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The long-run relationship between house prices and income reexamined: the role of mortgage interest deduction and mortgage product innovation

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The Long-Run Relationship between House Prices and Income Reexamined: the Role of Mortgage Interest Deduction and Mortgage Product Innovation.*

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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 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 ability to pay close to one. Ability to pay incorporates the effect of a decreasing trend in interest rates, changes in mortgage interest deduction and the recent innovation in mortgage products. 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 house prices have increased in almost every developed country. *The Economist* (November 26th, 2011) notes that "Never before had house prices risen so fast, for so long, in so many countries". 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) argues that many property markets "are still looking uncomfortably overvalued" based on price-to-income ratios. There are 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, Lunde and Whitehead 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.

For these reasons, income alone cannot explain house price behavior in the long run. Whether or not a long-run relationship exists between house prices and income continues to be a significant debate in the literature (Gallin 2006; Holly, Pesaran and Yamagata 2010). Income is a long-run fundamental if a cointegration test can indicate that the residuals from a regression of house prices on income are stationary. The debate focuses on the characteristics of the cointegration tests themselves and proposes to use panel cointegration tests as a solution for the low power in single cointegration tests. Panel cointegration tests have however a different null hypothesis, such that rejection should be careful interpreted (Maddala 1999; Pesaran 2012). Without a correctly estimated long-run equation, error-correction specifications may be inappropriate. Studies that use error-correction models for house prices and income may thus produce biased estimates if house prices and income are not cointegrated. Our goal is to estimate the long-run equilibrium properly.

Morgan (1965) has already concluded that empirical work does not need one, but a battery of measures related to the ability to pay for housing. We adjust the income variable because most households finance their home purchase with a standard annuity mortgage. Thus instead of using income alone we compute a variable that can be interpreted as the ability to pay of the average household. In a first extension we augment the model to allow for mortgage interest deduction where we assume that 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 mortgage interest deduction 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.

We thus assume 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 interest payments and innovative mortgage products. Changes in the mortgage interest deduction 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. Standard cointegration tests are, however, able to reject the null hypothesis of no cointegration between house prices and a measure of ability to pay that incorporates these regime shifts. We apply the model to a selection of 8 OECD countries: the United States of America, United Kingdom, Belgium, the Netherlands, Norway, Finland, Sweden and Denmark. Our results indicate that there exists a long-run relationship between house prices and the amount that households are able to pay adjusted for mortgage interest deduction and product innovation. Ability to pay Granger causes nominal house prices, while evidence in the other direction is almost inexistent. The elasticity of house prices, with respect to our measure of ability to pay adjusted for mortgage interest deduction and mortgage product innovation, is furthermore close to one, which indicates that ability has an important economic role.

A major contribution of the paper is that the model provides an alternative toolbox to study price forming in the housing market for a whole range of scenarios. As an example, we calculate the predicted effects on house prices from changes in the interest rate and the fiscal deductibility of mortgage interest.

2 Overview of the Literature

The question whether fundamentals can explain house price movements has initiated a whole debate in the literature. The evidence on a long-run relationship between house prices and fundamentals is mixed. 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 Linn (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. Holly, Pesaran and Yamagata (2010) are able to reject the null hypothesis of no cointegration between house prices and income using the CIPS panel unit root test described in Pesaran (2007).

So far, the discussion focuses on the statistical properties of the cointegration tests themselves. Panel tests are introduced as a solution for the low power of individual time-series cointegration tests. 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 careful interpreted (Maddala 1999; Pesaran 2012). In this paper, we prefer to use individual time-series cointegration tests instead of the panel alternatives to make sure that a rejection of the null hypothesis of no cointegration is not driven by a proportion of the countries in the study, but due to our house price fundamental itself.

The main contribution of this paper is to 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 2011; Brissimis and Vlassopoulos 2009; Gimeno and Martínez-Carrascal 2010; Oikarinen 2009; Fitzpatrick and McQuinn 2007; Gerlach and Peng 2005; Hofmann 2004; de Haas and De Greef 2000 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. McQuinn and O'Reilly apply their model to the Irish housing market and find evidence of a long-run relationship between house prices and the amount the average household can borrow. McQuinn and O'Reilly (2007) furthermore apply this model to a panel of 16 OECD countries. Their panel cointegration tests again indicate that a long-run relationship exists, but the authors do not report an estimate of the fraction of countries in which the long-run relationship exists. 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 model was not able to account for all the increase in the period 2001-2006. Madsen (2012) points to financial innovations, which lower initial mortgage payments, as a possible explanation.

Only a few studies have examined the financial innovation in models of residential credit and their effect on house prices. Addison-Smyth, McQuinn and O'Reilly (2009a) note that the period after 2000 corresponds to a period of excess credit due to the access to interbank markets of UK credit institutions. Their results indicate that the loan amount issued in itself caused UK house prices to increase to a level which is 30% greater than what they would have been without access to foreign credit markets. In another study Addison-Smyth, McQuinn and O'Reilly (2009b) apply their model to the Irish housing market. In addition to the funding in the form of interbank borrowing, the authors point to the greater importance of asset securitization since the late 1990s. This enabled financial institutions to raise funds at a lower cost, which was used by Irish banks to a large extent. The authors conclude that the inclusion of these financial innovations improves the model. Instead of using the observed loan amount, we will model the amount that borrowers are able to pay through the specific mortgage products that are available to them. The main advantage of this approach is that we can directly explore the theoretical expected link between economic fundamentals and house prices.

The literature that models residential credit often ignores the fiscal deductibility of mortgage interest payments. This has implications for the amount that people are able to borrow given their income. Vastmans and Buyst (2011) and Vastmans, Buyst, Helgers and Damen (2013) incorporate this insight. They show that a long-run relationship exists between house prices and the amount of money people can borrow by modeling the evolution of the net tax relief in combination with a mortgage lengthening in 2005 for Belgium.

The ability to deduct mortgage interest is however already incorporated in the user cost literature. This methodology 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 threats 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) prefer 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. The homebuyer has to make a minimum down-payment while his initial monthly mortgage payment cannot exceed the amount the bank is willing to accept. Poterba's (1984) 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 (1984) original assumption of perfect foresight is unrealistic. Himmelberg, Mayer and Sinai (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, Gottlieb and Gyourko (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 ability to pay 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

To understand why house prices may increase with the amount that households are able to pay, we develop a simple framework in which households maximize their utility subject to a budget constraint. 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 ability to pay.

As most home purchases are mortgage-financed, the amount of housing services 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_t). The loan amount (l_t) is then equal to the net present value of all future mortgage payments and therefore depends on the mortgage payments (m_t), the interest rate (i_t), and mortgage length (n):

$$l_t = \sum_{k=1}^{n} \frac{m_t}{(1+i_t)^k} \tag{1}$$

As the borrower has to make a downpayment (d_t), the loan amount equals the house price ($p_{h,t}$) minus the down payment: $l_t = p_{h,t} - d_t$. Substituting this in (1) and rewriting gives the fixed yearly mortgage payments (m_t) of the standard annuity mortgage as a function of the house price ($p_{h,t}$), downpayment (d_t), the interest rate (i_t), and the mortgage length (n):

$$m_t = \frac{p_{h,t} - d_t}{\left(\frac{1-(1+i_t)^{-n}}{i_t}\right)} \tag{2}$$

$$= \frac{(1-\beta)\,.p_{h,t}}{a_{n,i}} \tag{3}$$

The annuity formula $\left(\frac{1-(1+i_t)^{-n}}{i_t}\right)$ calculates the net present value of n future payments given interest rate i_t. In (3) we rename the annuity formula as $a_{n,i}$ and rewrite the downpayment (d_t) as a fixed percentage (β) of $p_{h,t}$.

Consider a model in which household preferences over housing services (h_t) and nonhousing consumption (c_t) are given by a standard Cobb-Douglas utility function. We assume that each period, J_t households who meet the requirement of a minimum downpayment ratio β are willing to buy a house. Household j then maximizes its utility with parameter α over h_t and c_t subject to a budget constraint.

$$\max_{h_t>0,c>0} U = h_t^{\alpha}.c_t^{1-\alpha} \tag{4}$$

$$s.t. \quad : \quad h_t.\frac{(1-\beta)\,.p_{h,t}}{a_{n,i}} + c_t.p_{c,t} = Y_t \tag{5}$$

Our budget constraint differs from the existing literature as the price of housing services ($p_{h,t}$) only enters through the mortgage payments. The budget constraint thus says that the sum of yearly mortgage payments and consumption expenditures should equal income (Y_t): households are not able to spend more than they earn. We assume, however, that households exhaust their budget constraint as they are in competition with other households for the scarce housing services. Maximization of (4) subject to (5) yields the optimal amount of housing services (h_t^*):

$$h_t^* = \frac{\alpha Y_t}{1-\beta}.a_{n,i}.\frac{1}{p_{h,t}}$$

Summing over the J_t individual demands for housing services, one arrives at the aggregate demand for housing services (H_t^*):

$$H_t^* = \sum_{j=1}^{J_t} h_t^*\left(p_{h,t}, a_{n,i}, Y_t\right)$$

$$= \underbrace{J_t}_{\text{Extensive}} \cdot \underbrace{\frac{\alpha Y_t}{1-\beta}.a_{n,i}.\frac{1}{p_{h,t}}}_{\text{Intensive demand}}$$

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_t^*) equals the aggregate supply of housing services (Q_t^S): $H_t^* = Q_t^S$. Solving for the house price ($p_{h,t}$) then yields

$$p_{h,t} = \frac{J_t}{Q_t^S} . \frac{\alpha Y_t}{1-\beta} . a_{n,i} \tag{6}$$

$$= \frac{J_t}{Q_t^S} . A_t \tag{7}$$

where we rename $\frac{\alpha Y_t}{1-\beta}.a_{n,i}$ to the household's ability to pay A_t. The house price is thus a function of a ratio of the demand on the extensive margin over the supply of housing services, multiplied with the household's ability to pay. Equation (7) indicates that house prices should be cointegrated with ability to pay if the ratio (J_t/Q_t^S) is constant over time. Similar assumptions are made in the existing literature: Head, Lloyd-Ellis and Sun (forthcoming) assume that available land grows at an exogenous rate equal to the growth rate of the population in the long run, which implies that the total stock of land relative to the aggregate population is a constant in equilibrium. Growth in the number of households is thus absorbed by growth in the supply of aggregate housing through housing construction such that the ratio J_t/Q_t^S is constant over time and a long-run relationship between house prices and ability to pay exists. Our current framework therefore does not necessarily require an inelastic housing supply.

A long-run relationship between house prices and income does not have to exist according to equation (6) 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). Notice that a similar argument can be made for the long-run relationship between house prices and ability to pay: if the ratio J_t/Q_t^S is not constant over time, standard cointegration tests would be unable to reject the null hypothesis of no cointegration. Whether or not such a long-run relationship exists is an empirical question.

The framework we describe is, however, not the only situation that gives rise to a long-run relationship between house prices and households' ability to pay. Many borrowers face a borrowing limit as mortgage payments are often limited to a certain fraction of income (for example: $\bar{\alpha} = 0.28$). If preferences for housing are such that households are willing to spend more on housing than the borrowing limit ($\alpha > \bar{\alpha}$), a binding borrowing constraint for the representative household gives rise to a relationship between house prices and ability to pay. A similar assumption that households exhaust their debt capacity was used in a study by Makarov and Plantin (2013) for subprime lending.

Hereafter, we augment the standard annuity mortgage to allow for mortgage interest deduction. 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. When we use the term “ability to pay adjusted for mortgage interest deduction and mortgage characteristics”, "adjusted ability to pay", 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.

3.1 *Standard Annuity Mortgage Adjusted for Mortgage Interest Deduction*

Due to the availability of mortgage interest deduction in many countries, the ability to pay of the borrower can be higher than A_t from the previous section. He can spend (a part of) the mortgage interest deduction to increase his yearly payments from αY_t to $\alpha Y_t + \tau_t.\bar{I}_t$, and ultimately, the borrowing limit. 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, his capital payments will be higher and he will deduct less. Hence it is reasonable to assume that that the average amount of interest deducted ($\bar{I}_t$) is capitalized into house prices such that his ability to pay increases to[1]:

$$A_t^{'} = \left(\frac{\alpha Y_t + \tau_t.\bar{I}_t}{1-\beta}\right) a_{n,i} \tag{8}$$

The rate at which the borrower can deduct interest is equal to τ_t. We assume that the households have static expectations regarding future tax rates and rules. The average yearly interest paid ($\bar{I}_t$) is equal to:

$$\begin{aligned} \bar{I}_t = \frac{1}{n}(& \underbrace{\left(\alpha Y_t + \tau_t.\bar{I}_t\right).n}_{\text{Total mortgage payments}} \\ & - \underbrace{(\alpha Y_t + \tau_t.\bar{I}_t).a_{n,i}}_{\text{Loan principal}}) \end{aligned} \tag{9}$$

Solve (9) for $\bar{I}_t$ and substitute this in (8) to get:

$$A_t^{'} = \left(\frac{\alpha Y_t}{1-\beta}\right)\left(\frac{1}{1-\tau_t.\left(1-\frac{a_{n,i}}{n}\right)}\right) a_{n,i} \tag{10}$$

This extension allows us to interpret the possible effects of the mortgage interest deduction on the ability to pay for housing. For a 20-year mortgage at an interest rate of 5%, a ceteris paribus increase in the maximum

[1] We assume that households use the average amount of interest paid ($\bar{I}_t$) to increase mortgage payments as a proxy for their willingness to smooth consumption (instead of the net present value of the fiscal advantage).

rate at which mortgage interest is deductible from 0% to 30% would lead to an increase in ability to pay of 13%. An increase in the tax rate from 0% to 50% would even cause the ability to pay to increase by 23%.

3.2 *Interest-Only Mortgage with Repayment Vehicle*

An endowment mortgage or savings mortgage is an interest-only loan where the principal is repaid at the end of the mortgage term through a repayment vehicle. The borrower pays only the interest and makes payments to an endowment policy. The savings mortgage often takes the form of a life insurance that pays the proceeds at the end of the mortgage. 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 purpose of the savings mortgage is to make maximum use of the mortgage interest deduction. Because he is able to deduct all the interest over the whole mortgage duration, he is able to increase his ability to pay to:

$$A_t^{'} = \left(\frac{\alpha Y_t + \tau_t . i_t . (1-\beta) . A_t^{'}}{1-\beta} \right) a_{n,i} \tag{11}$$

Solve (11) for $A_t^{'}$ to get:

$$A_t^{'} = \left(\frac{\alpha Y_t}{1-\beta} \right) \left(\frac{1}{1-\tau_t . i_t . a_{n,i}} \right) a_{n,i} \tag{12}$$

We can see that without the ability to deduct interest ($\tau_t = 0$), this mortgage wouldn't exist as it would be equivalent to a standard annuity mortgage. For a 20-year mortgage at a 5% interest rate, the ability to pay would be 23% higher in comparison to a standard annuity loan when interest is deductible at 30%. At even higher rates of 50%, the ability to pay would be 45% higher than a standard annuity loan.

3.3 *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, Lunde and Whitehead 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 can decide to spend his yearly payments on interest payments such that $\alpha Y_t = i_t . A_t^{'}$ (assuming no down payment). If the borrower is able to deduct interest his yearly payments can increase from αY_t to $\alpha Y_t + \tau_t . i_t . A_t^{'}$ which has to equal the yearly interest for the mortgage:

$$\alpha Y_t + \tau_t . i_t . A_t^{'} = i_t . A_t^{'} \tag{13}$$

Solve (13) for $A_t^{'}$ to get:

$$A_t^{'} = \frac{\alpha Y_t}{i_t .(1 - \tau_t)} \tag{14}$$

Equation (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. Ability to pay from a pure interest-only loan increases significantly at lower interest rates in comparison to other mortgage types. Ability to pay 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, the ability to pay is much lower. Ability to pay 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, the ability to pay 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.

4 Data

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 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. 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[2]. 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 the next section. In addition, we construct weights for the different mortgage types based on country reports or academic articles and interpolate for unknown periods. We assume a payment-to-income ratio (α) equal to 30% and a down-payment ratio (β) equal to 20%. Our results are independent of these assumptions as they only linearly transform our measure of ability to pay (assuming no pure interest-only loan). Mortgage maturity (n) is set equal to 20 years unless otherwise specified in the next section.

The OECD database provides nominal house price indices, aggregate household real disposable income (which we transform to nominal income per capita), 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 & 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 high spread indicates that it is very likely that rates will increase in the future. A prudent 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[3]. The use of long term bond rates is furthermore widespread in the literature such that our results are comparable to the existing literature.

5 Country Comparison: Mortgage Interest Deduction and Mortgage Characteristics

The mortgage interest deduction has been limited over time in the **United Kingdom** (Hendershott, Pryce and White 2002). From 1974 the deduction was restricted such that only mortgages below the £25000 threshold could deduct interest. From 1983, this limit was raised to £30000 and this amount was never adjusted to compensate for increasing house prices. The maximum rate at which interest could be deducted was limited to 25% from 1992 in comparison to maximum marginal income tax rates of 40% in the pre-1992 period. This limit decreased further to 20% (1994), 10% (1995), and 0% (1999). We use data from the Council of Mortgage Lenders (as presented in the Mortgage Market Review (2011) of the Financial

[2] 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 available upon request.

[3] For Belgium alone we would have to combine three different measured time series to construct a mortgage rate from 1980Q1 to 2009Q4. A robustness check with mortgage rates is available upon request for Belgium, the Netherlands and the United States of America. The results do not alter our conclusions.

Services Authority) for the relative share of the different mortgage types. In the early 1980s, the interest-only mortgage with repayment vehicle became a mainstream contract. Borrowers with so-called endowment mortgages did not repay any capital but made payments to an endowment policy that would be sufficient to repay the loan at the end of the term. Borrowers were thus able to make maximum use of the interest deductibility over the whole mortgage term. As the mortgage interest deduction was limited over time, this mortgage decreased in popularity. According to the Mortgage Market Review (2009, 2011) there is, however, a recent increase in pure interest only-loans from 9% in 2002 up to 24% in 2007. Since 2007, the share of interest-only mortgages has declined sharply such that pure interest-only loans were only 12% of total sales in 2009. We assume an average mortgage term of 25 years. The Mortgage Market Review (2009) indicates that the loan-to-value ratio at time of house purchase is approximately 80% in 2008.

In the **United States of America** the mortgage interest deduction is one of the largest tax expenditures. Owner-occupiers can deduct mortgage interest from income at their marginal tax rate on the first $1 million of debt used to acquire, construct, or improve a house. The United States has a high proportion of long-term fixed-rate mortgages (Lea 2010). The average mortgage term in the period 1980-2009 is equal to 27 years according to data from the Federal Housing Finance Agency's Monthly Interest Rate Survey. Over this period, the average loan-to-value ratio was equal to 76% according to the same data. Mortgages with affordability features such as interest-only or payment-option loans (requiring even lower mortgage payments) increased from only 2% of origination share in 2003 to almost 20% in 2005 according to a report from the Joint Center for Housing Studies of Harvard University[4]. The share of interest-only and payment-option loans decreased to 11% in 2007 and completely disappeared by 2009.

In **Belgium** (Van der Reysen, Vanrijckeghem and Vlasselaerts 2007) the mortgage tax relief before 2005 was mainly a capital deduction. Households were thus able to reduce taxable income dependent on the amount of capital the borrower repaid. Borrowers thus had no incentive to take mortgages with longer maturities as the fiscal advantage was higher in the final years of the mortgage. To our knowledge, Belgium is the only country in the world where capital payments were deductible. In practice, the tax relief was around 2500 euro per household for a mortgage of 20 years in 2004 (e.g. Valenduc 2008 cited in Vastmans and Buyst 2011). The amount deductible was thus limited per dwelling in contrast to the new mortgage tax relief since 2005 (woonbonus) that is limited per person. In 2005, the tax relief was equal to 1870 euro per person. In the first 10 years, this amount was increased by 620 euro. These amounts are indexed such that the maximum allowed tax relief was 2770 euro per person in 2010. For the majority of households, the tax relief thus more than doubled from 2500 euro per household in 2004 to 4980 euro in 2005. During the whole period, this tax relief was deductible at the marginal tax rate of the borrower. It has been shown by Plaut (1986), among others, that a decrease in the mortgage interest rate decreases the rate of amortization. Cheaper mortgages

[4]See Joint Center for Housing Studies of Harvard University. 2008. The State of the Nation's Housing 2008: Figure 19, page 18.

are thus repaid less quickly. Vastmans, Buyst, Helgers, and Damen (2013) confirm that the system of capital deductions before 2005 provided an incentive to borrow with a shorter maturity as the fiscal advantage was tilted to the end of the maturity. As the tax reform allows households to deduct mortgage interest since 2005, households borrow on longer terms since then (Vastmans and Buyst 2011). We therefore assume that the mortgage term increased from 20 years (before 2005) to 25 years in 2005. The appendix provides additional information on how we model the ability to pay in Belgium given its unique system of fiscal advantages for homeowners. The typical loan-to-value ratio for a first-time house buyer is equal to 80% according to ECB (2009).

Homeowners in the **Netherlands** can deduct interest payments at their marginal tax rate. Tax relief for second homes was abolished in 2001, and deductibility is limited to a 30-year period (Scanlon and Whitehead 2004). There are some significant changes in mortgage characteristics since the 1990s. During the last two decades interest-only mortgages (first savings-mortgages with repayment vehicle, later interest-only loans without repayment vehicle) increased in popularity. The share of interest-only loans was only 33% in 1989 (of which only 10% had no repayment vehicle), but was able to gain popularity such that 89% of mortgages in 2009 were interest-only (of which 50% had no repayment vehicle). We use data from the Housing Needs Surveys as presented in Rouwendal (2007) and the Dutch Housing Survey (2009) to construct the mortgage shares. The mortgage interest deduction is an important issue in Dutch policy debates. Policy makers decided that from 2014, the maximum rate at which mortgage interest is deductible will decrease by 0.5% every year until it is completely abolished in 2040. Since 2013, only borrowers with standard annuity mortgages and maturity of maximum 30 years are allowed to deduct mortgage interest. The framework allows us to study the impact of these changes in the mortgage interest deduction and mortgage characteristics on house prices.

The accelerating inflation in the 1970s transformed the effective **Swedish** housing subsidies into huge general subsidies to housing consumption (Englund, Hendershott and Turner 1995; Turner and Whitehead 2002). Not only could they fully deduct mortgage interest payments, most new housing units were entitled to interest-subsidized loans and there was a scheme of housing allowances for low-income families with children. Since the 1985 reform, the tax rate applicable to interest deduction was the same for all households. Interest payments can only be deducted at a maximum rate of 50 percent from 1985 to 1988 and declined to 47 percent in 1989, 40 percent in 1990, and to 30 percent since 1991 (Berger, Englund, Hendershott and Turner 2000). Before 1985, we assume a tax rate of 50%, but the results do not change when we use higher marginal tax rates of 60% or 70%.

Due to the 1987 tax reform in **Denmark**, borrowers were no longer able to deduct interest payments at the highest marginal tax rates (up to 70%). The taxable value of tax relief on interest decreased to 50%. The 1993 and 1998 tax reforms further reduced the tax rates at which interest payments could be deducted. This meant a continued decrease in the taxable value of tax relief on interest until it was equal to 33% for all taxpayers in 2001. It was expected that the tax adjustments of the "Whitsun-package" could dampen the real estate market and that these effects would be seen from the adoption in the summer of 1998[5]. A rational household will take into account the expected reduction in taxable value. As a proxy, we therefore assume that households' willingness to pay increases only up to a borrowing limit computed from a marginal taxable value of 33% from 1999. All other yearly marginal tax rates are taken from the Danish Ministry of Taxation (at the highest tax brackets)[6]. Since 2003, interest-only products were allowed. This innovation was able to gain popularity such that 31,5% of mortgages were interest-only in 2005. Two years later, this share increased further to 43% of owner-occupiers' outstanding mortgages (Scanlon & Whitehead 2008). Yearly data on the weights of the interest-only loans were taken from the annual reports of the Association of Danish Mortgage Banks.

Norway and **Finland** experienced tax reforms in 1992 and 1993, respectively (de Vries 2007). Since then, mortgage interest is deductible at proportional rates of 28% in Norway and 29% in Finland. Deductions were possible at the progressive marginal tax rates before the tax reforms. The changes in the Nordic tax systems are characterized as a move to a dual income taxation which separates the taxation of capital income from the taxation of other sources of income (Sørensen 1994). The typical loan-to-value ratio for a first-time house buyer is equal to 81% in Finland according to ECB (2009).

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). In the short run, deviations can occur from the long-run relationship, but in the long run the dependent variable will converge to the fundamental value. If two variables that are integrated of order one are not cointegrated, the regression results are spurious such that there exists no interpretation of the estimated coefficients. Table 1 presents results for Phillips-Perron stationarity tests (including an intercept) of nominal house prices and ability to pay in differences. The null hypothesis of no stationarity in differences is rejected in every country at the 10% significance level.[7] All variables are thus integrated of order one and cointegration tests can be applied to ensure that a possible relationship between house prices and our measure of ability to pay is not spurious. 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 Philips & Ouliaris

[5] See the Annex of the Convergence Program (1998-1999) from Denmark in accordance with the Council Regulation (EC) No 1466/97 of 7 July 1997: http://ec.europa.eu/economy_finance/economic_governance/sgp/pdf/20_scps/1998-99/01_programme/dk_1998-12-01_cp_annex_en.pdf.

[6] See for example http://www.skm.dk/skatteomraadet/talogstatistik/tidsserieoversigter/4638.html.

[7] Phillips-Perron tests do not reject the null hypothesis of no stationarity (with and without trend) of the time series in levels (results not reported here).

(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.

Tables 2 and 3 provide test results for the null hypothesis of no cointegration according to the test statistics described in the previous paragraph and in the appendix. Table 2 provides test results for the null hypothesis of no cointegration between nominal house prices and ability to pay measured with a standard annuity mortgage. At the 10% significance level, Norway and the United States of America are the only countries where we can reject the null hypothesis of no cointegration between nominal house prices and ability to pay. In all other countries we cannot reject the null hypothesis of no cointegration. The absence of cointegration in most countries indicates that the standard annuity mortgage is insufficient in explaining the evolution of house prices.

To capture the effect of mortgage interest deduction and financial innovation, we define the variable “ability to pay adjusted for mortgage interest deduction and mortgage characteristics”. This is a weighted average of the ability to pay with the annuity and interest-only mortgages where mortgage interest deduction is allowed. The weights equal the share of the particular mortgage as percentage of all mortgages. We plot the nominal house prices and adjusted ability to pay for each country in Figure A.1. The test results in table 3 indicate that we can reject the null hypothesis of no cointegration between house prices and adjusted ability to pay from 1980Q1 to 2009Q4 in all countries except Sweden. 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 ability to pay does exist from 1995 to 2009, when the Swedish market recovered.

Figure 1 presents the percentage change in adjusted ability to pay at time t due to a change in a specific variable from 1980 to t conditional on the other variables at time t. Due to the conditioning on the other variables at time t, the influence of a variable can change over time without a change in the variable itself. The effect of each determinant is thus dependent on the value of the other variables. Changes in "Mortgage Interest Deduction" refer to the effect of the marginal tax rate at which interest is deductible and the expansion of the fiscal advantage for homeowners in Belgium. "Interest Rate" refers to the effect of changes in the nominal long-term interest rates. "Mortgage Characteristics" includes the changes in the share of specific mortgage types and the lengthening of mortgage terms since 2005 in Belgium.

The figure shows the downward pressure on adjusted ability to pay in Sweden due to the reductions in the rate at which mortgage interest was deductible. Swedish house prices bottomed out in the mid-1990s when decreasing interest rates caused an upward pressure on the adjusted ability to pay. The evolution in Sweden is very different from the United Kingdom, where the decrease in mortgage interest deduction (and contemporaneous decrease in the endowment mortgage) was counteracted by decreasing interest rates. The simultaneous downward pressure on house prices due to the phased out mortgage interest deduction and upward pressure due to decreasing interest rates caused a comparatively minor change in house prices. The complete abolition in the United Kingdom can thus be seen as a perfectly timed counter-cyclical Keynesian policy.

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 (see Figure 1). In all these countries, we are unable to reject the null hypothesis of no cointegration if we do not adjust our measure of ability to pay for specific mortgage characteristics. The 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 mortgage interest deduction and specific mortgage product innovations to explain house price behavior since the 1980s.

We assume static expectations regarding future tax rates and rules[8]. Households thus naively expect the tax rates to be maintained in the future. We make this simplifying assumption as it is impossible to know the exact path of households' expectations over time. As a robustness check, we assume that future tax rules in the United Kingdom and Denmark are announced at the start of the tax reforms in 1992 and 1987, respectively, and that households are willing to pay, within their ability, calculated from the tax rate at the end of the reforms (0% in the United Kingdom and 30% in Denmark)[9]. In the United Kingdom we are then able to reject the null hypothesis of no cointegration at even lower significance levels. The results for

[8] An exception is the 1989-2001 period in Denmark where we assume that households are only willing to pay a borrowing limit calculated with the 2001-taxrate of 30% (see previous section).

[9] For evidence that borrowers in the United Kingdom were able to (partially) know future tax paths see Jones, R. (1999). "Time is right for mortgage relief to end," Guardian, Retrieved May 29, 2013, from http://www.guardian.co.uk/uk/1999/mar/10/rupertjones?INTCMP=SRCH

Denmark are similar to the baseline case. The results thus indicate that house prices incorporate expectations of future tax reforms.

6.2 *Granger Causality*

Our results indicate that a long-run relationship between nominal house prices and the ability to pay exists. For the interpretation of the results, we study the temporal ordering of the variables by means of Granger causality tests (Granger 1969). Because there exists a long-run relationship between nominal house prices and adjusted ability to pay we can apply the Granger causality tests to the I(1) series. In the bivariate cointegrated case, the test has an asymptotic $\chi^2(p)$ distribution, where p is equal to the order of the vector autoregressive (VAR) process (Lütkepohl and Reimers 1992). We apply the SIC to select the optimal order p, which is shown to be consistent under quite general conditions (Lütkepohl 2005). The results in tables 4 and 5 are in favor of the view that changes in the ability to pay Granger cause changes in house prices and not the other way around. At the 5% significance level, adjusted ability to pay Granger causes house prices in every country. In the other direction, the effects seem less strong, suggesting that higher house prices do not stimulate mortgage product innovation in order to keep housing affordable. As we are unable to find a long-run relationship in Sweden for the full sample period, the results for Sweden should be carefully interpreted[10]. An explanation for the mutual dependence in Belgium might be found in the indexation of nominal wages and the limits of the fiscal advantage. Due to an indexation with lagged inflation a bi-directional relationship in the short run might arise as borrowers can anticipate future indexations in wages and the limits of the fiscal advantage.

The causality from ability to pay 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) such that the "financial acceleration mechanism" (Bernanke, Gertler and Gilchrist 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 ability to pay.

6.3 *Economic Importance*

6.3.1 The elasticity of house prices with respect to ability to pay

To study the economic importance of ability to pay and its components we have to estimate the cointegration vector of house prices and ability to pay. The OLS estimator would yield a consistent estimate of the

[10] If we apply the Granger causality tests to the series in differences for Sweden, we are unable to reject the null hypothesis of no Granger causality in either way if the optimal number of lags is selected with the SIC.

cointegration vector, but is subject to a finite sample bias and the OLS standard errors will be inappropriate (Stock 1987, Zivot and Wang 2006). We therefore follow the approach of Stock and Watson (1993) and augment the static ordinary least squares estimator (SOLS) to include q leads and p lags of the regressor in differences ($\sum_{z=-q}^{p} \gamma_{i,z} \Delta x_{i,t-z}$) to construct the dynamic ordinary least squares estimator (DOLS). The DOLS model can be expressed as

$$p_{h,i,t} = \beta_{i,0} + \beta_{i,1}.x_{i,t} + \sum_{z=-q}^{p} \gamma_{i,z}.\Delta x_{i,t-z} + u_{i,t} \tag{15}$$

where $p_{h,i,t}$ is the nominal house price, $x_{i,t}$ our measure of ability to pay, and $u_{i,t}$ a stationary process (where subscripts i and t denote the country and time, respectively). We estimate equation (15) separately for each country. Newey-West HAC standard errors may be used for valid inference on $\beta_{i,1}$ (Zivot and Wang, 2006). Hayakawa and Kurozumi (2006) show that the DOLS estimator without leads substantially outperforms the DOLS estimator with leads and lags in case leads are unnecessary. We therefore estimate equation (15) without leads ($q = 0$), but provide robustness checks with both leads and lags in the appendix. The optimal number of lags is selected by the Schwarz and Akaike Information Criteria with a maximum of 8 quarters.

However, because our data consists of house price indices and not the actual house price itself, the estimated parameter $\hat{\beta}_{i,1}$ is difficult to interpret. We are however able to interpret the estimated parameter $\hat{\beta}_{i,1}$ if we compute the elasticity of house prices with respect to ability to pay ($\varepsilon_{i,t}$) as follows:

$$\begin{aligned}
\varepsilon_{i,t} &= \frac{d\hat{p}_{h,i,t}}{dx_{i,t}}.\frac{x_{i,t}}{\hat{p}_{h,i,t}} \\
&= \hat{\beta}_{i,1}.\frac{x_{i,t}}{\hat{p}_{h,i,t}} \\
&= \frac{\hat{\beta}_{i,1}.x_{i,t}}{\hat{\beta}_{i,0} + \hat{\beta}_{i,1}.x_{i,t}}
\end{aligned}$$

where $\hat{p}_{h,i,t}$ is the predicted value of the house price calculated with the consistent estimate of $\beta_{i,1}$ in equation (15): $\hat{p}_{h,i,t} = \hat{\beta}_{i,0} + \hat{\beta}_{i,1}.x_{i,t}$. The elasticity thus measures the percentage change in house prices from a change in ability to pay of 1%.

An alternative solution would be to estimate (15) with a logarithmic transformation of the house price index and our measure of ability to pay, such that the estimated coefficient can be interpreted as an elasticity. However, as Granger and Hallman (1991) point out, the existence of cointegration between two variables does not imply cointegration between any non-linear transformation of the variables. We are indeed unable to reject the null hypothesis of no cointegration between the logarithmic transformed variables (results not reported here). An intuitive explanation can be found in the interpretation of the shock in our specification.

Shocks that drive house prices temporarily from their long-run relationship are thus not proportional to the house price itself (multiplicative), but became relatively smaller over time in our current time span according to our results. This finding might be specific to the time span of this study, or a possible explanation might be a more efficient market over time with smaller relative shocks (and constant absolute shocks). In any case, it is an important finding, given that it is standard practice to apply a logarithmic transformation in the existing literature[11].

The estimated elasticities, calculated with the ability to pay in the last quarter of 2009 of country i ($\varepsilon_{i,t}|t = 2009Q4$), are presented in Table 6. The results where the optimal number of lags are selected with the Schwarz information criterion indicate that the smallest elasticity is found in Finland: a one percentage increase in ability to pay, increases the house price by 0.82 percent. The largest elasticity is found in Denmark, where a one percentage increase in ability to pay increases the house price by 1.16 percent. The estimated elasticities are remarkably close to one, and even statistically indistinguishable from one in the United Kingdom and Norway. The estimated elasticity in Sweden is also statistically indistinguishable from one, although the coefficient is probably spurious as we are unable to reject the null hypothesis of no cointegration in the full time span. The results are robust in the use of the Akaike information criterion for optimal lag selection (reported in Table 6) or using both leads and lags in the DOLS estimator (reported in the Table A.3 in the appendix).

An inspection of the relative error terms in Figure A.4 indicates that the number of house price cycles around our long-run equilibrium is rather limited. Deviations from the equilibrium may therefore have a large influence on the estimated cointegration vector in the relatively short time span of less than 30 years. Future research that would replicate our study when a longer time span is available might find elasticities closer to one as these estimates would be less influenced by housing cycles. Given the time span of the available data, a solution would be to estimate a Mean Group Estimator (Pesaran and Smith 1995) of the elasticities that could cancel out country-specific cyclical fluctuations. The Mean Group Estimator is a simple mean (Pesaran and Smith 1995):

$$\bar{\varepsilon} = N^{-1} \sum_{i=1}^{N} \varepsilon_{i,t}$$

with variance

[11] 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). Standard unit root tests are, however, 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).

$$\widehat{var}(\bar{\varepsilon}) = \frac{1}{N\,(N-1)} \sum_{i=1}^{N} (\varepsilon_{i,t} - \bar{\varepsilon})^2$$

The mean group estimator of all countries indicates that the elasticity is 0.99 or 0.98 when the optimal number of lags is selected with respectively the Schwarz and Akaike information criterion. If we exclude Sweden, the mean group elasticity equals 0.99 with a standard error of 0.05. A one percentage increase in ability to pay thus increases house prices with 0.99 percent on average in our sample of OECD countries.

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

Our results indicate that ability to pay has an economically important role on house prices. To get a sense of the economic role of the components of ability to pay we calculate the predicted effects on house prices and ability to pay from changes in interest rates and a reduction in the fiscal deductibility of mortgage interest. The first four columns in Table 7 indicate the percentage increase in ability to pay ($\Delta x_{i,t}/x_{i,t}$) and the house price ($\Delta p_{h,i,t}/p_{h,i,t}$) due to a one percentage 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 ability to pay ($\Delta x_{i,t}/x_{i,t}$) and the estimated elasticities ($\varepsilon_{i,t}$) from Table 6 (DOLS SIC). The semi-interest elasticity has the highest value in the Netherlands: an increase in the interest rate of one percentage point would decrease ability to pay by almost 17% and house prices by more than 18%. 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 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 The International Monetary Fund 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, Gottlieb and Gyourko (2013), and Campbell, Davis, Gallin and Martin (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 one percentage point in nominal interest rates decrease nominal house prices by 7.24%. From 1980Q1 till 2009Q4, nominal interest rates fell by 8.5 percentage 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 (see also Figure 1).

An important policy question is the degree of capitalization of the mortgage interest deduction in house prices. The last four columns in Table 7 summarize the effect of a complete abolishment of the mortgage interest deduction on house prices in the long run. A complete abolishment of the mortgage interest deduction in the USA would, *ceteris paribus*, decrease the amount that people are able to pay by 10.48% and house prices by 8.84%. 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 the tax rate at which households can deduct mortgage interest to zero, house prices would, *ceteris paribus*, decrease by 22.22%.[12] In Denmark, the abolishment of the mortgage interest deduction would also decrease the advantage of the repayment vehicle in the interest only loan: the result is an estimated decrease in house prices of 15.6%.

A similar change in the Netherlands would decrease house prices by almost 37%. The change in the Netherlands is so large because the rate at which mortgage interest is deductible is relatively high and the interest-only loan with repayment vehicle becomes identical to the standard annuity mortgage (with maturity of 20 years) in this scenario. 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. It would therefore be interesting to calculate the effect on house prices from the complete abolishment of mortgage interest deduction and a return to the standard annuity mortgage for different maturities. These calculations are summarized in Table 8. In the Netherlands, the complete abolishment of the mortgage interest deduction and a return to the standard annuity mortgage with maturity of 30 years would reduce the amount that people are able to pay by 34.17% and house prices by 37.47%. This scenario 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 it is completely abolished in 2040. Our framework indicates that the largest impact on the Dutch housing market will be through the decreasing share of interest only loans. As government regulation induces households to pay off their mortgage debt since 2013, the largest effect through changing mortgage characteristics will have

[12] The marginal tax rate of 54.92 provided by the OECD is an overestimation of the rate at which mortgage interest is fiscal deductible. Assuming a marginal tax rate of 50%, house prices would decrease by 20.77% due to a complete abolishment of the mortgage interest deduction in Belgium, *ceteris paribus*.

an immediate impact (or is partially anticipated). The abolishment of the mortgage interest deduction 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 mortgage interest deduction.

7 Conclusion

In this paper, we develop a simple static framework in which households maximize their utility subject to a budget constraint. The budget constraint is based on the observation that the average household faces borrowing limits because most house-purchases are mortgage-financed. Utility maximization of households, the market clearing condition, and housing investment that absorbs changes in demand on the extensive margin result in a relationship between house prices and the amount that households are able to pay. The amount that households are able to pay is dependent on the share of mortgage payments to income (α), down payment ratio (β), disposable income (Y_t), mortgage length (n), and the interest rate (i_t). We extend the model to allow for mortgage interest deduction such that the borrower is able to increase his mortgage payments and ultimately the ability to pay. Furthermore, we model financial innovations in the mortgage market, such as interest-only loans with a repayment vehicle and pure interest-only loans, to capture the different borrowing limits. This results in a relationship between house prices and a measure of adjusted ability to pay that is also dependent upon the rate at which mortgage interest is fiscal deductible (τ_t) and mortgage characteristics. 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.

We apply the model to a sample of 8 OECD countries and test for a long-run relationship between house prices and ability to pay on the one hand and ability to pay adjusted for mortgage interest deduction and mortgage characteristics on the other hand. Our results indicate that evidence for cointegration between house prices and the standard measure of ability to pay is rather limited for every single country. When ability to pay is adjusted for mortgage interest deduction and mortgage product innovation, the null hypothesis of no cointegration is rejected in almost every country. Granger causality tests indicate that the measure of adjusted ability to pay Granger causes house prices while evidence in the other direction is almost nonexistent. This is important for the interpretation of the long-run relationship as it indicates that the statement that high house prices cause product innovation and therefore more affordable housing seems incorrect according to the Granger causality tests.

To study the economic importance of ability to pay and its components, we estimate the elasticity of house prices with respect to ability to pay. The average elasticity is 0.99, indicating that a one percentage increase in adjusted ability to pay increases house prices with 0.99 percent on average in our sample of OECD countries. There is a whole discussion in the literature about the role of interest rates in housing bubbles (see Glaeser, Gottlieb and Gyourko 2013 among others). Our model argues that the long-term nominal interest rate explains a large part of house price increases. An important insight is that the semi interest elasticity of ability to pay differs between mortgage products. Countries with different mortgage products will thus react differently to interest-rate shocks. 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.

In any case, the model makes it possible to analyze house price changes for a whole range of scenarios. As our long-run house price fundamental is empirically confirmed by almost 30 years of data in eight different countries, our measure of ability to pay can be seen as a reliable long-run fundamental and provides an intuitive alternative to standard house price models.

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8 Appendix

8.1 *Cointegration tests*

The Engle and Granger's ADF test involves estimating the following cointegration regression with y_t and x_t integrated of order one, or I(1). In our analysis $p_{h,i,t}$ equals the nominal house price and $x_{i,t}$ our measure of ability to pay in country i.

$$p_{h,i,t} = \beta_{0,i} + \beta_{1,i} x_{i,t} + u_{i,t}$$

The null hypothesis is that the error term is I(1) (no cointegration). The alternative hypothesis is that there exists a linear combination such that the residuals are stationary (cointegration). Hence the next step involves applying the ADF test on the residuals:

$$\Delta \hat{u}_{i,t} = (\rho_i - 1)\, \hat{u}_{i,t-1} + \sum_{z=1}^{p} \xi_{i,z} \Delta \hat{u}_{i,t-z} + \upsilon_{i,t}$$

We report two ADF test statistics. The first is the standard t-statistic. As Engle and Granger (1987) note, OLS seeks the linear combination that minimizes the residual variance and hence is more likely to be stationary. Hence we use the appropriate critical values according to Mackinnon (1991, 1996) as reported by the software package Eviews.

$$\hat{t}_i = \frac{\hat{\rho}_i - 1}{se(\hat{\rho}_i)}$$

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).

$$\hat{z}_i = \frac{T(\hat{\rho}_i - 1)}{1 - \sum \hat{\xi}}$$

The Phillips and Ouliaris (1990) test statistics are related. These are non-parametric with respect to nuisance parameters and hence they allow for a very wide range of time series models in which there is a unit root (Phillips and Perron 1988). An estimate of ρ_i is obtained by regressing the unaugmented Dickey-Fuller equation:

$$\Delta \hat{u}_{i,t} = (\rho_i - 1)\, \hat{u}_{i,t-1} + v_{i,t}$$

Two test statistics are then given by:

$$\hat{t}_i = \frac{(\hat{\rho}_i - 1) - T\hat{\lambda}_i \left(\sum_t \hat{u}_{i,t-1}^2\right)^{-1}}{se(\hat{\rho}_i)}$$

$$\hat{z}_i = T(\hat{\rho}_i - 1) - \frac{T^2 \hat{\lambda}_i}{\sum_t \hat{u}_{i,t-1}^2}$$

Both test statistics allow for the effects of serially correlated and heterogeneously distributed innovations (Phillips and Perron 1988). The second term is an additional bias correction whose magnitude depends on the strict one-sided long-run variance ($\hat{\lambda}_i$) to capture the effects of serial correlation.

8.2 *Robustness check with gdp per capita*

As a robustness check we calculate adjusted ability to pay with gdp per capita instead of disposable income per capita. All results are available upon request. The results indicate that there exists a long-run relationship between house prices and adjusted affordability in Belgium, the Netherlands, United Kingdom, United States of America, Norway and Denmark. We are, however, unable to reject the null hypothesis of no cointegration in Sweden and Finland. The granger-causality tests provide strong evidence that the direction of causality goes from adjusted affordability to nominal house prices.

8.3 *Graphical representation of assumptions*

Figure A.3 presents 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 mortgages. Data sources and the construction of the time series are described in the Data section.

8.4 *Graphical representation of the relative error term*

Figure A.4 presents the relative error terms of a simple regression of house prices on adjusted affordability. The absolute error terms of these regressions are then divided by the dependent variable to construct the relative error terms. Note that we apply the cointegration tests to the absolute errors, but represent the relative errors here as they can be interpreted as percentage deviations from the long-run fundamental.

8.5 *Ability to pay in Belgium*

Given the complex and unique system of fiscal advantages for homeowners in Belgium, we choose to explain our model for Belgium in the appendix to avoid difficulties of readability. We assume that the yearly mortgage payments is equal to a fraction of income (αY_t) plus the net fiscal advantage for homeowners (FA_t) in the initial year of the mortgage. The ability to pay for a household in Belgium thus equals:

$$A_t^{'} = \frac{\alpha Y_t + FA_t}{1-\beta} a_{n,i}$$

Before 2005, the fiscal advantage for homeowners was mainly based on capital payments. The part of the mortgage that was eligible for the fiscal advantage was limited to a fixed amount per household ($LimitCP_t$). Other limits were of minor importance to most households. The net tax relief (FA_t) before 2005 was thus equal to the marginal tax rate multiplied by the capital payments that were eligible for fiscal deduction:

$$FA_t = \tau_t \left(\frac{LimitCP_t}{a_{n,i}} - LimitCP_t.i_t \right)$$

Since 2005, each person is allowed to deduct an amount that depends on a combination of the capital payments and interest payments. An average household with two earners is then able to deduct mortgage payments up to a yearly limit ($LimitWB_t$). The net fiscal advantage is then equal to $FA_t = \tau_t.LimitWB_t$ since 2005. $LimitCP_t$ and $LimitWB_t$ are presented in Table A.2. The evolution of the net fiscal advantage in the first year of the mortgage (conditional on i_t, n_t, τ_t and Y_t) is then presented in Figure A.2.

Table 1

Unit root tests of nominal house price and ability to pay (1980Q1-2009Q4)

Country	Nominal House Price	Ability To Pay
Belgium	0.00	0.00
Netherlands	0.03	0.00
United Kingdom	0.02	0.00
United States of America	0.07	0.00
Sweden	0.00	0.00
Norway	0.00	0.00
Finland	0.01	0.00
Denmark	0.00	0.00

Note: H_0: First difference of nominal house price or ability to pay has a unit root according to Phillips-Perron stationarity tests (including intercept). The results for ability to pay and ability to pay adjusted for mortgage interest deduction and mortgage characteristics are exactly the same.

Table 2

Cointegration Results: Nominal House Prices and Ability To Pay (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	xx	xxx	x			
	[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		x				
	[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]

Note: The ADF and PO columns report the test results for the null hypothesis of no cointegration. x, xx and xxx refer respectively to p-values lower than or equal to 0.10, 0.05 and 0.01. The p-values are in square brackets. The optimal lag orders in the ADF tests are determined with the Schwarz (SIC) and Akaike (AIC) Information Criteria.

Table 3

Cointegration results: nominal house prices and adjusted ability to pay (1980Q1-2009Q4)

Country	ADF t (SIC)	ADF z (SIC)	ADF t (AIC)	ADF z (AIC)	PO t	PO z
Belgium	xx	xxx	xx	xxx	xx	xx
	[0.02]	[0.01]	[0.02]	[0.01]	[0.03]	[0.02]
Netherlands	xxx	xxx	xx	xxx	x	xx
	[0.01]	[0.00]	[0.02]	[0.00]	[0.07]	[0.05]
United Kingdom		x		x		
	[0.14]	[0.08]	[0.14]	[0.08]	[0.34]	[0.29]
United States of America	xx	xxx	xx	xxx		
	[0.03]	[0.00]	[0.04]	[0.00]	[0.29]	[0.18]
Sweden						
	[0.50]	[0.37]	[0.50]	[0.37]	[0.58]	[0.50]
Norway		xx		xx		
	[0.11]	[0.04]	[0.11]	[0.04]	[0.39]	[0.30]
Finland			x	xxx		
	[0.21]	[0.17]	[0.10]	[0.01]	[0.37]	[0.36]
Denmark		x		x		
	[0.12]	[0.09]	[0.12]	[0.09]	[0.29]	[0.28]

Note: The ADF and PO columns report the test results for the null hypothesis of no cointegration. x, xx and xxx refer respectively to p-values lower than or equal to 0.10, 0.05 and 0.01. The p-values are in square brackets. The optimal lag orders in the ADF tests are determined with the Schwarz (SIC) and Akaike (AIC) Information Criteria.

Table 4

Granger causality (1980Q1 - 2009Q4)
H_0: nominal house price does not granger cause adjusted ability to pay

Country		Lag selection
Belgium	xxx	2
	[0.01]	
Netherlands		3
	[0.12]	
United Kingdom	x	2
	[0.07]	
United States of America	xx	4
	[0.04]	
Sweden		2
	[0.26]	
Norway	xxx	2
	[0.01]	
Finland		2
	[0.89]	
Denmark		2
	[0.74]	

Note: x, xx and xxx refer respectively to p-values lower than or equal to 0.10, 0.05 and 0.01. The p-values are in square brackets. The columns indicate the number of lags included (in quarters).

Table 5

Granger causality (1980Q1 - 2009Q4)
H_0: adjusted ability to pay does not granger cause nominal house price

Country		Lag selection
Belgium	xxx	2
	[0.00]	
Netherlands	xxx	3
	[0.00]	
United Kingdom	xxx	2
	[0.00]	
United States of America	xxx	4
	[0.01]	
Sweden	xx	2
	[0.02]	
Norway	xxx	2
	[0.00]	
Finland	xxx	2
	[0.00]	
Denmark	xxx	2
	[0.00]	

Note: x, xx and xxx refer respectively to p-values lower than or equal to 0.10, 0.05 and 0.01. The p-values are in square brackets. The columns indicate the number of lags included (in quarters).

Table 6

Elasticities of house prices with respect to ability to pay

	SOLS	DOLS (SIC)		DOLS (AIC)	
Country	Elasticity	Elasticity	Lags	Elasticity	Lags
Belgium	0.93	0.95	8	0.95	8
		(0.01)		(0.01)	
Netherlands	1.08	1.10	8	1.10	8
		(0.02)		(0.02)	
United Kingdom	1.04	1.04	5	1.04	7
		(0.04)		(0.04)	
United States of America	0.84	0.84	7	0.84	7
		(0.02)		(0.02)	
Sweden	0.97	0.97	0	0.97	8
		(0.03)		(0.04)	
Norway	1.00	0.99	6	0.99	8
		(0.04)		(0.04)	
Finland	0.84	0.82	5	0.81	7
		(0.05)		(0.05)	
Denmark	1.15	1.16	2	1.16	5
		(0.05)		(0.05)	
Mean group estimator		0.98		0.98	
		(0.04)		(0.04)	
Mean group estimator		0.99		0.98	
(excluding sweden)		(0.05)		(0.05)	

Note: This table presents the estimated elasticities of house prices with respect to changes in adjusted ability to pay. The elasticities are calculated from a static OLS regression or a dynamic OLS regression where the optimal number of lags is selected with the Schwarz (SIC) or Akaike (AIC) information criterion. Standard errors (in parentheses) are derived using the delta method.

Table 7

Predicted effects on ability to pay and house prices from changes in the interest rate and abolishment of mortgage interest deduction

Country	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	3.62	4.62	-9.97	-9.43	54.92	0	-23.51	-22.22
Netherlands	3.50	4.50	-16.72	-18.33	40.53	0	-33.64	-36.88
United Kingdom	3.74	4.74	-11.49	-11.98	0	0	0	0
United States of America	3.46	4.46	-8.58	-7.24	29.38	0	-10.48	-8.84
Sweden	3.26	4.26	-6.66	-6.46	30	0	-8.20	-7.96
Norway	4.03	5.03	-6.68	-6.63	28	0	-9.02	-8.96
Finland	3.52	4.52	-6.69	-5.50	29	0	-8.43	-6.92
Denmark	3.58	4.58	-5.76	-6.66	33	0	-13.48	-15.60

Note: This table presents the effect of a one percentage point increase in the interest rate, and a complete abolishment of the ability to deduct mortgage interest on adjusted ability to pay ($\frac{\Delta x_{i,t}}{x_{i,t}}$) and house prices ($\frac{\Delta p_{h,i,t}}{p_{h,i,t}}$) in 2009Q4. The effect on house prices is equal to $\frac{\Delta x_{i,t}}{x_{i,t}}$ multiplied with the estimated elasticities from a DOLS regression where the optimal number of lags is selected with the Schwarz Information Criterion.

Table 8

Predicted effects on ability to pay and house prices from abolishment of mortgage interest deduction and change to standard annuity mortgage for different maturities

	20 years		25 years		30 years		Original Values		
Country	$\frac{\Delta x_{i,t}}{x_{i,t}}$	$\frac{\Delta p_{h,i,t}}{p_{h,i,t}}$	$\frac{\Delta x_{i,t}}{x_{i,t}}$	$\frac{\Delta p_{h,i,t}}{p_{h,i,t}}$	$\frac{\Delta x_{i,t}}{x_{i,t}}$	$\frac{\Delta p_{h,i,t}}{p_{h,i,t}}$	Maturity	w_{RIO}	w_{PIO}
Belgium	-33.90	-32.05	-23.51	-22.22	-14.80	-14.00	25	0	0
Netherlands	-49.13	-53.88	-41.00	-44.97	-34.17	-37.47	20	39	50
United Kingdom	-16.45	-17.15	-3.52	-3.67	7.24	7.54	25	6	11
United States of America	-26.47	-22.32	-14.67	-12.37	-4.71	-3.97	27	0	0
Sweden	-8.20	-7.96	6.93	6.72	19.82	19.23	20	0	0
Norway	-9.02	-8.96	4.52	4.49	15.64	15.53	20	0	0
Finland	-8.43	-6.92	6.15	5.05	18.42	15.12	20	0	0
Denmark	-13.48	-15.60	0.19	0.22	11.65	13.48	20	52	0

Note: This table presents the effect of a complete abolishment of the ability to deduct mortgage interest and change to a standard annuity mortgage for different maturities on adjusted ability to pay ($\frac{\Delta x_{i,t}}{x_{i,t}}$) and house prices ($\frac{\Delta p_{h,i,t}}{p_{h,i,t}}$) in 2009Q4. The effect on house prices is equal to $\frac{\Delta x_{i,t}}{x_{i,t}}$ multiplied with the estimated elasticities from a DOLS regression where the optimal number of lags is selected with the Schwarz Information Criterion.

Table A.1

House price indices

Country	Source	Series
Belgium	National Bank of Belgium	Residential property prices, existing dwellings, whole country
Netherlands	Kadaster	Indice des prix immobiliers
United Kingdom	Department for Communities and Local Government	Mix-adjusted house price index
United States of America	Federal Housing Finance Agency (FHFA)	Purchase and all-transactions indices
Sweden	Statistics Sweden	Real estate price index for one- and two-dwelling buildings for permanent living
Norway	Statistics Norway	House price index
Finland	Tilastokeskus	Price of dwellings
Denmark	StatBank	Price index for sales of property

Source: Girouard, N., M. Kennedy, P. van den Noord, and C. André 2006

Table A.2

Limits to the loan amount that was eligible for fiscal deduction of capital payments and the net tax relief since 2005 in Belgium.

Year	$LimitCP_t$	$LimitWB_t$
1980-1988	49578.7	
1989	54536.58	
1990	56222.25	
1991	58180.61	
1992-1998	59990.23	
1999	60560.39	
2000	61229.7	
2001	63320	
2002	64880	
2003	65950	
2004	67000	
2005		4980
2006		5140
2007		5200
2008		5440
2009		5540

Source: Van der Reysen, Vanrijckeghem and Vlasselaerts 2007

Table A.3

Elasticities of house prices with respect to adjusted ability to pay

	SOLS	DOLS (SIC)			DOLS (AIC)		
Country	Elasticity	Elasticity	Leads	Lags	Elasticity	Leads	Lags
Belgium	0.93	0.94	1	7	0.93	8	7
		(0.01)			(0.01)		
Netherlands	1.08	1.14	8	8	1.14	8	8
		(0.02)			(0.02)		
United Kingdom	1.04	1.05	0	5	1.05	0	7
		(0.04)			(0.04)		
United States of America	0.84	0.84	3	5	0.85	3	7
		(0.02)			(0.02)		
Sweden	0.97	0.97	0	0	0.95	8	0
		(0.04)			(0.04)		
Norway	1.00	0.99	0	6	0.98	2	8
		(0.05)			(0.05)		
Finland	0.84	0.80	0	5	0.80	0	7
		(0.05)			(0.05)		
Denmark	1.15	1.17	0	2	1.17	0	5
		(0.05)			(0.06)		
Mean group estimator		0.99			0.98		
		(0.05)			(0.05)		
Mean group estimator		0.99			0.99		
(excluding sweden)		(0.05)			(0.05)		

Note: This table presents the estimated elasticities of house prices with respect to changes in adjusted ability to pay. The elasticities are calculated from a static OLS regression or a dynamic OLS regression where the optimal number of leads and lags is selected with the Schwarz (SIC) or Akaike (AIC) information criterion. Standard errors (in parentheses) are derived using the delta method.

Figure 1

Decomposition of changes in ability to pay

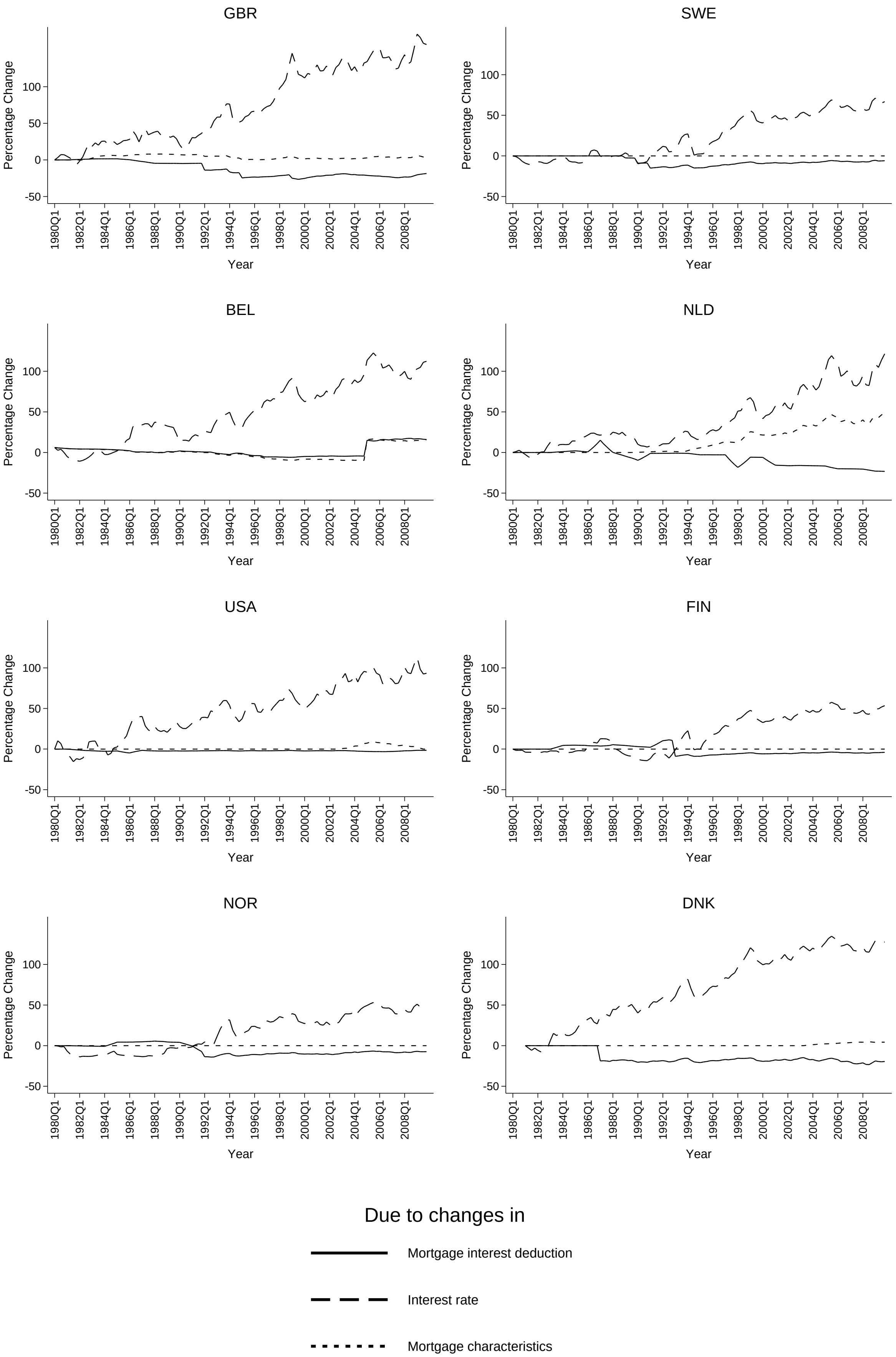

Figure A.1

Nominal house prices and adjusted ability to pay

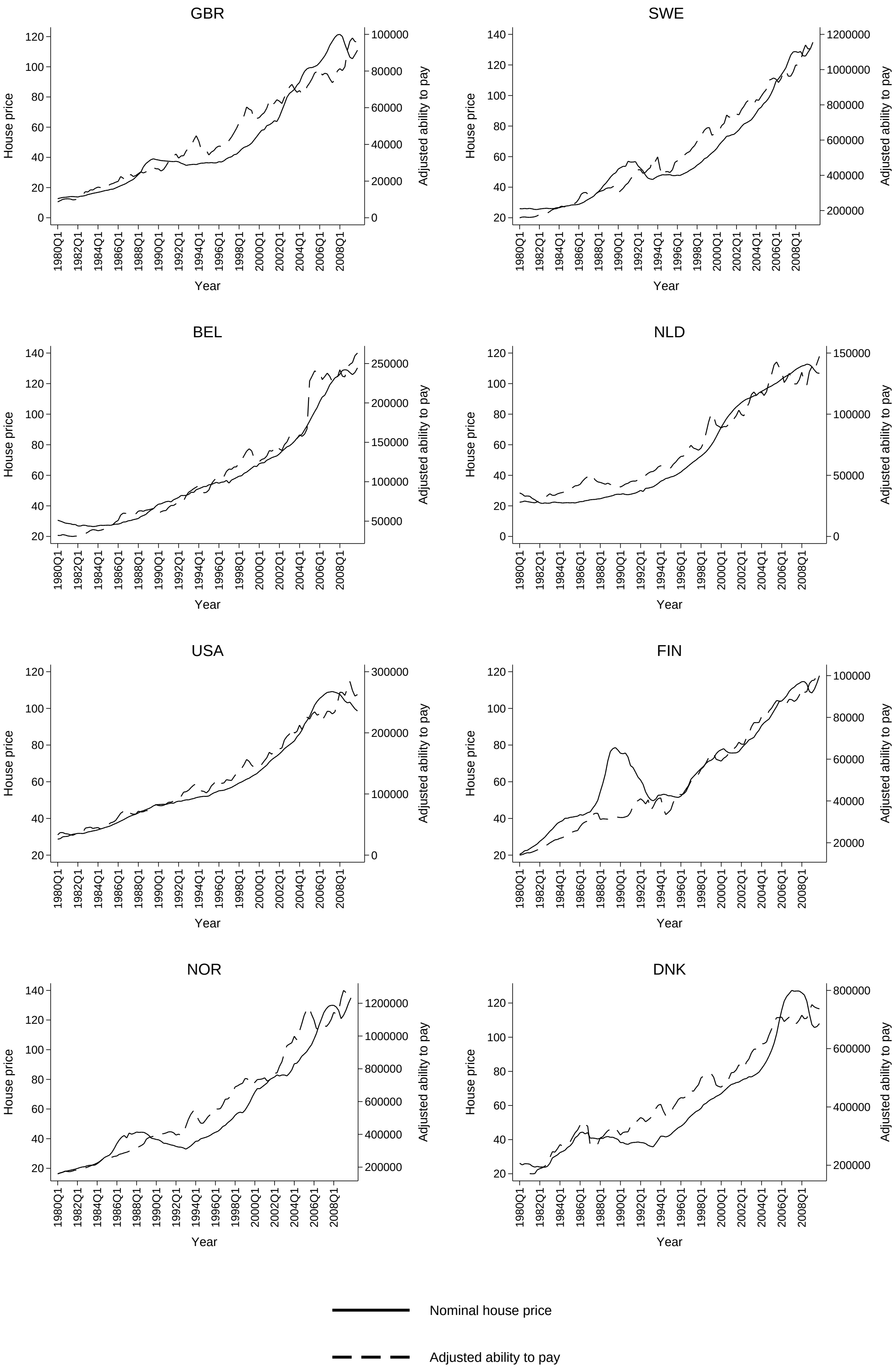

Figure A.2

Net fiscal advantage (EUR) in Belgium

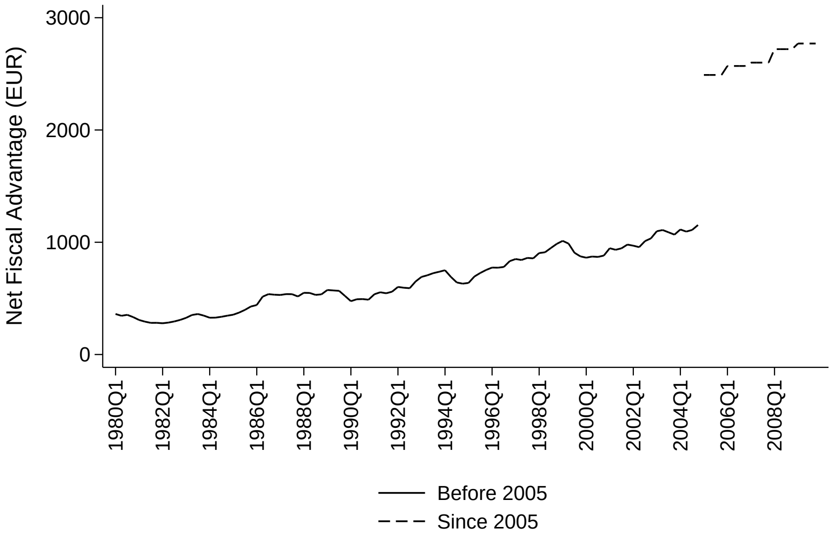

Figure A.3

Graphical representation of assumptions

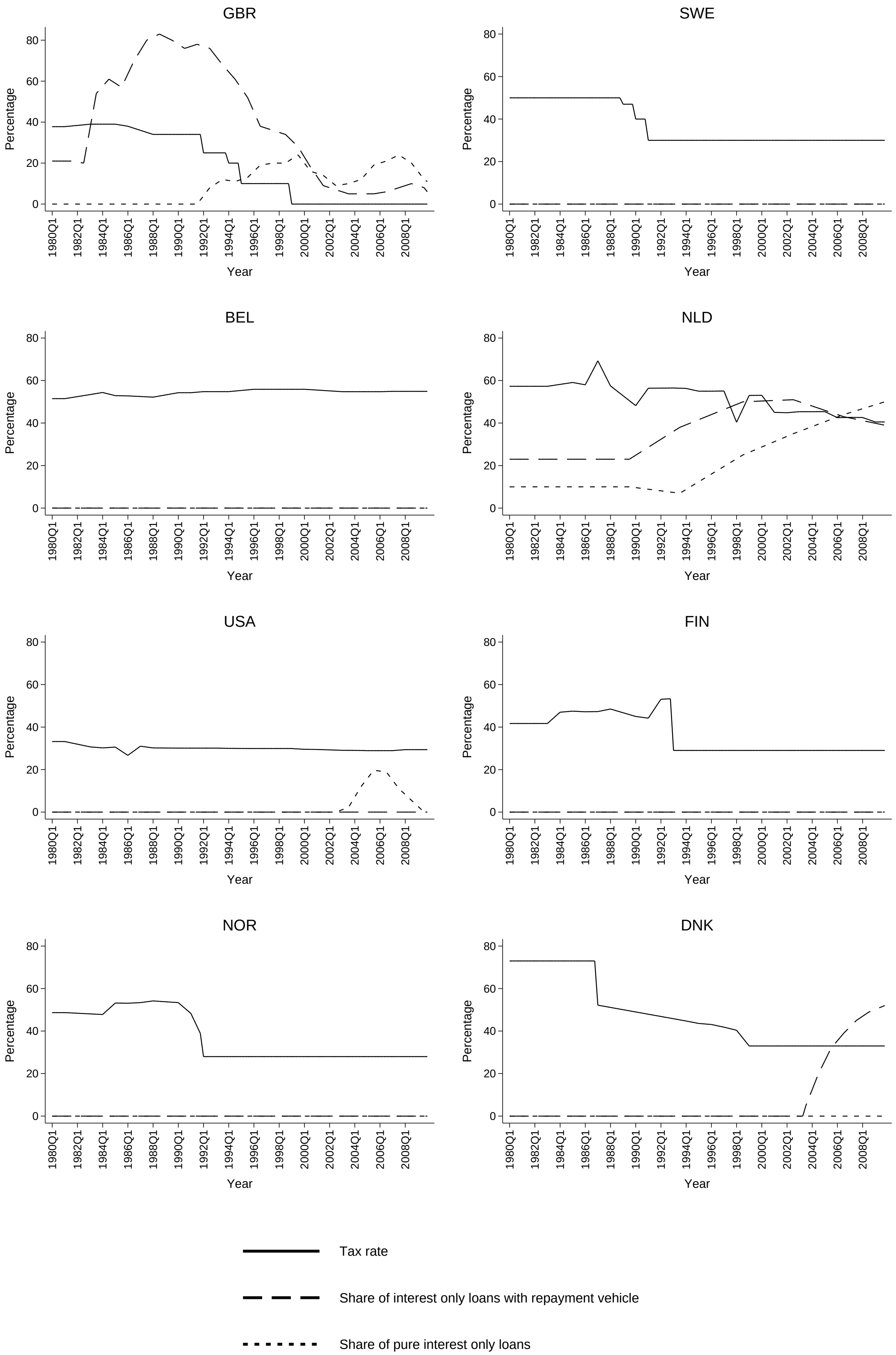

Figure A.4

Graphical representation of the relative error terms