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Modelling Irish Rents: Recent Developments in Historical Context

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Abstract

In recent years Ireland experienced strong growth in residential rents. To characterise current conditions in this market, this *Letter* investigates the dynamic behaviour of real Irish rents by applying two models to data from the 1980s/1990s. First, employing a univariate non-linear approach, average quarterly growth rates are benchmarked relative to historical trends. The results show that national rents move between high-growth and low-growth periods from the 1990s. From 2013 to 2016Q1, Irish rents are found to be in a high-growth regime. This *Letter* also models national real rents using quarterly data from 1985Q1 to 2016Q1. Employment and housing stock per capita are found to influence long-run rents over the sample. From end-2013, rents are found to be higher than would be expected by these long-run relationships.

1 Introduction

Irish residential rents have been rising steadily since late-2010 / early-2011 with national figures growing by over 9 per cent per annum for the past three years. According to data from the Central Statistics Office (CSO), average rents are more than 11 per cent higher than their previous peak level (in 2008). Furthermore, the 2016Q3 Daft.i.e. Rent Report shows that Dublin rents have increased by 12.1 per cent over the past year and by almost 60 per cent since their low point at the end of 2010.[2] Rent increases are no longer confined to cities and Dublin commuter counties. For example, in 2016Q3 the strongest annual rental growth of 19.4 per cent was recorded in Leitrim.

This growth has occurred against a backdrop of low levels of rental supply, a pick-up in economic growth and the recent introduction of the Central Bank of Ireland's macroprudential limits on Loan to Value (LTV) and Loan to

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[2]CSO rents are based on actual private rents paid by tenants, whereas the Daft.i.e. rental series is based on the asking rents of properties advertised on the Daft.i.e. website.

Income (LTI) ratios in mortgage lending (the regulations).[3] In October 2016, the number of units listed for rent on Daft.i.e. was down 12 per cent annually and by over 85 per cent since 2009. The situation in Dublin is particularly acute, with fewer than 1,500 units on offer, a fall of over 80 per cent from the mid-2009 peak.

Market experts suggest that demand is outpacing supply as the drop in the availability of rental units corresponds with a substantial addition to the stock of properties in the private rented sector (PRS). Research by McCartney (2016) estimates that 24,000 units were added to the PRS since 2011, but the strength of demand for rental accommodation since then has accounted for this additional stock.

To inform analysis of the Irish rental market and contribute to the limited research in the area, this *Economic Letter* investigates the behaviour of the Irish rental market over time. Specifically, using a univariate, regime switching approach, we first examine quarterly growth rates in national real rents from 1990Q1 to 2016Q1. This approach allows us to assess current developments relative to historical trends and to investigate both existence and timing of breaks in the data. The results show that national real rents move between periods of high growth (i.e., averaging 1 per cent per quarter) and those of low growth (i.e., averaging -2 per cent per quarter) over the sample. From 2013, national real rents are found to be in a high-growth period with no evidence of a further switch to a low-growth regime between 2013 and 2016Q1. We are also interested in identifying key driving factors for Irish rents and in estimating a long-run rental series (i.e., a series justified by long-run relationships with economic determinants). It is possible to benchmark actual rents relative to this estimated long-run level. Therefore, an error-correction model (ECM) is specified for real national rents over the period 1985Q1 to 2016Q1. Employment and housing stock per person are found to explain long-run rents over the sample. Actual rents are found to be below levels estimated by the long-run model between 2009 and 2013Q3 while from 2013Q4 to 2016Q1, rents are higher than estimated long-run levels. Quarterly changes in rents are found to respond to deviations from the estimated long-run level, lagged rental growth and lagged employment changes.

Of further interest is the period since the announcement of the mortgage market regulations in late 2014. While we cannot directly test for causality given the short period since the announcement of the regulations and the potential lagged effect on the rental market, we examine the rental series for potential statistical breaks or changes in the relationship with explanatory variables over this time. Our results suggest that the recovery in rents preceded the introduction of the regulations. There is also no evidence of a structural break in the national series in late 2014. However given the lack of data since late 2014 and the aggregate nature of this analysis, we cannot conclusively state or identify whether the regulations have or have not contributed to increased rental growth in recent times. These results, however, are in line with analysis at the regional level by McCann (2016), who shows that from mid-2013 rents in Dublin and its commuter belt began to surpass levels expected by a range of empirical models.

This *Letter* proceeds as follows. Section 2 provides an overview of selected related literature and Section 3 describes the data used in the analyses. Section 4 presents the regime switching analysis while Section 5 discusses the ECM results. A final section concludes.

[3] For more information please see http://www.centralbank.ie/stability/MacroprudentialPol/Pages/LoantoValueLoantoIncome.aspx.

2 Literature

Rental models are more common in the commercial real estate literature than in the residential area given the importance of forecasting future cash flows from commercial property, particularly in the office and multi-unit residential property markets for investors. However, there are a number of papers that forecast turning points in residential rents and/or specify an equilibrium residential rent equation. In this *Letter*, we draw on research from both sectors to inform our analysis of the Irish residential rental market.

In the residential property market, rents are primarily used as an input into valuation indicators to assess the sustainability of price movements. Case and Shiller (1989) and Gallin (2008), among others, state that the fundamental value of a property may be calculated as the present discounted value of its future rent flows. Rental income is thus viewed in a similar manner to dividends in the calculation of stock prices with the price-to-rent ratio analogous to the dividend-price ratio (Leamer, 2002). Indeed, as Gallin (2008) highlights, rents tend to be treated as a fundamental determinant of house values and so should not deviate far from prices.

Duca et al. (2016) assume a long-run relationship between real rents and real house prices in a rental equation specification.[4] The long-run equation controls for real incomes, real house prices and an eight-period moving average of the user cost of capital (UCC). Rents are assumed to be positively related to house prices, income and the UCC. The corresponding short-run model includes an error correction term, lagged real rental growth, lagged real energy prices and nominal inertia (inflation).

In this way rents may be considered as exogenous to house prices; however in reality house price changes tend to lead rent changes, indicating that housing price changes affect rental prices (Wang, Zhang and Dai, 2013). A body of empirical literature also casts doubt on the stability of the theoretical relationship between house prices and rents.[5]

Recent work analysing Irish residential rents is provided by McCartney (2016), which finds a long-run relationship between rents and the vacancy rate. McCartney (2016) estimates that 24,000 units were added to the Irish private rental sector since 2011. The strength of demand for rental accommodation since then, however, quickly accounted for the additional stock. McCartney (2016) suggests that this has left the current residential rental vacancy rate well below the natural vacancy rate, contributing to the sharp rise in rents of late.

McCann (2016) shows, in a quarterly panel of eight regions from 2006Q1 to 2016Q1, that regional rents are positively associated with house prices and population and negatively associated with unemployment rates and rental supply. These relationships are robust to models in levels and in growth rates. McCann (2016) uses residuals from these models to show that, in line with the results in this paper, rents in the Dublin market appear to have surpassed levels predicted by a range of empirical models from mid-2013, and have continued to grow disproportionately to these economic factors since. Some evidence is found that the introduction of the regulations was concurrent to disproportionate rental growth in the regions containing Galway and Cork City.

The commercial real estate literature employs a similar approach to that used for residential rents and generally finds that economic fundamentals and the vacancy rate are important drivers of rental adjustment (See Ball et al., 2006 for a full discussion). Much of the literature analysing this rental market uses some form of rental adjustment equa-

[4] Specifically, the paper includes a real rent equation using an error correction framework for apartments as part of a multi equation system.

[5] See Andre et al., (2014) for a discussion.

tion which highlights that vacancy rates are directly, inversely and linearly related to rental growth adjusted for changes in operating costs (see Hendershott, MacGregor and Tse ,2002, and Hendershott ,1995). Other studies, such as Key at al. (1994), assume a long-run relationship between real rents and long-term real interest rates.

In addition to determining equilibrium rents, many papers in both the residential and commercial areas investigate forecasting models for rents (for example see Farhi and Young, 2010, and Tsolacsos et al., 2014).

3 Data

Nominal residential rents for the sample period 1985Q1 to 2016Q1 are obtained from the CSO. The empirical analysis is performed on real rents so the nominal series is deflated using the CSO's Consumer Price Index (CPI).

Unit root testing indicates that the rental series is nonstationary in levels. In view of this we transform the series to first differences. Therefore log quarterly changes are used for the regime switching application which focuses on the period 1990Q1 to 2016Q1 [6]. For the error correction approach, we employ data from 1985Q1 to 2016Q1 as the establishment of long-run relationships requires historical data. Given the lack of historical data on regional rents or possible explanatory variables at a regional level, we focus on the national rental series. Explanatory variables used are seasonally adjusted employment levels sourced from the CSO and the Central Bank's internal dataset for its macro-modelling work and the estimated housing stock per capita from the CSO and Department of Housing, Community & Local Government.

Figure 1 shows the real rental series and both explanatory variables for our model in both log levels and annual percentage changes. In line with the broader housing market, real rents fell significantly in 2008/2009 and did not regain upward momentum until 2013. Indeed only the period from 1999/2000 recorded annual growth rates as high as those between 2014 and 2016Q1. It is likely that there were a number of factors at play during the Irish crisis. Homeownership rates in the Irish market declined with rates going from 78 per cent in 2007 to 70 per cent in 2013 based on Eurostat data, possibly reflecting both affordability pressures for prospective house purchasers due to income shocks and an increase in risk aversion towards housing. These delays in purchasing a house by prospective buyers may have added to rental demand at this time. On the other hand, during the crisis, the significant adjustment in the domestic economy may also have reduced the potential for paying higher rents and many may have withdrawn from the rental market. Furthermore, using the 2011 Census and preliminary population projections, numbers in the household formation category (i.e., 25 to 44 years) are estimated to have slowed since 2011 which may have reduced both rental and housing demand. The recent recovery in rental growth appears to coincide with improvements in the labour market following the Irish crisis and a stagnation in per capita housing stock. Since the crisis, new housing supply has been muted and turnover in the market is low by historical standards. Preliminary 2016 Census figures for the Irish population show an increase since 2011. Therefore the recent per capita housing stock figures have slowed.

4 Regime switching framework

In this Section we examine growth rates of national rents from 1990Q1 to 2016Q1, comparing recent trends to historical behaviour. We also investigate if there have been any breaks in the series over the sample and, if so, ex-

[6] 1990 was chosen as the starting point rather than 1985 due to convergence issues with the model.

actly when these occurred. Rather than specifying any break dates, we allow shifts in regime to be determined by the data. We assume two regimes or states, namely a high growth rate regime and a low growth rate regime, and take a univariate approach to assess if there is any evidence that quarterly log changes of real rents have shifted from one to the other over time. This allows us to characterise prevailing conditions in the real rental market. The approach is commonly applied to macroeconomic variables such as GDP, where it is assumed that such variables behave differently depending on whether an economy is experiencing an upswing or a contraction. Rents are generally considered to be cyclical and respond to movements in economic activity. This is confirmed in Section 5.

We employ a fixed transition probability Markov switching VAR (FTP MS-VAR), introduced by Hamilton (1990). In terms of applying such a framework to Ireland's rental market, preliminary observation of real rents suggests that a break may have occurred in the series around 2008 (see Figure 1) which indicates that two regression lines may better fit the data than one. Also, Wang, Zhang and Dai (2013) highlight that small open economies are subject to regime-switching in asset returns.

We employ a mean-switching model on quarterly log changes of national real rents. Specifically we model quarterly changes of national real rents in a two-regime, one-lag, framework, allowing the conditional mean to switch between states. This enables the identification of a low and high growth regime. The model is specified as follows:

$$\triangle Rent_t = \alpha(s_t) + \sum_{k=1}^{K} \beta_k \triangle Rent_{t-k} + \varepsilon_t \quad (1)$$

$$s_t \epsilon \{1, 2\},$$

in which $\triangle Rent_t$ is an n-dimensional time series vector of the log quarterly changes of the rental series and $\alpha(s_t)$ is a matrix of state dependent intercepts. As s_t is unobserved, we assume that it follows a first-order Markov process, which determines the regime path.

The smoothed probabilities obtained from this model are plotted against quarterly changes in real rental growth in Figure 2. This suggests that real rents were in a low growth regime broadly between 2001 and 2005 and again between 2008 and 2012. These timeframes correspond to periods when the rental market may have stalled due to factors such as the macroeconomic slowdown in 2001, oversupply in the housing market for the earlier period and the housing crisis for the later period. The system has been in a high growth regime since approximately 2013, which coincides with the pick-up in the housing market. Estimates from the model are reported in Table 1. The transition probabilities suggest that the low rent regime is persistent in nature while the signs of the conditional means in each regime meet a priori expectations, negative in the low growth regime (-0.02) and positive in the high growth regime (0.01). The smoothed probabilities also indicate that there have been no structural breaks in the series since the announcement (2014Q3) or the introduction (2015Q1) of the regulations.

In addition to a mean switching model we also employ a volatility switching FTP MS-VAR. This allows us to examine whether quarterly log changes of the real rental series experienced any significant structural changes in terms of volatility over the sample. This is of interest as an increase in volatility may lead to sharp upturns or downturns in rents themselves. The results, reported in the Appendix, correspond to those obtained from the mean switching specification in that they do not indicate a structural break in the national rental series in 2014/2015. They also indicate that this series is in a high volatility regime as at 2016Q1.

5 Error correction model (ECM)

We are also interested in determining the key factors driving rents over the sample. In this Section, therefore, we model national real rents using a single equation error correction model (ECM). This approach assumes that rents respond to both long- and short-run influences. We rely on the literature to provide a guide to these influences. A Two-Step Engle Granger (1987) approach is employed which allows direct estimation of long-run or equilibrium rents in addition to modelling quarterly changes in rents. Actual rents can then be benchmarked against this estimated equilibrium rental series. Our sample runs from 1985Q1 to 2016Q1.

As highlighted in Section 2, there are many possible determinants for rents, such as measures of economic activity, the User Cost of Capital (UCC) for housing services, interest rates, housing supply and vacancy rates. It is expected that an increase in economic activity should lead to an increase in rents, all other things being equal, as an increased demand for housing services should contribute to rental growth. A positive relationship with the UCC for housing services would be expected as prospective home buyers may prefer to rent if owning appears too costly. An increased housing supply might lead to a decrease in rents if there is a higher preference for homeownership within a market. Similarly high vacancy rates would lead to a decrease in rents. Unfortunately long-run data on vacancy rates are not widely available for the Irish rental market.[7] We do not include house prices in our rental equation given the potential endogeneity concerns in this single-equation approach.

For the Irish data, we estimate the following long-run model of log rents (lnr_t),

$$lnr_t = \beta_0 + \beta_1 lnemp_t - \beta_2 lnhs_t + u_t \quad (2)$$

where $lnemp_t$ is log of employment levels and $lnhs_t$ is log of per capita housing supply.[8]

Table 2 presents the results for the long-run model. The elasticity with respect to employment is high confirming our expectations that rents are cyclical. The significant point estimate on the per capita housing stock coefficient shows that there is negative elasticity of rents with respect to the interplay of housing supply and demographics over our sample. The fitted values from Equation 2 yield our estimated long-run rental series. As at 2016Q1 rents were above these long-run fitted values with the gap emerging in late-2013/early-2014. The macreconomic recovery since 2013 and the lack of housing supply in certain areas may have added to rental pressures leading to an increase in long-run rents. Other factors outside of economic activity, housing supply and demographics are clearly driving national rents since 2013Q4. While the regulations may have contributed to the increase in rental pressures, it is difficult to identify this influence from other possible factors in the market at this time.

It is also possible that our historical measure of housing supply is too broad to capture supply issues in the Irish rental market. As noted in Section 1, the stock of properties available for rent is considered historically low by market commentators. Housing stock covers properties that are available for both house purchase and rent. Also aggregate analysis masks the variation in rents at a regional or city level. Supply shortages are reported to be more acute at regional level and may exert a greater influence on rents than would be estimated using aggregate data. This issue is addressed in McCann (2016) who shows

[7] As noted, McCartney,(2016) uses new CSO data on private rental sector and Daft.ie data to calculate vacancy rates. This series, however, only begins in 2007Q1.

[8] The UCC and interest rate variables are insignificant or negatively signed which conflicts with a priori expectations.

that across the eight regions of Ireland defined by the Nomenclature of Territorial Units of Statistics, unemployment rates, rental supply, population and house prices are all associated with rents with the expected sign. In line with the findings for the national market in this *Letter*, McCann (2016) shows that rents appear to have grown disproportionately to developments in the explanatory factors from mid-2013 in the Dublin market.

In the short-run, we find that quarterly changes in rents adjust to deviations from long-run levels, in addition to past changes in rents and lagged employment changes (Table 3).

$$\triangle lnr_t = u_{t-1} + \sum_{i=1}^{p} \alpha_i \triangle r_{t-i} + \sum_{i=0}^{q} \alpha_i \triangle lnemp_{t-i} + \mu_t \quad (3)$$

The point estimate on the error correction term is small, implying a gradual adjustment back to long-run levels. Specifically, if there is a deviation between actual and long-run rental levels, 6 per cent of this deviation is closed in a quarter. The rental series also exhibits quite high levels of autocorrelation implying persistence in the quarterly series over the sample. Last quarter's employment changes are found to have a positive and significant influence on changes in rents this quarter. Figure 4 shows actual and fitted values for the short-run model along with the residuals. While the short-run model tracks the quarterly change in rents quite well, only 40 per cent of the variation in rents is fully explained by the model. As with the long-run model, we can see that real rental growth is much higher than the fitted values for our short-run model as at 2016Q1.

6 Conclusion

This *Letter* analyses trends in the Irish rental market over the period 1985Q1 through 2016Q1 using two models applied to real rents. We are also interested in examining the period since the announcement of the mortgage market regulations in late 2014 to investigate whether there has been any change in the dynamic behaviour of rents. While we cannot directly test for causality given the short period since the announcement of the regulations and the potential lagged effect on the rental market, we examine the rental series for potential statistical breaks or changes in the relationship with explanatory variables over this time.

Our first approach finds that between 1990Q1 and 2016Q1, Irish real rents move between periods of high growth and those of low growth. The recovery in the rental market appears to have begun earlier than late-2014, as Irish rents are assessed to be in a high-growth period from 2013 with no further evidence of a regime shift up to the end of the sample, 2016Q1. Our second approach presents a model for Irish real rents controlling for both the impact of economic activity (i.e., employment) and for total housing supply (i.e., housing stock per person) over the period 1985Q1 through 2016Q1. Both a long- and short-run model is specified. Rental levels can be benchmarked relative to the estimated long-run values. Since 2013Q4, real rents are higher than levels consistent with our long-run model. Other factors outside of employment, supply and demographics are clearly influencing rents at this time. While the regulations may have contributed to rental pressures since their introduction, the empirical evidence on this relationship cannot be identified clearly using the limited data available since late-2014.

Further work in this area will involve investigating the drivers of the identified regime shifts in rental growth rates. A non-linear ECM model is one possible explanation. Therefore our existing model for Irish rents will be tested for non-linearities.

References

Andre, Christophe, Luis A. Gil-Alana and Rangan Gupta, "Testing for persistence in price-to-income and price-to-rent ratios in 16 OECD countries", *Applied Economics*, 2014, 46 (18), pp. 2127-2138.

Ball, Michael, Colin Lizieri and Bryan D. MacGregor (2006), The Economics of Commercial Property Markets, Routledge, 2006.

Case, Karl and Robert Shiller, "The Efficiency of the Market for Single Family Homes", *The American Economic Review*, 1989, 79(1), 127-137.

Duca, John. V., John Muellbauer and Anthony Murphy, "Housing markets and the financial crisis of 2007-2009: Lessons for the future", *Journal of Financial Stability*, 2016 , pp.203-217.

Engle, Robert and Clive Granger, "Cointegration and Error Correction: Representation, Estimation and Testing", *Econometrica*, 1987, 55, pp.251-276.

Farhi, Christopher, and James Young, "Forecasting Residential Rents: The Case of Auckland, New Zealand", *Pacific Rim Property Research Journal*, 2010, 16(2), 207-220.

Gallin, Joshua, "The Long Run Relationship between House Prices and Rents", *Real Estate Economics*, 2008, 36(4), 635-658.

Hamilton, James, "Analysis of time series subject to changes in regime," *Journal of econometrics*, 1990, 45(1), 39-70.

Hendershott, Patric, "Real effective rent determination: evidence from the Sydney office market," *Journal of Property Research*, 1995, 12(2), 127-135.

Hendershott, Patric, Bryan MacGregor, and Raymond Tse, "Estimation of the rental adjustment process," *Real Estate Economics*, 2002, 30(2), 165-183.

Key, T., B.D. MacGregor, Nanthakumaran, N. and F. Zarkesh, "Economic Cycles and Property Cycles", *Main Report for Understanding the Property Cycle*, 1994, London, RICS.

Leamer, Edward, "Bubble Trouble? Your Home has a P/E Ratio Too," *UCLA Anderson Forecast*, June 2002.

McCann, Fergal, "Exploring developments in Ireland's regional rental markets". Central Bank of Ireland Economic Letter,Vol. 2016, No. 13, 2016.

McCartney, John, "A Rent Forecasting Model for the Privately Rented Sector in Ireland," 2016, Savills Report.

Tsolacos, Sotiris., Chris Brooks and Ogonna Nneji, "On the Predictive Content of Leading In-

dicators: The Case of U.S Real Estate Markets", 2014, *Journal of Real Estate Research*, 36, 4, pp. 541-573.

Wang, Honglin, Chu Zhang, and Weihang Dai, "Rental adjustment and housing prices: Evidence from Hong Kong's residential property market," 2013, HKIMR Working Paper 1(2013).

Figures and Tables

Figure 1: Real rents and explanatory variables

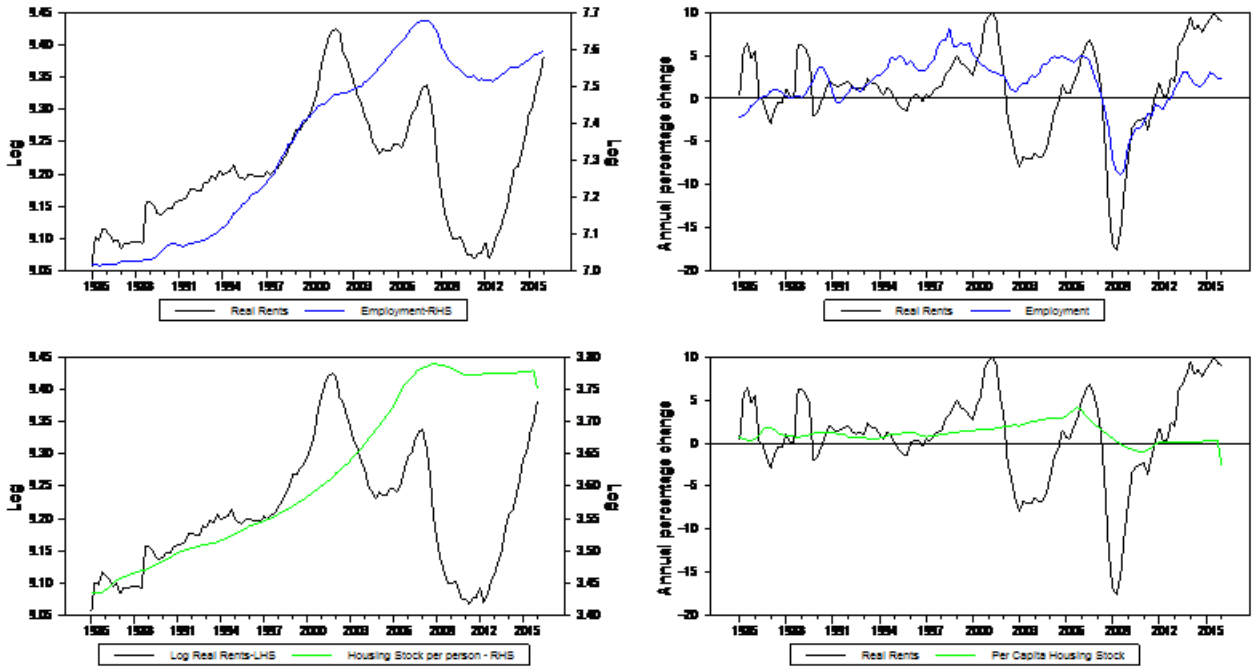
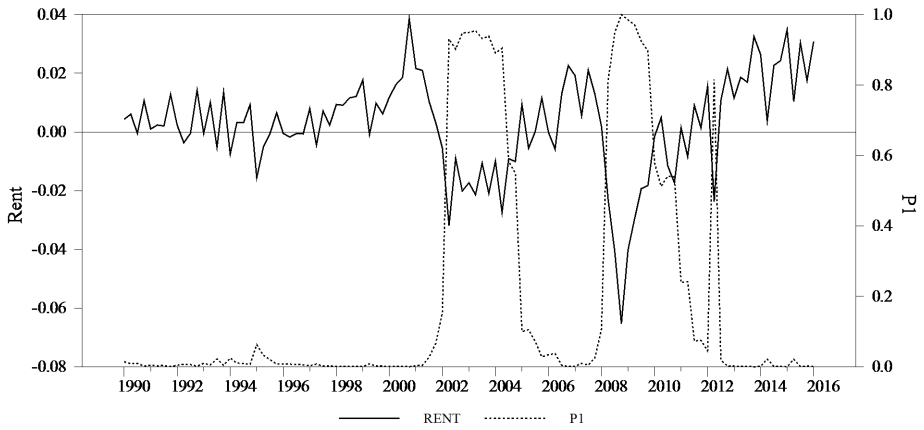


Figure 2: Smoothed probabilities of low National real rent growth and quarterly log changes of National real rents: 1990Q1-2016Q1



Notes: The above chart presents the smoothed probabilities estimated from Eqn. 1 (P1/dashed line) and quarterly log changes in National real rents (solid line).

Figure 3: Long-run model of Irish rents: 1985:Q1-2016:Q1

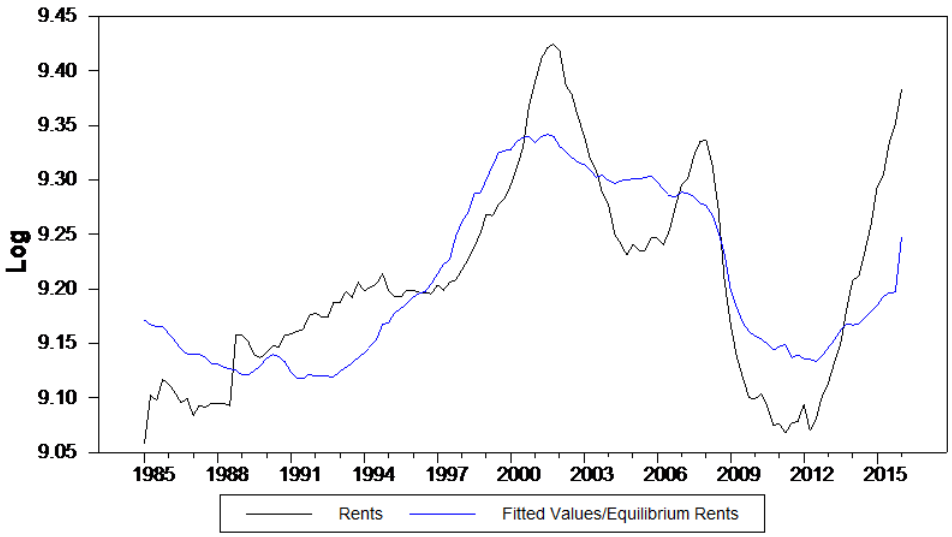


Figure 4: Short-run model of Irish Rents: 1985:Q1-2016:Q1

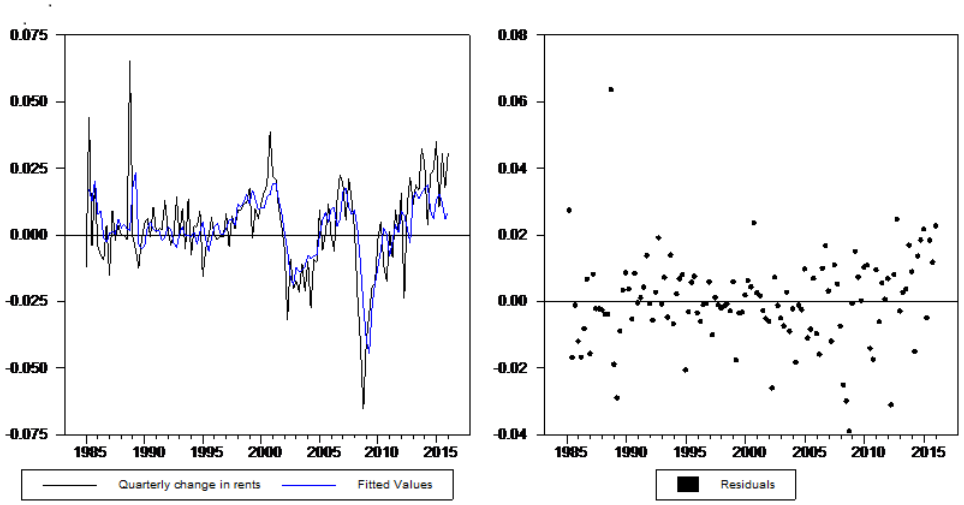


Table 1: Mean switching FTP MS-VAR:1990Q1-2016Q1

National real rents	
Variable	Coefficient
$P_{1,1}$	0.84^{**}
	(8.84)
$P_{1,2}$	0.03
	(1.24)
μ_{low}	-0.02^{**}
	(-3.38)
μ_{high}	0.01^{**}
	(2.71)

Notes: This table presents estimated transition probabilities and conditional means for the low and high growth rent regimes from the FTP MS-VAR model specified in Eqn. 1. ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. T-statistics are reported in parenthesis.

Table 2: Long and Short-Run Model of National Rents: 1985Q1-2016Q1

Dependent variable: lnr_t	
$Constant$	7.625
	(48.96)
$lnemp_t$	0.955
	(15.01)
$lnhs_t$	-1.501
	(-12.72)
Dependent variable: $\triangle lnr_t$	
ecm_{t-1}	-0.064
	(-2.42)
$\triangle lnr_{t-1}$	0.320
	(3.24)
$\triangle lnr_{t-2}$	0.400
	(3.72)
$\triangle lnemp_{t-1}$	0.207
	(1.93)
$\overline{R^2}$	0.40

Note: Absolute t-statistics in brackets. Dependent variable in long-run model is log real rents. $lnemp_t$ is log employment and $lnhs_t$ is housing stock per capita. Dependent variable in short-run model is first difference log real rents and $\triangle lnemp$ is first difference log employment. Heteroscedasticty-robust standard errors used when estimating the short-run model.

Appendix

The variance switching model allows the covariance matrix and coefficients to switch between states, enabling the identification of a low- and high-volatility regime. The below specification is employed:

$$\triangle Rent_{i,t} = \alpha(s_t) + \sum_{k=1}^{K} \beta_k(s_t) \triangle Rent_{i,t-k} + \varepsilon_{i,t}^{s_t} \tag{4}$$

$$s_t \epsilon \{1, 2\}$$

$$\varepsilon_{i,t}^{s_t} \sim i.i.d.N(0, \varepsilon_s^2),$$

in which $\triangle Rent_{i,t}$ is an n-dimensional time series vector of the rental series, $\alpha(s_t)$ is a matrix of state dependent intercepts, $\beta_1 ... \beta_k$are matrices of the state dependent autoregressive coefficients and $\varepsilon_{i,t}^{s_t}$ is a state dependent noise vector, which has a zero mean and constant variance within each regime. As s_t is unobserved, we assume that it follows a first-order Markov process, which determines the regime path.

Due to convergence issues with the model, the sample starts at 1990:04. The results correspond to those obtained for the mean switching specification and do not indicate that a structural break occurred since the announcement or introduction of the regulations.[9] As at 2016Q1 real rents are in a high volatility regime. Although the coefficient signs meet a priori expectations they are not significant in all cases. This could be due to the lack of data.

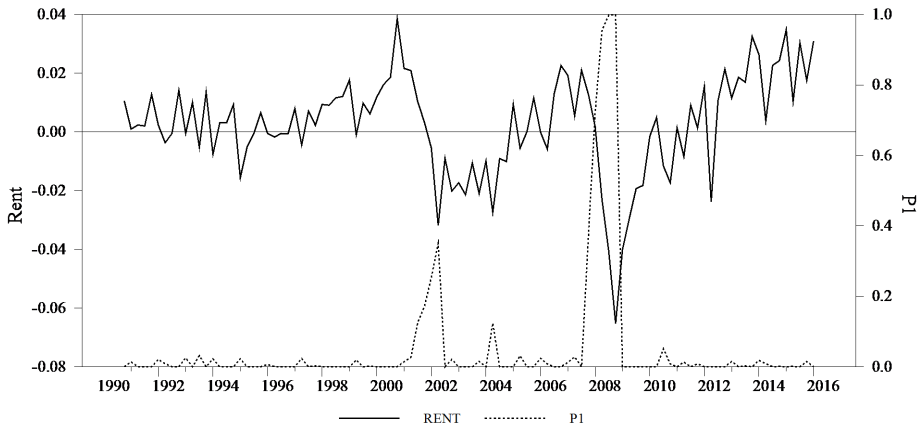
Table 3: Variance switching FTP MS-VAR

National real rents	
Variable	Coefficient
$P_{1,1}$	0.64^{**}
	(2.13)
$P_{1,2}$	0.02
	(0.52)
μ_{low}	-0.02
	(-1.47)
μ_{high}	0.01^{*}
	(1.70)

Note: This table presents estimated transition probabilities and conditional means for the low and high volatility rent regimes from the FTP MS-VAR model specified in Eqn. 4. ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. T-statistics are reported in parenthesis.

[9] For brevity, results for β_1 and β_2 and the volatility in each regime are not reported but are available from the authors upon request.

Figure 5: Smoothed probabilities of low volatility and quarterly log changes of real rents



Note: The above chart presents the smoothed probabilities estimated from Eqn. 4 (P1/dashed line) and quarterly log changes in National real rents (solid line).