House Price Convergence in the Euro Zone: A Pairwise Approach

Abstract

For the European Central Bank to incorporate euro-wide housing into its policy decisions, it is helpful if home values across the currency union are convergent in the long run. We apply a probabilistic pair-wise approach to the question of whether home values converge across eight euro-zone housing markets. Contrary to previous studies, we find only marginal evidence that euro housing markets converge. Moreover, for what convergence there appears to be, there is no evidence that the adoption of the euro itself played a role in creating such convergence. Finally, Germany's housing sector is rarely found convergent with those of other countries. This is worrying as Germany is the dominant economy of the currency union.

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Introduction

Housing has been shown to have an outsized influence on the business cycle, at least in the United States (Leamer, 2007, 2015). In the euro zone housing bubbles and later crashes have been associated with devastating recessions in Ireland, Greece and Spain. Central banks thus seek to take account of house prices in formulating monetary policy. The US Fed, for example, tracks American home values with the FHFA index.

While house prices can differ by region across the US, the ECB faces an additional challenge in that the different regions over which it conducts policy are separate sovereign countries, and housing markets can in principle (and practice) vary markedly across national borders. This variation across nations can make monetary policy very difficult to conduct with respect to the housing market. If, say house prices were booming in Finland, but crashing in Belgium, the appropriate tight monetary policy for Finland would be devastating for Belgium. And analogously the appropriate loose policy for Belgium could fuel a bubble and financial vulnerability in Finland.

Given this issue, there have been a number of studies on home value co-movement in the euro zone, such as those by Alvarez, Bulligan, Cabrero, Ferrara and Stahl (2010), Ferrara and Koopman (2010), Van Steenkiste and Hiebert (2011) and Gupta, Andre and Gil-Alana (2015). These papers have yielded mixed results on how closely home values co-move across euro zone countries.

In this study we test, not for cyclical co-movement but for long-run convergence between home values in the euro zone using the pair-wise approach of Pesaran (2007). House price convergence has been investigated for euro zone housing (Tsai, 2018) and also studied in the context of different regional UK markets (Cook (2003), Holmes (2007) and Holmes and Grimes (2008)), as well as for different regional housing markets in the US (Clark and Coggin (2009)). Pesaran's method avoids the issues of some previous studies on convergence that have employed panel unit root tests or tested for convergence by choosing a base or reference region. The method was originally developed to investigate output

convergence. It has also, however, been applied to the convergence of house prices between cities (Holmes, Panagiotidis and Otero (2011)), among city neighborhoods (Abbott and DeVita (2012), Holmes, Panagiotidis and Otero (2017, 2018)), and the different regions of the UK (Abbott and DeVita (2013), Kyriazakou and Panagiotidis (2018)).

Upon applying the method to different European countries, we find, based on using four different unit root tests, that the evidence for house price convergence among the euro countries is weak, although, by the standards of previous studies, it is not completely negligible. We find, contrary to Tsai (2018), however, no evidence that the euro itself created what convergence there appears to be. That is, it may be that countries that were more likely to have convergent housing markets, say Belgium and Ireland, were more likely to join the euro than countries such as the UK, whose home values appear less convergent with euro zone members, instead of the euro itself creating convergence. We also find that Ireland, and, to a lesser extent The Netherlands, Belgium and Finland exhibit some reasonable amount of convergence. However, Germany appears to show little tendency for convergence with the housing markets of the other currency union members. This is worrisome for the prospects of the ECB using housing in its monetary policy formulations, as Germany is the dominant economy of the zone.

This paper proceeds as follows. The next section describes the previous literature. The third explains the data and methodology. The fourth section reports the results, and the fifth section concludes.

Previous Literature

Whether home values converge across a set of nations or regions is obviously of interest to portfolio managers and lenders with exposure to house prices in different areas. In addition, housing is a sector central banks seek to account for in making policy. This is owing in no small part to the fact that in the US, housing has been shown to have a dominating impact on the business cycle (Leamer, 2007, 2015). And in the euro zone, housing bubbles and subsequent crashes have played a key role in devastating recessions in Greece, Spain and Ireland. The ECB thus would desire the ability to incorporate

housing into its decisions, but this would be a difficult task if home values diverge between countries. Indeed Ferrara and Koopman make the point that "the existence of a common housing cycle among the countries of the zone could lead the ECB to integrate more easily the evolution of this specific asset price into its assessment. On the other hand, if country-specific cycles were too large, this would complicate the task of the ECB" (p. 4).

A large literature on house price convergence has centered on different regions of the United Kingdom. Cook (2003), Holmes (2007) and Holmes and Grimes (2008) examine whether house prices in the twelve UK regions exhibit convergence, using somewhat different methodologies. This line of research is part of a large field of study concerning house price co-movement within the UK (see Ashworth and Parker, 1997 for an early example). Other research has focused on international house price co-movement. Beltratti and Morana (2007) study national housing market interactions across the G-7 countries. DeBandt, Barhoumi and Bruneau (2010) and Hirata, Kose, Otrok and Terrones (2013) examine home price co-movement across a larger set of nations.

As the euro zone has only one currency and hence one central bank, there have been several papers on house prices across euro zone nations. These papers have tended to focus on co-movement and whether changes in home values spill over between countries in the currency union, rather than convergence per se. Ferrara and Koopman (2010), as noted, point to the importance of a high level of housing co-movement for monetary policy in the currency union. Using state space models for the countries of France, Germany, Italy and Spain, the authors find mixed results on the extent to which housing developments in one country spill over to others. Alvarez, et al. (2010) also study the housing markets of France, Germany, Italy and Spain, with similarly mixed results. Van Steenkiste and Hiebert (2011), echoing a point made by Ferrara and Koopman (2010), state "Co-movement in house prices across countries may be particularly relevant in the euro area, given a general trend with monetary union" (p. 299). These authors also find, with a vector-autoregression (VAR), evidence of housing price spillovers across euro nations.

Gupta, Andre and Gil-Alana (2015) use cointegration methods to find relationships among Belgium, Finland, France, Germany, Ireland, Italy, The Netherlands and Spain. The authors develop a composite euro-wide index based on a weighted average of the eight nations' home values, and find that three of the eight nations-Belgium, Germany and France-are fractionally cointegrated with the euro-wide index. They also find that six of the twenty-eight possible bilateral pairs are fractionally cointegrated.

The focus here will be on whether house prices in the euro zone are convergent. There have been attempts to ascertain whether UK house prices are convergent. Cook (2003), as noted, was an early such study. The author tests for the stationarity of the ratio of regional UK home prices to the national UK index. The author finds there is evidence of convergence for a number of such ratios. Holmes (2007) tests for the convergence of UK regional house prices by applying a panel unit root test to the differential of regional versus national home values, and finds convergence (a stationary relationship) for a number of regions. Holmes and Grimes (2008) find evidence for convergence as the first principal component of the regional-national house price differential is stationary.

There has been a study on whether euro home prices are convergent. Tsai (2018) looks at housing data for euro and non-euro countries spanning 1984:1-2015:1. Tsai performs panel unit root tests on the ratios of different euro and non-euro country home indices to an average of euro zone home prices, then to German house prices-as Germany is the largest euro zone economy-and finally to UK home values, as the UK "has performed excellently in its financial and housing markets" (p. 277).

The author find that when the average of euro country house prices is used as the base, the null of a unit root in all series can be rejected when the sample is restricted to the pre-euro quarters (1984-1998), but not when the sample is restricted to the years since the euro. This would be evidence *against* the notion that the euro led to house price convergence. However, for the whole 1984-2015 sample convergence appears to hold for the euro countries by the panel unit root test, and it does not appear that non-euro countries are converging toward the euro-country average for any sample or sub-sample.

When Germany is used as the base, a panel unit root isn't rejected for the whole sample, or for the pre-euro years, but is rejected for the post-euro years, and this holds for both euro and non-euro countries. If these results are to be taken at face value, they suggest that both euro and non-euro countries have been converging to German home values irrespective of whether they were in the monetary union. Tsai then finds that the null of non-stationarity cannot be rejected (i.e. no convergence) when the UK is employed as the base, for either euro or non-euro countries, over any period, with the panel unit root test.

Lastly, the authors utilize a measure of convergence developed by Phillips and Sul (2007). The authors split the sample at 1992-the year the Maastricht Treaty was first signed. Tsai finds that "house prices did not converge in either the euro zone or the non-euro zone countries before 1992, as the statistics clearly reject the convergence hypothesis. However, after 1992, convergence was observed in the housing markets of both euro zone and non-euro zone countries, verifying that the convergence criteria for the overall variables regulated by the Maastricht Treaty also resulted in market convergence among other variables" (p. 279).

These papers on house price convergence are important contributions. There are, however, problems of interpretation. Panel unit root tests, employed in the Tsai and other studies, pose difficulties as the null hypothesis states that all series are nonstationary. A rejection of the null hypothesis indicates that at least one series is stationary-i.e. that at least one pair of countries are convergent. However it does not indicate how many or which series do or do not have unit roots. Thus using the Im, Persaran and Shin (IPS) panel unit test, as in Tsai, and finding that the null that all of the ratios of individual country prices to German housing values are can be rejected does not imply that all such country housing markets are convergent (see Taylor and Taylor, 2004 for a discussion of this issue in the context of the purchasing power parity debate). In addition, Holmes, Otero and Panagiotidis (2011) point out that the results of panel unit root tests can be rendered unreliable due to cross-sectional dependence among the series. Caporale and Cerrato (2006) specifically discuss how the IPS panel unit root test, employed by Tsai, suffers from this problem. Moreover, Abbott and DeVita (2013) note that results from tests for

convergence which involve, as the Cook (2003), Holmes (2007) Holmes and Grimes (2008) and Tsai (2018) studies did, examining regional home prices vis-à-vis a reference series, such as a national index, are sensitive to the choice of the reference, and ignore information from all of the other price ratios. In addition, using an average of home prices as the base, as Tsai (2018) did in one specification, implicitly assumes that all the regions are convergent, which may not be the case (see Clark and Coggin, p. 273, as well as Carvalho and Harvey, 2005 for a discussion of this issue). In addition, Tsai seems to find evidence for the converging effects of the euro by splitting the sample on panel unit root tests and Phillips and Sul (2007) procedures. This is analogous for testing for a structural break by splitting the sample at a time of a known policy change, which, as explained below, Hansen has shown to lead to erroneous conclusions of an actual effect where none may exist.

Fortunately, Pesaran (2007) has developed a method to test for convergence which obviates the problems with panel unit root tests. Pesaran was seeking a method to test for convergence in income across countries. His method has since also been applied to housing. Abbott and DeVita (2013) and Kyriazakou and Panagiotidis (2018) have applied variations of the method to UK regional home prices. Holmes, Otero and Panagiotidis (2011) have applied the method to MSAs in the United States. Abbott and DeVita (2012) utilized the method to examine convergence among house prices in different London neighborhoods, as did Holmes, Otero and Panagiotidis (2018). Holmes, Otero and Panagiotidis (2017) examine home values using the technique in different Paris neighborhoods.

Despite the research on cross-border home price co-movement, this method has not, to our knowledge, been applied to investigating home price movement across countries. Given the importance of home price convergence for the euro, we will apply it to the currency union.

Data and Methodology

The topic of output convergence has been a source of controversy starting with the first formal growth models of the 1950s. Empirically, determining whether income converges across nations has been

difficult, as the task is fraught with both definitional and testing issues (as was the case for housing convergence in the papers of Cook, Holmes, Holmes and Grimes and Clark and Coggins). Pesaran (2007) discussed some of the pitfalls of previous methods, and developed a testing procedure to address them. Consider N countries, or regions. For any 2 of the N regions to be convergent, the difference between the two must be stationary with a constant mean. This amounts to the two series not being merely cointegrated, but also having a cointegrating vector of (1, -1). In addition, a constant mean for the difference means the two series must be co-trending-the difference cannot have a linear trend.

The probabilistic approach to finding convergence among a group of N regions entails testing all N(N-1)/2 possible pairs for stationarity. Pesaran demonstrates that under the null hypothesis of no convergence, the fraction of rejections should be equal to the nominal size, α, of the unit root tests. Pesaran (2007), in testing output for large sets of countries, finds no convincing evidence for convergence, as the fractions of rejections for different data sets are all below or just slightly above the nominal test sizes.

As noted, the method has been applied to house prices in UK regions (Abbott and DeVita, 2013, Kyriazakou and Panagiotidis, 2018); among MSAs in the US (Holmes, Otero and Panagiotidis, 2011); among different housing districts in London (Abbott and DeVita, 2012, Holmes, Otero and Panagiotidis, 2018) and between the housing districts of Paris (Holmes, Otero and Panagiotidis, 2017). Ours is the first study, to our knowledge, to apply the method to house prices across national boundaries. While there have been other papers on cross-national home price movements, the euro zone is of particular interest as it is a currency union with one central bank and hence only one monetary policy for all member nations.

We obtain data on home values for the European countries from the Mack and Garcia (2011) database, available at the website of the Dallas Federal Reserve Bank (the database is continuously updated at https://www.dallasfed.org/institute/houseprice). Previous papers on cross-country house price movements have suffered from price indices that were compiled in inconsistent ways across the different

nations. Hirata, et al. concede that this is a problem, "House price series are subject to various problems given that different countries use different concepts to keep track of price movements in housing markets" (p. 8). The Mack-Garcia data set helps alleviate these problems by using methods that are more consistent across countries.

The data is quarterly, adjusted for inflation and seasonality, and runs from 1975:1 to 2018:1. We will examine the following eight euro-zone nations-Belgium, Finland, France, Germany, Ireland, Italy, The Netherlands and Spain. This is a greater number of countries than were examined in some other papers on cross-country home price movements in the euro zone such as Ferrara, et al. (2010) and Alvarez, et al, (2010) and these are the same eight nations analyzed in Gupta, et al. (2015). We will apply the Pesaran pair-wise method to these eight countries and see how convergent housing markets appear in the euro zone.

In addition to these euro countries, we will also include three non-euro (but European) housing markets-Denmark, Sweden and the UK. These countries were once potential members of the monetary union, but have declined to join. Examining these non-euro countries can provide a benchmark with which to compare evidence on convergence among euro-zone housing markets. This can yield a clearer picture of convergence than simply focusing on only euro housing markets. Miles and Vijverberg (2018), for instance, examine the impact of the euro on business cycle synchronization by including both euro and non-euro countries in their analysis. Graphs of the home prices are displayed in Figures 1 through 11.

In addition to examining whether euro-zone house prices seem convergent, we will also test specifically for whether the actual advent of a common currency appeared to have an impact on convergence. That is, if there is (or is not) apparent convergence among the housing markets of euro-zone countries, did the euro itself play a role in creating that convergence? It is not immediately clear whether a monetary union would promote or retard convergence between different housing markets. In terms of cyclical co-movement, the effects are a priori ambiguous for housing, as well as for other

variables. For example, a currency union may facilitate cross-border trade, which may, through demand channels, increase cyclical co-movement. But greater trade could also lead to more specialization among member countries, and thus more asymmetric responses to shocks and therefore less synchronization. Similarly, a common currency can increase capital flows across countries, which could lead to more synchronization if residents in different countries develop similar asset holdings. But such flows can also lead more capital out of slow-growing countries into the housing markets of fast-growing "bubble" countries, leading to eventual crashes in the latter and hence less synchronization.

For long-run convergence, it is similarly unclear what impact a common currency might have. Recent research (Franks, Barkbu, Blavy, Oman and Schloeman (2018)) indicates that, despite expectations at the currency's launch, convergence in income levels has failed to occur for the original euro members. Convergence of home prices, and in particular the impact of monetary union on such convergence, is thus an empirical question.

One option to investigate such convergence would be to split the sample before and after the euro's introduction and see if results are different in the two periods. This was the approach of Tsai (2018) in applying the Phillips and Sul (2007) method, where the sample was split at 1992, the date of the signing of the Maastricht treaty. Unfortunately, there are two problems with this approach. First, it will lead to smaller samples and clearly reduce the power of the unit root tests that must be employed in the Pesaran pair-wise method. A second problem is that to split the sample at a time of known economic change is to impose a "break date"; even if the lower power of the tests was not a problem, this could lead to erroneously finding an apparent effect where none exists. The same would be true for using the full sample but inserting a dummy variable at the point of the euro's launch. Hansen (1992) has demonstrated that testing for structural change in this manner often leads to "significant" results on the break dummy when no such change has actually occurred. This is owing to choosing the break date based on knowledge of actual economic events. Properly testing for change thus requires methods that allow break dates to be determined endogenously from the data, rather than imposed by the researcher.

We will thus employ, among other unit root tests, the Lee-Strazicich test. The Lee-Strazicich (LS) method is a unit root test that allows for endogenous breaks. Importantly, the LS test allows for breaks both under the null hypothesis of a unit root and the alternative hypothesis of stationarity. Some unit root tests which allowed for endogenous breaks did so only under the alternative; the possibility of a unit root process that also exhibited structural change was not permitted. The LS test is thus an improvement on other unit root tests which allowed for breaks only under the alternative hypothesis of stationarity.

The LS test will serve two purposes for our analysis. First, allowing for breaks may increase the power of the testing procedure compared to the standard ADF test. Indeed, other papers on the topic, such as Abbott and DeVita (2012, 2013) have employed the ERS and Ng-Perron tests in addition to the ADF as the former two techniques are known to have higher power than the latter. Secondly, we obtain information on the dates of any breaks, which are endogenously determined. We can thus see if any breaks we obtain are associated with euro adoption with the LS method. In this way, we can obtain evidence on whether the euro itself actually played a role in achieving convergence as opposed to having countries perhaps already convergent join a common currency area.

We also note that all papers on convergence which have used the Pesaran method have employed the ADF test. Others, such as Abbott and DeVita (2012, 2013) also utilize the ERS and Ng-Perron tests. The ERS test can have greater power than the ADF, as it entails de-trending the data before testing. The Ng-Perron method also helps obtain greater power and sometimes better size compared to the ADF by de-trending the data, as in the ERS test, and also using a lag selection criteria, the MAIC, designed to choose the proper lag length for the test with better accuracy than the standard AIC or SIC measures. We now turn to the results.

Results

Table 1 contains results for the ADF test. Altogether for the eleven countries-the eight euro members plus Denmark, Sweden and the UK-there are fifty-five pairs. For the eight euro nations, there are twenty-eight pairs. For the three non-euro countries, there are of course three pairs, and there are twenty-four pairs of euro and non-euro housing markets.

As displayed, there are only three of fifty-five total cases for which there appears convergence-no significant linear trend and a rejection of the unit root hypothesis at the five percent level. This means 5.454 percent of pairs are apparently convergent. The three pairs are Belgium-Ireland, Denmark-Finland, and Ireland-Netherlands. This makes two of twenty-eight (7.14%) cases of convergence for the euro zone, and one of twenty-four (4.16%) for euro-non-euro pairs. Given that Abbott and DeVita (2013) found that only 15.15% of UK regional house price pairs satisfied the criteria of no linear trend and stationarity, and concluded that this meant no evidence of convergence for the UK as a whole, the results of the ADF test yield no evidence in favor of convergence for the euro zone or the eleven European countries.

Given the low power of the ADF procedure we follow Abbott and DeVita (2012, 2013) and employ the ERS and Ng-Perron tests, which generally have greater power. Results for the ERS test are displayed in Table 2. These results are somewhat different from those using the ADF, although it is not clear if they indicate convergence. Twelve of the fifty-five (21.81%) overall cases indicate convergence, while a higher fraction indicate convergence just for the twenty-eight euro pairs (32.142%). Only 12.5% of the euro-non euro pairs appear convergent, and none of the three non-euro pairs are convergent. While the fraction of convergent pairs are higher than with the ADF test, and certainly exceed the nominal size of five prevent, by the standards of previous studies in the literature evidence for convergence is not strong. Abbott and DeVita (2012) found, when the ERS test was used, and the SBC criterion was employed to choose lag lengths, that 27.27 percent of London district house price pairs exhibited convergence, but stated "overall, therefore, no multidistrict convergence is found since pairwise convergence only pertains to a relatively small proportion of district combinations" (p. 727). At the same

time, Holmes, et al. (2011) are able to reject the null of a unit root for 31.83 and 37.5 percent of US pairs, using the ADF and ERS tests, respectively, and these authors do infer convergence based on this percentage of rejections.

When we employ the Ng-Perron procedure the results are similar to those from the ERS (see Table 3). There are nine of twenty-eight euro country pairs which seem convergent, or 32.14 percent. This is greater than Abbott and DeVita's (2012) high of 27.7 percent using the ERS, a finding they believed did not indicate convergence. And, it is slightly higher than the 31.83 percent of rejections Holmes, et al. (2011) found using the ADF test, which, combined with a 37.5% rejection rate with the ERS method led these authors to conclude convergence existed among US MSAs.

What to make of our results? The most that can be said for the euro zone is that there is, at best, decidedly marginal evidence in favor of convergence. While the percent of rejections, at 32.14 percent, using the powerful ERS and Ng-Perron tests, is just slightly above the rejection frequency Holmes, et al. (2011) found using the less powerful ADF, it is much lower than the fraction of rejections found in other studies, upon which convergence was inferred. Holmes, et al. (2018), for example, found a rejection rate of 70 percent for different London regions.

Although the evidence for the convergence of euro zone housing markets is highly tentative, these eight markets do seem more likely to be convergent than the non-euro European nations. For the overall sample, including the three non-euro countries, only eleven (Ng-Perron) or twelve (by the ERS) of fifty-five of the pairs are stationary, and have no significant linear trend. Only two (Ng-Perron) or three (ERS) of the twenty-four euro-non-euro housing pairs are convergent, and none of the three non-euro pairs are stationary. Thus to the extent there is convergence euro countries appear more likely convergent than non-euro countries.

Of course observing that euro zone housing markets give some indication of being more convergent than those markets outside the common currency is not the same as inferring the euro caused

convergence. Countries do not enter a currency union randomly. A nation which appears "ready", in terms of economic and financial compatibility with other members is more likely to join a monetary union than one that seems less compatible. For instance, Von Hagen and Neumann (1994) examined which countries seemed best suited for the euro before the currency's launch. The authors examined which countries had the lowest real exchange rate volatility vis-à-vis six German Lander. The authors found that three countries-Denmark, Italy and the UK-all had high real exchange rate volatility with the German states, while the other five countries in the study-Austria, Belgium, France, Luxembourg and The Netherlands-showed low real exchange rate volatility with Germany. And of course all of the five countries that appeared ready in the Von Hagen and Neumann study have joined the euro, while two of the three that did not seem ready did not. And Italy, the one nation that did not seem ready but joined anyway, has problems of adjustment and has been a source of conflict with officials in Brussels over economic policy.

There are other factors which affect the decision to join a common currency, but the key point is that a finding of a (possibly, tentatively) greater likelihood of convergence among euro zone home sectors compared to housing markets outside the currency union does not indicate a causal role for the euro itself in creating (possibly) greater convergence.

We thus, having run three different types of unit root tests, employ a fourth, which allows for endogenously determined structural change. As explained, this is different from Tsai's (2018) method of splitting the sample at the date of a known change related to the euro (the Maastricht treaty) and then testing for a break. Also, the Lee-Strazicich test allows for structural breaks under both the null and alternative hypotheses (nonstationarity and stationarity, respectively). Allowing for these breaks may increase the power of the unit root test-if indeed a break has occurred. This test has not, to our knowledge, been applied in any previous study which used the pair-wise approach to investigating house price convergence.

The second big advantage of the LS test is that finding and testing for the significance of endogenous breaks can shed light on whether euro adoption helped achieve convergence. If breaks appear around the time of euro adoption, and they were negative in sign, indicating a reduction in the price differentials, it would suggest that the euro may have played a role in getting home values to converge. Results are displayed in Table 4.

In interpreting Table 4, we note that there are two types of models with which the LS procedure can test for unit roots and breaks. If there is a linear trend, both the coefficients on the trend and intercept are tested for breaks-this is the "Break" model. If there is no linear trend, the test is for a break in the intercept-this is known as the "Crash" model. We thus use the break model if there is a significant linear trend, and the crash model if there is no significant trend. We allow for up to two breaks in the intercept and trend of each country differential. Of course a significant linear trend precludes convergence. However, we still test for stationarity, as well as breaks, on the chance a finding of breaks may give insight into the role of the euro.

As displayed, we find palpably *fewer* pairs which appear convergent when employing the LS test than we did with the ERS or Ng-Perron procedures. This may be owing to the greater number of parameters in the LS test, as more coefficients are required to test for breaks. This can actually lower, rather than raise the power of the test if no significant breaks actually occurred. Holmes, et al. (2017) found a similar result. They rejected the unit root hypothesis for their Paris home price pairs when using the SIC criterion more often than when they employed the MAIC criterion to choose lag lengths. This is because the MAIC leads to more lags included in the model, and hence more parameters thus lowering the power of the test.

With the LS test, in only five of fifty five cases for all of the European housing markets in our sample could the null of a unit root be rejected and no significant linear trend found. In only four of twenty-eight cases within the euro zone did there appear to be convergence.

We did examine the results over 1999 to 2002 to see if there were breaks which might indicate the euro played some role in convergence. There were no such breaks among the four convergent euro pairs. Thus the euro cannot be credited with leading to convergence for countries that actually display convergence by the LS test. There were breaks over 1999-2002 for five country pairs that were not convergent. Belgium/Spain (2001:3), France/UK (2000:3), Germany/Ireland (2001:1), Germany/UK (2001:1) and Netherlands/Sweden (2001:3). These breaks are all negative, which might suggest that an event-say the euro-played a role in helping convergence. There are two points that cast doubt on this possibility, however. First, regardless of the significance of breaks, none of the above pairs are convergent. Secondly, three of the five pairs-France/UK, Germany/UK, and Netherlands/Sweden-are between the euro and non-euro countries. Thus the evidence is clear that the adoption of the euro has not increased convergence within the currency zone.

We want to address Tsai's (2018) finding that 1992 was a point of significant change for euro housing convergence, as the author finds convergence with the Phillips-Sul measure after this date, but not prior. This finding again resulted from splitting the sample at a point of known policy change. In contrast, when we use the Lee-Strazicich test, and investigate endogenous structural change, we obtain a total of fifty-two significant breaks (results available upon request). Seventeen country pairs had no significant break, while there were multiple breaks in others. There were four breaks, out of the fifty-two, that occurred in 1992 for three country pairs. Two of these breaks were for one country differential-Finland/Italy, while France/Netherlands and Germany/Sweden experienced one break each in that year. For the latter two countries, the 1992 breaks were negative, which may suggest a convergent effect of this year, perhaps as a result of the Maastricht Treaty. However, while the France/Netherlands differential is stationary by the ERS and Ng-Perron tests, neither of these differentials are convergent by the Lee-Strazicich test. Moreover the Finland/Italy differential has both a positive break and a negative break in its trend and intercept, respectively, and is not convergent by any unit root test. Moreover, even if we attribute the convergence found for France/Netherlands by the ERS and Ng-Perron tests to the Maastricht

Treaty, it is one of fifty-five cases, and is not convergent when we allow for this very break in our specification. It is also telling that while there were four breaks in 1992, there were five in 2008, four in 2009, and four in 2010, which obviously cannot be attributed to any convergent effects of the euro. There were also twenty-three breaks before 1992. All of this casts doubt on the notion that the Maastricht Treaty-or the euro itself, played a role in creating what convergence there may be among euro-zone housing markets.

As for individual country convergence, Ireland, despite its notorious housing bubble and bust, appears more likely convergent with the housing sectors of other countries than any other nation. When the ADF test is employed, the only two euro zone country pairs that are convergent are both with Ireland (Belgium and The Netherlands are the two countries with which Ireland is paired in these cases). When the ERS test is employed, four of the nine convergent euro zone pairs are with Ireland, as was the case with the Ng-Perron test. For the LS test, two of the four convergent euro zone pairs are with Ireland. For all four tests Ireland's housing market is more often convergent than that of any other country.

The Netherlands comes in second to Ireland, being convergent in four cases with the ERS and in three with the Ng-Perron. Finland is convergent in three cases with both the ERS and Ng-Perron, while Belgium is convergent in two cases with the ERS and two with the Ng-Perron. Spain's housing market is never convergent under any test. Italy, and, most importantly Germany, are only convergent in one case each under the ERS and Ng-Perron tests.

This result for Germany stands in contrast to that of Tsai (2018). Again, the author calculated the ratio of each European country house price index to the German index, and using the IPS panel unit root test rejected the null hypothesis that all ratios were nonstationary over the post-euro years, but not for the pre-euro years. This result would seem to strongly indicate convergence toward the housing market of the dominant economy of the currency union. However, this inference is unwarranted. The null hypothesis in the panel unit root test is that all series being tested have unit roots, while the alternative is

that at least one of the series is stationary. Rejecting the null hypothesis gives no indication of how many or which series are stationary (Taylor and Taylor, 2004). Indeed, our results from the pairwise approach- that only one house price differential involving Germany is stationary by the ERS and Ng-Perron tests, are literally consistent with Tsai's findings for the panel unit root test. However, by using the pairwise approach we are able to determine that Germany is one of the less convergent housing markets in the euro zone. This highlights the criticisms of using the panel unit root test to investigate convergence made by Abbott and Devita (2013), Holmes, et al. (2011) and others, who thus favor the pairwise approach. And the relative lack of convergence for Germany's housing market of course augurs poorly for the ability of the ECB to use housing in its monetary policy deliberations, as Germany is the largest economy in the euro zone.

Conclusion

Results here indicate that while the evidence for convergent housing markets in the euro zone is not strong, it does appear that the countries within the monetary union are more likely convergent than those European countries that chose to retain their own currencies. At the same time, we have found that the euro itself did not appear to play a role in creating any tendency for convergence.

This finding should lead to caution for countries not yet in the euro zone but for whom membership is still a possibility, such as the Czech Republic, Hungary and Poland. Policymakers, both in prospective member countries and the ECB, should consider that if a country's housing market does not seem convergent prior to joining the euro, the act of joining the common currency will not likely make it convergent.

Finally, the findings on Germany indicate a low level of convergence with other countries' housing markets. This lack of convergence of the euro's largest and most dominant economy will likely be a source of continued difficulty for the ECB in attempting to conduct a monetary policy that is optimal across all nations of the euro.

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Table 1
ADF Results

Proportion of pairs both rejecting the null hypothesis of a unit root and having no significant linear trend:

Overall Sample	Euro-Zone	Euro-Non-Euro Pairs	Non-Euro Pairs
3/55	2/28	1/24	0
(5.454%)	(7.142%)	(4.16%)	

Pairs that were convergent: Belgium/Ireland, Denmark/Finland, Ireland/Netherlands.

Lag lengths for the test were chosen by the SIC criterion.

Table 2
ERS Results

Proportion of pairs both rejecting the null hypothesis of a unit root and having no significant linear trend:

Overall Sample	Euro-Zone	Euro-Non-Euro Pairs	Non-Euro Pairs
12/55	9/28	3/24	0
(21.81%)	(32.142%)	(12.5%)	

Euro-Zone pairs that were convergent: Belgium/Ireland, Belgium/Netherlands, Finland/France, Finland/Ireland, Finland/Netherlands, France/Ireland, France/Netherlands, Germany/Italy, Ireland/Netherlands.

Euro/Non-Euro pairs that were convergent: Belgium/UK, Denmark/Finland, France/UK.

Lag lengths for the test were chosen by the SIC criterion.

Table 3

Ng-Perron Results

Proportion of pairs both rejecting the null hypothesis of a unit root and having no significant linear trend:

Overall Sample	Euro-Zone	Euro-Non-Euro Pairs	Non-Euro Pairs
11/55	9/28	2/24	0
(20%)	(32.142%)	(8.33%)	

Euro-Zone pairs that were convergent: Belgium/Finland, Belgium/Ireland, Belgium/Netherlands, Finland/France, Finland/Ireland, France/Ireland, France/Netherlands, Germany/Italy, Ireland/Netherlands.

Euro/Non-Euro Pairs that were convergent: Belgium/UK, Denmark/Finland.

Lag lengths for the test were chosen by the MAIC criterion.

Table 4
Lee-Strazicich Results

Proportion of pairs both rejecting the null hypothesis of a unit root and having no significant linear trend:

Overall Sample	Euro-Zone	Euro-Non-Euro Pairs	Non-Euro Pairs
5/55	4/28	1/24	0
(9.09%)	(14.285%)	(4.16%)	

Pairs that were convergent: Belgium/Ireland, Denmark/Finland, Finland/France, Finland/Netherlands, Ireland/Netherlands.

Breaks over 1999-2002: Belgium/Spain (2001:3), France/UK (2000:3), Germany/Ireland (2001:1), Germany/UK (2001:1, Netherlands/Spain (2001:3).

Lag lengths for the test were chosen by the SIC criterion.

Figure 1

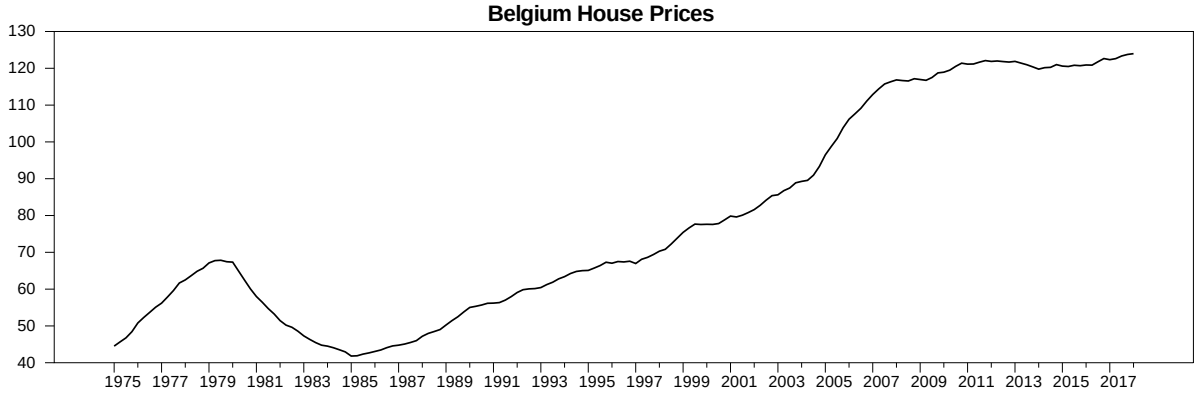
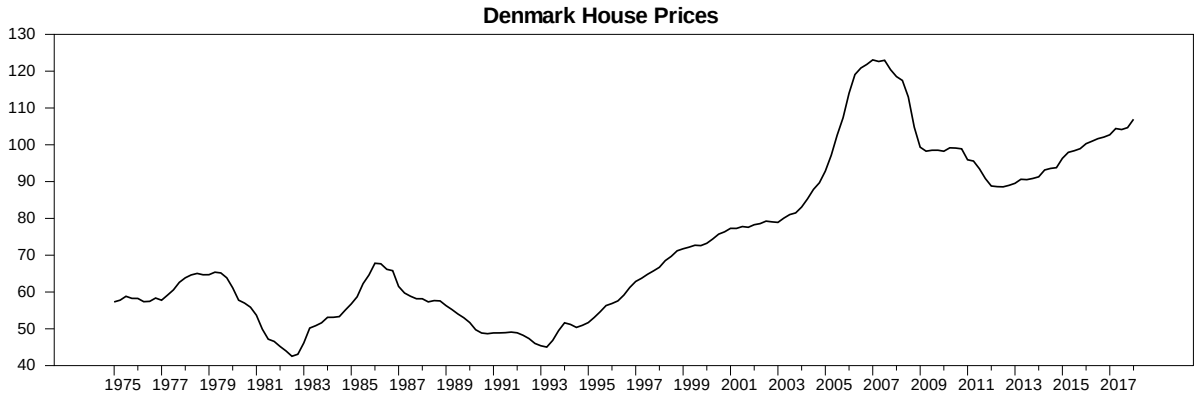


Figure 2



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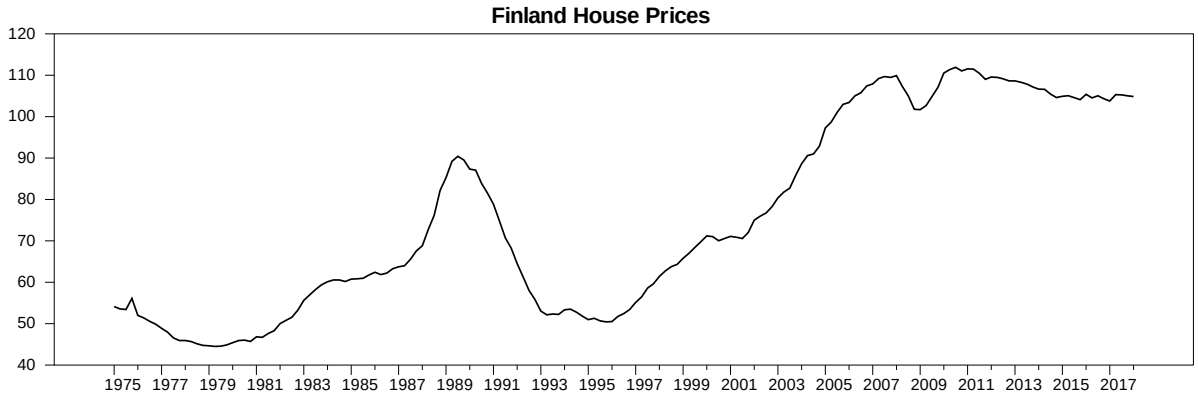

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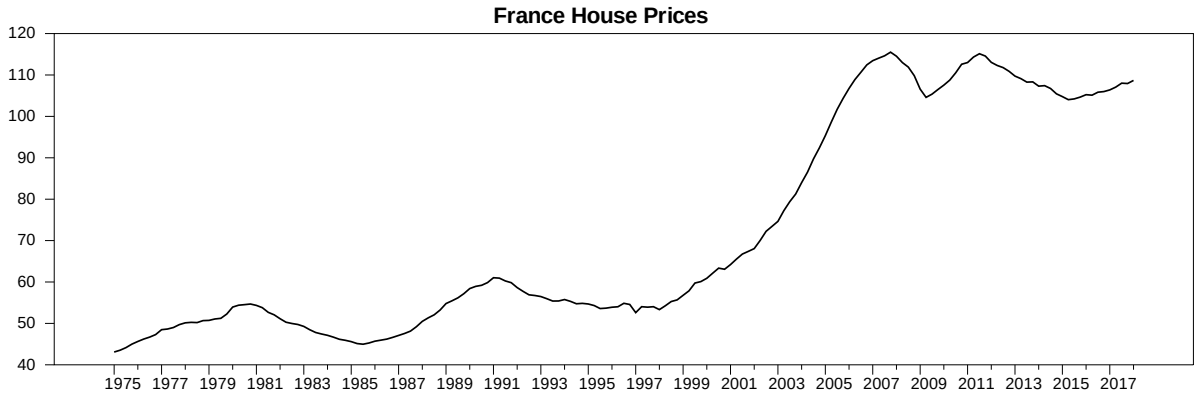
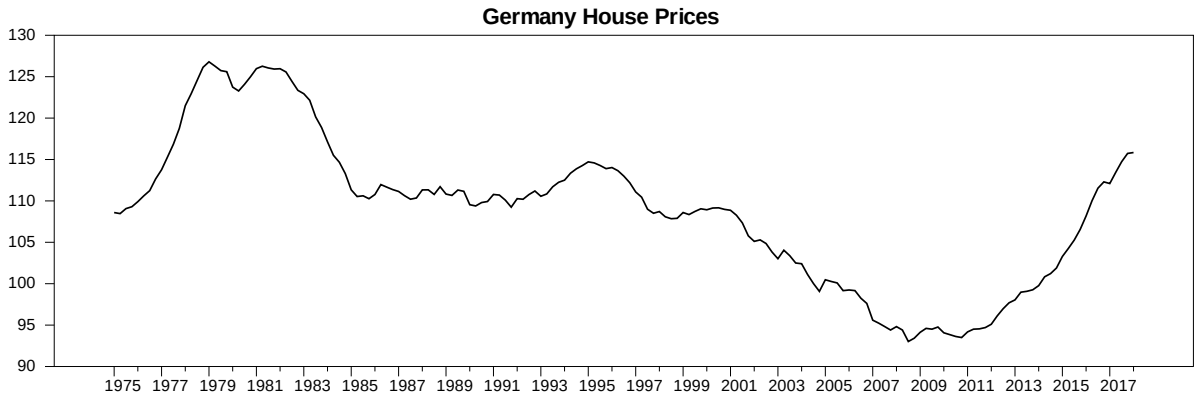


Figure 5



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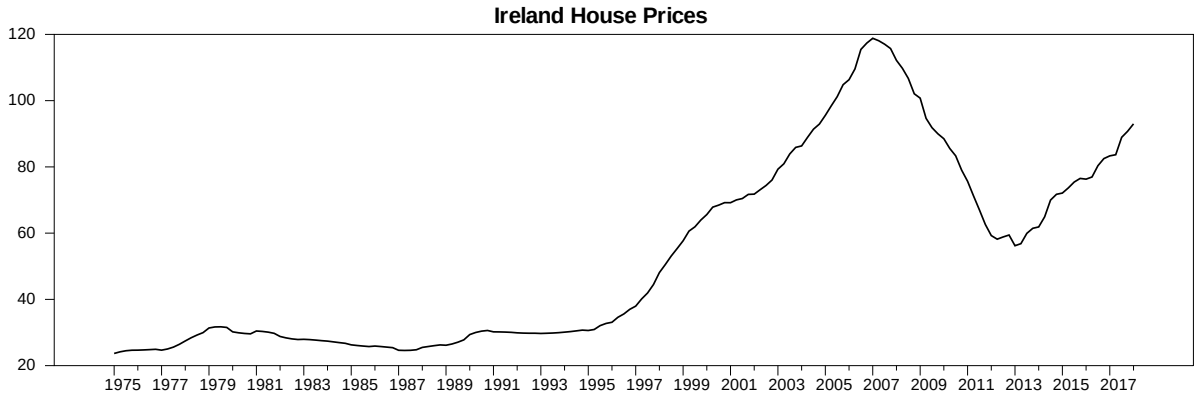

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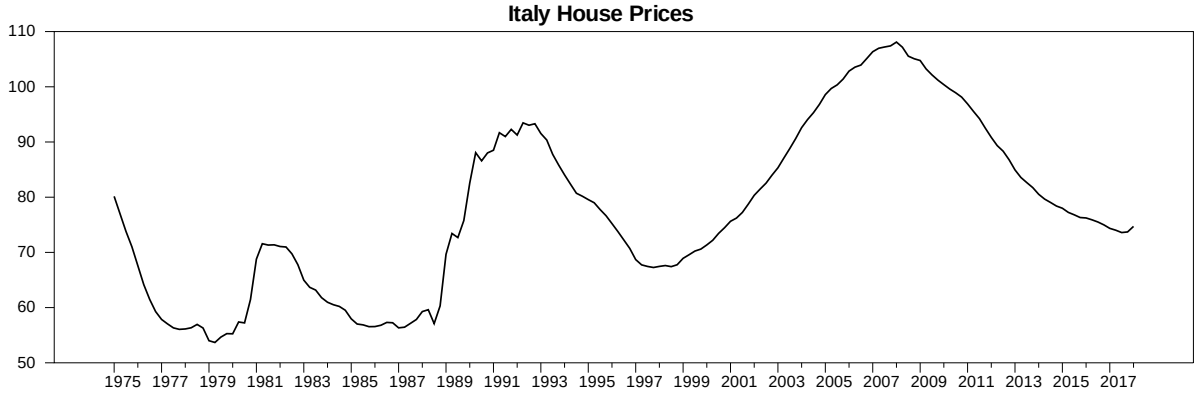

Figure 8

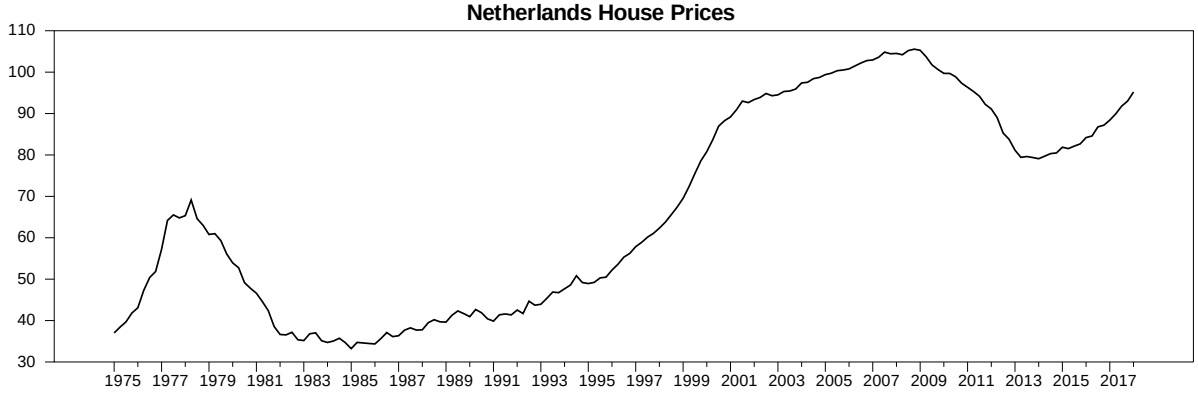

Figure 9

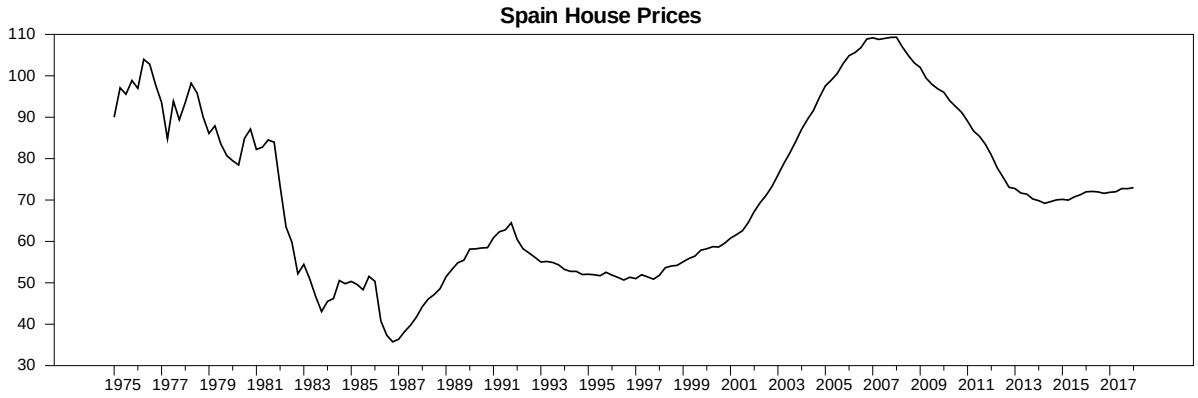

Figure 10

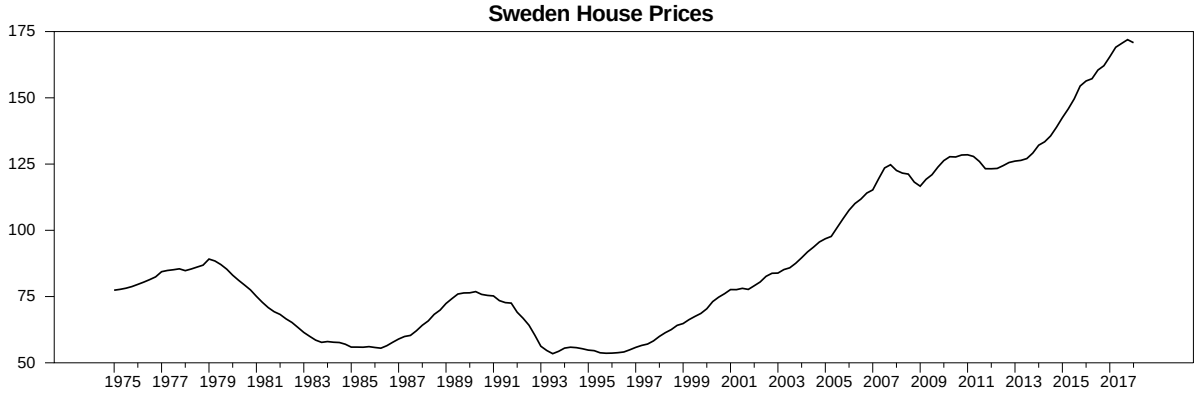

Figure 11