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Housing Bubbles and Monetary Policy: A Reassessment

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Abstract

This study contributes to the ongoing debate over the causes of housing bubbles. The argument that excessively low interest rates were responsible for the run up in house prices over the last decade has received considerable attention in the literature. However, few papers have attempted to quantify the extent of house price overvaluation in countries that have seen housing booms and busts, in addition to quantifying the looseness of monetary policy. For a sample of 10 OECD countries, we estimate fundamental house prices using demand and supply side characteristics of the housing market. This is supplemented with analysis of price to rent ratios and fundamental price to rent ratios. Loose monetary policy is defined as the deviation of the short term interest rate from the rate which the Taylor rule would prescribe. The empirical results suggest that for some countries deviations from the Taylor rule played a role in the surge in house prices and that a monetary policy stance less discretionary and more closely aligned with a Taylor rule could curtail some of the imbalance in the housing market.

Keywords: Housing Bubbles, Taylor Rule, Monetary Policy, Interest Rates
JEL Classification: E52; E58; R31; F33

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1 Introduction

Much of the recent interest in housing bubbles has emanated from the booms and busts observed in the housing markets of a number of OECD countries. We have seen that when housing bubbles burst, they tend to plunge an economy into recession through declines in consumption and investment. This occurs firstly because homeownership comprises a large proportion of national wealth, and secondly because financial institutions lending to the residential sector tend to hold a considerable volume of mortgage related assets on their portfolios, such that house price reversals cause disruption to the financial system.

It has been argued retrospectively that periods of low interest rates create an environment conducive to the build up of imbalances in the housing sector. Interest rates influence house prices by making credit cheap and increasing the demand for houses through a number of channels. Firstly, lower interest rates reduce the opportunity cost of buying a house compared with investing in other assets. Second, a type of financial accelerator effect creates a feedback loop between house prices and interest rates as the net worth of borrowers changes in response to changes in the value of their assets. A number of studies including Iacoviello (2005) and Calza et al. (2009) have shown that a reduction in interest rates increases the value of houses by increasing the present value of future user costs, enhancing borrowers' current debt capacity and demand for housing. Studies have also shown that more developed mortgage markets amplify the effect of monetary policy on housing variables (Assenmacher-Wesche and Gerlach (2010)) and that financial innovation and securitization can exacerbate the effect of interest rates on housing market activity (Diamond and Rajan (2009)). Finally, interest rates can affect house prices through the risk taking channel, where lower rates of interest encourage financial institutions to lever up in order to achieve a target rate of return - a search for yield effect (Rajan (2005) and Borio and Zhu (2008)).

A well cited and much disputed argument for the cause of the US housing bubble is that of Taylor (2007) who asserts that the deviation of the Federal Funds rate during the 2000s from the rate implied by his 1993 monetary policy rule made housing finance cheap and attractive, leading to a bubble. This position is supported by Robert Gordon (2009, p. 6):

> It is widely acknowledged that the Fed maintained short term interest rates too low for too long in 2003-04, in the sense that any set of parameters on a Taylor Rule type function responding to inflation and the output gap predicts substantially higher short term interest rates during this period than actually occurred. These low interest rates made it particularly profitable for banks and nonbanks to make mortgage loans and to pay large fees to the mortgage brokers who originated them, and thus indirectly the Fed's interest rate policies contributed to the housing bubble.

The idea that interest rates veered too far from a Taylor type rule has frequently appeared in the literature examining the housing bubble in the US, but has been given little or no attention in the cross country literature. As Taylor points out, the Fed's loose monetary policy stance was followed by several other central banks around the world.[1] Much of the crisis literature has modelled the effect of low interest rates on house prices, both linearly and non linearly.[2] However, few papers have looked at the effect of a deviation of interest rates from a monetary policy rule on the deviation of house prices from their fundamental value. Our approach differs from previous analyses in that it looks at the co-movements of these variables from their presupposed normative or equilibrium value, as opposed to just looking at the co-movement of these variables in their observed non equilibrium state. In this way, the paper gives a contribution to the literature from a different perspective by attempting to quantify the extent of house price overvaluation in countries that have seen house price booms, and to examine Taylor's (2007) hypothesis on a cross country basis.

We apply a standard model of house prices to estimate the size of housing bubbles for each country in the sample, in addition to looking at deviations of the price to rent ratio from the estimated fundamental price to rent ratio. We estimate a series of equations which explain housing bubbles by deviations from the Taylor rule as a group by using the Seemingly Unrelated Regressions technique and independently as a Vector Autoregressive system. We report a statistically significant relationship between Taylor rule deviations and the deviation of house prices from their fundamental value. While the impact of Taylor rule deviations on housing bubbles is more pronounced over the last decade, in line with Dokko et al. (2011) we find a quantitatively small impact of monetary policy on housing bubbles, and this is in tandem with a considerable body of literature which attributes a greater role to excessive credit provision in driving the run up in house prices. While interest rates affect lending and borrowing behaviour through the channels mentioned above, it is likely that the historical relationship between interest rates and house prices became less stable over the last decade in light of exurberant behaviour observed in the global financial system. We argue that a monetary policy stance more closely aligned with a Taylor type rule could reduce some of the imbalance in the housing market, but would not be all effective on its own without being complemented by instruments of macroprudential policy.

The paper proceeds as follows. Section 2 reviews the literature on fundamental house prices and outlines the house price model. Section 3 examines price to rent and fundamental price to rent ratios for the countries in the sample. Section 4 outlines the Taylor rule and reviews the literature on the impact of Taylor rule deviations on house prices. Section 5 presents the empirical results from examining the effect of Taylor rule deviations on housing bubbles. Section 6 concludes with a brief discussion of the policy implications.

[1] This point has been emphasised more recently in Taylor (2014).

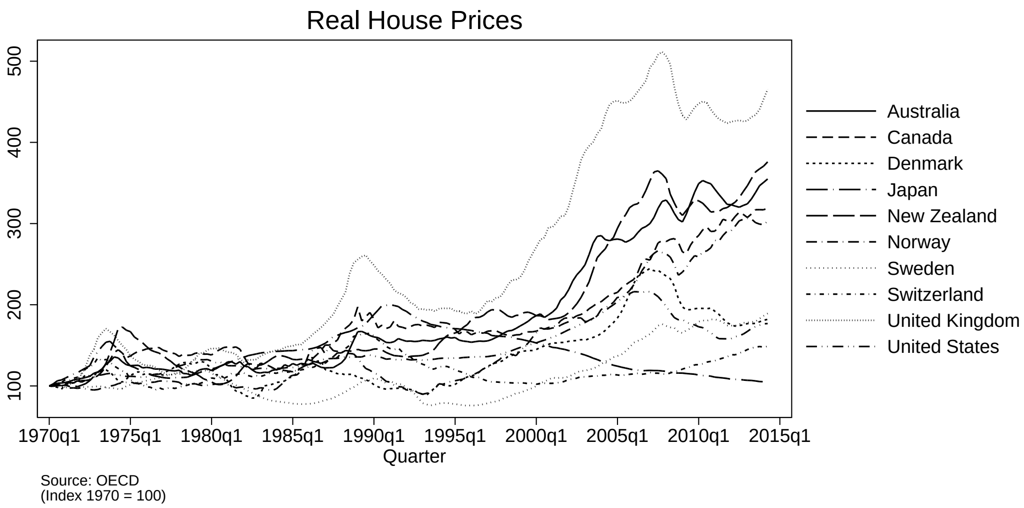
[2] See for example Ahearne et al. (2005), Goodhart and Hofmann (2008), Jarocinski and Smets (2008), Del Negro and Otrok (2007), Dokko et al. (2011) and Sá et al. (2014).

2 Fundamental House Prices

One of the classic definitions of an asset price bubble is that given by Stiglitz which states that 'if the reason the price is high today is only because investors believe that the selling prices will be high tomorrow when fundamental factors do not seem to justify such a price, then a bubble exists.' (1990, p. 3) We say that there exists a bubble when observed prices exceed those justified by fundamental factors, the latter referring to a collection of variables which we believe should drive asset prices.[3] In the present analysis, we take the term 'housing bubble' to be synonymous with house price overvaluation.

Figure 1 shows that house prices in many advanced market economies rose substantially above their previous long run trend in the last decade. In order to capture the fundamental price of housing or what house prices should have been in the absence of exuberant price inflation, it is necessary to construct a model of house prices. Economic theory suggests that factors which drive house prices should include permanent income, the user cost of housing, costs of construction, the availability of credit, and the size of the population. It is important to note that houses serve as both an investment and a consumption good; Holly and Jones (1997, p. 553) suggest that "the determination of house prices can be considered in two complementary ways: as the outcome of a market for the services of the housing stock and as an asset."

Figure 1: Real house prices 1970 - 2014



McCarthy and Peach (2002) present a model of the housing market in which the demand price of housing is determined by the housing stock, permanent income of households (proxied by nondurables and services consumption) and the user cost, while the supply price is determined by residential investment and the costs of construction. The results from a VECM show that the coefficient on consumption indicates a high long run income elasticity of housing demand, while the coefficient on user costs indicates a low long run

[3]For a very good overview of the bubble literature, see Brunnermeier and Oehmke (2012).

elasticity of housing demand.

In a similar vein, Gallin (2006) presents a supply and demand model of the housing sector, where the driving variables on the demand side include income, population, wealth and the user cost, and costs of construction and depreciation rates on the supply side. Interestingly, Gallin debunks the notion that house prices are strongly influenced by income as typically illustrated by cointegrated time series. Analysing 95 metropolitan cities in the US over 23 years, Gallin uses panel data tests for cointegration and argues that the error correction specification may in fact be inappropriate for modelling the housing sector.

Poterba (1984) expresses house prices as a function of the present value of its future net rents discounted by the home owner's real after tax interest rate. He argues that in equilibrium homeowners equate the marginal cost and benefits of the services derived from the housing which they own, where the marginal benefit is the real implicit rental price from the house, and the marginal cost is the user cost of the asset.

Himmelberg, Mayer and Sinai (2005) consider user cost to be the key determinant of house prices. They measure the cost of owning a home (user cost) by calculating the imputed annual rental cost of owning a home. 'A correct calculation of the financial return associated with an owner occupied property compares the value of living in that property for a year - the 'imputed rent' or what it would have cost to rent an equivalent property - with the lost income that one would have received if the owner had invested the capital in an alternative investment - the opportunity cost of capital.' (2005: 74) Equilibrium in the housing market occurs where the expected annual cost of ownership equates with the annual cost of renting: if ownership costs rise without a commensurate increase in market rents, house prices must fall to convince potential homeowners to buy instead of renting, and vice versa. Thus to evaluate whether house prices are too high or too low relative to fundamentals, Himmelberg et al. compare the true one year cost of owning a house (user cost) with the one year cost of renting a house. Within this framework, a bubble exists when homeowners (or potential homeowners) have unreasonably high expectations about the future value of a house relative to the current cost of ownership, causing them to pay too much for the house today.

Muellbauer and Murphy (1997) estimate a three equation model of the housing market: a demand equation which determines house prices as a function of the housing stock, real incomes and interest rates; a supply equation which determines the supply of new houses; and an equation showing how the stock of houses changes over time as new houses are completed. The house price equation is derived from the demand for housing services by inverting and rearranging the demand equation, so that the dependent variable is house prices as opposed to the quantity of housing services or the housing stock. Variants of this approach have appeared in Mankiw and Weil (1989), Poterba (1984, 1991), Meen (1990), Roche (2001) and Fitzpatrick and McQuinn (2007).

2.1 A Model of House Prices

In a similar approach to Muellbauer and Murphy (1997)[4] *inter alia* we specify demand side and supply side equations to estimate the equilibrium (fundamental) price of housing. The demand price for housing is specified as:

$$P_t^f = \alpha_t + \beta_1 y_t + \beta_2 pop_t - \beta_3 mort_t - \beta_4 supply_t + \beta_5 rent_t + \epsilon_t \tag{1}$$

Fundamental house prices (P_t^f) are a function of real disposable income per capita (y_t), the total population of the country (pop_t), the real (inflation adjusted) mortgage interest rate ($mort_t$)[5], the supply of new dwellings ($supply_t$) and the real cost of renting a property ($rent_t$). Housing supply is expected to have a negative effect on house prices, as increased supply should put downward pressure on prices, ceteris paribus. In the spirit of Himmelberg et al. (2005), a higher cost of renting should push up house prices if individuals can switch from renting to buying, all else equal. In addition, the real rental price is a good proxy for the real user cost, as in equilibrium the rental cost should equate with the user cost of housing. The residual ϵ_t in equation (1) constitutes the housing bubble - the difference between observed house prices and their estimated fundamental value ($P_t^a - P_t^f$). The focus of this paper is to examine if ϵ_t can be attributed to loose monetary policy.

The estimated supply equation is given by:

$$Supply_t = \alpha_t + \beta_1 permit_t - \beta_2 cost_t + \beta_3 rinv_t + u_t \tag{2}$$

where $permit_t$ is the number of permits issued for the construction of new housing units, $cost_t$ refers to the total cost of residential construction and $rinv$ refers to real residential investment.

The data for estimating equations (1) and (2) is quarterly and spans the period 1970Q1 to 2013Q4 for most countries. The majority of the data was obtained from the OECD Economic Outlook and Main Economic Indicators databases, as well as the IMF International Financial Statistics database, and various national sources. All relevant variables are seasonally adjusted and descriptions and sources for all data can be found in Table 9 of the Appendix.

The 10 OECD countries in the sample include: Australia, Canada, Denmark,[6] Japan, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States. We choose these countries as their monetary policy is not part of a currency union in which a single policy interest rate is confronted with very heterogenous development of house prices. For example, McQuinn and O'Reilly (2008) show that had the interest rate

[4]That is, excluding a third equation for how the stock of housing evolves over time.

[5]Where a representative mortgage rate is unavailable, we use the interest rate on 10 year government bonds, i.e. approximate long run rate.

[6]While the Danish krone is pegged to the euro and monetary policy follows that of the ECB, it is assumed here that its central bank can independently set interest rates as it did prior to joining the EMU in 1999.

in Ireland been 2% higher in 2005Q4, this would have reduced house prices by around 22%. Similarly, Honohan and Leddin (2006) show that since joining the EMU, Irish interest rates deviated substantially from various specifications of the Taylor rule over 1999-2004 and this is reported to have a lasting effect on property prices. Thus, a single policy rate may have been too low for countries like Ireland and Spain which experienced massive housing booms, but appropriate for other members of the EMU such as Germany. Therefore, we do not deem it plausible to examine if deviations from the Taylor rule were responsible for housing booms in countries whose monetary policy is administered by a central bank governing policy across a currency union, as the counterfactual scenario is unlikely to be an interest rate closer to the Taylor rule for each individual country in the union.

A log-linear specification of equation (1) relates the log of house prices to the log of all the driving variables. Note that in this specification, all variables are measured in levels (or percentages for mortgage interest rates). We find that for most countries the variables are integrated of order one (fail to reject the null hypothesis of a unit root), while the estimated residual is stationary, suggesting that there is a cointegrating relationship between the driving variables and the dependent variable. We therefore estimate error correction models for equations (1) and (2) using the method of Engle and Granger. The short run demand equation takes the form:

$$\triangle P_t^f = \alpha_t + \lambda_{t-1} + \beta_1 \triangle P_{t-1}^f + \beta 2 \triangle y_{t-1} + \beta_3 \triangle pop_{t-1} - \beta_4 \triangle mort_{t-1} - \beta_5 \triangle supply_{t-1} + \beta_6 \triangle rent_{t-1} + \epsilon_t \qquad (3)$$

where λ_{t-1} represents the error correction term, i.e. the deviation of house prices from their fundamental value - ϵ_t from equation (1). The short run supply equation is written as:

$$\triangle Supply_t = \alpha_t + \lambda_{t-1} + \beta_1 \triangle Supply_{t-1} + \beta_2 \triangle permit_{t-1} - \beta_3 \triangle cost_{t-1} + \beta_4 \triangle rinv_{t-1} + u_t \qquad (4)$$

2.2 Comparing Actual and Fundamental House Prices

The results of estimating equations (1) to (4) are presented in the Appendix, Tables 10-15. The long run models are presented in Tables 10-12, and the short run (error correction) models are presented in Tables 13-15.

We estimate the house price model (equation 1) over two time periods - 1970Q1 to 2013Q4 (Model 1) and 1970Q1 to 2000Q4 (Model 2). The latter period saw much less fluctuation in house prices for most countries, such that the relationship between prices and fundamental variables may be more stable, compared to the period from 2000 to 2008 and later, when rapid increases in mortgage lending were observed. We take the fitted values from both models and the first model can be seen as a lower bound for the extent of house price overvaluation while the second model can be seen as an upper bound (i.e.

maximum).[7]

The coefficients in the housing supply function (equation 2, Table 10) are similar across countries, with construction costs bearing a negative sign in line with the expectation that costs of constructing houses should reduce the number of new houses being built. The related short run models (equation 4, Table 13) show a negative and generally significant error correction term, but with varying sized coefficients - for example in the United States, according to the model, a supply gap corrects at 2.5% per quarter, while in Canada it corrects at 28% per quarter, all else equal. The residential investment variable becomes less significant in the short run models also.

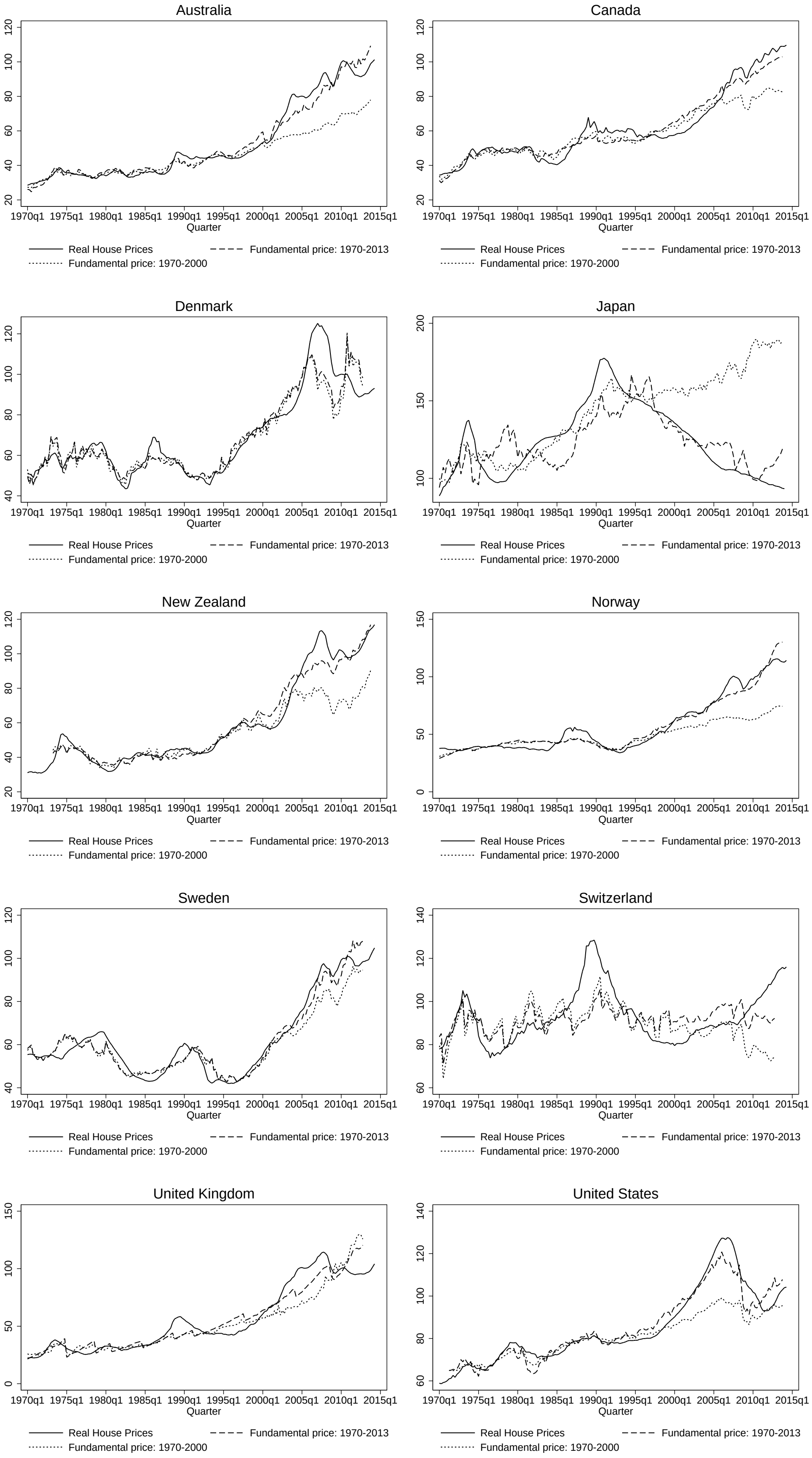
Turning to the housing demand estimates (equation 1, Tables 11 and 12), we find that most of the driving variables are statistically significant at the 1% level and have the correct signs in line with intuition. This is observed in Model 1 (1970Q1 to 2013Q4) and Model 2 (1970Q1 to 2000Q4). The income elasticity is similar in magnitude across countries: 1 for the United States, 0.87 for the United Kingdom, 1.28 for Australia and is a little higher for Sweden at 1.65. The mortgage interest rate is significant for only four countries, and while having the anticipated sign, is very small in absolute value for each country (from -0.01 to -0.001). This type of outcome has been reported and discussed previously in for example Case and Shiller (2003) and in McQuinn and O'Reilly (2008), and is a problem in reduced form models. The supply variable is highly significant and positive for most countries, which is at variance with the theoretical model. Only for some countries in Model 2 is the coefficient significant and negative, suggesting that a fall in supply should increase house prices. The R squared values average around 80%, suggesting that about 20% of observed house prices over the sample period can be attributed to non fundamental factors.

In terms of the error correction models for house prices (equation 3, Tables 14 and 15), the error correction term is significant and negative for most countries across both Model 1 and Model 2. The correction speeds to a disequilibrium in the long run relationship between house prices and the driving variables vary between 4% and 15% per quarter, with the UK showing a relatively low adjustment speed of 3% per quarter in both models.

To illustrate the types of predictions from the models, the fitted values from the two regressions are plotted in Figure 2. For nearly every country, the fitted values stay in line with the observed house prices before departing from the observed value in the post 2000 period. For the United States, Model 2 predicts a house price series closer to the long run series after 2000, suggesting that the size of the bubble was substantial. For the United Kingdom, we see a substantial deviation from fundamental value between 2001 and 2008, which is at odds with Cameron et al. (2006) who concluded that there was no housing bubble in the UK. Overall, we find that at least over the last decade, some deviations from fundamental house prices were observed, and the focal point of this paper is to try to assess of this was driven by a loose monetary policy stance.

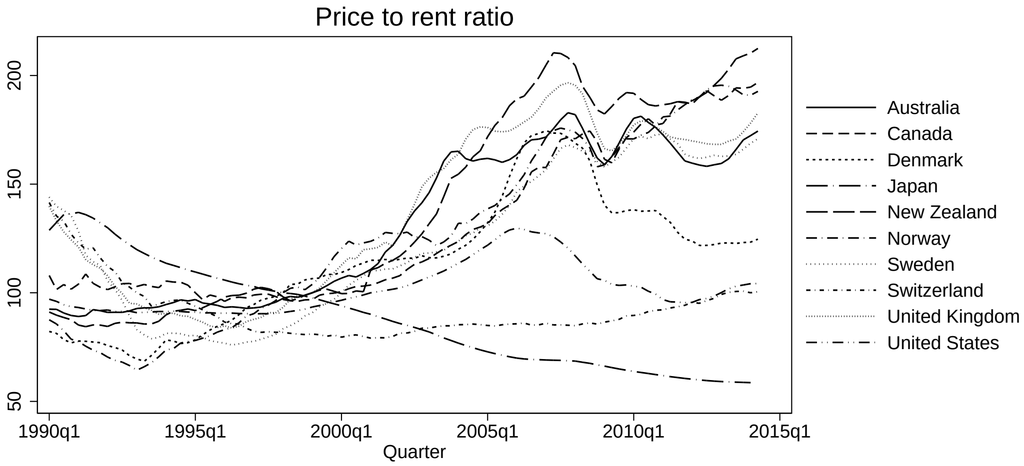
[7] As illustrated later, the second model predicts greater house price overvaluation in the period from 2000 onwards.

Figure 2: Real house prices and fundamentally implied value



3 Price to Rent Ratio Analysis

Figure 3: Price to Rent Ratio 1990 - 2013



Source: OECD
(Each series indexed to year in which that country's price to rent ratio was close to its long term average)

As discussed previously, the price to rent ratio is an important gauge of any over or undervaluation in the housing market. When house prices are high relative to current market rents, potential home buyers may find it more affordable to rent, driving demand away from home buying and thereby putting downward pressure on house prices. However, as with the modelling of fundamental house prices above, the price to rent ratio should be compared with some *fundamental* price to rent ratio. The appropriate comparator is the user cost of owning a home, which takes account of the financial and capital gains from owner-occupied housing, in addition to risk factors, tax costs and benefits and depreciation and maintenance costs (Girouard et al., 2006). An equilibrium in the housing market is reached when the user cost (or expected annual cost of owning a house) is of similar magnitude to the cost of renting a house. Any deviation of the price-to-rent ratio from the price to rent ratio based on the user cost implies some level of over or undervaluation.

The user cost of owning a home can be specified as:[8]

$$UC = P[i^{\theta} + \tau + \zeta - \pi] \tag{5}$$

where P is the house price, i^{θ} is the after tax mortgage interest rate, τ is the property tax, ζ is the maintenance costs of the house (including depreciation and a risk factor), and π is the expected increase in the price of the house. In equilibrium, the rental cost should equate with the user cost, so that the above can be re-written as:

$$R = P[i^{\theta} + \tau + \zeta - \pi] \tag{6}$$

where R is the rental cost. Rearranging equation (6) gives the equilibrium relationship

[8] Poterba (1992), Himmelberg et al. (2005) and Girouard et al. (2006, p. 21)

between the price to rent ratio (P/R) and the user cost UC:

$$\frac{P}{R} = \frac{1}{[i^{\theta} + \tau + \zeta - \pi]} \tag{7}$$

in other words,

$$\frac{P}{R} = \frac{1}{UC} \tag{8}$$

We compute the user cost of housing for each country on a quarterly basis from 1990 to 2009 using national data sources. As per Girouard et al. (2006) and André (2010), the maintenance costs ζ are set constant at 4% and the expected capital gains are computed as the five year moving-average of core consumer price inflation. The latter derives from Poterba (1992) and assumes that households expect real house prices to remain constant (such that capital gains are nominal) and as inflation expectations are backward looking, this justifies computing the expected capital gains component of user cost based on a moving average of past inflation.

Summary statistics relating to the deviation of actual price to rent ratios from their computed fundamental value are presented in the following tables. Table 1 presents summary statistics for the period 1990Q1-1999Q4 and Table 2 presents the summary statistics for 2000Q1-2009Q4.

Table 1: Summary statistics for deviation from Fundamental Price to Rent ratio 1990Q1 to 2000Q4

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Australia	10.889	13.348	-3.495	34.952
Canada	-3.668	9.884	-13.517	25.407
Denmark	-18.09	22.773	-46.756	7.672
Japan	31.761	40.988	-4.939	114.09
New Zealand	10.802	20.231	-11.302	44.701
Norway	-12.223	9.097	-21.713	13.756
Sweden	-28.114	21.723	-60.829	25.843
Switzerland	5.29	22.146	-10.442	66.06
United Kingdom	-3.876	22.868	-32.267	60.56
United States	-10.253	7.142	-24.547	1.742
N				40

As Himmelberg et al. (2005) point out, shocks to user costs (e.g. changes in interest rates or taxes) lead to predictable changes in the price to rent ratio which reflect fundamentals, not bubbles. If the user cost is 5% (i.e. the owner incurs costs of 5% of the value of the house per year), then homebuyers should be willing to pay up to 20 times (1/0.05) the market rent to buy a house: $P_t = R_t 20$. House price overvaluation or a bubble will occur where $P_t > R_t/U_t$. Himmelberg et al. also show that the real rate of interest is a key determinant of the user cost of housing: a lower rate reduces the user cost because the cost of borrowing is lower and alternative investments yield low returns.

Table 2: Summary statistics for deviation from Fundamental Price to Rent ratio 2001Q1 to 2009Q4

Variable	Mean	Std. Dev.	Min.	Max.
Australia	48.797	29.559	10.041	109.542
Canada	10.727	19.438	-11.073	47.683
Denmark	7.009	32.537	-31.321	69.431
Japan	-18.121	9.782	-33.294	-4.624
New Zealand	82.798	51.278	22.722	171.869
Norway	25.267	21.916	2.681	76.864
Sweden	3.17	12.294	-14.728	23.951
Switzerland	-10.035	2.714	-15.086	-4.526
United Kingdom	57.622	27.92	22.449	106.596
United States	4.645	9.702	-13.342	22.806
N				40

A caveat to be borne in mind with the user cost model is the assumption of low cost arbitrage between owning and renting: it is implausible to suggest that the transaction costs between renting and buying will be negligible. In addition, the model does not allow for innovations in the mortgage market such as lower origination costs which could lead to a permanent outward shift in the demand for housing if borrowers can obtain credit under less stringent conditions, which was observed in many countries over the last decade. Thus, the actual price to rent ratio is unlikely to track the fundamental ratio one for one, but can nonetheless be a useful benchmark against which to assess observed ratios.

4 Assessing the Stance of Monetary Policy

In order to assess whether monetary policy was 'loose fitting' over the sample period, we compare observed short term interest rates to those which the Taylor Rule would prescribe, this way examining the co-movement of house prices and interest rates from postulated equilibrium values. This is in contrast to previous papers in this area which have generally examined the impact of actual interest rates on house prices and other associated macroeconomic variables.[9] The standard Taylor rule takes the form:

$$i_t^* = \pi_t + r^* + \alpha(\pi_t - \pi^*) + \beta(y_t - y^*)$$

where i_t^* is the prescribed short term interest rate, π_t is the current inflation rate as measured by the core consumer price index[10], r^* is the equilibrium real rate or neutral rate, $(\pi_t - \pi^*)$ is the deviation of inflation from its target level π^*, and $(y_t - y^*)$ is the output gap - the deviation of real GDP from its potential level. When inflation is at its target and real GDP is at its potential, the short term interest rate should be equal to the

[9] For example Ahearne et al. (2005), Del Negro and Otrok (2007), Goodhart and Hofmann (2008), Jarocinski and Smets (2009) and Sá et al. (2014).

[10] We use π_t to look at what the interest rate would have been at time t and compare it to what the interest rate actually was at time t. When setting interest rates, central banks use $E_t\pi_t$, i.e. forecast values of inflation at time t.

real rate plus current inflation: $i_t^* = \pi_t + r^*$. The rule prescribes an adjustment of the interest rate when either inflation or real GDP are off target: the rate should be increased if inflation or output is above target and it should be decreased if inflation or output is below target. The rule adheres to the Taylor Principle - which argues that policymakers should adjust the (short run) nominal rate more than one for one with an increase in inflation relative to target. Such a response ensures that the real rate rises when inflation goes up so that monetary policy 'leans against inflationary pressures.'

We define loose monetary policy as the deviation of the observed short term interest rate from the rate which the Taylor rule would prescribe i.e. $i_t - i_t^*$. In order to test the hypothesis that deviations of short term interest rates from the Taylor rule contributed to or exacerbated the deviation of house prices from their fundamental value, it is necessary to compute Taylor rules for each country. The sample time scale spans 1981Q1 to 2008Q4. Despite having sufficient data to extend the sample period back to 1970Q1, the period prior to 1981 is abstracted from due to the volatility of inflation in many industrialised economies. The data used is the latest vintage as opposed to real time data available when policymakers set the rate - the key point is to assess the impact of monetary policy in retrospect rather than evaluate whether policy was appropriate at a particular point in time. We estimate potential output y^* by applying a Hodrick-Prescott filter to real GDP, and as the data is quarterly we set λ = 1,600 as advocated by Ravn and Uhlig (2002). The equilibrium real rates r^* are given by each country's respective estimate of the trend growth of potential real GDP. This allows the real rate to vary over time. Both α and β are set equal to 0.5 as per Taylor's (1993) original specification.[11] These coefficients are selected to give an indicative estimate of what the Taylor rule would prescribe.

For simplicity it is assumed that central banks pursued the same inflation objectives in the 1980s and 1990s as they do today even though inflation was higher in those decades than in the 2000s. Inflation targets are selected on the basis of central bank press releases and official documentation; for example, we select 2% for the United States following the announcement by Bernanke in 2012 of an official Federal Reserve inflation target of 2%. The 2% target for Denmark is the rate targeted by the European Central Bank according to its website[12] and the UK target is given on the Bank of England website.[13]

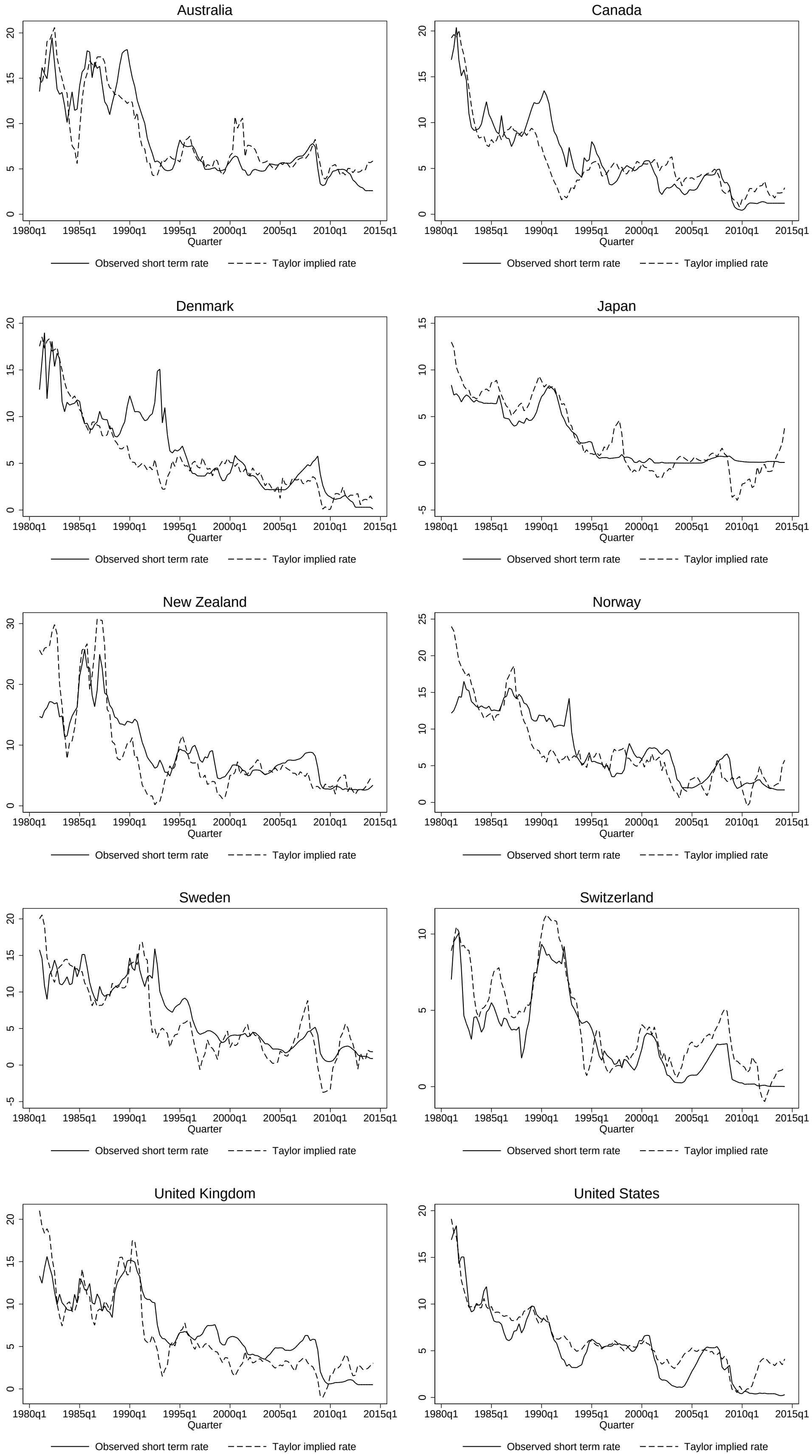
The Taylor rule and the observed short term interest rates are plotted in Figure 4 below. Sizeable deviations are found for some countries, including the United Kingdom, Norway, Sweden and Australia. The graph for the United States is similar to that presented in Taylor (2007). It is clear that over the sample period, there have been incidents of both overly tight and overly loose monetary policy relative to the Taylor rule and in this way we capture the effect of both stances on housing bubbles.

[11] Other specifications include Ball (1999) who suggests that the interest rate should be adjusted more aggressively in response to changes in output and Taylor (1999) who suggests setting β equal to 1, which would indicate greater weight on the output gap.

[12] http://www.ecb.int/mopo/html/index.en.html

[13] http://www.bankofengland.co.uk/monetarypolicy/Pages/framework/framework.aspx

Figure 4: Observed short term rate v. Taylor implied rate, with α and $\beta = 0.5$



4.1 Taylor Rule Deviations and Housing Bubbles

Taylor (2007, 2008) argues that the U.S. housing bubble can be attributed to the deviation of interest rates from his 1993 monetary policy rule, and shows that the Federal Funds rate in the United States was substantially below the rate which the Taylor rule would prescribe during the period 2001-2006.[14] Taylor contends that despite mass securitization and deregulation of deposit rates, the effect of the Federal funds rate on house prices has not diminished since the halcyon days of the Great Moderation. By estimating a simple housing starts equation using quarterly data from 1959-2007 with the Funds rate as an explanator, Taylor (2007) shows that there is a statistically significant effect of the funds rate on housing starts which occurs with a lag. A counterfactual simulation with the Taylor rate substituted for the Funds rate over the last decade shows that had the funds rate followed the Taylor rate, the housing boom would have been less excessive while the subsequent bust would have been less severe.

Kahn (2010) examines the relationship between Taylor rule deviations and financial indicators for the US economy, including stock prices, house prices, leverage and commodity prices and finds that the strongest and most robust relationship is between Taylor rule deviations and house prices. 'With 20/20 hindsight, lagged Taylor rule deviations appear to help predict the housing bubble and, to a lesser extent, commodity price movements. All three variants of the Taylor rule deviations helped predict home price growth and the home price-to-rent ratio.' (2010, pp. 87)

Ahrend et al. (2008) also find a close relationship between negative deviations from the Taylor rule and several measures of housing market buoyancy (mortgage lending, investment in housing construction and house prices) for most OECD countries in the last decade. The major cases were the United States (2001-2006), Canada (2001-2007), Norway (2004-2007), Denmark (2001-2004) and Australia (2000-2003).

Hott and Jokipii (2012) look at the impact of Taylor rule deviations on house price overvaluation for a number of countries in the EMU. They report a strong statistical link for most countries and show that a prolonged period of low interest rates has a commensurately higher impact on house prices. In our analysis, we do not look at countries in a currency union as the counterfactual outcome is unlikely to be an optimal interest rate (i.e. interest rates more in line with a Taylor rule) for each country in the union.

In its Fall 2009 World Economic Outlook, the IMF examined the relationship between deviations from Taylor rules during 2002 and 2006 and the rise in house prices in a large sample of countries, and report negative but weakly statistically significant correlations between the two.

Bernanke (2010) highlights that the Taylor rule implies that monetary policy should use currently observed values of inflation and the output gap (i.e. in the same quarter as

[14] *The Economist* (2007) similarly notes that "By slashing interest rates (by more than the Taylor rule prescribed), the Fed encouraged a house-price boom which offset equity losses and allowed households to take out bigger mortgages to prop up their spending."

the policy decision is made); however, monetary policy works with a lag such that policy must be forward looking and take into account the forecast values of the target variables. This effectively means that Taylor rules do not distinguish between increases in inflation expected to be temporary or long lasting, for example changes in energy prices. Using real time forecasts and the PCE index, Bernanke illustrates that in fact the Federal funds rate followed a simple policy rule throughout the 2000s.[15] Bernanke argues that only small increases in house prices can be attributed to monetary policy and that a potential reason for the stronger *effect* of monetary policy on house prices in recent times could be the fact that the policy rate feeds through to some mortgage rates which are based on short term rates. Bernanke simulates the effect of an interest rate in line with the original Taylor (1993) rule using the Fed's principal macroeconometric model, and shows that during 2003 and 2004, adjustable rate mortgages would have only been 0.71 percentage points higher, with the associated monthly payment for a borrower only $75 higher, all else equal.

5 Empirical Results and Discussion

Having discussed the relevant literature and the estimation of fundamental house prices, we now attempt to empirically test the proposition that deviations of short term interest rates from the Taylor rule contribute to or are significant determinants of housing bubbles. We estimate a series of equations which explain housing bubbles by deviations from the Taylor rule using the Seemingly Unrelated Regressions technique and independently as a Vector Autoregressive (VAR) system.

5.1 Basic Model

The baseline regression for analysing the impact of deviations from the Taylor rule on housing bubbles takes the form:

$$P^a_{jt} - P^f_{jt} = \delta + \beta_1 TRdev_{jt} + \epsilon_{jt} \tag{9}$$

where P^a_{jt} is the log actual house price observed (for country j at time t) and P^f_{jt} is the log fundamental value (as estimated in equation (1)), so that $P^a_{jt} - P^f_{jt}$ is the bubble - the difference between fundamental and actual house prices (i.e. ϵ_t from equation (1)); δ is a constant term; and β_1 is the coefficient on the deviation from the Taylor rule ($TRdev$). We measure $P^a_{jt} - P^f_{jt}$ in terms of the percentage deviation of actual house prices from the fundamental value predicted by the models. This way both the dependent and independent variables are in percentage form, while the deviation of the actual price to rent ratio from the fundamental price to rent ratio is also measured in terms of percentage deviations. The vectors of deviations for each variable contain both positive and negative values - there have been periods of house price undervaluation and periods where monetary policy has

[15] Taylor (2007) rebuts this stance by asserting that the Fed's forecasts of inflation were too low during this period.

been overly tight relative to a Taylor rule. We would expect $TRdev$ to have a positive effect on $P^a_{jt} - P^f_{jt}$ in line with Taylor's (2007) argument. Equation (9) rests on the assumption that deviations from the Taylor rule are exogenous to housing bubbles. This assumption is relaxed in section 5.2.

While equation (9) can be estimated separately for each country, it is not implausible to suggest that the error terms across equations are contemporaneously correlated. Often macroeconomic shocks are common across countries and an example relevant to our discussion was made by Taylor (2007) who showed that deviations from the Taylor rule by the Federal Reserve were correlated with deviations from the Taylor rule by the European Central Bank. Thus, loose fitting monetary policy in one country may cross borders into another country.

The Seemingly Unrelated Regressions (SUR) estimator estimates all equations as a group and improves efficiency when the error terms across equations are correlated. Unlike fixed effects and random effects panel data estimation whose large sample justification is based on "small T, large N" datasets where N tends to infinity, the SUR estimator is based on the large sample properties of "large T, small N" datasets in which T tends to infinity, so it may be considered a multiple time series estimator. The error series is assumed to have mean zero and an NT $\times$ NT covariance matrix of Ω. Our dataset contains a balanced panel and each variable relates to a specific country (i.e. deviations from Taylor rules are different for each country) so that regressors are different across equations. The SUR requirement that T exceed N so that Ω is of full rank and invertible is therefore fulfilled. We assume the errors are correlated across equations but not within an equation, i.e. $\mathrm{E}[\epsilon_{it}\epsilon_{js}] = \sigma_{ij}$ for $t = s$. The efficient estimator is Generalised Least Squares and where the level of correlation between residuals is high and the level of correlation across X variables is low, there is an efficiency gain in using GLS as opposed to OLS. The correlation between the residuals can be tested using the Breusch Pagan test of independence where the null hypothesis is zero contemporaneous covariance between the errors of the equations.[16] Sizeable correlations in the errors (both negative and positive) are found, and therefore the null hypothesis of zero contemporaneous covariance is rejected, making our choice of the SUR estimator appropriate.

5.1.1 Estimation results

Tables 3 to 5 below present the estimates of equation (9) using our three measures of housing bubbles based on Model 1, Model 2 and the fundamental price to rent ratios. In general, $TRdev$ is statistically significant at the 1% level for each country. In Table 3, where we use Model 1 for estimating house price overvaluation, Taylor rule deviations are significant for all countries except the United Kingdom. For example, for the United States, a 1% deviation from the Taylor rule implies that house prices will be overvalued by about

[16] $\lambda_{LM} = T \sum_{N}^{i=2} \sum_{i-1}^{j=1} r^2_{ij}$.

1.24%. However, the R squareds do not attribute much explanatory power to the models, ranging from 1% to 20% and this suggests that $TRdev$ is only a small driver of house price overvaluation. This is similar to the finding earlier when estimating fundamental house prices that interest rates have a small and weakly significant impact on house prices.

Using Model 2 yields similar outcomes. In this case, $TRdev$ is not significant for the United States, and only significant at the 10% level for the United Kingdom. The R squareds are also generally lower for each country with the exception of Sweden. Recall that Model 2 gives an upper bound for the magnitude of house price overvaluation. This suggests that Taylor rule deviations have limited explanatory power in explaining our upper bound estimate of the housing bubble.

Using the deviation of the price to rent ratio from its fundamental value as our measure of house price overvaluation (Table 5), we find that Taylor rule deviations are significant for most countries, but as before the low magnitude of the R squareds points toward their limited explanatory power, an exception being Denmark where the model accounts for 18% of housing overvaluation. The coefficients are considerably bigger for each country, for example, for the United States, a 1% deviation from the Taylor rule suggests that house prices will be overvalued (with respect to price to rent ratios above fundamental ratios) by about 2.5%.

Taken together, these preliminary results suggest that Taylor rule deviations played a role in house price overvaluation for most of the countries in the sample, as evidenced by the statistical significance of the key variable, but have economically insignificant meaning based on the low explanatory power of the SUR models. Indeed, these findings are not out of line with other research in the literature cited previously that has looked at the relationship between actual interest rates and housing variables. For the case of the United States, these findings provide some limited support for Taylor's (2007) hypothesis, as across the three models, $TRdev$ is reported to explain only between 1% and 10% of house price overvaluation for the US, depending on the measure of the latter used.

Table 3: SUR estimation of Equation (9) 1981Q1-2012Q4 using deviation from Model 1

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	0.890***	1.759***	0.333*	-1.825***	0.332***	0.623***	-0.478***	1.470***	0.265	1.244***
	(0.177)	(0.191)	(0.192)	(0.349)	(0.107)	(0.196)	(0.164)	(0.354)	(0.302)	(0.252)
Constant	0.485	-0.635	-0.0276	2.692***	0.516	0.421	0.574	3.258***	1.897	1.150**
	(0.632)	(0.714)	(0.863)	(0.884)	(0.723)	(0.875)	(0.599)	(1.149)	(1.392)	(0.526)
Observations	128									
R^2	0.099	0.197	0.010	0.103	0.036	0.090	0.085	0.005	0.000	0.107

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: SUR estimation of Equation (9) 1981Q1-2012Q4 using deviation from Model 2

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	1.204***	1.092***	0.817***	-3.693***	0.466***	0.776***	-0.389**	1.620***	0.701*	0.00438
	(0.226)	(0.236)	(0.239)	(0.459)	(0.129)	(0.260)	(0.165)	(0.403)	(0.398)	(0.206)
Constant	12.73***	3.396***	0.807	-13.37***	9.055***	14.77***	3.892***	7.322***	7.361***	6.031***
	(1.611)	(1.074)	(0.962)	(1.415)	(1.479)	(2.052)	(0.745)	(1.372)	(1.757)	(0.901)
Observations	128									
R^2	0.012	0.003	0.001	0.268	0.014	0.015	0.046	0.024	0.025	0.000

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: SUR estimation of Equation (9) 1990Q1-2009Q4 using deviation from fundamental P/R ratio

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	1.511***	0.977***	-3.122***	-3.915***	0.254	1.607***	-1.924***	-1.330**	1.734***	2.560***
	(0.539)	(0.246)	(0.409)	(0.864)	(0.566)	(0.436)	(0.453)	(0.548)	(0.612)	(0.481)
Constant	30.07***	2.984	-0.891	7.129*	46.27***	4.620	-9.529***	-3.376*	23.71***	-0.936
	(3.291)	(1.866)	(3.085)	(4.144)	(5.976)	(2.843)	(2.408)	(1.929)	(4.581)	(1.294)
Observations	80									
R^2	0.007	0.023	0.185	0.059	0.003	-0.017	0.166	0.037	0.001	0.003

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.1.2 Estimating the model over sub sample time periods

We perform a robustness check on the preceding analysis by splitting the sample period into the decades from 1981Q1 to 2000Q4 and from 2001Q1 to 2012Q4 (2001Q1 to 2009Q4 for price to rent ratios) to examine if the relationship with $TRdev$ is consistent through time. The results of these regressions are reported in Tables 16 to 21 of the Appendix.

Taking first the period up to 2000Q4, the variable of interest $TRdev$ is significant at the 1% level for most countries, as before. The coefficients are of similar magnitude, for example, in the case of Canada, using fundamental house price Model 1, a 1% deviation from the Taylor rule pushes house prices above their fundamental value by about 1.27% (Model 1) or 1% (Model 2). However, the SUR models now have greater explanatory power, with $TRdev$ accounting for 19% of house price overvaluation for Australia using Model 1 and 30% using Model 2. In addition, for the United States, a 1% deviation from the Taylor rule accounts for a 5% deviation of the price to rent ratio from its fundamental ratio. The R squared values are also higher for the US, ranging from 6% to 60%.

Turning to the more recent period from 2001Q1 onwards, the outcomes are generally similar, but for some countries the coefficients on $TRdev$ and the explanatory power of the regressions are increased. Using Model 1, a 1% deviation from the Taylor rule is found to push US house prices above their fundamental value by 3%. For Australia, Switzerland, United Kingdom, and the United States the R squared values increase across all three measures of house price overvaluation. Using the fundamental price to rent ratio metric, a 1% deviation from the Taylor rule leads to a 1.8% house price overvaluation for Switzerland, and for the United Kingdom the response is 7%. We find a fairly limited impact of $TRdev$ on housing bubbles for Japan, Norway and Sweden.

The results are consistent in terms of statistical significance, but the fluctuating size of the R squareds would suggest that Taylor rule deviations have affected house price overvaluation differently through time. Estimating equation (9) over the full sample time period points towards a limited impact of loose monetary policy on housing bubbles, whereas estimating it over the pre and post 2000 periods show results that vary substantially and that in the more recent period, the explanatory power of the models is higher for most countries. The link between Taylor rule deviations and housing bubbles is undisputed, and the robustness tests have served to highlight that in the more recent period, monetary policy may have played a greater role in house price overvaluation for some countries including Australia, Denmark, Switzerland, the United Kingdom and the United States. This finding can be reconciled with previous literature which has shown that while monetary policy was loose in the early years of the 2000s for many OECD countries, at the same time credit provision, in terms of quantities of mortgages lent, increased significantly. Thus, while it would be tempting to conclude that over the last decade house price overvaluation can be linked one for one with loose monetary policy, given that a quantitatively strong relationship between housing bubbles and Taylor rule deviations is not observed over the whole sample period (1981Q1 to 2012Q4), we would argue that monetary policy may have been only one factor against the backdrop of an era of excess credit provision.

5.1.3 Comparing the results with previous literature

From the previous results and robustness tests, the analysis points towards a fairly limited impact of loose monetary policy on housing bubbles over the whole sample period, with a quantitatively higher impact observed in the post 2000 period for most countries. It is important to contextualise these findings in light of similar studies and try to explain the limited role of monetary policy in driving housing bubbles. This has been shown in previous literature which has examined the impact of interest rates on house prices, one of the most comprehensive of which is Dokko et al. (2011). The latter presented a number of Granger causality tests that pointed towards a statistically significant link between the nominal policy rate and housing market variables in nine of the fourteen countries in the sample. However, conditional forecasting using a seven variable VAR for each country from 2003-2008 ascribed a modest role of monetary policy to the recent boom in house prices. Dokko et al. (2011) argue that lending behaviour and the provision of excess credit played a more influential role in the run up in house prices during this period. Among the factors driving excess credit provision included adjustable rate mortgages, mortgages with exotic features, securitization and lending by non bank financial institutions. Furthermore, a feedback loop between mortgage credit and house prices emerged in many countries, where consistent house price appreciation induced greater mortgage lending and greater demand for housing and hence higher house prices.[17]

The role of credit also counters the open economy or 'saving glut' argument that excessive flows of capital in the early 2000s from emerging to advanced market economies were responsible for the run up in house prices. For example, Borio and Disyatat (2011) address the argument that current account surpluses of emerging economies fuelled credit booms and risk taking in advanced economies through the impact on long term interest rates.[18] They show that simply examining inflows of capital to an economy, along with the use of the saving investment framework to explain interest rates does not allow one to infer that excess savings among emerging economies underpinned the financial crisis. Rather, the monetary and financial systems in advanced economies failed to prevent the build up of excess credit due to their 'excess elasticity' or lack of sufficiently strong anchors that could restrain credit and asset booms. Borio and Disyatat call for greater appreciation that monetary economies are centred around credit creation, the financing of which can be endogenous regardless of the underlying real resources.

[17]See for example Keys et al. (2009), Diamond and Rajan (2009), Mayer et al. (2008) and Mian and Sufi (2009).

[18]See for example Bernanke (2005) and Warnock and Warnock (2009).

5.2 Vector Autoregression Analysis

We estimate a series of reduced form vector autoregressions in order to account for dynamic relationships between the variables and possible endogeneity of the explanatory variables. In the case of interest rates and housing bubbles, it is wholly possible that interest rates affect housing bubbles while housing bubbles also affect interest rates. For example, it is no coincidence that in 2005 Alan Greenspan, former Chairman of the Federal Reserve, referred to 'froth' in the US housing market at the same time that interest rates were increased by 200 basis points. Furthermore, as house prices rise, consumption and investment increase through the wealth effect and Tobin's Q effect, leading to increases in economic activity and the price level. This is an example of a feedback loop such that neither variable is strictly exogenous to the other. It is therefore necessary to relax the previous assumption of $TRdev_t$ being exogenous to $P^a_{jt} - P^f_{jt}$.

In addition, we need to take account of dynamic relationships between the variables, where for example a one basis point increase in $TRdev$ may affect $P^a_{jt} - P^f_{jt}$ two or three quarters in the future, as opposed to in the same quarter as the increase. By estimating a VAR for each country in the sample, we can simultaneously account for these factors.

The estimated VARs are of the form:

$$AP_t = \Gamma + BP_{t-1} + \epsilon_t \tag{10}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} (P^a_t - P^f_t) \\ TRdev_t \end{bmatrix} = \begin{bmatrix} \gamma_{10} \\ \gamma_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & b_{11} \\ a_{21} & b_{22} \end{bmatrix} \begin{bmatrix} (P^a - P^f)_{t-1} \\ TRdev_{t-1} \end{bmatrix} \tag{11}$$

where as before $(P^a_t - P^f_t)$ is the housing bubble; $TRdev_t$ is the deviation from Taylor rule; γ are vectors containing a constant; e are independent and identically distributed disturbance terms with mean zero, variance σ and no serial correlation between e_t and e_{t-1}.

Lags vary by country and lag lengths are selected on the basis of AIC, HQIC and LR statistics and inspection of the autocorrelation and partial autocorrelation functions. We assume that no contemporaneous interactions can occur - that any effect from $TRdev_t$ on $(P^a_t - P^f_t)$ happens in the next quarter as opposed to the current quarter - this assumption is reasonably plausible as monetary policy occurs with a lag. Our interest lies in the Granger causality tests, where x_t is said to Granger cause y_t if a model

$$y_t = a + \sum_{i=1}^{m} \gamma_i B^i y_t + \sum_{i=1}^{m} \delta_i B^i x_t + e_t \tag{12}$$

has a lower error sum of squares than a model that restricts $\delta_i = 0$ for i = 1,.....m, where B is the lag operator defined such as $B^i x_t = x_{t-i}$. To test for Granger causality, the lag m must be sufficiently long so as to remove all significant autocorrelation in e_t.

Granger causality tests are presented in Tables 6 to 8 below using our three measures of house price overvaluation from Model 1, Model 2 and the fundamental price to rent ratio. Across each measure of house price overvaluation, the countries for which $TRdev$ is said to *Granger cause* $P_t^a - P_t^f$ are New Zealand, Sweden, and the United States, where the p values on the null of no Granger causality reject at the 1%, 5% and 10% levels respectively. These findings are similar to before, but combining the VAR analysis with the previous SUR analysis fortifies the case for a role, albeit economically insignificant, of loose monetary policy driving house price overvaluation in these countries. For the other countries, the evidence of Granger causality between housing bubbles and $TRdev$ varies by the measure of the housing bubble, which hinders the ability to make draw sound inferences. As expected, there is very little evidence of causality in the opposite direction, i.e. from $P_t^a - P_t^f$ to $TRdev$.

Table 6: Granger causality tests: Taylor rule deviations and housing bubbles (Model 1)

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.319	0.935
Canada	0.725	0.149
Denmark	0.016	0.541
Japan	0.069	0.456
New Zealand	0.001	0.074
Norway	0.474	0.049
Sweden	0.038	0.012
Switzerland	0.004	0.747
United Kingdom	0.176	0.002
United States	0.016	0.679

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

Table 7: Granger causality tests: Taylor rule deviations and housing bubbles (Model 2)

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.026	0.500
Canada	0.619	0.670
Denmark	0.809	0.458
Japan	0.240	0.261
New Zealand	0.007	0.205
Norway	0.477	0.791
Sweden	0.007	0.044
Switzerland	0.012	0.691
United Kingdom	0.153	0.087
United States	0.002	0.933

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

Table 8: Granger causality tests: Taylor rule deviations and housing bubbles (Fundamental price to rent ratio)

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.186	0.792
Canada	0.065	0.186
Denmark	0.000	0.984
Japan	0.616	0.541
New Zealand	0.012	0.881
Norway	0.045	0.421
Sweden	0.000	0.003
Switzerland	0.226	0.019
United Kingdom	0.753	0.093
United States	0.040	0.289

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

As before, we also estimate each VAR over the sub sample time periods 1981Q1 to 2000Q4 and 2001Q1 to 2012Q4 (1990Q1 to 2000Q4 and 2001Q1 to 2009Q4 for the fundamental price to rent ratio measure of overvaluation). The Granger causality tests are presented in Tables 22 to 27 of the Appendix. We find that $TRdev$ is consistently significant for only New Zealand and Sweden, and for the other countries we fail to reject the null of no causality depending on the time period and the measure of house price overvaluation. In the post 2000 period, we reject the null for the United States across all three measures, and this provides some tentative support for Taylor (2007). There is also some evidence for causality for Australia, Japan and Norway in the recent period. Interestingly, there is some evidence for causation in the opposite direction (i.e. from Taylor rule deviations to housing bubbles) in the post 2000 period for Denmark, Canada, the United Kingdom and the United States.

For some countries, a monetary policy stance that is less discretionary and more closely aligned with a Taylor rule could potentially reduce some of the overvaluation in the housing markets of these countries. However, in line with previous literature, it is important to qualitatively highlight the role which loose credit conditions in addition to monetary policy may have had in driving housing bubbles over the last decade. This would imply that while a monetary policy stance closer to a Taylor rule could trim some of the overvaluation in housing markets, this would probably need to be complemented with instruments of macroprudential policy.

6 Conclusions

In this paper, we have attempted to give an updated assessment of the impact of monetary policy on housing bubbles. In doing so, we have examined the argument that a run up in house prices can be attributed to excessively low interest rates. This paper contributes to the literature by attempting to assess this argument by firstly quantifying the extent of overvaluation in countries that have seen booms and busts in their housing markets, and by addressing the interest rates question by looking at the deviation of observed rates from a representative rule. The latter involved testing an hypothesis put forth by Taylor (2007).

We tried to quantify the extent of house price overvaluation in 10 OECD countries over the past three decades by specifying a house price model and taking the residual from this model as the deviation of house prices from their fundamental value, or in other words, the housing bubble. In addition, we examined price to rent ratios and fundamental price to rent ratios for each country, and the respective deviation of the former from the latter. Having estimated the housing bubble for each country and the deviation of short term interest rates from a standard Taylor rule, we estimated a series of equations which explain housing bubbles by deviations from the Taylor rule as a group using the Seemingly Unrelated Regressions technique and independently as a Vector Autoregressive (VAR) system.

The SUR analysis showed that Taylor rule deviations were statistically significant across countries and across time. However, the explanatory power of the models and the size of the coefficients varied by country and particularly over sub sample time periods. In the recent post 2000 period, we report a quantitatively higher impact of Taylor rule deivations on housing bubbles, based on the size of the coefficients and the R squareds of the models. The VAR analysis presented mixed results and pointed toward a role for loose monetary policy in driving housing bubbles for only a small number of countries. In the post 2000 period, we reported Granger causality for Australia, Japan, Norway and the United States.

The empirical findings align with the literature despite addressing the question from a different angle. The finding that Taylor rule deviations are generally significant in explaining house price overvaluation for the United States provides some tentative evidence in favour of Taylor's (2007) hypothesis. It could be argued however, in line with Dokko et al. (2011), that housing bubbles over the last decade can be attributed to excess credit provision and less so to the looseness of monetary policy. Previous studies have shown that low interest rates can exacerbate the impact of interest rates on credit provision through the financial accelerator and risk taking channels. Thus, while we can agree that excess lending to the residential sector during the last housing bubble was a key driver of house price overvaluation, it could be argued that loose monetary policy helped to create an environment conducive to excess mortgage lending. The latter is evidenced through the quantitatively higher impact of Taylor rule deviations on housing bubbles reported in the present analysis.

From a policy persective, the concern surrounds the effect of a housing bust on the real economy and the fiscal costs of containing a financial crisis. Our emphasis in this work has therefore been on the ex ante conditions which lead to housing market bubbles and the policy implications apply to actions a central bank or government can take to pre-emptively mitigate the fallout from a collapse in house prices. Our assessment of the impact of Taylor rule deviations on housing bubbles leads one to argue that there is some scope for stricter adherence to a Taylor type rule to restrain some of the imbalance in housing markets. However, the literature argues against targeting asset prices and asset market bubbles given the likely negative impact on other macroeconomic variables. For example, by trying to restrain booms in house prices, a higher short term interest could well induce a rise in unemployment. For this reason, macroprudential tools, including loan to value and loan to income ratios as well as capital buffers, have been reported to be more effective in curbing exuberance in housing markets by disciplining both banks and borrowers. It would be interesting to look at how deviations from the Taylor rule affected securitization and financial innovation which has been shown to enhance the transmission mechanism from monetary policy to house prices. Furthermore, a Taylor rule which targets the housing market could prescribe an interest rate that is in synchrony with activity levels in that market, and this is a potential avenue for further research.

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Appendix

Table 9: Data Description and Sources

Variable	Description	Source
Real House prices (P_t^a)	Index	OECD House Price Database[19]
Income (y_t)	Real disposable income per capita[20]	OECD EO
Population (pop_t)		Penn World Tables
Real Mortgage rate ($mort_t$)	Fixed rate deflated by CPI ($r = i - \pi$)[21]	IMF IFS
Rent ($rent_t$)	Rent component of CPI; index	OECD MEI
Supply ($supply_t$)	Number of new dwelling units constructed	OECD MEI and national sources
Permits ($permit_t$)	Permits issued for construction of dwellings and residential buildings	OECD MEI
Construction costs ($cost_t$)	Total cost of residential construction; index	OECD MEI
Real residential investment ($rinv_t$)	Gross fixed capital formation (housing) deflated by associated deflator	OECD MEI
Price to rent ratio	Ratio of nominal house prices to rent component of CPI; index	OECD MEI
Fundamental price to rent ratio	Equation (7)	OECD MEI and national sources
GDP		OECD EO
Inflation (π_t)	Core CPI (PCE Index for US)	OECD EO
Short term interest rates (i_t)		IMF IFS

[19]Kindly made available by Christophe André.

[20]Where unavailable sufficiently far back in time, real GDP per capita is used.

[21]Where unavailable, long run rate on government bonds is used.

Table 10: Equation (2) Housing Supply 1970Q1-2013Q4

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	United Kingdom	United States
$permit_t$	0.891***	0.321***	0.714***		0.850***				0.879***
	(0.0247)	(0.0268)	(0.0647)		(0.0322)				(0.0673)
$cost_t$	0.0703***	-0.748***	-0.173***	0.199***	-0.0163	-1.346***	0.596***	-0.0731	2.553***
	(0.0127)	(0.0748)	(0.0648)	(0.0485)	(0.0123)	(0.0670)	(0.0973)	(0.0786)	(0.0633)
$rinv_t$	0.0454***	1.189***	0.267***	0.922***	0.141***	1.130***	0.883***	0.455***	-0.237***
	(0.0126)	(0.0366)	(0.0509)	(0.0452)	(0.0432)	(0.0495)	(0.0450)	(0.0707)	(0.0908)
Constant	0.911***	-25.64***	-4.418***	-16.77***	-0.905	-22.57***	-14.25***	-0.867	23.76***
	(0.336)	(1.045)	(1.000)	(1.407)	(0.779)	(1.339)	(1.208)	(1.852)	(2.208)
Observations	178	178	178	178	130	178	178	145	176
R^2	0.921	0.862	0.855	0.757	0.946	0.641	0.806	0.547	0.919

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Equation (1) Fundamental House Prices 1970Q1-2013Q4 (Model 1)

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
y_t	1.286***	1.096***	0.168	0.704**	0.106	0.0828	1.657***	0.781***	0.873***	1.002***
	(0.117)	(0.166)	(0.102)	(0.276)	(0.0878)	(0.0564)	(0.166)	(0.168)	(0.100)	(0.208)
pop_t	-0.422	0.443*	9.211***	-12.74***	4.031***	6.825***	-0.0899	-1.373***	5.837***	-2.261***
	(0.426)	(0.268)	(0.683)	(2.151)	(0.183)	(0.404)	(0.689)	(0.407)	(0.856)	(0.461)
$mort_t$	-0.00999***	-0.00452	-0.00490	0.00553	-0.00318	-0.00276	-0.0137***	-0.0282***	-0.000531	-0.0122***
	(0.00224)	(0.00576)	(0.00362)	(0.00476)	(0.00215)	(0.00460)	(0.00338)	(0.00518)	(0.00369)	(0.00297)
$supply_t$	0.352***	0.105***	0.308***	0.532***	0.198***	0.405***	0.160***		0.0876	0.184***
	(0.0409)	(0.0329)	(0.0292)	(0.0590)	(0.0303)	(0.0483)	(0.0258)		(0.114)	(0.0243)
$rent_t$	-0.0846	-0.285***	-0.0799**	1.736***	-0.164***	-0.186***	-0.142***	0.143**	0.0384	-0.0599
	(0.0619)	(0.0881)	(0.0397)	(0.244)	(0.0251)	(0.0586)	(0.0376)	(0.0607)	(0.0638)	(0.0620)
Constant	-26.95***	-33.15***	-142.4***	205.0***	-59.03***	-103.8***	-41.38***	17.03***	-110.1***	14.87***
	(4.255)	(3.443)	(10.17)	(33.92)	(2.145)	(5.934)	(7.552)	(5.292)	(14.36)	(4.651)
Observations	176	176	172	176	163	176	172	172	172	171
R^2	0.965	0.924	0.895	0.523	0.950	0.925	0.915	0.222	0.906	0.917

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Equation (1) Fundamental House Prices 1970Q1-2000Q4 (Model 2)

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
y_t	0.182*	0.124	-0.154**	1.515***	0.0432	0.116*	1.376***	0.977***	0.344***	0.352***
	(0.131)	(0.200)	(0.0733)	(0.213)	(0.0866)	(0.0741)	(0.227)	(0.184)	(0.125)	(0.125)
pop_t	1.295***	0.544**	8.443***	4.875***	2.498***	2.506*	-0.328	-3.693***	10.44***	-1.248***
	(0.272)	(0.268)	(0.839)	(1.830)	(0.235)	(1.748)	(0.905)	(0.717)	(1.764)	(0.293)
$mort_t$	-0.0110***	-0.0196***	-0.0104***	0.00328	-0.00256*	-0.00560	-0.0179***	-0.0327***	0.00931***	-0.0111***
	(0.00148)	(0.00612)	(0.00305)	(0.00281)	(0.00182)	(0.00547)	(0.00364)	(0.00612)	(0.00359)	(0.00230)
$supply_t$	0.228***	0.205***	0.380***	-0.121**	0.352***	0.351***	0.128***		-0.561***	0.0835***
	(0.0357)	(0.0357)	(0.0294)	(0.0605)	(0.0327)	(0.0540)	(0.0330)		(0.158)	(0.0234)
$rent_t$	-0.0440	0.239*	0.0667**	-1.413***	-0.0118	0.0801	-0.109***	0.421***	-0.266***	0.189***
	(0.0473)	(0.129)	(0.0314)	(0.215)	(0.0257)	(0.135)	(0.0461)	(0.0820)	(0.0737)	(0.0434)
Constant	-24.85***	-11.77*	-127.6***	-128.4***	-37.22***	-38.97*	-29.63**	50.24***	-179.0***	14.60***
	(2.999)	(6.603)	(12.49)	(29.71)	(2.937)	(25.47)	(12.80)	(9.818)	(30.03)	(3.258)
Observations	124	124	124	124	111	124	124	124	124	119
R^2	0.905	0.804	0.793	0.814	0.875	0.568	0.653	0.367	0.771	0.888

Standard errors in parentheses

* $p < 0.20$, ** $p < 0.05$, *** $p < 0.02$

Table 13: Equation (4) Error Correction Model - Housing Supply 1970Q1-2013Q4

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	United Kingdom	United States
λ_{t-1}	-0.843***	-0.289***	-0.396***	-0.000413	-0.341	-0.0990**	-0.205***	-0.298***	-0.0250*
	(0.139)	(0.0930)	(0.0824)	(0.0583)	(0.263)	(0.0462)	(0.0607)	(0.0733)	(0.0145)
$\triangle Supply_{t-1}$	0.144	-0.321***	-0.132	-0.0577	0.328	-0.339***	-0.152*	-0.449***	0.207***
	(0.101)	(0.0925)	(0.0869)	(0.0879)	(0.204)	(0.0798)	(0.0789)	(0.0733)	(0.0727)
$\triangle permit_{t-1}$	0.285**	0.780***	-0.00742		-0.220				0.185***
	(0.118)	(0.0902)	(0.0784)		(0.158)				(0.0282)
$\triangle cost_{t-1}$	0.262	-0.662	0.558	-1.656***	0.236	2.123*	1.697	-0.710**	0.747
	(0.734)	(1.121)	(0.668)	(0.608)	(0.730)	(1.262)	(1.205)	(0.315)	(0.530)
$\triangle rinv_{t-1}$	-0.119*	-0.0126	-0.103	-0.196*	-0.0750	0.393	0.325*	-0.0253	0.271***
	(0.0635)	(0.159)	(0.182)	(0.110)	(0.128)	(0.255)	(0.189)	(0.0652)	(0.0608)
Constant	-0.000647	-0.00833	-0.0133	0.00310	-0.000995	-0.0167	-0.0125	-0.00254	0.00788**
	(0.00566)	(0.00930)	(0.0125)	(0.00607)	(0.0127)	(0.0109)	(0.0167)	(0.00753)	(0.00381)
Observations	176	177	176	177	129	177	176	143	174
R^2	0.514	0.449	0.193	0.064	0.022	0.157	0.140	0.460	0.588

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14: Equation (3) Error Correction Model - Fundamental House Prices 1970Q1-2013Q4 (Model 1)

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
λ_{t-1}	-0.0364*	-0.0765***	-0.0589***	-0.0107*	-0.0498***	-0.0430***	-0.0290**	-0.00823	-0.0254**	-0.0673***
	(0.0190)	(0.0239)	(0.0207)	(0.00573)	(0.0129)	(0.0160)	(0.0131)	(0.0148)	(0.00999)	(0.0142)
$\triangle P^f_{t-1}$	0.488***	0.284***	0.604***	0.822***	0.761***	0.469***	0.725***	0.371***	0.759***	0.592***
	(0.0671)	(0.0749)	(0.0682)	(0.0469)	(0.0487)	(0.0689)	(0.0533)	(0.0763)	(0.0538)	(0.0594)
$\triangle y_{t-1}$	0.0451	-0.116	-0.00794	-0.0464	0.0204**	-0.00541	-0.0398	-0.0475	-0.0144	-0.186**
	(0.0704)	(0.117)	(0.0329)	(0.0655)	(0.00943)	(0.0213)	(0.0709)	(0.0376)	(0.0217)	(0.0733)
$\triangle pop_{t-1}$	0.926	4.626	0.840	1.676**	1.273	2.302	-0.286	0.990	-0.341	-0.751
	(0.846)	(3.512)	(3.600)	(0.704)	(0.857)	(2.198)	(1.469)	(1.562)	(1.808)	(1.537)
$\triangle mort_{t-1}$	-0.000346	-0.00402*	0.00170	0.000125	-0.00192**	-0.000732	-0.000380	-0.00410**	-0.000696	0.00161*
	(0.00119)	(0.00204)	(0.00176)	(0.000595)	(0.000805)	(0.00152)	(0.000858)	(0.00205)	(0.00108)	(0.000863)
$\triangle supply_{t-1}$	0.0646***	0.0138	-0.0240*	0.00925	0.0111	0.0376	0.0266*		-0.0182	0.00545
	(0.0223)	(0.0223)	(0.0135)	(0.0137)	(0.00971)	(0.0412)	(0.0137)		(0.0248)	(0.00712)
$\triangle rent_{t-1}$	0.0167	-0.138	-0.158*	-0.0838	0.0408	0.0204	-0.150***	-0.0562	0.00523	0.137
	(0.0546)	(0.133)	(0.0918)	(0.0773)	(0.0448)	(0.0885)	(0.0427)	(0.125)	(0.0359)	(0.140)
Constant	-0.000413	-0.00604	0.00272	-0.00114	-0.00229	-0.000540	0.00360**	0.000321	0.00218	0.00304
	(0.00330)	(0.00957)	(0.00362)	(0.000961)	(0.00237)	(0.00410)	(0.00181)	(0.00293)	(0.00223)	(0.00417)
Observations	175	175	171	175	162	175	171	171	171	170
R^2	0.393	0.181	0.371	0.704	0.721	0.280	0.613	0.166	0.566	0.523

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15: Equation (3) Error Correction Model - Fundamental House Prices 1970Q1-2000Q4 (Model 2)

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
λ_{t-1}	-0.101***	-0.151***	-0.0927**	-0.0174	-0.0922***	-0.0446**	-0.0334**	-0.0105	-0.0360**	-0.0378
	(0.0341)	(0.0373)	(0.0414)	(0.0135)	(0.0262)	(0.0210)	(0.0147)	(0.0222)	(0.0147)	(0.0332)
$\triangle P^f_{t-1}$	0.365***	0.236***	0.520***	0.867***	0.757***	0.462***	0.754***	0.377***	0.752***	0.384***
	(0.0794)	(0.0892)	(0.0900)	(0.0612)	(0.0578)	(0.0858)	(0.0595)	(0.0902)	(0.0682)	(0.0976)
$\triangle y_{t-1}$	0.103	-0.121	0.000198	-0.133	0.0207**	-0.0111	0.0243	-0.0489	-0.00814	-0.0500
	(0.0818)	(0.140)	(0.0387)	(0.0999)	(0.00967)	(0.0250)	(0.0843)	(0.0451)	(0.0237)	(0.104)
$\triangle pop_{t-1}$	0.980	11.01**	3.786	1.740*	1.525	6.389	-0.545	-0.198	4.740	-2.120
	(0.874)	(4.789)	(4.360)	(0.946)	(1.065)	(6.665)	(2.021)	(2.448)	(5.144)	(2.616)
$\triangle mort_{t-1}$	-0.000512	-0.00448*	0.00132	0.000242	-0.00170*	-0.00129	-0.000839	-0.00551**	-0.000970	-0.000105
	(0.00128)	(0.00252)	(0.00207)	(0.000750)	(0.000878)	(0.00200)	(0.000934)	(0.00260)	(0.00123)	(0.00117)
$\triangle supply_{t-1}$	0.0742***	-0.0153	-0.0333*	0.00767	-0.000942	0.0416	0.0275*		-0.0194	0.0100
	(0.0271)	(0.0283)	(0.0195)	(0.0176)	(0.0124)	(0.0549)	(0.0149)		(0.0410)	(0.00891)
$\triangle rent_{t-1}$	0.0228	-0.139	-0.188*	-0.0502	0.0355	0.00953	-0.121**	-0.00323	0.0130	-0.165
	(0.0554)	(0.153)	(0.107)	(0.0939)	(0.0477)	(0.0974)	(0.0527)	(0.153)	(0.0395)	(0.231)
Constant	-0.00119	-0.0258*	0.00194	-0.00121	-0.00348	-0.00552	0.00313	0.000393	-0.000415	0.0101
	(0.00343)	(0.0134)	(0.00424)	(0.00164)	(0.00282)	(0.00868)	(0.00199)	(0.00371)	(0.00321)	(0.00870)
Observations	123	123	123	123	110	123	123	123	123	118
R^2	0.382	0.233	0.297	0.694	0.726	0.271	0.643	0.174	0.557	0.188

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 16: SUR estimation of Equation (9) 1981Q1-2000Q4 using deviation from Model 1

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	0.845***	1.274***	-0.454***	-0.349	0.0678	0.689***	-0.785***	1.255***	-1.218***	1.347***
	(0.177)	(0.200)	(0.114)	(0.280)	(0.0806)	(0.197)	(0.163)	(0.343)	(0.284)	(0.381)
Constant	-2.074***	-0.950	-0.0353	8.035***	0.619	-1.686	0.697	4.651***	0.534	-0.723
	(0.662)	(0.977)	(0.736)	(1.056)	(0.718)	(1.250)	(0.780)	(1.542)	(1.774)	(0.556)
Observations	80									
R^2	0.199	0.195	0.012	0.011	0.008	0.103	0.199	0.021	0.048	0.062

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 17: SUR estimation of Equation (9) 1981Q1-2000Q4 using deviation from Model 2

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	0.997***	0.999***	-0.221	-1.796***	0.121	0.591***	-0.598***	1.475***	-0.555*	0.908***
	(0.132)	(0.247)	(0.137)	(0.315)	(0.0831)	(0.199)	(0.160)	(0.334)	(0.300)	(0.182)
Constant	-0.314	-1.378	-0.0131	-0.183	0.299	0.277	0.709	3.201**	2.990*	0.338
	(0.523)	(0.870)	(0.676)	(0.816)	(0.529)	(1.269)	(0.796)	(1.367)	(1.626)	(0.306)
Observations	80									
R^2	0.306	0.186	0.008	0.152	0.017	0.063	0.129	0.010	0.011	0.182

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 18: SUR estimation of Equation (9) 1990Q1-2000Q4 using deviation from fundamental P/R ratio

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	-0.310	0.906***	-4.934***	-2.193*	-2.240***	0.102	-1.949***	-3.367***	-0.580	5.383***
	(0.712)	(0.257)	(0.277)	(1.323)	(0.625)	(0.240)	(0.379)	(0.865)	(0.444)	(0.412)
Constant	12.06***	-4.891***	-4.960***	27.63***	18.41***	-9.491***	-20.72***	3.196	-0.0576	-6.246***
	(1.952)	(1.255)	(1.425)	(6.008)	(3.122)	(1.888)	(3.074)	(2.665)	(3.580)	(0.787)
Observations	44									
R^2	0.016	0.221	0.840	0.013	0.201	0.007	0.192	0.201	0.008	0.595

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 19: SUR estimation of Equation (9) 2001Q1-2012Q4 using deviation from Model 1

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	2.557***	3.677***	6.351***	2.723***	3.059***	0.527**	0.844***	4.721***	3.104***	3.072***
	(0.343)	(0.422)	(0.754)	(0.381)	(0.322)	(0.230)	(0.170)	(0.701)	(0.491)	(0.286)
Constant	5.967***	2.804***	0.0431	-7.480***	-1.365	3.970***	0.390	4.172***	3.533**	6.672***
	(0.971)	(1.048)	(1.246)	(0.851)	(1.196)	(0.827)	(0.762)	(1.472)	(1.461)	(0.734)
Observations	48									
R^2	0.237	0.288	0.536	0.081	0.406	0.036	0.063	0.211	0.404	0.535

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 20: SUR estimation of Equation (9) 2001Q1-2012Q4 using deviation from Model 2

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	5.430***	4.569***	8.176***	-0.747*	3.661***	-0.932**	0.826***	7.500***	5.320***	2.478***
	(0.504)	(0.591)	(0.878)	(0.388)	(0.491)	(0.426)	(0.217)	(1.005)	(0.984)	(0.411)
Constant	37.62***	15.15***	2.393*	-34.68***	21.67***	40.53***	9.087***	20.41***	12.17***	19.26***
	(0.955)	(1.963)	(1.380)	(1.473)	(2.539)	(2.281)	(0.954)	(2.513)	(2.737)	(1.297)
Observations	48									
R^2	0.668	0.195	0.587	0.043	0.156	0.040	0.053	0.171	0.372	0.246

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 21: SUR estimation of Equation (9) 2001Q1-2009Q4 using deviation from fundamental P/R ratio

	Australia	Canada	Denmark	Japan	New Zealand	Norway	Sweden	Switzerland	United Kingdom	United States
TRdev	12.80***	10.49***	12.78***	-1.712***	15.89***	2.897***	-0.547**	1.867***	7.425***	-0.0565
	(1.097)	(1.016)	(1.672)	(0.506)	(1.448)	(0.695)	(0.277)	(0.359)	(1.776)	(0.647)
Constant	61.96***	21.40***	1.638	-18.50***	71.98***	22.91***	3.383	-8.029***	48.15***	4.479**
	(3.658)	(2.082)	(4.564)	(1.539)	(4.846)	(3.572)	(2.128)	(0.561)	(4.963)	(1.811)
Observations	36									
R^2	0.472	0.640	0.336	0.035	0.635	0.115	0.003	0.397	0.207	0.000

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 22: Granger causality tests: Taylor rule deviations and housing bubbles (Model 1) - 1981Q1 - 2000Q4

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.238	0.553
Canada	0.084	0.028
Denmark	0.005	0.836
Japan	0.088	0.764
New Zealand	0.000	0.000
Norway	0.134	0.288
Sweden	0.016	0.134
Switzerland	0.008	0.814
United Kingdom	0.242	0.001
United States	0.184	0.641

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

Table 23: Granger causality tests: Taylor rule deviations and housing bubbles (Model 2) - 1981Q1 - 2000Q4

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.823	0.137
Canada	0.473	0.387
Denmark	0.896	0.816
Japan	0.199	0.363
New Zealand	0.000	0.000
Norway	0.704	0.462
Sweden	0.001	0.254
Switzerland	0.025	0.821
United Kingdom	0.971	0.668
United States	0.025	0.005

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

Table 24: Granger causality tests: Taylor rule deviations and housing bubbles (Fundamental price to rent ratio) - 1990Q1 - 2000Q4

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.000	0.000
Canada	0.823	0.135
Denmark	0.000	0.000
Japan	0.972	0.595
New Zealand	0.010	0.359
Norway	0.075	0.256
Sweden	0.000	0.000
Switzerland	0.331	0.118
United Kingdom	0.000	0.000
United States	0.268	0.021

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

Table 25: Granger causality tests: Taylor rule deviations and housing bubbles (Model 1) - 2001Q1 - 2012Q4

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.000	0.000
Canada	0.743	0.060
Denmark	0.120	0.000
Japan	0.015	0.906
New Zealand	0.777	0.045
Norway	0.024	0.020
Sweden	0.104	0.001
Switzerland	0.461	0.256
United Kingdom	0.329	0.046
United States	0.003	0.010

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

Table 26: Granger causality tests: Taylor rule deviations and housing bubbles (Model 2) - 2001Q1 - 2012Q4

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.385	0.012
Canada	0.455	0.333
Denmark	0.302	0.001
Japan	0.057	0.576
New Zealand	0.013	0.006
Norway	0.003	0.013
Sweden	0.063	0.008
Switzerland	0.783	0.153
United Kingdom	0.177	0.000
United States	0.004	0.007

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.

Table 27: Granger causality tests: Taylor rule deviations and housing bubbles (Fundamental price to rent ratio) - 2001Q1 - 2009Q4

Country	$TRdev \rightarrow (P_t^a - P_t^f)$	$(P_t^a - P_t^f) \rightarrow TRdev$
Australia	0.005	0.846
Canada	0.255	0.013
Denmark	0.000	0.000
Japan	0.061	0.332
New Zealand	0.001	0.002
Norway	0.070	0.211
Sweden	0.001	0.150
Switzerland	0.045	0.002
United Kingdom	0.002	0.000
United States	0.001	0.119

P values for null hypothesis of no Granger causality between $TRdev$ and $(P_t^a - P_t^f)$ and vice versa.