A Repayment Model of House Prices[1]

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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 by lower housing repayment, decreasing nominal interest rates, and a large inflow of migrants. Empirical estimates give strong support for the model.

Key words. House prices, institutions, affordability, financial innovations, Tobin's *q*.
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Rising income per household, increasing share of the population in the age of 20-35, lower nominal interest rates, and capital market innovations, in conjunction with an inelastic supply of houses in the short run are regarded as being responsible for the recent house price run-up in the OECD countries (McCarthy and Peach, 2004, IMF, 2004, OECD, 2005, and Brunnermeier and Julliard, 2006). However, there is no well-developed theory connecting house prices to income, demographic factors, nominal interest rates and capital market innovation. Although income per capita or income per household remains the principal driving variable in the short run as well as the long run in almost all models of house prices (Burkley and Ermisch, 1982, Meen, 1990, 2002, IMF, 2004, OECD, 2005, Gallin, 2006, and Girouard *et al*., 2006), it has thus far not been established theoretically why house prices should be positively related to income and, particularly, not why the income elasticity of house prices tends toward one in empirical estimates that are, typically, estimated over a relatively short

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period.[2] Nor has it been shown why house prices are positively related to migration and demographic factors in the short run but not in the long run and why house prices respond to financial innovations that change the mortgage payment profile over time-span of the 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).

The contribution of this paper is to establish a simple housing price model in which house prices are driven by demand in the short run but determined by supply in the long run. In the short run house prices adjust to the level at which nominal mortgage expenditure is in a fixed proportion to the after tax income of potential house buyers. From this relationship it is shown that, in the short run, house prices are determined by the nominal mortgage interest rate, the principal, the down payment, the after tax disposable income of house-buyers and house owners, financial innovations, and net inflow to the housing market. In the long run house prices are determined by the acquisition cost of houses under the assumption that house buyers and developers have an incentive to build new homes if house prices exceed their acquisition costs.

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 income and, to some extent, also expected income, which 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).

However, affordability has never been taken seriously in the academic literature as a factor determining house prices, despite it being the principal factor in the lending provision. Guttentag *et al*. (1991) argue that the two most important quantitative constraints on borrowers in loan provisions are the maximum ratio of initial total expenses to income and a maximum loan-to-appraised-value. Furthermore, the survey evidence of Miles (2003) for the UK shows that house buyers concentrate on immediate mortgage payments relative to their income when they decide on the amount to borrow. In their survey of the housing market 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). This evidence is consistent with the finding of Miles (2003) that

[2] See Girouard *et al*., 2006, for an overview of estimated income elasticities and Madsen, 2008, for a critical assessment of income in conventional house price models.

house buyers ignore longer term risks associated with the mortgage repayments. Coupled with the fact that households tend to concentrate on the immediate monthly mortgage costs (IMF, 2004) it follows that financial innovations that lower the immediate nominal mortgage costs, without necessarily lowering the real cost of capital, will drive house prices up in the short run.

House prices are only determined by housing affordability in the short run because builders and potential house buyers have direct monetary incentives to build new houses if house prices exceed acquisition costs and *vice versa*. Since potential house buyers will always prefer the cheapest option they will build their own house if acquisition costs are noticeably below house prices and builders will see a profit opportunity by building a new house and selling it at a higher price. Consequently, building investment will endogenously adjust to close the gap between house prices and house acquisition costs, and house prices will automatically be determined by acquisition costs in the long run. Thus, the model shares the same properties as the Tobin's *q* model of investment in which the price of a non-fixed income asset is determined by effective acquisition costs in steady state (see Madsen and Davis, 2006).

The model suggested in this paper deviates from conventional house pricing models in which house prices are determined either by the consumers' intertemporal decision or by the present value of rent/housing services. In conventional models user costs of housing are used to determine the allocation of housing services over the life cycle for a given time-preference and the marginal utility of housing services are 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 example Gallin, 2006, and Girouard *et al*., 2006). In the model in this paper the relevant measure of the cost of capital is the weighted average after-tax nominal mortgage interest rate plus principals. The income of existing and would-be house owners only has a short-tem effect on house prices.

The 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 a demand and a supply side where demand determines the house price in the short run while supply determines house prices in the long run. The model will be referred to as the repayment model. The validity of the behavioral assumptions underlying the model is discussed in the next section. 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 time, however, it is rarely above 30% (Weicher, 1977, Hulchanski, 1995, Bourassa, 1996, and Savage, 1999). Based on the households' income, fixed expenses, mortgage expenses and other information, the bank estimates the maximum obtainable loan of the household and, therefore, the maximum house price that is affordable for the household. 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:

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

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, θ_i is the income tax rate of the representative house buyer, 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 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, $1 > \alpha > 0$.

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

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

where N is the net number of would-be house owners and Y is the sum of the income of potential house buyers. The lower is Ψ the more affordable it is to own 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:

$$P_t^h = \Psi_t \frac{Y_t\ (1-\theta_t)(1+g_{t+1}^e)^{1-\alpha}}{[(i_t + t_t^p)(1-\tau_t) + \phi_t]M_t \cdot N_t} = \Psi_t \frac{Y_t\ (1-\theta_t)(1+g_{t+1}^e)^{1-\alpha}}{[(i_t + t_t^p)(1-\tau_t) + \phi_t]H_t}, \tag{3}$$

where H is the real housing stock demanded by house buyers, and g_{t+1}^e is expected nominal income growth.

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

$$\ln(P_t^h / P_t) = \ln(\Psi_t) + \ln[Y_t^r (1-\theta_t)] - \ln H_t - \ln[(i_t + t_t^p)(1-\tau_t) + \phi_t] + (1-\alpha)\ln(1+g_{t+1}^e), \tag{4}$$

where Y^r is the real income of all 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 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.

At first glance the model resembles conventional house price models. However, there are large differences between the proposed model and conventional models. 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 for example Buckley and Ermisch, 1982, Meen, 1990, 2002, Muellbauer and Murphy, 1997, and Girouard *et al*., 2006). Thus, a sudden decline in the population due to emigration, war or epidemics, for example, would, keep per capita income approximately constant in conventional models and, thus, have no affect on house prices in the proposed model while 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 important for house prices in the repayment model in the short run as well as 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 is absent from conventional models because they do not affect the true cost of capital. In the repayment model principal 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 will, therefore, increase house prices in the repayment model, but not in user-cost-based models. Furthermore, there is an inbuilt assumption of inflation illusion in the repayment model in the sense that 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, while the relevant interest rate in user-cost-based models is the long 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. 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 loan type, the resulting house price increase can be calculated straightforwardly using Equation (3). This way of calculating the effects of financial innovations on house prices differs from the literature in which credit constraints are often measured as the ratio of lending to house value of first time buyers or the ratio of lending to income (see for example Muellbauer and Murphy, 1997 and Koskela *et al*., 1992). While these indexes will capture quantitative credit constraints, they may not adequately capture the direct effects on house prices of financial liberalizations that influence the $[i_t(1-\tau_t)+\phi_t]$-term. Financial innovations may also transmit to house prices through the income term in the repayment model to the extent that financial innovations lower down payments and, therefore, increase the pool of potential house buyers and their aggregate income. The appearance of the sub-prime market in the US in the mid 1990 lowered the effective down-payment and, consequently, increased the number of potential house buyers.

The influence on 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 future: $U'(c_t) = \beta(1+r)U'(c_{t+1})$, 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 payment (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_{it}-term and the income term through the channel of down-payments.

In this connection an interesting possibility arises, namely that the repayment model may be able to explain the dynamics of house prices in the short run although the assumptions underlying the model do not hold because house buyers are credit constrained to such a degree that they will always take a loan whenever possible without borrowing beyond the point at which they optimize intertemporally. However, as pointed out by Miles (2003) the availability of credit in the UK and, presumably, also in other high-income countries, has been increasingly abundant since the financial market deregulations started in the early 1980s and potential house buyers would, therefore, not have been credit constrained – at least not over the past couple of decades. Furthermore, the key point of the seminal paper on credit constraints by Stiglitz and Weiss (1981) is that banks do not increase their lending rate in states of tight credit because it increases the average riskiness of the projects that a bank is financing. The sub-prime market is a clear example of interest rates that are positively related to the loan-to-house value at the margin. Thus, it is highly unlikely that credit constraints have been binding in the housing loan market over the past few decades and the excessive focus on initial payments among borrowers and lenders, is unlikely to be a rational choice among house buyers.

2.2 Supply of houses

The demand model of house prices is only applicable in the short run during which the supply of houses is inelastic. However, it is unrealistic to assume that increasing income and population size will continue to put upward pressure on house prices while the stock of houses remains unaltered – otherwise the stock of houses would not have increased over the past century. In the long run building activity will be driven by the ratio of house prices and acquisition costs of houses as in the Tobin's *q* principle and house prices will, consequently, be determined by the acquisition costs of houses in the long run. In any event, Tobin's *q* need not be derived from an intertemporal optimization problem for builders and owner builders. The simple principle here is that builders and would-be house owners initiates housing investment if it costs less to build a house than it costs to buy an identical house. Thus, investment in new houses is determined by Tobin's *q*:

$$\dot{H} = \psi[q_t - 1], \tag{5}$$

where *q* is the shadow price of housing stock, which is measured by the ratio of house prices divided by the effective acquisition costs. The acquisition costs are predominantly given by construction costs plus costs of urban land. Since there are no value-added taxes on the re-sale of houses, indirect taxes on building materials, builders, and land render increase the cost of building and, consequently, lower the potential profit from building a new house.

2.3 Equilibrium

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

$$P_t^h = \Psi_t \frac{Y_t \ (1-\theta_t)(1+g_{t+1}^e)^{1-\alpha}}{[i_t(1-\tau_t)+\phi_t]H_t}, \tag{3}$$

$$\dot{H}_t = \psi\left[\frac{P_t^h}{\Omega(H)_t(1+t_t^i)} - 1\right], \tag{5}$$

where Ω (H) is pre-tax replacement costs of houses, Ω '(H) $\geq$ 0. Whether or not acquisition costs are positive functions of the housing stock is an empirical issue. While building costs are not affected by the housing stock 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, which suggests that prices of developed land are likely to be related to the demand for houses. For the US, by contrast, 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).

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 $\Omega(H)_t = lc^{\beta} cc^{(1-\beta)}(1+n \cdot i/12)$, $0 < \beta < 1$, where *n* is the number of months it takes to complete the building multiplied by the average fraction of working capital.[3] 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:

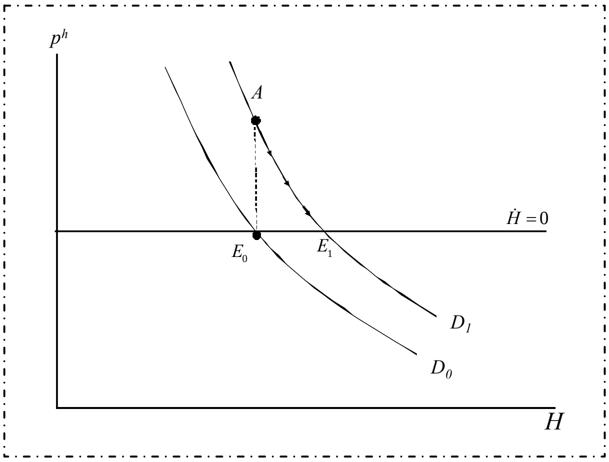
$$p_t^{h^*} = (1+t_t^i)(1+n \cdot i/12) lc^{\alpha} cc^{(1-\alpha)}, \tag{6}$$

where an asterisk signifies steady state. This equation shows that house prices in the long run are determined entirely by acquisition costs.

[3] Since value-added taxes are not paid on interests this relationship is only an approximation.

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 lowers housing affordability and, therefore, induces house buyers to move into smaller houses to keep the fraction of income going to mortgage payments constant.

Figure 1.



Consider an unexpected increase in income that increases 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 jumps 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 towards its new steady state at the point E_1.

The shift to the point A is likely to result 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, 2008).

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 under the assumption that interest payments are tax deductable. 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 inflation-induced reduction in the 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, 2005, Brunnermeier and Julliard, 2006). 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 and the potential adverse effects of increasing interest rates on flexible rate loans; 2) suffer from inflation illusion; and 3) 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 question is whether these assumptions are valid.

The repayment model focuses on the initial costs and not payments over the whole 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 time-span of the loan, they are running the risk of not being able to honour the debt obligations in adverse event occurrences. 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 (2003) 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). 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 is found by Roszbach (2004) for Sweden. Roszbach (2004) 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 current affordability has a large weight in the lending provision.

Experimental evidence gives support to this shortsighted behavior. Experimental evidence suggests that mental accounting plays an important role for consumer spending and behavior (Shefrin and Thaler, 1988). Some mental accounts, such as wealth, are less tempting for spending 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 for the household 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 events of divorce, unemployment, higher interest rates, property tax hikes, and declining house prices that bring down their collateral. Therefore, the immediate mortgage payment has a much higher weight than future payments. The introduction of interest-rate-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 honour their debt. That people give too low 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, which in terms of the housing market 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 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 honour their debts are unlikely to occur.

The risk of failure to be able to pay 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 have a moderate probability each but jointly carry a significant 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 complex system is substantially higher than appreciated by even the experienced individual, because the risk factors are highly positively correlated. For example, a downturn in the economy is often associated with increasing nominal interest rates, lower stock and house prices, and unemployment. Finally, individuals place overly narrow confidence intervals under uncertainty; that is, individuals 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.[4] An inflation-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 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 (2006) find evidence of widespread inflation illusion among house buyers. Finally, experimental studies give strong support for widespread money illusion among

[4] The affordability index is repeatedly used by commentators in the public debate to justify the current house prices (see for example Leahey, 2005). An inflation-induced increase in mortgage payments, according to this hypothesis, lowers house prices although the real user costs of housing have been reduced. The repeated use of the affordability index as an indicator of house price disequilibrium suggests that inflation illusion is not only limited to the majority of house buyers but also to many ‘expert’ commentators.

people (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).

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 the measure of cost of capital (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 the Euler equation must, in most instances, be violated and the lending must, to a large degree, be dictated by the lending institution's 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 the borrower, 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, mortgage lenders and borrowers' interest rate predictions will be biased towards the low starting values of interest rates.

Finally, the survey evidence by Shiller (1996) supports the view that house buyers are keen to buy now rather than later, because they have unrealisticly high expectations about real house price appreciations, 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 a 10-year period and yet real house prices in the US have increased on average 5.7% on a 10-year period basis over the period from 1900 to 2006 (the corresponding figure in nominal terms is 44.8%)! This result shows that people's expectations are heavily influenced by the recent past experience and that house buyers have highly unrealistic expectations about increases in real house prices in the long run.

Finally, in the repayment model it has been assumed that house buyers are rational to the extent that they will build new houses if house prices exceed the acquisition costs. This may appear to contradict the assumptions of inflation illusion and other judgmental errors. However, it does not. Judgmental errors in financial dispositions are quite different from consumers being able to distinguish prices of the same or similar products. House buyers may not have a hedonic price formula in their head, however, they will always go for the cheaper option; otherwise grocery stores would not advertise cheap deals.

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 income but the total income of potential and existing house owners; and 3) the relevant cost of housing variable is not real user costs based on the long mortgage rate but the total nominal mortgage costs based on the short interest rate. The model is estimated for a panel of 16 OECD countries.

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

Equations (3) and (5) yield the following error correction model in which demand and supply factors determine house prices in the short run while house prices gravitate toward acquisition costs in the long run:

$$\Delta lnP_t^h = \alpha_0 + \alpha_1 \Delta lnP_{t-1}^h + \alpha_2 \Delta lnY_t + \alpha_3 \Delta ln[i_t(1-\tau_t)] + \alpha_4 \Delta lnPop_t + \alpha_5 \Delta lncc_t$$
$$+\alpha_6 \Delta \ g_{t+1} + \alpha_{7j} \sum_{j=1}^{3} \Delta \ g_{t-j} + \alpha_8 TD + \alpha_9 ECT_{t-1} + \varepsilon_t, \qquad (9)$$

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, Pop is the size of the population, ECT is an error correction term which is the residual from regressing the log of house prices on the log of building costs, g is growth in nominal income, and cc is construction costs. Following the common practice g is also measured as consumer and house price inflation. The term $Y_t^{r}(1-\theta_t)$ is proxied by real GDP because a large fraction of taxes are transferred back to households as welfare payments.

Total GDP will not be a useful scale variable in the event of large shifts in the home ownership rate or a shift in the fraction of the population in the 20-35 year age group relative to other age cohorts. Based on the Celsius surveys in 1970 and 1980, Mankiw and Weil (1989) show that the demand for houses is increasing sharply for the 20-30 year age cohort. The model is estimated for the following 16 OECD countries over the period from 1971 to 2004: Canada, the US, Japan, Australia, New Zealand, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Sweden and the UK. The data construction and data sources are detailed in the data appendix.

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 cointegration estimates but was subsequently omitted because it was statistically and economically insignificant at any conventional significance level. 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 lending rate is measured as the interest rate on 3-months treasury bonds and as the interest rate on long-term government bonds in some of the estimates. 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 deductable (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 the after-tax interest 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 further reduced 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.

Lagged values of g are included in the estimates following the literature in which user costs are usually computed as the *post*-tax interest rate minus lagged inflation rates. Contemporaneous values of g are not included in the estimates because they form a linear combination with contemporaneous and lagged house price changes in the estimates in which g is measured by house price inflation. One period ahead expected g is also included in the estimates to allow for the possibility that the expected value of g is based on rational expectations, where g_{t+1} is instrumented using g_{t-1} and g_{t-2}, $\Delta \ln M1_{t-1}$, and $\Delta \ln M1_{t-2}$.

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 principals as a percentage of the total housing loans (see Leahey, 2005, and, particularly, OECD, 2005, 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 data are used to gain efficiency. To gain further efficiency, the generalized instrumental variable method, where the covariance matrix is weighted by the correlation of the disturbance terms between countries is used. More specifically the following variance-covariance structure is assumed:

$$E\{\varepsilon_{it}^2\} = \sigma_i^2, \quad i = 1, 2, \ldots 16,$$
$$E\{\varepsilon_{it}, \varepsilon_{jt}\} = \sigma_{ij}, \quad i \neq j,$$

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.

Table 1. Parameter estimates of Equation (9).

	1	**2**	**3**	**4**
ΔlnP_{t-1}^h	0.39(11.4)	0.41(12.1)	0.38(8.71)	0.38(11.1)
$\Delta ln[i_t(1-\tau_t)]$	-0.27(3.32)	-0.18(2.15)	-0.20(2.13)	0.01(1.39)
ΔlnY_t	0.42(6.28)	0.45(6.55)	0.46(6.86)	0.41(6.11)
$\Delta lncc_t$	0.24(4.91)	0.26(5.27)	0.25(5.18)	0.23(4.51)
$\Delta lnPop_t$	0.32(1.16)	0.39(1.31)	0.34(1.22)	0.31(1.06)
Δg_{t+1}	0.01(1.46)	0.00(0.05)	-0.01(2.41)	0.01(1.66)

Δg_{t-1}	0.32(5.49)	0.00(0.42)	0.17(3.73)	0.30(5.01)
Δg_{t-2}	0.18(2.96)	0.00(0.60)	0.00(0.08)	0.15(2.28)
Δg_{t-3}	0.14(2.47)	0.00(0.23)	0.01(1.06)	0.12(2.12)
ECT_{t-1}	-0.13(8.10)	-0.14(8.36)	-0.09(6.11)	-0.13(8.02)
R^2(Buse)	1.00	1.00	0.99	0.99
DW	1.89	1.89	1.94	1.88

Notes. Estimation period: 1971-2004. Constant terms and time dummies are included in the estimates but not shown. The numbers in parentheses are absolute *t*-statistics. **Column 1**. *g* is measured as nominal income growth and a 3-months interest rate is used. **Column 2**. *g* is measured as consumer price inflation and a 3-month interest rate is used. **Column 3**. *g* is measured as house price inflation and a 3-month interest rate is used. **Column 4**. *g* is measured as nominal income growth and a long interest rate is used.

The results of estimating Equation (9) are shown in Table 1. The estimated coefficients of population growth are insignificant in all estimates, which suggests that it is economy-wide income, and not per capita income, that is the relevant scale variable as predicted by the repayment model. The estimated coefficients of income are statistically highly significant and the income elasticity is approximately 0.45 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, on average, -0.12 and is statistically highly significant in all estimates, which suggests that house prices can deviate from their long-run equilibrium over prolonged periods – only 12% 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 real house prices in the 1970s, during which real construction cost increases of 25% were not unusual in the OECD countries; thus contributing to an increase in real house prices of almost 25% during in the same period, noting that the coefficient of building costs is close to one in the cointegration estimates. During the recent house price boom real building costs have not contributed to the increase in real house prices.

The estimated coefficients of the nominal after tax interest rates are negative and statistically significant at the 1 percent level in the estimates in the first three columns in which the short interest rate is used. In the final column in Table 1 the cost of capital is measured by the long interest rate. The estimated coefficient of the long interest rate is positive but insignificant at conventional significance levels, which, in conjunction with the negative coefficient of the short interest rate, indicates myopic behavior among house buyers. If both house buyers and the financial markets are rational, house prices should be related to long and not short rates, provided that the financial markets and households have the same information set. The results here are consistent with the econometric findings for the UK (Miles, 2003, p 42).

In the estimates in the first column of Table 1 in which g is measured as the nominal income growth, the estimated coefficients of lagged g are economically and statistically significant, which suggests that expected nominal income, in addition to the current nominal income, is the relevant scale variable in the lending provision. Three period lags of g are significant, which gives an indication that it takes a long time for expectations to adjust to innovations in income. The sum of the coefficients of nominal income growth is 0.65, which suggests that current and expected income have weights of 0.35 and 0.65, respectively, in the lending provision. This has the very important implications that lenders and borrowers are willing to accept a higher repayment to income ratio in periods with strong nominal income growth.

Turning to the estimates in the second column in which g is measured by consumer price inflation, the estimated coefficients of g are insignificant, which shows 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 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 positive and, consequently, use the nominal interest rate as an indicator of the cost of capital.

In the estimates in the third column in Table 1, g is measured by house price inflation. The estimated coefficient of g_{t-1} is highly significant and has a magnitude that is equal to, but of opposite sign, to the coefficient of the after-tax nominal interest rate. This result is consistent with user-cost-biased models. There is a problem associated with this interpretation, however. In an intertemporal framework from which user costs are derived, it is only changes in real interest rates that are expected to be permanent that affect the intertemporal decision. This implies that it is permanent changes in growth in house prices that are relevant for real user costs. Actual changes in house price inflation are a very bad proxy for the permanent house price inflation because they fluctuate substantially around their long run equilibrium. That is, presumably, why consumer price inflation is used in the estimates of real user cost in most house price models in the literature. It is more likely that lagged house price inflation captures speculative inertia as argued by Abraham and Hendershott (1996) and Shiller (2007). The survey evidence of Shiller (2007) supports the hypothesis that expected house price inflation depends on past house price inflation. In other words, house prices are pushed up by expectations of extraordinarily high house price inflation.

Overall, the estimates give 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.

5 Implications of the repayment model

5.1 Income and house prices

The 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. Figures 1 and 2, which show the relationship between house prices and income at long-term and short-term frequencies, support this prediction. For the US the ratio of house prices and total income and the ratio of house prices and per capita income have declined by approximately 95% and 80%, respectively, over the past century, which indicates a long-run income elasticity of house prices that is well below one. The ratio of house prices to (per capita) income declined substantially more before than after WWII despite the growth in (per capita) income being much stronger after WWII than before. This suggests a significant increase in the income elasticity of house prices over time, which 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 of house prices, the long-run relationship between income and house prices does not reveal the income elasticity of house prices but that house prices are determined by factors that are, at least to some extent, independent of income.

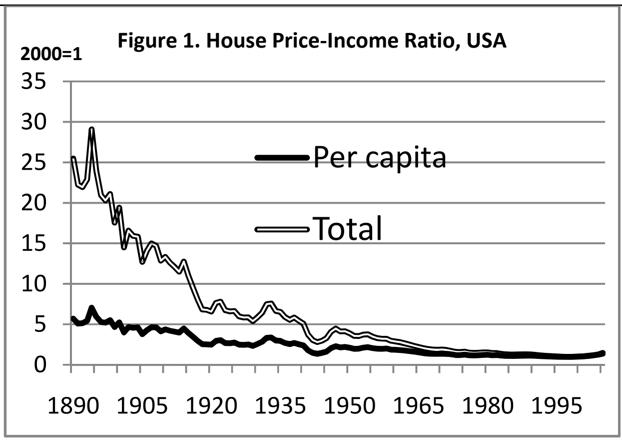


Figure 1. House Price-Income Ratio, USA

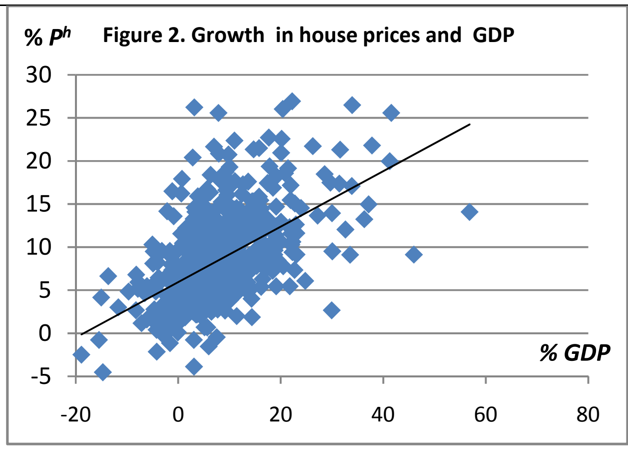


Figure 2. Growth in house prices and GDP

Notes. Income is measured as nominal GDP. The data in Figure 2 are from the OECD countries covered in the empirical section over the period from 1970 to 2006.

On year-to-year frequencies there is a close and an almost one-to-one relationship between income and house prices in the short run (see Figure 2). These results are consistent with the predictions of the repayment model in which 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 and, therefore,there is no supply response to depreciation expenses.[5] 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 such as an increase 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 important contributors to the world-wide house price declines in the period immediately following WWI. Immigration will increase the total income

[5] 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: $\dot{H}_t = I(q)_t - \delta H_t$. From this model it follows that permanent demand shocks have permanent effects on house prices.

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 as by the disposable income of a median income earner divided by interests and principals of a standard loan with 80% 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 and, therefore, does not represent a housing price bubble. This suggests that the recent house price run-up 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 principals and interest rates of 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.

5.4 Output-capital ratio in the long run

Solving (6) and (3) in steady state yields the *Y*-*H* ratio as follows:

$$\left(\frac{H_t}{Y_t^r}\right)^* = \Psi_t \frac{(1-\theta_t)(1+(1-\alpha)g_t)}{[i_t(1-\tau_t)+\phi_t]} \frac{P_t^{va}}{P_t^{inv}}, \tag{10}$$

where P_t^{inv} is acquisition cost of houses and P_t^{va} is the value-added price deflator. Since interest rates and taxes are constant in steady state the *Y*-*H* ratio varies proportionally with real acquisition costs of houses. Given that relative prices are constant in standard growth models the prediction of this model is similar to the prediction of most growth models that the *Y*-*K* ratio is constant in the long run.

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 and nominal mortgage payments in the short run while house prices 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 the per capita 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 interest rate and not the long interest rate, which is the relevant discount rate in intertemporal model; 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 exiting and would be house owners is one in the short run, implies that an immigration wave that increases net income among existing and would-be house owners will increase house prices by the fraction of the income of immigrants and 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 the 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 suffer in periods of inflation, which stands in contrast to the predictions of rational expectional models in which inflation-induced interest rate hikes have positive effects on real house prices. 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 payments 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 and after-tax income has been relatively constant during the recent house price run-up in the OECD countries.

Data appendix

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