A preliminary investigation of northern Ireland’s housing market dynamics

Derek Bond and Emer Gallagher and Elaine Ramsey

Ulster Business School, University of Ulster

3. July 2012

Online at https://mpra.ub.uni-muenchen.de/39806/
A Preliminary Investigation of Northern Ireland’s Housing Market Dynamics*

Derek Bond, Emer Gallagher and Elaine Ramsey
University of Ulster at Coleraine
July 3, 2012

Abstract

In this paper recent developments in dynamic econometric methodology are used to explore the possibility of asset bubbles in the Northern Ireland housing market. This market is interesting as its house price trajectory is quite unlike any neighbouring market. In recent years it seems to have been influenced both by the general UK market and the Republic of Ireland’s housing market. The dynamics of the market are explored through univariate analysis, using sequential unit root tests and fractional integration. The findings provide an indication of the principle developments in the market and could provide the basis for further causal analysis.

JEL Classification: G2, C2, C5, E3

1 Introduction

The Northern Ireland housing market can be seen as unique in its behaviour. For most of the latter part of the last century house prices in Northern Ireland moved independently of both the other regions of the United Kingdom (UK) and the Republic of Ireland (RoI). In recent years it experienced volatile movements in house prices, with both rapid increases and decreases over a short period compared to other housing markets. This paper, using recent

*We are grateful for S. McGreal making his datasets available for this study and Zhongjun Qu for allowing us to use his program
developments in the econometric analysis of time series, attempts to investigate these dynamics. This is done by placing the analysis in the context of asset bubbles.

Asset bubbles have been a topic of significant interest to both academics and policy makers for decades as a result of their reoccurring nature (Reinhart and Rogoff 2009, Kindleberger 1989). These episodes are often initiated by significant and persistent movements in asset prices and affect both developed and emerging economies (Ahamed 2009, Ferguson 2008) by impeding the efficient functioning of the financial sector and moreover the economy as a whole (Iacoviello 2005, Iacoviello and Neri 2010, Vargas-Silva 2008).

The aim of this paper is, through univariate analysis, to explore the dynamics of the Northern Ireland housing market and attempt to identify the structure of the house price trajectory from the early 1990s. In the next section the trajectory of house price movements is outlined and the theoretical and empirical literature on asset market bubbles discussed. The paper focuses primarily on the rational bubble literature. The methodology is described in section 3. Section 4 discusses the results and finally in section 5 conclusions are drawn.

2 Background

The historical development of house prices in Northern Ireland is quite different from the rest of the UK (McCord, McIlhatton, and McGreal 2011). During the late 1980s other regions of the UK experienced a sharp rise in house prices whereas in Northern Ireland house prices barely kept pace with the rate of inflation. It was in the late 1990s, after a long period of nearly static house prices, that Northern Ireland house prices began to rise in real terms like the rest of the UK. (Hicks and Baxter 2006). At the same time the Republic of Ireland was experiencing sharp rises in house prices (Gibb, Livingston, Williams, Berry, Brown, and McGreal 2007). During the earlier years of this century the annual increase in house prices accelerated in Northern Ireland. This increase gathered pace until, by 2007, Northern Ireland was experiencing a faster growth in house prices than any other part of the UK.
Northern Ireland house prices reached a peak in the third quarter of 2007 and since then have been declining more steeply than the rest of the UK and the Republic of Ireland. Figure 1 displays this movement in Northern Ireland house prices in real terms.

Many explanations have been given as to why these movements happen. At a macro level, liberal monetary policy coupled with the deregulation of the mortgage market is argued to have played a crucial role (Muellbauer and Murphy 1997, Baddeley 2005). The apparent cyclical relationship between mortgage lending and house price growth meant that the resulting gradual relaxation of credit standards increased demand for housing (see Hott 2011, for details). Evans (2004) and Gibb, Livingston, Williams, Berry, Brown, and McGreal (2007) discuss the role played by the planning system in constraining supply and thereby further increasing house prices. At a more local level, Government policy advocating homeownership as a means to address the social and economic disparity that existed within the region has also been suggested as a key contributor to the house price growth in Northern Ireland (McCord, McGreal, Berry, Haran, and Davis 2011). There is also anecdotal evidence that external investment coming from the Republic of Ireland, following the saturation of their market, prolonged the increase in house prices (Adair, Berry, Haran, Lloyd, and McGreal 2009). Gibb, Livingston, Williams, Berry, Brown, and McGreal (2007) argued at the height of the price rises that the almost continuous increase in house prices was seen as providing the opportunity for many to realise capital gain or secure a constant income from the rental market. They argued that this was creating a market characterised by speculative investment.

Most of the discussion has therefore been based on the argument that Northern Ireland may have experienced a house price bubble. However, it is still unclear when such a bubble, if it existed, started and how long it persisted. Graphs such as figure 1 are open to many interpretations. By considering what is meant by an asset bubble and how it might be measured, this paper attempts both to place the discussion of the Northern Ireland housing market in a more formal framework and provide insights into its development.
Asset bubbles

As O’Hara (2008, p.11) notes ‘bubbles are both a topic of great importance and great controversy’. As yet there is no generally accepted definition of what an asset bubble is or how to identify and measure it. The lack of consensus over how best to define a bubble appears to emerge from different paradigms being adopted. For example, Kindleberger (1996) suggests that a bubble indicates an upward price movement over a prolonged period that subsequently explodes. Similarly, Brunnermeier (2007) suggests that a bubble describes a situation of dramatic price increases followed by a period of subsequent decline. In contrast, Garber (2000, p.7) contends that a bubble is merely ‘a fuzzy word filled with import but lacking any solid operational definition’.

Gutierrez (2011) suggests that there are two divergent viewpoints within the literature on asset market bubbles. One view is that prices always reflect the market value of the asset and therefore bubbles do not exist. Proponents of this view (Garber 1990, Tirole 1982, Tirole 1985) argue that asset prices are always equal to the present discounted value of its future income. The other viewpoint that asset bubbles do exist can be divided into a number of different theoretical standpoints. Gutierrez (2011) highlights the following views: rational bubble behaviour (Shiller 1981), irrational bubbles (Vissing-Jorgensen 2004), intrinsic bubbles (Froot and Obstfeld 1991), fads (Shiller 1984) and informational bubbles (Grossman and Stiglitz 1980).

Considerable work has been undertaken to try and identify whether bubbles exist or not (Yin and Jin 2012). Most of this work has used the rational bubble literature as a starting point given that it is fairly easy to quantify. A rational bubble emerges when investors willingly pay more than the fundamental value to purchase an asset. They believe the price will continue to increase and thus the asset will significantly exceed its fundamental value in the future (Lansing 2010). In other words, as Stiglitz (1990, p.13) defined it ‘If the reason that the price is high today is only because investors believe that the selling price is high tomorrow-when fundamental factors do not seem to justify such a price-then a bubble exists’.
The literature on the testing for asset bubbles reflects the developments in econometric analysis of time series (see Gurkaynak 2005, Flood and Hodrick 1990, for a review of traditional analysis). Using the rational asset bubble approach, early literature looked at the difference between the variance of the asset and the variance of the discounted future value of the asset. During a period of an asset bubble the difference between the two variables should be large. ‘Simple’ variance bounds test were used by Shiller (1981) and LeRoy (1981) and they found strong evidence of bubble behaviour in stock prices. Their analysis assumed that the series were stationary around a time trend (Marsh and Merton 1986) and had questionable small sample properties caused by not being able to correctly estimate the future value (Kleidon 1986). In West (1988) a variance bound test was introduced that addressed these issues. The work also found strong evidence of bubbles in stock market prices.

As the issue of stationarity became better understood, unit root and co-integration techniques were widely utilised (Campbell and Shiller 1987, Diba and Grossman 1988). In these tests the underlying assumption is that the price of the asset and its fundamental value are co-integrated and a bubble occurs when the co-integrated relationship breaks down. All these methods have been criticised due to their inherent limitations and their vulnerability to subjectivity ((Driffill and Sola 1998, Gurkaynak 2008, Evans 1991), which often led to ambiguous results. For example, Diba and Grossman (1988) and Taylor and Peel (1998) found that the S&P 500 stock market index did not contain a bubble, whilst others reported the existence of one (Froot and Obstfeld 1991).

More recent approaches to the identification of bubbles include techniques based on fractional integration (see, Cunado, Gil-Alana, and de Gracia 2005, Frammel and Kruse 2011, for details) and sequential unit roots (Phillips, Wu, and Yu 2011). In the first approach the return series is tested for non-stable fractional integration ($0.5 < d$). This is an implication of bubble behaviour in the levels series. In the second approach the levels series is tested for a mildly explosive root using a right-tailed unit root test. If it is assumed that the fundamental value series is stationary, the simple price
series may be used in both approaches, though this is open to debate (Yin and Jin 2012, Phillips, Wu, and Yu 2011). This paper applies the technique of sequential unit roots to the Northern Ireland house price data to identify the parameters of any bubble. It also investigates the usefulness of recent tests (Smith 2005, Qu 2011) against spurious fractional integration in identifying and understanding bubbles.

3 Methodology and Data

In this paper the concept of a financial bubble is operationalised using Phillips and Yu’s (2011) method of using forward recursive regressions coupled with sequential right sided unit root tests. This approach is based on the work of Phillips, Wu, and Yu (2011) and makes use of the fact that during a bubble the financial series (house prices) departs from the strict, efficient martingale behaviour of markets. If, as the Phillips and Yu (2011) test assumes, house prices deviate from standard unit root behaviour during the bubble by exhibiting mildly explosive behaviour; it follows that the returns series is likely to have long memory at least during the period of the bubble (Cunado, Gil-Alana, and de Gracia 2005). However, exploring long memory in a series during the time of a financial bubble is complicated by the possibility that non-linearities in the series can lead to spurious results. It is well known that the short memory process affected by regime changes or smoothly varying trends can exhibit what appears to be long memory behaviour. In an attempt to overcome these issues, this paper uses the recent tests of Smith (2005) and Qu (2011) to examine the possibility of long memory in house prices. In Frammel and Kruse (2011) the test proposed by Sibbertsen and Kruse (2009) is used to explore the possibility of a bubble using the assumption that the nature of the memory will be different before and after a bubble.

Firstly, the now standard I(0)/I(1) analysis is conducted using two unit root test: the Augmented Dickey Fuller (ADF) and the more powerful ADF-GLS test of Elliott, Rothenberg, and Stock (1996). These unit root tests are compared to the stationarity test of Kwiatkowski-Phillips-Schmidt-Shin
The bubble analysis of Phillips and Yu (2011) is then used to explore the likelihood of a bubble and its possible structure. The tests of Lobato and Velasco (2007), Smith (2005) and Qu (2011) are then used to further explore the possible long memory behaviour of the time series of house prices. As many of these methods are not yet standard procedures in time series analysis, each is explained in turn below.

The Phillips and Yu max\(DF^{t_r}_r\) and \(DF^{t_r}_r\) tests

In Phillips and Yu (2011) the issue of dating the timeline of financial bubbles is explored. They modify a technique proposed by Phillips, Wu, and Yu (2011) and provide a methodology for identifying bubble behaviour with consistent dating of their origination and collapse. Whilst the Phillips and Yu’s (2011) provides a methodology for testing for bubble migration, this paper uses only their tests for a single series.

The methodology is based on the analysis of the mildly explosive stochastic process developed in Phillips and Magadalinos (2007a) and Phillips and Magadalinos (2007b). The methodology is to recursively estimate:

\[ X_t = \mu + \delta X_{t-1} + \epsilon_t, \quad \epsilon_t \sim iid(0, \sigma^2). \]

To test for an explosive root the critical values of the standard Dickey Fuller test are obtained for the right-tailed alternative hypothesis \(H_1: \delta > 1\) rather than the normal left-tailed test \(H_1: \delta < 1\). The regression in the first recursion uses \(\tau_0 = \lfloor nr_0 \rfloor\) observations for some fraction \(r_0\) of the total sample, where \([..]\) denotes the integer part of the argument. Subsequent regression build on this original data using successive observations giving a sample of size \(\tau = \lfloor nr \rfloor\) for \(r_0 \leq r \leq 1\). The standard Dickey-Fuller \(t\) test can be written as:

\[ DF^{t_r}_r := \left( \frac{\sum_{j=1}^{\tau} \tilde{X}^2_{j-1}}{\hat{\sigma}^2} \right)^2 (\hat{\delta}_r - 1) \]

where \(\hat{\delta}_r\) is the least squares estimate of \(\delta\) based on the dfirst \(\tau\) observations,
\( \sigma^2 \) is the corresponding estimates of \( \sigma^2 \) and \( \tilde{X}_{j-1}^2 = X_{j-1} - \tau^{-1} \sum_{j=1}^\tau X_{j-1} \).

To test if a bubble exists Phillips and Yu (2011) suggest the \( maxDF^t \) test that compares the sup statistics \( sup_r DF^t_r \) with the right tail critical values obtained from the limit distribution \( sup_{r \in [r_0, 1]} r \int_0^r \tilde{W}dW/(\int_0^r \tilde{W}^2)^{1/2} \). Using simulation they obtain a 5% critical values a sample size of 100 of 1.5073.

To explore the timeline of the bubble they suggest that the start of the bubble can be identified by \( \hat{\tau}_e = \lfloor n \tilde{r}_e \rfloor \), where:

\[
\hat{\tau}_e = \inf_{s \geq r_0} s : DF^t_s > cv_{\beta_n}^{df}
\]

\( cv_{\beta_n}^{df} \) is the right sided 100\( \beta \)% critical value of the limit distribution of \( DF^t_r \) statistic based on \( \tau_s = \lfloor ns \rfloor \) observations and \( \beta_n \) is the size of the one-sided test. Similarly, assuming the existence of \( \hat{\tau}_e \), they date the collapse of the bubble by \( \hat{\tau}_f = \lfloor n \tilde{r}_f \rfloor \) where:

\[
\hat{\tau}_f = \inf_{s \geq \hat{\tau}_e + \gamma \ln(n)/n} s : DF^t_s < cv_{\beta_n}^{df}
\]

\( \gamma \) is used so that the duration of the bubble is nonnegligible. For practical implementation they set the critical value sequence for \( cv_{\beta_n}^{df} \) using an expansion rule, so \( cv_{\beta_n}^{df} = -0.08 + \ln(\lfloor nr \rfloor)/C \). The value of the constant \( C \) can be varied to make the test more or less conservative. In Phillips and Yu (2011) a value \( C = 5 \) is used.

**The LV-Wald Test**

The Lobato and Velasco Wald (LV-Wald) test is an efficient extension of the fractional Dickey Fuller (FADF) test suggested by Dolado, Gonzalo, and Mayoral (2002). This earlier work proposed testing for fractionality against the alternative of a unit root by constructing the t ratio test on \( \phi_1 \) in the ordinary least squares regression

\[
\Delta y_t = \phi_1 \Delta^{d_1} y_{t-1} + u_t \quad (t + 1, 2, \ldots, T)
\]
Lobato and Velasco (2007) argues that using $\Delta^d_1 y_{t-1}$ as the regressor is inefficient and suggest using instead the ordinary least squares regression:

$$\Delta y_t = \phi_2 z_{t-1}(d_2) + u_t \quad (t + 1, 2, \ldots, T) \quad (1)$$

where

$$z_{t-1}(d_2) = \frac{(\Delta^{d_2-1} - 1)}{(1 - d_2)} \Delta y_t$$

Assuming $d_2 > 0.5$ they suggest using a simple left sided t-test to test the significance of $\phi_2$ denoted by $t_\phi$.

### Smith’s modified-GPH test

In Smith (2005) the properties of $d$, estimated (incorrectly) from a fairly general Mean-plus-Noise (MN) model, are considered. The general MN model has the form:

$$y_t = \mu_t + \epsilon_t \quad t = 1, 2, \ldots, T \quad (2)$$

and

$$\mu_t = (1 - p)\mu_{t-1} + \sqrt{p}\eta_t \quad 0 < p < 1, \quad (3)$$

where $\epsilon_t$ and $\eta_t$ are short-memory random variables each with zero mean and finite non-zero variance, $\epsilon_t$ and $\eta_s$ are independent of each other for all $t$ and $s$. The parameter $p$ determines the persistence of the level component $\mu_t$. This MN specification encompasses models such as Markov switching and stationary random level shift.

The GPH estimate of $d$ for the MN model (2) and (3), say $\hat{d}_{m}$, is consistent under standard Gaussian assumptions but, as Smith (2005) shows, is biased upwards. By exploring the nature of this bias, Smith (2005) derives a modified version of the GPH that has a smaller bias. The modification is essentially the addition of another term to the GPH regression. If $\hat{f}_j$, $j = 1, 2, \ldots, m$, is the periodogram, the modified regression is:

$$\log \hat{f}_j = \alpha + dX_j + \beta Z_{kj} + \hat{u}_j, \quad (4)$$
where $X_j$ is the standard $GPH$ term:

$$X_j = -\log(2 - 2\cos(\omega_j)) \quad \omega_j = \pi j / T$$

and $Z_{kj}$ is the additional term:

$$Z_{kj} = -\log \left( (k j)^2 / T^2 + \omega_j^2 \right) ,$$

where $k$ is a nuisance parameter, which Smith (2005) suggests has a value between 1 and 5. Smith (2005) also shows that in many circumstances a value of $k = 3$ is optimal.

The modified-$GPH$ estimator, $\hat{d}_m^k$, can be used to investigate whether the apparent fractional nature of a series is really due to mean shift. If $\hat{d}_m^k < \hat{d}_m$, then it is possible that the series contains a mean shift. If $\hat{d}_m^k > \hat{d}_m$, then it is unlikely that the evidence for fractional behaviour is due to mean shifts. Importantly, Smith (2005) points out that $\hat{d}_m^k$ should not be viewed as an estimate of the ‘true’ value of $d$ as this requires non-trivial modelling.

A major issue with estimating $GPH$ is choosing the number of frequencies $m$. Increasing the frequencies normally leads to smaller root mean square error but larger bias (Hurvich, Deo, and Brodsky 1999). Smith (2005) uses the rule of thumb, fixed value of $m = T^{1/2}$, suggested in Geweke and Porter-Hudak (1983) and the ‘Plugin’, root mean square minimizing value suggested by Hurvich and Deo (1999).

**Qu’s local Whittle-based test**

Qu (2011) uses the properties of the local Whittle estimator of $d$, say $\hat{d}_w$, obtained by minimising the concentrated, in $G$, Whittle likelihood function $R(d) = \log G(d) - 2m^{-1}d \sum_{j=1}^m \log \lambda_j$ with respect to $d$ to test whether the series has long memory or a break. In the function $R(d)$, $\lambda$ is the frequency, $G(d) = m^{-1} \sum_{j=1}^m \lambda_j^{2d} I_j$, $m$ is some integer that is small relative to $n$ and $I_j = I_x(\lambda_j)$ the periodogram of $x_t$ evaluated at frequency $\lambda_j$. In particular he notes that the quantity $m^{-1/2} \sum_{j=1}^{[mr]} v_j (I_j \lambda_j^{2d_0} / G_0) - 1$ derived by differentiating $R(d)$ with respect to $d$ where $[\cdot]$ means the ‘integer part of’, $r \in [\epsilon, 1]$, where
\( \epsilon \) is a small trimming parameter, and \( G_0 \) is the true value of \( G \); when treated as a process in \( r \) satisfies a functional central limit theorem and is of \( O_p(1) \) under the null hypothesis of long memory in the series \( x_t \). Whereas, if the series \( x_t \) is short memory and affected by either regime change or a trend, the quantity diverges. Thus Qu suggests the following test statistic:

\[
W = \sup_{r \in [\epsilon, 1]} \left( m \sum_{j=1}^{m} v_j^2 \right) \left| \sum_{j=1}^{[mr]} v_j \left( \frac{I_j}{G(\hat{d}_w \lambda_j^{-2d_w})} - 1 \right) \right| \tag{5}
\]

Using monte-carlo methods Qu derives 5% critical values of 1.252 when \( \epsilon = 0.02 \) and 1.155 when \( \epsilon = 0.05 \)

**The Data**

The data utilised in the paper was sourced from the University of Ulster House Price Index (UUHPI), a survey which analyses the performance of NI house prices quarterly, based on a significant and representative sample size of open market transactions within the region. The data range covers the period 1990 Q1 to 2011 Q3. The real house price was computed as the nominal house price divided by the CPI. The issue of finding a series to represent the fundamental value of houses in Northern Ireland was explored, no readily available series for average rent was obtainable. In addition, whether the concept of ‘average rent’ is a safe a proxy for fundamental value given the distortions caused by a large ‘social housing sector’ in Northern Ireland is debatable. Thus, for this preliminary study the (logged) prices series was used. This means that the assumption being made is that the fundamental value is constant for the analysis period.

**4 Results and discussion**

Table 1 gives the results of the basic stationarity analysis of the series. From this it can be seen that the house price series appears to be \( I(1) \) and the returns \( I(0) \). This is in line with the finding of Diba and Grossman (1988)
and would suggest that no bubble exists. This is because if prices were ‘explosive’ one would expect the returns series to be non-stationary. Despite using the more powerful $ADF - GLS$ test Evans’s (1991) criticisms of this simple analysis may still be valid and the results fit with his observation that ‘periodically collapsing bubbles are not detectable by using standard tests’ Evans (1991, p.927).

The results of the Phillips and Yu’s (2011) analysis is given in table 2 and figure 2. These suggest that there was a short but intense house price bubble between 2005 Q3 and 2009 Q1 reaching a peak in 2007 Q2. The trajectory of the t-statistic also suggests that there was perhaps a minor bubble at the turn of the century. These results need to be carefully interpreted. In particular the apparent bubbles could be due to the ‘fundamental values’ not being constant, as assumed. Whilst this might be the reason for the earlier bubble, it is unlikely to explain fully the more major result. However, as Phillips, Shi, and Yu (2012) shows the power of the $t - statistic$ test is less if there are multiple bubbles. Thus, it would seem safe to assume that the 2005-2009 bubble did exist.

Table 3 gives the $gph \hat{d}_m$ and local-Whittle $\hat{d}_w$ estimates of the fractional differencing parameter $d$. As expected both the $FADF$ and $LV - Wald$ tests fail to accept the null hypothesis that the series are $I(1)$ rather than $I(d)$. For the full period only the local-Whittle estimate of $d$ is greater than 0.5, which is needed to support the hypothesis of a bubble during the period. This could be due to the period under consideration being too long. For the period 2002Q1 to 2011Q3 both of the $gph$ estimates support the hypothesis of a bubble. The local-Whittle estimate is just slightly less than 0.5. For the earlier period only the ‘plugin’ $gph$ estimate is greater than 0.5. The local-Whittle estimate is suggesting ‘negative stable memory’.

Whether these fractional results are spurious or not is explored in tables 4 and 5. Table 4 gives the results of the modified gph analysis of Smith, again for the full period and also for the sub-period 2002Q1-2011Q3 and 1990Q1 - 2002Q1. For the full period the plugin analysis supports the hypothesis that the series contains a mean-shift whereas the fixed analysis does not. For the sub-period 2002Q1 - 2011Q3 the results are reversed. Finally for the period
1990Q1 - 2002Q1 there is no evidence to support the mean shift hypothesis. It is difficult to interpret these results as the choice of \( m \) the number of frequencies used seen to highly influence the results obtained. In table \( 5 \) the results for the local-Whittle test for full period are not really applicable as \( \hat{d}_w > 0.5 \) and a basic assumption of the test is that \( d \in (-0.5, 0.5) \). With this in mind the table suggests that the only period where the local-Whittle estimate of \( d \) could be spurious is the period 1990Q1 - 2002Q1. Thus the fractional analysis through the obtaining on non-stationary estimates of \( \hat{d}_w \) or \( \hat{d}_m \) seems to support the idea of a bubble, though the tests are unclear as to whether the estimates obtained are really due to long memory or to some other non-linearity in the series.

5 Conclusions

In this paper a preliminary econometric analysis of the dynamics of the Northern Ireland housing market has been presented. The results are interesting. They show the limitations of traditional \( I(1)/I(0) \) analysis and suggest that both sequential unit root tests and fractional analysis could provide useful tools for further analysis. The sequential unit root tests seem to provide a method of simple analysis whilst the fractional analysis requires careful interpretation.

The paper has made the strong assumption that the real fundamental value of houses is stationary. The question remains as to whether this assumption is safe and if not, what series should be utilised as a proxy for the concept?

It would be easy at this stage to attempt to provide explanations for the behaviour discovered. For example, the apparent minor bubble at the turn of the century might be explained by the pushing out of first time buyers by rising prices (the number of mortgages to first-time buyers peaked in 2001). However, it might also be explained by the changes in the macro economic environment brought about by the availability of cheap money in the island of Ireland associated with the introduction of the euro. Exploring such issues is a major research exercise and beyond the scope of this paper. However,
the paper provides the basis for such analysis.

References


15


Table 1: Basic $I(1)/I(0)$ analysis

<table>
<thead>
<tr>
<th>Series</th>
<th>$ADF_{\text{Prob.}(1)}$</th>
<th>$KPSS^{(2)}$</th>
<th>$ADF - GLS_{\text{Prob.}(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prices</td>
<td>-1.45 (0.56)</td>
<td>2.17</td>
<td>0.02 (0.69)</td>
</tr>
<tr>
<td>Returns</td>
<td>-3.50 (0.01)</td>
<td>0.24</td>
<td>-2.50 (0.01)</td>
</tr>
</tbody>
</table>

1: Probabilities derived from MacKinnon (1996) unless otherwise noted
2: Null of stationarity 5% critical value 0.466

Table 2: Testing the presence of bubbles and date stamping

<table>
<thead>
<tr>
<th>Series</th>
<th>$\max DF^t_r$</th>
<th>$\hat{\tau}_c(\hat{\tau}_0)$</th>
<th>$\hat{\tau}_f(\hat{\tau}_0)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prices</td>
<td>2.66 (2007Q2)</td>
<td>2005Q3</td>
<td>2009Q1</td>
</tr>
</tbody>
</table>
Table 3: Fractional Analysis

<table>
<thead>
<tr>
<th>Method</th>
<th>J</th>
<th>$d_{(s.e.)}$</th>
<th>$FADF$</th>
<th>$LV - Wald$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Full period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$gph$</td>
<td>Plugin</td>
<td>0.35 (0.36)</td>
<td>-5.2</td>
<td>-6.5</td>
</tr>
<tr>
<td>$gph$</td>
<td>Fixed</td>
<td>0.28 (0.3)</td>
<td>-5.2</td>
<td>-6.6</td>
</tr>
<tr>
<td>Whittle</td>
<td>Fixed</td>
<td>0.55</td>
<td>-5.6</td>
<td>-6.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2002Q1 - 2011Q3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$gph$</td>
<td>Plugin</td>
<td>0.56 (1.3)</td>
<td>-2.5</td>
<td>-2.9</td>
</tr>
<tr>
<td>$gph$</td>
<td>Fixed</td>
<td>0.73 (0.44)</td>
<td>-2.5</td>
<td>-2.9</td>
</tr>
<tr>
<td>Whittle</td>
<td>Fixed</td>
<td>0.47</td>
<td>-2.4</td>
<td>-2.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1990Q1 - 2002Q1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$gph$</td>
<td>Plugin</td>
<td>0.61 (0.3)</td>
<td>-7.4</td>
<td>-7</td>
</tr>
<tr>
<td>$gph$</td>
<td>Fixed</td>
<td>0.32 (0.39)</td>
<td>-7.4</td>
<td>-7.8</td>
</tr>
<tr>
<td>Whittle</td>
<td>Fixed</td>
<td>-0.20</td>
<td>-3.1</td>
<td>-7.2</td>
</tr>
</tbody>
</table>
### Table 4: Modified GPH

<table>
<thead>
<tr>
<th>J</th>
<th>GPH (s.e.)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plugin</td>
<td>0.35 (0.38)</td>
<td>-0.13 (3)</td>
<td>-0.036 (1.3)</td>
<td>-0.26 (0.89)</td>
<td>-0.073 (0.69)</td>
<td>0.027 (0.58)</td>
</tr>
<tr>
<td>Fixed</td>
<td>0.28 (0.32)</td>
<td>0.46 (2.4)</td>
<td>0.43 (1.3)</td>
<td>0.43 (0.98)</td>
<td>0.43 (0.85)</td>
<td>0.43 (0.79)</td>
</tr>
<tr>
<td>2002Q1 - 2011Q3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plugin</td>
<td>0.56 (1.3)</td>
<td>-2.4 (71)</td>
<td>-0.36 (23)</td>
<td>2.9 (7.9)</td>
<td>2.1 (5.4)</td>
<td>0.74 (3.3)</td>
</tr>
<tr>
<td>Fixed</td>
<td>0.73 (0.44)</td>
<td>-2.2 (5.1)</td>
<td>-0.67 (2.3)</td>
<td>-0.36 (1.7)</td>
<td>-0.24 (1.4)</td>
<td>-0.18 (1.3)</td>
</tr>
<tr>
<td>1990Q1 - 2002Q1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plugin</td>
<td>0.61 (0.3)</td>
<td>3.5 (1.4)</td>
<td>2.1 (0.75)</td>
<td>1.1 (0.56)</td>
<td>0.65 (0.45)</td>
<td>0.63 (0.39)</td>
</tr>
<tr>
<td>Fixed</td>
<td>0.32 (0.39)</td>
<td>5.2 (3.8)</td>
<td>2.8 (1.8)</td>
<td>2.2 (1.3)</td>
<td>2 (1.1)</td>
<td>1.9 (1)</td>
</tr>
</tbody>
</table>

### Table 5: Qu’s local Whittle test

<table>
<thead>
<tr>
<th>$\epsilon$</th>
<th>0.02</th>
<th>0.05</th>
<th>0.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{d}_w$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Full period</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2002Q1-2011Q3</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.47</td>
<td>0.54</td>
<td>0.54</td>
<td>0.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1990Q1-2002Q1</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.20</td>
<td>1.33</td>
<td>1.33</td>
<td>1.33</td>
</tr>
</tbody>
</table>

5% critical value
1.252 | 1.155 | *

22
Figure 1: Real House Prices Northern Ireland

Figure 2: Recursive values of the $t$ statistics