



A Repayment Model of House Prices¹

Jakob B Madsen

Abstract:

This paper proposes a model in which house prices are determined by housing affordability in the short run, while being determined by acquisition costs in the long run. Housing affordability is, in turn, determined by nominal income and nominal mortgage payments. The model explains the recent housing market run-up in the OECD countries by lower housing repayments, decreasing nominal interest rates, and a large inflow of migrants. Empirical estimates give strong support for the model and suggest that it explains house prices in the OECD better than the mainstream models.

Key words: house prices, institutions, affordability, financial innovations, Tobin's q .

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The house price run-up in the OECD countries in the period 1995-2007 has often been attributed to rising income per household, increasing proportions of the population in 20-35 years age group, lower nominal interest rates, and capital market innovations, in conjunction with an inelastic supply of houses in the short run (McCarthy and Peach, 2004, IMF, 2004, OECD, 2005a, and Brunnermeier and Julliard, 2008). However, there is no well-developed theory connecting house prices to income, demographic factors, nominal interest rates and capital market innovations. Income per capita or income per household remains one of the principal driving variables in the short as well as the long run in almost all models of house prices (Burkley and Ermisch, 1982, Meen, 1990, 2002, IMF, 2004, OECD, 2005a, Gallin, 2006, and Girouard *et al.*, 2006). However, thus far it has not been established theoretically why house prices should be positively related to income and, particularly, why the income elasticity of house prices is close to one in empirical estimates that are, typically, calculated over relatively short periods. Nor has it been shown why house prices are responsive to migration and demographic factors in the short run but not in the long run and why they respond to financial innovations that change the mortgage payment profile over the time-span of a loan without changing the real user cost of capital. While liquidity constraints influence the shadow price of borrowing in traditional intertemporal optimization models, the testable implications of the theory have been difficult to derive due to the unobservability of key variables in the models (see for example Chah *et al.*, 1995).

This research establishes a simple behavioural housing price model in which prices are driven by demand in the short run but by supply in the long run. The model is henceforth referred to as a repayment model. In the short run house prices adjust to the level at which the nominal mortgage expenditure is a fixed proportion of the after-tax income of house buyers based on the lending rules of banks. Anybody who has taken a mortgage loan knows that banks are willing to lend up to the amount at which the mortgage payments are equal to a fixed proportion of current and expected income. This rule has long been stressed in the literature on loan provisions (see for example Weicher, 1977, Guttentag *et al.*, 1991, Hulchanski, 1995, Savage, 1999, and McCarthy and Peach, 2004). From this relationship it is shown that house prices are determined by the nominal mortgage interest rate, the principal repayment, the down payment, the after tax disposable income of house-buyers and house owners, financial innovations, and the net flow of potential house owners into the housing market. In the long run it is assumed that house prices are determined by replacement costs of houses under the principle that house buyers and developers have an incentive to build new homes if house prices exceed their replacement costs.

The repayment model is behavioural in the sense that house buyers fail to acknowledge that inflation lowers the real value of debt and, as such, is consistent with the notion of money illusion

(Shafir, Diamond, and Tversky, 1997). Thus, house buyers are willing and able to take larger loans in periods of low inflation and low nominal interest rates than in periods of high inflation and high nominal interest rates because nominal mortgage expenses per dollar borrowed are lower. Thus, the repayment model deviates from conventional house price models in which house prices are determined entirely by the consumers' intertemporal decision, by the present value of rent/housing services, or by the replacement costs of houses (Tobin's q models). In consumers' intertemporal models the optimal allocation of housing services over the life cycle is determined by real user costs of housing and the marginal rate of substitution between housing services and consumption of non-durables. This marginal rate of substitution is usually assumed to be a positive function of income and demographic variables in the short run as well as in the long run (see for survey Gallin, 2006, and Girouard *et al.*, 2006). In the repayment model the relevant measure of the cost of capital is the current after-tax *nominal* mortgage interest rate plus principal repayments. Furthermore, house prices are determined entirely by the supply side and, therefore, replacement costs, in the long run following the Tobin's q principle.

Present value models of house prices follow conventional stock valuation models in which the fundamental value of an asset is the discounted value of future rents or the discounted value of future services in the case of owner-occupied houses (Burkley and Ermisch, 1982, Himmelberg *et al.*, 2005). Thus, the house price is positively related to the rental value of the house and inversely related to real user cost minus the growth rate in rental values. In most of these models house services are assumed to be functions of demographic factors and income (as for example in the model of Burkley and Ermisch, 1982).

The repayment model not only differs from consumers' intertemporal optimization models and present value models by assuming that the demand for houses depends on the nominal after-tax interest rate plus principal repayment in the short run but also by letting house prices be determined by supply in the long run. As such the repayment model shares the long-run properties of the Tobin's q model of Madsen (2009) and, to some extent, Poterba (1984). However, while short-run determinants of house prices are well-defined in the affordability model they are not in the Tobin's q model.

The repayment model is outlined in the next section and the behavioral assumptions underlying the model are discussed in Section 3. Empirical estimates for the OECD countries are presented in Section 4 and the implications of the model are discussed in Section 5. Section 6 concludes the paper.

2 The model

The model consists of both a demand and a supply side with house prices being determined by demand in the short run and supply in the long run. First consider the short run.

2.1 Demand for houses

When a household applies for a housing loan, the bank and the household agree on a maximum fraction of the household's after-tax income that is available for mortgage repayments after other expenses are paid. The maximum is usually in the range of 25-30% depending on the country and the economic circumstances at the time, however, it is rarely above 30% (Weicher, 1977, Hulchanski, 1995, Bourassa, 1996, and Savage, 1999). Based on the household's income, fixed expenses, mortgage expenses and other information, the bank estimates the maximum obtainable loan and, therefore, the household's highest affordable price. Since the housing stock is fixed in the short run, the nominal housing affordability of the average house buyer and the number of house buyers will, therefore, determine the average house price. The validity of this hypothesis is discussed in the next section.

To show how house prices are related to repayments consider the fraction of the current and expected disposable income of the representative house buyer, i , that is required to service the mortgage debt:

$$\Psi_{it} = \frac{[(i_{it} + t_{it}^p)(1 - \tau_{it}) + \phi_{it}]M_{it} \cdot P_t^h}{[Y_{it}^\alpha E(Y_{i,t+1}^{1-\alpha})]}, \quad (1)$$

where Y_i is current nominal disposable income (including government transfers) of the representative house buyer, E is the expectation operator, t^p is property taxes, τ is the tax rate at which interest rates and property taxes can be deducted, i is the nominal lending rate, ϕ is the ratio of the principal repayment as a percentage of the housing loan, P^h is the per square meter house price, M_i is the size of the representative house buyers house in square meters, Ψ_i is the fraction of the representative house buyer's current and expected disposable income that is used to service the mortgage debt, and α is the relative weighting of contemporaneous and expected income in the lending provision, $0 \leq \alpha \leq 1$.

Equation (1) is closely related to the *inverse* affordability index that is typically computed as the median disposable income divided by principal repayment and interest on a standard 25-year fixed rate housing loan (see for example McCartney and Peach, 2004). The affordability index is often used by lending institutions and commentators 1) as a common metric for measuring

affordability (see for example Bourassa, 1996); 2) as an indicator of the fundamental value of houses (see for example Muellbauer and Murphy, 1997, McCartney and Peach, 2004); and 3) to determine the maximum value of ψ_{it} for the individual borrower based on scoring methods (see for example Roszbach, 2004). Referring to the affordability index Muellbauer and Murphy (1997) write that “this measure is much referred to by all informed commentators on the housing market” (p 1702).

Assuming that all house buyers are identical Equation (1) can be written as:

$$\Psi_t = \frac{[(i_t + t_t^p)(1 - \tau_t) + \phi_t]M_t \cdot P_t^h}{[Y_t^\alpha E(Y_{t+1}^{1-\alpha})]/N_t}, \quad (2)$$

where N is the net number of would-be house owners and Y is the sum of the disposable income of potential house buyers. The lower is Ψ the more affordable is ownership of a house for the average house buyer and the higher is the potential for house prices to increase and *vice versa*.

Isolating housing prices on the left hand side of Equation (2) yields:

$$P_t^h = \Psi_t \frac{[Y_t^\alpha E(Y_{t+1}^{1-\alpha})]}{[(i_t + t_t^p)(1 - \tau_t) + \phi_t]M_t \cdot N_t} = \Psi_t \frac{[Y_t^\alpha E(Y_{t+1}^{1-\alpha})]}{[(i_t + t_t^p)(1 - \tau_t) + \phi_t]H(\dot{p}_t^h / p_t^h)}, \quad (3)$$

where H is the housing stock on the market, which, among other things, is assumed to be a negative function of the growth in house prices, $H' < 0$, since the number of houses completed and for sale is low in periods of falling house prices and *vice versa*.

Dividing through by the GDP price deflator, P , and taking logs yields:

$$\ln(P_t^h / P_t) = \ln(\Psi_t) + \alpha \ln Y_t^r - \ln H(\dot{p}_t^h / p_t^h) - \ln[(i_t + t_t^p)(1 - \tau_t) + \phi_t] + (1 - \alpha) \ln E[Y_{t+1}^r] \quad (4)$$

where Y^r is the real disposable income of all potential house-buyers (first-time buyers and immigrants) and existing house owners minus the income of house owners exiting the housing market due to death or emigration etc., which implies that Y^r is the real disposable income of existing and would-be house owners. Provided that the income is distributed evenly among existing and would-be house owners and those living in rental accommodation, Y^r is the income of all households over the age of 20 multiplied by the home ownership ratio. In regression analysis a constant ratio between income of would-be house owners and those living in rental accommodation is a sufficient condition for identification of the coefficient of Y^r .

At first glance the repayment model resembles conventional house price models. However, there are large differences between the proposed model and most house price models in which real house prices are a function of real income and real user cost. First, Equation (4) only applies to the

short run, while in conventional house price models per capita income and user costs determine house prices in the short-run as well as in the long run. Second, Equation (4) uses *total* real disposable income of existing and potential house owners, while real GDP *per capita* or *per household* is used in conventional house price models (see Girouard *et al.*, (2006) for a survey of the literature). Thus, a sudden decline in the population due to emigration, war or epidemics, for example, would keep per capita income approximately constant in conventional house price models and, thus, have no effect on house prices. In the affordability model, by contrast, house prices are reduced in the short run because the demand for houses has been reduced. Third, supply variables are, in most circumstances, not included in conventional models. As shown below supply factors are influential for house prices in the repayment model in the short run and, particularly, in the long run. Fourth, while it is real user costs of a standard mortgage loan that are the relevant user costs in conventional house price models, it is nominal mortgage repayments as a percentage of the value of an average loan that are the relevant costs of capital in the repayment model.

Principal repayment is absent from conventional models because it does not affect the true cost of capital. In the repayment model principal repayment influences house prices because it affects the initial mortgage costs and, therefore, the capacity of house buyers to service their debt. Financial innovations that lower the initial principal repayment will, therefore, increase house prices in the repayment model, but not in user-cost-based models. Furthermore, there is an inbuilt assumption of money illusion in the repayment model. Lenders and borrowers do not take into account that inflation erodes the real value of debt on a one-to-one basis. The validity of this assumption is discussed in the next section. Finally, the repayment model uses a weighted average of long and short term interest rates, where the weights reflect the share of each loan type for the average house buyer. By contrast, the relevant interest rate in user-cost-based models is the long run interest rate because it reflects interest over the life span of the loan expected in financial markets.

The repayment model has clear predictions about the effects of financial innovations on house prices. Most financial innovations affect house prices through the $[i_t(1-\tau_t)+\phi_t]$ -term and the income-term in the model. Examples of financial innovations that lower the value of $[i_t(1-\tau_t)+\phi_t]$ are the introduction of interests-only loans, lengthening the time to maturity of mortgage loans, introduction of adjustable-rate-loans, and increasing competition among lenders. Consider the interest-only loans introduced recently in many OECD countries (Girouard *et al.*, 2006). Using data on the fraction of new housing loans that are of the interest-only type, the resulting house price increase can be calculated directly using Equation (3). This way of calculating the effects of financial innovations on house prices differs from the literature in which financial liberalization is often

measured as the ratio of lending to house value for first time buyers or the ratio of lending to income (see for example Koskela *et al.*, 1992, and Muellbauer and Murphy, 1997). While these indexes will capture quantitative credit constraints, they do not adequately capture the direct effects on house prices of financial liberalizations that influence the $[i_t(1-\tau_t)+\phi_t]$ -term.

The influence of financial repression/liberalization, which is captured by the $[i_t(1-\tau_t)+\phi_t]$ -term in the repayment model, resembles the credit constraints that are based on the Euler equation. Consider the Euler equation in which the unconstrained consumers allocate consumption over the life cycle until the marginal utility of consumption today equals the pricing kernel times the marginal utility of consumption in the next period: $U'(c_t) = \beta(1+r)U'(c_{t+1})$, where U is utility, r is the real interest rate on savings, β is the subjective discount factor and c is per capita consumption. Supposing that the returns from saving for a house, r_h is higher than the returns on other forms of savings, r , the Euler equation becomes $U'(c_t) > \beta(1+r_h)U'(c_{t+1})$, or $U'(c_t) = \beta(1+r_h)(1+\mu)U'(c_{t+1})$, $\mu > 0$, for the household that is accumulating down payments. The intuition is that if the cost of renting exceed the user cost of housing the rate of returns from saving for a home will exceed the returns to other assets (see, for an elaboration of this point, Engelhardt, 1996). In other words the shadow costs of financing for the credit constrained consumer exceed the financing costs of credit of the unconstrained consumer. Since the shadow costs of lending cannot be measured some identifying assumptions need to be imposed on the model. In the repayment model the identifying assumption is that a significant proportion of would-be house owners have a desire to own a house, however, they are constrained by the Ψ_t -term and the income term through the channel of down-payments.

As it stands the repayment model does not explicitly allow for quantitative credit constraints as stressed in the models of Murphy and Muelbauer (1997) and Carrington and Madsen (2009) following the predictions of the model of Stiglitz and Weiss (1981). However, quantitative credit constraints affect down-payments and, thus, the Ψ_t -term by increasing it in states of easy credit conditions and lowering it when credit conditions are tight. Thus, the Ψ_t -term will fluctuate over time along with banks' willingness to lend.

Equation (4) suggests that current house prices are unrelated to lagged house prices and house price inflation. The empirical estimates of Case and Shiller (1989) suggest that house prices are serially correlated. However, past house prices can easily be incorporated into the model following the models of Stein (1995), Abraham and Hendershott (1996), and Stein and Lamont (1999). Stein and Lamont (1999) suggest that some existing house owners use their equity as down payments to move up the housing ladder. Thus previous house price increases feed into current house prices. In a

falling housing market, by contrast, the housing equity among existing home owners may not be sufficient to buy a more costly house. Consequently, the demand for houses among existing home owners shrinks along with lower house prices.

A final question is whether the model needs to be modified to allow for optimizing house buyers who act according to the predictions of perfect foresight models. This is particularly important for cost of capital, which is one of the principal variables distinguishing the repayment model from the perfect foresight models. Suppose mortgage interest rates increase in response to an increase in expected inflation. Provided that interest payments are tax deductible the optimal response among potential house buyers would be to increase their demand for houses since the real after-tax interest rate has fallen. If, on the other hand, myopic house buyers dominate the housing market the increase in the nominal interest rate reduces demand for houses. This suggests that the real as well as the nominal interest rate should be relevant for house prices.

However, there are two reasons why real user cost of capital may not be a relevant determinant of house prices even when some would-be house buyers have perfect foresight. First, credit constraints may prevent rational house buyers from exploiting profit opportunities. In the late 1970s and the early 1980s, for example, nominal interest and inflation rates reached double-digit figures in most OECD countries and yet, real house prices declined. Even if the optimal decision would have been to buy, the nominal interest payments on mortgages were so high that liquidity constrained would-be house buyers would have to increase their borrowing at every installment to meet their mortgage repayment. It is well known, that partial mortgage repayment has not, except during the last house price run-up, been common practice and, therefore, rational house buyers may be prevented from capitalizing on low real user cost of housing in periods of high inflation.

Second, it may not be rational to buy houses in periods of low and negative real after-tax interest rates and sell in periods of high real after-tax interest rates if most would-be house buyers are myopic or if credit constraints are binding. Rational house buyers would have made significant real capital losses during the late 1970s and the early 1980s with low and negative real after-tax interest rates and would have missed out on the capital gains during the 1995-2007 house-price run-up despite stable or increasing after-tax real interest rates. Thus, in general, it does not pay off for optimizing house buyers to go against the market if it is dominated by liquidity constrained or myopic house buyers. This effect may be amplified by unpredictable shocks in demand for houses initiated by myopic house buyers following the hypothesis of De Long *et al.* (1990) regarding the stock market in which unpredictable noise traders in the stock market render it difficult for smart investors to exploit profit opportunities. These considerations suggest that even if a fraction of house buyers are rational

it may not be optimal to buy in periods of low after-tax real interest rates and *vice versa*. This issue is investigated further in the empirical section.

2.2 Supply of houses

Thus far it has been assumed that the supply of houses is inelastic. However, it is unrealistic to assume that positive per capita income and population growth rates will continue to put upward pressure on house prices without affecting the stock of houses – otherwise the stock of houses would not have increased over the past century. In the long run it is assumed that building activity will be driven by the ratio of house prices and their acquisition costs following the Tobin's q principle. House prices will, consequently, be determined by the replacement costs of houses in the long run. In any event, Tobin's q needs not be derived from an intertemporal optimization problem for builders and owner builders as in Madsen (2009). The simple principle here is that builders and would-be house owners initiate housing investment if it costs less to build a house than it costs to buy an identical house. Thus, the investment ratio for new houses is determined by Tobin's q :

$$\dot{H}_t / H_t = \psi [q_{t-1} - 1], \quad (5)$$

where q is the shadow price of housing stock, which is measured by the ratio of house prices and the effective acquisition costs. The acquisition costs are predominantly given by construction costs plus costs of urban land marked up by sales taxes, as discussed below. It is assumed that investment lags q by one period (year) to allow for the period it takes for urban planning, zoning laws, building permission, architect time etc.

The identifying assumptions that house buyers follow the affordability principle while suppliers of houses act on economically sound principles may appear asymmetric in the sense that house buyers do not optimize intertemporally while builders do. However, some economic principles are obvious while others are less so. Almost everybody can compare prices of the same product, will buy the cheapest product and are even willing to spend a considerable amount of traveling time to save a few dollars (Thaler and Sunstein, 2008). Almost all adults also understand that the real value of their money falls in inflationary periods (Shafir *et al.*, 1997). A natural extension of this principle is that individuals are able to see a profit opportunity by building houses when sales prices exceed acquisition costs. Conversely, there is ample evidence suggesting that individuals, including those with ample experience with finance, do not understand that inflation erodes the real value of debt (Modigliani and Cohn, 1979, Shafir *et al.*, 1997, Brunnermeier and Julliard, 2008) as implicitly assumed in the repayment model. Almost everybody understands the advantages of buying cheap and

selling dear while very few understand the principles underlying more complex financial instruments (Thaler and Sunstein, 2008). Supporting evidence for the underlying identifying assumptions in the model is given in the next section.

2.3 Equilibrium

The dynamics of the system are governed by Equations (3) and (5):

$$P_t^h = \Psi_t \frac{[Y_t^\alpha E(Y_{t+1}^{1-\alpha})](1-\theta_t)}{[i_t(1-\tau_t) + \phi_t]H(\dot{p}_t^h / p_t^h)}, \quad (3)$$

$$\dot{H}_t = H_t \psi \left[\frac{P_{t-1}^h}{\Omega_{t-1}(1+t_{t-1}^i)} - 1 \right], \quad (5)$$

where t^i is indirect or sales taxes, Ω is pre-tax replacement costs of houses.

Before considering the dynamics of the model it is useful to consider the steady state equilibrium of house prices. Letting lc be the cost of urban land and cc construction costs, pre-tax acquisition costs are given by $\Omega = lc^\beta cc^{(1-\beta)}(1+n \cdot i/12)$, $0 < \beta < 1$, where n is the number of months it takes to complete the building multiplied by the average fraction of working capital.² Thus, Tobin's q is given by

$$q_t = \frac{p_t^h}{lc_t^\alpha cc_t^{(1-\alpha)}(1+t_t^i)(1+n \cdot i/12)},$$

and the steady state for house prices (Equations (3) and (5)) is given by:

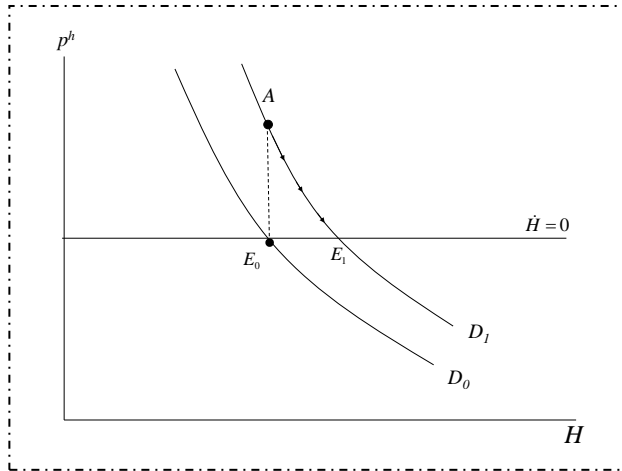
$$p_t^{h*} = (1+t_t^i)(1+n \cdot i/12)lc^\alpha cc^{(1-\alpha)}, \quad (6)$$

where an asterisk signifies steady state. This equation shows that house prices in the long run are determined entirely by acquisition costs as in Tobin's q models of house prices. Pre-tax acquisition costs are estimated as a geometric average of land prices and construction costs because the data are usually available in index form. If un-indexed data are available the correct expression for replacement costs is $(lc + cc)$ and not $lc^\alpha cc^{(1-\alpha)}$. While building costs are not affected by housing demand in the long run, the cost of developed vacant land may be a positive function of the housing stock if there is a shortage of land for development. For the UK, for example, the ratio of house prices and the unweighted geometric average of building costs and agricultural land prices has increased over the past 50 years, for which data are available, suggesting that prices of developed land have

² Since sales taxes are not paid on interest this relationship is only an approximation.

been driven up by inelastic supply of land. For the US, on the other hand, the ratio has fluctuated around a constant level over the past century, which suggests that land is more abundant in the US than the UK (data sources are listed in the data appendix).

Figure 1. The dynamic relationship between house prices and housing stock.



Turning to the adjustment towards the steady state following an exogenous shock, Equations (3) and (5) are drawn in Figure 1 under the assumption that the price of urban land is independent of the housing stock. The house demand schedule is downward sloping because increasing house prices lower housing affordability and, therefore, induces house buyers to move into smaller units to keep the fraction of income going to mortgage payments constant.

Consider an unexpected rise in income that improves housing affordability and, therefore, shifts the demand curve to the right from D_0 to D_1 . Starting from the steady state equilibrium at the point E_0 , house prices jump to the point A . Since house prices exceed acquisition costs, the building stock starts increasing and the housing market moves down the demand schedule as the housing stock adjusts toward its new steady state at the point E_1 .

The shift to the point A results in a much stronger price increase than under the alternative assumption of intertemporal optimization among house buyers. In the repayment model the relative increase in house prices equals the relative increase in income among house-buyers. A 10% increase in income for example, will lead to a 10% increase in house prices on impact. In an intertemporal optimization framework house prices will only jump to such an extent that the expected capital loss in the transitional path from a point between E_0 and A to the point E_1 is counterbalanced by the temporary higher housing rent or housing services so that the required returns remain constant (see, for an exposition, Madsen, 2009).

A more interesting case is the effect on house prices of inflation-induced shifts in nominal interest rates. In rational expectations models an inflation-induced reduction in interest rates results in lower house prices in the short run because the real user cost of housing has increased provided that interest payments are tax deductible. The repayment model predicts the opposite. The demand curve shifts to the right and we get a dynamic path that is similar to the positive demand shock as depicted in Figure 1. This result is consistent with findings that the strong disinflation-induced reduction in interest rates since the early 1980s has been an important factor behind the house price hike in most OECD countries in the same period (OECD, 2005a, Brunnermeier and Julliard, 2008). If nominal interest rates remain permanently lower, the reduced acquisition costs will result in a permanently lower $\dot{H}_t = 0$ schedule.

3 Are the assumptions underlying the repayment model realistic?

In the repayment model it is implicitly assumed that a significant fraction of house buyers 1) focus on the initial cost of housing and disregard the payment over the whole time-span of the loan; 2) disregard the potential adverse effects of increasing interest rates on flexible rate loans; 3) suffer from inflation illusion; and 4) react to price level incentives and will, therefore, build their own house if it is noticeably cheaper than buying a similar house and, by the same token, builders will exploit a profitable opportunity if house prices exceed acquisition costs. The validity of these suppositions is discussed in this section with the exception of 4), which was dealt with in the previous section.

The repayment model focuses on the initial costs and not payments over the entire time span of the loan. If house buyers with low initial real repayments of loans fail to acknowledge that real repayments may remain constant or even increase over the life of the loan, they are running the risk of not being able to honor the debt obligations in adverse circumstances. The survey evidence of Miles (2003) for the UK shows that house buyers focus on immediate mortgage payments relative to their income when they decide on the amount to borrow. Miles writes that “borrowers seem to attach excessive weight on the level of initial payments on loans and pay too little attention to how affordability of loans would be affected by changes in interest rates,” (p 16). In their survey of the housing market the IMF (2004) concludes that “there is evidence that consumers tend to prefer mortgage contracts that they consider to have the ‘most competitive rate’ (that is, the ones with the lowest initial costs)” (p 82). Similarly, the Financial Services Authority (2001) notes that “the research confirms that, taking consumers as a whole, information needs are limited and primarily focused on immediate cost factors. Most consumers tend not to trade off different aspects of a mortgage or compare products or consider long-term benefits”. Furthermore, increasing availability

of loans with lower initial payments than previously has not been counteracted by higher precautionary savings, and consequently higher down payments (Miles, 2003). These statements are supported by the fact that the choice between a variable-rate and a fixed-rate loan is determined almost entirely on the basis of the spread between the two rates, which again supports the survey finding that house buyers focus almost entirely on the initial costs of the mortgage (Miles, 2003, p 40). Econometric support for the focus on the initial payments even among lenders is found by Roszbach (2004) for Sweden. Roszbach finds that lending policies are based on naïve and subjective evaluation procedures and tend to be rather shortsighted; thus, giving further support to the hypothesis that initial affordability has a large weight in the lending provision.

For economists it appears obvious that 1) interest payments on adjustable interest rate loans are positively related to the interest rate; and 2) that interest payments on a significant fraction of subprime loans and variable rate loans in some European countries, will increase after a low starter rate. However, this does not appear obvious to all potential house buyers. In the Michigan Surveys of Consumers only 77 per cent of the adults respond affirmatively to the question “if the interest rate on an adjustable-rate mortgage loan goes up, your monthly mortgage payments will go up” (Hilgert *et al.*, 2003). This evidence shows that a non-negligible fraction of potential house buyers have an extremely poor understanding of even the most trivial financial arithmetic.

Understanding of interest compounding is essential for financial planning. However, survey evidence among Baby Boomers shows that only 18% of them are able to do very simple interest compounding (Lusary and Mitchell, 2007). This is a particularly low number since Baby Boomers should already have dealt with many financial decisions. This suggests that many house buyers are likely to have little understanding of the financial implications of different mortgage loan types and, as such, that the financial risks associated with the cheapest loans may not weigh heavily in the decision making process.

Experimental evidence gives support to this shortsighted behavior. It suggests that mental accounting plays an important role for consumer spending and behavior (Shefrin and Thaler, 1988). Due to the presence of mental accounts the temptation to spend out of wealth is less than current income. Coupled with the concepts of self control and framing, Shefrin and Thaler (1988) argue that the temptation to spend is greater for current than for future income. Their model can be readily translated into mortgage borrowing: The temptation to be able to buy the house that is currently affordable may be given a larger weight in the household’s borrowing decision than the prospect of not being able to honor future obligations in the event of divorce, unemployment, higher interest rates, property tax hikes, or declining house prices that brings down the collateral. Therefore, the immediate mortgage payment has a much higher weight than future payments. The introduction of

interest-only loans in many OECD countries over the past decade, for example, may have induced higher lending because the future payment of the principal has a lower weight in the decision making.

Psychological experiments also find evidence that individuals put too little weight on probabilities of adverse events that may jeopardize the ability of house owners to honor their debt. That people give too low a probability to extreme events that may severely impact their welfare is referred to as “overconfidence” in the psychological literature (Kahnemann and Tversky, 1979). Koriat *et al.* (1980) find that information search is directed toward evidence supporting one’s initially preferred alternative. In terms of the housing market this means that would-be house buyers with a high desire to own a house in a certain price bracket will, unconsciously, suppress non-zero probabilities of events that may impair their ability to service their debt. The recent tendency towards interest-only loans and variable-interest rate loans that enable some buyers to afford better houses may well be based on overconfidence and, thus, the presumption that events that could impair their ability to honor their debts are unlikely to occur.

The risk of failure to be able to pay a mortgage is likely to be further underestimated because the evaluation of risk is underestimated in disjunctive systems (Tversky and Kahneman, 1974). The probability of being able to pay the mortgage in the future is composed of many complex risk factors which may individually have a moderate but collectively a high probability. The risk of being unable to pay a mortgage is the joint probability of being unemployed, an interest rate hike, getting divorced, a house prices fall, income decline of self employed, stock market decline that lowers the collateral *etc.* Most of these components carry a moderate probability, however, the joint probability in such a complex system is substantially higher than appreciated by even experienced individual, because these risk factors are highly positively correlated. For example, a downturn in the economy is often associated with increasing nominal interest rates, decreasing stock and house prices, and increasing unemployment. Finally, individuals place overly narrow confidence intervals under uncertainty; that is, they place more certainty on an event than is justified by their prior knowledge (Tversky and Kahneman, 1974).

An important implication of the repayment model is that nominal and not real interest rates are the relevant determinants of house prices and, therefore, that house buyers suffer from inflation illusion.³ A disinflation-induced reduction in the interest rate leads to higher housing affordability and thus to higher house prices in the repayment model as analyzed above. The notion of inflation illusion

³ The affordability index was repeatedly used by commentators in the public debate to justify the high house price level in many countries before the bubble burst around 2007 (see for example Leahey, 2005). An inflation-induced increase in mortgage payments render house prices less affordable. Advocates of the affordability index as an indicator of equilibrium in the housing market would argue that lower house prices under these circumstances are justified although the real user costs of housing have been reduced. The frequent use of the affordability index as an indicator of house price equilibrium suggests that inflation illusion among the majority of house buyers is shared by many ‘expert’ commentators.

among house buyers is consistent with the inflation illusion hypothesis of Modigliani and Cohn (1979) in which they argue that the stock market discounts earnings using the nominal interest rate and fails to acknowledge that inflation erodes the real value of debt.

Strong evidence of the inflation illusion hypothesis has been found in the empirical stock market literature (see for example Campbell and Vuolteenaho, 2004). If inflation illusion is prevalent among stock investors, who presumably have some understanding of economics, it is difficult to believe that inflation illusion should not prevail among house buyers, the majority of who have little or no knowledge of economics. Furthermore, Brunnermeier and Julliard (2008) find evidence of widespread inflation illusion among house buyers. Finally, experimental studies give strong support for widespread money illusion (Shafir *et al.*, 1997). Research carried out by the Office for National Statistics found that half of the adult population was unable to understand percentages and other concepts vital to financial literacy (ONS, 1997). Finally, “almost 40 per cent of adults and students think the statement ‘Money holds its value well in times of inflation’ is correct’ (OECD, 2005b, p 102). By implication it is unlikely that these 40 percent will understand that inflation lowers the real value of debt and, therefore, that it is the real and not the nominal interest rate that is the essential determinant for the cost of borrowing.

The assumptions of inflation illusion and myopic behavior in the lending decision are inconsistent with the assumption of intertemporal optimization. Most housing price models that are based on the Euler equation use the real user cost of capital as its measure (see for example Meen, 1990, and Muellbauer and Murphy, 1997). However, the survey evidence for the UK suggests that professional advice is often taken at face value and house buyers feel that they have to meet the lenders’ criteria and not their own (Financial Services Consumer Panel, 1999). If this is the case then the Euler equation must, in most instances, be violated and the lending, be dictated to a large degree, by the providers lending guidelines and not by the individual’s time preference.

Even if lenders provide borrowers with the information they think is in the best interest of their clients we may end up with a myopic outcome. Tversky and Kahneman (1974) find that experienced researchers are prone to the same biases when they think intuitively. Individuals that have extensive training in probabilities pay equally insufficient attention to prior probabilities. Furthermore, Tversky and Kahneman (1974) suggest that anchoring is prevalent in most prediction; i.e. that predictions are biased towards initial values. Thus, in an environment of low interest rates, lenders and borrowers’ interest rate predictions will be biased towards the low end.

The survey evidence by Shiller (1996) supports the view that house buyers are keen to buy now rather than later, because they have unrealistically high expectations of real price appreciation, and that their expectations are anchored in the experience of the recent past. In a 1988 survey Case

and Shiller asked house buyers the following question: “On *average* over the next ten years, how much do you expect the value of your property to change each year?” (Shiller, 1996). In the boom city of San Francisco the answer was 14.8% and for Milwaukee, where prices were virtually flat in the previous 5 years, the answer was 7.3%. Since consumer price inflation was approximately 4% during the same period, these numbers would correspond to an 179% and 38% increase in real terms, respectively, over 10 years and yet real house prices have increased at an average 5.7% on a 10-year period basis between 1900 and 2006! This result shows that people’s expectations are heavily influenced by recent experience and that house buyers have highly unrealistic expectations about prices in the long run. The result is consistent with the finding that 1) most consumers do not understand compounding and, as such, do not understand how expected growth in house prices translates into increases in prices in the long run; and 2) that consumers think in nominal as opposed to real terms.

4 Empirical evidence

This section tests the following implications of the repayment model: 1) house prices are driven by demand factors and acquisition costs in the short run and acquisition costs in the long run; 2) the relevant income variable is not per capita permanent income but the total income of potential and existing house owners; and 3) the relevant cost of housing is not real user costs based on the long mortgage rate but the total nominal mortgage costs based on the short interest rate. The section tests whether the model holds up against conventional house price models. The models are estimated using data over the period 1970-2004 for a panel of 16 OECD countries (Canada, the US, Japan, Australia, New Zealand, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Sweden and the UK).

4.1 Pooled time-series and cross section evidence for the OECD countries

To derive the testable implications of the model differentiate the log of Equation (3) and substitute Equation (5) for $\Delta \ln H$, which is approximately equal to \dot{H}/H . This yields the following model:

$$\Delta \ln P_t^h = \Delta \ln \Psi_t + \alpha \Delta \ln Y_t + (1 - \alpha) \Delta \ln E[Y_{t+1}] + \Delta \ln [i_t(1 - \tau_t)] - \psi [P_{t-1}^h / (\Omega_{t-1}(1 - t_{t-1}^i))],$$

where the last term can be interpreted as an error-correction term in the sense that building activity closes the gap between house prices and replacement costs. This model is stochastically specified as follows:

$$\begin{aligned} \Delta \ln P_t^h = & \alpha_0 + \alpha_1 \Delta \ln P_{t-1}^h + \alpha_2 \Delta \ln Y_t + \alpha_3 \Delta \ln Y_{t-1} + \alpha_4 \Delta \ln Y_{t-2} \\ & + \alpha_5 \Delta \ln [i_t(1 - \tau_t)] + \alpha_6 \Delta \ln cc_t + \alpha_7 TD + \alpha_8 ECT_{t-1} + \varepsilon_t, \end{aligned} \quad (7)$$

where Y is measured as economy-wide nominal GDP as a proxy for nominal disposable income of would-be and existing house owners, TD is time-dummies, ECT is an error-correction term, cc is construction costs, and ε is a stochastic error term. Country dummies were initially included in the regressions but excluded from the final regressions because they were insignificant. The data construction and data sources are detailed in the data appendix.

The ECT is estimated from the following co-integration model:

$$\ln P_{it}^h = \beta_{i0} + \beta_{i1} \ln(cc)_{it} + \beta_3 ECT_{it},$$

which is estimated for each individual country and, therefore, allows the constant term and the slope coefficient to vary across countries.

Lagged values of nominal income are included in Equation (7) to allow for the possibility that income expectations are based on past income. Expected income measured as a one-year forecast of income based on the information set available at period t , was included in initial regressions but was consistently insignificant and, consequently, omitted from the final regressions. Lagged values of interest rates were not included in the regressions because they were insignificant. Acquisition costs are measured as building costs since data on prices of developed land are only available for a couple of countries and the available data are of very low quality since sales of developed land are relatively infrequent. The short-term nominal interest rate was initially included in the co-integration regressions but was subsequently omitted because it was statistically and economically insignificant. Construction costs are included in Equation (7) to allow acquisition costs to have immediate effects on house prices. Finally, lagged house prices are included in the estimates following the predictions of the models of Stein (1995), Abraham and Hendershott (1996), and Stein and Lamont (1999) as discussed in Section 2.1.

The lending rate is measured as the interest rate on 3-month treasury bonds and, in one set of regressions, as the interest rate on long-term government bonds. The tax rate used for tax deductions is estimated as total direct taxes divided by nominal income. This tax rate is set to zero for countries in which interest payments are not tax deductible (Canada, Japan, New Zealand, Australia, and France). Clearly, there are large errors associated with the measurement of the after tax interest rate which are likely to bias the coefficient of this rate towards zero. The measurement errors are twofold. First, the tax rate used for tax deductions is the marginal income tax rate in some countries while other countries use a fixed rate that has changed over time. The rate used for tax deductions in

Denmark, for example, was well above 50% before it was reduced to 50% in 1986 and then to 30% in 2001. Second, the mortgage lending rate and treasury rate are not entirely determined by the same factors and, therefore, need not have moved in tandem during the estimation period.

Clearly a much more detailed study would allow for financial innovations and the availability of credit (see for instance Miles, 1992, and Muellbauer and Murphy, 1997). An important missing variable from the regression is total principal repayments as a percentage of total housing loans (see Leahey, 2005, and, particularly, OECD, 2005a, for a discussion of how different financial innovations have changed the costs of loans over time). An investigation of these issues is beyond the scope of this paper.

Panel estimates of Equation (7) are carried out to gain efficiency. The covariance matrix weighted by the correlation of the disturbance terms between countries is used to gain further efficiency. More specifically the following variance-covariance structure is assumed:

$$E\{\varepsilon_{it}^2\} = \sigma_i^2, \quad i = 1, 2, \dots, 16,$$

$$E\{\varepsilon_{ib}, \varepsilon_{jt}\} = \sigma_{ij}, \quad i \neq j,$$

where σ_i^2 = the variance of the disturbance terms for country i , σ_{ij} = the covariance of the disturbance terms across countries i and j , and ε is the disturbance term. The variance σ_i^2 is assumed to be constant over time but to vary across countries and the error terms are assumed to be mutually correlated across countries, σ_{ij} , as random shocks are likely to impact on all countries within the same period. The parameters σ_i^2 and σ_{ij} are estimated using the feasible generalized least squares method (FGLS).

Table 1. Parameter estimates of Equation (7).

	1	2	3	4
$\Delta \ln P_{t-1}^h$	0.43(11.6)	0.42(11.5)	0.42(11.4)	0.41(10.4)
$\Delta \ln[i_t(1 - \tau_t)]$	-0.21(2.50)	-0.20(2.39)	0.00(0.81)	-0.18(2.28)
$\Delta \ln Y_t$	0.51(8.31)	0.50(8.00)	0.51(9.00)	0.51(9.00)
$\Delta \ln Y_{t-1}$	0.16(2.45)	0.14(2.17)	0.13(1.97)	0.21(3.15)
$\Delta \ln Y_{t-2}$	-0.21(3.12)	-0.21(3.15)	-0.19(2.81)	-0.21(3.32)
$\Delta \ln(cc)_t$	0.18(3.62)	0.20(3.97)	0.17(3.38)	0.17(3.74)
$\Delta \ln(Pop)_t$		0.34(1.20)		
$\Delta \ln f_{t+1}^e$				-0.01(1.30)

ECT_{t-1}	-0.11(6.90)	-0.11(6.82)	-0.11(6.86)	-0.11(6.80)
R^2 (Buse)	0.98	0.98	0.98	0.99
DW	1.89	1.89	1.88	1.89

Notes. Estimation period: 1973-2004, except for the regression in the last column in which the estimation period is 1973-2003. Constant terms and time dummies are included in the estimates but not shown. The numbers in parentheses are absolute t -statistics. **Column 3:** The interest rate term is based on a nominal long interest rate (the nominal interest rate is used in the other columns). Inf^e is inflation expectations estimated by regressing consumer price inflation on two lags of inflation, growth rates in $M1$ and time-dummies. Pop is the size of the population.

The results of estimating Equation (7) are shown in the first column of Table 1. The estimated coefficients of nominal income are statistically highly significant and the income elasticity is 0.5 on impact and 0.8 after two years, which is close to the predictions of the repayment model. The estimated coefficient of the error correction term is -0.11 and is statistically highly significant, which suggests that house prices can deviate from their long-run equilibrium over prolonged periods – only 11 percent of the disequilibrium is, on average, eliminated every year. The estimated coefficients of construction costs are statistically and economically highly significant, which shows that supply shocks are not only influential for house prices in the long run but also in the short run. In real terms building cost shocks were influential for house prices in the 1970s, during which construction cost increases of 25% were not unusual in the OECD countries; thus contributing to an increase in house prices of almost 25% during the same period since the estimated coefficient of building costs is close to one in the cointegration estimates (the results are not shown). During the recent house price boom real building costs have not contributed to the increase in real house prices.

The estimated coefficients of lagged income are 0.16 (first lag) and -0.21 (second lag). Since these coefficients are of almost the same value but of opposite sign these dynamics imply that it is the acceleration, and not the growth, in lagged nominal income that is important for the growth in house prices. This result indicates increasing growth in nominal income builds into expectations of a continued strong growth in nominal income and, therefore, affordability. This implies that lenders and borrowers are willing to accept a higher repayment to income ratio in periods of increasing as compared to stable nominal income growth. Finally, the estimated coefficient of the nominal after-tax interest rate is negative and statistically significant at the 1 percent level. The estimated long-run interest rate elasticity is -0.35. This elasticity is about a third of the predictions of the model and probably reflects that the after-tax interest rate is a bad proxy for the repayment rate and the measurement errors that are associated with the after-tax interest rate.

4.2 Testing the affordability model against alternative models

Although the regression results in the first column in Table 1 are largely consistent with the predictions of the affordability model they do not necessarily imply that the affordability model is better than conventional models. This sub-section tests the affordability against conventional house price models. The two dominating models in the empirical house price literature are the present value model and models based on that of Dougherty and Van Order (1982) (see Gallin, 2006, and Girouard, 2006, for surveys of most popular empirical house price models). The conventional house price models are based on the present value principle. Tobin's q models of Poterba (1984) and Madsen (2009) are not considered because the affordability model is based on the Tobin's q principle in the sense that house prices are determined by demand factors in the short run and entirely by the supply side in the long run.

Almost all conventional house price models are based on the present value principle in which the fundamental value of the house is the present value of expected services/cash-flow or the marginal rate of substitution between housing services and consumption of non-durables (see Madsen, 2009, for a formal exposition). Under the assumption that the expected discount factor and expected services or cash-flow remain constant to infinity, the fundamental value of houses is equal to the services/cash-flow divided by the real user cost of capital. Measuring cash-flow as rental income yields the following present value model:

$$P_t^h = \frac{R_t}{[i_t(1-\tau_t) - g_{t+1}^e]}, \quad (8)$$

where R is nominal rental income and g_{t+1}^e is expected growth in house prices at period $t+1$. This model is commonly used to explain house prices (see for example Buckley and Ermisch, 1982, and Himmelberg *et al.*, 2005).

Another popular model, which is based on the same principle as the present value model, is the model of Dougherty and Van Order (1982):

$$P_t^h = P_t^c \frac{U'(h_t)/U'(c_t)}{[i_t(1-\tau_t) - g_{t+1}^e]}, \quad (9)$$

where $U'(h)$ is the marginal utility of per capita housing stock, $U'(c)$ is the marginal utility of per capita non-durable consumption and P^c is non-durable prices. The marginal rate of substitution, $U'(h_t)/U'(c_t)$, is the rate at which the consumer is willing to give up one unit of non-durable consumption in exchange for a unit of housing services at the margin. In empirical expositions the

marginal rate of substitution is assumed to be a function of real per capita income, demographic factors, wealth and other factors that depend on the study in question.

Strictly speaking, the discount rate is only allowed to vary in the models given by equations (8) and (9) if the changes represent permanent shifts in expected user costs, noting the models are derived under the assumption of a constant discount rate. Under the assumption of rational expectations the concurrent user cost can *only* be a correct measure of the expected user costs if user costs follow a random walk in which the best predictor of user costs tomorrow is user costs today. If user costs are mean-reverting, which they appear to be, the expected user costs cannot be allowed to vary over time under the maintained assumption of rational expectations. Following the convention real user costs are allowed to vary over time in the estimates below.

Equation (8) has the very clear prediction that house prices are positively related to rental income and inversely related to the real user cost of capital. Equation (9) predicts that real house prices are negatively related to the real user cost and positively related to the ratio of consumption of non-durable and housing stock (assuming conventional utility functions - for instance constant-relative-risk-aversion utility function).

The implications of the two present value models are tested against the affordability model in columns 2 to 4 in Table 1 and in all the columns in Table 2. Adding population growth to Equation (7) yields the estimates in the second column of Table 1. Population is included in the model to test whether the relevant scaling variable is income (repayment model) or income per capita (conventional models). If per capita income is the relevant scale variable the estimated coefficient of population will take the same value as the coefficient of income, but of the opposite sign. The estimated coefficients of population growth are insignificant, which suggests that it is economy-wide income, and not per capita income, that is the relevant scale variable in house price models as predicted by the repayment model.

The long-term after-tax interest rate is used instead of the short-term after-tax interest rate in the regression in the third column in Table 1. Going from the short to the long interest rate renders the estimated coefficient of the interest rate insignificant; thus, suggesting that house buyers consider the short interest rate more relevant than the long rate in house investment decisions. In fact, the long rate is the relevant interest rate in present-value models because it embeds expected future short interest rates over the term to maturity of the housing loan and, as such, is the relevant interest rate in the house buying decision. The results here are consistent with the econometric findings for the UK (Miles, 2003, p 42).

Consumer price inflation expectations are included as an additional regressor to Equation (7) in the estimates in the last column in Table 1. The estimated coefficient of expected consumer price

inflation is insignificant. The coefficients of inflation remain insignificant if contemporaneous and lagged consumer price inflation are added to the model (the results are not shown). These results suggest that house buyers consider nominal user costs as opposed to real user costs as the relevant cost of capital variable. If house buyers are aware that inflation erodes the real value of debt, the sum of the estimates of the change in consumer price inflation should be the same as the coefficient of the nominal interest rate but of opposite sign. This result is, to some extent, consistent with the estimates by the IMF (2004, Box 2.1) for a sample of 18 countries in which they find that the real interest rate elasticity of house prices is insignificant and, consequently, use the nominal interest rate as an indicator of the cost of capital.

Expected house price inflation is included instead of expected consumer price inflation in the regression in the first column of Table 2. The higher is the expected house price inflation the lower is the real user cost of housing and the higher is the present value of housing services. However, the estimated coefficient of expected house price inflation is negative, which supports further the result above that house prices are not positively related to expected consumer price inflation.

Table 2. Parameter estimates of various house price models.

	1	2	3
$\Delta \ln P_{t-1}^h$	-0.06(2.35)	0.55(15.6)	0.41(10.6)
$\Delta \ln[i_t(1 - \tau_t)]$	-0.04(0.91)	0.08(1.12)	-0.10(1.93)
$\Delta \ln Y_t$	0.50(11.9)		0.52(9.22)
$\Delta \ln Y_{t-1}$	0.31(6.78)		0.22(3.31)
$\Delta \ln Y_{t-2}$	0.06(1.41)		-0.18(2.72)
$\Delta \ln(cc)_t$	0.15(4.20)		0.21(4.43)
$\Delta PhInf_{t+1}^e$	-0.51(27.6)		
$\Delta \ln(rent)_t$		0.14(3.08)	-0.14(3.15)
ΔInf_{t+1}^e		-0.01(2.42)	-0.002(0.71)
ECT_{t-1}	-0.17(9.78)	-0.09(6.85)	-0.11(6.59)
$R^2(\text{Buse})$	0.97	0.93	0.99
DW	1.16	1.94	1.92

Notes. See notes to Table 1. $Phinf^e$ is expected house-price inflation and is estimated by regressing it on two period lags of house price inflation, time-dummies and growth in money supply ($M1$). “rent” is an index of rental income. **Second column:** The ECT-term is created from regressing house prices on housing rent, time-dummies and fixed-effect dummies.

The pure present value model, in which house prices depend on real user costs and rental income, is estimated in the second column of Table 2. Inflation expectations are now significantly negative reinforcing the results above that it is nominal, as opposed to real, after-tax interest rates that are relevant for the house buying decision. The estimated coefficient of rental income is statistically significant; however, the estimated coefficient is well below the predictions of one. The short-run rental elasticity is 0.14 and the long-run elasticity is 0.3. The low elasticity estimate may reflect three things. First, that rental accommodation may not be a close substitute for owner occupation. If this is the case movement in housing services may not echo rental prices. Second, the rental income statistics are the average rent of the entire rental market including government housing. The relevant rental income in the present value models is the marginal rental income in the private rental market because the opportunity cost of owner occupying in most circumstances is rental cost at the margin. Third, the low elasticity may suggest that the present value model is not an adequate house price model. This appears, indeed, to be the case. When the nominal income is added to the present value model in the last column of Table 2 the coefficient of rent becomes significantly negative.

Finally, it worth noting that the error-correction terms are highly significant in all regressions in Tables 1 and 2. These results are inconsistent with the present value models in which the supply side is suppressed. In present value models house prices should only respond to changes in rental income or the marginal rate of substitution without allowing for supply responses that render the long-term effect of changes in rental income or the marginal rate of substitution lower than the short-term effects as explained in Figure 1. However, in the affordability model and Tobin's q models an increasing demand for houses leads to house prices in excess of replacement costs and, consequently, triggers a supply response that is captured by the error-correction term.

Overall, the regressions give strong evidence in favor of the repayment model over conventional house price models on several counts. First, it is total income as opposed to income per capita which is the relevant scale variable in the estimates. Second, the relevant interest rate is the short rate as predicted by the repayment model. Third, house prices gravitate towards acquisition costs in the long run as predicted by the repayment model and not per capita income as in most house price models. Fourth, the relevant cost of capital measure is the nominal as opposed to the real interest rate. Fifth, supply shocks, such as building cost shocks, are influential for house prices in the short run as well as the long run. Sixth, house prices are independent of rental income when income is allowed for in the estimates, which suggests that cost of rental accommodation is not an important decisive variable for would-be house buyers.

4.3 Mean Group and Pooled Mean Group estimates

While the FGLS method used above is an efficient estimator it has the disadvantage of restricting the short-run coefficients to be the same across countries. To test for the sensitivity of the results to alternative estimators, the Mean Group (MG) estimator of Pesaran and Smith (1995) and Pesaran *et al.* (1996) and the Pooled Mean Group (PMG) estimator of Pesaran *et al.* (1997, 1999) are applied to the regressions in Tables 1 and 2. While the MG estimator allows the slope coefficients to vary across cross-section units in the short-run as well as in the long-run the PMG estimator provides the weighted average of individual group estimators, where the weights are proportional to the inverse of their variance. The PMG estimator averages the short-run parameters and pools the long-run parameters, thereby combining the efficiency of the pooled estimation while avoiding the inconsistency problem associated with the pooling heterogeneous dynamic relationships.

Table 3. Parameter estimates of Equation (7) using the MG and PMG estimators.

	1		2		3		4	
	MG	PMG	MG	PMG	MG	PMG	MG	PMG
$\Delta \ln P_{t-1}^h$	0.46(7.69)	0.49(8.10)	0.42(7.05)	0.48(8.16)	0.46(8.59)	0.48(9.53)	0.43(6.89)	0.46(7.21)
$\Delta \ln [i_t(1 - \tau_t)]$	-0.02(1.30)	-0.02(1.16)	-0.02(1.24)	-0.02(1.17)	-0.03(1.07)	-0.03(1.02)	-0.01(0.47)	-0.01(0.46)
$\Delta \ln Y_t$	0.48(2.41)	0.37(2.20)	0.47(2.17)	0.36(2.30)	0.55(2.86)	0.46(2.67)	0.47(2.34)	0.36(2.08)
$\Delta \ln Y_{t-1}$	0.12(0.67)	-0.02(0.10)	0.13(0.70)	-0.02(0.11)	0.07(0.44)	-0.06(0.40)	0.16(0.82)	-0.01(0.07)
$\Delta \ln Y_{t-2}$	-0.09(0.75)	-0.18(1.75)	0.001(0.01)	-0.13(1.24)	-0.14(1.32)	-0.23(2.04)	-0.08(0.64)	-0.16(1.48)
$\Delta \ln(cc)_t$	0.28(1.63)	0.22(1.27)	0.36(2.24)	0.27(1.64)	0.24(1.59)	0.19(1.31)	0.26(1.62)	0.20(1.13)
$\Delta \ln(Pop)_t$			0.60(0.30)	0.73(0.47)				
$\Delta \ln f_{t+1}^e$							-0.00(0.34)	-0.00(0.42)
ECT_{t-1}	-0.12(3.56)	-0.10(3.21)	-0.12(3.78)	-0.11(3.46)	-0.11(3.43)	-0.10(3.03)	-0.15(4.57)	-0.13(4.02)
Hausman (<i>p</i> -val)	0.06		0.03		0.05		0.12	

Notes. Hausman is the Hausman (1978) test for the poolability restriction of the long-run parameters in the PMG estimator under the null hypothesis that the restriction holds. Estimation period: 1973-2004, except for the regression in the last column in which the estimation period is 1973-2003. Constant terms and time dummies are included in the estimates but not shown. The numbers in parentheses are absolute *t*-statistics. **Column 3:** The interest rate term is based on a nominal long interest rate (the nominal interest rate is used in the other columns). Inf^e is inflation expectations estimated by regressing consumer price inflation on two lags of inflation, growth rates in *M1* and time-dummies. *Pop* is the size of the population.

The results of estimating Equation (7) using the MG and PMG estimators are presented in Table 3. The null hypothesis of poolability restriction of the long-run parameters in the PMG estimator is rejected at the 5 percentage level in two of the cases and in none of the cases at the 1 percentage levels suggesting that there is some long-run parameter heterogeneity in the PMG estimates; however, the heterogeneity problem is not serious. The coefficient estimates are very similar to the estimates in Table 1, which suggests that the parameter restrictions imposed on the FGLS estimates

are unbiased. The statistical significance of the coefficients are lower than the FGLS estimates, which is unsurprising since the allowance for the cross-country correlation between the error terms render the FGLS estimates more efficient than the MG and PMG estimates.

The long-run income elasticity remains close to one and the coefficients of population growth and expected inflation remain insignificant in the MG and PMG estimates. The coefficients of the after tax nominal interest rates have lost their statistical significance in the regressions in Table 3; however, the coefficients retain the right sign. Finally, the systematic pattern found in the regressions in Table 1 between the first and the second lag of income growth have been lost in the results in Table 3, which suggests that changing income growth rates may not be as influential for house price dynamics as indicated in Tables 1 and 2. However, this result has no bearing on the validity of the housing price models tested in this paper.

Table 4. Parameter estimates of various house price models using the MG and PMG estimators.

	1		2		3	
	MG	PMG	MG	PMG	MG	PMG
$\Delta \ln P_{t-1}^h$	0.43(8.57)	0.46(8.77)	0.57(10.98)	0.59(10.79)	0.46(7.76)	0.46(7.57)
$\Delta \ln[i_t(1 - \tau_t)]$	-0.001(0.07)	-0.001(0.07)	-0.02(1.11)	-0.02(1.22)	-0.01(0.64)	-0.01(0.44)
$\Delta \ln Y_t$	0.32(1.55)	0.24(1.39)			0.50(2.39)	0.52(3.92)
$\Delta \ln Y_{t-1}$	0.16(0.82)	0.01(0.05)			0.28(1.58)	0.23(1.13)
$\Delta \ln Y_{t-2}$	-0.06(0.56)	-0.15(1.71)			0.11(0.60)	0.07(0.57)
$\Delta \ln(cc)_t$	0.19(1.29)	0.14(0.90)			0.26(1.47)	0.11(0.76)
$\Delta \text{PhInf}_{t+1}^e$	-0.003(10.2)	-0.003(9.07)				
$\Delta \ln(\text{rent})_t$			0.27(1.85)	0.33(2.27)	-0.02(0.10)	0.06(0.45)
$\Delta \text{Inf}_{t+1}^e$			-0.00(0.96)	-0.00(0.47)	-0.00(0.15)	-0.00(1.20)
ECT_{t-1}	-0.17(5.83)	-0.14(5.25)	-0.17(5.34)	-0.13(3.66)	-0.24(5.51)	-0.12(3.85)
Hausman (p-val)	0.24		0.08		0.56	

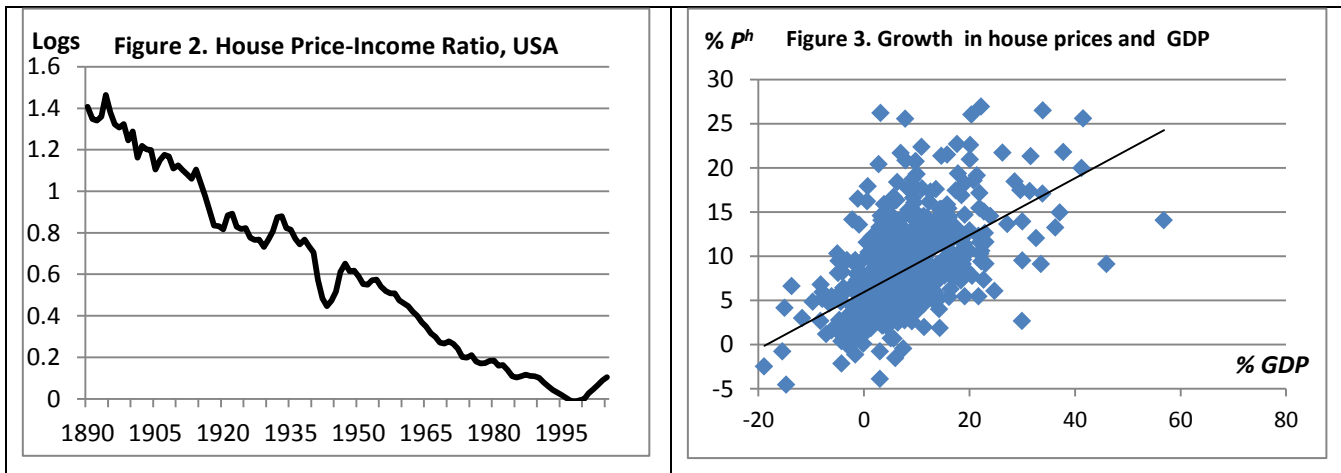
Notes. See notes to Table 1. MG stands for Mean Group estimator and PMG stands for Pooled Mean Group Estimator. Phinf^e is expected house-price inflation and is estimated by regressing it on two period lags of house price inflation, time-dummies and growth in money supply ($M1$). “rent” is an index of rental income. **Second column:** The ECT-term is created from regressing house prices on housing rent, time-dummies and fixed-effect dummies. **Third column:** The ECT-term is created from regressing house prices on construction costs, housing rent, time-dummies and fixed-effect dummies.

Finally, the tests of the affordability model against conventional house price models in Table 4 are quite similar to the regression results in Table 2. Rental income loses its significance when income is included as the scale variable in the model and house price inflation expectations, consumer price inflation expectations and population growth remain insignificant in the regressions. These results reinforce the results in the previous sub-section that the affordability model dominates the two conventional house pricing models considered here.

5 Implications of the repayment model

5.1 Income and house prices

The affordability model predicts that house prices are related to income on a one-to-one basis in the short run but are unaffected by income in the long run. This prediction is supported by the evidence in Figures 2 and 3. For the US the log of ratio of house prices and total nominal income has declined substantially, over the past century. This indicates a long-run income elasticity of house prices below one. This decline may be difficult to explain in an intertemporal framework from which conventional house pricing models are derived. According to the repayment model and a standard Tobin's q model house prices are determined by factors that are, at least to a large extent, independent of income.



Notes. Income is measured as nominal GDP. The data in Figure 3 are from the OECD countries covered in the empirical section over the period from 1970 to 2006.

The short-run nexus between house prices and nominal income is displayed in the scatter plot in Figure 3. On year-to-year frequencies there is a close and an almost one-to-one relationship between income and house prices; a relationship that is consistent with the predictions of the repayment model in which a higher income increases the ability to pay for the mortgage.

5.2 House prices and demographic shifts

In their influential paper Mankiw and Weil (1989) argued that house prices in the *long run* are strongly influenced by the fraction of the population aged 20 to 30. Demographics permanently influence house prices in their model because depreciation expenses are positively related to demand

factors. Thus there is no supply response to depreciation expenses in their model.⁴ The relevant age cohort in the repayment model is the size of the population aged 20 years and above, which means that life expectancy, epidemics, emigration and the number of individuals entering the 20+ age cohort are all relevant determinants of house prices in the short run. This implies that the demand for houses can change without an increase in income per capita or income per household for instance when there are increases in the proportion of the households entering the age at which households are formed, emigration waves and epidemics such as the Spanish flu. The large number of deaths among young males during the world wars and the Spanish flu from 1918 to 1920 were potentially important contributors to the world-wide house price decline in the period immediately following WWI. Immigration will increase the total income of would-be house buyers and, consequently, it increases the demand for housing and has been a potentially important contributor to the recent house price run-up.

5.3 The recent house price run-up and the affordability index

The affordability index, which, as defined above, is measured by the disposable income of a median income earner divided by interest and principal repayments of a standard loan with 20% down-payment, has been ‘surprisingly’ constant in the OECD countries during the recent house price boom. Girouard *et al.* (2006) find that the affordability index was stable in the OECD countries over the period from 1990 to 2003, which was the entire period covered in their analysis. Similarly McCarthy and Peach (2004) find that the recent house price run-up in the US can be explained by declining nominal interest rates and increasing nominal income. Based on this evidence they conclude that the house price level in 2004 did not represent a housing price bubble. This suggests that the recent house price run-up, at least up to 2004, can be explained by income growth and the reduced nominal interest rate of a long-term mortgage loan. Following the predictions of the repayment model, in which principal repayments and interest rates on variable interest loans are also influential for house prices, the recent increase in interest-rate-only loans and variable-interest-rate loans would potentially also have fuelled the recent house price run up. The easier access to credit during the latest run-up in the housing market has reduced downward payment and fueled house prices (Carrington and Madsen, 2009). Although this aspect has not been considered in the empirical estimates this feature is consistent with the affordability model.

⁴ Their result is an outcome of the assumption that housing investment is assumed to be a function of Tobin’s q and the depreciation of the existing housing stock: $\dot{H}_t = I(q)_t - \delta H_t$, where q is the shadow price of housing stock, I is gross investment and δ is the rate of depreciation. From this model it follows that permanent demand shocks have permanent effects on house prices. Note that this model is not derived from an optimizing framework.

6 Conclusion

This paper has established a repayment model of house prices that is based on the principle of affordability. In this model housing loans and, therefore, house prices depend on the ratio of income or nominal mortgage repayments in the short run while they are determined by acquisition costs in the long run. Using data for 16 OECD countries, estimates of the model gave evidence in favor of the repayment model over conventional house price models in which house prices are predominantly driven by per capita income, rental income and real user cost of capital. In particular, the empirical estimates gave the following results that are all consistent with the repayment model: 1) Nominal as opposed to real user cost of capital is the relevant cost of capital variable; 2) house prices depend on the short and not the long interest rate, which is the relevant discount rate in intertemporal models; 3) the income elasticity of house prices is close to one in the short run; 4) it is total GDP and not per capita GDP that is the relevant scaling variable; and 5) house prices are driven by acquisition costs in the long run.

The repayment model has important macroeconomic implications. First, that the house price elasticity of income among existing and would be house owners is one in the short run. This implies that an immigration wave that increases total disposable income among existing and would-be house owners will increase house prices by the increase in income of immigrants as a percentage of total income. This prediction is not shared by conventional house price models in which house prices are a function of income per capita. Second, the nominal mortgage short-term interest rate elasticity of house prices is close to one. This renders monetary policy, which targets short interest rates, a powerful tool in controlling house price inflation in the short run. Third, house prices are independent of expected consumer price or house price inflation under the maintained assumption that house buyers suffer from inflation illusion. Thus, real house prices decline in periods of inflation, which stands in contrast to the predictions of rational expectation models in which inflation-induced interest rate hikes have positive effects on real house prices when mortgage interest rates are tax deductible. Fourth, the model is able to account for the recent house price run-up in most OECD countries. The disinflation-induced interest rate reductions, financial innovations that have reduced mortgage repayments and the cyclical upturn in the economy have increased the potential to service debt to such an extent that the ratio of the effective mortgage payments to after-tax income has been relatively constant during the last house price run-up in the OECD countries.

Data appendix

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