Regional Convergence and Structural Change in US Housing Markets

Abstract

If house prices are convergent at the national level, monetary policy is easier to implement and labor has an easier time achieving mobility across regions. There have accordingly been a number of studies on home price convergence. Some of these previous papers have methodological problems. In this paper we examine home price convergence across the different regions of the US using Pesaran's pairwise approach. This method obviates some of the methodological issues which have plagued previous studies. We also test with a method that allows for structural breaks in the relationships between regional markets. We find, first, that overall the US housing market is not convergent across regions. We find some evidence that the high-priced regions of New England and the Pacific exhibit convergence. Analysis of structural change reveals that some of the increase in co-movement between these expensive markets, and the decrease in co-movement between these and other markets accelerated in the early-to-mid 1980s. The early 1980s saw major changes in US housing. Financialization, in the form of a greater role for non-depository investors such as REITs, a big take-off in securitization, falling interest rates, and more capital from abroad led to greater commodification of housing, in terms of movement away from housing's role as shelter and towards the exchange value of homes. These changes made credit available from new sources. This greater credit, including from global sources, appears to have played a role in creating divergent prices in regions which likely have differing elasticities of housing supply.

Keywords: Convergence, Pairwise Approach, Regional House Prices, Structural Change.

JEL Classifications: G2, R21, R23, R2.

Introduction

If home prices converge, labor mobility is easier, sending workers where they can benefit themselves, and the economy, the most. Ganong and Shoag (2017) show how large home price differentials across the US inhibit such labor mobility. In addition, convergence makes it easier to conduct monetary policy. If the west coast is experiencing a housing bust, while the south eastern portion of the US is booming, the tight money policy that would cool a potential bubble in the south east would be devastating for the west coast. Similarly, the loose money that would help the west coast could lead to overheating in the south east market. Moreover, the degree to which house prices converge has implications for housing policy (i.e. should such policies be national in scope or more tailored to local conditions), as well as portfolio management for investors in the housing market.

Unsurprisingly, there have been a number of papers on house price convergence. Much of this literature began with studies of the housing market of the United Kingdom, and on whether its different regions exhibited convergence in house prices. Cook (2003), Holmes (2007) and Holmes and Grimes (2008) are prominent examples. In the US, Pollakowski and Ray (1997) examined house price co-movement, and Clark and Coggin (2009) and Kuketayev (2013) studied house price convergence for the same US regions that will be analyzed in this paper.

Some previous studies of convergence for housing markets have had methodological issues. Some, for instance, test whether different regions are convergent with a reference region or index. The results of such an exercise are sensitive to the choice of the reference. Others employ panel unit root tests, which suffer from the problem of cross-sectional dependence affecting the results. Accordingly, in this paper we employ the pairwise method of Pesaran (2007). This entails testing the difference of each regional house price pair for stationarity and the lack of a linear trend. If both stationarity and co-trending are obtained for a given pair, the pair is said to be convergent.

With Pesaran's methodology, under the null hypothesis of no convergence, the portion of convergent pairs within a country should not be much larger than the nominal size of the test. This method avoids problems with previous techniques used to investigate convergence.

Pesaran originally developed the pairwise method to test for convergence in income. It has since been applied to housing markets. Abbott and DeVita (2013) and Holmes, Otero and Panagiotidis (2018) are two studies which used the pairwise method to examine whether home prices across the twelve different regions of the UK were convergent.

We will apply this method to US regions using standard unit root tests that have been employed in other studies of home price convergence that used the pairwise approach. These tests all impose constant parameters over the whole sample. Thus in addition to these, we will use the Lee-Strazicich test (Lee and Strazicich, 2003) which allows for structural breaks. There are two reasons for using the Lee-Strazicich test. First, over our sample, which spans 1975-2018, there have been important financial and economic changes. At the beginning of the sample, for instance, home buying was largely funded by depository banks. Since then, there has been an increase in the "financialization" of housing (see Aalbers, 2016). A much greater role is now played by non-depository institutions such as REITs, which began playing a larger role in housing in the 1980s. Securitization also grew very quickly in the 1980s. In addition, globalization, in the form of international capital flows, now has a substantial effect on domestic home values (Miles, 2019). These changes can mean much higher home values in areas that have a low elasticity of housing supply. Failure to allow for such breaks, if they exist for a given differential, can lower the power of univariate unit root tests. Secondly, allowing for structural change can indicate where important events had an impact on convergence or divergence.

To anticipate our results, we find that, overall, there is little evidence of US home prices being convergent, as only a low proportion of regional pairs are both stationary and co-trending by any of the unit root tests. We do find, however, evidence that the northern east coast (the New England region) is convergent with the Pacific, and some evidence the former is also convergent with the Mountain region.

These are the three housing markets that have risen fastest in price. It thus seems high price regions can converge with each other, but not with the rest of the regions in the country.

We also find there were numerous structural breaks, all of which were in the 1980s or the crisis years of 2007-2010. It appears that some of the co-movement between New England and the west coast, as well as divergence between high-priced and low-priced regions, accelerated in the 1980s. It seems likely more widely available credit raised prices and aided in the commodification of homes more in regions known for already low elasticity of housing supply than in other areas.

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

Previous Literature

Previous studies on home price convergence have typically ignored structural change, or dealt with it by splitting the sample at a known date. This is unfortunate, as there have been many changes in US housing that could affect findings on convergence. For instance, to anticipate our results, we find changes in convergence measures in the 1980s and 2000s. The 1980s appear to be when high-priced markets in New England, The Pacific and to some extent the Mountain regions began to show signs of convergence with each other, and divergence with other, less costly regions.

This may reflect major changes in regulation, policy, finance and globalization and their interaction with housing, which began in the 1980s. As an example, Real Estate Investment Trusts (REITs) have been in existence since 1960. However, policy changes in 1986 allowed REITs to become more active, and by 2002 REITs were the largest property owners in New York City (see the first chapter of Madden and Marcuse, 2016, for a detailed discussion). In addition, housing finance used to consist of traditional banks taking deposits and loaning out the proceeds in the form of (often thirty-year, fixed rate) mortgages. While government entities like Fannie Mae and Freddie Mac have existed since the 1930s,

Madden and Marcuse point out that the process of securitization "exploded" (page 14) starting in the 1980s. This means that more financing is available for house purchases.

These changes also occurred in a context of a policy push to increase homeownership. In 2003, the US Congress passed and then President Bush signed the "American Dream" Down Payment Act, which lowered down payment requirements for first-time home buyers. Homeownership did increase in the wake of the legislation, but so did financial vulnerability for new homebuyers with no equity cushion in case of a decline in home prices, which did fall later in the decade. The United Kingdom instituted similar policies, such as the "Right to Buy" initiative of 1980 which allowed tenants in public housing to purchase their residences.

In the US, a tax change in 1997 meant lower capital gains taxes on home sales. This of course gave buyers, especially those seeking purchases for investment rather than residential purposes a greater incentive to buy, which could further raise prices especially in areas with inelastic housing supply.

Globalization has also played a role in making more financing available for home purchases. Cabellero, Farhi and Gourinchas (2008) describe the capital flows from around the world, especially Asia, which helped drive up US house prices. Miles (2019) documents the impact of foreign capital on the housing markets of the US, UK and euro zone countries of Ireland and Spain. Capital flows from Germany helped create housing bubbles in Ireland and Spain which led to devastating home price drops and subsequent banking crises.

Aalbers (2016) describes these changes as the "financialization" of housing, where housing and the financial system come to rely on each other. Jorda, Schularick and Taylor (2015) also document how housing booms and increased credit for home purchases increase the chances of financial instability.

All of this leads to less emphasis on housing's "use value" as shelter and more on its "exchange value", or commodification. In the same vein, Sassen (1991) describes "global cities" such as London, New York and Tokyo that play key roles in the global economy. Housing in these cities is a separate

"asset class" compared to housing in slower-growing areas. Indeed Badarinza and Ramadorai (2018) find that home price in London are driven in part by political developments in Russia, the Middle East and Africa, as wealthy residents seek housing as an asset. All of these changes have driven home values in some regions much higher than simple supply and demand for housing as shelter would do, and these effects are most keenly felt in expensive regions such as the north east and west coasts.

In terms of previous studies on convergence, the division of the United Kingdom housing markets into twelve clearly delineated regions has led the UK to be the focus of numerous studies on home price co-movement across different areas.

A subset of the literature on UK house price co-movement focused on convergence-that is, do prices across the UK converge to some long run level, or at least a stationary difference? One of the first studies on this topic was by Cook (2003). The author examines the twelve differences between each nation's home price index and the national UK home value index for stationarity. Using the standard ADF unit root test (Dickey and Fuller, 1979), Cook finds no such difference is stationary at the five percent level, which would indicate a clear lack of convergence. However, upon applying the MTAR unit root test of Enders and Granger (Enders and Granger, 1998), the author finds stationary relationships in seven of twelve cases.

Holmes (2007) examines the same twelve regional-national house price differences as Cook, and tests for convergence with a somewhat different methodology. Like Cook, Holmes first uses standard unit root tests on all twelve differentials, and finds stationarity in just two cases. Holmes notes the low power of standard univariate unit root tests and employs a panel unit root test. Holmes states that some early panel unit root tests, while having greater power than univariate tests, suffer from a couple of defects. First, the null hypothesis in such tests is that all series in the panel are nonstationary, while the alternative is that at least one of the series is stationary. A rejection of the null with such a test does not yield information on which or exactly how many series appear stationary. In addition, early panel unit root tests suffered from cross-sectional dependence among the series, which could distort test results.

Holmes thus employs a newer panel procedure, the Seemingly Unrelated Regression ADF (SURADF) test (Breuer, McNown and Wallace, 2002), which was developed to address these two issues. Upon applying this method to the twelve UK regional-national differentials, he finds greater evidence for convergence than with univariate procedures.

Holmes and Grimes (2008) also test for convergence in the UK with the twelve regional/national home value differentials. In this study the authors extract principal components from the set of differentials, and find the first principal component is stationary, which leads the authors to infer convergence.

In the US, there have been several studies of house price co-movement and convergence across the nine US Census regions. While not examining whether house prices in these regions converge, Pollakowski and Ray (1997) tested for Granger causality in house prices between US regions and find prices in one region can predict prices in another.

Clark and Coggin (2009) investigate the nine US regional housing markets and test for convergence. The authors test for convergence in a manner that in some ways presages the pairwise approach we will employ here. Convergence between two regions would mean that the difference in the two regions' indices must be stationary. Citing Carvalho and Harvey (2005) the authors note that a significant linear trend in the difference of two indices is incompatible with convergence, and thus do not include a trend in their ADF test equations. They do allow for a constant, however, in their test specifications. If the estimated constant is statistically significant, and the null of a unit root is rejected, the authors say the two tested regions exhibit relative convergence. If the estimated constant is not significant and the differentials are stationary by the ADF test, they are said to exhibit absolute convergence.

Clark and Coggin drop some regions based on preliminary state space analysis. There are twenty-eight possible regional pairs in their sample. The authors find absolute convergence between the

East North Central and Mountain regions, and relative convergence for the Middle Atlantic/Pacific and New England/Pacific pairs at the five percent level. If the ten percent level of significance is considered as an appropriate threshold, there is also convergence for the housing markets of Mountain and West North Central, as well as New England/South Atlantic. As this is only, even at the ten percent level, five of twenty-eight possible pairs, the authors conclude that "the evidence for regional convergence is mixed" (p. 264).

Having noted, based on the result of the state-space modeling, a possible break in the indices during the mid-to-late 1990s, the authors test for convergence with the Zivot-Andrews method (Zivot and Andrews, 1992), which tests for unit roots while allowing for a structural break under the alternative hypothesis of stationarity. This makes sense, as standard unit root tests, which impose parameter constancy, can lack power if a break has actually occurred. However, results from the Zivot-Andrews test indicate only one regional pair (New England and Pacific) is stationary. It is worth noting that while unit root tests that allow for breaks can have greater power than standard linear tests like the ADF which do not allow for such change, they also, in allowing for changing coefficients add more parameters to be estimated, which could also lower power.

Kukateyev (2013) examines house price convergence among the nine US Census regions by testing the ratio of each region's index to the national index for stationarity. The author employs the MTAR test of Enders and Granger, and finds he can reject the null hypothesis of nonstationarity for the ratios of Middle Atlantic, Pacific and West North Central at the five percent level and New England at the ten percent level.

These previous studies do have issues of methodology. First, all of the above-cited papers on home price convergence, save for Clark and Coggin (2009), conduct tests by investigating whether a regional index is stationary vis-à-vis a national or reference index. If the reference is an average of the different regional indices, "such a specification implicitly assumes *a priori* that all regions are converging" (Clark and Coggin, p. 273). But of course it may well be that not all regions are converging.

Abbott and DeVita (2013) go on to point out that this method misses information on all the cross-regional relationships. Moreover, it is not robust to the choice of the reference (Abbott and DeVita, p. 1228). Furthermore, although Holmes (2007) employs a panel unit root test (the SURADF) which was developed to improve on the problems of earlier panel stationarity tests with cross-sectional dependence, Holmes, Otero and Panagiotidis (2011) question whether these "second generation" tests have adequately addressed this issue of dependence.

Given these issues, several papers on home price convergence in recent years have thus adopted a technique created by Pesaran (2007). Pesaran was interested in the topic of income convergence across countries. The method is called the pairwise approach. It measures convergence in terms of the portion of a group of regional incomes (or house prices) that exhibit a stationary relationship with one and other. Holmes, Otero and Panagiotidis (2011) first applied this method to different MSA home prices in the US. Later, Abbott and Devita (2012) and Holmes, Otero and Panagiotidis (2018) examined house price convergence in different parts of London with the pairwise approach. Other studies by Abbott and DeVita (2013) and Kyriazakou and Panagiotidis (2018) applied the method to house prices in different UK regions, and Holmes, Otero and Panagiotidis (2017) employed it in investigating house prices in different parts of Paris. As an example of results, and the fraction of rejections which lead to a conclusion that a given series were convergent, Abbott and DeVita (2012) found only 27.27 % of different London neighborhoods stationary and co-trending, and concluded this fraction was too low to conclude convergence occurred across the city. Holmes, et al. (2017) in contrast used a slightly different methodology and found 70 % of different London neighborhoods stationary and co-trending and did infer, with this high fraction of convergent districts that the city's housing market was convergent. We apply the pairwise method here to the different housing markets of the United States.

Data and Methodology

Pesaran's (2007) pairwise method has been utilized for studies on both output and house price convergence as it overcomes problems with previous methods such as panel unit root tests. Pesaran

defines convergence between two regions as follows: if the difference between two regional house price indices (or some other variable) is stationary, *and* the difference exhibits no significant linear trend, the two regions are convergent. This means the two regions must not merely be cointegrated, but exhibit a cointegrating vector of (1, -1); the additional lack of a linear trend means the two regions are, in Pesaran's terminology, co-trending.

The pairwise method is in some ways similar to Clark and Coggins' (2009) approach to convergence in which they tested the differentials of different regional home price indices for stationarity. There are some differences, however. First, while both Pesaran and Clark and Coggin indicate that a significant linear trend is inconsistent with convergence, Clark and Coggin simply do not include a trend in their ADF specification to test for significance. Pesaran, in contrast, explicitly includes a linear time trend in the test specification of the differential to see if the trend is significant. A significant trend, even if the null of a unit root is rejected, indicates the two regions are not co-trending and hence not convergent.

In some applications where the Pesaran method is employed, a constant is also included in the ADF test regression, and if the null of a unit root is rejected, and there is no linear trend, the difference tested is simply termed convergent-being stationary around a constant mean. In contrast, Clark and Coggin (2009) cite Carvalho and Harvey (2005) and distinguish between relative convergence, which means for two series, their difference is stationary around a constant mean, and absolute convergence, in which the differential is stationary and the constant is not significantly different from zero. Although the distinction between absolute and relative convergence is not usually made with the Pesaran method, in this study we will note which regions appear absolutely or relatively convergent.

In determining how convergent a group of N regions is the Pesaran method entails testing all N(N-1)/2 possible pairs (differences) for stationarity as well as co-trending. Pesaran posits the null hypothesis as no convergence. If this null hypothesis is true, the portion of pairs for which we can reject stationarity should be α, or the size of the test. As an example, in his 2007 paper Pesaran concludes that

income is not convergent across different countries, since the fraction of income differences between countries found stationary and co-trending was always, regardless of which measures were employed, at most just slightly above the nominal test size.

Note that there is no "official" fraction of rejections which leads to a conclusion that there is convergence among a group of N regions. Again, Pesaran found just slightly more than five percent of countries stationary and co-trending, but did not infer convergence. And, as noted, Abbott and DeVita (2012) found 27.27 percent of London districts stationary and co-trending, but, despite this fraction being higher than five percent, the authors concluded the London housing market was not convergent. Holmes, et al. (2011) used slightly different methods and found 70 percent of London district pairs were stationary and co-trending, and did infer convergence.

Our data is quarterly, and obtained from the Federal Housing Finance Administration (FHFA) database. It is divided into the same nine regions (East North Central, East South Central, Middle Atlantic, Mountain, New England, Pacific, South Atlantic, West North Central and West South Central) analyzed in Pollakowski and Ray (1997), Clark and Coggin (2009) and Kuketayev (2013). Table 1 shows all the states in each region. Figure 1 displays a map of the regions. Like Clark and Coggin we adjust the data for inflation by dividing each index by the CPI Less Shelter index. The data runs from 1975:1 to 2018:3. The real house price indices for all nine regions are displayed in Figures two through ten. Table 2 ranks each region by the growth rates in real house prices over the sample. As displayed, the Pacific, New England and Mountain regions have exhibited the largest increases in housing costs.

Given that there are nine regions, we have (9*8)/2 or thirty-six possible pairs. We will follow the standard procedure by estimating the difference of two regions as an autoregressive process, with the number of lags chosen by the SIC criterion. A constant and trend will be included in the initial specification. If the trend is significant, the two regions are not co-trending and so are not convergent.

We then check to see if the constant is significant. If it is, we run an ADF test with a constant. If the constant is not significant, we perform an ADF test with no constant. If there is no linear trend, but there is a significant intercept, and the null of a unit root can be rejected, the two regions are relatively convergent. Of course, if there is neither a significant trend nor constant, and we reject a unit root, the two regions are absolutely convergent. Table 3 displays an algorithm for determining convergence between regions.

Given the notoriously low power of the ADF test, especially if a trend or constant are included in the regression, we will follow other researchers who have studied house price convergence with the pairwise method such as Abbott and DeVita (2013) and Holmes, et al. (2011) and employ the ERS test (Elliott, Rothenberg and Stock, 1996). If there is a constant (or trend) in the model, the ERS method de-trends the data before applying the test. In addition, we will utilize the Ng-Perron test (Ng and Perron, 2001), which, like the ERS first de-trends the data in the presence of a constant or trend. The Ng-Perron method also chooses the number of lags in the ADF regression based on what the authors term the Modified AIC criterion, which can lead to a more accurate number of lags compared to standard methods such as AIC or SBC. The Ng-Perron test can lead to both better power and size properties compared to other unit root tests (note that we will, for purposes of pure inquiry, add a constant to those pairs that did not actually display a significant intercept and test for stationarity with the ERS and Ng-Perron methods, as it is standard practice in pairwise studies to include a constant in all tests).

Finally, the differential between regions can change over time. Clark and Coggin (2009) acknowledged this issue by employing, in addition to the ADF test, which imposes constant parameters, the Zivot-Andrews test. A stationary autoregressive process, which is subject to a structural change at some point over the observed sample may resemble a unit root process, and standard unit root tests will have low power in the presence of a break. The Zivot-Andrews test was developed to help address this issue by positing the null hypothesis of a unit root, and the alternative as a stationary process subject to an endogenous break. This test can have greater power compared to tests that do not allow for parameter

change. On the other hand, tests that allow for breaks also entail more parameters to estimate, which can lower power, and lead to fewer, rather than more rejections of the unit root null hypothesis than standard tests like the ADF. Clark and Coggin, for instance, experienced fewer rejections with the Zivot-Andrews test compared with the ADF.

One problem with the Zivot-Andrews test is that it does not allow for a break under the null hypothesis of a unit root. But of course it is possible that a nonstationary process could experience a break. This lack of a possible break under the null could lead to incorrectly accepting *or* rejecting the null hypothesis of a unit root, and also lead to a failure to detect structural change.

We accordingly use the Lee-Strazicich test, which allows for structural change both under the null hypothesis of a unit root and under the alternative of stationarity. Using this test will give us another set of results with which to discern convergence, or the lack thereof, between US housing markets. We also employ the test to discern breaks in the relationships between regional markets. That is, was there a point in time when markets started moving closer together, or further apart? Were these breaks associated with greater financialization, commodification or globalization? The breaks uncovered by the Lee-Strazicich method can help us in addressing this question.

Results

Table 4 displays results for the ADF test. As displayed, only a minority-thirteen of thirty-six, or 36.11 percent of the regional pairs did *not* have significant linear trends. Of these thirteen pairs, just four, or 11.11 percent of the thirty-six, were also stationary. By the standards of previous studies using the pairwise approach, the small fraction of stationary, co-trending pairs indicates that the US housing market is not convergent.

Two of the regional pairs-East North Central/East South Central, and Mountain/South Atlantic, exhibit absolute convergence, having no significant constant. Two others-Mountain/New England and New England/Pacific, display relative convergence.

Given the low power of the ADF test, especially in the presence of a constant or trend, we next test the regional differentials for stationarity with the ERS method, with results in Table 5. It has been established that only 36.11 % of the pairs lack a significant trend. However, with the ERS, we can reject a unit root for five of these non-trending pairs, as opposed to only four with the ADF. This fraction of apparently convergent pairs is still low by the standards of previous pairwise studies. Four of the five regional pairs which display convergence (East North Central/East South Central, East North Central/West South Central, East South Central/West South Central, and Middle Atlantic/Mountain), did not have significant constants in their initial specification for the ADF test, but appear convergent by the ERS test when a constant is employed. Note that it is standard practice in other studies which have employed the pairwise approach to include a constant in all tests. The New England/Pacific differential is convergent by the ERS test, just as it is with the ADF.

There were two regional pairs (Mountain/New England and Mountain/South Atlantic) for which there was no significant constant and for which the null of a unit root was rejected with the ADF, but the null of a unit root was not rejected with the ERS test, where a constant was by necessity added to the specification. The failure to reject with the ERS may reflect the loss of power that occurs when a constant that is not significant is added to the specification (see Carvalho and Harvey, 2005). If these two differentials are included among the convergent pairs, seven of the thirty-six, or 19.44 %, of the regional differentials may be considered convergent. This is still too low by the standards of previous studies to conclude that US home markets are convergent overall.

Table 6 displays results from the Ng-Perron test. The number of rejections is slightly higher-six compared to five, relative to what was obtained with the ERS test (and of course also higher than the results with the ADF). The six pairs are East North Central/West North Central, East North Central/West South Central, East South Central/West South Central, Middle Atlantic/Mountain, Mountain/South Atlantic and New England/Pacific. Note that of these six pairs, all but New England/Pacific and East North Central/West North Central did not have significant constants in their ADF specifications.

In two cases (East North Central/East South Central and Mountain/New England) in which rejection was not obtained with the Ng-Perron test the intercept was not significant and rejection was obtained with the ADF test. This again may reflect the fact that adding a constant that is not significant can lower test power. If these two pairs are counted as convergent, 22.22 percent of the differentials seem to converge, which is still too low by previous standards to lead to the conclusion that the national US housing market is convergent overall.

We also note that, as discussed, the Ng-Perron procedure employs a different lag length criterion compared to other methods. For the ADF, we use SIC to choose lags, as it has been shown to be superior to the older AIC metric. However, the Ng-Perron method utilizes the *Modified* AIC (MAIC) criterion. We display the lags chosen for each test in Table 7. As displayed, in six cases, lags chosen by the SIC for the ADF exceeded those chosen by the MAIC for the Ng-Perron test. In twenty-four cases, there were more lags for the Ng-Perron than for the ADF, while in the six remaining cases the lag lengths for each test were identical.

Given that changes have occurred in the housing market over the years, and the possibly greater power with tests that allow for breaks, we test all regional pairs for unit roots with the Lee-Strazicich method. If the differential had a significant trend (which would of course preclude convergence), we allow for a break in both the intercept and trend, to see if there are breaks corresponding to important financial events. If the differential has no significant trend, we test for a break in the intercept. Initial results are displayed in Table 8.

As shown, allowing for breaks, and hence more parameters, leads to fewer rejections of the unit root hypothesis than was the case with any of the other tests which impose parameter stability, including the ADF. This result is similar to that of Clark and Coggin (2009) who found fewer rejections of the null when using the Zivot-Andrews test, which allowed for a break, compared to the ADF.

Only the Mountain/New England and New England/Pacific pairs exhibited stationarity and co-trending with the Lee-Strazicich test. This is a recurring pattern; the New England/Pacific differential is convergent by all four unit root tests, and the Mountain/New England pair is stationary by the Lee-Strazicich and the ADF. So it appears that three regions (Mountain, New England and Pacific) seem most likely of all US regions to be convergent with each other, with little evidence of their convergence with other housing markets in the US. These three regions, which include the expensive west coast, part of the expensive east coast and booming mountain markets in Arizona, Colorado and Nevada, are also, as displayed in Table 2, the three regions exhibiting the fastest house price growth since 1975. These results thus indicate convergence among the most expensive US housing markets, but a lack of convergence nationally. The fraction of convergent pairs with any of the four tests is well below that of any study which has concluded convergence existed across a wide housing market. This lack of convergence is evident from Table 2, which shows the tremendous variation in house price growth in the last forty years. Regions such as the Pacific, New England, and, depending on the test, Mountain exhibit some level of convergence as their house price growth has soared above that of other regions.

The breaks determined by the Lee-Strazicich test are displayed in Table 9. One notable result is that all breaks are either in the 1980s (most in the early and middle part of that decade) or in the years 2007-2010. These latter years of course spanned the global financial crisis, the epicenter of which was the US housing market. There were six regional pairs with positive breaks in those crisis years, while there were eight with negative breaks (the New England/West South Central pair had both a positive break in the intercept and a negative break in the trend). New England also had a positive break with East South Central at this time, while the Pacific region pulled away from the Mountain and West North Central regions.

Among the negative breaks over the crisis years, the Pacific region seemed to grow closer to the East North Central, East South Central and West South Central markets over the episode. New England also grew closer to West South Central. Of course none of these relationships ended up being convergent

in the long run, but in times of crisis asset prices can move closer together (see Miles, 2015 for a discussion of co-movement of US house prices across regions during the late 2000s financial turmoil).

There were eight positive and eight negative breaks in the 1980s. One pair, East South Central and Mountain, had a positive break in the trend but a negative break in the intercept at 1984:2. While there is a somewhat mixed pattern, five of the remaining seven positive breaks (East North Central/Middle Atlantic, East North Central/Mountain, Middle Atlantic/Pacific, Middle Atlantic/West North Central, and Mountain/South Atlantic) indicate a divergence between the four fastest growing regions and the slower growing markets. In contrast, three of the seven negative breaks (between Middle Atlantic/Mountain, Middle Atlantic/New England and New England/Pacific) are between the four markets with the fastest price growth. The early 1980s may thus be a period in in which there was a clear movement away from house price convergence across the regions of the US.

This is consistent with other findings. Ganong and Shoag (2017) show that in the US, per-capita incomes exhibited clear convergence for about a century, from 1880-1980, but that starting in 1980, this convergence dramatically slowed, and, since the last recession ended completely. It is not clear if the lack of income convergence implies a lack of house price convergence, however, as the causality could actually be in the opposite direction. The authors note that migration of workers from low income to high income areas, which would drive income convergence, has slowed. They point to higher housing costs as a reason. For workers in many relatively low income and low housing cost regions, moving to a wealthy area with better job opportunities actually yields a lower real wage, once the wage is adjusted for housing costs.

The 1980s were also a time of changes in US housing, particularly it's financing. Before 1980, funds for mortgages came mostly from deposit banks. These banks were constrained in the interest they could pay on deposits by Regulation Q, which meant that if the economy were strong and growing, and interest rates were rising, these banks would see a drop in available deposits as savers sought outlets paying higher interest, and thus funds for mortgages would be limited. Abolishing Regulation Q in 1980 and allowing for interest on deposits freed up more funds for mortgages. In addition, the 1980s were a

time when the securitization of mortgages began to allow non-depository institutions to originate housing loans. Pozdena (1990) describes the process thusly: "In addition, the technology of the mortgage marketplace was changing in the early 1980s. As a result of the continued development of the secondary mortgage market, in particular the newly-originated mortgages no longer needed to be funded within the bank or thrift portfolio. Instead, mortgages could be used to create mortgage-backed securities which could then be sold to a variety of institutional and private investors. This process, known as securitization, was facilitated by government-backed mortgage agencies which provided credit enhancement in the form of principal and interest guarantees to investors in the securities. Development of the secondary mortgage market was particularly rapid in the early 1980s. The volume of contracted mortgage commitments of the Federal Home Loan Mortgage Corporation (FHLMC), for example, grew from about $7 billion in 1981 to almost $33 billion in 1983." (p. 7). See also Gauger and Snyder (2003) for a discussion of these changes.

Moreover, financialization of housing, beyond simply securitization, proceeded apace starting in the 1980s. REITs started to play a major role in housing finance, thanks to legislation passed in 1986. Global capital flows have provided a new source of funds to increase demand for housing. In some "global cities", housing is seen by investors as a separate asset class compared to homes in less wealthy regions, leading to greater emphasis on the exchange (asset) value of housing compared to its use value as shelter.

The early 1980s also marked the beginning of a secular decline in interest rates, which makes homes more affordable for buyers. Mulheirn (2016) cites lower interest rates as a cause of increasing home values in Britain, another country with has experienced both strongly rising overall home prices in recent decades as well as sharp divergence in living costs in different regions. These lower interest rates, in addition to helping buyers purchase homes and drive up prices, also serve as an incentive to investors globally to purchase housing-related securities which further drive up housing costs (see Miles, 2019 on the role of foreign capital in driving home prices in the US and other countries). If housing markets

across the country differ in their responsiveness to higher demand i.e. some regions have lower elasticity of housing supply than others-then it could be expected that this additional credit could spur divergence, rather than convergence of home values across regions.

Conclusion

Results here indicate that by the standards of previous pairwise studies of housing, where in some cases around seventy percent of pairs exhibited stationarity and co-trending, there is no evidence the US housing market is convergent across regions. These results are not what was found for some pairwise studies of convergence across different neighborhoods in a given city (Abbott and DeVita, 2012, Holmes, et al. 2017). They are, however, consistent with a prior study on the UK (Abbott and DeVita, 2013). Given the greater variation in incomes, economic growth and other structural factors, it may not be reasonable to expect convergence across the different housing markets of an entire nation.

There does appear to be convergence between the high-priced markets of the northern east coast (New England) and the west coast (Pacific) regions. There is also some evidence for convergence between the New England and Mountain regions. Otherwise, the vast majority of regions do not exhibit convergence.

Our structural break analysis suggests that some of this convergence between pricey markets and divergence with other regions accelerated in the early and middle 1980s. This was a point in time identified by Ganong and Shoag (2017) as being the end of a century-long movement of convergence in incomes across the US. It was also a time of rapid change in how housing in the US was financed. This change has allowed funds from a much wider array of sources-including from abroad-to be available for housing than was the case in years past, when deposit banks were the main source of mortgages.

The financialization of housing is part of a larger context of financialization for the United States and other economies. This increase in credit for cars, education and everyday expenses has lead to an all-

time high for household debt in the US in the second quarter of 2019 (Wall Street Journal, 2019, p. 1). This is worrying for the future; Mian, Sufi and Verner (2017) show that increases in household debt predict a decline in output several years in the future. And of course greater financialization means an increase in financial fragility.

The lack of convergence would imply that to the extent that housing policies are desirable, they are best tailored to the local, and very divergent conditions across the US. It also suggests some difficulty for the Federal Reserve, as trying to conduct monetary policy when conditions are very different across the country risks helping some regions while hurting others. For example, loose policy is good for stagnant regions but risky for faster-growing markets. Moreover, the analysis here does not merely indicate housing markets move away from each other temporarily - significant linear trends have been found for a number of regional pairs, suggesting these differences are likely to actually grow through time, making the US housing market all the more segmented and divergent.

The methods employed here have been helpful in examining output and house price co-movement. These techniques could in principle also be applied to other regional economic variables. For instance, do differences across regions in unemployment or labor force participation tend to dissipate over time, or are they highly persistent? Similarly, do wage levels show a propensity towards convergence across geographic areas? These are of course topics for future research.

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Table 1

States in Each Region

East North Central	Indiana, Illinois, Michigan, Ohio, Wisconsin
East South Central	Alabama, Kentucky, Mississippi, Tennessee
Middle Atlantic	New York, New Jersey, Pennsylvania
Mountain	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Pacific	Alaska, California, Hawaii, Oregon, Washington
South Atlantic	Delaware, DC, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia

West North Central	Iowa, Kansas, Minnesota, Missouri, North Dakota, South Dakota
West South Central	Arkansas, Louisiana, Oklahoma, Texas

Table 2
Regions Ranked by Percentage Growth in Real Home Indices over 1975:1-2018:3

Region	**Percentage Growth**
Pacific	252.477
New England	135.204
Mountain	95.698
Middle Atlantic	80.727
South Atlantic	52.183
West North Central	35.092

West South Central	34.074
East North Central	22.255
East South Central	18.047

All regional indices are adjusted for inflation with the CPI Less Shelter Index.

Table 3

Decision Process for Determining Convergence between Two Regions

Step 1: Each difference between pairs of regions is modeled as an autoregressive process, with the number of lags chosen by the Schwarz (SIC) criterion and with a constant and linear trend included.
Step 2: The first step is to test the linear trend for significance. If significance is found, the pair are not convergent. If the trend is not significant, we proceed to step 3. A significant trend leads to a unit root test still being conducted with a linear trend included, but regardless of test outcome, the pair are not convergent.
Step 3: If the trend is not significant, the constant is tested for significance. If the constant is not significant, proceed to step 3. If the constant is significant, test for a unit root with a constant included. If we can reject the null of a unit root, we conclude the pair are relatively convergent. If we cannot reject the null of a unit root, we conclude the pair are not convergent.
Step 4: If the constant is not significant, we test for a unit root with no trend or constant. If we reject the null of a unit root, we conclude the pair is absolutely convergent. If we cannot reject, we conclude the pair are not convergent.

Table 4
ADF Results

Pairs with no Significant Linear Trend	Of Which Stationary	Pairs Displaying Absolute Convergence	Pairs Displaying Relative Convergence
13/36	4	2	2
(36.11%)	(11.11%)	(5.55 %)	(5.55%)

Pairs that displayed absolute convergence: East North Central/East South Central, Mountain/South Atlantic.

Pairs that displayed relative convergence: Mountain/New England, New England/Pacific.

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

Table 5
ERS Results

Pairs with no Significant Linear Trend	Of Which Stationary (Relative Convergence)
13/36	5
(36.11%)	(13.88%)

Note that for pairs that did not display a significant constant or trend, the ERS is test is in principle not applicable. For purposes of pure inquiry, a constant was added for those pair differentials that did not also have a significant linear trend, as it is standard practice in other studies which have employed the pairwise approach to employ a constant in all tests.

Pairs that displayed relative convergence: East North Central/East South Central, East North Central/ West South Central, East South Central/West South Central, Middle Atlantic/Mountain and New England/Pacific. We note that all of the above differentials except New England/Pacific did not have a significant constant in the ADF specification.

In two cases, Mountain/New England, and Mountain/South Atlantic, rejection was obtained with the ADF test, when no constant was included in the specification, as the constant was not significant in either case. The failure to reject with the ERS test may reflect the decrease in power that occurs when a constant is added to the specification that is not significant (See Carvalho and Harvey, 2005). If these two differentials are included among the convergent pairs, seven of thirty-six, or 19.44% of the regions may be considered convergent.

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

Table 6
Ng-Perron Results

Pairs with no Significant Linear Trend	Of Which Stationary (Relative Convergence)
13/36	6
(36.11%)	(16.67%)

Note that for pairs that did not display a significant constant or trend, the Ng-Perron is test is in principle not applicable. For purposes of pure inquiry, a constant was added for those pair differentials that did not also have a significant linear trend, as it is standard practice in other studies which have employed the pairwise approach to employ a constant in all tests.

Pairs that displayed relative convergence: East North Central/West North Central, East North Central/ West South Central, East South Central/West South Central, Middle Atlantic/Mountain, Mountain/South Atlantic and New England/Pacific. We note that all of the above differentials except New England/Pacific and East North Central/West North Central did not have a significant constant in the ADF specification.

In two cases, East North Central/East South Central and Mountain/New England, rejection was obtained with the ADF test, when no constant was included in the specification, as the constant was not significant in either case. The failure to reject with the Ng-Perron test may reflect the decrease in power that occurs when a constant is added to the specification that is not significant (See Carvalho and Harvey, 2005). If these two differentials are included among the convergent pairs, eight of thirty-six, or 22.22% of the regions may be considered convergent.

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

Table 7
Lag Lengths used in the ADF and Ng-Perron tests

Region Pair	ADF Lags	Ng-Perron Lags		Region Pair	ADF Lags	Ng-Perron Lags
ENC/ESC	5	10		MA/SA	3	13
ENC/MA	3	3		MA/WNC	4	4
ENC/MT	3	8		MA/WSC	4	3
ENC/NE	4	1		MT/NE	4	11
ENC/PAC	3	6		MT/PAC	3	6
ENC/SA	3	12		MT/SA	4	4
ENC/WNC	2	9		MT/WNC	4	11
ENC/WSC	4	4		MT/WSC	4	13
ESC/MA	4	4		NE/PAC	2	1
ESC/MT	6	10		NE/SA	4	11
ESC/NE	5	10		NE/WNC	4	11
ESC/PAC	3	6		NE/WSC	4	13
ESC/SA	4	3		PAC/SA	3	6
ESC/WNC	1	13		PAC/WNC	3	9
ESC/WSC	4	13		PAC/WSC	3	7
MA/MT	4	4		SA/WNC	13	10
MA/NE	4	12		SA/WSC	4	8
MA/PAC	3	1		WNC/WSC	4	9

This shows the lag lengths that were employed for the ADF test (the number of lags in this case was chosen by the SIC criterion), and the Ng-Perron test (for which the modified AIC criterion is employed).

Table 8
Lee-Strazicich Results

Pairs with no Significant Linear Trend	Of Which Stationary (Relative Convergence)
13/36	2
(36.11%)	(5.55%)

Only for Mountain/New England and New England/Pacific was there convergence.

Table 9
Lee-Strazicich Breaks

Region Pair	Break	Sign		Region Pair	Break	Sign
ENC/ESC	1983:1	Positive		MA/SA	None	
ENC/MA	1982:4	Positive		MA/WNC	1983:2	Positive
ENC/MT	1988:1	Positive		MA/WSC	2007:4	Negative
ENC/NE	None			MT/NE	None	
ENC/PAC	2008:3	Negative		MT/PAC	2008:1	Positive
ENC/SA	2008:4	Negative		MT/SA	1982:3	Positive
ENC/WNC	None			MT/WNC	1986:1	Negative
ENC/WSC	1985:4	Negative		MT/WSC	2008:4	Positive
ESC/MA	1983:1	Negative		NE/PAC	1982:2	Negative
ESC/MT	1984:2	Both		NE/SA	None	
ESC/NE	2010:4	Positive		NE/WNC	None	
ESC/PAC	2008:4	Negative		NE/WSC	2008:4	Both
ESC/SA	2008:4	Negative		PAC/SA	None	
ESC/WNC	1981:4	Positive		PAC/WNC	2008:4	Positive
ESC/WSC	None			PAC/WSC	2008:1	Negative
MA/MT	1983:4	Negative		SA/WNC	2008:4	Positive
MA/NE	1981:1	Negative		SA/WSC	2007:4	Negative
MA/PAC	1983:1	Positive		WNC/WSC	1985:4	Negative

This shows all of the dates for which there was a significant break in the trend or intercept. For the ESC/MT differential, the intercept break was negative while the trend break was positive, while for the NE/WSC differential the opposite was the case.

Figure 1
Map of US Census Divisions

See table 1 for a list of each state in each region.

Source: US Bureau of the Census.

Figure 2

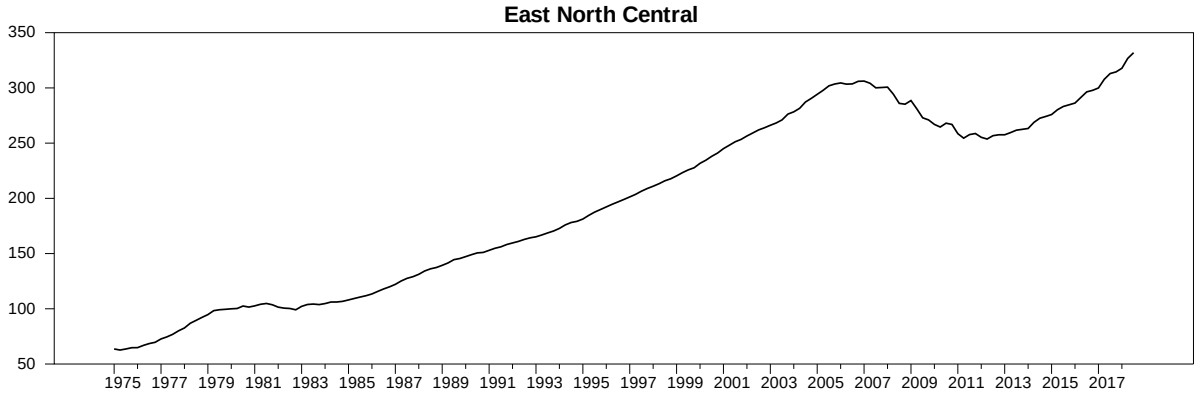


Figure 3

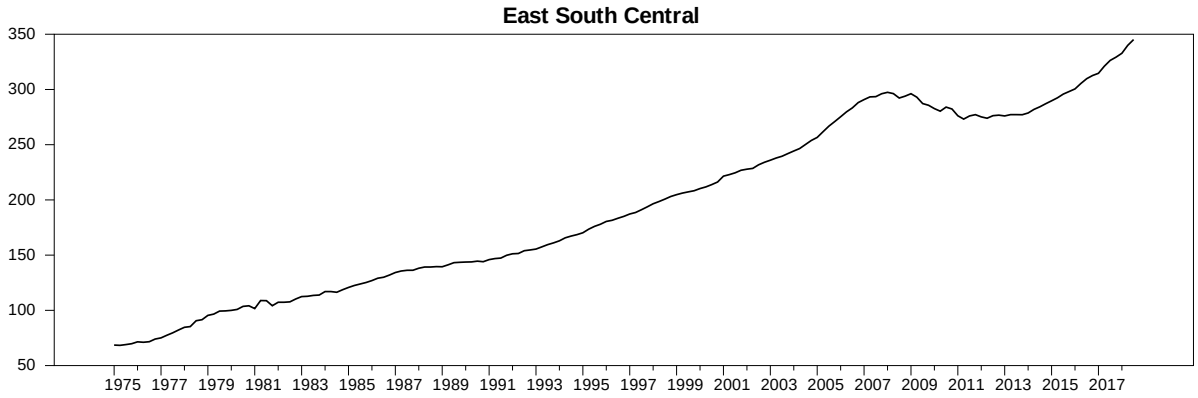


Figure 4

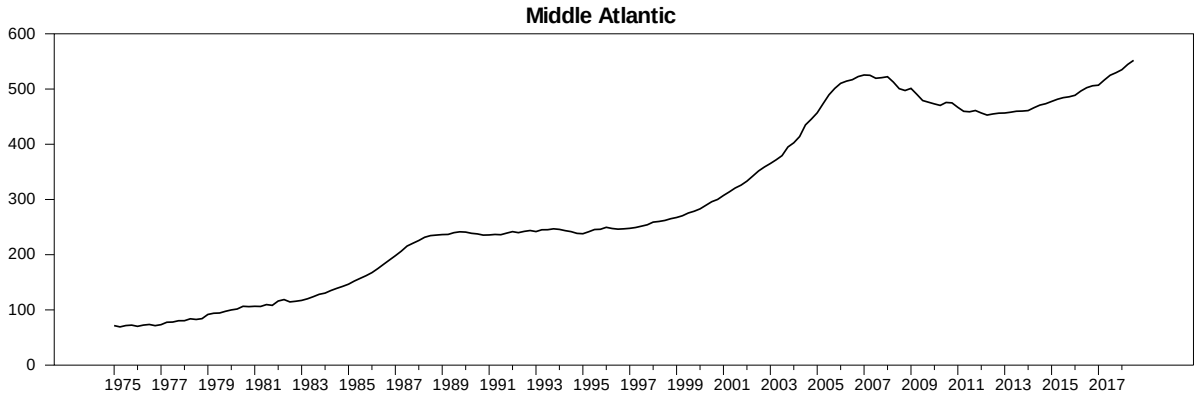
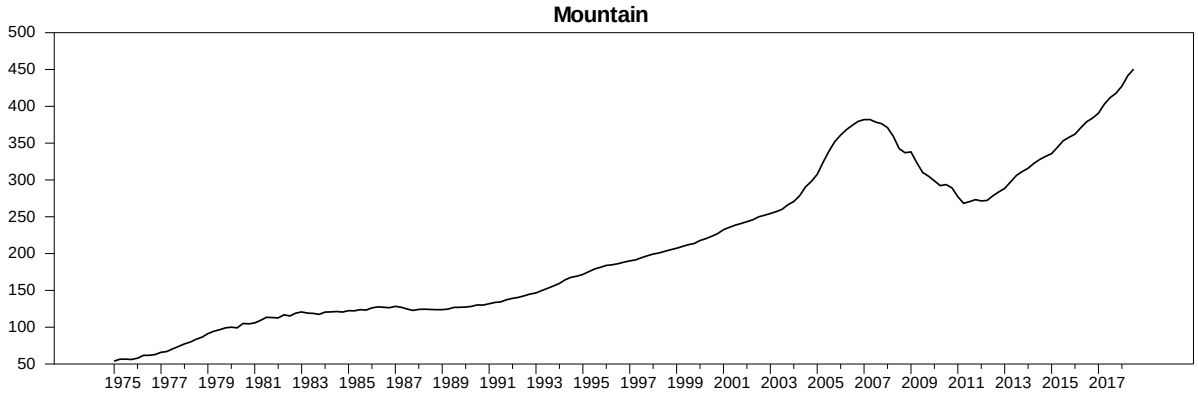


Figure 5



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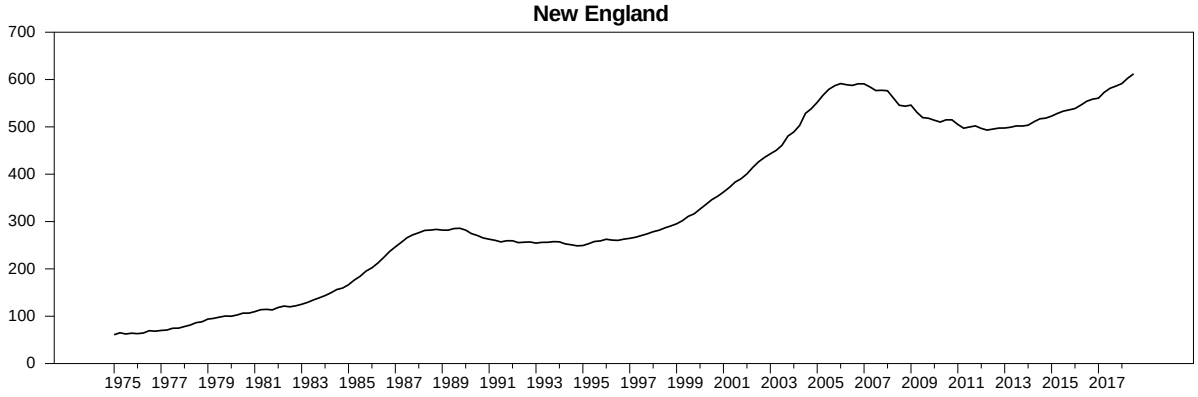

Figure 7

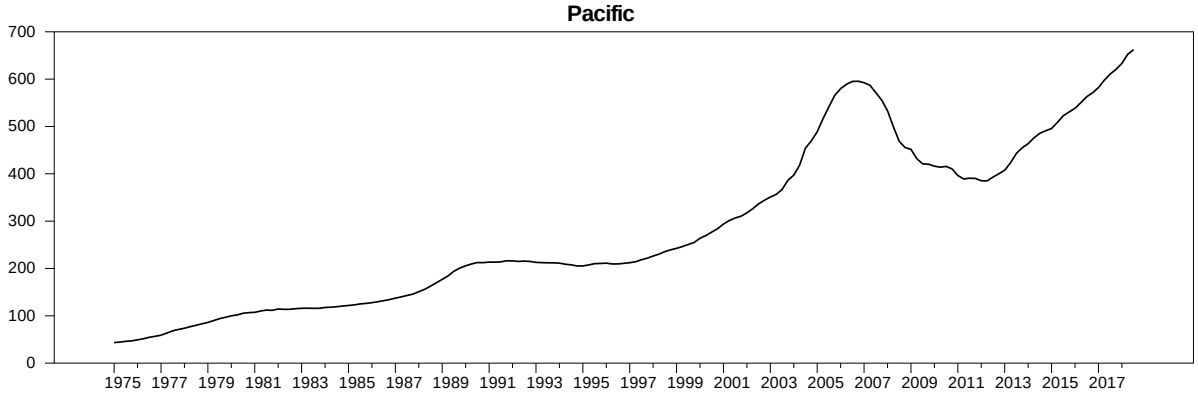

Figure 8

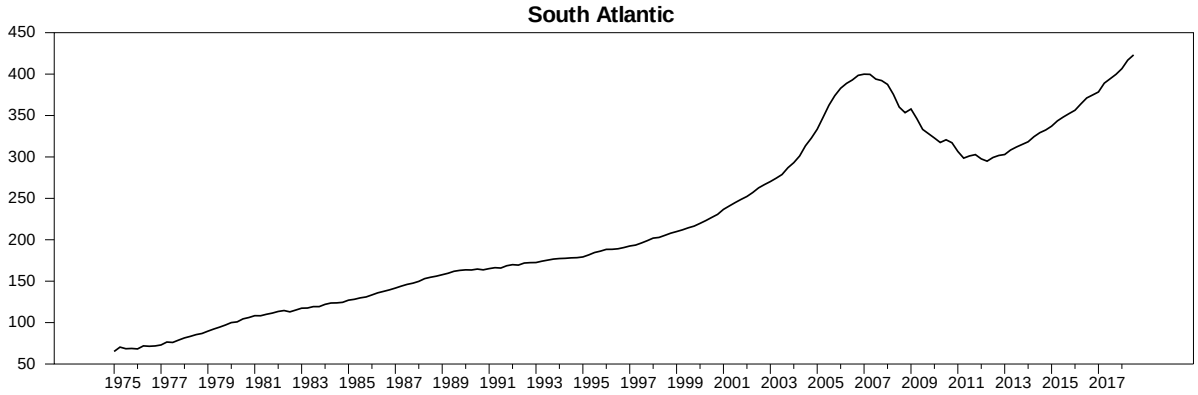

Figure 9

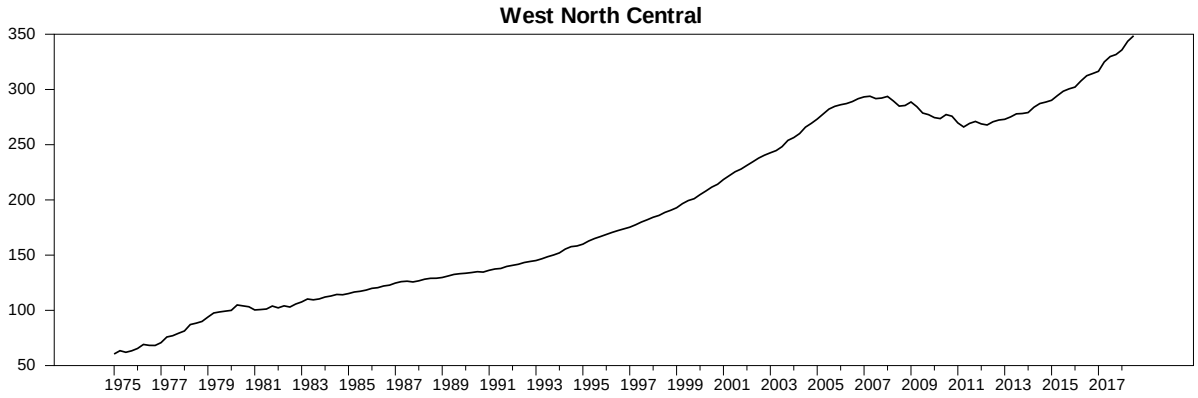
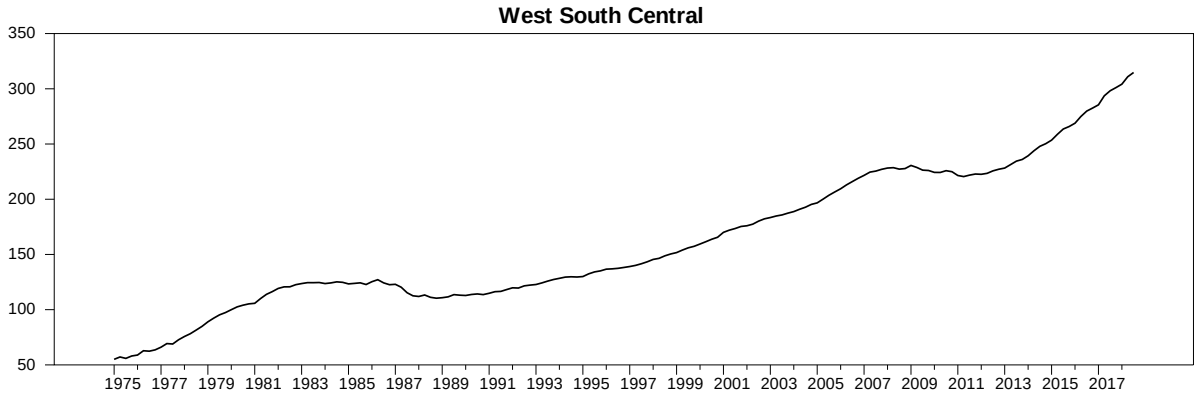
Figure 10