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SHORT NOTE

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House price convergence in the very long run

Lei Pan[1,2,3] | **Takashi Matsuki**[4]

[1]School of Accounting, Economics and Finance, Curtin University, Perth, Western Australia, Australia

[2]Centre for Development Economics and Sustainability, Monash University, Clayton, Victoria, Australia

[3]Centre for Global Finance, SOAS University of London, United Kingdom

[4]Faculty of Economics, Ryukoku University, Kyoto, Japan

Correspondence
Lei Pan, School of Accounting, Economics and Finance, Curtin University, Kent St, Perth, WA 6102, Australia.
Email: lei.pan@curtin.edu.au

Abstract

We examine the house price convergence across 12 OECD countries over the period 1905–2016. Using novel quantile unit root tests which allow for smooth breaks via a Fourier expansion series, we find that nine countries show the presence of relative house price convergence at all the quantiles. Focusing on several specific quantiles, 11 countries have significant convergence tendencies. Moreover, there are four definite patterns related to shocks in the relative house prices across quantiles.

KEYWORDS
convergence, Fourier expansion, house prices, quantile regression, unit root

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O18, R31

1 | INTRODUCTION

The usual consideration of houses as the most important asset in homeowners' portfolios makes the issue of house price convergence a topic of profound interest among economists. House prices largely reflect country's distribution of wealth. In addition, relative house prices relate to labour mobility through housing affordability and relocation costs. According to the life-cycle theory of consumption developed by Modiglinai and Brumberg (1954), an individual's consumption is determined by the entire lifetime expected income and the value of tangible and financial assets (Deaton, 1992). If such is the case, a housing market downturn can lead to slowing household consumption and hence an economic downturn. Housing, as a consumption good, has a lion's share of non-traded component (e.g. land and labour) and a tiny share of traded component. The non-traded component is likely to limit the prospect of house price convergence across different regions. However, in the long run, to the extent that economic fundamentals such as income or productivity levels may converge across countries. In such an environment, country-level house prices are expected to reflect country's fundamentals. If the fundamentals converge among countries, house prices may also converge. In growth empirics, moreover, real per capita GDP is reported to have the tendency of convergence among developed countries, especially for OECD member countries (e.g. Li & Papell, 1999; Oxley & Greasley, 1995; Strazicich et al., 2004). On the asset pricing side, the market risk component associated with housing assets could co-move across countries as the desirability of this asset class varies. In addition, the co-movements of house prices at country level driven by the global common factors, such as linkages in trade, financial markets, are suggested by some researchers (e.g. Ha et al., 2020; Hirata et al., 2013). In the right of these findings, one of the unresolved important issues is to investigate whether house prices are globally converging among developed countries. We strive to answer this question in the present study.

Empirical studies examining house price convergence have employed a variety of methodologies notably unit root test (Canarella et al., 2012; Meen, 1999) and cointegration test (Alexander & Barrow, 1994; Gupta & Miller, 2012). There is a large body of literature that focuses on regional comparisons, examining within-country convergence (Apergis & Payne, 2019; Holmes et al., 2011). Factors such as population growth (Unal et al., 2024), income levels (André et al., 2024), housing supply constraints (Kim & Rous, 2012) and financial market conditions (Zhang & Huang, 2024) have been identified as important determinants of convergence dynamics. Past empirical evidence on house price convergence, however, was mixed. An extensive studies examined club convergence of regional house prices using log *t* convergence test proposed by Phillips and Sul (2007) and found evidence of convergence among subgroups of states and cities to their common housing prices (see e.g. Holmes et al., 2019; Kim & Rous, 2012; Montagnoli & Nagayasu, 2015). Nevertheless, other studies presented no supporting evidence for regional house price convergence (see e.g. Awaworyi Churchill et al., 2018; Holmes & Grimes, 2008). The extant literature on house price convergence has mainly focused on the state or city level. There is however only limited research on house price convergence at country level such as Tsai (2018). We fill this gap in the literature by exploring whether a unique long-run equilibrium exists for house prices where all OECD countries converge to.

The contribution of this paper is twofold. First, to the best of our knowledge, this is the first study that uses long historical data for multiple countries to investigate convergence of house prices. The long data enable us to understand how evolution of house prices, in what are now the world's richest countries. Moreover, we are able to capture considerable variation in housing prices over time. Our second contribution is that we employ a novel quantile unit root test developed by Bahmani-Oskooee et al. (2018). The test is appealing over conventional unit roots and standard quantile unit root tests for several reasons. First, regardless of whether house prices at a country level are above or below its steady state value, it may exhibit different behaviour to shocks. The quantile regression allows for different speeds of adjustment at various quantiles of house price distribution and captures its asymmetric behaviour. Second, to capture asymmetric behaviour, most unit root tests rely upon particular nonlinear models. In contrast, the quantile unit root test does not need to specify assumptions regarding the functional form of nonlinearities. Third, since most of the OECD member countries involved armed conflicts and global economic shocks, World Wars and Financial Crises during our long sample period, it is plausible to expect their house prices experienced structural breaks in some years. Our data series therefore may have outliers. The quantile regression enables us to control for non-normally distribution and for the presence of such outliers. Fourth, due to the low frequency of the annual data we used, a Fourier expansion allows us to capture structural breaks in the house prices series. Given the above-mentioned advantages of the approach, it has been adopted in a recent study that examines the tourism markets' convergence in South Korea (Matsuki & Pan, 2023).

Foreshadowing the main results, we find that nine countries out of 12 show evidence in favour of the convergence in their relative house prices in the Fourier quantile Kolmogorov–Smirnov (QKS) test. In particular, eight of them have strongly supportive results. Bahmani-Oskooee et al.'s (2018) *t* ratio statistic reveals that except for Germany, all the relative house prices are stationary at some quantiles, meaning that the convergence hypothesis holds at some specific quantiles. The estimated autoregressive coefficients across quantiles indicate four definite patterns related to shocks on the relative house prices across quantiles.

The remainder of this paper is organised as follows. Section 2 describes the data. Section 3 explores the econometric approaches we adopt in this study. Section 4 presents and discusses the empirical results. Section 5 concludes.

2 | DATA

We use a historical dataset[1] for 12 OECD member countries spanning from 1905 to 2016 on house price index (nominal index, 1990 = 100) and consumer prices index (CPI) (1990 = 100) constructed by Jordà et al. (2017). To obtain the real house price index (RHP), we deflate the nominal house price using CPI (i.e. $\frac{\text{Nominal index} \times 100}{\text{CPI}}$). Our sample includes Australia, Belgium, Denmark, Finland, France, Germany, Netherlands, Norway, Sweden, Switzerland, the United Kingdom and the United States.[2] We select the average house price across all countries as a benchmark and take the natural logarithm of each country's real house price index divided by the mean value of all countries' house price indices.[3]

The summary statistics are presented in Table 1. Over the sample period, Norway has the highest mean house price. Second is Netherlands, followed by Denmark, Sweden, Belgium, the United States, OECD average, Australia, Germany, Switzerland, France and the United Kingdom. Finland has the lowest mean house price. To test the non-normality hypothesis of the RHP series, we also report the Jarque and Bera (1980) test statistic. Our results provide firm evidence of non-normal distribution for most of the RHP series except, Switzerland and the United States. As argued by Koenker and Xiao (2004), the quantile autoregressive-based unit root test has higher power than conventional unit root tests in the presence of non-normality. Therefore, we, in the present study, adopt quantile regression approach to test the convergence hypothesis.

TABLE 1 Descriptive statistics for real house prices index (1905–2016).

Country	Obs	Mean	SD	Min	Max	J-B stat
OECD average	112	78.92	40.70	33.36	190.50	33.63***
Australia	112	71.16	57.92	21.65	247.8	44.98***
Belgium	112	88.05	51.96	14.25	217.22	33.59***
Denmark	112	93.82	49.5	35.61	237.94	17.21***
Finland	112	54.26	32.41	4.13	121.95	6.84***
France	112	62.67	48.81	7.63	182.55	17.07***
Germany	112	68.07	30.36	1.45	110.82	9.56***
Netherlands	112	103.04	62.12	39.8	265.67	38.13***
Norway	112	107.17	65.38	50.05	329.16	129.81***
Sweden	112	89.92	40.36	38.64	260.59	196.12***
Switzerland	112	65.91	18.33	34.01	116.01	3.92
United Kingdom	112	57.39	35.76	14.16	188.53	41.72***
United States	112	85.57	24.57	41.29	150.45	4.54

Note: OECD average denotes average house price for all sample countries.
***Statistical significance at the 1% level.

[1]Available online at: http://www.macrohistory.net/data/

[2]The data of house price index for Belgium, Germany and United Kingdom have some missing observations. We replace missing values using linear interpolation.

[3]That equivalents for taking the difference of natural logarithm of each country's real house price index and natural logarithm of the mean value of all countries' house price indices, which is the form defined in Equation (1).

3 | EMPIRICAL METHODOLOGY

We attempt to examine the deterministic convergence hypothesis for real house prices of each of the 12 OECD countries towards the group mean as a benchmark. The real house price of country i will converge towards that of the benchmark if, and only if:

$$n\infty \lim\left(Y_{i,t+h} - \lambda Y_{b,t+h} | \Omega_t\right) = 0 \quad (1)$$

where $Y_{i,t+h}$ and $Y_{b,t+h}$ stand for the natural logarithm of the real house prices of country i and benchmark at time $t+h$; Ω_t represents the information set at time t. Given our long historical data, it is reasonable to expect the possibility of structural breaks. To this end, we employ the most recent developed quantile unit root test by Bahmani-Oskooee et al. (2018) that allows for smooth breaks in the trend component.

Suppose that the data-generating process of a stochastic variable is[4,5]:

$$Y_t = \alpha_1 + \alpha_2 t + \alpha_3 \sin\left(\frac{2\pi kt}{T}\right) + \alpha_4 \cos\left(\frac{2\pi kt}{T}\right) + o_t \quad (2)$$

where Y refers to the natural logarithm of relative real house prices (RRHP)[6]; α_1 is the intercept; t stands for a trend term; o_t represents the residuals of the regression; k denotes the frequency of the Fourier function to capture the smooth breaks in the RRHP; α_3 and α_4 measure the amplitude and displacement of the frequency component, respectively. The integer value of k is associated with transitory shocks and fractional value is related to permanent shocks.[7] We use the Becker et al. (2004) method to find the optimum frequency (k^*). Specifically, we set k at a value over the range [0.1, 5] that minimizes the sum of squared residuals (SSR) of ordinary least squares (OLS) estimation applied to Equation (2). The null hypothesis of unit root in τth conditional quantile of the residuals $(\hat{o}_t)$ from Equation (2) is tested by estimating the quantile regression below:

$$Q_{\hat{o}_t}\left(\tau | \xi_{t-1}\right) = \delta_0(\tau) + \delta_1(\tau)\hat{o}_{t-1} + \sum_{p=1}^{p=l} \delta_{1+p}(\tau)\Delta\hat{o}_{t-p} + \vartheta_t \quad (3)$$

where $Q_{\hat{o}_t}\left(\tau | \xi_{t-1}\right)$ stands for τ_{th} quantile of $\hat{o}_t$ conditional on the past information set, ξ_{t-1}; $\delta_0(\tau)$ denotes τ_{th} quantile of ϑ_t and it measures the size of the observed shock that hits the real house prices within the τ_{th} quantile. Positive (negative) sign represents positive (negative) shock. Optimum lags (p^*) are selected by the Akaike's Information Criterion (AIC).

Although Equation (3) follows the standard ADF test at each quantile, our focus is on estimating the vector δ. Following Bahmani-Oskoee et al. (2018), we test the unit root hypothesis within the τ_{th} quantile using the following t ratio statistic:

$$t_n\left(\tau_i\right) = \frac{\hat{f}\left(F^{-1}\left(\tau_i\right)\right)}{\sqrt{\tau_i\left(1-\tau_i\right)}}\left(E'_{-1}P_x E_{-1}\right)^{\frac{1}{2}}\left(\hat{\delta}_1\left(\tau_i\right) - 1\right) \quad (4)$$

[4]A semi-parametric approach seems conceptually possible; however, constructing its feasible unit root test may have some difficulties in practical aspects. The Fourier structure in the trend function adopted here takes two advantages: (i) it has the flexibility of representing smooth transitional movements of a time series and (ii) it has the high practical applicability to many time series with multiple structural breaks occurring at unknown dates. In addition, the Fourier series expansion theoretically secures that the Fourier function can trace any time path of a time series.

[5]Enders and Lee (2012) suggested several types of model specifications to capture smooth breaks in the trend function, which provides useful insights in this field.

[6]Same as earlier, Y is defined in the form of ln(real house prices of country i)−ln(mean value of all countries' house price indices).

[7]Many factors can lead to deviations of real house price from its long run steady state. For instance, interest rates, consumer confidence, wars and geopolitical risks. Some of them have permanent effects, while others have transitory effects.

where E_{-1} is the vector of lagged dependent variable $(\hat{o}_{t-1})$; P_x stands for the projection matrix onto the space orthogonal to $X = (1, \Delta\hat{o}_{t-1}, \ldots, \Delta\hat{o}_{t-k})$. We follow Koenker and Xiao's (2004) method to obtain a consistent estimator of $\hat{f}(F^{-1}(\tau_i))$:

$$\hat{f}(F^{-1}(\tau_i)) = \frac{(\tau_i - \tau_{i-1})}{X'(\Theta(\tau_i) - \Theta(\tau_{i-1}))} \tag{5}$$

where $\Theta(\tau_i) = (\delta_0(\tau_i), \delta_1(\tau_i), \delta_2(\tau_i), \ldots, \delta_{1+p}(\tau_i))$ and $\tau_i \in [\underline{\mu}, \overline{\mu}]$. In the present study, we set $\underline{\mu} = 0.1$ and $\overline{\mu} = 0.9$. Bahmani-Oskooee et al. (2018) recommend the following quantile Kolmogorov–Smirnov (QKS) test statistic to test the unit root hypothesis over a range of quantiles:

$$QKS = \sup_{\tau_i \in [\underline{\mu}, \overline{\mu}]} |t_n(\tau)| \tag{6}$$

Since the limiting distribution of $t_n(\tau_i)$ and *QKS* test statistics are nonstandard and depend on nuisance parameters, we calculate the critical values using Bahmani-Oskooee et al. (2018) re-sampling procedures.

4 | EMPIRICAL RESULTS

As a benchmark exercise, we first use three traditional unit root tests, namely ADF (Dickey & Fuller, 1979), DF-GLS (Elliott et al., 1996) and KPSS (Kwiatkowski et al., 1992), to examine the stochastic properties of relative real house price index (mean value of real house price index across countries as a benchmark). The results are presented in Table 2. The results suggest that the unit root null hypothesis cannot be rejected for any of the countries by the ADF and DF-GLS tests. The KPSS test results indicate that the null of stationarity is rejected for all countries. This test results may conclude that all relative real house prices follow random walk processes over the sample period. Such finding, however, could be attributable to the low power or size distortions of the tests due to the ignorance

TABLE 2 Conventional unit root test results (model with constant without trend).

	OECD average as benchmark		
Country	**ADF**	**DF-GLS**	**KPSS**
Australia	−1.845 [0]	−0.174 [0]	1.161*** (9)
Belgium	−0.081 [11]	−0.528 [8]	0.974*** (8)
Denmark	−0.456 [2]	0.365 [2]	1.091*** (9)
Finland	−1.707 [1]	−1.136 [1]	0.990*** (8)
France	−0.854 [1]	−0.897 [1]	0.810*** (9)
Germany	−1.723 [2]	−1.712* [2]	0.782*** (9)
Netherlands	−0.416 [2]	−0.406 [2]	0.811*** (9)
Norway	0.607 [1]	0.630 [1]	0.677** (9)
Sweden	0.359 [5]	−0.196 [5]	0.709** (8)
Switzerland	−1.585 [1]	−1.018 [1]	1.086*** (8)
United Kingdom	0.242 [2]	0.743 [2]	1.116*** (9)
United States	−0.605 [4]	0.703 [4]	1.140*** (9)

Note: OECD average denotes average house price for all sample countries. The numbers in the bracket and parenthesis indicate optimum lag length (determined using AIC criteria) and Bartlett (as suggested by Newey and West (1987)).
*, **, *** Denote statistical significance at the 10%, 5% and 1% levels, respectively.

of structural changes (e.g. Great Depression, World Wars and global financial crises) and/or non-normal distribution.[8] Therefore, we should view this finding cautiously. On the other hand, Equation (2) allows for multiple structural breaks even at unknown break dates. This model advantage helps us avoid the issue described above and conduct the unit root tests based on Equation (2) more precisely.

We then estimate the Fourier function represented in Equation (2). Figure 1 shows the time paths of relative house prices and the estimated Fourier functions. Although, we need to conduct some specification tests to discuss the goodness of fit of the estimated Fourier functions shown in Figure 1, overall, each of the Fourier functions seems to be one of the possible candidate models to capture the fluctuations of the relative house prices over time, though some series such as Belgium and Germany temporarily deviate from the estimated lines around 1920. In addition, the *F*-test shown in Table 3 strongly supports the presence of sine and cosine terms in the trend functions of all the house price series. From the plots in Figure 1, we should note that the relative house price

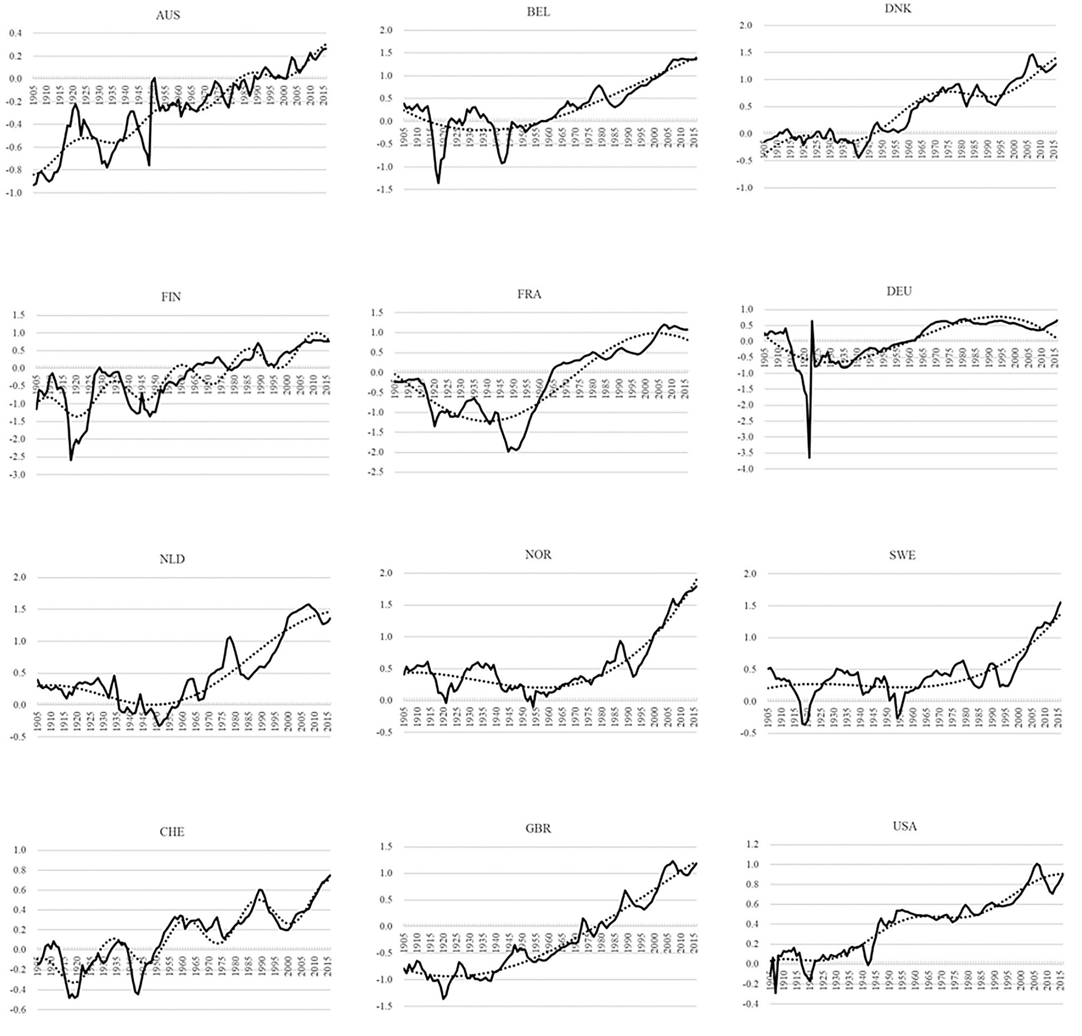

FIGURE 1 Actual data and estimated Fourier expansion series. *Note*: The abbreviations of countries are AUS, Australia; BEL, Belgium; DNK, Denmark; FIN, Finland; FRA, France; DEU, Germany; NLD, Netherlands; NOR, Norway; SWE, Sweden; CHE, Switzerland; GBR, the United Kingdom; USA, the United States.

[8]Perron (1989), Leybourne et al. (1998) and Montanes and Reyes (1998) have discussed this issue.

TABLE 3 Results of quantile unit root test with smooth breaks.

			Fourier QKS statistic			
Country	**K^***	***F* statistic**	**Test statistic**	**10%**	**5%**	**1%**
Australia	3.5	331.081***	5.124***	2.968	3.256	3.877
Belgium	0.1	163.854***	4.301***	2.792	3.140	3.896
Denmark	2.1	514.789***	4.000***	3.067	3.333	3.927
Finland	4.4	146.873***	3.985***	2.820	3.107	3.920
France	0.9	288.841***	2.153	2.884	3.211	3.961
Germany	0.1	85.209***	1.145	2.528	2.886	3.944
Netherlands	1.0	312.137***	2.840	2.973	3.281	4.010
Norway	0.3	403.606***	3.118*	3.022	3.330	4.008
Sweden	0.1	113.975***	4.882***	2.939	3.266	4.022
Switzerland	4.1	322.002***	5.183***	2.972	3.276	3.993
United Kingdom	0.1	1078.12***	5.614***	3.195	3.504	4.215
United States	2.1	585.961***	4.902***	2.917	3.211	4.008

Note: K^* is the optimum frequency. The critical values of the *F* test and the Fourier QKS test are computed via Monte Carlo simulation with 5000 replications.

* and *** Denote statistical significance at the 10% and 1% levels, respectively.

series may have various types of structural breaks occurring at unknown dates. Therefore, our Fourier approximations seem to be supported by the data visualization.

Table 3 indicates the results of the Fourier QKS statistic, which tests the unit root null hypothesis at all the quantiles ranging from 0.1 to 0.9 against the stationarity alternative hypothesis. The test results show that nine countries out of 12 significantly reject the null; in particular, except for Norway, the other eight countries strongly support the stationarity, meaning that the relative house price for each country converges with the cross-sectional country mean. K^* indicates the optimum frequency for each series, which is between 0.1 and 4.4. As noted by Bahmani-Oskooee et al. (2018), these optimum frequencies imply structural breaks rather than short-term business cycles. For example, Finland, which has the largest frequency of 4.4, shows at least a 25.5-year cycle of its data variation. On the other hand, Belgium, Germany, Sweden and the United Kingdom have the minimum $K^*(0.1)$. As shown in Figure 1, the whole cycles of these countries appear to be much longer than the sample period because each fitted line is only a part of the cycle. In this case, its optimum frequency is estimated to be the minimum value. If we try to avoid such corner solutions, we may need a longer time span to cover a larger range of data movements. Moreover, except for Netherlands, since all these frequencies are fractional, the results imply the possibility that the breaks may permanently affect the movements of the relative real house prices. The *F*-test statistic, which tests the null of no sine and cosine terms in the model, also supports the inclusion of trigonometric functions because all the null hypotheses are rejected under the 1 per cent significance level.[9]

Table 4 displays the *p*-values of $t_n(\tau)$ tests for each quantile. Obviously, Denmark, Finland, Netherlands, the United Kingdom and the United States have strong tendencies of stationarity, that is, the mean convergence of relative house prices, in all the quantiles with only a few exceptional 0.1- or 0.9-quantile cases. The converging trends of Australia, Belgium, Norway and Switzerland are also comparable to those mentioned above. For each country, the null is rejected in seven or eight quantiles. On the other hand, France and Sweden show only two and four cases of relative price convergence, respectively. No case is observed in Germany. In sum, nine countries

[9]The critical values of the *F* test for our sample size are computed via Monte Carlo simulation with 10,000 replications. The 1% critical values are 4.871, 4.875, 4.967, 5.030 and 4.978 for frequencies of 1, 2, 3, 4 and 5, respectively.

TABLE 4 Results of quantile unit root test with smooth breaks.

	p-Value of $t_n(\tau)$								
Country	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
Australia	0.340	0.136	0.005	0.000	0.000	0.000	0.000	0.051	0.487
Belgium	0.502	0.189	0.025	0.006	0.000	0.002	0.023	0.091	0.044
Denmark	0.002	0.005	0.006	0.014	0.103	0.048	0.011	0.054	0.020
Finland	0.480	0.088	0.002	0.002	0.003	0.001	0.024	0.021	0.036
France	0.444	0.420	0.141	0.133	0.327	0.274	0.057	0.056	0.135
Germany	0.924	0.955	0.837	0.755	0.951	0.923	0.977	0.712	0.139
Netherlands	0.024	0.075	0.058	0.019	0.040	0.015	0.009	0.149	0.087
Norway	0.110	0.094	0.059	0.006	0.020	0.035	0.068	0.152	0.382
Sweden	0.714	0.397	0.139	0.081	0.139	0.138	0.038	0.000	0.022
Switzerland	0.309	0.013	0.000	0.000	0.000	0.000	0.014	0.024	0.296
United Kingdom	0.062	0.000	0.000	0.000	0.000	0.010	0.004	0.053	0.109
United States	0.132	0.023	0.009	0.000	0.001	0.002	0.001	0.018	0.017

firmly support the presence of relative house price convergence, and two countries have weaker but significant converging tendencies. No house price convergence exists in Germany.

Figure 2 shows the estimated coefficients ($\delta_0(\tau)$ and $\delta_1(\tau)$) of Equation (3) for the selected nine relative house prices, significant in the Fourier QKS test. In Panel A of Figure 2, all the estimated quantile intercepts $\delta_0(\tau)$ have upward trends across quantiles. This means that when a relative house price receives a negative shock, which makes its quantile lower, the intercept value correspondingly decreases. When a relative house price receives a positive shock, which makes its quantile higher, the intercept value correspondingly increases.

Panel B of Figure 2 observes four groups of the estimated autoregressive coefficients $\delta_1(\tau)$ in their shapes. First, Australia has a *U*-shaped curve, which means that when a negative shock on a relative house price occurs between its 0.1- and 0.4-quantiles, the impact of the shock is more persistent (the house price needs more time to converge to the cross-sectional mean) because the autoregressive coefficient becomes closer to one. When a positive shock occurs in more than its 0.7-quantile, the impact is also more persistent. However, in the middle of quantiles, any shock is transitory. Second, Belgium, Finland and Sweden have downward trends in their estimated $\delta_1(\tau)$. In particular, their slopes are steeper at higher quantiles. This implies that a positive shock raising a relative house price level is more transitory, and it promotes convergence to the mean because the autoregressive coefficient becomes smaller. Third, Denmark and the United States have concave curves. This is the opposite case to Australia. When a negative shock in lower quantiles or a positive shock in higher quantiles occurs, its impact becomes more short-lived. In middle quantiles, any shock is more persistent. Fourth, Norway Switzerland and the United Kingdom show upward trends. If a relative house price rises, which means deviating from the cross-sectional mean, the tendency of deviation lasts longer. Interestingly, except for Norway's relative house price, all the other eight series strongly support convergence to the mean; moreover, there are four definite patterns related to shocks on the relative house prices across quantiles.

5 | CONCLUDING REMARKS

This paper examines the house price convergence across 12 OECD countries from 1905 to 2016. The novel quantile unit root tests allow us to consider smooth breaks in the relative house prices, expressed as a Fourier expansion series. As a result, we find evidence of convergence toward the cross-sectional mean in

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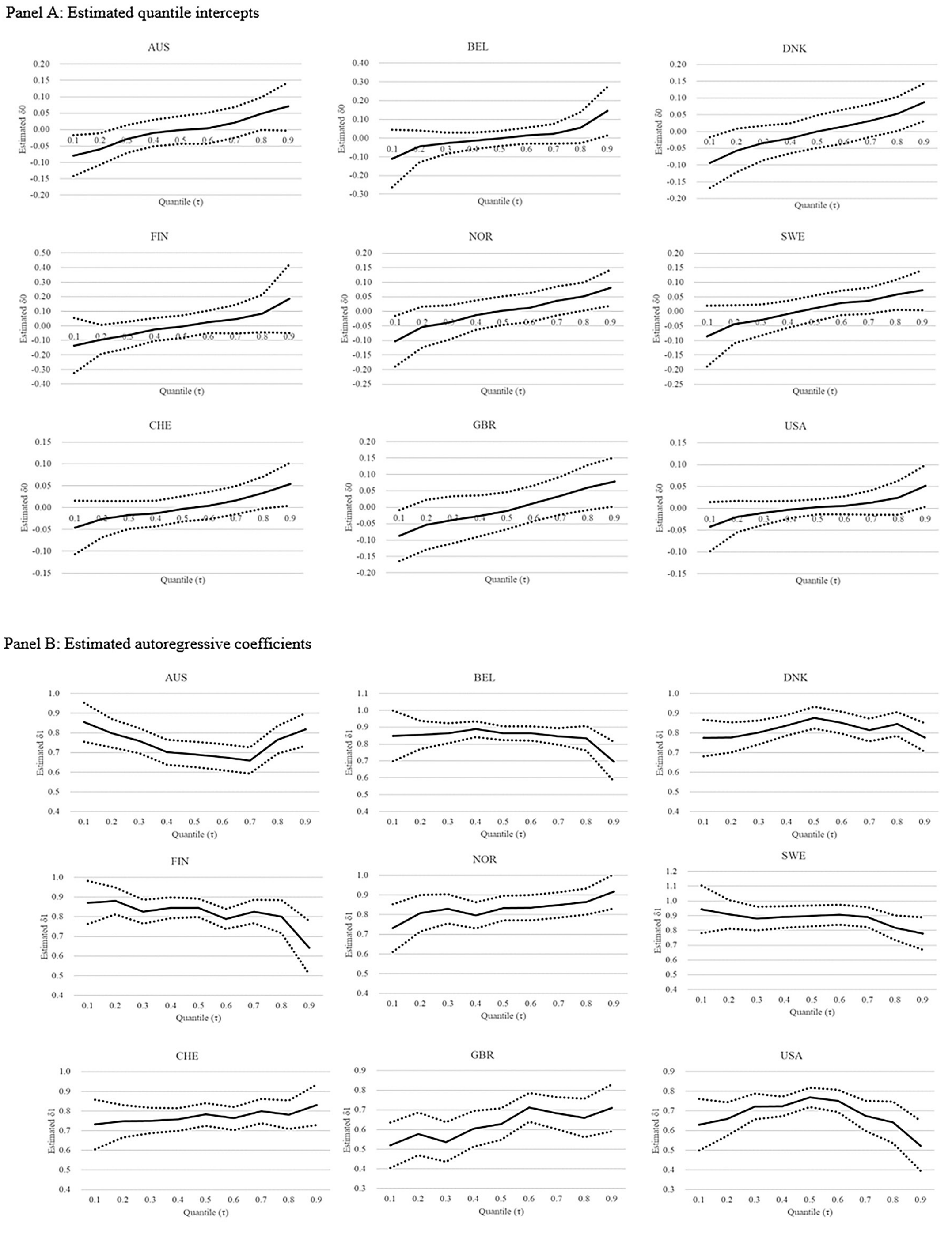

FIGURE 2 Selected estimated quantile intercepts $\left(\delta_0(\tau)\right)$ and autoregressive coefficients $\left(\delta_1(\tau)\right)$.

nine countries in the Fourier QKS test. Eight of their test results are firmly supportive. Moreover, Bahmani-Oskooee et al.'s (2018) t-ratio test suggest that except for Germany, the convergence hypothesis holds in all the countries at some specific quantiles. In addition, among the nine countries that reject the unit root null in the Fourier QKS test, there are four definite patterns related to shocks on their relative house prices across quantiles.

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REFERENCES

Alexander, C. & Barrow, M. (1994) Seasonality and cointegration of regional house prices in the UK. *Urban Studies*, 31, 1667–1689.

André, C., Christou, C. & Gupta, R. (2024) Revisiting international house price convergence using house price level data. *Economic Systems*, 48, 101181.

Apergis, N. & Payne, J.E. (2019) Florida metropolitan housing markets: examining club convergence and geographical market segmentation. *Journal of Housing Research*, 28(2), 145–163.

Awaworyi Churchill, S., Inekwe, J. & Ivanovski, K. (2018) House price convergence: evidence from Australian cities. *Economics Letters*, 170, 88–90.

Bahmani-Oskooee, M., Chang, T., Elmi, Z. & Ranjbar, O. (2018) Re-testing prebisch-singer hypothesis: new evidence using Fourier quantile unit root test. *Applied Economics*, 50(4), 441–454.

Becker, R., Enders, W. & Lee, J. (2004) A general test for time dependence in parameters. *Journal of Applied Econometrics*, 19(7), 899–906.

Canarella, G., Miller, S.M. & Pollard, S.K. (2012) Unit roots and structural change: an application to US house-price indices. *Urban Studies*, 49, 757–776.

Deaton, A. (1992) *Understanding consumption*. New York, NY: Oxford University Press.

Dickey, D.A. & Fuller, W.A. (1979) Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74(366), 427–431.

Elliott, G., Rothenberg, T.J. & Stock, J.H. (1996) Efficient tests for an autoregressive unit root. *Econometrica*, 64(4), 813–836.

Enders, W. & Lee, J. (2012) A unit root test using a Fourier series to approximate smooth breaks. *Oxford Bulletin of Economics and Statistics*, 74(4), 574–599.

Gupta, R. & Miller, S.M. (2012) The time series properties of house prices: a case study of the southern California market. *Journal of Real Estate Finance and Economics*, 44(3), 339–361.

Ha, J., Kose, M.A., Otrok, C. & Prasad, E.S. (2020) Global macro-financial cycles and spillovers. NBER Working Paper Series, No. 26798.

Hirata, H., Kose, M.A., Otrok, C. & Terrones, M.E. (2013) Global house price fluctuations: synchronization and determinants. *NBER International Seminar on Macroeconomics*, 9(1), 119–166.

Holmes, M. & Grimes, A. (2008) Is there long-run convergence among regional house prices in the UK? *Urban Studies*, 45(8), 1531–1544.

Holmes, M.J., Otero, J. & Panagiotidis, T. (2011) Investigating regional house price convergence in the United States: evidence from a pair-wise approach. *Economic Modelling*, 28(6), 2369–2376.

Holmes, M.J., Otero, J. & Panagiotidis, T. (2019) Property heterogeneity and convergence club formation among local house prices. *Journal of Housing Economics*, 43, 1–13.

Jarque, C.M. & Bera, A.K. (1980) Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economic Letters*, 6(3), 255–259.

Jordà, Ò., Schularick, M. & Taylor, A.M. (2017) Macrofinancial history and the new business cycle facts. *NBER Macroeconomics Annual*, 31(1), 213–263.

Kim, Y.S. & Rous, J.J. (2012) House price convergence: Evidence from US state and metropolitan area panels. *Journal of Housing Economics*, 21, 169–186.

Koenker, R. & Xiao, Z. (2004) Unit root quantile autoregression inference. *Journal of the American Statistical Association*, 99(467), 775–787.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P.J. & Shin, Y. (1992) Testing the null hypothesis of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root. *Journal of Econometrics*, 54(1–3), 159–178.

Leybourne, S.J., Mills, T.C. & Newbold, P. (1998) Spurious rejection by Dickey-Fuller tests in the presence of a break under the null. *Journal of Econometrics*, 87(1), 191–203.

Li, Q. & Papell, D. (1999) Convergence of international output: time series evidence for 16 OECD countries. *International Review of Economics and Finance*, 8, 267–280.

Matsuki, T. & Pan, L. (2023) Exploring the tourism markets' covergence hypothesis in South Korea. *Tourism Economics*, 29(7), 1960–1971.

Meen, G. (1999) Regional house prices and the ripple effect: a new interpretation. *Housing Studies*, 14, 733–753.

Modiglinai, F. & Brumberg, R.H. (1954) Utility analysis and the consumption function: an interpretation of cross-section data. In: Kurihara, K.K. (Ed.) *Post-Keynesian economics*. New Brunswick, NJ: Rutgers University Press, pp. 388–436.

Montagnoli, A. & Nagayasu, J. (2015) UK house price convergence clubs and spillovers. *Journal of Housing Economics*, 30, 50–58.

Montanes, A. & Reyes, M. (1998) Effect of a shift in the trend function on Dickey–Fuller unit root tests. *Econometric Theory*, 14(3), 355–363.

Newey, W.K. & West, K.D. (1987) A simple positive semi-definite, heteroscedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55(3), 703–708.

Oxley, L. & Greasley, D. (1995) A time-series prospective on convergence: Australia, UK and US since 1987. *Economic Record*, 71, 259–270.

Perron, P. (1989) The great crash, the oil price shock, and the unit root hypothesis. *Econometrica*, 57(6), 1361–1401.

Phillips, P.C. & Sul, D. (2007) Transition modelling and econometric convergence tests. *Econometrica*, 75, 1771–1855.

Strazicich, M.C., Lee, J. & Day, E. (2004) Are incomes converging among OECD countries? Time series evidence with two structural breaks. *Journal of Macroeconomics*, 26, 131–145.

Tsai, I.-C. (2018) House price convergence in euro zone and non-euro zone countries. *Economic Systems*, 42(2), 269–281.

Unal, U., Hayo, B. & Erol, I. (2024) Housing market convergence: evidence from Germany. *Applied Economics*, 1–16.

Zhang, X. & Huang, Q. (2024) The differential effects of credit policy on real estate prices from the perspective of club convergence. *Singapore Economic Review* (in press).

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