

# Revisiting International House Price Convergence Using House Price Level Data

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## Abstract

The literature on house price convergence largely relies on house price indices, based in an arbitrary year, rather than on actual price levels. This is essentially due to the scarcity of comparable house price level data. However, this severely constrains the analysis. In particular, it often forces to discard a large part of the data sample, which leads to a great loss of information and hampers analysis on sub-periods. In this paper, we combine the price level estimates produced by Bricongne et al. (2019) with long OECD house price series to analyse long-run house price convergence across 18 OECD countries. Applying the Phillips and Sul (2007) procedure, we find convergence in OECD nominal house prices, but two separate convergence clubs in real house prices. We find some convergence in euro area real house prices, but no evidence of strengthening after the introduction of the euro.  $\beta$ -convergence regressions (linking changes in house prices to their initial levels) point to conditional convergence, related to the evolution of gaps in real GDP per capita, long-term interest rates and population growth across countries.

Keywords: Convergence; House prices; Housing markets; OECD; Panel data models.

JEL codes: C33, R21, R31, F45.

## 1. Introduction

Most economists investigating long-run house price convergence across countries or regions use house price indices, based in an arbitrary year, rather than house price levels, essentially because of a lack of comparable price level data. This is a serious limitation, as the choice of the base year can affect the results. For example, taking the first observation as the base will suggest divergence, at least during an initial period, while taking the last observation as the base will suggest convergence towards the end of the sample. The base problem is generally addressed by setting the base period at the beginning of the sample and discarding initial observations, as in Phillips and Sul (2007), who study the behaviour of consumer prices in US metropolitan areas, or in Kim and Rous (2012), who examine house price convergence across US states and metropolitan areas. However, the cost in terms of lost observations is high, which limits the possibility to study sub-samples, such as those separated by the introduction of the euro.<sup>1</sup>

We overcome this difficulty by using a recent house price level dataset (Houselev) produced by Bricongne et al. (2019), which provides comparable estimates of house price levels for a large set of countries in 2016, and can be extended in time using house price indices going back to the early 1970s for 18 countries, including eight euro area members. We test the convergence of these series using the methodology of Phillips and Sul (2007), which has a number of advantages over alternative methods. First, it does not require stationarity of the time series. Second, it provides a framework for modelling transitional dynamics as well as long run behaviour. Finally, in case not all countries are converging, it allows the endogenous identification of convergence clubs.

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<sup>1</sup> Phillips and Sul (2007) use annual series starting in 1918, but discard the first 42 observations. Kim and Rous (2012) use quarterly data from 1975Q1 to 2009Q2, but discard the first half of their sample.

We supplement the analysis by  $\beta$ -convergence regressions (linking changes in house prices to their initial levels), which allow assessing whether convergence is conditional on income, interest rates and population growth.

From a theoretical standpoint, whether housing prices should converge across locations is not obvious. On the one hand, as dwellings are non-tradable goods, arbitrage is unlikely to fully clear price differences. Moreover, differences in preferences, the quality of dwellings and amenities justify price level disparities across locations. On the other hand, migration and converging house price determinants could lead to some degree of price convergence. Meen (1999), analysing the ripple effect running from house prices in the South-East of Great Britain to the rest of the country, distinguishes four potential explanations for house price spillovers: migration, equity transfer, spatial arbitrage and spatial patterns in the determinants of house prices. Importantly, he shows that house price spillovers do not require the presence of spatial links and largely result from patterns in underlying house price determinants. This is very relevant for international house price diffusion, where migration, equity transfer and spatial arbitrage are likely to be even weaker than within a single country. Kim and Rous (2012) argue that even though theoretical underpinnings for house price convergence are weak, there may be reasons to investigate house price convergence across the US. In particular, convergence in economic and demographic variables could lead to house price convergence. While house price convergence throughout the US looks unlikely given the heterogeneity of the country, convergence within groups of places that share similar economic fundamentals and amenities would not be surprising. Similarly, countries that experience convergence in income, interest rates and population growth could see house price convergence. Altogether, house price convergence is an empirical issue.

Using the Phillips and Sul (2007) procedure, we find long-run convergence in nominal house prices in a sample of 18 OECD countries. Since nominal convergence may be partly driven by common developments in general inflation, we also test for convergence in real house prices. Doing so, we identify two convergence clubs in our sample. Focussing on a nine-country euro area sample (including Denmark, which has an exchange rate peg with the euro), we find convergence over the period 1972Q1-2020Q4, but two separate convergence clubs before 1992 and one convergence club along with two diverging countries after 1992.  $\beta$ -convergence regressions point to convergence, both in the OECD and the euro area sample, albeit at a slow speed. The introduction of GDP per capita, long-term interest rates and population growth in the model suggests that convergence is conditional on these variables. Finally, we find no evidence that the introduction of the euro has significantly altered the convergence process. Our results are robust to a wide range of robustness tests.

This paper is organised as follows: Section 2 briefly reviews the literature on house price convergence. Section 3 and 4 describe the data and the methodology. Section 5 and 6 present the results and robustness checks and Section 7 concludes.

## **2. Overview of the literature**

The literature has investigated different forms of convergence among economic variables. One strand focusses on the convergence of business and financial cycles. In particular, several papers document the growing role of the financial cycle, largely characterised by swings in the credit-to-GDP ratio and property prices, in macroeconomic developments since the 1980s (Drehmann et al., 2012; Borio, 2014; Miranda-Agrippino et al., 2020). Other studies focus on the synchronisation of business cycles within the euro area, which is crucial for the success of a monetary union. Results

are mixed, pointing to some increase in business and financial cycle synchronisation, but with diverging amplitudes (Franks et al., 2018). In this paper, we do not study cyclical synchronisation, first because the issue is already widely covered in the literature and second, because the new set of comparable house price level series we are using is more useful to shed light on steady states than on cycles, which can be captured by indices.<sup>2</sup>

Our paper is related to another strand of the literature, which studies the long-term behaviour of selected economic variables, such as real GDP per capita, inflation or interest rates. While cyclical convergence is key for monetary and financial policy, long-term convergence has structural implications, especially in integrated economic areas. For example, while convergence in income per capita is not essential for the functioning of a monetary union, it is key for European economic integration and cohesion. GDP per capita in the euro area slowly converged in the 1990s, but this trend stopped in the early 2000s and the post-GFC period saw divergence (Franks et al., 2018). Von Lyncker and Thoennessen (2017) document geographic clustering among EU regions, with a North-South divide and high-income clusters for capital cities. Antonakakis et al. (2017) find that despite short-run divergences, as occurred in the wake of the euro sovereign debt crisis, euro area sovereign bond yields tend to converge, with the exception of Cyprus and Greece. GDP per capita and interest rates are well-known drivers of house prices and affect their convergence, as our conditional convergence analysis shows. Structural features of housing markets may also contribute to house price convergence in the euro area. Żelazowski (2018) finds evidence of

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<sup>2</sup> It is worth noting, however, that some underlying factors may affect both cyclical synchronisation and long-term convergence. For example, Drehmann et al. (2012) point to financial liberalisation and credible anti-inflation regimes as factors affecting the global financial cycle. If these factors lead to a permanent narrowing of differences in financing conditions across countries, they will also result, all else equal, in house price convergence.

convergence in the share of housing in household consumption, the number of dwellings per inhabitant and the homeownership rate in European housing markets. However, this is a very slow process, with half-lives ranging from about 15 years to more than 30 years. In turn, house price differentials may impact the single market, notably through labour mobility, household wealth and investment flows.

A number of studies have identified relations between house prices across countries. Gupta et al. (2015), adopting a fractional cointegration approach, find some comovement in euro area house prices, although they note that German house prices tend to move in the opposite direction from other euro area countries. Miles (2019a) finds no sustainable increase in house-price comovement attributable to the euro. Tsai (2018) finds higher correlation in nominal house prices among euro area countries than among a set of four non-euro area European countries, as well as an increasing influence of Germany on other markets since the introduction of the single currency. Applying the Phillips and Sul (2007) methodology, he finds that house prices did not converge before 1992, but converged thereafter in both euro area and non-euro area countries. Miles (2020), employing a probabilistic pairwise approach finds only marginal evidence of euro area price convergence. He also notes that German house prices rarely converge with those of other countries. Maynou et al. (2021) find five convergence clubs among twelve European countries over the period 2004Q2-2016Q3, but no evidence of a euro convergence club. They argue that convergence clubs reflect geographical proximity and similarities in market structures.

The literature on the diffusion of house prices within a single country also sheds light on convergence patterns and drivers. Since the 1990s, several papers have studied house price connections within the United Kingdom (Alexander and Barrow, 1994; Meen, 1999; Cook, 2003; Holmes and Grimes, 2008) and the United States (Pollakowski and

Ray, 1997; Canarella et al., 2012; Gupta and Miller, 2012, Miles, 2019b), using various statistical techniques, notably unit-root and cointegration test, as well as various types of autoregressive models and Granger causality tests. Similar studies have covered Australia, Finland, Ireland, Malaysia, New Zealand, Spain, South Africa, Sweden and Taiwan.<sup>3</sup> Holmes et al. (2011), using a pairwise approach, find evidence of long-run house price convergence across US states and metropolitan statistical areas (MSAs), with the adjustment speed inversely related to distance. Overall, this literature generally finds evidence of house price convergence between some regions or cities, but also segmentation between sub-national housing markets.

Given widespread evidence of segmentation in housing markets, many recent studies investigate house price convergence using the Phillips and Sul (2007) methodology, which allows endogenously identifying groups of spatial entities (e.g. states, regions, countries) within which house prices converge, so-called convergence clubs. They generally find multiple convergence clubs, suggesting that despite the strength of national drivers of house prices, differences in local factors prevent full convergence. Montagnoli and Nagayasu (2015) and Holmes et al. (2019) identify several convergence clubs in the UK. The latter article, which exploits a large dataset including median prices for different types of dwellings in 348 local authorities, points to location, distance, income, population density, congestion and education as the main drivers of club formation. It also shows that convergence is less likely among detached, semi-detached and terraced houses than among flats.

Apergis and Payne (2012, 2019a, 2019b) investigate US house price convergence at different levels (states, metropolitan areas in Florida and condominiums in five major

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<sup>3</sup> For a review, see Gupta et al. (2015) and Meen (2016).

metropolitan areas) and find in all cases several convergence clubs, whose composition largely reflects spatial proximity. They point to spatial arbitrage, income per capita, availability of mortgage financing, labour mobility, rental market features, land-use and housing supply regulations, demographics and weather conditions as potential factors driving club formation. Kim and Rous (2012) find several house price convergence clubs in US states and MSAs and show that housing supply regulations and climate are important determinants of convergence club membership. Montañés and Olmos (2013) find four convergence clubs among 19 US MSAs. They also show that the number of convergence clubs changes over time, with in particular a reduction in their number when the sample extends beyond the first quarter of 2010, suggesting that the bursting of the subprime bubble has affected house price dynamics. Christou et al. (2019) find 11 convergence clubs in the cost of living indices of the 50 US states. To shed further light on the lack of convergence in the cost of living across US states, they extend their analysis to house prices, which are among the most significant determinants of geographical differences in the cost of living. They find seven convergence clubs, with convergence partly related to the distance between states and some of their characteristics, such as the share of rural population.

Matysiak and Olszewski (2019) find three convergence clubs among the primary residential markets of Poland's seven largest cities, with club membership related to the initial price level, population and housing stock growth, the unemployment rate and wage growth. Blanco et al. (2016) find that population growth, the initial housing stock and vacancies, the size of the rental market and location appear as the main determinants of club membership among Spanish regions. Apergis et al. (2015) find convergence clubs in different housing market segments across the nine South African provinces. They relate convergence to labour mobility, notably to mining and

manufacturing provinces, as well as income convergence, especially among the higher income groups.

The present paper adds to the literature by using price level data to investigate the long-run convergence of house prices and the presence of convergence clubs in a set of 18 advanced economies, of which eight belong to the euro area. The availability of reliable price level series allows overcoming the base problem faced when using price indices. We complement the analysis by  $\beta$ -convergence regressions to shed light on the role of income, interest rates and population growth in the convergence process.

### **3. Data**

Most studies investigating relations between house prices across countries use price indices, which are adequate to study comovement, but suffer from using an arbitrary base period for long-term convergence analysis. Indices do not provide information on the relative house price levels of countries at any point in time. Hence, a fall in house prices in one country when prices rise in the others could reflect divergence, but also convergence if the starting level of house prices in that country was higher than elsewhere. The main novelty of the present paper is to use house price levels, rather than indices, which is made possible by a recent dataset (Houselev) produced by Bricongne et al. (2019) that provides comparable estimates of house price levels across a wide range of countries.

The authors use information on the total value of the dwelling stock in national accounts statistics and on its floor area from census statistics to produce house prices per square meter in 2016 (Figure 1). House price indices from the OECD Analytical house price database<sup>4</sup> are combined with the 2016 price levels to build house price level time series

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<sup>4</sup> Available at [https://stats.oecd.org/Index.aspx?DataSetCode=HOUSE\\_PRICES](https://stats.oecd.org/Index.aspx?DataSetCode=HOUSE_PRICES).

for 18 countries, of which eight belong to the euro area. Combining level estimates and house price indices to construct house price level time series has two advantages. First, in most countries the total value of dwellings in national accounts statistics is only available over a much shorter period than house price indices. Second, house price indices are adjusted for quality and are designed to reflect pure price change, whereas the total value of dwellings is also affected by changes in the number and the quality of dwellings.

**[Figure 1]**

First, we generate nominal quarterly series in euros by extrapolating house prices backwards and forward using the OECD nominal house price index and exchange rates from the OECD Economic Outlook database. Second, we deflate the nominal house price series by the euro area private consumption deflator to get real (constant price) house price series.

For the  $\beta$ -convergence regressions, we use three variables from the OECD Economic Outlook database. Real GDP per capita at constant purchasing power parity (PPP) is used as a measure of income, except for Ireland, for which we use a measure of gross value added excluding sectors dominated by foreign-owned multinational enterprises, converted at PPP and scaled by population.<sup>5</sup> Given the massive influence of multinational companies on Irish GDP, this is a better measure of income as a determinant of housing demand. The 10-year government bond yield is used as a proxy for the mortgage rate, as the latter is generally not available and comparable across countries over our full time sample. Although mortgage finance characteristics vary

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<sup>5</sup> Gross value added excluding sectors dominated by foreign-owned multinational enterprises from the OECD Economic Outlook database is roughly comparable to the Modified Total Domestic Demand series produced by the Irish Central Statistics Office, but is less volatile.

across countries, in the long run, which is relevant for convergence analysis, mortgage rates are closely related to long-term interest rates. Finally, we use total population growth as a measure of demographic pressure on housing demand.

#### 4. Methodology

##### 4.a. Phillips and Sul convergence test

Phillips and Sul (2007) (henceforth PS) developed a methodology to test for convergence in a panel of countries and to identify convergence clubs. It uses a nonlinear time-varying factor model and provides the framework for modelling transitional dynamics as well as long-run behaviour.

Let  $y_{it}$  denote the house price of country  $i$  at time  $t$ . To focus on the long-term behavior of the series, the cyclical component has been removed using the HP filter (Hodrick and Prescott, 1997). The objective is to test whether house prices  $y_{it}$ ,  $i = 1, 2, \dots, N$  tend to converge to a single steady state as  $t \rightarrow \infty$ . PS adopt a factor representation:

$$y_{it} = \delta_{it} \mu_t, \quad (1)$$

where  $\mu_t$  is a single common component and  $\delta_{it}$  is a time-varying idiosyncratic element that captures the deviation of country  $i$  from the common path defined by  $\mu_t$ . Within this framework, all  $N$  countries will converge, at some point in the future, to the steady state, if  $\lim_{k \rightarrow \infty} \delta_{it+k} = \delta$  for all  $i = 1, 2, \dots, N$ , irrespective of whether countries are near the steady state or in transition. This is important given that the paths to the steady state (or states) can differ significantly across countries.

The factor  $\mu_t$  is assumed common across economies, while the transition dynamics are captured by the idiosyncratic components  $\delta_{it}$ , which are allowed to vary across cross sections and time. PS do not assume any parametric form for  $\mu_t$ ; they just factor it out and concentrate on  $\delta_{it}$ . In particular, they eliminate the common component  $\mu_t$  through rescaling by the panel average:

$$h_{it} = \frac{y_{it}}{\frac{1}{N} \sum_{i=1}^N y_{it}} = \frac{\delta_{it}}{\frac{1}{N} \sum_{i=1}^N \delta_{it}}. \quad (2)$$

The relative measure  $h_{it}$  captures the transition path with respect to the panel average.

To define a formal test for the convergence hypothesis, PS construct the cross sectional variance ratio  $H_1/H_t$ , where  $H_t = \frac{1}{N} \sum_{i=1}^N (h_{it} - 1)^2$  and  $h_{it}$  is defined in equation (2).

Under the convergence hypothesis,  $h_{it} \rightarrow 1$  and  $H_t \rightarrow 0$  as  $t \rightarrow \infty$  for given N. PS show that the convergence hypothesis can be tested within the framework of the following regression:

$$\log \frac{H_1}{H_t} - 2 \log L(t) = c + b \log t + u_t, \quad (3)$$

Where  $L(t)$  is a slowly varying function, increasing and diverging at infinity. Thus, the null hypothesis of convergence takes the form:  $\mathcal{H}_0: b \geq 0$  and can be tested using a simple one-sided t test. Under the divergence hypothesis  $\mathcal{H}_A$ ,  $H_t$  converges to a positive quantity as  $t \rightarrow \infty$  and the dependent variable in (3),  $\log(H_1/H_t) - 2 \log L(t)$  diverges to  $-\infty$ . Hence, the t test on the coefficient of the  $\log t$  regressor discriminates the behaviour of the dependent variable under the alternative hypothesis of divergence  $\mathcal{H}_A$ , from its behaviour under the null hypothesis of convergence  $\mathcal{H}_0$ . The  $t$ -test statistic follows asymptotically the standard normal distribution and is constructed using a

heteroskedasticity and autocorrelation consistent standard error.<sup>6</sup> PS call the one-sided  $t$ -test, the  $\log t$  test due to the presence of the  $\log t$  regressor in equation (3). The null hypothesis of convergence is accepted at the 5% level if the  $\log t$  test is greater than -1.65.<sup>7</sup>

The empirical convergence literature also deals with the possible existence of multiple equilibria. In that case, the rejection of the null hypothesis that all countries in the sample converge does not rule out the presence of convergence clubs in the panel. In this study, we implement the club convergence and clustering procedure proposed by PS. We summarize that procedure as follows: (1) Order the  $N$  countries with respect to the last-period value of the time series; (2) Form all possible core (club) groups by selecting the first  $k$  highest countries, with  $k = 2, 3, \dots, N$ . Then, test for convergence using the  $\log t_k$  test within each subgroup of size  $k$ . Finally, define the core club of size  $k^*$  as the club for which the maximum computed  $\log t_{k^*}$  statistic occurs, given that the  $\log t_k$  statistics supports the convergence hypothesis; (3) From the remaining  $N-k^*$  countries, add one country at a time to the core club and test for convergence through the  $\log t$  test. If the test strongly supports the convergence hypothesis ( $\log t \geq 0$ ), then include the country to the core group. Find all countries that, according to the  $\log t$  test, converge to the same steady state as the core group; these countries together with the countries of the core group form the first convergence club in the panel; (4) Then, for the remaining countries (if any), repeat the procedure described in steps 1-3 to

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<sup>6</sup> Standard errors are estimated using the Newey-West HAC estimator (1987) with the Quadratic Spectral kernel. Bandwidth is set equal to the “optimal” bandwidth which is automatically selected using the parametric methodology suggested by Andrews (1991).

<sup>7</sup> Antonakakis et al. (2017) show through Monte Carlo simulations that the  $\log t$  test is robust to the presence of structural breaks.

determine the next convergence club, if one exists. Finally, terminate the procedure when the remaining economies fail to converge.

#### ***4.b. $\beta$ -convergence regressions***

We estimate convergence regressions similar to those traditionally used in the economic growth literature, which focusses on GDP per capita convergence, to shed light on the factors driving convergence. The simplest equation relates the change in the gap between the real house price in a country and its average across countries to the level of this gap in the preceding quarter:

$$\Delta(rhp\_gap_{it}) = \gamma + \alpha_i + \beta rhp\_gap_{it-1} + \varepsilon_{it}, \quad (4)$$

where  $rhp\_gap_{it}$  is the percentage difference between real house prices in country  $i$  at time  $t$  and the average real house price at time  $t$  in the relevant country sample,  $\gamma$  is a constant,  $\alpha_i$  are country fixed effects and  $\varepsilon_{it}$  is a zero-mean disturbance term.  $\beta$  is the coefficient of interest, which is negative in the case of convergence.

The economic growth literature has shown that the inclusion of fixed effects to account for unobserved country heterogeneity is essential to get reliable convergence estimates (Islam, 1995; Acemoglu and Molina, 2021). Similarly, in the same way as unobserved time-invariant (or very slow-moving) factors affect economic growth, unobserved time-invariant factors are bound to affect house price levels. These include in particular geography, urban shape, as well as housing and mortgage market structures. Hence, fixed effects need to be included.

Estimating equation (1) involves a number of difficulties. First, house prices exhibit inertia, which leads to autocorrelation in the residuals of equation (1). This biases the coefficient estimates. To address this problem, we supplement equation (1) with lags of the dependant variable:

$$\Delta(rhp\_gap_{it}) = \gamma + \alpha_i + \beta rhp\_gap_{it-1} + \delta(L)\Delta(rhp\_gap_{it}) + \varepsilon_{it}, \quad (5)$$

where  $\delta(L)$  is a lag polynomial.

Second, the bias in ordinary least square (OLS) estimates in dynamic panel regressions with fixed effects is well-known (Nickell, 1981). However, the bias is small in long time samples (Judson and Owen, 1999).<sup>8</sup> Hence, OLS will yield asymptotically unbiased coefficients in our dataset, as the full sample contains 196 quarters and the shortest sub-sample includes 80 quarters. Third, the ordinary standard errors of the regression coefficients are likely biased, due to cross-sectional dependence. Hence, we use the Driscoll and Kraay standard errors, which are robust to heteroscedasticity and general forms of cross-sectional and temporal dependence (Driscoll and Kraay, 1998; Hoechle, 2007).

The  $\beta$  coefficient in equations (1) and (2) provides an unconditional measure of convergence. However, differences in house prices across countries may be related to differences in house price determinants, notably income, mortgage rates and population growth. Income is measured by GDP per capita at purchasing power parity and the mortgage rate is proxied by the 10-year government bond yield, as comparable mortgage rate series are not available on the full sample. As for house prices, gaps with the sample average are used. This yields the following equation:

$$\begin{aligned} \Delta(rhp\_gap_{it}) = & \gamma + \alpha_i + \beta rhp\_gap_{it-1} + \delta(L)\Delta(rhp\_gap_{it}) + \theta_1 gdp\_gap_{it} + \\ & \theta_2 irl\_gap_{it} + \theta_3 popg\_gap_{it} + \varepsilon_{it}, \end{aligned} \quad (6)$$

where  $gdp\_gap_{it}$ ,  $irl\_gap_{it}$  and  $popg\_gap_{it}$  are the gaps (in percentage or percentage points) between the country  $i$  values at time  $t$  of GDP, interest rate and population

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<sup>8</sup> For  $T > 30$ , the bias due to endogeneity will be less than the bias potentially introduced by an instrumental variable method like the general method of moments (GMM), whose estimator for samples with a sizeable time dimension inevitably suffers from instrument proliferation (weak instrumentation).

growth and the corresponding country sample averages. Note that we use the gap in the nominal interest rate, not the real interest rate. The literature suggests that given that higher nominal rates imply a frontloading of repayments, they tend to act as a borrowing constraint, which may add to the impact of real mortgage rates on housing prices (Meen, 2008). Our estimates yield a similar result, with the nominal interest rate having much higher statistical significance than the real interest rate.

## **5. Results**

### ***5.1. Phillips and Sul convergence tests***

We first investigate convergence in nominal house prices, converted into euros at current exchange rates. If dwellings were subject to perfect arbitrage, we would expect house prices to converge across countries, according to the law of one price. However, dwellings are non-tradable goods. In addition, house prices reflect specific amenities present in the places where dwellings are located, and are therefore affected by a wide range of factors, such as urban shape, transport networks or the quality of schools. Although such factors are local, they are likely to be reflected in national price aggregates, for example because the degree of urbanisation or the development of transport networks vary across countries. Besides, nominal house price convergence may partly reflect the global narrowing in general inflation spreads across countries as central banks moved towards inflation targeting with similar targets. Convergence criteria to join the currency union have also contributed to narrowing inflation spreads within the euro area. Hence, to focus on developments specifically related to housing

markets, we subsequently focus on convergence in real house prices<sup>9</sup> as is done in much of the literature.

### *5.1.1. OECD sample*

#### *Nominal house prices*

We first test for convergence in nominal house prices across our 18-country sample over the period 1972Q1-2020Q4, where we discard the first 10% of observations.<sup>10</sup> Convergence cannot be rejected in the full sample (Table 1, Panel A). The results are in line with Tsai (2018), who finds house price convergence both among 11 euro area countries and among four non-euro European countries over the period 1984Q1-2015Q1. However, nominal house price convergence may be partly driven by convergence in general inflation. To abstract from this effect, we will now test convergence in real house prices.

### **[Table 1]**

#### *Real house prices*

Convergence in the full sample can clearly be rejected (Table 1, Panel B). The Phillips and Sul (2007) procedure identifies two convergence clubs: one groups Japan and the United States with Finland and Italy (club 2), while the other (club 1) groups the rest of the sample. Relative transition curves derived from equation (2) show a tendency for the two clubs to converge until 2000, but clear divergence thereafter (Figure 2). Since 2001, club 1 exhibits strong average real house price increases, only briefly interrupted by the

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<sup>9</sup> We adjust house prices for general inflation using the private consumption deflator rather than the consumer price index, as consistent time series are generally available from the national accounts over a longer period.

<sup>10</sup> Phillips and Sul (2007) recommend discarding a small fraction of the data to better focus on the series' long-term behaviour.

GFC, while club 2 shows relatively stable prices on average, despite ample cycles in some of its members.<sup>11</sup>

## [Figure 2]

### *5.1.2. Euro area sample*

The euro area has not emerged as a convergence club in the analysis of our sample of 18 OECD countries. In particular, Finland and Italy are in a different convergence club from the other euro area countries. However, the result may be influenced by the inclusion of non-euro area countries, which contribute to define the common trend. Hence, we apply the Phillips and Sul (2007) procedure to a restricted sample, which only includes euro area countries and Denmark. The latter is included with euro area countries as it is closely integrated with euro area economies and has maintained a fixed exchange rate against the euro.<sup>12</sup>

Real house prices across the euro area sample are found to converge when the whole period (1972Q1-2020Q4) is considered (Table 1, Panel C). Even though euro area countries are split between two convergence clubs when the whole OECD sample is considered, convergence cannot be rejected when only euro area countries are included in the analysis. Although this may look surprising at first glance, it is consistent with the intermediate position of the euro area house price trend, relative to the two OECD convergence clubs in recent years.<sup>13</sup> To assess the potential impact of the introduction of the euro, we examine the two sub-periods separated by the Maastricht treaty.<sup>14</sup> We

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<sup>11</sup> See Figure A.1 in the appendix.

<sup>12</sup> Robustness checks show that the inclusion of Denmark does not alter the euro area results significantly, see section 6 and appendix.

<sup>13</sup> See Figure A.1 in the appendix.

<sup>14</sup> The quarter in which the Maastricht treaty was signed (1992Q1) is chosen as the breakpoint, as a convergence in economic policies started before the effective introduction of the euro. Robustness checks show that results are qualitatively similar when the date of the introduction of the euro (1999Q1) is chosen, see section 6 and appendix.

find two convergence clubs before the introduction of the euro, one including Belgium, Denmark and the Netherlands and the other grouping the six other countries. After the introduction of the euro, we find a convergence club including seven countries, but two diverging countries, Ireland and Italy. House prices in these two countries exhibit very different patterns. In Italy, real house prices were lower at the end of 2020 than in early 1992, contrasting with the rising trend in the euro area as a whole. The upswing from the mid-1990s to the 2007-08 global financial crisis was relatively modest compared with many other euro area countries and was followed by a significant fall. In Ireland, real house prices increased faster than the euro area average during the period, but with ample cycles.

Summing up, we find some long-term convergence among euro area countries, but the introduction of the euro does not seem to have speeded up convergence. Furthermore, the evidence of convergence for the euro area sample is not much stronger than for the OECD sample, even though the latter distinguishes two convergence clubs. In the next section, we relate gaps in house prices across countries to gaps in some well-known house price determinants, to shed light on the forces behind house price convergence.

## **5.2. $\beta$ -convergence regressions**

In this section, we estimate regressions similar to those traditionally used in income convergence analysis to analyse further the convergence process, to evaluate the speed of convergence and to assess the extent to which convergence is conditional on traditional determinants of house prices. For the latter, we consider real GDP per capita<sup>15</sup>, long-term interest rates and population growth. Housing supply factors, like physical and regulatory constraints on building new dwellings, also affect house price

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<sup>15</sup> A different measure is used for Ireland, see data section.

developments and may also influence convergence. However, obtaining relevant and comparable supply measures for all countries in our sample over the whole period would be challenging. Furthermore, physical and regulatory constraints are likely to be largely time-invariant and hence to be captured by country fixed-effects. Hence, our model does not include any supply variable.

Figure 3 shows the standard deviation of gaps<sup>16</sup> in house prices and their determinants, which is generally referred to as  $\sigma$ -convergence. On this measure, little convergence is apparent in house prices in the OECD sample, while a mild convergence trend is observed in the euro area sample. Conversely, GDP per capita and interest rates have converged in all samples.<sup>17</sup> Finally, population growth differences show no clear trend but relatively large time variation, especially in the euro area sample.

### [Figure 3]

The regression results suggest convergence (the  $\beta$  coefficient is negative and statistically significant), albeit at a very slow pace (Table 2). When lags of the dependant variable are included to account for house price inertia, convergence would take about 20 years. Adding house price determinant gaps, the  $\beta$  coefficient increases in magnitude and the coefficients on gaps are of the expected sign and statistically significant (at least at the 10% level on the whole period), which points to some degree of conditional convergence. Taking into account that different developments in house price determinants across countries affect the convergence process, it would take on average about 11 years to close gaps in real house prices. Table 2 also shows sub-periods, with the break date corresponding to the quarter in which the Maastricht treaty

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<sup>16</sup> Gaps are percentage (or percentage point) deviations of country values from the relevant group average, see methodology section.

<sup>17</sup> The spike in standards deviation in 2020 is due to the COVID-19 pandemic, which has affected countries to various degrees.

was signed. The purpose is to investigate whether the convergence process has changed in the euro area after the decision to create a monetary union. Looking at changes between sub-periods in a broader sample of OECD countries and in a sample only made of non-euro area countries (see below) helps check that eventual changes in the convergence process in the euro area are not driven by global factors that also affect other countries. In the OECD sample, the pattern of convergence is fairly similar across sub-periods, although the speed of convergence and the role of house price determinant varies.

**[Table 2]**

Tables 3 and 4 show convergence regressions for the euro area (including Denmark) and non-euro area samples respectively. The results are not very different for the two groups. Convergence actually appears somewhat faster in the non-euro area group, both before and after the introduction of the euro. Population growth has a stronger role after 1991 than before in both groups, but even more so outside the euro area. The impact of the income gap on house prices decreases markedly in the euro area after the introduction of the euro, while it rises outside the currency union. This is hardly surprising, as Figure 3 suggests that real GDP per capita has diverged in the euro area sample since around 2005. Conversely, the interest rate impact on house prices strengthens in the euro area after the introduction of the common currency. This results, combined with the long-term tendency for euro area sovereign bond yields to converge (Antonakakis et al., 2017), suggests that over the long run, convergence of interest rates will contribute to the convergence of house prices in the euro area.

**[Table 3]**

**[Table 4]**

To sum up, we find convergence in both the euro area and non-euro area countries, but at a slow pace. The convergence process does not look very different in the two country groups. This is true both before and after the introduction of the euro. While the model with no exogenous variables does not exclude some degree of unconditional convergence, regressions including real GDP, interest rates and population growth point to conditional convergence. This is consistent with the view that, as dwellings are non-tradable goods, movements in underlying fundamentals are likely to be the main drivers of convergence.

Our results complement, but also show some differences with the literature on house price convergence across the euro area. First, they shed light on the tendency of German house prices to move in the opposite direction from those of other euro area countries documented by Gupta et al. (2015) and Miles (2019a). As Germany had higher house prices than other euro area countries before the mid-1990s, opposite movements are compatible with long-term convergence. Second, while our results on long-term convergence in nominal house prices are consistent with Tsai (2018), contrary to him we find little evidence that convergence has strengthened after 1992. This difference may stem from the use of price level data rather than indices, a longer pre-1992 sample in our study and a focus on real rather than nominal house prices. Maynou et al. (2021) find five convergence clubs among twelve European countries, pointing to more segmentation than in our study. However, their sample covers the period 2004Q2-2016Q3, a relatively short period including the GFC and the euro sovereign debt crisis, in which short-term developments and volatility in fundamental drivers of house prices may have obscured long-term convergence patterns.

## **6. Robustness checks**<sup>18</sup>

To make sure the  $\beta$ -convergence regressions results are not driven by outliers, we run the  $\beta$ -convergence regressions for the two separate convergence clubs that were identified using the Phillips and Sul (2007) procedure and obtain very similar results as on the full sample.

Similarly, we run regressions for the euro area convergence clubs identified on sub-periods, which also support our main findings.

Next, we replicate our analysis of sub-samples using 1999Q1 (the effective introduction of the euro) instead of 1992Q1 (the signing of the Maastricht treaty) as the breakpoint. This does not alter our results significantly. We also check that excluding Denmark, which has retained its own currency, although it is pegged to the euro, from our euro area sample does not affect our results significantly.

Finally, as the literature suggests that asymmetry can be present in house price behaviour, we test whether the convergence process differs according to whether house price levels are below or above the sample average, a hypothesis that is rejected.

## **7. Conclusion**

In this paper, we have used the recent Houselev dataset of house price levels produced by Bricongne et al. (2019) to revisit the issue of house price convergence in a sample of OECD and euro area countries. Using the Phillips and Sul (2007) procedure, we found long-run convergence in nominal housing prices across a sample of 18 OECD countries. However, real house prices form two separate convergence clubs. We could not reject convergence in a euro area real house price sample, even though two

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<sup>18</sup> To save space, the detailed results are in the appendix.

convergence clubs were identified before 1992 and two countries, Italy and Ireland, did not converge with the other members after 1992.  $\beta$ -convergence regressions point to a slow convergence process among OECD countries. House price convergence appears to be conditional on real GDP per capita, long-term interest rate and population growth convergence. Finally, the convergence process is fairly similar in our euro area and non-euro area samples and we found no evidence that the introduction of the single currency has significantly altered the long-run convergence process in the euro area. The Houselev dataset provides very valuable information for house price convergence analysis. Further expansion of house price level data to more countries and to sub-national entities will hopefully allow enriching house price convergence analysis in the near future.

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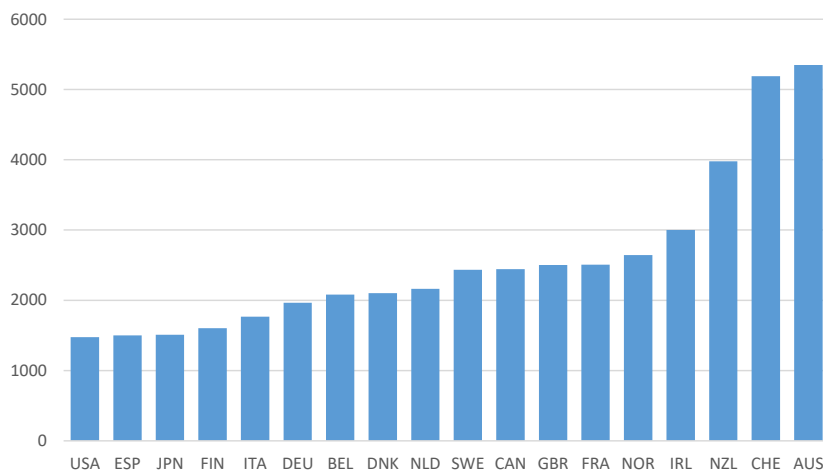
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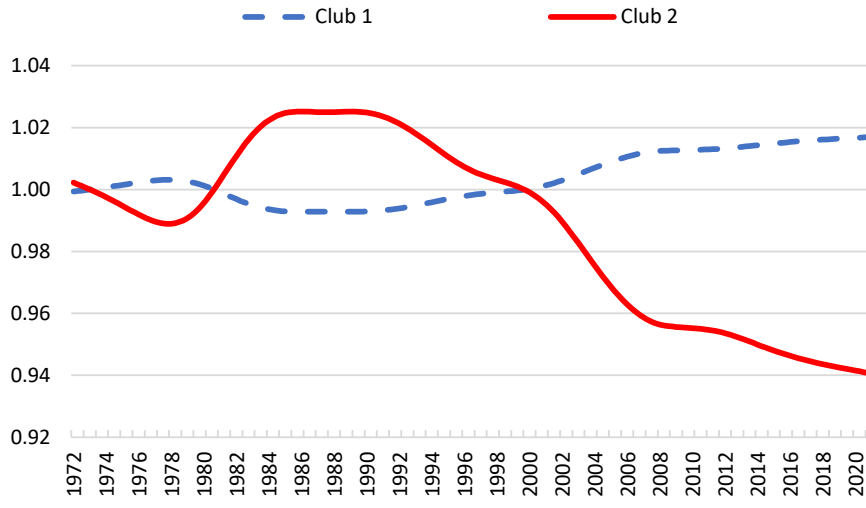
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**Figure 1. Prices in euro per square meter in 2016**



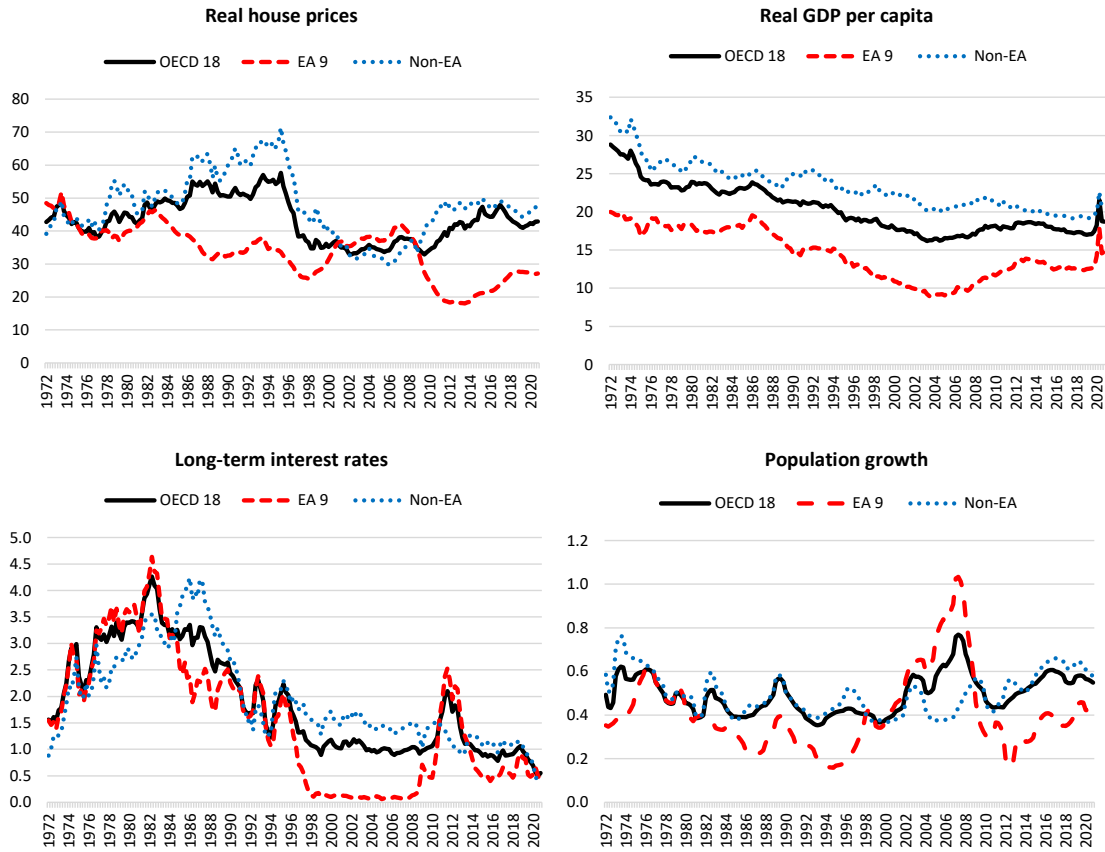
Source: Bricongne et al. (2019).

**Figure 2. Relative transition curves across clubs**



Note: Club 1 includes Australia, Belgium, Canada, Denmark, France, Germany, Ireland, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland and the United Kingdom. Club2 includes Finland, Japan, Italy and the United States. Relative transition curves across clubs are derived from equation (2).  
 Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

**Figure 3.  $\sigma$ -convergence of real house prices and its main determinants**



Note: The graphs display the standard deviation of percentage gaps (percentage point gaps for long-term interest rates and population growth) to the relevant group average. Real house prices are converted at current exchange rate and deflated by euro area private consumption prices. Real GDP is measured at constant purchasing power parity. Long-term interest rates refer to 10-year government bond yields.

Source: Authors' calculations based on Bricongne (2019), OECD House price database and OECD Economic Outlook database.

**Table 1: Convergence of house prices in OECD and euro area countries (1972Q1-2020Q4)**

	Countries	t-statistic	b coefficient
<b>Panel A. OECD, Nominal house prices</b>			
Full sample	AUS, BEL, CAN, DNK, FIN, FRA, DEU, IRL, ITA, JPN, NLD, NZL, NOR, ESP, SWE, CHE, GBR, USA	-1.036	-0.051
<b>Panel B. OECD, Real house prices</b>			
Full sample	AUS, BEL, CAN, DNK, FIN, FRA, DEU, IRL, ITA, JPN, NLD, NZL, NOR, ESP, SWE, CHE, GBR, USA	-5.145***	-0.167
First convergence club	AUS, BEL, CAN, DNK, FRA, DEU, GBR, IRL, NLD, NZL, NOR, ESP, SWE, CHE	1.546	0.109
Second convergence club	FIN, ITA, JPN, USA	2.549	0.229
<b>Panel C. Euro area, Real house prices</b>			
<b>Convergence for the period 1972Q1-2020Q4</b>			
Full sample	BEL, DNK, FIN, FRA, DEU, IRL, ITA, NLD, ESP	3.885	0.296
<b>Club convergence in sub-periods</b>			
<b>1972Q1-1991Q4</b>			
Full sample	BEL, DNK, FIN, FRA, DEU, IRL, ITA, NLD, ESP	-12.993***	-0.363
First convergence club	FIN, FRA, DEU, IRL, ITA, ESP	0.111	1.597
Second convergence club	BEL, DNK, NLD	-0.287	-0.468
<b>1992Q1-2020Q4</b>			
Full sample	BEL, DNK, FIN, FRA, DEU, IRL, ITA, NLD, ESP	-7.031***	-0.167
First convergence club	BEL, DNK, FIN, FRA, DEU, NLD, ESP	-0.437	-0.016
Non converging countries	IRL, ITA	-2.258***	-1.733

Notes: \*, \*\* and \*\*\* denote the rejection of the null hypothesis of convergence at the 10%, 5% and 1% significance level, respectively. Denmark is included in the euro area sample since it has maintained a fixed exchange rate with the euro.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

**Table 2.  $\beta$ -convergence regressions for the OECD sample**

Dependent variable: Change in the real house price gap	1972Q1-2020Q4			1972Q1-1991Q4			1992Q1-2020Q4		
Real house price gap (t-1)	-0.008*	-0.012***	-0.023***	-0.022**	-0.035***	-0.039***	-0.012*	-0.014***	-0.032***
Real GDP gap (PPP)			0.059***			0.088***			0.116***
Interest rate gap			-0.093*			-0.072			-0.146
Population growth gap			1.037***			0.225			1.373***
Time to close the gap (years)	33.0	21.5	11.1	11.4	7.1	6.4	20.2	18.4	7.9
R <sup>2</sup>	0.01	0.15	0.17	0.02	0.16	0.18	0.03	0.17	0.21
Standard error of regression	3.53	3.26	3.22	3.91	3.62	3.60	3.19	2.94	2.88
Durbin-Watson	1.25	2.01	2.01	1.27	2.01	2.01	1.26	2.03	2.03
Number of countries	18	18	18	18	18	18	18	18	18
Number of quarters	196	196	196	80	80	80	116	116	116
Total observations	3528	3528	3528	1440	1440	1440	2088	2088	2088
Lags of dependent variable	0	2	2	0	2	2	0	2	2

Note: All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*,\*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

**Table 3.  $\beta$ -convergence regressions for the euro area sample**

Dependent variable: Change in the real house price gap	1972Q1-2020Q4			1972Q1-1991Q4			1992Q1-2020Q4		
	Real house price gap (t-1)	-0.007	-0.010***	-0.017***	-0.010	-0.026***	-0.043***	-0.017**	-0.013***
Real GDP gap (PPP)			0.049***			0.195***			0.025*
Interest rate gap			-0.105**			0.026			-0.298**
Population growth gap			0.356**			-0.421			0.566**
Time to close the gap (years)	33.6	25.0	14.7	25.6	9.5	5.9	15.1	19.4	12.2
R <sup>2</sup>	0.01	0.32	0.33	0.02	0.27	0.30	0.07	0.46	0.49
Standard error of regression	2.51	2.09	2.07	3.18	2.76	2.71	1.87	1.42	1.39
Durbin-Watson	0.91	2.03	2.02	1.02	2.02	2.01	0.77	2.09	2.05
Number of countries	9	9	9	9	9	9	9	9	9
Number of quarters	196	196	196	80	80	80	116	116	116
Total observations	1764	1764	1764	720	720	720	1044	1044	1044
Lags of dependent variable	0	2	2	0	2	2	0	2	2

Note: All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*,\*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

**Table 4.  $\beta$ -convergence regressions for the non-euro area sample**

Dependent variable: Change in the real house price gap	1972Q1-2020Q4			1972Q1-1991Q4			1992Q1-2020Q4		
Real house price gap (t-1)	-0.008	-0.012**	-0.025***	-0.033*	-0.047***	-0.059***	-0.013	-0.014*	-0.039***
Real GDP gap (PPP)			0.064***			0.063***			0.244***
Interest rate gap			-0.089			-0.231*			0.323
Population growth gap			1.261***			0.241			1.642***
Time to close the gap (years)	31.3	21.1	10.0	7.5	5.4	4.3	19.1	17.9	6.4
R <sup>2</sup>	0.01	0.11	0.13	0.03	0.13	0.14	0.03	0.13	0.17
Standard error of regression	3.76	3.57	3.53	3.98	3.77	3.75	3.54	3.36	3.28
Durbin-Watson	1.37	2.00	2.00	1.40	2.01	2.01	1.39	2.00	1.99
Number of countries	9	9	9	9	9	9	9	9	9
Number of quarters	196	196	196	80	80	80	116	116	116
Total observations	1764	1764	1764	720	720	720	1044	1044	1044
Lags of dependent variable	0	2	2	0	2	2	0	2	2

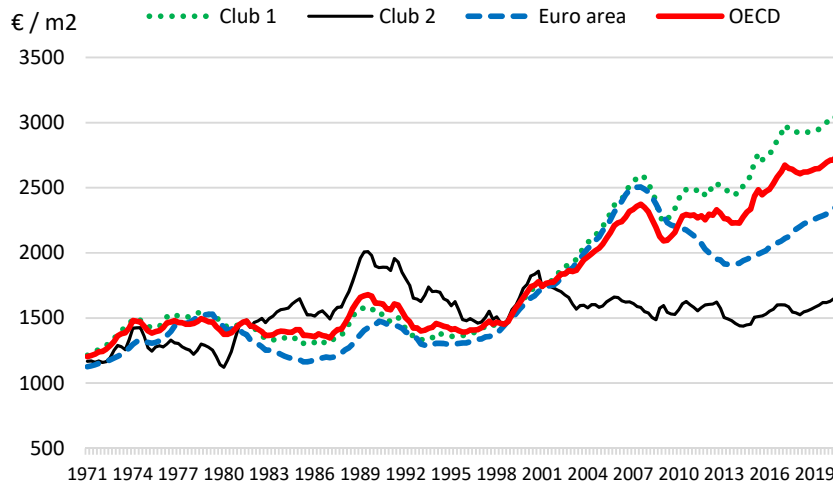
Note: All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*,\*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

## Appendix

### Additional Figure

**Figure A.1. Real house price trends**



Note: Club 1 includes Australia, Belgium, Canada, Denmark, France, Germany, Ireland, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland and the United Kingdom. Club 2 includes Finland, Japan, Italy and the United States.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

### Robustness checks

#### 1. $\beta$ -convergence regressions convergence clubs

In section 5.2, we have estimated regressions on the full OECD and euro samples. However, the Phillips and Sul (2007) procedure identified two convergence clubs in the OECD sample. Including countries that do not converge to the same trend in the same regression could bias the results and lead to erroneous conclusions. Therefore, we run the  $\beta$ -convergence regressions for the two separate clubs that were identified (Table

A.1). The results are very close to those obtained on the full sample. Moreover, the convergence speed is quite similar in the two convergence clubs.<sup>19</sup>

**[Table A.1]**

While the Phillips and Sul (2007) indicated convergence in real house prices within the euro area over the full period, it identified two convergence clubs prior to the Maastricht treaty and two diverging countries in the post-1992 period. Therefore, we run the  $\beta$ -convergence regressions on the separate clubs in the pre-Maastricht period and on the convergence club (i.e. excluding the non-converging countries, Italy and Ireland) in the post-Maastricht period (Table A.2). In the pre-1992 period, the results for the largest convergence club (Finland, France, Germany, Ireland, Italy and Spain) are close to those obtained on the full sample. The smaller club (Belgium, Denmark and the Netherlands) shows faster convergence and a much greater coefficient for the GDP per capita gap than in the other club, pointing to income convergence as a driver of real house price convergence in that group. Excluding Ireland and Italy during the post-Maastricht period does not alter the results significantly, even though the convergence coefficient falls somewhat and the statistical significance of some exogenous variables declines. Altogether, the results of the  $\beta$ -convergence regressions on the convergence clubs support the conclusions from the analysis of the full OECD and euro area samples.

**[Table A.2]**

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<sup>19</sup> Another robustness check is to allow the  $\beta$  coefficient to vary across countries (Acemoglu and Molina, 2021). When doing so, the convergence coefficient is negative for all countries, ranging from -0.009 to -0.060, with an average of -0.029, which is equal to the median and slightly larger than the panel convergence coefficient in absolute terms. For the euro area, country-specific convergence coefficients range from -0.010 to -0.033, with an average of -0.023. For non-euro area countries, country-specific convergence coefficients range from -0.016 to -0.064, with an average of -0.034. Hence, the panel convergence coefficients do not appear distorted by country heterogeneity or outliers.

## **2. Alternative break date**

To examine whether the introduction of the euro has had an impact on the convergence process within the currency union, we have split the sample in the quarter in which the Maastricht treaty was signed (1992Q1). This choice was motivated by the fact that economic policies started converging before the effective introduction of the euro. However, an alternative choice for the breakpoint could be 1999Q1, the quarter in which the euro was effectively introduced. Table A.3 shows that the choice of the breakpoint does not influence the results significantly.<sup>20</sup>

[Table A.3]

## **3. Excluding Denmark from the euro area sample**

Denmark has been included in the euro area sample, as it is closely integrated with euro area economies and has maintained a fixed exchange rate policy against the euro. However, the country is not a member of the euro area. Hence, we check that our results for the euro area sample are robust to the exclusion of Denmark. Table A.4 shows that the regression coefficients do not change much when Denmark is excluded. This is true both before and after 1992.

[Table A.4]

## **4. Testing for asymmetry**

A number of articles have documented asymmetry in house prices (Cook, 2006; Li, 2015; Canepa and Chini, 2016; André et al., 2019). This could imply different speeds

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<sup>20</sup> Miles (2020) argues against splitting the sample at a time of a known policy change, as this may lead to finding an effect of the policy change that in fact does not exist. However, this is not an issue in the present paper, as we find no significant change in convergence associated with the introduction of the euro.

of convergence for countries with low and high prices. To test whether this is the case, we split real house price gaps between positive and negative values. We find similar coefficients on positive and negative gaps and a Wald test clearly accepts equality between the coefficients on both gaps (Table A.5). Hence, potential asymmetry does not seem to affect the convergence process.

[Table A.5]

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**Table A.1.  $\beta$ -convergence regressions for OECD convergence clubs (1972Q1-2020Q4)**

Dependent variable: Change in the real house price gap	Club 1			Club 2		
Real house price gap (t-1)	-0.009**	-0.013***	-0.024***	-0.009	-0.015**	-0.030***
Real GDP gap (PPP)			0.057			0.110***
Interest rate gap			-0.098*			-0.188*
Population growth gap			0.829***			2.039***
Time to close the gap (years)	26.6	19.1	10.6	26.4	17.1	8.3
R <sup>2</sup>	0.01	0.15	0.17	0.00	0.21	0.24
Standard error of regression	3.33	3.09	3.05	3.29	2.93	2.87
Durbin-Watson	1.28	2.02	2.01	1.10	2.02	1.99
Number of countries	14	14	14	4	4	4
Number of quarters	196	196	196	196	196	196
Total observations	2744	2744	2744	784	784	784
Lags of dependent variable	0	2	2	0	2	2

Note: Club 1 includes Australia, Belgium, Canada, Denmark, France, Germany, Ireland, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland and the United Kingdom. Club2 includes Finland, Japan, Italy and the United States. All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*,\*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

**Table A.2.  $\beta$ -convergence regressions for euro area convergence clubs**

Dependent variable: Change in the real house price gap	1972Q1-1991Q4						1992Q1-2020Q4		
	Club 1			Club 2			Club 1		
Real house price gap (t-1)	-0.012	-0.025**	-0.038***	-0.019	-0.039**	-0.107***	-0.015***	-0.011***	-0.015***
Real GDP gap (PPP)			0.169***			0.312***			0.010
Interest rate gap			0.065			-0.239			-0.264
Population growth gap			-0.471			0.354			0.508**
Time to close the gap (years)	21.1	9.9	6.6	13.0	6.4	2.3	16.3	22.6	17.2
R <sup>2</sup>	0.03	0.21	0.23	0.01	0.22	0.29	0.07	0.50	0.52
Standard error of regression	3.06	2.76	2.73	2.19	1.95	1.88	1.54	1.13	1.11
Durbin-Watson	1.14	2.00	2.00	1.15	2.05	1.98	0.73	2.10	2.06
Number of countries	6	6	6	3	3	3	7	7	7
Number of quarters	80	80	80	80	80	80	116	116	116
Total observations	480	480	480	240	240	240	812	812	812
Lags of dependent variable	0	2	2	0	2	2	0	2	2

Note: In the 1972Q1-1991Q4 period, Club 1 includes Finland, France, Germany, Ireland, Italy and Spain. Club 2 includes Belgium, Denmark and the Netherlands. In the 1992Q1-2020Q4 period, Club1 includes all our 9 country euro area sample, except Ireland and Italy. All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*,\*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricogne (2019) and OECD House price database.

**Table A.3.  $\beta$ -convergence regressions for the euro area sample, alternative breakpoint**

Dependent variable: Change in the real house price gap	1972Q1-1998Q4			1999Q1-2020Q4		
Real house price gap (t-1)	-0.012	-0.025***	-0.039***	-0.012	-0.014***	-0.022***
Real GDP gap (PPP)			0.144***			0.009
Interest rate gap			-0.005			-0.228***
Population growth gap			0.002			0.291*
Time to close the gap (years)	21.2	9.8	6.5	20.6	17.9	11.4
R <sup>2</sup>	0.01	0.27	0.30	0.03	0.65	0.66
Standard error of regression	3.09	2.66	2.61	1.54	0.93	0.91
Durbin-Watson	1.01	2.03	2.02	0.46	2.05	2.02
Number of countries	9	9	9	9	9	9
Number of quarters	108	108	108	88	88	88
Total observations	972	972	972	792	792	792
Lags of dependent variable	0	2	2	0	2	2

Note: All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*,\*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

**Table A.4.  $\beta$ -convergence regressions for the euro area sample, excluding Denmark**

Dependent variable: Change in the real house price gap	1972Q1-2020Q4			1972Q1-1991Q4			1992Q1-2020Q4		
Real house price gap (t-1)	-0.007	-0.009***	-0.017***	-0.010	-0.025***	-0.039***	-0.016**	-0.013***	-0.021***
Real GDP gap (PPP)			0.046***			0.181***			0.023
Interest rate gap			-0.106			0.031			-0.292**
Population growth gap			0.361*			-0.367			0.573**
Time to close the gap (years)	34.2	26.4	15.0	23.9	9.9	6.3	15.6	19.7	12.1
R <sup>2</sup>	0.02	0.31	0.33	0.03	0.26	0.29	0.07	0.48	0.50
Standard error of regression	2.50	2.09	2.06	3.15	2.74	2.70	1.88	1.41	1.37
Durbin-Watson	0.92	2.03	2.02	1.03	2.01	2.01	0.76	2.11	2.05
Number of countries	8	8	8	8	8	8	8	8	8
Number of quarters	196	196	196	80	80	80	116	116	116
Total observations	1568	1568	1568	640	640	640	928	928	928
Lags of dependent variable	0	2	2	0	2	2	0	2	2

Note: All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*, \*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.

**Table A.5. Test for asymmetry in  $\beta$ -convergence**

Dependent variable: Change in the real house price gap	1972Q1-2020Q4			1972Q1-1991Q4			1992Q1-2020Q4		
Equation	1	2	3	1	2	3	1	2	3
Real house price gap (t-1)									
Positive gaps	-0.007	-0.011**	-0.022***	-0.025*	-0.038***	-0.039***	-0.009	-0.011*	-0.028***
Negative gaps	-0.009	-0.013***	-0.024***	-0.017	-0.031***	-0.040***	-0.022***	-0.021***	-0.040***
Wald coefficient equality test - p value	0.83	0.73	0.78	0.66	0.60	0.95	0.19	0.19	0.07

Note: Equation 1 only contains the lagged real house price gap, split between positive and negative values; equation 2 adds two lags of the dependent variable; equation 3 adds real GDP, interest rate and population growth gaps. All regressions include country fixed-effects. Significance levels are based on Driscoll-Kraay standard errors. \*, \*\* and \*\*\* denote significance at respectively 10%, 5% and 1%.

Source: Authors' calculations based on Bricongne (2019) and OECD House price database.