



The effect of mortgage interest deduction and mortgage characteristics on house prices



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ABSTRACT

In many countries, house prices are overvalued according to price-to-income ratios. We propose that the borrower's ability to pay (ATP) through a mortgage is a long-run house price fundamental and find convincing evidence by means of cointegration tests, granger causality, and an elasticity of house prices with respect to ATP close to one. ATP incorporates the effect of a decreasing trend in interest rates, changes in mortgage interest deduction and mortgage characteristics. We apply the model to the United States of America, United Kingdom, Belgium, the Netherlands, Sweden, Norway, Finland and Denmark. The results provide an intuitive alternative to standard house price models.

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1. Introduction

From the mid-1990s until the recent financial crisis, house prices have increased at an astonishing growth rate in almost every developed country. This sharp increase raised concern about housing bubbles and strong overvaluation in the housing market. Assessing the possibility of overvaluation with price-to-income ratios or price-to-rent ratios would indeed suggest that many housing markets were overvalued. Even after the crisis, The Economist (November 26th, 2011; January 4th, 2014) and various policy institutions argue that many property markets “are still looking uncomfortably overvalued” based on price-to-income ratios.

There are, however, several reasons why a price-to-income ratio fails to reflect the true cost of housing. The metric does not incorporate the interest rate and therefore has ignored the effect of the decreasing long-term interest rates on house prices since the 1980s. Moreover, the maximum rate at which mortgage interest is deductible differs between countries and over time. This can lead to differences in the amount that households are able to pay that a simple price-to-income ratio ignores. Finally, in this low interest-rate environment, the standard annuity mortgage with fixed periodic mortgage payments that clear the mortgage at the end of

the term has been losing popularity recently in favor of interest-only alternatives (Scanlon et al., 2008). Mortgage product innovation can lead to higher amounts that people are able to pay such that income alone is insufficient in explaining house prices.

To gain further insight in the evolution of house prices in the long run, we develop a model in which households maximize their lifetime utility. The optimal solution results in a relationship between house prices and a variable that can be interpreted as the ability to pay (ATP) of the average household. In a first extension we augment the model to allow for mortgage interest deduction (MID) where the fiscal deduction of mortgage interest payments leads to higher house prices through a higher amount that households are able to pay. A second extension will be mortgage product innovations. Besides the standard annuity mortgage, we model two groups of mortgages. The first are the interest-only loans with repayment vehicle, such as endowment or savings mortgages. The borrower is able to make maximum use of the MID as the principal is only repaid at the end of the mortgage term through a repayment vehicle. The second group contains pure interest-only loans where the borrower has no repayment vehicle. The borrower does not accumulate equity as he only makes interest payments and hopes to refinance or pay off the mortgage through the sale of the house at the end of the term.

The model indicates that there is a constant fraction of income that goes to housing payments, which results in an amount that people are able to pay based on the possibility to deduct mortgage

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interest payments and innovative mortgage products. Changes in the MID or mortgage characteristics can be interpreted as regime shifts such that standard cointegration tests are unable to reject the null hypothesis of no cointegration (Gregory and Hansen, 1996) between house prices and income alone. Conventional and panel cointegration tests are, however, able to reject the null hypothesis of no cointegration between house prices and the measure of ATP that incorporates the MID and mortgage characteristics. We apply the model to a selection of 8 OECD countries in which the tax rate at which mortgage interest is deductible or mortgage characteristics have changed over time. ATP Granger causes nominal house prices, while evidence in the other direction is much weaker. The elasticity of house prices, with respect to our measure of ATP adjusted for MID and mortgage product innovation, is furthermore close to one, which indicates that ATP has an important economic role.

We contribute to the existing literature in multiple ways. A first contribution of the paper is that we propose a new long-run fundamental of house prices that incorporates the MID and mortgage characteristics. Therefore, the model provides an alternative toolbox to assess overheating in the housing market and study price forming for a whole range of scenarios. An important insight is that under reasonable assumptions, full capitalization of the MID into house prices is larger than the net present value of all future net tax benefits. The economic intuition from the model is that impatient households want to transfer future wealth to the present, but a borrowing constraint prevents this. Therefore, the borrower increases housing consumption as if the initial net tax benefits of the MID would not decrease over time even if interest deductions do decrease over time due to amortization. This may be of interest to policy makers who want to study the impact of changes in tax rules on house prices. Moreover, the model can be used for stress tests of mortgage lenders as the framework allows us to study the effect of changes in interest rates on house prices, which varies across countries depending on tax rules and the shares of the different mortgage products. As an example, we calculate the predicted effects on house prices from changes in the interest rate and the fiscal deductibility of mortgage interest. Finally, whereas other studies often focus on a single country, we examine the housing markets in a sample of 8 OECD countries, which makes the results of interest to a large readership.

The paper proceeds as follows. We start with an overview of the existing literature which is followed by a description of the theoretical model. The subsequent sections describe extension to the baseline model that include the mortgage interest deduction and different mortgage characteristics. Section 3 describes the data that we use in the empirical exercise. The empirical results are presented in Section 4 and include cointegration analyses, the estimation of a VECM model, an analysis of the economic importance of ATP and its components, Granger causality tests and a comparison with conventional user cost models. Section 5 describes some sensitivity analyses and we conclude in the final section.

2. Can fundamentals explain house prices? An overview of the literature

The question whether fundamentals can explain house price movements has initiated a whole debate in the literature. A variable is a long-run fundamental if a cointegration test can indicate that the residuals from a regression of house prices on that variable (and possibly other explanatory variables) are stationary. Using national data, Meen (2002) reports test statistics that are unable to reject the null hypothesis of no cointegration between house prices and fundamentals. Individual time-series cointegration tests are, however, known to have low power when the time span of the data is small. Other studies use panel cointegration

tests in the hope for more variation in the data that will increase the power of the test (Baltagi, 2008). Malpezzi (1999) is able to reject the null hypothesis of no cointegration in a panel of 133 metropolitan areas from 1979 through 1996 using panel unit root tests described in Levin and Lin (1992). Gallin (2006), however, pointed out that the critical values of the unit root test are incorrect when they are applied to residuals from the first-stage estimation such that the null hypothesis is rejected too often. The unit root tests have also been criticized as they assume cross-sectional independence. Gallin (2006) adopts a bootstrap approach that allows for cross-sectional dependence and shows that none of the tests rejects the null hypothesis of no cointegration in the USA. Using Australian data, Costello et al. (2011) provide evidence of “sustained deviations of house prices from values warranted by income” and Ambrose et al. (2013) find evidence that the correction of deviations from fundamentals can take decades using a unique data set for houses in Amsterdam from 1650 through 2005. Holly et al. (2010) are able to reject the null hypothesis of no cointegration between house prices and income in the USA using the CIPS panel unit root test described in Pesaran (2007).¹

A crucial element that deserves more attention is, however, the difference in null hypothesis between cointegration tests that use individual time-series and panel tests. The null in panel unit root tests says that *all* the series are integrated of order one. Rejection, therefore, does not mean that *all* the series are stationary, as a rejection of the null hypothesis only indicates that a significant fraction of the series is stationary. The results of panel unit root tests should therefore be carefully interpreted (Maddala, 1999; Pesaran, 2012). So far, panel tests are introduced as a solution for the low power of individual time-series cointegration tests whereas the difference in null hypothesis is ignored. In this paper, we also present individual time-series cointegration tests in addition to panel tests to make sure that a rejection of the null hypothesis of no cointegration is not driven by a small proportion of the countries in the study, but due to our house price fundamental itself.

Therefore, we augment income as a long-run house price fundamental as most households finance their house purchase through a mortgage loan. The housing market indeed depends critically on credit market conditions (Case, 2008) and the link between house prices and credit lending has recently attracted considerable interest in empirical papers (Anundsen and Jansen, 2013; Brissimis and Vlassopoulos, 2009; De Haas and de Greef, 2000; Fitzpatrick and McQuinn, 2007; Gerlach and Peng, 2005; Gimeno and Martinez-Carrascal, 2010; Hofmann, 2004; Oikarinen, 2009 among others). Most studies find a bi-directional relationship between credit and house prices and offer support for the view that both markets are dependent on each other. McQuinn and O'Reilly (2006) propose an intuitive theoretical model of the housing market based on the observation that most house purchases are mortgage-financed. Hence the amount that households are able to borrow depends on their income and interest rates – given plausible assumptions of the fraction of income that goes to mortgage repayments and the duration of the mortgage terms. Madsen (2012) proposes a model that explains house prices by demand in the short run and supply in the long run. In the short run, house prices are driven by the maximum obtainable loan and the number of house buyers. In the long run, the housing stock is unlikely to remain constant such that the most important determinant of housing will be the replacement cost. His model is able to explain the 1995–2007 house price run-up in the OECD countries with declining interest rates as one of the important factors. The

¹ Other papers that study the relationship between house prices and fundamentals are Gallin (2008), Mikhed and Zemcik (2009a), Mikhed and Zemcik (2009b), Duca et al. (2011b), Duca et al. (2011a), Muellbauer (2012), André et al. (2014), and Anundsen (2015) among others.

model was not able to account for all the increase in the period 2001–2006. Madsen points to financial innovations, which lower initial mortgage payments, as a possible explanation. In this paper we will model the amount that borrowers are able to pay through the specific mortgage products that are available to them.

In addition, we will also model the ability to deduct mortgage interest, which is also incorporated in the user cost literature. This literature is based on a rational model of asset price equilibrium where a rational homebuyer should equate the price of a house with the present value of its future service stream (Poterba, 1984). Mayer and Sinai (2007) augment the user cost model to include proxies for low risk premia in the capital markets, inflation illusion and backwards-looking expectations of price growth. The results suggest that changes in lending market efficiency with increased subprime lending in recent years is related to excess growth in price-to-rent ratios. The user cost threatens the financial cost as a lifetime payment of interest, which makes the measure highly sensitive to changes in the interest rate. In reality, houses do not have an infinite horizon and most households (especially first time home buyers) have to finance their home-purchase with a mortgage. The homebuyer thus faces a financial constraint that is dependent on the willingness of the bank to provide credit and the specific mortgage products that are offered by the mortgage provider. In addition, the homebuyer has to make a minimum down-payment while borrowing constraints prevent the household from borrowing against future wealth. Poterba's measure of the cost of housing services assumes complete equity financing or a pure interest-only mortgage, both of which do not reflect the true practice of most households in many countries. Another drawback with user cost models is the expected capital gain. Poterba's original assumption of perfect foresight is unrealistic. Himmelberg et al. (2005) assume that homeowners have the static expectation that house prices increase at the long-run average rate. If decreasing interest rates in combination with innovative mortgage products, have a significant effect on house prices, the assumption of a static expected capital gain is likely incorrect with current record-low interest rates. Even if households are able to make rational forecasts of future house price increases, banks might be unwilling or unable to lend the full amount if the initial value of the house is too low to guarantee a sufficient low loan-to-value ratio. Glaeser et al. (2013) furthermore conclude that the actual empirical relationship between house prices and interest rates is much weaker than predicted by Poterba's standard theoretical model. We will see that this observation is in line with our framework of ATP where we augment the assumption of an infinite horizon and introduce a financial constraint that limits the amount that households are able to borrow.

3. The model

In this section we develop a simple framework in which households maximize their lifetime utility that allows us to understand the evolution of house prices. We keep the framework as simple as possible as our main goal is to gain insights into the assumptions that are needed or the circumstances that give rise to a long-run relationship between house prices and the measure of ATP that we propose in this paper.

As most home purchases are mortgage-financed, the amount of housing the average house buyer is able to pay is critically dependent on how much mortgage providers are willing to lend. The most important mortgage product is the standard annuity mortgage such that the borrower has to make a fixed yearly mortgage payment (m). The initial loan amount (l) is then equal to the net present value of all future mortgage payments and therefore depends on the mortgage payments, the nominal interest rate (i), and

mortgage length (n):

$$l = \sum_{k=1}^n \frac{m}{(1+i)^k} \quad (1)$$

As the borrower has to make a downpayment (d), the loan amount equals the price of a representative house (p_h) times the amount of housing consumption (h) minus the down payment: $l = p_h \cdot h - d$. Substituting this in (1) and rewriting gives the fixed yearly mortgage payments of the standard annuity mortgage as a function of the price of a representative house, downpayment, the interest rate, and the mortgage length:

$$\begin{aligned} m &= \frac{p_h \cdot h - d}{\left(\frac{1 - (1+i)^{-n}}{i} \right)} \\ &= \frac{(1 - \beta) \cdot p_h \cdot h}{a_{n,i}} \end{aligned} \quad (2)$$

The annuity formula $\left(\frac{1 - (1+i)^{-n}}{i} \right)$ calculates the net present value of n future payments given interest rate i . In (2) we rename the annuity formula as $a_{n,i}$ and rewrite the downpayment as a fixed percentage (β) of the housing expenditures.

Consider a model in which household preferences over housing (h) and non-housing consumption at time θ (c_θ) are given by the log transformation of a standard Cobb-Douglas utility function. Due to high transaction costs associated with the purchase of a new house and moving, housing consumption is held fixed over time. Furthermore, we assume that it is financially attractive to own rather than rent due to income tax advantages of owning or due to an externality associated with renting (Henderson and Ioannides, 1983) such that all households who meet the requirement of a minimum downpayment ratio are willing to buy a house.² When purchasing a home, household j maximizes its lifetime utility with parameter ϕ over housing and non-housing consumption subject to a budget constraint:

$$\max_{h>0, c_\theta>0} U = \sum_{\theta=1}^T \delta^{\theta-1} (\phi \ln(h) + (1 - \phi) \ln(c_\theta)) \quad (3)$$

$$s.t. : a_{\theta+1} = [a_\theta + y_\theta - m - c_\theta \cdot p_\theta] \cdot (1 + i) \quad \text{all } 1 \leq \theta \leq n \quad (4)$$

$$: a_{\theta+1} = [a_\theta + y_\theta - c_\theta \cdot p_\theta] \cdot (1 + i) \quad \text{all } n + 1 \leq \theta \leq T \quad (5)$$

$$\begin{aligned} : a_\theta &\geq 0 \quad \text{all } 1 \leq \theta \leq T; a_T = 0 \\ : p_{\theta+1} &= p_\theta \cdot (1 + \pi) \\ : y_{\theta+1} &= y_\theta \cdot (1 + \pi) \cdot (1 + g) \end{aligned} \quad (6)$$

where δ is the subjective discount factor $1/(1 + \rho)$ with ρ the pure rate of time preference (subjective discount rate). The evolution of nominal non-housing assets (a_θ) until the final mortgage payment is given by Eq. (4). Non-housing assets at time $\theta + 1$ are thus equal to $(1 + i)$ times non-housing assets plus income minus the mortgage payments and consumption expenditures at time θ . After the mortgage maturity date, the mortgage payments are no longer present in the evolution of non-housing assets in Eq. (5). Our budget constraint differs from the existing literature as the price of a representative house only enters through the mortgage payments.

² Therefore, we do not model the choice on the extensive margin (whether or not to become a home-owner), which may explain deviations around the long-run house price fundamental from our model.

In (6) we assume that there is a borrowing constraint that prevents the household from borrowing beyond the initial housing mortgage (see [Wheaton, 1985](#) among others). Households are thus able to save to increase future consumption, but non-housing assets can never be negative. The price of non-housing consumption grows with the inflation rate π . Nominal income y_θ grows with inflation and real income growth g .

In this paper, we study the case in which the borrowing constraint (6) is binding. The constraint will be binding if the subjective discount rate is higher than the real market rate. In this case, the household would like to borrow, but the constraint prevents this, such that the borrower exhausts his budget constraint every period without accumulating assets. If expected income growth is positive or the household's horizon T is longer than the mortgage term to maturity n , the required subjective discount rate for the constraint (6) to be binding is even lower.³ A higher discount rate than the market rate is, however, also used by [Glaeser et al. \(2013\)](#) who argue that “it is easy for us to imagine that individuals are more impatient than the market, but considerably harder to believe that they are more patient (...)”. A literature review by [Frederick et al. \(2002\)](#) indeed reports a predominance of discount rates well above the market rate.

One could extend the model to consider the investment aspect of housing by including the expected sale price in the budget constraint of the final period. Doing so would not change our conclusions. The expected increase in housing wealth due to real income growth would only strengthen the case of a higher willingness to borrow against future wealth and consequently a binding borrowing constraint.⁴

Substitution of (2) into (4) and maximization of (3) subject to the budget constraints and a binding borrowing constraint (6) yields the optimal amount of housing consumption (h^*) at the time of the house purchase:

$$h^* = \frac{\phi Y_1}{1 - \beta} \cdot a_{n,i} \cdot \frac{1}{p_h}$$

Summing over the J individual demands for housing consumption, one arrives at the aggregate demand for housing consumption (H^*):

$$\begin{aligned} H^* &= J \cdot h^*(p_h, a_{n,i}, Y_1) \\ &= \underbrace{J}_{\text{Extensive}} \cdot \underbrace{\frac{\phi Y_1}{1 - \beta} \cdot a_{n,i} \cdot \frac{1}{p_h}}_{\text{Intensive demand}} \end{aligned}$$

We make a distinction between demand on the extensive and intensive margin. The former denotes the demand from an additional household that would like to become homeowner and the latter denotes the amount of housing services each household buys. In equilibrium, the market clearing condition ensures that aggregate housing demand (H^*) equals the aggregate supply of housing (Q^S): $H^* = Q^S$. Solving for the price of a representative house p_h then yields

$$p_h = \frac{J}{Q^S} \cdot \frac{\phi Y_1}{1 - \beta} \cdot a_{n,i} \quad (7)$$

Each period t , J_t households maximize their lifetime utility and market clearing in each period ensures that the price of a repre-

sentative house evolves over time according to:

$$\begin{aligned} p_{h,t} &= \frac{J_t}{Q_t^S} \cdot \frac{\phi Y_{1,t}}{1 - \beta} \cdot \left(\frac{1 - (1 + i_t)^{-n}}{i_t} \right) \\ &= \frac{J_t}{Q_t^S} \cdot A_t \end{aligned} \quad (8)$$

where we rename $\frac{\phi Y_{1,t}}{1 - \beta} \cdot \left(\frac{1 - (1 + i_t)^{-n}}{i_t} \right)$ to the household's ATP (A_t).

The price of a representative house is thus a function of a ratio of the demand on the extensive margin over the supply of housing, multiplied with the household's ATP. We assume that preference parameter ϕ and the down-payment requirement β are fixed in the long run whereas the number of households, supply of housing services, income and the interest rate do change over time.⁵ Eq. (8) indicates that house prices should be cointegrated with ATP if the ratio (J_t/Q_t^S) is constant over time. It is unfortunately very difficult to find a good observable indicator of the ratio. The ratio is, only determined by the households interested in trading a house. Some households will not meet the minimum down payment requirement and should therefore not be part of the variable J_t . In addition, some houses may not be on the market, as the owner does not want to sell. These properties should therefore be excluded from Q_t^S . Note that if our assumption does not hold, standard cointegration tests would be unable to reject the null hypothesis of no cointegration between house prices and ATP. Whether or not such a long-run relationship exists is an empirical question. Therefore, we are looking for the “minimum adjustment” in the empirical model that is necessary in order to reject the null hypothesis of no cointegration.

Notice that a similar argument can be made for the long-run relationship between house prices and income. A long-run relationship between house prices and income does not have to exist according to Eq. (8) as changes in the interest rate induce changes in the annuity formula ($a_{n,i}$). These changes could be interpreted as structural breaks (or parameter instability), such that standard cointegration tests are unable to reject the null hypothesis of no cointegration between house prices and income ([Gregory and Hansen, 1996](#)).

4. Extensions with mortgage interest deduction and different mortgage products

In this section we augment the standard annuity mortgage to allow for MID. Furthermore, we model interest-only loans with and without repayment vehicles. These innovative mortgage products result in a different budget constraint such that the households are able to pay more than with a standard annuity mortgage.⁶ When we use the term “ATP adjusted for MID and mortgage characteristics”, “adjusted ATP”, or notation $x_{i,t}$ we refer to the weighted average of all the mortgages for the country of interest. The weights are the share of the particular mortgage product as a percentage of all mortgages.

⁵ [Duca et al. \(2011b\)](#) study the effect of variation in the LTV ratio on house prices and report a positive relationship between the LTV and price-to-rent ratios. Our model implies that house prices are falling when LTV increases. However, our results do not necessarily contradict the results from [Duca et al. \(2011b\)](#) as the negative relationship in our model is derived from keeping all other factors constant (including the mortgage payments). Our model, furthermore, does not consider the effect of changes in the down-payment requirement on demand on the extensive margin, which may explain a positive relationship between variation in LTV ratios and deviations from the long-run house price fundamental.

⁶ We believe these extensions capture the most important evolutions. Additional mortgage products or tax rules might, however, explain additional variation in house prices in these countries.

³ Even in the case of a subjective discount rate of zero, the assumptions that are required (with respect to income growth or the household's horizon) for the constraint to be binding are reasonably low. A graphical representation is available from the authors upon request.

⁴ A similar argument can be made for an extension that includes the possibility to refinance.

4.1. Standard annuity mortgage adjusted for mortgage interest deduction

The literature on the sensitivity of mortgage debt to the deductibility of mortgage interest reports that the amount of mortgage debt is significantly affected by changes in the rate at which mortgage interest is fiscal deductible (see [Hendershott and Pryce, 2006](#); [Ling and McGill, 1998](#) among others). Due to the availability of MID in many countries, the evolution of the non-housing assets in [Eq. \(4\)](#) should change to include the net tax benefits from the MID (κ_θ). In the first years of an annuity mortgage, the interest payments will be higher and the borrower can deduct more interest. In the later years, the net tax benefit will be lower due to higher capital repayments⁷. The net tax benefit at time θ is thus equal to:

$$\kappa_\theta = \tau \cdot i \cdot \left(m \cdot a_{n,i} \cdot (1+i)^{\theta-1} - m \cdot \left[\frac{(1+i)^{\theta-1} - 1}{i} \right] \right),$$

where the term between brackets is equal to the loan balance after $\theta - 1$ mortgage payments. We are then able to augment the evolution of the non-housing assets to include the net tax benefit from the MID:

$$\begin{aligned} a_{\theta+1} &= [a_\theta + y_\theta + \kappa_\theta - m - c_\theta \cdot p_\theta] \cdot (1+i) \\ &= \left[a_\theta + y_\theta + \tau \cdot i \cdot \left(m \cdot a_{n,i} \cdot (1+i)^{\theta-1} - m \cdot \left[\frac{(1+i)^{\theta-1} - 1}{i} \right] \right) \right] \\ &\quad \cdot (1+i) - [m + c_\theta \cdot p_\theta] \cdot (1+i), \quad \text{all } 1 \leq \theta \leq n \end{aligned} \quad (9)$$

Substitution of [\(2\)](#) into [\(9\)](#) and maximization of [\(3\)](#) in the case where the constraint [\(6\)](#) is binding such that the household does not accumulate non-housing assets, yields an optimal amount of housing consumption at $\theta = 1$ equal to:

$$h^* = \frac{\phi Y_1}{1 - \beta} \cdot \left(\frac{1}{1 - \tau \cdot i \cdot a_{n,i}} \right) \cdot a_{n,i} \cdot \frac{1}{p_h}$$

When every period t , J_t households maximize their lifetime utility and the market clears, the solution yields an adjusted expression for ATP:

$$A'_t = \frac{\phi Y_{1,t}}{1 - \beta} \cdot \frac{1}{1 - \tau_t \cdot i_t \cdot a_{n,i}} \cdot a_{n,i} \quad (10)$$

A remarkable result is that the increase in ATP is larger than the net present value of all future tax benefits from the MID. We think this is an important result, as other studies often consider an increase in house prices by the net present value of the subsidy as “full capitalization” (see [Oates, 1969](#), [Palmon and Smith, 1998](#) and [Hilber and Turner, 2014](#) among others). The possibility of capitalization higher than the net present value of MID is entirely due to the binding borrowing constraint from [Eq. \(6\)](#). As future wealth is inaccessible, the household uses the MID to tilt the future stream of wealth towards the present.

4.2. Interest-only mortgage with repayment vehicle

An endowment mortgage or savings mortgage is an interest-only loan where the borrower does not repay the principal until the maturity date. The savings mortgage often takes the form of a life insurance that pays the proceeds at the end of the mortgage.

The borrower thus only pays interest and payments (v) to a vehicle that will be sufficient to repay the principal at the end of the mortgage term. If the repayment vehicle is sufficient to repay the loan at the end of the mortgage term, this mortgage type is not riskier than the standard annuity mortgage. The future value of the payments to the repayment vehicle should thus be equal to the loan amount:

$$v \cdot \sum_{\theta=1}^n (1+i)^{\theta-1} = (1-\beta) \cdot p_h \cdot h$$

The payments to the repayment vehicle are thus equal to:

$$v = \frac{(1-\beta) \cdot p_h \cdot h}{s_{n,i}}$$

where $s_{n,i} = ((1+i)^n - 1)/i$. The purpose of the savings mortgage is to make maximum use of the MID over the whole mortgage term such that $\kappa_\theta = \tau \cdot i \cdot (1-\beta) \cdot h \cdot p_h$. The evolution of non-housing assets can therefore be rewritten as:

$$\begin{aligned} a_{\theta+1} &= [a_\theta + y_\theta + \kappa_\theta - i \cdot (1-\beta) \cdot h \cdot p_h - v - c_\theta \cdot p_\theta] \cdot (1+i) \\ &= \left[a_\theta + y_\theta - \frac{(1-\beta) \cdot h \cdot p_h}{a_{n,i}} \cdot (1 - \tau \cdot i \cdot a_{n,i}) - c_\theta \cdot p_\theta \right] \cdot (1+i), \\ &\quad \text{all } 1 \leq \theta \leq n \end{aligned} \quad (11)$$

When every period t , J_t households maximize their lifetime utility and the market clears, the utility maximization in the case where the constraint [\(6\)](#) is binding yields the following alternative measure of ATP for interest-only borrowers with a repayment vehicle:

$$A'_t = \frac{\phi Y_{1,t}}{1 - \beta} \cdot \frac{1}{1 - \tau_t \cdot i_t \cdot a_{n,i}} \cdot a_{n,i} \quad (12)$$

We can see that this measure of adjusted ATP is exactly equal to the adjusted ATP from the standard annuity mortgage with MID. The initial budget constraint is indeed equivalent such that the optimal amount of housing consumption is exactly the same. The tax benefits after the initial period are not equivalent, which will result in different consumption paths between both mortgage products. We can see that without the ability to deduct interest ($\tau_t = 0$), the interest-only mortgage with repayment vehicle wouldn't exist as it would be equivalent to a standard annuity mortgage. For a 20-year mortgage at a 5% interest rate, ATP is 23% higher in comparison to ATP from a standard annuity loan when interest is deductible at 30%. At even higher rates of 50%, ATP is 45% higher than with a standard annuity loan.

4.3. Interest-only mortgage without repayment vehicle

Another mortgage product that lowers monthly payments is the pure interest-only loan. The borrower only pays interest throughout the whole mortgage duration. At the end of the mortgage term, the borrower has to repay the entire principal. This product differs from the interest-only loans with repayment vehicle because the borrower does not accumulate equity. They hope to refinance or pay off the mortgage through the sale of the house at the end of the term. One reason why interest-only mortgages have become popular in recent years is due to the low interest payments ([Scanlon et al., 2008](#)). At low interest rates, the percentage of principal repayments are high and hence the difference between mortgages with and without a repayment vehicle becomes larger. Instead of repaying principal, the borrower only pays interest and plans to refinance in period $n + 1$ such that the evolution of non-housing assets until the maturity date is equal to:

$$\begin{aligned} a_{\theta+1} &= [a_\theta + y_\theta + \kappa_\theta - i \cdot (1-\beta) \cdot h \cdot p_h - c_\theta \cdot p_\theta] \cdot (1+i) \\ &= [a_\theta + y_\theta + \tau \cdot i \cdot (1-\beta) \cdot h \cdot p_h - i \cdot (1-\beta) \cdot h \cdot p_h - c_\theta \cdot p_\theta] \end{aligned}$$

⁷ In a previous version of the paper we assumed that the borrower increased her mortgage payments with the average amount of interest deducted over the whole mortgage term. This assumption was, however, not derived from the theory but rather a proxy or rule-of-thumb. The new measure of adjusted ATP in this version seems to better fit the data as the results suggest stronger evidence in favor of rejecting the null of no cointegration.

$$\begin{aligned} & \cdot (1 + i) \\ & = [a_\theta + y_\theta - (1 - \beta) \cdot h \cdot p_h \cdot i \cdot (1 - \tau) - c_\theta \cdot p_\theta] \cdot (1 + i), \\ & \text{all } 1 \leq \theta \leq n \end{aligned} \quad (13)$$

When every period t , J_t households maximize their lifetime utility and the market clears, the solution in the case where the constraint (6) is binding yields the following alternative measure of ATP for pure interest-only borrowers:

$$A'_t = \frac{\phi Y_{1,t}}{(1 - \beta) \cdot i_t \cdot (1 - \tau_t)} \quad (14)$$

Eq. (14) is equivalent to the model by De Vries and Boelhouwer (2009), that seeks to identify a long-run equilibrium between interest payments and household income in the Netherlands from 1978 to 2008. We will, however, use a weighted average of the different mortgage types. ATP from a pure interest-only loan increases significantly at lower interest rates in comparison to other mortgage types. ATP is indeed 157% higher in comparison to a standard 20-year annuity mortgage with an interest rate of 5%. In a country where interest payments are deductible at lower tax rates, ATP is much lower. ATP is “only” 83% higher in comparison to a standard annuity mortgage when the maximum taxable value of the tax relief equals 30%. When interest payments are deductible at lower tax rates, ATP increases less strongly when interest rates decrease which could explain the relative late use of pure interest only loans in Denmark and the United Kingdom in comparison to the Netherlands during the last decade.

5. Data

The model indicates that we need time series for income at the time of the home purchase, the interest rate, the tax rate at which mortgage interest is deductible, mortgage term to maturity, and the share of mortgage products. The preference parameter α and the loan-to-value ratio do not influence the results as they only linearly transform our measure of ATP. As time series for the maximum rate at which mortgage interest is fiscally deductible and the mortgage shares are not available, we have to construct them ourselves. Because we need to construct them for a relatively long time span, we make a selection of a time span and countries that are relatively well documented in the literature. Our analysis includes 8 OECD countries in which it is possible to deduct mortgage interest or where the maximum rate at which interest is deductible has changed over time in the period from 1980q1 to 2009q4. The countries of interest are Belgium (BEL), Netherlands (NLD), United Kingdom (GBR), United States of America (USA), Sweden (SWE), Norway (NOR), Finland (FIN), and Denmark (DNK). The sample includes countries where the fiscal advantage has increased (BEL), remained constant (USA, NLD), partially diminished (SWE, NOR, FIN, DNK), and has been completely phased out (GBR). Furthermore, the sample includes countries where interest-only mortgages have increased (NLD, DNK), decreased (GBR), or both increased and decreased (USA) in popularity.

Marginal tax rates were taken from the CEP-OECD institutions data set (Nickell, 2006) for the period 1980–1999 and the OECD Taxing Wage Statistics from 2000 onwards. They are based on a principal earner who is married with two children earning the average wage with a spouse earning 67% of the average wage. The yearly data are linearly interpolated to construct quarterly series.⁸

In several countries, tax reforms have limited the rate at which mortgage interest is deductible over time. We therefore limit the taxable value of the tax relief according to the descriptions in section A in the appendix that presents a detailed comparison of the countries. In addition, we construct weights for the different mortgage types based on country reports or academic articles and interpolate for unknown periods. Fig. 1 presents our assumptions of the evolution of the tax rate at which mortgage interest is deductible, the share of interest-only mortgages with a repayment vehicle, and the share of pure interest-only loans. The mortgage term to maturity (n) is set equal to 20 years unless otherwise specified in section A in the appendix. Given the unique system of fiscal advantages for homeowners in Belgium, section B describes how we model the measure of ATP in Belgium.

The OECD database provides nominal house price indices, aggregate household real disposable income (which we transform to nominal income per capita as a proxy for income at the time of the home purchase)⁹, population and 10-year government bond rates. The source and description of the nominal house price indices is given in Table A.1 in the appendix. In our analysis, we will use 10-year government bond rates for all countries, irrespective of the popularity of fixed or variable mortgages. This is in contrast to McQuinn and O'Reilly (2007) who use short and long-term interest rates depending on the popularity in the country. At first sight, lower short-term interest rates indicates that one can borrow more. On the other hand, a short term interest rate introduces the possibility of short-term volatility in future real consumption. A prudent risk-averse homebuyer will understand this risk and therefore it is not certain whether or not the term spread (i.e. the difference between the long-term and short-term rates) is capitalized into house prices. We also prefer to use the 10 year government bond over mortgage rates because the former is consistently measured over time and across countries.¹⁰ However, as mortgages with long-term interest rates are not available in some countries, we also present a robustness check with short or long-term interest rates depending on the most common mortgage type in each country. We also present a robustness check with mortgage rates for three countries for which we have data on mortgage rates over the entire time span: Belgium, the Netherlands and the United States of America. The results do not alter our conclusions.

6. Empirical results

6.1. The long-run relationship

If two time series achieve stationarity after differencing (i.e. they are integrated of order one), but a linear combination is already stationary, these time series are said to be cointegrated according to Engle and Granger (1987). If two variables that are integrated of order one are not cointegrated, the regression results are spurious such that we are unable to interpret the estimated coefficients. As usual, we first examine the order of integration of the series. Table 1 presents the results for the ADF and Phillips–Perron unit root tests of nominal house prices and adjusted ATP in levels (including intercept) and differences. The overall conclusion is that the series are integrated of order one and cointegration tests can be applied to ensure that a possible relationship between house prices and our measure of ATP is not spurious.¹¹

⁹ For Denmark, data on disposable income is only available from 1981q1. In all other countries, the time span of the data is 1980q1–2009q4.

¹⁰ For Belgium alone we would have to combine three different measured time series to construct a mortgage rate from 1980Q1 to 2009Q4.

¹¹ The United States of America is the only country where the ADF and Phillips–Perron suggest a different conclusion for the evolution of house prices. Given the dominance of difference-stationarity in the other countries, we assume that the

⁸ As we are restricted by a relatively short time span of 30 years of data, we use quarterly data to increase the frequency of the data which may yield considerable power gains (Zhou, 2001). We expect the gains from the increased frequency to be higher than the loss of the linear interpolation of the tax rates and mortgage shares as these series evolve slowly over time. A robustness check with yearly data is presented in the sensitivity section.

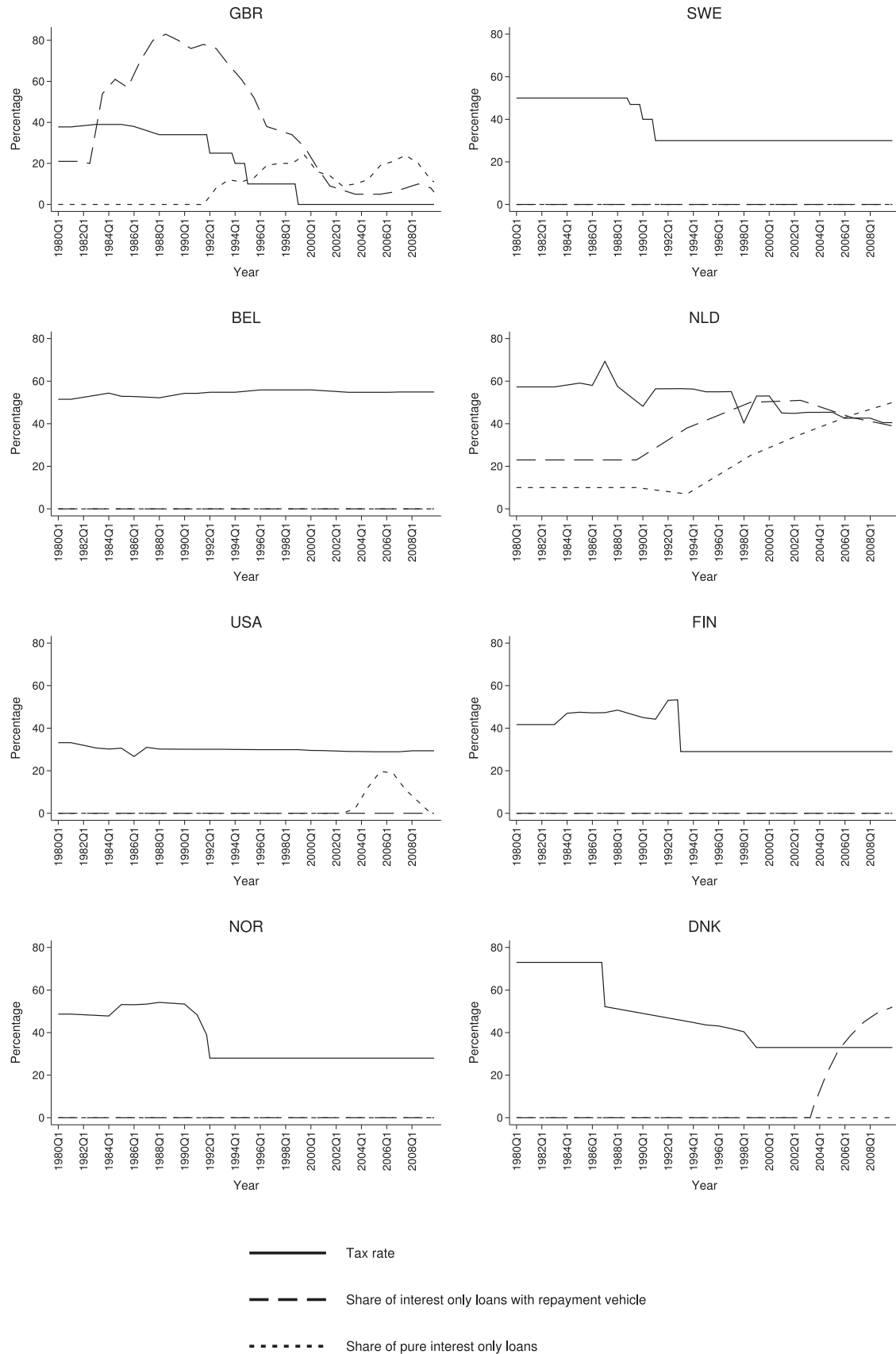


Fig. 1. Graphical representation of assumptions.

Table 1
Unit root tests of nominal house price and ATP (1980Q1–2009Q4).

Country	ADF				PP			
	$p_{h, i, t}$	$\Delta p_{h, i, t}$	$x_{i, t}$	$\Delta x_{i, t}$	$p_{h, i, t}$	$\Delta p_{h, i, t}$	$x_{i, t}$	$\Delta x_{i, t}$
Belgium	1.00	0.07	1.00	0.00	1.00	0.00	1.00	0.00
Netherlands	0.77	0.06	0.99	0.00	1.00	0.00	1.00	0.00
United Kingdom	0.99	0.01	0.98	0.00	0.99	0.00	0.99	0.00
United States of America	0.16	0.28	0.99	0.00	0.95	0.01	0.99	0.00
Sweden	1.00	0.03	1.00	0.00	1.00	0.02	1.00	0.00
Norway	1.00	0.00	0.99	0.00	1.00	0.00	1.00	0.00
Finland	0.89	0.00	1.00	0.00	0.89	0.00	1.00	0.00
Denmark	0.85	0.00	0.80	0.00	0.94	0.04	0.77	0.00

Note: This table present p -values from an Augmented Dickey–Fuller (ADF) and Phillips–Perron unit root test in levels (including intercept) and in differences. The optimal lag orders in the ADF tests are determined with the Schwarz Information Criteria with a maximum number of 12 lags. The results for ATP and ATP adjusted for the MID and mortgage characteristics are exactly the same.

We follow the guidance of Haug (1996) and use more than one cointegration test to deal with the trade-off between power and size distortions. He advises to use the Phillips and Ouliaris (1990) test statistics, that seem to have higher power when the researcher deals with weakly exogenous regressors. Because the test statistics are non-parametric with respect to nuisance parameters, they allow for a very wide range of time series models in which there is a unit root (Phillips and Perron, 1988). In addition he recommends to use the ADF test as this is one of the tests with the least size distortions. We report two ADF test statistics: the first is the standard t -statistic, the second test statistic is based directly on the autocorrelation coefficient after a correction such that the limiting distribution does not depend on nuisance parameters controlling serial correlation (Hayashi, 2000). Optimal lag length is determined by the Schwarz and Akaike Information Criteria with a maximum of 12 lags¹².

To deal with the low power of conventional cointegration tests when applied to time series of moderate length, we also report the results of Pedroni's group cointegration tests (Pedroni, 2004). The Pedroni group-mean statistics average the results of the individual country test statistics and permit both the short-run dynamics and the long-run slope coefficient to be heterogeneous. The panel cointegration tests study the null hypothesis that "all of the individuals of the panel are not cointegrated" against the alternative hypothesis that "a significant portion of the individuals of the panel are cointegrated" (Pedroni, 2004). For this reason we also report the conventional country-specific cointegration tests to have an idea of the economic importance of the relationship in the individual countries. We interpret the panel test as a summary of the pervasiveness of the cointegration relationship. An important caveat of the Pedroni tests is the assumption of cross-sectional independence, which is unlikely to hold in practice. Therefore, we also present Fachin's bootstrapped panel cointegration tests that are robust to both short- and long-run dependence across units (Fachin, 2007). Fachin proposes a group mean and robust median statistics based on the Continuous-Path Block Bootstrap (CBB).¹³ Monte Carlo simulations show that the tests have good size and power properties.

Table 2 provides test results for the null hypothesis of no cointegration between nominal house prices and ATP measured with a standard annuity mortgage. At the 10% significance level, Norway and the United States of America are the only countries where at least one cointegration test can reject the null hypothesis of no cointegration. In all other countries we cannot reject the null hypothesis of no cointegration. This is confirmed by the panel cointegration tests as they cannot reject the null hypothesis that all of the individuals of the panel are not cointegrated. The absence of cointegration indicates that the standard annuity mortgage is insufficient in explaining the evolution of house prices.

To capture the effect of MID and financial innovation, we define the variable "ATP adjusted for MID and mortgage characteristics". This is a weighted average of ATP with the annuity and interest-only mortgages where MID is allowed. The weights equal the share of the particular mortgage as percentage of all mortgages. We plot the nominal house prices and adjusted ATP for each country in Fig. 2. The test results in Table 3 indicate that Sweden is the only country where no cointegration test is able to reject the null hypothesis of no cointegration between house prices and adjusted ATP from 1980Q1 to 2009Q4. The inability to reject the null hypothesis of no cointegration in Sweden is likely due to the extraordinary asset price boom caused by the deregulated credit markets since 1985 (Englund, 1999). This was followed by the Swedish banking crisis in the early 1990s that triggered a downward spiral in real estate prices until the mid-1990s. An important finding is that a long-run relationship between nominal house prices and adjusted ATP does exist from 1995 to 2009, when the Swedish market recovered.

The panel cointegration tests, furthermore, confirm that a statistically significant fraction of the individual series are cointegrated. As the panel cointegration test by Fachin is robust to both short- and long-run dependence across units, we are able to conclude that no degree of cross-sectional dependency would be sufficient to overturn the conclusion of cointegration in a significant fraction of the panel.

The use of the different mortgage types in the model is an important factor in the evolution of house prices in several countries. The popularity of the endowment mortgage in the 1980s and the increasing share of pure interest-only loans seem to improve the model significantly for the United Kingdom. In the Netherlands, the run-up in house prices since the mid-1990s was mainly driven by an increasing share of interest-only mortgages, whereas the recent increase in house prices in Belgium was caused by a simultaneous increase in the fiscal advantage for homeowners and a lengthening in the mortgage term. In all these countries, we are unable to reject the null hypothesis of no cointegration if we do not adjust our measure of ATP for specific mortgage characteristics. The

variable is integrated of order one according to the Phillips–Perron results. If this assumption is incorrect, we will be unable to reject the null hypothesis of no cointegration in the cointegration analysis that follows.

¹² Our results are not sensitive to minor changes in the maximum number of lags. For example, if we limit the maximum number of lags to 5 our conclusions are not affected.

¹³ As data for Denmark start from 1981q1, we use the time span 1981q1–2009q4 to construct the pseudo-data set by CBB and apply the cointegration test to this time span.

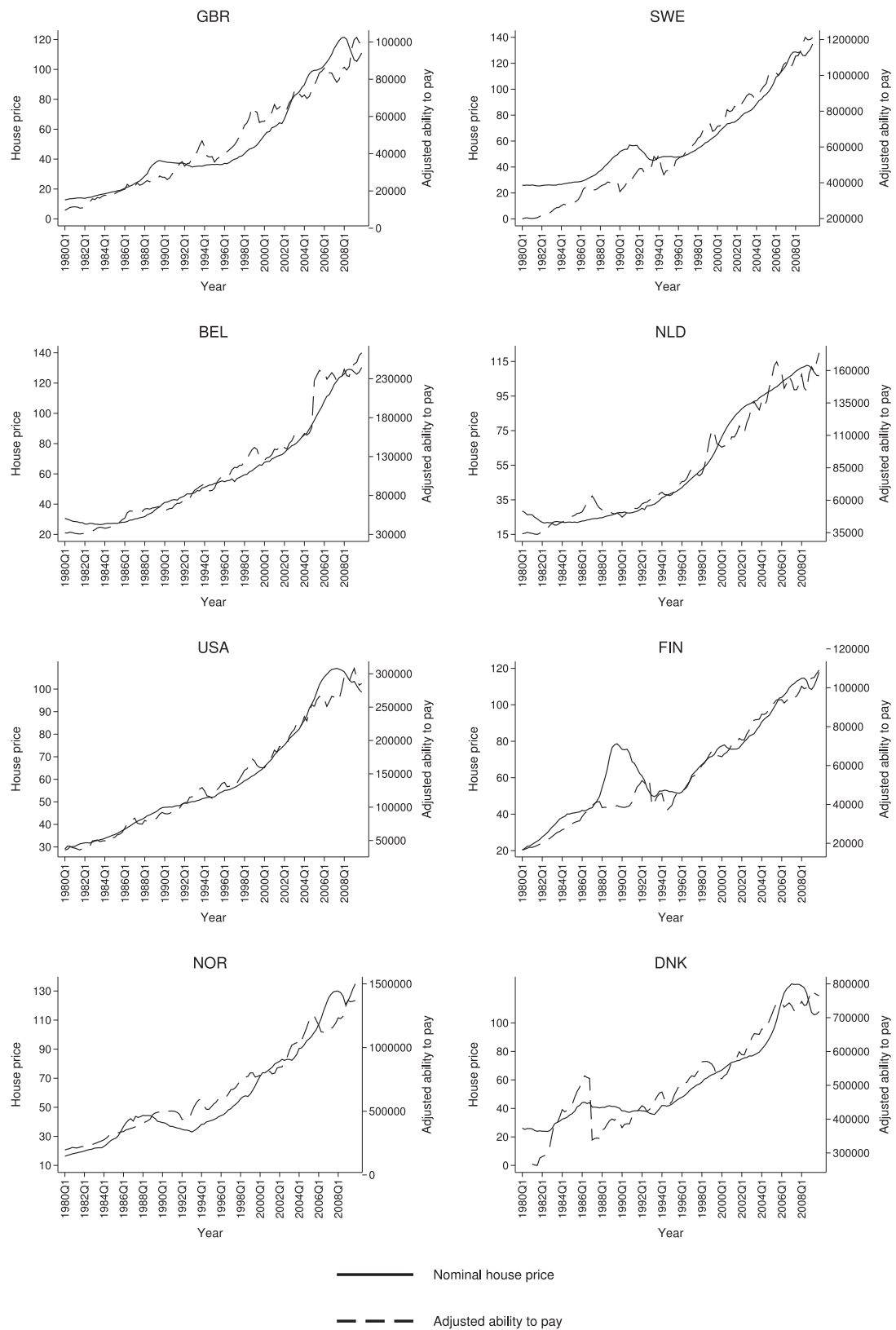


Fig. 2. Nominal house prices and adjusted ability to pay.

Table 2

Cointegration results: nominal house prices and ATP (1980Q1–2009Q4).

Country	ADF t (SIC)	ADF z (SIC)	ADF t (AIC)	ADF z (AIC)	PO t	PO z
Belgium	0.79	0.76	0.79	0.76	0.81	0.80
Netherlands	0.12	0.16	0.12	0.12	0.15	0.27
United Kingdom	0.26	0.19	0.26	0.19	0.52	0.47
United States of America	0.02	0.00	0.10	0.99	0.40	0.25
Sweden	0.45	0.32	0.45	0.32	0.59	0.50
Norway	0.20	0.10	0.67	0.20	0.47	0.39
Finland	0.24	0.21	0.24	0.21	0.42	0.45
Denmark	0.29	0.23	0.29	0.23	0.50	0.49
Panel cointegration tests						
Pedroni's group stats				Fachin t-stats		
rho-stat		t-stat	adf-stat	group	median	
0.56		0.40	0.11	0.14	0.19	

Note: The Augmented Dickey–Fuller (ADF) and Phillips–Ouliaris (PO) columns report p -values from the test results for the null hypothesis of no cointegration. The optimal lag orders in the ADF tests are determined with the Schwarz and Akaike Information Criteria with a maximum number of 12 lags. The ADF and PO cointegration tests are described in an online appendix. The panel cointegration results are the Pedroni group cointegration tests and the test proposed by Fachin that is robust to cross-sectional dependence.

Table 3

Cointegration results: nominal house prices and adjusted ATP (1980Q1–2009Q4).

Country	ADF t (SIC)	ADF z (SIC)	ADF t (AIC)	ADF z (AIC)	PO t	PO z
Belgium	0.02	0.01	0.02	0.01	0.03	0.02
Netherlands	0.02	0.00	0.02	1.00	0.08	0.05
United Kingdom	0.14	0.08	0.14	0.08	0.34	0.29
United States of America	0.04	0.00	0.08	0.00	0.24	0.15
Sweden	0.50	0.38	0.50	0.38	0.54	0.47
Norway	0.06	0.02	0.06	0.02	0.30	0.22
Finland	0.21	0.16	0.04	0.00	0.29	0.26
Denmark	0.08	0.05	0.08	0.05	0.11	0.10
Panel cointegration tests						
Pedroni's group stats				Fachin's t-stats		
rho-stat		t-stat	adf-stat	group	median	
0.00		0.01	0.00	0.00	0.00	

Note: The Augmented Dickey–Fuller (ADF) and Phillips–Ouliaris (PO) columns report p -values from the test results for the null hypothesis of no cointegration. The optimal lag orders in the ADF tests are determined with the Schwarz and Akaike Information Criteria with a maximum number of 12 lags. The ADF and PO cointegration tests are described in an online appendix. The panel cointegration results are the Pedroni group cointegration tests and the test proposed by Fachin that is robust to cross-sectional dependence.

United States of America is the only country where we do not have to model the pure interest-only loans to reject the null hypothesis of no cointegration, but the p -values decrease if we do adjust for these mortgage characteristics. The results indicate that it is necessary to model changes in MID and specific mortgage product innovations to explain house price behavior since the 1980s.

6.2. Economic importance

6.2.1. Methodological approach

To study the economic importance of ATP and its components we jointly model the dynamics of house prices and ATP in a vector error-correction model (VECM). The VECM takes the form

$$\Delta \mathbf{X}_t = \mathbf{v} + \mathbf{\Pi} \mathbf{X}_{t-1} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_i \Delta \mathbf{X}_{t-i} + \varepsilon_t$$

where $\mathbf{X}_t$ is a column vector of house prices and the ATP measure, $\mathbf{v}$ is a 2×1 vector of constants, $\mathbf{\Pi}$ and $\mathbf{\Gamma}_i$ are 2×2 matrices of coefficients and ε_t is a vector white noise process. $\mathbf{\Pi}$ contains long-run information of the data and can be written as $\mathbf{\Pi} = \alpha \beta'$ under the hypothesis of cointegration. α and β are $2 \times r$ matrices, where r equals the number of linear combinations of the elements

of $\mathbf{X}_t$ that are stationary. The matrix β can be interpreted as a matrix of the cointegrating vectors, while matrix α consists of error-correction parameters. We apply the SIC to select the optimal lag order, with a maximum number of 12 lags.

The results are presented in Table 4. The first column indicates the number of lags selected by the SIC. For completeness, we also present the test results for cointegration using the trace test of Johansen (1988). In the majority of the countries, the trace test provides evidence for cointegration. In the estimation of the VECM, we therefore impose the reduced rank assumption according to the theory and the cointegration test results from both the residual based and trace tests.

The loading coefficients in the house price equation are all negative and statistically significant at the 5% level. The negative sign indicates that when house prices deviate from the long-run equilibrium relationship with ATP in the previous period, house prices will adjust to restore equilibrium. The size of the coefficient represents the disequilibrium pricing that is corrected in one quarter. The speed of adjustment is the fastest in Belgium and slowest in Netherlands, Sweden and Denmark. The loading coefficients in the ATP equation are only significant in the Netherlands and the USA at the 5% significance level. As we will see below, these are the only countries in which we find a bi-directional granger

Table 4
Vector error correction model results.

	Lags	Rank		$\Delta p_{h,i,t}$ equation		$\Delta x_{i,t}$ equation		Long-run equation
		Trace	Imposed	α_p	R^2	α_x	R^2	β_x
Belgium	2	2	1	−0.05*** (0.01)	0.68	0.08* (0.04)	0.14	1.19*** (0.05)
Netherlands	3	1	1	−0.02*** (0.01)	0.83	0.12*** (0.04)	0.28	0.94*** (0.05)
United Kingdom	2	1	1	−0.03*** (0.01)	0.72	0.04* (0.02)	0.20	1.08*** (0.09)
United States of America	4	1	1	−0.04*** (0.01)	0.86	0.09** (0.04)	0.27	0.94*** (0.03)
Sweden	2	1	1	−0.02*** (0.01)	0.68	−0.01 (0.01)	0.18	1.52*** (0.17)
Norway	2	2	1	−0.04*** (0.01)	0.60	0.02 (0.02)	0.39	1.12*** (0.09)
Finland	2	0	1	−0.04*** (0.01)	0.71	0.01 (0.02)	0.16	1.00*** (0.09)
Denmark	2	1	1	−0.02** (0.01)	0.70	0.08* (0.04)	0.09	1.04*** (0.08)

Note: This table presents a summary of the main results from the VECM. Standard errors are in parentheses. *, ** and *** refer respectively to p-values lower than or equal to 0.10, 0.05 and 0.01.

Table 5
Predicted effects on ATP and house prices from changes in the interest rate and abolishment of MID.

Country	elasticity	Interest rate		$\frac{\Delta x_{i,t}}{x_{i,t}}$	$\frac{\Delta p_{h,i,t}}{p_{h,i,t}}$	Tax rate		$\frac{\Delta x_{i,t}}{x_{i,t}}$	$\frac{\Delta p_{h,i,t}}{p_{h,i,t}}$
		Old value	New value			Old value	New value		
Belgium	0.99	3.62	4.62	−9.97	−9.87	54.92	0	−23.51	−23.77
Netherlands	1.13	3.50	4.50	−17.36	−19.62	40.53	0	−35.02	−39.57
United Kingdom	1.15	3.74	4.74	−11.82	−13.59	0	0	0	0
United States of America	1.13	3.46	4.46	−7.62	−8.61	29.38	0	−17.65	−19.94
Sweden	0.73	3.26	4.26	−5.51	−4.02	30	0	−14.19	−10.36
Norway	0.99	4.03	5.03	−5.83	−5.77	28	0	−15.29	−15.14
Finland	1.01	3.52	4.52	−5.67	−5.73	29	0	−14.48	−14.62
Denmark	1.15	3.58	4.58	−5.20	−5.98	33	0	−16.68	−19.18

Note: This table presents the effect of a 1% point increase in the interest rate, and a complete abolishment of the ability to deduct mortgage interest on adjusted ATP ($\Delta x_{i,t}/x_{i,t}$) and house prices ($\Delta p_{h,i,t}/p_{h,i,t}$) in 2009Q4. The effect on house prices is equal to $\Delta x_{i,t}/x_{i,t}$ multiplied with the estimated elasticities.

causality at the 5% significance level. In the other countries, the measure of ATP does not respond to deviations from the long-run relationship.

Because the data consists of house price indices rather than the actual house price itself, the estimated long-run cointegration vector is difficult to interpret. Therefore, we standardize each variable to have a mean of zero and a standard deviation of one such that the cointegration vector represents the standard deviation increase in house prices due to one standard deviation increase in ATP. An alternative solution would be to use a logarithmic transformation of the house price index and our measure of ATP, such that the estimated coefficient can be interpreted as an elasticity. However, as Granger and Hallman (1988) point out, the existence of cointegration between two variables does not imply cointegration between any non-linear transformation of the variables. Standard unit root tests are, furthermore, known to be non-robust to inappropriate transformations and the usual practice of taking logs is not always warranted (Kramer and Davies, 2002; Franses and Koop, 1998). We are indeed unable to reject the null hypothesis of no cointegration in some of the country-specific cointegration tests between the logarithmic transformed variables (results not reported here). The logarithmic transformation is often applied to stabilize the variance of a time series (Lütkepohl and Xu, 2012) or to linearize an exponential growing trend (Ermini and Hendry, 2008). A log transformation of our house price series in differences would, however, increase the variance of the series (especially in the 1980s). Standard asymptotic theory of cointegration requires the error shocks

to satisfy some regularity conditions. These conditions are violated when the variance experiences a shift over time (Kourogenis and Pittis, 2008).

6.2.2. Predicted impact of the interest rate and mortgage interest deduction on house prices

Our results indicate that ATP has an economically important role on house prices. To get a sense of the economic role of the components of ATP we calculate the elasticity of house prices with respect to ATP and the predicted effects on house prices and ATP from changes in interest rates and a reduction in the fiscal deductibility of mortgage interest. The first column in Table 5 presents the estimated elasticities, calculated with ATP in the last quarter of 2009. The elasticity is 1.04 on average. A 1% increase in ATP thus increases house prices with 1.04% on average in our sample of OECD countries. The next four columns indicate the percentage increase in ATP ($\Delta x_{i,t}/x_{i,t}$) and the house price ($\Delta p_{h,i,t}/p_{h,i,t}$) due to a 1% point increase in the interest rate of 2009Q4. The percentage increase in house prices ($\Delta p_{h,i,t}/p_{h,i,t}$) is calculated as a multiplication of the percentage increase in ATP ($\Delta x_{i,t}/x_{i,t}$) and the estimated elasticities from the first column. The semi-interest elasticity has the highest value in the Netherlands: an increase in the interest rate of one percentage point would decrease ATP by 17% and house prices by more than 19%. The high sensitivity to changes in interest rates is not remarkable, given the high share of pure interest only loans which implies semi-interest elasticities similar to those from Poterba's user cost

approach. Previous studies in the Netherlands indeed impose models similar to the user cost methodology (see [De Vries and Boelhouwer, 2009](#) among others) and the high (and non-linear) sensitivity to changes in interest rate is also confirmed empirically by [McQuinn and O'Reilly \(2007\)](#).

The semi-interest elasticity in the United Kingdom is also high relative to other countries. In the literature (see [IMF, 2004](#) among others), the relative high sensitivity of house prices is often attributed to a higher share of borrowers with adjustable rate mortgages. To the best of our knowledge, we are the first to explain the relative high semi-interest elasticity in the United Kingdom with mortgage characteristics other than the high share of adjustable rate mortgages. In our framework, the UK's house prices are more sensitive to changes in interest rates due to the presence of interest-only loans and the inability to deduct mortgage interest in recent years.

[Gallin \(2008\)](#) shows that the relationship between the real user cost and subsequent price adjustments in the USA is small. Also [Glaeser et al. \(2013\)](#), and [Campbell et al. \(2009\)](#) report that changes in interest rates cannot explain the large house price movements. These studies, however, document the role of *real* interest rates. Our study focuses on the *nominal* interest rate due to its important role in the borrowing constraint. The estimates for the semi-interest elasticity of house prices in the USA indicate that an increase of 1% point in nominal interest rates decrease nominal house prices by 8.61%. From 1980Q1 till 2009Q4, nominal interest rates fell by 8.5% points, such that a large part of the increases in house prices since 1980 can be attributed to a decrease in the *nominal* interest rate. This is consistent with [Brunnermeier and Juliard \(2008\)](#), who document the important role of the nominal interest rate due to money illusion.

An important policy question is the degree of capitalization of the MID in house prices. The last four columns in [Table 5](#) summarize the effect of a complete abolishment of the MID on house prices in the long run. A complete abolishment of the MID in the USA would, *ceteris paribus*, decrease the amount that people are able to pay by 17.65% and house prices by 19.94%. The effect is, however, larger in other countries where mortgage interest is deductible at higher tax rates or interest-only loans are more popular. If the Belgian government changes would have changed the tax rate at which households can deduct mortgage interest to zero in 2009, house prices would, *ceteris paribus*, decrease by 23.27%.¹⁴

A similar change in the Netherlands would decrease house prices by more than 39%. The change in the Netherlands is so large because the rate at which mortgage interest is deductible is relatively high and a relatively high share of borrowers use pure interest-only loans. The change to a standard annuity mortgage with maturity of 20 years probably overstates the effect on house prices, as many households may borrow on 25 or 30 years instead of the assumed 20 years. On the other hand, the share of pure only-loans would likely decrease, such that the effect on house prices is underestimated. The scenario of a reduction in the MID and a reduction of interest-only loans is of particular interest in the Netherlands: since 2013, only borrowers with standard annuity mortgages and maturity of maximum 30 years are allowed to deduct mortgage interest. The maximum rate at which mortgage interest is deductible will furthermore decrease by 0.5% every year until 2042. Our framework indicates that the largest impact on the Dutch housing market is through the decreasing share of pure interest only loans. As government regulation induces households to pay off their mortgage debt since 2013, the largest effect through

Table 6
Granger causality tests.

Country	$H_0: x_{i,t} \not\Rightarrow p_{h,i,t}$	$H_0: p_{h,i,t} \not\Rightarrow x_{i,t}$
Belgium	0.00	0.14
Netherlands	0.02	0.04
United Kingdom	0.00	0.15
United States of America	0.00	0.04
Sweden	0.00	0.80
Norway	0.00	0.09
Finland	0.00	0.81
Denmark	0.04	0.14

Note: This table presents the *p*-values of the test for the null hypothesis of no Granger causality from adjusted ATP to house prices (left) and no Granger causality from house prices to adjusted ATP (right). The optimal number of lags are selected with the Schwarz Information Criterion with a maximum of 12 lags.

changing mortgage characteristics will have an immediate impact (or is partially anticipated). The reform of the MID is, on the other hand, planned over a relatively long horizon such that income increases could be sufficient to counteract the negative effect of the reduction in MID.

6.3. Granger causality

Our results indicate that a long-run relationship between nominal house prices and ATP exists. For the interpretation of the results, we study the temporal ordering of the variables by means of Granger causality tests in the VECM ([Granger, 1969](#)). The results in [Table 6](#) are in favor of the view that changes in ATP Granger cause changes in house prices and not the other way around. At the 5% significance level, adjusted ATP Granger causes house prices in every country. In the other direction, the effect seems less strong, suggesting that higher house prices do not stimulate mortgage product innovation in order to keep housing affordable.

The causality from ATP to house prices seems surprising given the large empirical literature that reports a mutual dependence of mortgage lending and property prices or a strong positive effect of property prices on bank lending (see [Hofmann, 2004](#) among others). These studies report, however, a relationship that is often conditional on economic fundamentals (interest rate, income) and/or use the stock of credit rather than the initial mortgage credit of recent home buyers. Therefore, the “financial acceleration mechanism” ([Bernanke et al., 1999](#)) is studied and not the effect of economic fundamentals through mortgage lending. The financial acceleration mechanism states that increased house prices will raise the value of the borrowers' collateral such that they are able to borrow more, which could indeed explain deviations from our long-run relationship between house prices and ATP.

6.4. Testing the ATP model against alternative models

In this section we compare the ATP model against conventional user cost alternatives. We choose to benchmark the ATP model against two alternative models. In the first model we substitute the inverse user cost for the annuity formula to yield a relationship where house prices depend on income (Y_t) divided by the user cost (u_t):

$$p_{h,t} = \frac{Y_t}{u_t}$$

In the second specification we divide the services/cash-flow dividend of housing by the user cost to yield a relationship where house prices depend on rent (R_t) divided by the user cost:

$$p_{h,t} = \frac{R_t}{u_t}$$

¹⁴ The marginal tax rate of 54.92 provided by the OECD is an overestimation of the rate at which mortgage interest is fiscal deductible in 2009. Assuming a marginal tax rate of 50%, house prices would decrease by 21.75% due to a complete abolishment of the mortgage interest deduction in Belgium, *ceteris paribus*.

Table 7

Comparison of the speed-of-adjustment parameter in the house price equation (α_p) of two user cost alternatives and the ATP model.

	Y_t/u_t	R_t/u_t	ATP
Belgium	-0.0141	-0.0119	-0.0533
Netherlands	-0.0114	-0.0094	-0.0205
United Kingdom	-0.0311	-0.0236	-0.0300
United States of America	-0.0280	-0.0258	-0.0407
Sweden	-0.0380	-0.0160	-0.0172
Norway	-0.0428	-0.0326	-0.0376
Finland	-0.0360	-0.0347	-0.0412
Denmark	-0.0289	-0.0267	-0.0246
Average	-0.0288	-0.0226	-0.0331

Note: This table presents the loading coefficients from the house price equation in the VECM.

We follow Himmelberg et al. (2005) who define the user cost as $u_t = i_t^{rf} + \omega_t - \tau_t(i_t^m + \omega_t) + \delta_{h,t} - g_{h,t+1} + \gamma_t$, where i_t^{rf} is the risk-free interest rate, ω_t is the property tax rate, τ_t is the rate at which mortgage interest and property taxes are deductible, i_t^m is the mortgage interest rate, $\delta_{h,t}$ is the maintenance cost as a fraction of home value. The expected one-year capital gain is given by $g_{h,t+1}$ and γ_t represents an additional risk premium. Himmelberg, Mayer and Sinai illustrate the user cost with an annual depreciation rate $\delta_h = 2.5\%$, property tax rate $\omega = 1.5\%$, risk premium $\gamma = 2\%$, long-run appreciation rate of 3.8% (expected inflation of 2% plus a real expected appreciation rate of housing of 1.8%), and a mortgage rate that is 1% point higher than the risk-free interest rate. We use the same values in our analysis and use the long-term government bond as the risk-free interest rate, and our constructed time series of the tax rate at which mortgage interest is deductible. Finally we use disposable income per capita and rent price indices from the OECD.

To compare the ATP model with the conventional user cost models we estimate the VECM for the three models (Y_t/u_t , R_t/u_t and ATP) and compare the speed-of-adjustment parameter (loading coefficient) from the house price to deviations from the long-run equilibrium. By doing so, we are able to see which house price model is best in explaining future house price corrections from deviations from the long-run relationship. The results are presented in Table 7. We can see that the speed-of-adjustment of the ATP model is 15% stronger relative to the user cost model with income and even 47% stronger relative to the user cost model with rents.

Of course, the assumptions that we use for the risk premium, property tax rate, depreciation rate and the long-run appreciation rate of housing are derived from the USA and may not be applicable for the other countries in the sample. An important finding is, however, that the speed of adjustment of the ATP model is also much stronger relative to the user cost models in the USA, the country in which the assumptions are the most realistic.

Unfortunately, we are not aware of any other international study that applies and tests the user cost model in detail in all these countries. Lacking such information, we also did a robustness check with a user cost that only includes the interest rate and the tax rate at which mortgage interest is deductible ($u_t = i_t^{rf}(1 - \tau_t)$). These results (not reported here) confirm that the adjustment speed is stronger in the ATP model: 7% stronger relative to the model with income and 24% stronger relative to the model with rents.

The results indicate that the speed-of-adjustment towards equilibrium is faster in the ATP model, which indicates that the ATP framework provides an alternative toolbox to assess overheating in the housing market. Therefore, it is possible to look at the residuals from a regression of house prices and ATP or the deviations from a price-to-ATP ratio as a measure of housing market imbalances. The relative error terms are presented in Figure A.1 in the appendix.

For the USA, the results indicate that house prices were overvalued in 2006 by approximately 10%. During the crisis, house prices declined and decreased even below the long-run fundamental.

6.5. Sensitivity analyses

Table 8 presents a whole range of sensitivity analyses. Housing-market observers that use deviations from the historical price-to-income ratio as a measure of overvaluation in the housing market implicitly assume a long-run relationship between house prices and income. In a first case we study the possibility of a cointegrated relationship between house prices and disposable income per capita only. As expected, the panel cointegration tests are unable to reject the null hypothesis that all of the countries in the panel are not cointegrated. This confirms the argument of this paper that income alone as a measure of overheating in the housing market is insufficient. The second robustness check examines the case in which the MID is only partially capitalized into house prices. We consider an alternative measure of ATP in which the tax rate at which mortgage interest is deductible is only a third of the actual rate at which mortgage interest is deductible. This case may be instructive if households view the tax benefit as income and therefore spend a proportion of it on consumption.¹⁵ The results, however, indicate that this hypothesis is not confirmed by the panel cointegration test that is robust to cross-sectional dependence.

Other sensitivity analyses indicate that the conclusion of a cointegrated relationship when ATP is adjusted for the MID and mortgage characteristics is robust to different model specifications. In case 3 we use short-term interest rates in countries where the ARM is the most popular mortgage type.¹⁶ In case 4 we use GDP per capita in the measure of adjusted ATP instead of disposable income. In addition we study the relationship when data is only available at yearly frequency (case 5). Case 6 examines the relationship for 3 countries in which we have mortgage rates (at yearly frequency) over the entire time span: the United States of America, Belgium and the Netherlands. And finally we examine cointegration of the panel when nominal house prices and adjusted ATP have been transformed using the logarithmic function¹⁷ (case 7). All these cases are consistent with the hypothesis that there exists a cointegrated relationship between house prices and adjusted ATP in a significant fraction of the countries.

7. Conclusion

Although the price-to-income ratio is a commonly used measure of housing market imbalances at many policy institutions, income alone seems insufficient to explain the evolution of house prices. As unsustainable house prices may raise concerns about financial stability, it is important to understand the factors behind the evolution of house prices. Therefore, we develop a model in which households maximize their lifetime utility. An important element is that the budget constraint depends on mortgage

¹⁵ Note that in our model, borrowers who spend (a part of) the mortgage interest deduction on non-housing consumption would always be able to increase their lifetime utility if they spend it on housing consumption as the tax benefit itself is dependent upon the level of housing consumption.

¹⁶ The countries are the United Kingdom, Finland, Norway and Sweden. All short-term interest rates are from the OECD. As observations are missing in some years we construct a new time series for Sweden based on the Riksbank discount rate from 1980q1 to 1983q4 and the 12 month government bond yield thereafter and for Finland with the base rate from the Finnish Central Bank in the period 1980q1–1986q4 and the OECD data thereafter.

¹⁷ Although the cointegration in the individual countries is less strong, the cointegrated relationship in the case of a logarithmic transformation does carry over for the panel as a whole.

Table 8
Sensitivity analyses.

		Pedroni			Fachin	
		rho	t	adf	Mean	Median
1.	Income per capita only	0.97	0.89	0.89	0.83	0.86
2.	$\tilde{\tau} = 0.3\tau$ (adjusted ATP)	0.10	0.10	0.01	0.14	0.25
3.	Short and long-term interest rate (adjusted ATP)	0.00	0.02	0.00	0.01	0.01
4.	GDP per capita instead of disposable income (adjusted ATP)	0.01	0.04	0.05	0.03	0.03
5.	Yearly data (adjusted ATP)	0.04	0.00	0.00	0.00	0.00
6.	Mortgage rate (adjusted ATP)	0.06	0.03	0.01	0.00	0.00
7.	Logarithmic transformation (adjusted ATP)	0.14	0.04	0.01	0.01	0.06

Note: This table presents *p*-values from test results from the Pedroni group cointegration tests and the test proposed by Fachin that is robust to cross-sectional dependence. Case 6 only includes BEL, NLD and USA.

characteristics and the MID. An additional borrowing constraint and market clearing results in a relationship between house prices and a measure of the amount that households are able to pay. We argue that standard cointegration tests are unable to reject the null hypothesis of no cointegration between house prices and income alone due to changes in mortgage characteristics, the interest rate and the rate at which mortgage interest is fiscally deductible.

Conventional and panel cointegrations tests indicate that house prices and our measure of ATP adjusted for the MID and mortgage characteristics are cointegrated in a statistically significant fraction of the countries. When the mortgage product innovations and the MID are excluded from the measure of ATP, the null hypothesis of no cointegration in all countries is not rejected. This confirms our hypothesis that it is necessary to model the changes in mortgage characteristics and tax rules.

Although modern finance theory suggests that many households would benefit from innovative mortgage products, our results indicate that we should also consider the aggregate effects of mortgage characteristics on house prices. The elasticity of house prices with respect to changes in adjusted ATP is indeed close to one and Granger-causality tests indicate that the measure of adjusted ATP Granger causes house prices. Evidence in the other direction is much weaker. The statement that high house prices caused product innovation and therefore more affordable housing seems incorrect according to the Granger causality tests. The semi interest elasticity of ATP, furthermore, differs between tax rules and mortgage products. In our framework, the UK's house price sensitivity to changes in interest rates is relatively high due to the inability to deduct mortgage interest and the presence of interest-only loans. A high share of pure interest-only loans also explains the relatively high semi-interest elasticity in the Netherlands, whereas the lower sensitivity in the USA is due to the MID and the dominance of the standard annuity mortgage. In any case, the model argues that the long-term nominal interest rate can explain a large part of house price increases, which is important for the discussion on the role of interest rates in the recent evolution of house prices.

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Supplementary material

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