (0.00) | (0.00) | (0.10) | (0.00) | (0.95) |
| SR | | | | | | |
| Δ housing stock (t-1) | -1.09* | -3.11 | 2.82 | -2.91 | 0.17 | -4.58** |
| | (0.06) | (0.20) | (0.12) | (0.11) | (0.71) | (0.01) |
| interest rate (t-1) | -0.17*** | 0.18** | 0.30** | -0.37** | -0.23** | -0.14 |
| | (0.00) | (0.04) | (0.03) | (0.01) | (0.02) | (0.43) |
| country | Italy | France | Spain | Belgium | Ireland | Germany |
| modello | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | .r | .r | .r | .r | .r | .a |
| ec_5 | .r | .r | .r | . | .r | .a |
| ec_1 | .r | . | .r | .a | .a | .a |
| min | 1990q1 | 1990q3 | 1990q1 | 1991q3 | 1990q1 | 1990q3 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.75 | 0.76 | 0.65 | 0.16 | 0.56 | 0.22 |

*p*-values in parentheses

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

*Notes:* ec10, ec5 and ec1 stand for the result of the bounds test at the 10%, 5%, 1% significance levels, respectively. The symbol .r means that the null hypothesis is rejected, .a accepted and . means that the test is inconclusive.

[20]Expressing the real interest rate in log (instead of levels, like in the main specification) does not change the main results and slightly worsens the fit of some country regressions.

[21]As an example, Zhu et al. (2017) consider five indicators that capture the degree of mortgage market liberalization: i) the type of mortgage rate (fixed or variable); ii) the possibility of mortgage equity withdrawal; iii) the maximum loan-to-value; iv) mortgage securitization; and v) government participation (eg. subsidies to first-time and low-income buyers).

Figure 2 represents the contribution of each component of equation (6) to the actual q-o-q growth rate of real house prices. Notice that lagged house price growth can be interpreted as expected house price appreciation, which reduces the user cost. Indeed, the empirical evidence suggests that households tend to form expectations by extrapolating past house price dynamics, thereby amplifying the housing cycle (Kuchler et al., 2022).

The contribution of the different drivers varies over time and across countries. In the case of Italy, the adjustment to the long-run fundamental value (blue bars) exerts mainly a positive contribution, although with varying intensity over time: it was quite relevant from the late '90s until the Great Recession and again in the recent years. Despite the different approach adopted, this result is consistent with Nobili and Zollino (2017), who find that demand factors – and especially developments in the disposable income – provided the main positive contribution to house price dynamics over the '90s and the 2000s. Indeed, according to our estimates, the long-run value of house prices started to increase already in the mid-'90s – driven by rising income – but the expansion of actual house prices began a few years later (Figure A.1a). Similarly, following the double-dip recession the fundamental value started to recover already in 2015, while actual dynamics remained subdued until 2020. The interest rate contributed negatively to house price growth but its negative drag markedly reduced since the beginning of the 2000s (orange bars), with the inception of the euro and the low inflation period, which drove borrowing costs down.[22] This pattern is common to most countries, which all experienced a sharp reduction in mortgage financing costs over time (in nominal terms, in 2016 they were on average 9 percentage points lower than in 1990). A partial exception is represented by Spain, where interest rate on mortgages, although sharing the common negative long-run trend, have always remained substantially higher (on average 5 percentage points higher than in the other countries considered in the analysis) and rose somewhat in the immediate aftermath of the Sovereign Debt Crisis. This is reflected in the substantial contribution of financial conditions to house price dynamics in Spain over the whole sample period. Expectations amplified the cycle around the Great

[22]In line with our findings, Nobili and Zollino (2017) observe that the positive contribution to house prices provided by monetary policy gained momentum in the path to the Monetary Union, as the cost of credit largely benefited from the decline in both the short-term and long-term interest rates. Through the lens of their structural model, Nobili and Zollino (2017) can further consider developments in the credit supply factors due to banks' deleveraging, which are instead neglected in our framwork.

Recession, fuelling house price growth in the preceding years and contributing to their fall in its aftermath.

In France, the adjustment to the long-run value provided a negative contribution to house price growth in the 90s; since the early 2000s, however, actual and fundamental house prices have moved almost in tandem (Figure A.1b), so that this component has become almost irrelevant. The increase in housing supply contributed to moderating house prices growth until 2017, although the correspondent regression coefficient is not statistically significant. Expected appreciation was a major driver of the expansion preceding the Great Recession and its relevance has been increasing again since 2016. In both Italy and France household income affected house prices mainly through its long-run implications on the fundamental value, while short-run fluctuations played a minor role (light yellow bars).

In Spain the contribution of long-run adjustment is always negative, given to the fact that actual prices lie always above the estimated fundamental value (Figure A.1c). This driver is relevant for almost all the period, mostly balanced by a persistent positive effect of interest rates. Also in this case some periods are characterized by a relevant role of expected appreciation, especially in the aftermath of strong increases or decreases of prices. On the opposite side of Spain, Belgium features actual prices always below the estimated long-run values, which implies a persistent positive contribution of the long-run adjustment component. This positive driver is counterbalanced by the negative impact of interest rates and housing stock. In Ireland the adjustment to the long-run value provides sometimes a positive and sometimes a negative contribution, depending on the relative growth of actual and fundamental prices (Figure A.1e): the largest positive impact is estimated around 2013–2014, when actual house prices fell by more that the estimated long-run value. This period further records a large negative effect of house prices expectations, which amplifies the negative cycle. Short-run income dynamics are more relevant than in other countries, mostly with a positive sign.

As for Germany, given that it is not possible to find a long-term relationship between house prices and any of the drivers, we report the results of an alternative OLS specification estimated in growth rates (Table A.7).[23] Like in Belgium and Italy, financing conditions and housing supply contribute negatively to house price dynamics and their importance declines over time. The main driver of the strong expansion underway since 2015–2016 appears to be the expected house price appreciation, raising concerns of the run-up in house prices being fuelled mostly by speculative motives. To address the question of misalignment in house price valuations we now turn to

[23]In this specification expected appreciation is the average growth rate of house prices in the previous four years.

the next Section.

## 3.2 Misalignment indicators for house prices

The literature has proposed several measures of over/under-evaluation of house prices. The simplest ones are deviations of the price-to-rent or the price-to-income to their long-run average value. These indicators have the advantage of being easy to compute and widely applicable, but they are not very informative about the drivers of house price dynamics and are heavily dependent on the period used to compute the long-run average. A second approach adopts an asset pricing perspective and interprets misalignments as deviations from an arbitrage condition between the sale and the rental market. In this paper we follow a third strategy, the popular inverted-demand approach, which allows estimating the contribution of "fundamental" drivers to actual house price dynamics.

Within this class of models, Anundsen (2019) proposes two misalignment indicators. The first one is the difference between actual house prices and their long-run "fundamental value", namely the distance between the blue and the yellow lines in Figure A.1. The second indicator is the difference between actual house prices and the predicted value according to the baseline model. We propose a third intermediate measure, that overcomes some drawbacks of the previous ones. The first measure – the deviation from the long-run fundamental value – has two shortcomings: i) it cannot be computed for the countries for which the data do not support the existence of a long-term relationship, like Germany, and ii) it does not consider the impact of housing supply and interest rates that, although vanishing in the long-run, may still explain a relevant share of non-speculative house price growth. The second measure is instead based on the predicted value and therefore takes into account both long-run (income) and short-run drivers but also lagged housing appreciation, which captures expected future price dynamics. We argue that the latter factor should not be included among the "fundamental" drivers, as it can be interpreted as a *bubble builder* component which captures extrapolative expectations (Anundsen, 2019; Abraham and Hendershott, 1996). Therefore we define the misalignment of house prices based on our model (model-based approach) as the difference between the actual house prices and the predicted value once deducted the contribution of expected appreciation. Notice that in some countries – most notably in France and Spain – the component related to expected appreciation played a significant positive role in the run-up of house prices preceding the Great Recession.[24] Therefore, for that period our indicator suggests that prices were overvalued and this eventually led to a sharp price reversal.

Figure 3 reports for each country both our model-based misalignment indicator and the price-to-income ratio, for the period 2017Q1-2021Q4.[25] To compute our measure, we estimate the model until the end of 2016 and then we project it forward conditional on the actual evolution of the different components. To facilitate comparisons we assume that prices are in equilibrium at the beginning of the out-of-sample period. The price-to-income ratio is represented in deviation from its long-run average (1990-2016).

In the case of Italy the misalignment indicator points to a persistent undervaluation, at about -5% in the last three years. This result is confirmed by the price-to-income ratio, although to a lesser extent. On the contrary, in the case of Spain and France both indicators signal that house prices have been overvalued since 2017, and increasingly so in the most recent years. In France the model-based indicator signal a moderate overvaluation of about 4% at the end of the sample period, less than half of the indication provided by the price-to-income ratio. In Spain the estimated overvaluation is much stronger, reaching 20% in 2020 and slightly decreasing afterwards. In this case the indications coming from the price-to-income ratio are somewhat more moderate. In Belgium we find consistent signals of an overvaluation of about 4% in 2021. In Ireland there are signs of overvaluation till the beginning of 2020. With the outbreak of the pandemic, however, the two indicators diverge: our measure indicate undervaluation while the income-based indicator still reports some overvaluation, with the exception of some quarters in 2020. In Germany, the model-based indicator is based on the OLS specification given that the ECM model is not appropriate. Both our measure and the price-to-income detect an increasing overvaluation, exceeding 20% in the second half of 2021.[26]

Overall both our measure and the price-to-income ratio provide consistent results, but we detect also significant quantitative differences, due to the fact that the the latter measure is disproportionately affected by income developments and does not take into account other possible drivers. Major differences arise from 2020 onward, when the large drop in income due to the Covid-19 crisis determined a strong increase

[24]The important role played by the auto-regressive component is partly due the high number of lags included in the model. For Italy, Loberto and Zollino (2016) and Nobili and Zollino (2017) find a significant positive contribution only of the first three lags.

[25]Figure A.2 represents the evolution of actual and predicted values, both with and without the component related to expected house prices appreciation.

[26]When computed on the overall sample, we detect significant overvaluation in the run-up

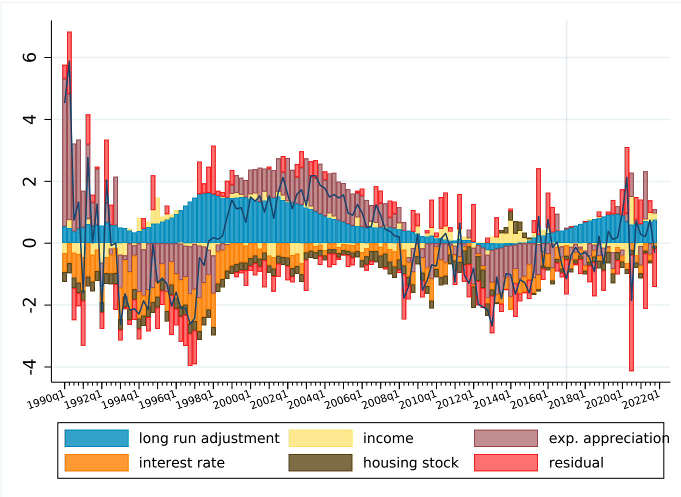
in the price-to-income ratio in all countries. Our model-based indicator, which takes into account a wider variety of factors, is less sensitive to such large swings and sometimes offers a different perspective on house price dynamics.

Our results can be further compared to over(under)-valuation measures computed by the ECB (for a recent example, see European Central Bank, 2021, chapter 1.5). The ECB uses four methods to detect imbalances between residential property prices and their fundamentals: two methods are based on the price-to-rent ratio, one on the price-to-income ratio and the fourth is a regression-based approach similar in spirit to that adopted in this paper (European Central Bank, 2011, 2015).[27] Overall, the signals provided by our model-based misalignment indicator are broadly consistent with the view of the ECB. Like in our model, at the beginning of 2021 residential property prices were deemed undervalued in Italy and Ireland, although the extent of misalignment is greater in ECB estimates. In all the other countries house prices appear more or less overvalued: in both our and ECB estimates the most worrisome situation regards Germany. Spain is the only case in which our methodology detects a larger overvaluation compared to ECB estimates: in our model, this is driven by extrapolative expectations based on past growth.[28] In France and Belgium we find a degree of overvaluation more moderate than what reported in the ECB Financial Stability Review.

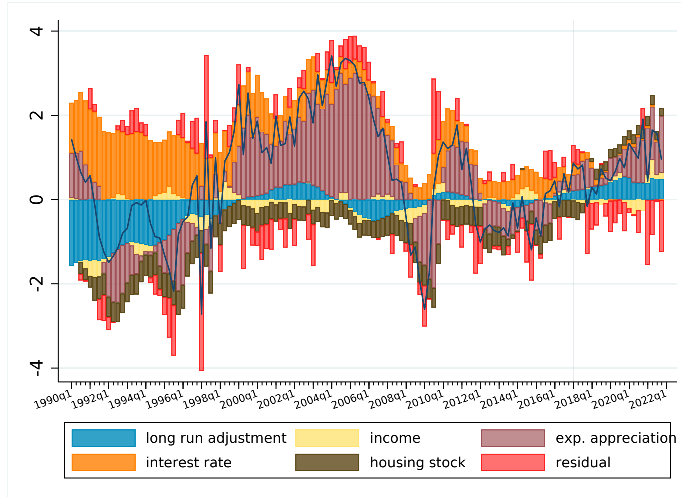
[27]Since the ECB aims at developing tools that can be applied to all euro area countries, it is constrained by the length of the sample period and the econometric approach that can be adopted. For instance, the inverted-demand model used by the ECB does not identify any long-term relationship, as we do instead in this paper. Focusing on a subset of countries, we can use longer time series and use a flexible econometric model within a unified framework.

[28]According to ECB confidential data, the size of overvaluation based only on the inverted demand approach is much larger, in line with our results.

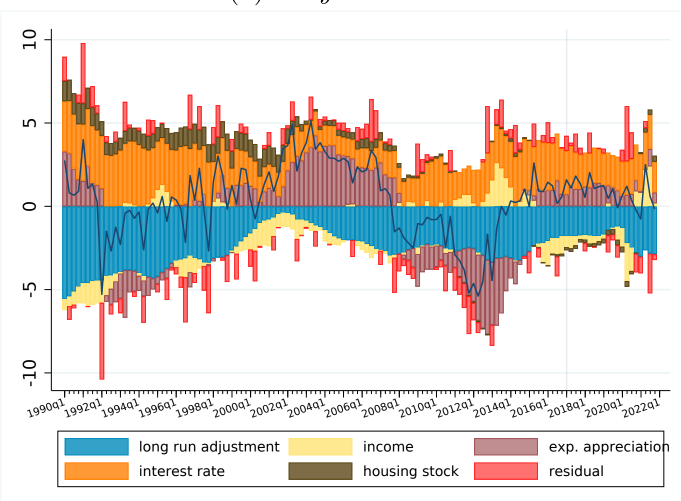
Figure 2: Drivers of log(real house prices)



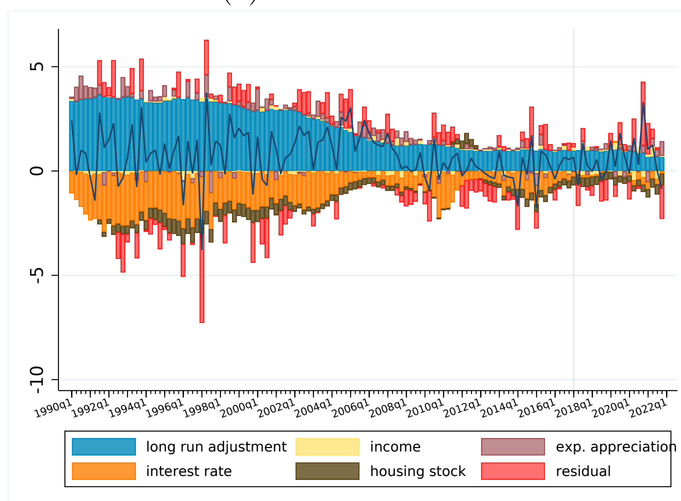

(a) *Italy*



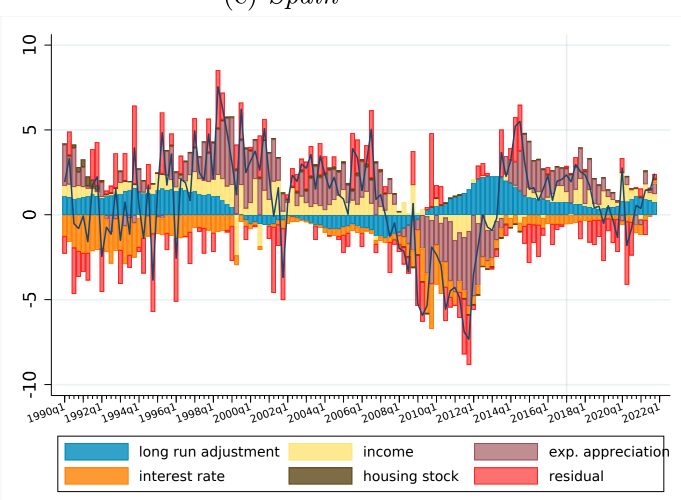

(b) *France*



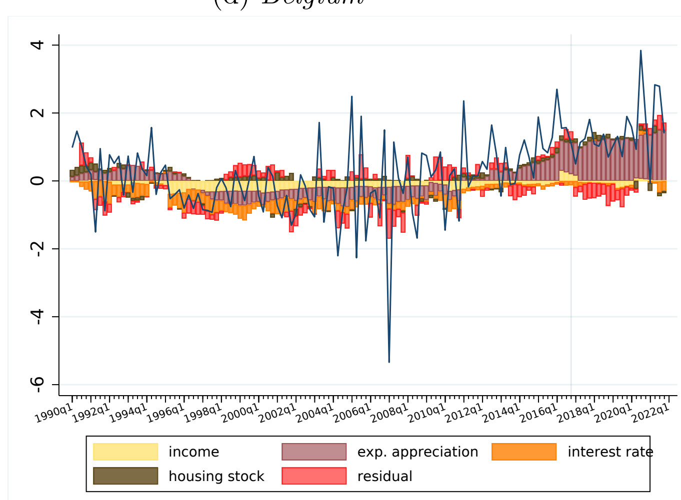

(c) *Spain*




(d) *Belgium*




(e) *Ireland*




(f) *Germany*

**Notes:** Based on the estimates reported in Table 1. The solid line represents the actual q-o-q growth rate of real house prices. The vertical shaded line signals the end of the estimation period.

Figure 3: Indicators for house prices misalignment


(a) *Italy* (b) *France*

(c) *Spain* (d) *Belgium*

(e) *Ireland* (f) *Germany*

**Notes:** Based on the estimates reported in Table 1. The solid line represents the actual q-o-q growth rate of real house prices. The vertical shaded line signals the end of the estimation period.

## 3.3 Robustness and additional analyses

Our previous analysis omits important drivers of house prices dynamics, as we relied on a parsimonious model to ensure comparability across countries and the availability of relatively long time series. In this Section we discuss the role of such previously neglected factors and test the robustness of our results to alternative specifications.

Although in the baseline model we took into account demographic trends by expressing variables in *per capita* terms, we did not discuss the role of the demographic structure. This may be relevant for house prices dynamics because individual demand for housing varies over the life cycle (Attanasio et al., 2012). Over the last thirty years the old-age dependency ratio (i.e. the ratio between the population aged 65 and over and the working age population) has considerably increased in all countries except Ireland (Figure A.3). Although the empirical evidence is not conclusive, population ageing most likely attenuates house price growth (Bodnár and Nerlich, 2022). Therefore, absent this shift in the demographic structure of Continental and Southern Europe the recent expansion might have been even more pronounced.

Another factor we did not incorporate in our baseline analysis relates to heterogeneous and potentially time-varying tax systems. To take them into account, we estimate an alternative specification of model (6) where the real interest rate is replaced by the user cost of owner-occupied housing (UCOH), as reported in the European Commission taxation database (Barrios et al., 2019). The UCOH measures the annual cost of owning the main dwelling per additional euro of house value and is estimated at the country level following the approach proposed by Poterba and Sinai (2008). The indicator takes into account the interest rate paid on mortgage and the forgone on equity investment, the estimated annual maintenance costs, the tax rate on interest income (as a proxy of the tax on risk-free investment), the economic depreciation rate and the specific tax rules that apply to owner-occupied housing. The latter include recurrent property taxes, taxes on the flow of services from ownership (imputed rents), tax reliefs on debt financed housing, transfer taxes on house sale and capital gains taxes.[29] The UCOH and the underlying data are available at annual frequency for the period 1996-2020 (from 2005 for Belgium). To re-estimate our econometric model using the UCOH, we thus make the series quarterly by linear interpolation and we extend them back in time using the variations in interest rates. The results of this alternative specification confirm those of the

[29]The latest release of the database proposes a new definition of the user cost indicator, allowing for more flexibility and a more realistic representation of housing financing. Indeed, differently from the previous version where a unique interest rate was considered, the new methodology introduces a separate interest rate for new mortgages, which is different from the rate capturing forgone capital income of alternative investments. See Thiemann et al. (2022) for additional details.

baseline model (Table A.8). The semi-elasticity of house prices to the user cost is more negative and significant in Italy and Ireland, is slightly less negative (but still significant) in Belgium and turns insignificant in France. The other coefficients are broadly unchanged.

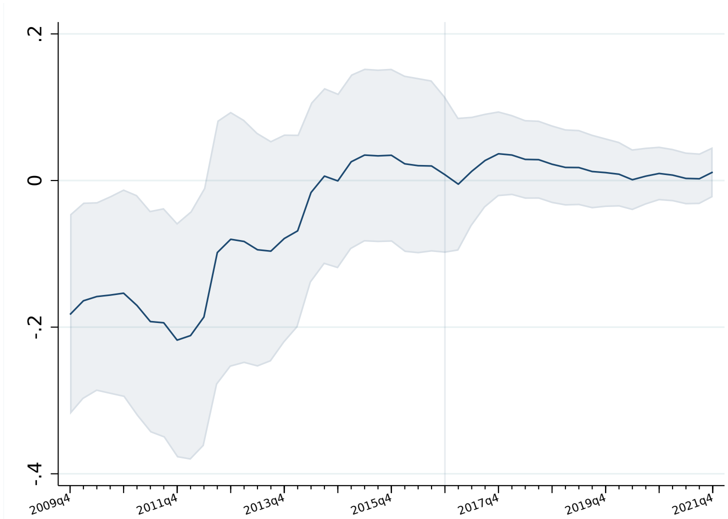
Finally, we extend the analysis to consider possible changes in the relationship between house prices and the underlying factors included in the baseline specification. We estimate model (6) on rolling windows of 20 years, starting from the sample 1990-2010. This allows us to study the evolution of the different coefficients over time and test the robustness of our results.

First, we consider the long-run adjustment coefficient. As argued by Anundsen (2019), the loss of equilibrium correction to a previously existing long-term relationship indicates the possible build-up of a bubble. This is what we find for Germany: before approaching to zero, the adjustment coefficient is negative and statistically significant up to 2012 (Figure 4). Although the PSS bounds test is not conclusive about the existence of a cointegrating relationship even excluding the last ten years of data, this provides additional evidence in favor of a rising overvaluation of the German housing market, consistent with the above-mentioned indicators. For the other countries the adjustment coefficients do not vary significantly over time.[30]

Other interesting results regard the evolution of the price semi-elasticity to financing conditions (Figure A.4). In Italy, Belgium and Ireland, the effect of the interest rate is negative and significant for sample periods ending around 2012. After the Sovereign Debt crisis the interest rate loses significance, as the ECB policy rate hit the zero lower bound and unconventional monetary policies were put in place. For this reason interest rates provided little information about actual credit supply conditions over the last decade and this is reflected in our estimates. In France and Spain the effect of the interest rate maintains a positive coefficient throughout the sample period, but in the latter country from 2016 onward it is not significantly different from zero. Moreover, in these economies there have been multiple changes in tax reliefs and fiscal benefits related to residential properties: as previously seen, in France the semi-elasticity of house prices to a broader concept of user cost is not significant.

[30]Results are available upon request.

Figure 4: Germany: adjustment coefficient based on rolling regressions




*Notes:* The figure represents the adjustment coefficient from rolling regressions estimated on a 20-years window starting from the sample 1990–2010. The coefficient is represented at the end of the corresponding sample period. The shaded area represents the 5% significance level.

# 4 Conclusions

In the current fast-changing economic environment with rising interest rates, it is crucial to monitor the housing market to prevent the build-up (and the burst) of speculative bubbles. This work offers some guidance in interpreting house price dynamics in the main European economies, adopting a unified and data-driven methodological approach. The methodology and the set of drivers included in the analysis are deliberately kept simple to facilitate interpretation and cross-country comparisons. Based on the model, we propose a new indicator of house price misalignment. The evolution of *fundamental* house prices is assumed to be driven by both long and short-run factors, but we crucially exclude the component related to extrapolative expectations that usually signals the emergence of a bubble.

Looking ahead, our methodology can be integrated with additional aspects, like housing taxation, mortgage reliefs and rental controls, that differ across countries and possibly over time. Moreover, it would be interesting to investigate the impact of macroprudential measures and their interaction with country-specific features. These extensions may represent a valuable contribution to further advance in the understanding of housing market developments and take appropriate policy actions.

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# A Additional figures and tables

Table A.1: ARDL model for log(real house prices): Italy

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | -0.04*** | -0.04*** | -0.03*** | -0.04*** | -0.04*** | -0.04*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| LR | | | | | | |
| housing stock (t-1) | 1.56** | 0.25 | | | | |
| | (0.04) | (0.60) | | | | |
| income | 3.76*** | 2.70*** | 3.06*** | 2.55*** | 2.86*** | 2.59*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| interest rate | 5.26 | | -2.07 | | | |
| | (0.18) | | (0.31) | | | |
| SR | | | | | | |
| interest rate | | -0.12 | | | | |
| | | (0.11) | | | | |
| Δ housing stock | | | 0.32 | | | |
| | | | (0.86) | | | |
| Δ housing stock (t-1) | | | -1.95 | -1.01* | -1.34** | -1.09* |
| | | | (0.28) | (0.09) | (0.03) | (0.06) |
| interest rate (t-1) | | | | -0.02 | | -0.17*** |
| | | | | (0.91) | | (0.00) |
| modello | ARDL(6,6,6,6) | ARDL(6,6,6) | ARDL(6,6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | .r | .r | .r | .r | .r | .r |
| ec_5 | . | .r | . | .r | .r | .r |
| ec_1 | . | .r | .a | .r | .r | .r |
| min | 1990q1 | 1990q1 | 1990q1 | 1990q1 | 1990q1 | 1990q1 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.77 | 0.74 | 0.75 | 0.75 | 0.74 | 0.75 |

*p*-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: ARDL model for log(real house prices): France

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | -0.04*** | -0.03*** | -0.03*** | -0.04*** | -0.02*** | -0.03*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| LR | | | | | | |
| housing stock (t-1) | -4.47 | -3.42 | | | | |
| | (0.20) | (0.29) | | | | |
| income | 4.51*** | 4.74*** | 3.32*** | 3.66*** | 3.76*** | 3.82*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| interest rate | -0.20 | | 3.36 | | | |
| | (0.96) | | (0.36) | | | |
| SR | | | | | | |
| interest rate | | 0.11 | | | | |
| | | (0.37) | | | | |
| $\Delta$ housing stock | | | 0.24 | | | |
| | | | (0.96) | | | |
| $\Delta$ housing stock (t-1) | | | -2.39 | -3.06 | -2.91 | -3.11 |
| | | | (0.61) | (0.21) | (0.24) | (0.20) |
| interest rate (t-1) | | | | -0.03 | | 0.18** |
| | | | | (0.93) | | (0.04) |
| modello | ARDL(6,6,6,6) | ARDL(6,6,6) | ARDL(6,6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | .a | . | .r | . | .r | .r |
| ec_5 | .a | . | . | .a | . | .r |
| ec_1 | .a | .a | .a | .a | .a | . |
| min | 1991q3 | 1991q3 | 1990q3 | 1990q3 | 1990q3 | 1990q3 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.75 | 0.76 | 0.75 | 0.76 | 0.76 | 0.76 |

$p$-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: ARDL model for log(real house prices): Spain

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | -0.07*** | -0.07*** | -0.07*** | -0.06*** | -0.06*** | -0.06*** |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| LR | | | | | | |
| housing stock (t-1) | 0.78 | 0.74 | | | | |
| | (0.53) | (0.58) | | | | |
| income | 2.63*** | 4.09*** | 2.92*** | 4.04*** | 3.94*** | 4.21*** |
| | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| interest rate | 1.68 | | 1.14 | | | |
| | (0.53) | | (0.65) | | | |
| SR | | | | | | |
| interest rate | | 0.40*** | | | | |
| | | (0.01) | | | | |
| Δ housing stock | | | 11.15 | | | |
| | | | (0.12) | | | |
| Δ housing stock (t-1) | | | -9.62 | 2.27 | 2.33 | 2.82 |
| | | | (0.18) | (0.23) | (0.21) | (0.12) |
| interest rate (t-1) | | | | -0.14 | | 0.30** |
| | | | | (0.76) | | (0.03) |
| modello | ARDL(6,6,6,6) | ARDL(6,6,6) | ARDL(6,6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | .r | .r | .r | .r | .r | .r |
| ec_5 | .r | .r | .r | .r | .r | .r |
| ec_1 | . | . | .r | .r | . | .r |
| min | 1990q1 | 1990q1 | 1990q1 | 1990q1 | 1990q1 | 1990q1 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.67 | 0.66 | 0.67 | 0.65 | 0.64 | 0.65 |

$p$-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.4: ARDL model for log(real house prices): Belgium

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | -0.08** | -0.07*** | -0.08*** | -0.04** | -0.05*** | -0.05*** |
| | (0.02) | (0.01) | (0.00) | (0.02) | (0.01) | (0.00) |
| LR | | | | | | |
| housing stock (t-1) | 6.82* | 7.13* | | | | |
| | (0.08) | (0.05) | | | | |
| income | -1.93 | -1.41 | 0.80 | 0.42 | 1.67** | 1.21 |
| | (0.29) | (0.47) | (0.16) | (0.76) | (0.02) | (0.10) |
| interest rate | -4.04 | | -8.75*** | | | |
| | (0.24) | | (0.00) | | | |
| SR | | | | | | |
| interest rate | | -0.19 | | | | |
| | | (0.23) | | | | |
| Δ housing stock | | | -1.06 | | | |
| | | | (0.88) | | | |
| Δ housing stock (t-1) | | | -3.05 | -3.15* | -2.62 | -2.91 |
| | | | (0.65) | (0.09) | (0.15) | (0.11) |
| interest rate (t-1) | | | | 0.09 | | -0.37** |
| | | | | (0.84) | | (0.01) |
| modello | ARDL(6,6,6,6) | ARDL(6,6,6) | ARDL(6,6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | .a | .a | .r | .a | . | .r |
| ec_5 | .a | .a | . | .a | .a | . |
| ec_1 | .a | .a | .a | .a | .a | .a |
| min | 1992q3 | 1992q3 | 1991q3 | 1991q3 | 1991q3 | 1991q3 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.23 | 0.17 | 0.19 | 0.16 | 0.14 | 0.16 |

$p$-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.5: ARDL model for log(real house prices): Ireland

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | -0.06*** | -0.06*** | -0.05*** | -0.07*** | -0.07*** | -0.05*** |
| | (0.01) | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) |
| LR | | | | | | |
| housing stock (t-1) | -0.84 | -0.36 | | | | |
| | (0.69) | (0.87) | | | | |
| income | 1.85 | 1.84 | 1.11** | 1.49*** | 1.67*** | 1.54*** |
| | (0.19) | (0.17) | (0.04) | (0.00) | (0.00) | (0.00) |
| interest rate | -6.26* | | -7.77** | | | |
| | (0.06) | | (0.05) | | | |
| SR | | | | | | |
| interest rate | | -0.26*** | | | | |
| | | (0.01) | | | | |
| $\Delta$ housing stock | | | -0.94 | | | |
| | | | (0.34) | | | |
| $\Delta$ housing stock (t-1) | | | 0.71 | -0.20 | -0.05 | 0.17 |
| | | | (0.47) | (0.67) | (0.92) | (0.71) |
| interest rate (t-1) | | | | -1.05*** | | -0.23** |
| | | | | (0.00) | | (0.02) |
| modello | ARDL(6,6,6,6) | ARDL(6,6,6) | ARDL(6,6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | . | . | . | .r | .r | .r |
| ec_5 | . | . | . | .r | .r | .r |
| ec_1 | .a | .a | .a | .r | .r | .a |
| min | 1990q1 | 1990q1 | 1990q1 | 1990q1 | 1990q1 | 1990q1 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.59 | 0.57 | 0.59 | 0.59 | 0.57 | 0.56 |

*p*-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.6: ARDL model for log(real house prices): Germany

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | 0.03 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 |
| | (0.52) | (0.43) | (0.15) | (0.17) | (0.24) | (0.14) |
| LR | | | | | | |
| housing stock (t-1) | -3.24 | -2.45 | | | | |
| | (0.61) | (0.65) | | | | |
| income | 3.73 | 1.83 | -0.49 | 0.24 | 0.84 | 0.10 |
| | (0.62) | (0.77) | (0.81) | (0.89) | (0.74) | (0.95) |
| interest rate | 0.71 | | 1.37 | | | |
| | (0.95) | | (0.86) | | | |
| SR | | | | | | |
| interest rate | | 0.04 | | | | |
| | | (0.86) | | | | |
| $\Delta$ housing stock | | | -2.85 | | | |
| | | | (0.67) | | | |
| $\Delta$ housing stock (t-1) | | | -2.06 | -4.50** | -4.31** | -4.58** |
| | | | (0.75) | (0.01) | (0.02) | (0.01) |
| interest rate (t-1) | | | | -0.24 | | -0.14 |
| | | | | (0.61) | | (0.43) |
| modello | ARDL(6,6,6,6) | ARDL(6,6,6) | ARDL(6,6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | .a | .a | .a | .a | .a | .a |
| ec_5 | .a | .a | .a | .a | .a | .a |
| ec_1 | .a | .a | .a | .a | .a | .a |
| min | 1991q3 | 1991q3 | 1990q3 | 1990q3 | 1990q3 | 1990q3 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.20 | 0.20 | 0.21 | 0.21 | 0.23 | 0.22 |

$p$-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.7: OLS model for log(real house prices): Germany

| | (1) |
|---|---|
| Δ income (t) | 0.348** |
| | (0.02) |
| Δ income (t-1) | -0.074 |
| | (0.60) |
| Δ housing stock (t) | 3.355 |
| | (0.13) |
| Δ housing stock (t-1) | -4.285** |
| | (0.05) |
| interest rate (t) | 0.003*** |
| | (0.00) |
| interest rate (t-1) | -0.004*** |
| | (0.00) |
| exp. appreciation | 0.975*** |
| | (0.00) |
| Constant | 0.004*** |
| | (0.00) |
| r2 | 0.715 |

*p*-values in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.8: ARDL model for log(real house prices) with user cost measure

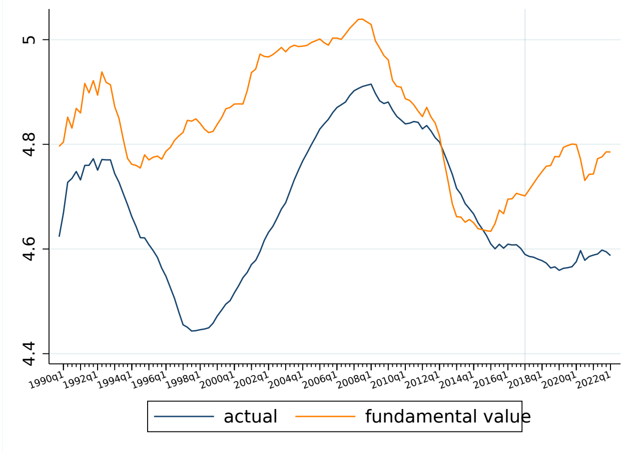
| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ADJ | | | | | | |
| house price (t-1) | -0.03*** | -0.03*** | -0.06*** | -0.05*** | -0.05*** | 0.03 |
| | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.18) |
| LR | | | | | | |
| income | 2.37*** | 4.29*** | 3.21*** | 1.48** | 1.53*** | -0.26 |
| | (0.00) | (0.00) | (0.00) | (0.03) | (0.00) | (0.84) |
| SR | | | | | | |
| Δ housing stock (t-1) | -0.99* | -2.15 | 1.42 | -3.67* | 0.40 | -5.03*** |
| | (0.08) | (0.40) | (0.35) | (0.06) | (0.36) | (0.00) |
| user cost (t-1) | -0.29*** | 0.22 | 0.33* | -0.29** | -0.41*** | -0.09 |
| | (0.00) | (0.13) | (0.08) | (0.03) | (0.00) | (0.53) |
| country | Italy | France | Spain | Belgium | Ireland | Germany |
| modello | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) | ARDL(6,6) |
| ec_10 | .r | .r | .r | . | .r | .a |
| ec_5 | .r | .r | .r | .a | .r | .a |
| ec_1 | .r | .a | .r | .a | .a | .a |
| min | 1990q2 | 1990q3 | 1990q2 | 1991q3 | 1990q2 | 1990q3 |
| max | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 | 2016q4 |
| r2_a | 0.74 | 0.76 | 0.64 | 0.14 | 0.59 | 0.22 |

*p*-values in parentheses

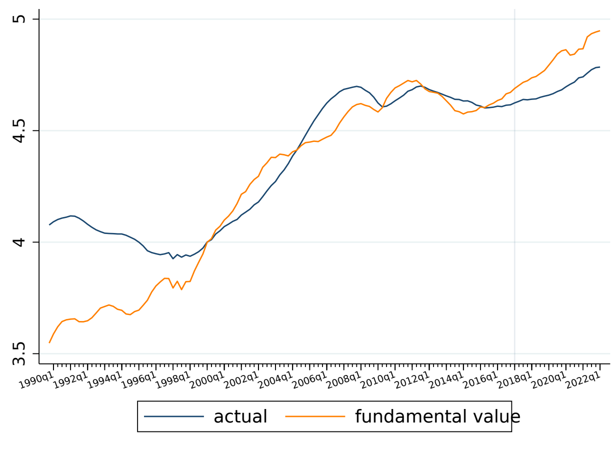
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

*Notes:* ec10, ec5 and ec1 stand for the result of the bounds test at the 10%, 5%, 1% significance levels, respectively. The symbol .r means that the null hypothesis is rejected, .a accepted and . means that the test is inconclusive. The user cost measure is taken from the European Commission (Barrios et al., 2019).

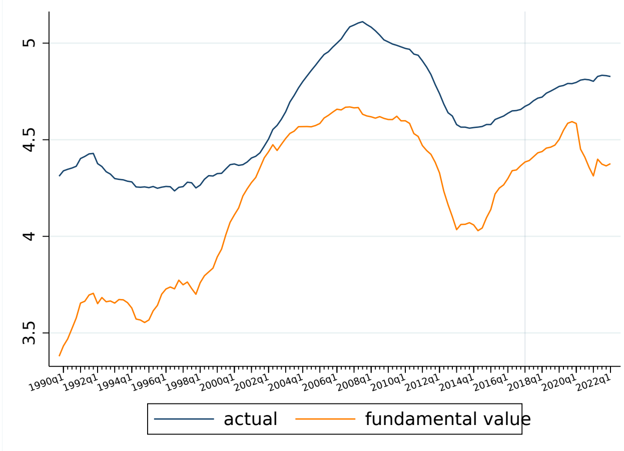
Figure A.1: Actual and long-run fundamental value of log(real house prices)



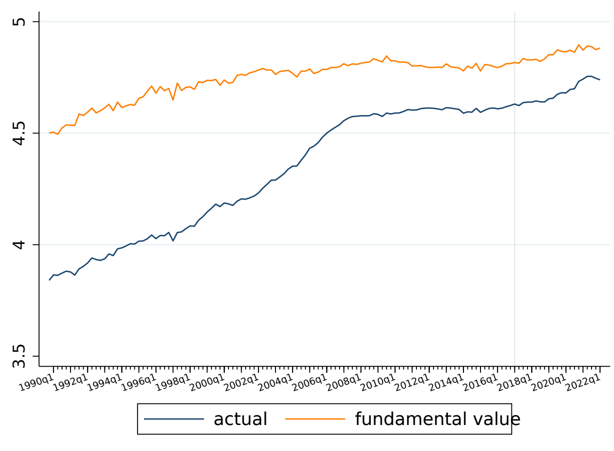

(a) *Italy*



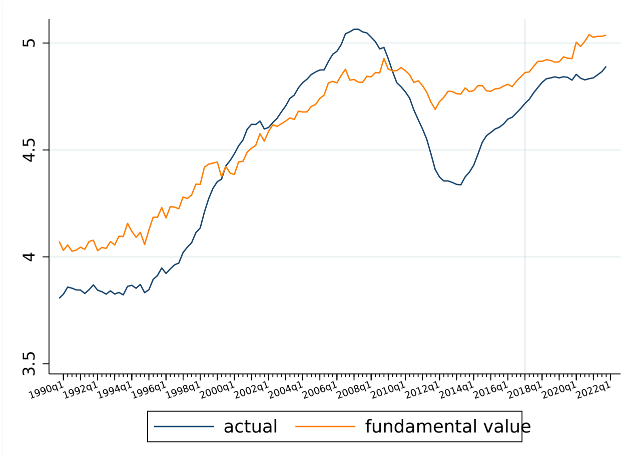

(b) *France*




(c) *Spain*



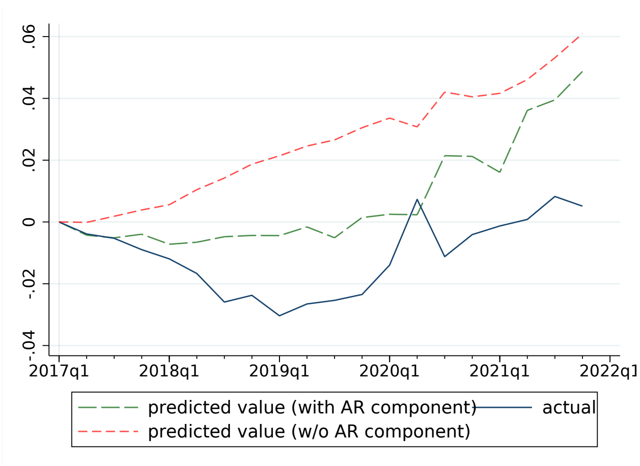

(d) *Belgium*



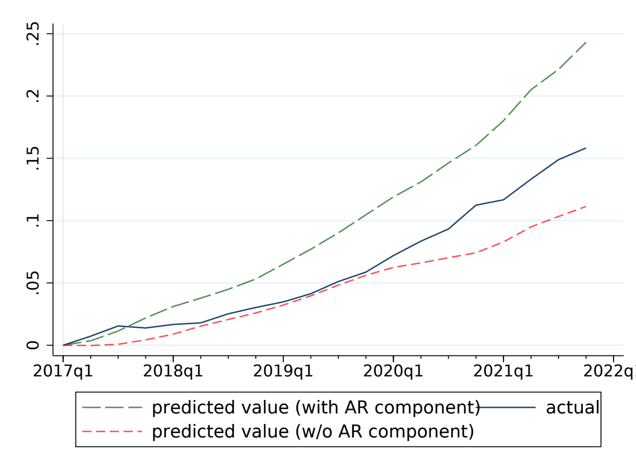

(e) *Ireland*

**Notes:** The blue line represents the actual log of real house prices. The yellow line represents the long-run fundamental value based on the estimates reported in Table 1. The vertical shaded line signals the end of the estimation period.

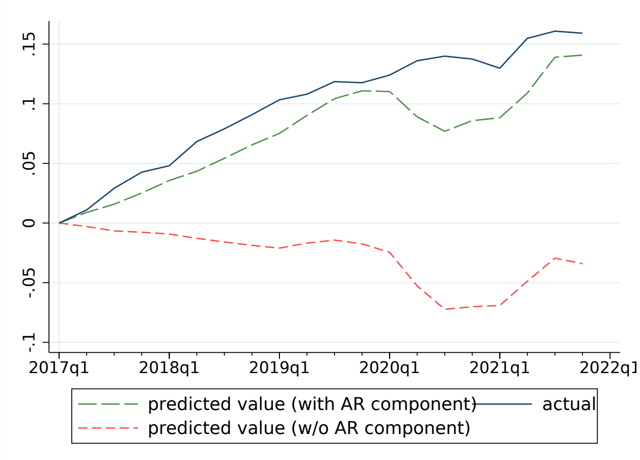
Figure A.2: Actual and predicted log(real house prices) excluding the autoregressive component



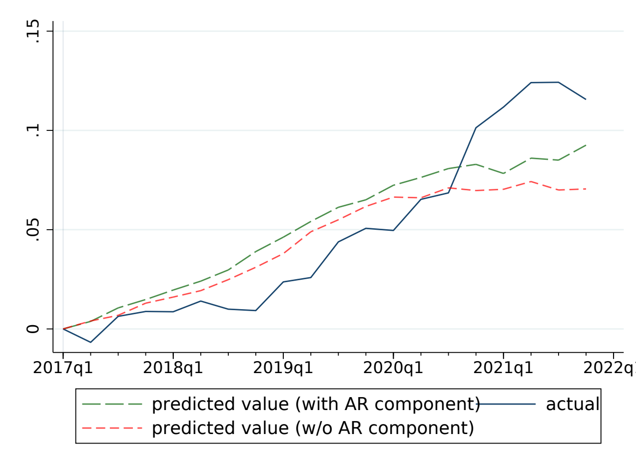

(a) *Italy*



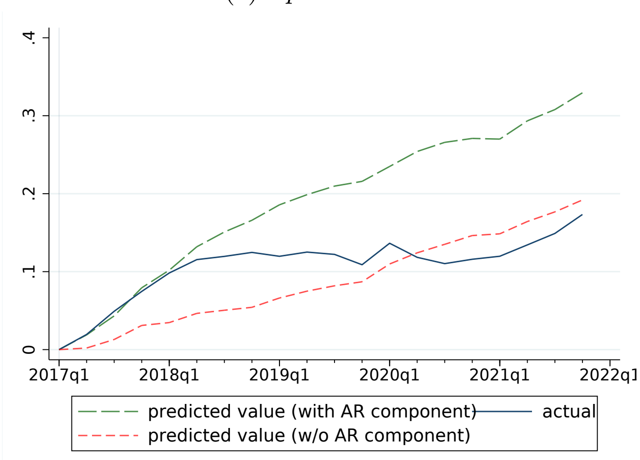

(b) *France*



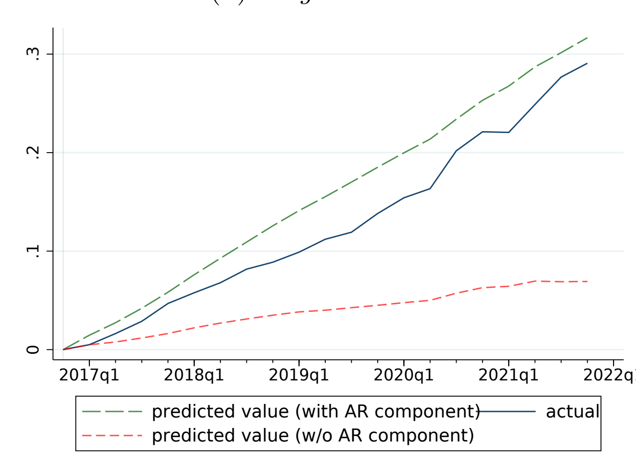

(c) *Spain*




(d) *Belgium*



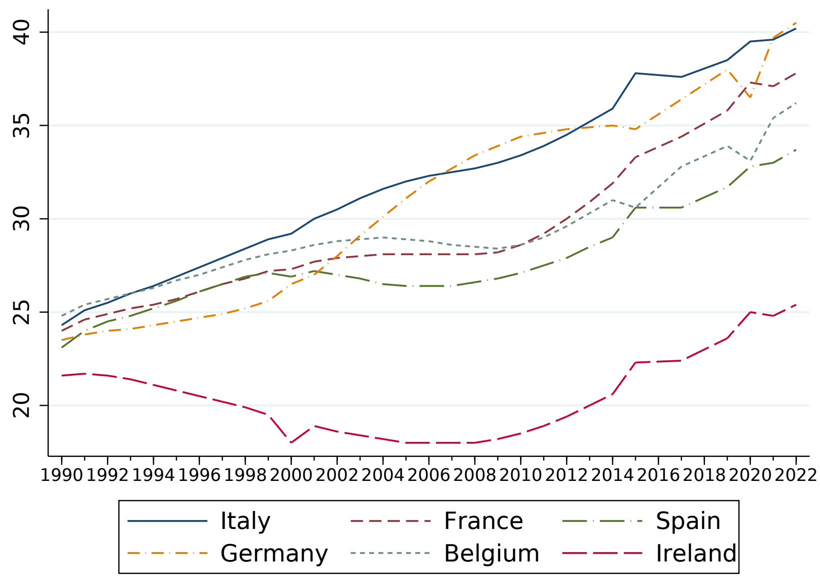

(e) *Ireland*




(f) *Germany*

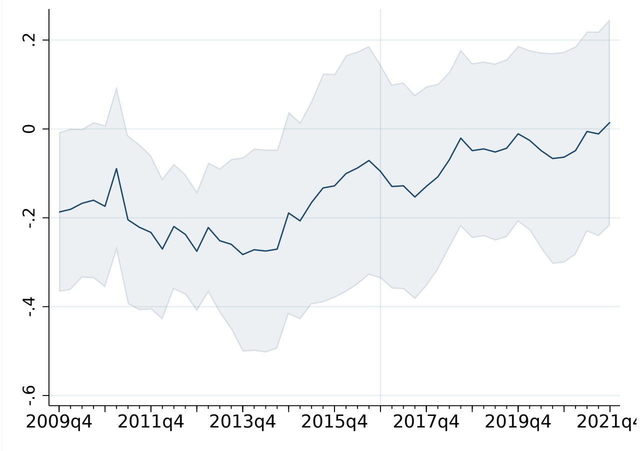
**Notes:** The blue line represents the actual log of real house prices after normalizing to zero its value in 2016q4. The red line represents the predicted value based on the estimates reported in Table 1 after subtracting the contribution of the autoregressive component.

Figure A.3: Old-age dependency ratio

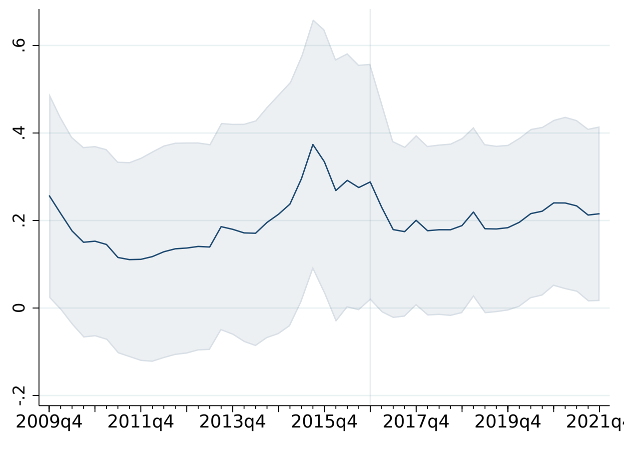



*Notes:* Data are taken from the OECD. The old-age to working-age demographic ratio is defined as the number of individuals aged 65 and over per 100 people of working age defined as those at ages 20 to 64.

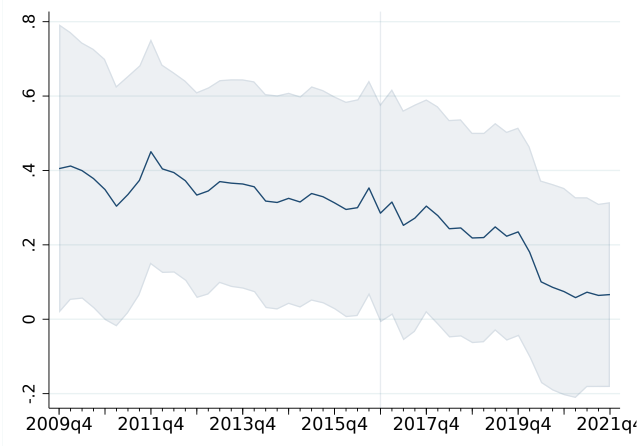
Figure A.4: Impact of the interest rate on house prices based on rolling regressions



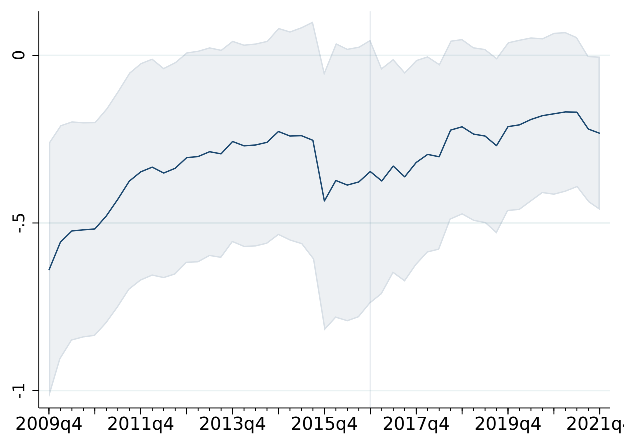

(a) *Italy*



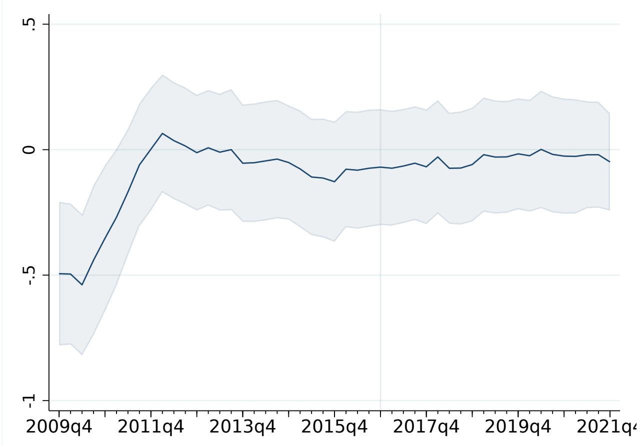

(b) *France*



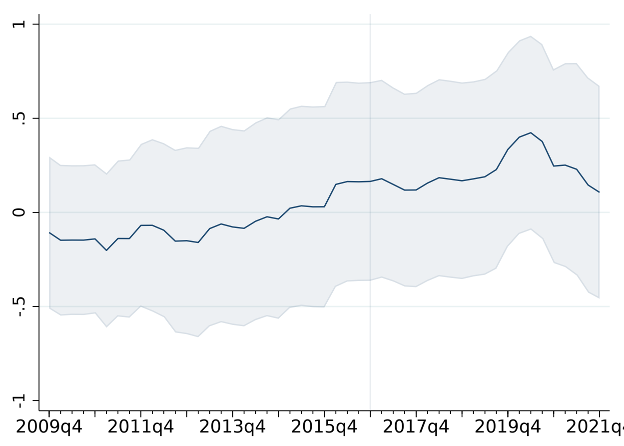

(c) *Spain*




(d) *Belgium*




(e) *Ireland*




(f) *Germany*

**Notes:** The figure represents the coefficient on the real interest rate from rolling regressions estimated on a 20-years window starting from the sample 1990–2010. The coefficient is represented at the end of the corresponding sample period. The shaded area represents the 5% significance level.