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Abstract

Low repayment rates on mortgages have probably contributed to increased macroeconomic imbalances for several countries in recent years. The objective of this paper is to analyze how the introduction of interest-only-mortgages in 2003 affected the Danish housing market. Using quarterly data between 2001 and 2013, we analyze the long- and short-run relationships between mortgage repayments and three dependent variables: real house prices; the number of property sales; and mortgage debts in relation to disposable income. We find that including mortgage repayments in nominal housing payments improves the econometric fit when predicting house prices and mortgages in relation to disposable incomes in both the long run and the short run, but not when modeling sales. Also, the conventional user cost variable either turn out insignificant or with the "wrong" (i.e. positive) sign, while nominal housing payment, including mortgage repayments, are significantly negative. However, some regression results are sensitive to specification and there are some indications of reversed causality issues. We therefore perform complementary event studies. The results of the event studies suggest that real house prices and the mortgage debt ratio increased considerably faster than otherwise expected between the introduction of interest-only-mortgages and the start of the financial crisis in 2007. Results are similar when using the results from our long- and short-run regressions to simulate the effects of introduction interest-only-mortgages. Our most conservative estimates suggest that the introduction of interest-only-mortgages raised real house prices and the mortgage debt ratio by about twenty and ten percent between 2003 and 2013, respectively. Our results raise questions of whether households base their decisions on real or nominal variables, actual costs, or cash flows, and if introduction of interest-only-mortgages have promoted housing affordability or have rather contributed to increased house prices and household debts.

Keywords: debts; house prices; mortgages; repayments; Denmark

JEL CODES: R31, G210

1 Introduction

Conventional house price models do not include mortgage repayments among the explanatory variables (see e.g. Madsen, 2012; Thom, 1983). During the past 20 years, inflation-adjusted house prices and the stock of mortgage debts have increased rapidly in several countries. Several new financial innovations, such as interest-only mortgages and reduced mortgage repayment rates, were introduced before the outburst of the financial crisis in 2007 (Scanlon et al., 2008; European Central Bank, 2009). Many scholars have emphasized that generous mortgage conditions may have contributed to increased macroeconomic imbalances in several countries, including Australia, Belgium, Canada, Denmark, England, France, Greece, Iceland, Ireland, the Netherlands, Portugal, Spain, Italy, Sweden, and the US. It has been pointed out that mortgage conditions can affect housing markets considerably (André, 2010; Dam et al., 2011; Frisell and Yazdi, 2010; Muellbauer, 2012; Muellbauer et al., 2015; IMF, 2012; Mian and Sufi, 2010; 2012; Duca et al., 2011; Case, 2008). In addition, recent research indicates that periods with high debt levels and/or rapid growth of household debts are often succeeded by falling aggregate demand (IMF, 2012; Bornhorst and Ruiz-Arranz, 2013; Jordà et al., 2013; Mian and Sufi, 2010; 2012; Mian et al., 2013; Cecchetti et al., 2011). Furthermore, after 2007/2008, falling house prices were accompanied by tightening mortgage standards in several countries (see e.g. Scanlon et al., 2011; Duca et al., 2011; IMF, 2012; European Central Bank,¹ 2015, p. 58). For example, Canada, Sweden and the Netherlands have recently sharpened regulations regarding mortgage amortization schemes (Schembri, 2014; De Vries and Burrows, 2013; Financial Supervisory Authority, 2017). Since then, a small but growing number of studies have been conducted on the effects of mortgage repayment rates on housing markets.

Cocco (2013) employed a panel of about 3 600 households in the UK between 1991 and 2008 and found that households are more likely to take interest-only mortgages the higher their level of education and expected future income, which implies that being able to temporarily abstain from mortgage repayments can facilitate consumption smoothing. Hull (2015) evaluated the upcoming mortgage repayment regulation in Sweden and predicted a small but negative effect on household debts.² Forlati and Lambertini (2014) employed a dynamic stochastic general equilibrium model and concluded that reduced mortgage repayments reduce the welfare of credit-constrained households in the long run because they inflate house prices and force households to reduce their consumption and/or to work longer hours. Johansson et al. (2014) formulated a theoretical short-run model, building on the work by McQuinn and O'Reilly (2007), in which housing expenditures are assumed to be a constant fraction of households' disposable income. They found that the effects of reduced mortgage repayments on house prices depend on other credit conditions such as the mortgage interest rate level, the loan-to-value (LTV) ratio, and whether households choose linear amortizations or annuity mortgages. Damen et al. (2016) developed a model in which house buyers are borrowing-constrained and house prices depend on house buyers' overall ability to pay (ATP). They discovered a co-integrating relationship between house prices and ATP for eight countries between 1980 and 2008. The results strongly indicated that ATP changes Granger cause house prices for all countries, while the researchers "only" found support for Granger causality from house prices to ATP for three countries. Furthermore, the estimated elasticity of house prices from a change in ATP is close to one that suggests that, for example, increased interest rate deduction will translate into higher house prices with full effect, and will not promote housing affordability in the long run. Dam et al. (2011) employed Danish data to estimate an empirical house price model, assuming that mortgage borrowers made no repayments during the first year after buying, after interest-only mortgage loans were introduced in 2003. They concluded that including first-year payments—with mortgage repayments set to zero—improved their model, and that the introduction of deferred amortization mortgages can explain about 5 percent of the 38 percent increase in real house prices between 1999 and 2010. Recently, Allen et al. (2017) used a microsimulation model of mortgage demand in Canada. The Canadian government loosened the mortgage insurance qualifying rules between 2006 and 2007 by increasing the maximum allowable amortization period from 40 to 25 years and by increasing the maximum allowable LTV from 95 to 100 percent. In order to secure the long-term stability of the mortgage market mortgage lending rules were tightened 2008-2012 (Schembri, 2014). A key finding in Allen et al.

¹ The bank lending survey (BLS) of the European Central Bank suggests that mortgage standards tightened for the European area in general, starting at the end of 2007.

² Starting in June 2016, new mortgage borrowers with LTV ratios from 70–85 percent and from 50–70 percent must repay 2 percent and 1 percent of their mortgage each year, respectively.

(2017) is that households are more constrained by wealth constraints than monthly cash flows. However, Allen et al. (2017) also found that the average house buyer does not use lower amortization requirements to reduce their monthly mortgage expenses. Moreover, their microsimulation findings suggest that lower/tighter amortization requirements increased/decreased mortgage demand among first time house buyers. Madsen (2012) employed a panel of 18 OECD countries for the period from 1973–2008 and developed a model in which house prices are affected by nominal mortgage payments. He found that including nominal mortgage payment improved the econometric fit, while the conventional user cost variable turned out to be insignificant and/or having the “wrong” (i.e. positive) sign. However, even though Madsen (2012) merged repayment rates with other nominal housing payments in his theoretical model, he was unable to include repayment rates when testing the model empirically, presumably due to lack of data. Similarly, Damen et al. (2016) “construct weights for the different mortgage types based on country reports or academic articles and interpolate for unknown periods.”³ This is in line with our observations that the ability to empirically assess how housing markets are affected by changing mortgage repayment rates is limited by a lack of data at the aggregated level. In fact, we are not aware of any study that has employed actual repayment rates and empirically estimated their effects on housing markets at the aggregated level in recent years. Moreover, until now, most studies have been concerned with the effects on house prices, and do not examine the effects on sales, which are typically more volatile and responsive to changes in housing demand than are prices (see Figures 1–2 in Section 2). Studies on the effects of repayment rates on household debts are also rare. Thus, our understanding of how changes in cash flows for existing as well as potential home owners affect housing markets and the economy, even when real user costs are constant, is incomplete.

The objective of this paper is to analyze how the introduction of interest-only mortgages in 2003 affected the Danish housing market. We employ data from 2001–2013 and estimate ordinary least squares (OLS) regressions to analyze how nominal mortgage payments (including actual mortgage repayments to mortgage credit institutes, (MCIs), which grant the majority of all mortgages) relate to a set of three dependent variables: (1) real house prices, (2) the number of property sales, and (3) household mortgage debts in relation to disposable incomes. We proceed as follows: First, we compare statistical information criteria to investigate whether including mortgage repayments in nominal housing payments improves the econometric fit of our OLS regressions. Second, we test whether repayments are statistically different from the remaining nominal housing payments. Third, we follow Madsen (2012) and include a measure of real user costs alongside nominal mortgage payments as explanatory variables, in order to investigate which variable is more important in explaining the movements of the dependent variables. Our study is also related to Damen et al. (2016) who found a stronger relationship between house buyers’ overall ability to pay and house prices than between real user costs and house prices for seven out of eight countries. Our analysis can contribute to an increased understanding regarding whether (1) agents make decisions about housing consumption based on real (user) costs or on nominal mortgage payments/costs; and (2) whether mortgage repayments (which are a kind of expenditure but not a cost) belong to the set of housing expenditures that affect the behavior of housing consumers.

We model the long run and estimate the relationships between the dependent and explanatory variables in level form and then estimate the short-run determinants by employing error-correction models. The second step might provide insights into the reaction speeds of the dependent variables with respect to changes in housing payments. We use our regression results to simulate the effects of the introduction of mortgage-only loans in 2003 and the dynamic impact of a permanent one-time shock of nominal housing payments. Furthermore, we complement our conventional regressions and perform event studies because we cannot guarantee causal effects of changes in repayment rates on the dependent variables. The purpose of our event study is to investigate whether our dependent variables developed in a non-normal fashion in connection to the introduction of interest-only-mortgages.

The rest of this paper is organized as follows: Sections 2 and 3 describe recent housing market developments in Denmark and explain why we should pay attention to mortgage repayments. Section 4 describes the model. Empirical results are in Section 5, and Section 6 concludes the paper.

³ Damen et al. (2016), p. 20.

2 Background

Figures 1 and 2 show how real house prices, the number of property sales, and the total mortgage debts in relation to disposable income developed between 1994 and 2013. House prices and household debts increased dramatically before the financial crisis in 2007/2008. In addition, the number of property sales peaked around 2006, although these did not increase as dramatically as did the prices and debts prior to the crisis. The introduction of interest-only mortgages in 2003 was succeeded by accelerating growth rates of house prices and household mortgage debts (Figures 1 and 2). Between the first quarter in 2003 and the third quarter in 2007, the ratio of total mortgages to disposable income grew from 1.29 to about 1.86. Real house prices increased by 54 percent during the same period and, as seen in Figure 3, the portion of deferred amortization mortgages out of all mortgages granted by MCIs (we exclude banks because they do not offer deferred mortgages) increased from zero to almost 50 percent between 2003 and 2007.⁴ However, after 2007/2008, house prices and the number of property sales decreased and the growth rate of mortgage debts slowed down.

Figure 1. House prices and property sales, 1994-2013.

Source: Statistics Denmark. House prices have been deflated using the consumer price index (CPI) and are in 2013 prices.

⁴ According to Jakob Kongsgaard Olsson at Realkreditrådet (2016-05-20), mortgages with deferred amortization for 30 years were introduced in 2007. These mortgages only apply to loans with a maximum LTV ratio of 75 percent and have been used sparsely.

Figure 2. Households mortgage debts in relation to disposable income, 1994-2013.

Source: Statistics Denmark and authors' calculations.

Traditionally, Danish households have financed the lion's share of a house purchase by borrowing from an MCI. Before 2003, mortgages granted by MCIs were normally designed as 30 year annuity loans, and borrowers paid a fixed amount to their creditors each month. The essential feature of an annuity mortgage is keeping the annual nominal mortgage expenditure (including interest rates and repayments) fixed over the entire duration of the loan; this means that the repayments will successively increase in value as the loan approaches maturity because the accumulated repayments result in reduced interest rate payments. In Denmark, mortgages granted by MCIs have a maximum LTV ratio of 80 percent; households either use their own savings or borrow from a bank to come up with the remaining 20 percent (Scanlon et al., 2011).⁵ To the best of our knowledge, there are no formal requirements on repayments on bank mortgages⁶ but they have traditionally been repaid within 10 years to 30 years⁷ and their associated lending rates are normally substantially higher⁸ than those offered by MCIs, which may explain why the majority of mortgages are granted by MCIs. However, choosing an interest-only-mortgage is a voluntary agreement between the MCI and the customer.

A number of reforms have been introduced during the past 20 years. In 1996, MCIs started to issue mortgages with adjustable interest rates. The housing tax was frozen in 2002. In October 2003, regulations were changed and MCIs were then allowed to issue "interest-only mortgages." Starting in October 2003, a mortgage can be exempted from repayments for a period of up to 10 years, after which the mortgage can be refinanced/renewed (Bocian et al., 2014).⁹ There is a break in the data after 2013. However, according to the new data series, the share of interest-only-mortgages issued by MCIs have decreased from about 56 % to about 48 % percent between 2013 and 2017, which indicates that MCI borrowers have started to repay their

⁵ As of November 1, 2015, borrowers are only allowed to borrow up to 15 percent from banks, and 5 percent down payment is required. Source: Email correspondence with Jakob Kongsgaard Olsson at Realkredittædet.

⁶ Source: Email correspondence with Rune Egstrup at Danmarks Nationalbank (2013-02-07), Banks offer a variety of mortgage products which makes it hard to say something in general. And according to Jørn Andersen at Finanstilsynet (email correspondence 2017-12-20) "Lending requirements reflected the individual credit policies of the individual banks".

⁷ Source: Email correspondence with Jakob Kongsgaard Olsson at Realkredittædet.

⁸ On average, the interest rates offered by MCIs and banks were 4.2 and 6.1 percent, respectively, between 2003 and 2013. Source: Statistics Denmark and the authors' calculations.

⁹ According to Bocian et al. (2014), borrowers have three options when renegotiating their loans: (i) amortize within the remaining maturity, that is, within 20 years; (ii) refinance the loan to a 30 year annuity mortgage; or (iii) refinance the loan to a new interest-only mortgage with a maximum LTV of 80 percent.

mortgages at a faster rate since 2013¹⁰. Yet, a substantial share (48 %) are still classified as interest-only-mortgages.

Interest-only mortgages were partially introduced to make housing more affordable (Økonomi- og Erhvervsministeriet, 2003). For example, they permit other more expensive loans to be repaid at a faster rate, which should positively affect housing investments and retirement savings. Furthermore, changing life circumstances, such as a divorce or losing a job, may require individual-level adjustments that are more easily realized if one can choose to temporarily abstain from amortizing (Realkreditrådet, 2011a). There is a possibility that deferred amortizations on MCI mortgages have resulted in larger repayments on bank mortgages.¹¹ However, as can be seen in Figure 2, the majority of mortgages are granted by MCIs; thus, it is not probable that an increased repayment rate on bank loans has been able to fully compensate for reduced installments on MCI mortgages.¹² Consequently, as the repayment rate on MCI mortgages has declined, it is likely that the repayment rate on the total mortgage stock has decreased as well.

Figure 3 shows how the portion of interest-only mortgages granted by MCIs increased after 2003, and Figure 4 shows the average repayment rates on MCI mortgages.

Figure 3. The portion of deferred mortgages granted by mortgage credit institutes (MCIs)

Source: Statistics Denmark and the authors' calculations.

¹⁰ Source: Statistics Denmark and the authors' calculations.

¹¹ In a survey by Realkreditrådet (2011a), 30 percent of respondents stated that they used the cash flow from a deferred amortization mortgage to repay other debts (Realkreditrådet, 2011a).

¹² For example, assuming the same home buyer before and after 2003: A home buyer choosing to defer amortizations on his MCI mortgage would need to increase the repayment rate on a bank loan from 5 percent to about 18 percent, assuming that he reduces the repayment rate on MCI mortgages from 3.3 to zero percent, in order to maintain the same repayment rate before and after the reform. (This assumes an LTV of 100 percent, with 80 percent coming from MCIs and 20 percent from banks.) Source: Authors' calculations.

Figure 4. Repayment rates and after tax mortgage interest rates on loans granted by MCIs.

Source: Statistics Denmark and the authors' calculations.

Falling mortgage interest rates during the 2000s (Figure 4) probably stimulated Danish households to defer amortizations on their mortgages. We lack data regarding the extent to which the reduced repayment rates were due either to new homeowners choosing not to amortize or to existing homeowners choosing to refinance their loans. The Danish mortgage system has no prepayment penalty and a borrower can benefit by refinancing a mortgage. “Mortgage rescheduling” is common and will reset the maturity to full length.¹³ According to Madsen and Rasmussen (2013), a widely used ruled of thumb is that a borrower should refinance a mortgage if the interest rate falls by 2 percentage points. In the mid-2000s, mortgage refinancing increased (Madsen and Rasmussen, 2013), which may be the result of many home owners choosing to defer amortizations. Figure 5 shows that, until mid-2006, the increase of the value of deferred mortgages was larger than the value of new mortgages or the net increase of total mortgages. This development was reversed in 2008, after which new mortgages started to exceed the increase of deferred amortization mortgages. By the end of 2012, the value of the total mortgage stock started to increase faster than the total value of deferred mortgages. Overall, Figure 5 indicates that the majority of new mortgages and a large portion of refinanced mortgages after 2003 were, in fact, deferred amortization mortgages.

¹³ Jakob Kongsgaard Olsson at Realkreditrådet, email, 2016-05-20.

Figure 5. Deferred amortization mortgages in relation to flows of mortgages

Source: Statistics Denmark and the authors' calculations.

3 Why should we care about mortgage repayments?

Mortgage repayment rates will affect the housing market if they affect the total mortgage stock, which means that they must affect credit supply and/or credit demand. Dam et al. (2011) and Madsen (2012) discuss a number of reasons why one should expect mortgage repayment to affect the housing market: (1) Liquidity-constrained households are not able to smooth consumption over time, which means that they may use reduced repayments rates as a way of borrowing more. (2) Households are short-sighted, and focus strongly on first-year payments, which means that they do not acknowledge that amortizing less today indicates higher interest rate payments later; in addition, they ignore the possibility that future interest rates may rise. (3) When home owners can refinance their loans and defer amortizations, it may reduce the housing supply because lower nominal housing payments/costs reduce the incentive to sell. (4) House buyers (and/or lenders) are irrational and suffer from money illusion, which means that they attach a greater weight to nominal expenditures than they do to real costs.

In addition to the studies mentioned in Section 1, which focus specifically on repayment rates, some additional evidence provides reason to suspect that repayment rates affect the housing market (see Madsen (2012) for a more detailed review). Miles (2003), Rozbach (2004), and Shefrin and Thaler (1988) find evidence of short-sighted and irrational consumers who focus strongly on initial repayment rates, and of consumers adhering to “mental accounting”¹⁴. Several studies have also confirmed the existence of money/inflation illusion and the fact that consumers do not fully understand inflation (see e.g. Brunnermeier and Juliard, 2008; OECD, 2005; Shiller, 1996). However, in a Danish context, Realkreditrådet (2011b) claims that creditors demand that borrowers must always be able to serve a 30 year annuity mortgage, regardless of what amortization scheme they choose. If true, this implies that deferred amortizations can only affect the housing market if they affect credit demand. In addition, a survey performed by Realkreditrådet (2011c) suggests that the effects of changed repayment rates on credit demand may be weak as well. Of the respondents who chose to defer amortizations, 15 percent agreed with the statement that they had taken a larger mortgage because of reduced nominal housing expenditures. However, a low self-reported willingness to take on larger debts does not rule out the scenario that reduced repayment rates might have pushed house prices upward and forced house buyers to borrow more. A house buyer who perceives herself as a price taker may not realize that she is forced to bid a higher price than she would have if interest-only mortgages had not

¹⁴ The concept was first proposed by Richard Thaler and refers to the subjective process through which individuals base their decisions to consume or to save.

been introduced in the first place. This is because other potential buyers may use the opportunity to reduce their repayment rates in order to be able to offer a higher price, which may particularly be the case when there are many buyers in relation to the number of sellers. Hence, the behavior of a small percentage of all potential house buyers may have a very large impact on the macroeconomic outcome (see e.g. Piazzesi and Schneider, 2009). An objective of this paper is to generate an increased understanding regarding these matters.

4 Methodology

4.1. Error Correction Models

In line with previous research (see e.g. de Wit et al., 2013; Hort, 2000), we model real house prices and the number of property sales as a function of set of common fundamental variables. In addition, we model mortgage debts in relation to disposable income with a basic set of common explanatory variables. There are several reasons why we should expect that property sales, house prices, and mortgage debts are related, some of which are discussed in de Wit et al. (2013). For example: (1) Higher prices and more sales increase the value of newly granted mortgages (the average LTV ratio of housing market entrants should exceed the average LTV ratio of sellers, which means that more sales should have a positive impact on the value of total mortgages). (2) An increased demand, such as reduced mortgage costs allowing new buyers to enter the housing market, can result in both higher prices and more sales. (3) Asymmetric information, where supply information is publicly available but information about the demand side is not, means that an increase in the number of buyers may have an immediate impact on the number of sales, while prices adjust gradually. This is because sellers need time to adjust their reservation prices when knowledge about current housing demand is limited. (4) Increased housing demand, for example due to increased incomes, allows existing homeowners to upgrade to a “better” house; this means that sales and prices are determined simultaneously by a set of common variables. (5) In addition, loss aversion among homeowners may explain why there might be a positive price-volume correlation when housing demand is falling, and why the number of sales will decrease before the prices do. Altogether, these five aspects imply that a set of common factors determine prices, sales, and mortgage debts. The majority of studies that have looked into the correlation between sales and prices have found that changes in sales precede price changes in countries such as Sweden (Hort, 2000), Hawaii (Miller and Sklarz, 1986), and the UK (Andrew and Meen, 2003), whereas price adjustments are slower. Studies also typically find that sales are more strongly affected by a shock to fundamentals than are prices (see e.g. Clayton et al., 2010). However, contradictory findings also exist. Stein (1995) finds that price changes precede changes in sales in the US. Follain and Velz (1995) find a negative relationship between sales and price employing a system of four equations. We are not aware of any study that has simultaneously analyzed property sales and house prices in Denmark. However, as seen in Figure 1, between 2005 and 2008, the number of property sales started to fall before the house prices did, and the relative decline in the number of property sales was stronger than the fall in housing prices, which is in line with the results of most previous studies.

We estimate six equations. Equations 1-3 estimate how real house prices, the number of real property sales, and mortgage debts in relation to disposable incomes covary with the explanatory variables in the long run. Equations 4-6 are first difference and are thus estimated to investigate how the dependent variables correlate with the explanatory variables in the short run. Consequently, equations 1-3 include all variables in level form, implying that the estimated relationships may be spurious if some variables contain unit roots and if they are not co-integrated (Yule, 1926; Granger and Newbold, 1974; Harris and Sollis, 2005), although it is important to note that causal relationships may exist even if there is no support for co-integration (see e.g. Burzynska et al., 2016). Equations 4-6 involves estimating error-correction models; consequently, all variables are transformed to first differences, and we add the lagged residuals from the “level regressions” to the set of explanatory variables (Engle and Granger, 1987; Harris and Sollis, 2005). This second step can yield insights into the reaction speeds of the dependent variables due to changes in housing expenditures. Altogether, we estimate six equations:

$$P_t = \mathbf{X}_1 \mathbf{B}_1 + \varepsilon_{1t} \quad (1)$$

$$TR_t = \mathbf{X}_2 \mathbf{B}_2 + \varepsilon_{2t} \quad (2)$$

$$\text{DEBTS}_t = \mathbf{X}_3 \mathbf{B}_3 + \varepsilon 3_t \quad (3)$$

$$\Delta P_t = \Delta \mathbf{X} \mathbf{B}_4 + \varepsilon 4_t + Y_4 \varepsilon 1_{t-1} \quad (4)$$

$$\Delta \text{TR}_t = \Delta \mathbf{X}_1 \mathbf{B}_5 + \varepsilon 5_t + Y_5 \varepsilon 2_{t-1} \quad (5)$$

$$\Delta \text{DEBTS}_t = \Delta \mathbf{X}_3 \mathbf{B}_6 + \varepsilon 6_t + Y_5 \varepsilon 3_{t-1} \quad (6)$$

where t indicates time period. We use quarterly data between the third quarter in 2001 and the third quarter in 2013 because repayments to MCIs are available for that period. Our main objective is to analyze how repayment rates, which are included in total housing expenditures, affect real house prices (P_t), the number of property sales (T_t) and the total mortgages in relation to disposable incomes (DEBTS_t). $\mathbf{X}_1$ – $\mathbf{X}_6$ are $n \cdot m_i$ matrices of explanatory variables (where n is the number of time periods and m_i is the number of explanatory variables of equation i). $\mathbf{B}_1$ – $\mathbf{B}_6$ are the $m \cdot 1$ row vectors with the associated parameter estimates of the explanatory variables in Equations 1–6. $\varepsilon 1$ – $\varepsilon 6$ are the residuals. Equations 4–6 are error-correction models and represent the short run, which means that they have lagged residuals from Equations 1–3 ($\varepsilon 1_{t-1}$ – $\varepsilon 3_{t-1}$) on the right-hand side, in order to control for the speed at which the dependent variables revert back to the long-run equilibrium.

In line with conventional studies, where house prices in a steady state are derived from the condition that the marginal cost of housing equals the value that the housing services provide (see e.g. Poterba, 1984; Hort, 1998; Dam et al., 2011; Oikarinen, 2009), we include real user costs as one of the explanatory variables. However, due to the objective of this paper, we need to consider expenditures that are not costs, although conventional house price models are primarily concerned with the associated costs of living. Consequently, we follow Madsen (2012) and include measures of nominal housing payments along with our measure of user costs. In comparison with Madsen (2012), our paper contributes by including mortgage repayments in nominal housing payments when estimating the empirical regression.

There are some essential differences between real user costs and nominal housing payments: (1) Real user costs are usually defined as the sum of interest rates (net of tax), the property tax, depreciation, and operating costs minus the expected house price appreciation and expected (consumer price) inflation, whereas nominal housing payments exclude expectations. (2) The two variables can include different measures of the interest rate. The full cost of capital should include the opportunity of the cost of investing in one unit of capital; consequently, we follow Dam et al. (2011) and include the interest rate on 30 year mortgage bonds in real user costs.¹⁵ In contrast, we include an approximation of the average interest rate on mortgages of all durations (net of tax) in our measure of nominal housing payments.¹⁶ This also means that we are deducting the capital tax from the user costs, but taking the mortgage interest rate deductions from nominal housing payments (see Table 1). (3) Mortgage repayments can/should be included in nominal housing payments but not in real user costs (as repayments are not costs).

Some elements of real user costs and nominal housing payments are unknown and must be approximated: (1) Data on mortgage repayments to MCIs is available between 2001 and 2013. However, there is no data on repayments to banks. Therefore, we calculate two measures on mortgage repayment rates (**REPAY1** and **REPAY2**). Mortgage repayments to MCIs only includes planned repayment rates on mortgages granted by MCIs. These include repayments on new mortgages and old mortgages, which means that our estimated relationship between repayments may capture both supply-side, and demand side effects. For instance, reduced repayments on old mortgages (through refinancing) may result in higher house prices through a reduced supply while reduced repayments on new mortgages is expected to raise household demand.

In the second measure (**REPAY2**), we have used available information to approximate bank repayments, which we have merged with repayments to MCIs (Table 1). To see which measure is preferable, we estimate Equations 1–6 for both measures, and compare their respective information criteria. However, although the lack of data on bank repayments might result in some bias of the parameter estimate, recall from Figure 2 that the majority of all mortgages are granted by MCIs. (2) We lack reliable data on expectations; thus, we assume that expected house price appreciation and expected inflation follow an autoregressive process with 4

¹⁵ Our series refer to bonds granted by MCIs.

¹⁶ However, we also performed a sensitivity check and included the average mortgage interest rate in both nominal housing payments and user costs when running the regressions; there was virtually no impact on the results.

lags (see Table 1), which we estimate using OLS regressions. Although theory often assumes that agents possess rational expectations with perfect foresight (see e.g. Hort, 1998), it has often been acknowledged that expectations are probably better described as backward-looking (see e.g. Dipasquale and Wheaton, 1994; André, 2010; Muellbauer, 2012). (3) Depreciation and operating costs are typically assumed to be a constant fraction of the value of the house (see e.g. Hort, 1998; Oikarinen, 2012); similar to Dam et al. (2011), we set this constant to zero. (4) Data on the average mortgage interest rate (in nominal housing payments) is only available from 2003, but we need values from 2001 in order to be able to use estimate regressions for the full period for which mortgage repayments to MCIs are available. We approximate the mortgage interest rate by regressing the average mortgage interest rate on the rate of interests on 30 year real credit bonds and unit mortgage bonds (see Figure 6 to compare the predicted value with the actual value).

We mainly include common control variables. In standard models (see e.g. Hort, 1998), house prices are often expressed as a function of per capita incomes, population, and housing supply (approximated with the housing stock). As suggested by Dam et al. (2011), we include total disposable incomes (which are a function of per capita incomes and population) in relation to the housing stock (Y/D_{well}). This reduces collinearity issues, as population is highly correlated with the housing stock and total disposable incomes relate to both per capita incomes and population. Consequently, the obtained parameter estimate associated with Y/D_{well} shows the estimated impact of an income increase on housing prices without any supply response. Furthermore, we include periodical time trends ($PREQ22008$ [Equations 1 and 3] and $POSTQ32005$ [Equation 2]) because visual observations suggest that trend effects may exist for some sub periods (see Figures 1–3). We also include the percentage gross increase of the existing housing stock through new construction (NEW) because new construction is included in average housing prices and in the number of property sales. NEW refers to completed dwellings. We expect a positive correlation between new construction and all the dependent variables. We elaborate between including current and lagged values of NEW . Also, in Equation 3, we include the share of homeowners (OWN) of the total population, as an increased portion of homeowners should increase the number of households that need mortgages.

We include lags of dependent variables (P_{t-1} , TR_{t-1} , $DEBT_{t-1}$), which may push dynamic terms out of the residual and reduce problems with autocorrelation, particularly in a finite sample such as ours. It is recommended to choose a generous lag length (see e.g. Harris and Sollis, 2005). However, choosing many lags reduces the number of degrees of freedom and we have few observations. Thus, we employ a parsimonious approach and start with one lag and add extra lags one at a time until the information criteria do not improve. Thus, we employ one lag in Equations 1 and 3, and two lags in Equation 2. Furthermore, we employ only one lag of the dependent variables in Equations 4–6.¹⁷ All variables are defined in Table 1.

Including lagged dependent variables means that we are estimating dynamic models. An implication of including lagged dependent variables is that the long-run relationships between the remaining explanatory variables and the independent variables are not given by the parameter estimates of the associated variables. For instance, the long-run relationship between repayments and some dependent variable equals $\beta_1/(1 - \beta_2)$, where β_1 and β_2 are, respectively, the estimated regression coefficients for repayments and the lagged dependent variable itself¹⁸. This is important to remember when comparing regression coefficients from different estimations where lagged dependent variables have been both included and excluded.

¹⁷ If we employ more than one lag in Equations 4–6, we find that any shock that causes the dependent variables to deviate from the long-run equilibrium also causes the dependent variables to never converge toward the long-run equilibrium again. Instead, oscillations around the long-run level amplify over time, which is not the case when only one lag is included. If we include only one lag, oscillations gradually become smaller and eventually converge at the long-run level. See for example Figures 10–12.

¹⁸ For more complex dynamic processes with more than one lag, the long-run relationship becomes $\sum Y^i/(1 - \sum \alpha^i)$, where i represents lag order. See e.g. Harris and Sollis (2005).

Table 1. Definition of variables

Variable	Description
P	The natural logarithm of average real house prices in period t . Deflated with the CPI. Base period = 2013. Housing prices are computed as the weighted average of sales prices for houses, apartments, and weekend cottages.
T	The natural logarithm of the number of total real property sales, including sales of houses, apartments, and weekend cottages.
DEBTS	The natural logarithm of household mortgage debts in relation to disposable incomes.
t	Property tax.
REPAY1	Annual planned repayments rates on all current mortgages granted by MCIs. Unplanned repayments e.g. repayments of paying off ones loans during sales are not included.
REPAY2	Approximated annual repayment rate on the current total mortgage stock. For a motivation of our assumptions, see discussion in Section 2. Total repayment rate = $(\text{Bank Repayments} + \text{MCI Repayments}) / (\text{Total bank mortgages} + \text{Total MCI mortgages})$. We assume an LTV equal to 100 percent, that house owners borrow 80 percent from MCIs and the remaining 20 percent from banks, and that 30 percent of the interest-only MCI mortgage stock is used to repay bank loans faster (i.e. in 10 years (see discussion in Section 2)). Remaining bank loans are assumed to be repaid in 20 years. Thus, we approximate the value of total bank repayments with the following formula: $\text{Value interest-only-MCI mortgages} \times 0.3 \times 0.25 \times 0.1 + (\text{Total bank mortgages} - \text{value interest-only MCI mortgages} \times 0.3 \times 0.25) \times 0.05$.
s	Interest rate deductions on mortgage loans.
Capital tax	Tax on capital gains.
r	Weighted approximated average mortgage interest rate on all mortgages (including both new and old mortgages and mortgages granted by banks and MCIs). Because we lack data on the mortgage interest rate for the full period (2001–2013), it has been approximated by regressing on 30 year real credit bonds and unit mortgage bonds (which are both available for a longer time period) for the period 2003–2013. We then replaced actual values with the predicted values for the full period.
r ₃₀	Interest rate on 30 year mortgage bonds granted by mortgage credit institutes.
HEA1	Total housing payments measure 1: $r \times (1 - s) + t + \text{REPAY1}$.
HEA2	Total housing payments measure 2: $1 \ r \times (1 - s) + t + \text{REPAY2}$.
HE	Housing payments excluding mortgage repayments = $r \times (1 - s) + t$
EXP	The sum of approximated expected annual inflation and expected annual house price appreciation.
UC	Real user cost: $r_{30} \times (1 - \text{Capital tax}) + t - \text{exp}$
Y/Dwell	The natural logarithm of household disposable incomes deflated by the CPI in relation to the total housing stock. The housing stock has been interpolated from annual data.
PREQ22008	Time trend variable, set to zero after the first quarter in 2008.
POSTQ32005	Time trend variable, set to zero before the fourth quarter in 2005.
NEW	Relative gross increase of housing stock through new construction = $\ln(\text{new dwellings} + \text{old dwellings}_{t-1}) - \ln(\text{old dwellings}_{t-1})$
OWN	The share of homeowners in the Danish population.
Q1	Dummy variable indicating the first quarter of the year.
Q3	Dummy variable indicating the third quarter of the year.
Q4	Dummy variable indicating the fourth quarter of the year.

<i>Variables used in robustness check</i>	
ΔP_{US}	Annual real house price growth in the US. First difference of the natural logarithm of real house prices in the U.S.
ΔP_{Den}	Annual real house price growth in Denmark. First difference of the natural logarithm of real house prices in the U.S.
OTHER DEBTS	The natural logarithm of household non-mortgage debts in relation to disposable incomes.

Source: Statistics Denmark. Danmarks Nationalbank, the Danish Customs and Tax Administration and OECD.

4.2. Dealing with endogeneity

Because we lack suitable instrument variables for mortgage repayments, our analysis in 5.1 does not guarantee causal effects of repayments on our dependent variables. Endogeneity can arise (amongst other things) due to reversed causality or omitted variables. Several studies have established a two-way relationship between credit and house prices (see Anundsen and Jensen, 2013; Brissimis, and Vlassopoulos, 2009; Fitzpatrick and McQuinn, 2007). Consequently, there may be a two-way relationship between house prices and factors that affect credit demand and/or credit supply. For instance, increased house prices means that new homeowners must take on larger debts and that the increased financial burden may result in lower repayment rates. Furthermore, existing homeowners may have lower incentives to repay their debts as their wealth is increasing. However, the opposite effect may also emerge if households feel urged to repay at a faster rate as their debts are increasing. We therefore apply the Toda and Yamamota (1995) variant of the Granger non-causality on our level regressions and the traditional Granger causality test on our difference regressions. The modified Wald test proposed by Toda and Yamamota addresses issues about non-stationarity and cointegration between series, which are ignored by the ordinary granger causality test. We report the results from these tests in appendix 1. In our level regressions, the tests suggest that the causalities are working in the “right” direction i.e. that nominal housing payments granger cause our dependent variables but not the other way around in our level regressions. This is in line with the results in Damen et al. (2016) who found that that ATP (ability to pay) changes Granger cause house prices for all eight countries in their study, while the researchers “only” found support for Granger causality from house prices to ATP for three countries. However, when estimating the difference regressions, we find some indications that mortgage debts and property sales granger cause nominal housing payments (and repayments), while we still find that “causality” goes in the “right” direction when modeling house prices.

To skirt the potential endogeneity problem we complement our regressions described in section 4.1 and perform “event studies”. The objective of an event study is to identify whether there have been abnormal developments of some variable after a particular event e.g. whether stock returns have been unusually low or high due to news announcements. We use an event study to investigate whether there was an abnormal development of our three dependent variables after the introduction of interest-only-mortgages in the final quarter of 2003. The basic idea behind an event study is simple and straightforward; obtain estimates of the “normal/expected developments” of your variable of interest (e.g. change of house prices) and compare to the actual developments for some period in connection to the event. Then obtain the difference between actual and expected developments and test whether this difference is significantly different from zero¹⁹. Usually, one obtains estimates of the normal/expected developments using linear regression analysis based on data for some time period before the event, leaving a window before and after the event, and then obtaining out-of-sample predictions of the “normal” development for some period in connection to the event.

¹⁹ We use the procedure explained in Kothari and Warner (2007). The test-statistic is obtained by dividing the sum of abnormal developments by the estimated standard error of normal returns. The test statistic is assumed to follow a unit normal distribution. The performed procedure is available on request.

5 Empirical results

5.1 Regression results

We have estimated both level regressions and difference regressions. First differences, however, usually exhibit more variation and may therefore suffer less from collinearity issues than level regressions. In this section, we focus on the results from the difference regressions (Equations 4–6), while results from the level regressions (equations 1–3) are shortly commented. Regressions results from the level regressions are in table A7 in the appendix. As explained in section 4.1., we added the error correction term (lagged residuals) that was obtained from the level regressions (long-run regressions) in order to control for the speed of adjustment towards the long-run equilibrium. An error-correction model which incorporates the long-run equilibrium into the difference regressions relies on a cointegrating relationship between the the independent and dependent variables. If they are not cointegrated, any relationship between non-stationary variables may be spurious (Harris and Sollis, 2005). We have performed Augmented Dickey-Fuller and Phillips-Perron tests for non-stationarity and co-integration. Results indicate that our level variables are non-stationary but that that the residuals from our level regressions are stationary, supporting cointegration. Consequently, we can proceed and estimate error correction models. The results from testing stationarity and cointegration tests are in the appendix (tables A3 and A7, appendix).

We estimate our difference regressions in four stages. In each stage, we compare the information criterion of regressions where repayments are merged with (ΔHEA_{1t}) and separated from nominal housing payments ΔHE_{1t} . We then compare the econometric fit of each regression and test whether the regression coefficient for $\Delta REPAY_{1t-1}$ equals that of ΔHE_{1t-1} in order to get indications of whether repayments should be included in other nominal housing payments. These comparisons can provide insight regarding (1) whether agents make decisions about housing consumption based on real (user) costs or on nominal mortgage payments/costs; and (2) whether mortgage repayments (which are a kind of payment but not a cost) belong to the set of nominal expenditures that affect the behavior of housing consumers.

In the first stage, we regress the dependent variable on the repayment rate ($\Delta REPAY_{1t-1}$) and on nominal housing payments (ΔHEA_{1t} , ΔHE_{1t-1}) only. In the second stage, we add a number of conventional control variables and the third step includes the error correction term obtained from the level regressions. In the final stage, we add to the control variables some additional proxies for sentiments among debt investors (lagged real house price growth the past year in the US, in Denmark and the ratio of other loans to disposable income). House prices as well as mortgage debts increased at an astonishing pace between 2003 and 2008 and this development was not only limited to Denmark. While generous mortgage conditions and new financial innovations may have contributed this development, there may be other contributing factors. Other loans besides mortgages have increased (see figure A1 in the appendix), although at a slower pace than mortgages. Regression results from modeling house prices, the number of property sales and the mortgage debt ratio are in tables 2–4.

The repayment variable $\Delta REPAY_{t-1}$ is mainly insignificant and is, unexpectedly, positive, when modelling property sales. However, when modelling real house prices and mortgage debts, we find that nominal housing payments (ΔHEA_{t-1} and ΔHE_{t-1}) are significant and negative in all regressions and that merging repayments with nominal housing payments improves the econometric fit. Also, we are unable to reject the hypotheses that $\Delta HE_{t-1} = \Delta REPAY_{t-1}$. Thus, the results favor including repayments in nominal housing payments and do not support treating it as separate variable. However, when modelling property sales, we do not find that including repayment as a separate variable or merging them with other nominal housing payments generate a better fit, although we are still not able to reject that $\Delta HE_{t-1} = \Delta REPAY_{t-1}$. Combined with the fact that $\Delta REPAY_{t-1}$ is positive, and insignificant, the results provide no evidence that repayments affect property sales.

The regression coefficients for ΔHE_{t-1} and ΔHEA_{t-1} support a faster instant reaction of sales due to changes in nominal housing expenditures than of prices and mortgage debts. This is in line with most previous research findings that property sales react more instantly and strongly to a shock than prices. However, results only support that a shock to repayments, channeled through lowering nominal housing, will have an

impact on house prices and the mortgage debt ratio, but not on the number of sales. The results from the level regressions (table A7 in the appendix) follow the same patterns as our difference regressions and including repayments in nominal housing payments improve the econometric fit when modelling real house prices and mortgage debts. And, like in the difference regressions, we cannot reject that the regression coefficients of $HE_{t-1} = REPAY_{t-1}$. Comparing the level regressions to the difference regressions, we can see that $REPAY_{t-1}$ and nominal housing payments display a considerably stronger relationship with prices in the difference regressions (we also see this pattern for the mortgage debt ratio, although the difference is much smaller). This suggests that house prices may overreact as a response to economic shocks before adjusting towards the long-run equilibrium.

In line with intuition, if mortgage repayments affect house prices (and consequently mortgage debts) but not the number of house sales, this implies that the introduction of interest-only mortgages should have primarily affected the behavior of house bidders, and not the number of bidders in relation to the number of sellers. One possible explanation is that potential house buyers might focus strongly on nominal mortgage payments when deciding how much they are willing to pay for a house, but that they are always able to obtain a mortgage, regardless of the availability of different amortization schemes. This is in line with the discussion in Section 2, where we mentioned that MCIs always demand that a borrower must be able to repay a mortgage through 30 year annuity payments (regardless of the chosen repayment rate). In addition, although the amortization scheme might affect what potential house buyers are willing to pay, it may not necessarily affect their decision to buy (as it most certainly should not affect their underlying need for housing). Hence, the possibility of deferring amortizations may have imposed positive effects on credit demand, but not necessarily on credit supply. If so, this may also explain why merging $\Delta REPAY_{t-1}$ with ΔHE_{t-1} does not improve the econometric fit when modeling real property sales because other nominal housing payments (such as the level of interest rates) are known to affect the behavior of creditors and consequently affect credit supply as well.²⁰

An additional finding that should be specifically mentioned is that the regression coefficients of real user costs (ΔUC_{t-1}) are insignificant in all regressions and/or have the “wrong (i.e. positive) sign, indicating that home owners make decisions based on nominal variables as opposed to real ones. These results follow the same pattern when regressions are estimated in level form (see table A7 in the appendix). These results are also in line with the findings of Madsen (2012). However, for the sake of academic honesty, we should also mention that this particular result may reflect a lack of consistent measures of expected inflation and expected house price appreciation, which are two variables that are included in the definition of real user costs.

In general, control variables are not significant, but have expected signs when they are. The independent variables are positively and significantly correlated with their own lags in each regression and the error-correction terms are robustly negative for all dependent variables, indicating a strong tendency of reverting to the long-run equilibrium and that that error correction models should be used. That some control variables are insignificant does not necessarily mean that they are not important, recall that we have few observations. Also, a lack of short-run relationships does not rule out the explanatory variables matter in general equilibrium. In fact, control variables display higher statistical significance in our level regressions (table A7 in the appendix).

Some results are sensitive to the inclusion of control variables, particularly when modelling the mortgage debt ratio. For example, $\Delta HEA1_{t-1}$, change from -3.45 to -1.47 when the baseline controls are included (step 2). The repayment variable ($REPAY_{t-1}$) appears sensitive to specification but is rarely significant anyway. These findings may indicate multicollinearity and/or problems with endogeneity. Combined with the fact that our granger causality test suggested that that mortgage debts and property sales granger cause nominal housing payments (and repayments) give us reasons to address causality issues. Regression results are more, but not completely robust when modeling prices. The regression coefficient for $\Delta HEA1_{t-1}$ vary between -8.49 and -5.86, and the difference corresponds to about one standard error.

²⁰ For example, according to monetary policy theory, creditors will perceive an increased risk associated with lending to private individuals and consequently they will buy more bonds instead.

We find no indication that adding extra control variables (stage 4) improve the econometric fit when modelling house prices and mortgage debts. However, the regression coefficients for nominal housing payments and repayments display slightly weaker relationships with the dependent variables and standard errors increase. And, when modelling property sales, the estimated coefficients for ΔHEA_{t-1} and ΔHE_{t-1} change considerably and information criterion suggest that the extra controls improve the regression. But results still suggest that repayment should be included in nominal housing payments when explain house prices and mortgage debts, but not when modelling sales.

In sum, there are indications that including mortgage repayments in nominal housing payments can improve our models, particularly matter for house prices and mortgage debts and that house buyers may act on nominal variables rather than real ones. However, causal effects cannot be guaranteed.

Table 2. Modelling real house prices (difference regressions)

Dependent variable: First difference of of logarithm of number of real house prices (ΔP)													
	No controls				Baseline controls			Baseline controls + error correction term			Extra controls		
$\Delta Y_t/Dwell_t$					0.00496 (0.526)	0.0663 (0.540)	0.100 (0.535)	0.11 (0.415)	0.14 (0.42)	0.11 (0.42)	0.135 (0.475)	0.210 (0.476)	0.161 (0.475)
$\Delta HEA1_{t-1}$	-8.487*** (2.277)				-	8.263***		-6.21*** (1.82)			-5.855** (2.441)		
ΔHE_{t-1}		-7.873*** (2.500)	-7.753*** (2.472)			-7.925** (2.452)	-7.737*** (2.430)		-6.18*** (1.935)	-6.08*** (1.93)		-5.314** (2.498)	-5.704** (2.506)
$\Delta REPAY1_{t-1}$			-18.40 (12.65)	-19.72 (13.78)			-17.18 (12.51)			-7.78 (7.214)			-13.27 (11.09)
ΔUC_{t-1}					-0.0676 (0.101)	-0.0500 (0.104)	-0.0741 (0.104)	-0.09 (0.08)	-0.08 (0.081)	-0.1 (0.082)			
$\Delta PREQ22008$					0.000639 (0.00043)	0.000551 (0.000450)	0.000668 (0.000454)	0.0008** (2.32)	0.0007 (0.0004)	0.0008** (0.0004)	0.000823** (0.000373)	0.000785** (0.000381)	0.000862** (0.000384)
ΔNEW					9.076 (7.384)	9.238 (7.595)	8.725 (7.526)	9.93* (5.83)	10.11* (5.912)	9.87* (5.904)	9.845 (6.032)	10.02 (6.121)	9.544 (6.099)
Lagged dependent variable					0.333** (0.130)	0.379** (0.133)	0.342** (0.134)	0.82*** (0.14)	0.88*** (0.139)	0.81*** (0.152)	0.813*** (0.183)	0.883*** (0.180)	0.805*** (0.191)
$\Delta P_{UST-t-1}$											-0.0408 (0.212)	-0.0455 (0.215)	-0.00499 (0.216)
$\Delta P_{Dent-t-1}$											0.0648 (0.116)	0.0357 (0.118)	0.0729 (0.122)
$\Delta OTHER$ $LOANS_{t-1}$											0.0321 (0.166)	0.0853 (0.160)	0.0173 (0.169)
EC term								-1.02*** (0.20)	-1.06*** (0.199)	-1.01*** (0.204)	-1.041*** (0.212)	-1.064*** (0.214)	-1.051*** (0.213)
Wald test $\Delta HE_{t-1} = \Delta REPAY_{t-1}$ P-value	-	-	0.42	-	-	-	0.47	-	-	0.82	-	-	0.5
Durbin-Watson	1.5	1.36	1.5	1.36	2.33	2.27	0.276	1.94	1.87	1.94	1.93	1.89	1.96
BG P-value	0.045	0.024	0.028	0.021	0.1	0.08	0.03	0.24	0.25	0.22	0.26	0.28	0.24
Akaike	0.212	0.157	0.176	0.021	-213.3	-210.6	-210.8	-235.2	-233.84	-233.2	-229.7	-228.3	-228.2
Schwarz	-212.1	-208.9	-209.1	-201.8	-202.1	-199.4	-197.7	-222.1	-220.7478	-218.3	-211.0	-209.6	-207.6
Adjusted R ²	-210.3	-207.0	-205.3	-199.9	0.301	0.260	0.279	0.564	0.552	0.5541	0.535	0.522	0.527
Obs.	48	48	48	48	48	48	48	48	48	48	48	48	48

Source: Authors' estimations. *, **, and *** denote significance at the 10, 5 and 1 percent, respectively. The BG P-value is the Breusch-Godfrey P-value of testing the null hypothesis of no autocorrelation, allowing for autocorrelation of the 4th order. The lagged residuals (EC terms) are obtained from regression P2 in Table A7.

Table 3. Modelling property sales (difference regressions)

Dependent variable: first difference of logarithm of number of property sales													
	No controls				Baseline controls			Baseline controls + error correction term			Extra controls		
$\Delta Y_t / \text{Dwell}_t$					5.390*	4.891*	3.895	4.69*	4.36	4.27	0.473	-0.285	-0.41
					(2.906)	(2.862)	(2.993)	(2.724)	(2.71)	(2.76)	(2.785)	(2.724)	(2.803)
ΔHEA1_{t-1}	-11.90 (10.21)				-23.07** (9.005)			-20.23** (8.471)			-33.14*** (9.999)		
ΔHE_{t-1}	-16.62 -17.15 (10.72) (10.59)				-26.40*** -26.22*** (8.992) (8.968)			-22.37** -22.3** (8.643) (8.755)			-36.85*** -36.60*** (9.681) (9.861)		
$\Delta \text{REPAY1}_{t-1}$	81.44 78.51 (54.19) (55.09)				47.68 (43.14)			7.71 (30.579)			9.766 (37.67)		
ΔUC_{t-1}					0.410 (0.346)	0.412 (0.337)	0.445 (0.338)	0.59* (0.3297)	0.58* (0.326)	0.59* (0.330)	0.847** (0.321)	0.852*** (0.309)	0.853** (0.313)
$\Delta \text{POSTQ32005}$					0.00262 (0.00176)	0.00298* (0.00167)	0.00343* (0.00172)	0.0018 (0.0017)	0.0023 (0.0016)	0.0024 (0.0018)	0.000555 (0.00153)	0.00117 (0.00144)	0.00128 (0.00152)
ΔNEW_{t-1}					-21.47 (26.61)	-20.39 (26.04)	-19.18 (25.99)	-13.84 (24.2996)	-13.59 (24.72)	-13.56 (25.029)	-10.21 (22.21)	-9.507 (21.40)	-9.336 (21.71)
Lagged dependent variable					0.234 (0.184)	0.215 (0.180)	0.212 (0.180)	0.98*** (0.33)	0.92*** (0.337)	0.90** (0.346)	1.009*** (0.348)	0.912** (0.341)	0.898** (0.349)
Q3					-0.147*** (0.0376)	--0.138*** (0.0372)	-0.129*** (0.0379)	-0.24*** (0.0514)	-0.23*** (0.052)	-0.23*** (0.055)	-0.281*** (0.0519)	-0.262*** (0.0511)	-0.258*** (0.0537)
Q4					-0.150*** (0.0398)	--0.149*** (0.0384)	-0.140*** (0.0392)	-0.08* (0.0452)	-0.09* (0.045)	-0.09* (0.045)	-0.0840* (0.0424)	-0.0880** (0.0410)	-0.0880** (0.0415)
Q1					0.0848** (0.0416)	0.0815* (0.0407)	0.0729* (0.0413)	0.16*** (0.0477)	0.15*** (0.048)	0.15*** (0.049)	0.0885* (0.0504)	0.0741 (0.0494)	0.0717 (0.0509)
$\Delta \text{P}_{\text{US}t-1}$											3.108*** (0.844)	3.290*** (0.821)	3.279*** (0.833)
$\Delta \text{P}_{\text{Dent}t-1}$											-0.285 (0.374)	-0.313 (0.361)	-0.312 (0.366)
$\Delta \text{OTHER LOANS}_{t-1}$											-1.028 (0.635)	-1.068* (0.593)	-1.037 (0.614)
EC term								-0.99*** (0.379)	-0.92*** (0.379)	-0.9** (0.392)	-1.167*** (0.367)	-1.065*** (0.358)	-1.044*** (0.372)
Wald test	0.082				0.1			0.35			0.23		
$\Delta \text{HE}_{t-1} = \Delta \text{REPAY}_{t-1}$													
P-value													
Durbin-Watson	1.9	1.92	1.85	1.83	2.17	2.20	2.17	2.11	2.13	2.13	2.1	2.15	2.13
BG P-value	0.00	0.00	0.00	0.00	0.22	0.25	0.33	0.20	0.21	0.21	0.47	0.5	0.53
Akaike	-68.07	-69.10	-69.40	-68.73	-92.88	-95.00	-94.52	-98.79	-99.87	-97.95	-109.1	-112.6	-110.7
Schwarz	-66.20	-67.22	-65.65	-66.86	-76.04	78.16	-75.80	-80.07	-81.15	-77.37	-84.73	-88.25	-84.47
Adjusted R ²	0.007	0.028	0.054	0.021	0.489	0.511	0.514	0.555	0.565	0.554	0.656	0.680	0.671
Obs.	48	48	48	48	48	48	48	48	48	48	48	48	48

Source: Authors' estimations. *, **, and *** denote significance at the 10, 5 and 1 percent, respectively. The BG P-value is the Breusch-Godfrey P-value of testing the null hypothesis of no autocorrelation, allowing for autocorrelation of the 4th order. The lagged residuals (EC terms) are obtained from Equation T3 in Table A7.

Table 4. Modelling the mortgage debt ratio (difference regressions)

Dependent variable: first difference of logarithm of mortgage debt ratio (ΔDEBTS)													
	No controls				Baseline controls			Baseline controls + error correction term			Extra controls		
ΔY _t /Dwell _t					0.0701 (0.189)	0.0568 (0.191)	0.0324 (0.197)	-0.11 (0.139)	-0.11 (0.143)	-0.09 (0.142)	-0.111 (0.148)	-0.106 (0.151)	-0.0888 (0.151)
ΔHEA1 _{t-1}	-3.746*** (1.222)				-1.179 (0.767)			-1.47*** (0.556)	-		-1.578** (0.755)		
ΔHE _{t-1}		-2.480* (1.379)	-2.358* (1.270)			-1.236 (0.789)	-1.265 (0.797)		-1.39** (0.579)	-1.37** (0.574)		-1.397* (0.765)	-1.518* (0.770)
ΔREPAY1 _{t-1}			-19.50*** (6.450)	-19.88*** (6.620)			2.672 (4.586)			-3.71 (2.846)			-4.413 (3.969)
ΔUC _{t-1}					0.0495 (0.0312)	0.0505 (0.0311)	0.0531 (0.0317)	0.04 (0.023)	0.04 (0.023)	0.03 (0.02)	0.0321 (0.0278)	0.0325 (0.0282)	0.0311 (0.0281)
ΔPREQ22008					-0.0000513	-0.0000576 (0.000137)	-0.0000695 (0.000140)	0.00006 (0.0001)	0.00005 (0.0001)	0.00007 (0.0001)	0.0000533 (0.000107)	0.0000478 (0.000109)	0.0000696 (0.000111)
ΔNEW					-0.921 (2.780)	-0.812 (2.793)	-0.560 (2.851)	3.81* (2.157)	3.69* (2.19)	3.72* (2.17)	3.821* (2.258)	3.756 (2.294)	3.609 (2.290)
ΔNEW _{t-1}					-2.635 (2.695)	-2.602 (2.694)	-2.454 (2.730)	0.18 (2.002)	0.08 (2.029)	0.2 (2.012)	0.192 (2.087)	0.0689 (2.113)	0.0558 (2.105)
ΔOWN _t					-0.949 (1.394)	-0.890 (1.397)	-0.771 (1.424)	0.06 (1.033)	0.16 (1.040)	0.06 (1.033)	0.156 (1.250)	0.0199 (1.261)	0.176 (1.264)
Lagged dependent					0.814*** (0.0811)	0.839*** (0.0776)	0.867** (0.0919)	0.96*** (0.063)	0.99*** (0.062)	0.91*** (0.08)	0.973*** (0.0998)	1.015*** (0.0981)	0.956*** (0.111)
ΔP _{US} _{t-1}											-0.0163 (0.0888)	-0.0338 (0.0887)	0.000690 (0.0937)
ΔP _{Dent} _{t-1}											-0.00621 (0.0301)	-0.00391 (0.0305)	-0.00734 (0.0306)
ΔOTHER LOANS _{t-1}											-0.0102 (0.0468)	0.000141 (0.0888)	-0.0146 (0.0887)
EC term								-1.03*** (0.172)	-1.01*** (0.174)	-1.06*** (0.177)	-1.061*** (0.200)	-1.051*** (0.203)	-1.101*** (0.207)
Wald test ΔHE _{t-1} = ΔREPAY _{t-1} P-value	-	-	0.012	-			0.41	-	-	0.43	-	-	0.47
Durbin-Watson	0.4	0.25	0.52	0.43	2.55	2.54	2.53	2.04	2.02	2.04	2.04	2.05	2.04
BG P-value	0.00	0.00	0.00	0.00	0.09	0.1	0.11	0.99	0.88	0.91	0.86	0.85	0.87
Akaike	-261.5	-256.0	-262.6	-261.2	-310.0	-310.1	-308.5	-339.1	-337.8	-338	-333.3	-332.1	-331.8
Schwarz	-259.7	-254.1	-259.0	-259.3	-295.3	-295.4	-292.0	-322.6904	-321.38	-319.6771	-311.4	-310.1	-308.0
Adjusted R ²	0.154	0.046	0.192	0.148	0.752	0.753	0.749	0.8709	0.867	0.87	0.860	0.856	0.857
Obs.	46	46	46	46	46	46	46	46	46	46	46	46	46

Source: Authors' estimations. *, **, and *** denote significance at the 10, 5 and 1 percent, respectively. The BG P-value is the Breusch-Godfrey P-value of testing the null hypothesis of no autocorrelation, allowing for autocorrelation of the 4th order. The lagged residuals (EC terms) are obtained from regression D2 in table A7.

5.2. Event Studies

The results from our regressions indicate that if the introduction of interest-only-mortgages in 2003 contributed to the post millennial surge of house prices and increased mortgage debts, the effect was channeled through reduced nominal housing payments. However, we lack suitable instrumental variables for repayments and identification is not guaranteed. In this section, we complement the previous analysis in section 5.1 and perform “event studies”. We thus estimate the abnormal developments (i.e. out-of-sample residuals) of our three dependent variables for different periods in connection to the 4th quarter of 2003 and have tested whether the cumulative abnormal residuals are significantly different from zero. Figures 6-8 plots the residuals from our underlying regressions (where a positive residual means that the actual value exceeds the predicted value). All underlying regressions have been estimated using first differences. When estimating the regressions, we have included our base line controls (see tables 2-4) but dropped time trend variables because they can absorb (partially or completely) effects of events that occur at a specific point in time, thereby undermining the purpose of an event study. Naturally, we excluded mortgage repayments from nominal housing payments, because any variation of the dependent variables that is caused by changing repayment rates should be absorbed by the residual. Also, we exclude the error correction term from the control variables, because any deviation from the long-run equilibrium that is caused by changing repayment rates should be in the residual. We have used the sample period 1994q3-2003q1 when estimating the regressions that are used to obtain estimates of the “normal” development (i.e. the predicted values). Estimating the regressions based on some period before the event is the normal procedure in event studies²¹.

Figures 6-8 plots our estimations the abnormal developments for prices, transactions and mortgage debts from 2000 until 10. Results from testing the significance of “abnormal” developments are in table 5.

Figure 6. Real house prices residuals

Figure 6 reveals that the residuals from our house price regressions were mainly positive between October 2003 until the second quarter in 2007. The accumulated residuals between the first quarter of 2004 and the 2nd quarter of 2007 implies that house prices increased 32.2 percent more than their predicted development, (using the base period 1994-2003). After 2007, the residuals are more on the negative side, which should be related to the outbreak of the financial crisis in 2007/2008. We see similar patterns for mortgage debts (Figure 12) and residuals are mainly positive from the period around the introduction of interest-only-mortgages until 2007/2008. Patterns are less clear for property sales, which have higher volatility.

²¹ The results of the estimated regression used to obtain the abnormal development are available upon request.

Figure 7. Number of property sales residuals

Figure 8. Mortgage debt ratio residuals

Table 5. Significance test of abnormal developments, event studies.

Period	Dependent variable		
	House prices	Property Sales	Mortgage debt ratio
2003q2-2005q1	1.73* (15.7 %)	2.14** (55.6 %)	1.07 (3.1 %)
2004q1-2007q2	2.51*** (32.2 %)	0.54 (15.94 %)	2.4*** (9.5 %)
2003q1-2007q2	2.42*** (35.8 %)	1.4 (54.4 %)	2.45*** (11.1 %)
2004q1-2005q4	2.48*** (23.4 %)	1.59 (25.9)	1.69* (4.94 %)
2004q1-2004q4	1.28 (7.95)	1.58 (25.9)	1.07 (2.21)
2002q3-2003q3	0.38 (2.28)	1.16 (18.5 %)	0.12 (0.24)

Note: Numbers are test-statistics of the null that the cumulative abnormal developments is zero.

*, **, and *** denote significance at the 10, 5 and 1 percent, respectively.

Numbers in parenthesis are the estimated cumulative abnormal developments during the period of the associated event windows.

Table 5 lists statistical tests of whether the cumulative abnormal development (i.e. accumulated residual) for different periods in connection to October 2003 is statistically different from zero. For house prices and mortgage debts, the results are statistically different from zero at least at the ten percent level for most periods occurring either after or overlapping with October 2003. For instance, the results strongly suggest that house prices and mortgage debts increased more than predicted from 2004q1 to 2007q1. However, the isolated year of 2004 does not display significant abnormal developments, which is related to the fact that the 3rd quarter of 2004 had lower house price growth than predicted (i.e. a negative residual). When stretching the period an additional year (2004q1-2005q4), the accumulated abnormal developments are significant. Our analysis shows that the majority of quarters between 2004-2006/early 2007 was dominated by periods of higher than expected growth of house prices and mortgage debts.

To get an indication of whether the introduction interest-only-mortgages served as an igniting spark for house prices growth and increasing mortgages, we also estimate the level of abnormal returns for a short period before October 2003 (2002q3-2003q3). However, the results give no support of abnormal developments for the year prior to the 4th quarter of 2003, which indicate that that fourth quarter of 2003 represent a triggering point. The estimated accumulative effects are higher for house prices than for the mortgage debt ratio. This makes sense because house prices are average prices for houses that were sold during the given period, which only constitute a minor fraction of the total housing stock.

5.3. Simulations

Next, we use our regression results in section 5.1 to perform an in-sample simulation of how the introduction of interest-only mortgages in 2003 affected real house prices and mortgage debts in relation to disposable incomes up until 2013. We do not make the corresponding simulation for property sales, because results did not strengthen that they are affected by mortgage repayments. We base our simulations on the regressions where mortgage repayments were merged with other nominal housing payments, using both our level regressions (table A7 in the appendix) and difference regressions (table 2 and 4).

We compare actual house prices and mortgage debts relative to disposable income with the estimated values that would have occurred, had interest-only mortgages not been introduced in 2003. Thus, we have estimated the counterfactual repayment rates that would have occurred, had interest-only mortgages not been introduced, and had borrowers continued to pay off their debts to MCIs as 30 year annuity mortgages. As mentioned earlier, the essential feature of an annuity mortgage is keeping the annual nominal mortgage expenditure (including interest rates and repayments) fixed over the entire duration of the loan, which means that (i) the repayment rate will continue to increase as the loan approaches maturity because previous repayments result in reduced interest rate payments, and (ii) the initial repayment rate is inversely related to the mortgage interest rate. At the aggregated level, this implies that repayment rates should be negatively correlated with current mortgage interest rates.

As can be seen in Figure 9, our estimation of the counterfactual repayment rate²² increases gradually because the mortgage interest rate fell between 2001 and 2013. One can observe a dramatic decline in the average mortgage repayment rate starting in the first quarter of 2004 directly after interest-only mortgages were introduced. Actual repayment rates decreased gradually until the first quarter in 2010, and have stabilized since then. Consequently, the difference between the actual and the counterfactual repayment rate increased from almost 0 to about 1.6 percentage points between 2004 and 2013. The increasing gap between the actual and counterfactual repayment rates implies that the effect of the introduction of interest-only mortgages should grow successively stronger over time. The increasing difference between the actual and counterfactual nominal housing payments is entirely driven by the increased gap between the actual and counterfactual mortgage repayments. Table 6 report the results.

Figure 9. Counterfactual and actual nominal housing expenditures/repayment rates

Source: Statistics Denmark. Danmarks Nationalbank and the Danish Customs and Tax Administration.

Table 6. Simulation results on the impact of interest-only-mortgages up until 2013

	Estimated Effect (%)	Regression result used
House prices (level regressions)	25.2 %	Table A7, column 3
House prices (difference regressions)	22.3 %	Table 2, Column 9
House prices (difference regressions without error correction term)	22.4 %	Table 2, Column 6
Mortgage debt ratio level regressions	22.9 %	Table A7, column 11
Mortgage debt ration difference regressions	24.4 %	Table 4, Column 9
Mortgage debt (difference regressions without error correction term)	10.3 %	Table 4, Column 6

Source: Author's estimations.

Our simulations yield similar result irrespective of whether they are based on results in level on difference regressions. Our simulations based on difference regression including an error correction term suggest that the introduction of interest-only mortgages increased real house prices and the mortgage debt ration by 22.3 and 24.4 percent respectively up until 2013. Simulation results based on the level regressions (table A7, columns 3 and 11) are very similar. Further, we tried to perform the simulations based on difference regressions without an error correction term. These results suggest that the effect on house prices and the

²² See Appendix A2 for information regarding how we estimated the counterfactual repayment rate.

mortgage debt ratio where 22.4 and 10.3 percent respectively. The estimated effect on mortgage debts is thus considerably lower when dropping the error correction terms. This result may in fact, be the most logically sensible of all. In the very long run, one expects that reduced repayment would have about the same impact on house prices and mortgage debts. But because only a minor fraction of all houses change owner each year, converging towards the long-run equilibrium should be a much more protracted process for mortgages than for house prices. Therefore, one should expect a larger impact on house prices than on mortgage debts, even ten years after interest-only-mortgages were introduced. This point can be seen in table 2 and 4 where regression coefficient of nominal housing payments display a relatively weak relationship with mortgage debts in comparison to real house prices.

We illustrate the convergence towards long-run equilibrium in figures 10-12, where we have simulated the dynamic impact of a “shock” corresponding to a one-time and permanent increase of nominal mortgage payments by one percentage point. Thus, the simulations in figures 10-12 are based on the regression estimates from both the level regressions and the difference regressions. For illustrative purposes, we also include simulations on the impact of property sales, but those results are based on the regressions where mortgage repayments were not included in nominal housing payments (column 9, table 3 and column 8, table A7). Thus, figure 11 illustrates the effects of property sales of shock to nominal housing payments which are not mortgage repayments.

The dynamic impact of a “shock” in one of the explanatory variables is not only a function of the parameter estimate of the associated variables, but also depends on the speed at which the dependent variables converge toward the long-run equilibrium and the lag structure of the dependent variables. The error correction term is strongly significant and close to one in all regressions, which implies, *ceteris paribus*, that deviations from the long-run equilibrium will be fully restored within one quarter. However, the strong dynamic effects represented by the lagged dependent variables may counteract this process, and any demand-side or supply-side “shock” may cause the dependent variables to deviate from the long-run equilibrium for more than one quarter.

Figure 10. Dynamic effect of a one-percentage point increase of nominal housing payments at quarter zero on real house prices.

Figure 11. Simulated dynamic effect of a one-percentage point increase of nominal housing payments at quarter zero on real property sales.

Figure 12. Simulated dynamic effect of a one-percentage point increase of nominal housing payments at quarter zero on real mortgage debt in relation to disposable incomes.

A comparison between Figures 10-12 reveals the following: (1) Sales react faster to changes in housing payments than prices do, and prices react faster than debts do. One period after the shock occurred (i.e., quarter 1), property sales, prices, and the mortgage debt ratio fell by about 20, 6, and 1.5 percent, respectively. (2) Sales and the debt ratio are more strongly affected than prices in the long run (which was also shown in Section 5.2). (3) The debt ratio never deviates substantially from the long-run equilibrium level. The maximum deviations from the long-run equilibrium level are 15.7 and 3.4 percent, respectively, for sales (2 quarters after the shock) and prices (1 quarter after the shock). However, mortgage debts never deviate more than 0.72 percent. (4) The stabilization of the long-run equilibrium level is a more protracted process for mortgage debts than for prices and sales. After 100 quarters, the long-run level of mortgage debts was still falling, while prices and sales stabilized between 10 and 20 quarters after the shock. We know that real house prices are based on actual sales prices, and that the number of sales each year only constitutes a minor part of the total housing stock. Thus, because most homeowners are likely to have some mortgage, it is expected that the long-run equilibrium of debts needs longer to converge to a constant value. In addition, mortgages are usually repaid over a long period of time.

Conclusions

The results in this paper indicate that the introduction of interest-only mortgages in Denmark in 2003 contributed to the surge in real house prices and to the increase of household mortgage debts during the 2000s. We have found that merging mortgage repayment rates with other nominal housing payments improves the econometric fit when modeling house prices and mortgage debts in relation to disposable income. Also, the conventional real user costs variable either turned out to be insignificant or to have the "wrong" sign, while nominal housing payments are significantly negative. These findings contradict traditional models, which are typically concerned with the associated real costs of housing, and not with nominal expenditures.

However, identification of causal effects could not be guaranteed. We therefore performed complementary event studies, which strengthened our supposition that interest-only-mortgages have contributed to increased house prices and mortgage debts. The results are however, less supportive of interest-only mortgages having also affected the number of property sales. We found that merging repayments with nominal housing payments did not improve the econometric fit when modeling sales and our event study did not confirm significant effects of introduction of interest-only-mortgages on the number of sales.

Overall, our results raise questions regarding whether house buyers base their decisions on real or nominal variables, and whether they generally consider actual costs or cash flows. As such, the results generate questions regarding to what extent interest-only mortgages can/should be used as a tool to achieve affordability of housing. Policy makers should thus consider the increased risk that households are exposed to when taking on larger debts as a result of repaying less on their loans.

Our most conservative estimates suggest that interest-only mortgages increased real house prices and the mortgage debt ratio by about 20 and 10 percent between 2004 and 2013, respectively. Efforts to restore repayment rates to the "pre-2003" level may therefore have strong negative effects on aggregate demand if implemented too quickly. Furthermore, it is important to note that markets may behave differently when they are rising as opposed to when they are declining. Trying to restore debt levels to pre-2003 ratios by, for example, removing the possibility of interest-only mortgages may generate unintended side effects. For example, nominal loss aversion on the part of potential home sellers may cause the number of sales to drop more than it would cause prices to drop.

Ultimately, in order to better understand how changes in cash flows and mortgage repayment rates affect housing supply and housing demand, it is necessary to be able to distinguish between repayment rates on new and old mortgages as they are likely to affect the housing market differently. We have only been able to use data on total planned repayments covering a limited time period. But although reduced repayment rates probably contributed to the surge in housing prices in several countries during the 2000s, data availability is limited. Clearly, researchers need more and better-diversified data to be able to perform future research on how mortgage conditions in general, and repayments in particular, affect the housing market and the economy. Furthermore, coming up with suitable instruments for repayments in order to address identification issues would make a major contribution.

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Appendix A. Data sources, descriptive statistics, and regression results.

Figure A1. Non-mortgage loans in relation to disposable income

Table A1. Listing of data sources

Variable	Detail	Source
Average sales price	Houses, apartments, weekend cottages	Statistics Denmark, Table EJEN77
Real property sales	Houses, apartments, weekend cottages	Statistics Denmark, Table EJEN77
Interest rate	MCI, 30 year unit mortgage bonds	Statistics Denmark, Table MPK3
Interest rate	MCI, new mortgages	Statistics Denmark, Table DNRNRI
Interest rate	MCI, stock	Statistics Denmark, Table DNRURI
Interest rate	Banks, stock	Statistics Denmark, Table DNRUPI
Interest rate	Banks, new mortgages	Statistics Denmark, Table DNRNPI
Interest rate	Real credit bonds, 30 years	Danmarks Nationalbank
Interest rate deduction		SKAT, Danish Customs and Tax Administration, email correspondence
Disposable income	Household sector	Statistics Denmark, Table NASD23:2.4.1
Property tax		Nationalbanken, email correspondence
Capital tax		Skatteministeriet/Ministry of Taxation
Stock of dwellings		Statistics Denmark, Table BOLRD, data is interpolated
Population		Statistics Denmark, Table BEV21
Homeowners		Statistics Denmark, Table BOLRD
Construction (completed dwellings)		Statistics Denmark, Tables BYVG9 and BYVG99
Total mortgage stock, banks	Banks, stock	Statistics Denmark, Table DNULD2
Total mortgage stock, MCIs	MCI, stock	Statistics Denmark, Table DNEJER
Deferred amortization mortgages	MCI, stock	Statistics Denmark, Table DNEJER
Actual repayments to MCIs	MCI, flow	Statistics Denmark, Table DNEJER
US real house price index	Residential properties	OECD, Table RPPI

Interest rate	Central government bonds, 10 years	Statistics Denmark, Table DNRENTM
Interest rate	Mortgage credit bonds, 10 years	Statistics Denmark, Table DNRENTM

Table A2. Descriptive statistics

Variable	Mean	Std.dev.	Min	Max	Period
P_t	14.34	15.04	14.05	14.52	2001Q3– 2013Q3
T_t	9.88	0.24	9.43	10.36	2001Q3– 2013Q3
$DEBTS_t$	0.506	0.18	0.16	0.68	2001Q3– 2013Q2
UC_{t-1}	-0.033	0.064	-0.018	0.13	2001Q3– 2013Q3
$Y/DWELL_t$	12.75	0.025	12.7	12.79	2001Q3– 2013Q3
NEW_{t-1}	0.002	0.0007	0.0009	0.004	2001Q3– 2013Q3
HEA_{t-1}	0.064	0.011	0.049	0.084	2001Q3– 2013Q3
HE_{t-1}	0.045	0.008	0.033	0.061	2001Q3– 2013Q3
OWN_{t-1}	0.52	0.006	0.509	0.533	2001Q3– 2013Q1
$\Delta P_{US,t-1}$	0.049	0.038	-0.063	0.11	2001Q3– 2013Q1
$\Delta P_{Den,t-1}$	0.029	0.075	-0.14	0.2	2001Q3– 2013Q1
$OTHER\ DEBTS_{t-1}$	-0.17	0.10	-0.33	-0.018	2001Q3– 2013Q1

Table A3. Testing for stationarity. Null hypothesis: Variables do not contain a unit root

Variable	Philipps Perron P-value, no trend	Philipps Perron P-value, trend	ADF P- value, no trend	ADF P- value, trend included	Variable	Philipps Perron P-value, no trend	Philipps Perron P-value, trend	ADF P- value, no trend	ADF P- value, trend
P_t	0.41	0.95	0.35	0.75	ΔP_t	0.00	0.00	0.02	0.03
T_t	0.00	0.00	0.87	0.64	ΔT_t	0.00	0.00	0.0004	0.002
$DEBTS_t$	0.07	1.00	0.12	0.89	$\Delta DEBTS_t^*$	0.24	0.03	0.61	0.36
$Y/Dwell_{t-1}$	0.09	0.14	0.05	0.53	$\Delta Y/Dwell$	0.00	0.00	0.0077	0.095
UC_{t-1}	0.12	0.29	0.29	0.46	ΔUC	0.00	0.00	0.003	0.016
NEW_t	0.16	0.15	0.27	0.36	ΔNEW	0.00	0.00	0.26	0.51
HE_{t-1}	0.7	0.65	0.65	0.56	ΔHE	0.00	0.00	0.0006	0.004
$REPAY1_{t-1}$	0.75	0.97	0.61	0.87	$\Delta REPAY1_{t-1}^*$	0.12	0.28	0.21	0.35
$REPAY2_{t-1}$	0.72	0.91	0.57	0.77	$\Delta REPAY2_{t-1}$	0.02	0.1	0.11	0.31
$HEA1_{t-1}$	0.68	0.57	0.65	0.42	$\Delta HEA1_{t-1}$	0.00	0.00	0.0009	0.005
$HEA2_{t-1}$	0.61	0.42	0.67	0.38	$\Delta HEA2_{t-1}$	0.00	0.00	0.0007	0.005
OWN_t	0.99	0.93	0.97	0.41	ΔOWN	0.04	0.1	0.21	0.32

Note: The number of lags of the first differenced dependent variable is chosen based on Akaike Information Criteria allowing for a maximum of 12 lags in the Augmented Dickey-Fuller (ADF) test. The Philipps Perron test includes 3 Newey-West lags based on

choosing “ $\text{int}\{4(T/100)^{(2/9)}\}$ ” as the number of lags. The null hypothesis is that the variables do not contain a unit root. *DEBTS and REPAY1 may be integrated of order 2. When taking the 2nd difference, all tests reject a unit-root at the one percent level.

Table A4. Todo-Yamamoto tests for non-causality. Level regressions

Original model	Ho:	P-value	Ho:	P-value
Model 1, table 3 ($Y_t=P_t$)	$HEA_{t-1} \nRightarrow P_t$	0,001	$P_{t-1} \nRightarrow HEA_t$	0,24
Model 2, table 3 ($Y_t=P_t$)	$HE_{t-1} \nRightarrow P_t$	0,001	$P_{t-1} \nRightarrow HE_t$	0,19
Model 2, table 3 ($Y_t=P_t$)	$REPAY_{t-1} \nRightarrow P_t$	0,36	$HE \nRightarrow P_t$	0,01
	$P_{t-1} \nRightarrow REPAY_t$	0,72	$P_{t-1} \nRightarrow HE_{t-1}$	0,13
	$REPAY_{t-1} \nRightarrow HE_t$	0,26	$HE_{t-1} \nRightarrow REPAY_t$	0,1
Model 3, table 3 ($Y_t=P_t$)	$REPAY \nRightarrow P_t$	0,76	$HE \nRightarrow P_t$	0,006
	$P_{t-1} \nRightarrow REPAY_t$	0,57	$P_{t-1} \nRightarrow HE_{t-1}$	0,14
	$REPAY_{t-1} \nRightarrow HE_t$	0,9	$HE_{t-1} \nRightarrow REPAY_t$	0,08
Model 1, table 3 ($Y_t=T_t$)	$HEA_{t-1} \nRightarrow T_t$	0,01	$T_{t-1} \nRightarrow HEA_{t-1}$	0,34
Model 2 table 3 ($Y_t=T_t$)	$HE_{t-1} \nRightarrow T_t$	0,006	$T_{t-1} \nRightarrow HE_t$	0,27
Model 3 table 3 ($Y_t=T_t$)	$REPAY \nRightarrow T_t$	0,22	$REPAY_{t-1} \nRightarrow HE_t$	0,32
	$HE \nRightarrow T_t$	0,04	$T_{t-1} \nRightarrow REPAY_t$	0,54
	$T_{t-1} \nRightarrow HE_{t-1}$	0,09	$HE_{t-1} \nRightarrow REPAY_t$	0,54
Model 1, table 3 ($Y_t=DEBTS_t$)	$HEA_{t-1} \nRightarrow DEBTS_t$	0,02	$DEBTS_{t-1} \nRightarrow HEA_{t-1}$	0,56
Model 2, table 3 ($Y_t=DEBTS_t$)	$HE_{t-1} \nRightarrow DEBTS_t$	0,04	$DEBTS_{t-1} \nRightarrow HE_t$	0,49
Model 3, table 3 ($Y_t=DEBTS_t$)	$REPAY_{t-1} \nRightarrow DEBTS_t$	0,45	$DEBTS_{t-1} \nRightarrow REPAY_t$	0,13
	$HE \nRightarrow DEBTS_t$	0,14	$DEBTS_{t-1} \nRightarrow HE_{t-1}$	0,29
	$REPAY_{t-1} \nRightarrow HE_t$	0,49	$HE_{t-1} \nRightarrow REPAY_t$	0,82

Note: The Todo-Yamamoto-tests have been estimated according to the procedures described in e.g. Wolde-Rufael (2005) and Todo and Yamamoto (1995). We have included the other control variables on the right hand side of each regression. In each regression we have added m number of lags of the tested variables to the original number of lags in table 3. m was set according to the maximum order of integration for the variables tested. For example, when testing for non-causality between HE and P, we set m to 1 as they both appeared to be integrated of order one (see table 2). The P-values of Todo-Yamamoto tests of the null hypothesis of non-causality were then obtained by testing the null hypothesis whether the regressions coefficient for d lags of the variable in question is equal to zero. In equation 3, m was set to 2.

Table A5. Todo-Yamamoto tests for granger-causality. Difference regressions

Original model	Ho:	P-value	Ho:	P-value
Model 1, table 3 ($Y_t=P_t$)	$HEA_{t-1} \nRightarrow P_t$	0.002	$P_{t-1} \nRightarrow HEA_t$	0.81
Model 2, table 3 ($Y_t=P_t$)	$REPAY_{t-1} \nRightarrow P_t$	0.45	$HE \nRightarrow P_t$	0.007
	$P_{t-1} \nRightarrow REPAY_t$	0.14	$P_{t-1} \nRightarrow HE_{t-1}$	0.73
	$REPAY_{t-1} \nRightarrow HE_t$	0.26	$HE_{t-1} \nRightarrow REPAY_t$	0.93
Model 1, table 3 ($Y_t=T_t$)	$HEA_{t-1} \nRightarrow T_t$	0.00	$T_{t-1} \nRightarrow HEA_{t-1}$	0.07
Model 3 table 3 ($Y_t=T_t$)	$REPAY \nRightarrow T_t$	0.04	$REPAY_{t-1} \nRightarrow HE_t$	0.68
	$HE \nRightarrow T_t$	0.44	$T_{t-1} \nRightarrow REPAY_t$	0.06
	$T_{t-1} \nRightarrow HE_{t-1}$	0.09	$HE_{t-1} \nRightarrow REPAY_t$	0,54
Model 1, table 3 ($Y_t=DEBTS_t$)	$HEA_{t-1} \nRightarrow DEBTS_t$	0.001	$DEBTS_{t-1} \nRightarrow HEA_{t-1}$	0.04
Model 3, table 3 ($Y_t=DEBTS_t$)	$REPAY_{t-1} \nRightarrow DEBTS_t$	0.57	$DEBTS_{t-1} \nRightarrow REPAY_t$	0.08
	$HE \nRightarrow DEBTS_t$	0.02	$DEBTS_{t-1} \nRightarrow HE_{t-1}$	0.13
	$REPAY_{t-1} \nRightarrow HE_t$	0.63	$HE_{t-1} \nRightarrow REPAY_t$	0.8

Table A6. Regression results for Equations 1–3 using REPAY2

Independent variables	P_t	P_t	T_t	T_t	$DEBTS_t$	$DEBTS_t$
$Y_t/Dwell_t$	0.20*** (0.045)	0.31*** (0.08)	0.216** (0.09)	0.19* (0.094)	-0.02 (0.013)	-0.02 (0.015)
$HEA2_{t-1}$	-3.06*** (0.633)	—	-5.59* (3.072)	—	-0.69* (0.368)	—

HE _{t-1}	—	-3.32*** (0.641)	—	-3.13 (3.744)	—	-0.71* (0.4)
REPAY _{t-1}	—	-12.17** (5.627)	—	15.16 (18.40)	—	-0.86 (1.724)
UC _{t-1}	0.04 (0.066)	-0.02 (0.073)	0.014 (0.28)	0.72 (0.284)	0.01 (0.019)	0.01 (0.019)
PREQ22008	0.00055*** (0.00022)	0.0008*** (0.00027)	—	-0.0012 (0.0013)	0.0002** (0.00009)	0.0002** (0.00009)
POSTQ32005	—	—	-0.002*** (0.0008)	-0.001 (0.0013)	—	—
NEW	21.81*** (6.203)	25.96*** (6.599)	38.85* (21.27)	35.67 (21.37)	3.91* (2.248)	3.95* (2.313)
NEW _{t-1}	—	—	—	—	3.63* (1.923)	-3.67* (1.992)
OWN _t	—	—	—	—	0.57* (0.34)	0.57 (0.34)
1 st lag- dependent variable	0.83*** (0.038)	0.75*** (0.063)	1.066*** (0.152)	1.05*** (0.152)	0.98*** (0.015)	0.98*** (0.024)
2 nd lag- dependent variable	—	—	-0.29 (0.288)	-0.31 (0.2)	—	—
Q3	—	—	-0.22*** (0.032)	-0.22*** (0.03)	—	—
Q4	—	—	-0.219*** (0.036)	-0.21*** (0.037)	—	—
Q1	—	—	-0.11*** (0.035)	-0.1*** (0.035)	—	—
Wald test HE _{t-1} = REPAY _{t-1} P-value	—	0.11	—	0.26	—	0.92
BG P-value	0.39	0.29	0.56	0.78	0.86	0.84
Akaike	-230.37	-231.367	-118.65	-118.31	-337.74	-335.76
Schwarz	-219.02	-218.1242	-99.74	-97.503	-322.94	-319.11
Durbin- Watson	1.89	1.9	2.04	1.98	2.11	2.11
P-value ADF test	0.0004	—	0.000	0.00	0.00	0.02
Obs.	49	49	49	49	47	47

Source: Authors' estimations. *, **, and *** denote significance at the 10, 5 and 1 percent, respectively. The associated standard errors are in parenthesis. The Augmented Dickey-Fuller (ADF) test for co-integration (i.e., stationarity of the residuals, where the null hypothesis is that the residuals are not stationary) includes a constant but no time trend, and the number of lags of the first differenced dependent variable is chosen based on the Akaike Information Criteria. The BG P-value is the Breusch-Godfrey P-value of testing the null hypothesis of no autocorrelation, allowing for autocorrelation of the 4th order.

Table A7. OLS regressions results from estimating Equations 1–3

Independent variables	Dependent variables											
	Natural logarithm of real house prices				Natural logarithm of number of property sales				Natural logarithm of mortgage debt ratio			
	P1	P2	P3	P4	T1	T2	T3	T4	D1	D2	D3	D4
Y/Dwell _t		0.22*** (0.049)	0.16*** (0.041)	0.29*** (0.099)		0.21** (0.092)	0.21** (0.09)	0.20** (0.088)		−0.021* (0.0127)	−0.021 (0.013)	−0.02 (0.0137)
HEA1 _{t-1}		−2.74*** (0.576)	—	—		−4.37 (2.973)	—	—		−0.75** (0.364)	—	—
HE _{t-1}		—	−2.83*** (0.625)	−2.53*** (0.655)		—	−5.3* (2.648)	−3.34 (2.91)		—	−0.6*** (0.331)	−0.78** (0.375)
REPAY1 _{t-1}	−29.76*** (3.440)	—	—	−5.46 (3.898)	44.73*** (5.699)	—	—	15.49 (10.219)	−42.22*** (1.735)	—	—	−1.31 (1.265)
UC _{t-1}		0.025 (0.066)	0.053 (0.068)	−0.004 (0.079)		−0.032 (0.281)	0.044 (0.281)	0.10 (0.28)		0.02 (0.018)	0.015 (0.019)	0.02 (0.0186)
PREQ22008		0.0006*** (0.0002)	0.00045** (0.00022)	0.0007** (0.0003)		—	—	—		0.00019** (0.0001)	0.0002** (0.00009)	0.0002** (0.0001)
POSTQ32005		—	—	—		−0.0025** (0.0009)	−0.0022*** (0.00066)	−0.0003 (0.014)		—	—	—
NEW		—	—	—		—	—	—		4.1* (2.241)	3.66 (2.217)	4.26* (2.289)
NEW _{t-1}		22.08*** (6.273)	19.83*** (6.209)	23.78*** (6.759)		36.49* (21.446)	38.38* (21.025)	39.58* (20.7)		3.76* (1.914)	3.43* (1.91)	3.94* (1.974)
OWN _t		—	—	—		—	—	—		0.62* (0.338)	0.57 (0.344)	0.6* (0.344)
1 st lag-dependent variable		0.81*** (0.042)	0.86*** (0.036)	0.76*** (0.085)		1.09*** (0.152)	1.06*** (0.151)	1.03*** (0.15)		0.97*** (0.018)	0.99*** (0.013)	0.96*** (0.033)
2 nd lag-dependent variable		—	—	—		−0.32 (0.2)	−0.282 (0.159)	−0.3 (0.193)		—	—	—
Q3		—	—	—		−0.22*** (0.032)	−0.22*** (0.035)	−0.21*** (0.031)		—	—	—
Q4		—	—	—		−0.21*** (0.037)	−0.22*** (0.034)	−0.21*** (0.035)		—	—	—
Q1		—	—	—		−0.11*** (0.035)	−0.11*** (0.034)	−0.1*** (0.034)		—	—	—
Constant	15.03*** (0.0877)				9.071*** (0.106)				1.279*** (0.0322)			
Wald test HE _{t-1} = REPA1 _{t-1}	—	—	—	0.49	—	—	—	0.05	—	—	—	0.645
P-value												
BG P-value	0.00	0.37	0.42	0.26	0.00	0.55	0.65	0.8	—	0.86	0.84	0.79
Akaike	−40.81	−229.855	−228.196	−228.429	−40.81	−117.3029	−119.45	−120.3214	0.00	−338.4922	−337.4513	−336.76
Schwarz	−37.03	−218.5041	216.8451	−215.1861	−37.03	−98.38465	−100.53	−99.5114	−152.7	−323.6911	−322.6502	−320.11
Durbin-Watson	0.57	1.84	1.87	1.81	0.57	2.05	2.02	1.94	−149.0	2.13	2.07	2.16
P-value ADF test	0.02	0.0002	0.0002	0.0001	0.02	0.00000	0.0000	0.00	0.008	0.026	0.000	0.0334
Obs.	49	49	49	49	49	49	49	49	0.33	47	47	47

Source: Authors' estimations. *, **, and *** denote significance at the 10, 5 and 1 percent, respectively. The associated standard errors are in parentheses. The ADF test that tests for co-integration (i.e., stationarity of the residuals, where the null hypothesis is that the residuals are not stationary) includes a constant but no time trend, and the number of lags of the first differenced dependent variable is chosen based on the Akaike Information Criteria. The BG P-value is the Breusch-Godfrey P-value of testing the null hypothesis of no autocorrelation, allowing for autocorrelation of the 4th order.

Appendix B. Estimating the counterfactual repayment rate

To be able to simulate the effects of the introduction of interest-only mortgages in 2003, we need an estimate of the level of counterfactual repayment rates; that is, the mortgage repayment rates that would have occurred had interest-only mortgages not been introduced. Because all mortgages granted by mortgage credit institutes (MCIs) before 2003 were 30 year annuity mortgages, we need to estimate the repayment rates that would have occurred, had MCIs continued to grant all their mortgages as annuity mortgages. The essential feature of annuity mortgages is keeping the annual nominal mortgage expenditure (including interest rates and repayments) fixed over the entire duration of the loan, which means that (i) the repayment rate will continue to increase as the loan approaches maturity because previous repayments result in reduced interest rate payments; and (ii) the initial amortization rate is inversely related to the mortgage interest rate. We estimate the counterfactual repayment rate by treating the entire mortgage stock as an annuity mortgage stock with 30 years duration. Yearly annuity payments (*Annuity*) in relation to the original loan L_0 are given by (see e.g. Thom, 1983):

$$\underbrace{Annuity}_{rc_n + a_n} = \frac{r}{(1-(1+r))^{-i}} \quad (B.1)$$

Annuity is a function of the mortgage interest rate (r) and the duration time of the loan, i , where $n = 1, \dots, i$. rc_n and a_n are interest rate payments and mortgage repayments in relation to the original loan, respectively. For given values of r and i , one can obtain the value of annuity payments for each period (*Annuity*).

However, there are two complications:

1. rc_n and a_n vary over the duration of the loan, although *Annuity* is fixed. a_n will increase successively as the loan approaches maturity because rc_n decreases when the remaining loan shrinks because of previous repayments. This means that rc_n and a_n depend on the total duration of the loan as well as on the current average age of the mortgage stock (n). n is the average number of years that has passed since all mortgages in the current mortgage stock were granted. However, n is unknown, and must be estimated.
2. Second, having estimated n and using Equation B.1, we can only obtain the repayment rates expressed in relation to the original loan (a_n), but we need to express them as a portion of the remaining loan (i.e., as a portion of the current stock of mortgages).

Below, we describe how we performed steps 1 and 2.

Step 1: Estimating n (the age of mortgage stock)

To estimate the average age of the mortgages stock (n), we compare actual repayment rates with an estimated benchmark repayment rate for a period when interest-only mortgages had not yet been introduced (2003Q1–2003Q3). We estimate n by finding the value that give the smallest difference between actual repayment and the benchmark, given the development of the mortgage interest rate (r) during the same period.

To obtain our benchmark repayment rate, we use the fact that the value of all loans equals the value of the original loan plus interest rate payments minus the value of paid annuities. Starting with the latter, when *Annuity* = 1, the value of all paid annuities up until the n^{th} period, S_a , is (see e.g. McCutcheon and Scott, 1986):

$$S_a = \sum_{k=0}^{n-1} (1+r)^k = (1+r)^{n-1} + (1+r)^{n-2} + \dots + (1+r)^1 + \underbrace{(1+r)^0}_{=1}. \quad (B.2)$$

where the first element in the series is the value of the annuity payment made in period 1 and the last element is the value of the annuity paid in the current period, n . A borrower will not pay interest on repaid amounts or the paid interest that would otherwise have been added to the loan. We develop the expression for S_a as follows (McCutcheon and Scott, 1986):

$$\begin{aligned}
S_a &= (1+r)^{n-1} + (1+r)^{n-2} + \dots + (1+r)^1 + (1+r)^0 \\
S_a(1+r) &= (1+r)^n + (1+r)^{n-1} + \dots + (1+r)^2 + (1+r)^1 \\
S_a(1+r) - S_a &= (1+r)^n - \underbrace{(1+r)^0}_{=1} \\
((1+r) - 1)S_a &= (1+r)^n - 1 \\
S_a &= \frac{(1+r)^n - 1}{(1+r) - 1} = \frac{(1+r)^n - 1}{r} \quad (B.3)
\end{aligned}$$

If the value of the periodical annuity payment (*Annuity*) is not equal to 1, the value of all paid annuities is calculated by multiplying S_a (from Equation B.3) with *Annuity*, ($S_a \times \text{Annuity}$).

If the borrower would have paid zero annuities until period n , the loan would have increased to:

$$L_n = L_0 \times (1+r)^n \quad (B.4)$$

where L_0 is the original loan and L_n is the value of the remaining loan in period n .

We obtain the value for an annuity mortgage in period n by subtracting Equation B.3 from Equation B.4. If the original mortgage equals one unit of capital, ($L_0 = 1$), the remaining loan (L_n) in period n equals:

$$L_n = \underbrace{L_0}_{=1} \times (1+r)^n - \left(\frac{(1+r)^n - 1}{r} \right) \times \text{Annuity} \quad (B.5)$$

We calculate the remaining loan (L_n) for all periods using Equation B.5. Note that when $L_0 = 1$, (L_n) is also the portion of the original loan that is still to be repaid. After estimating L_n , we estimate the interest costs, rc_n , for every period by:

$$rc_n = r \times L_n \quad (B.6)$$

By subtracting Equation B.6 from Equation B.1, we obtain an estimate of a_n :

$$a_n = \text{Annuity} - rc_n \quad (B.7)$$

a_n is the repayment rate expressed in relation to the original mortgage, L_0 , and we need to express it in relation to the remaining mortgage (L_n). This is done by multiplying a_n by $L_0 (=1)$ and dividing by L_n .

$$ar_n = \frac{a_n}{L_n} \times L_0 = \frac{a_n}{L_n} \quad (B.8)$$

We get our estimate of n by comparing ar_n for different values of n with the actual amortization rate over the period 2003Q1–2003Q3. We choose the value of n that minimizes the difference between the actual repayment rates and ar_n . Using this procedure, n is estimated to be 5.3 years. This is within the interval proposed by Madsen and Rasmussen (2013), who state that borrowers normally keep their mortgages for an average of five to eight years before repaying or refinancing their loans. Danish borrowers generally repay

their mortgage quarterly (Falch et al., 2013) and the average yearly repayment rate for the period 2003Q1–2003Q3 is calculated to be 2.39 percent.

Step 2: Estimating the counterfactual repayment rate, assuming that the mortgage stock is 5.3 years old

The counterfactual annual repayment rate for 2004Q1–20013Q3 is calculated under the assumptions that the mortgage stock is 5.3 years old on average and that all mortgages should be repaid within 30 years as annuity mortgages. Consequently, we reuse the same set of equations as when estimating n in step 1; however, we now set $n = 5.3$ years and fix r at the average interest rate for outstanding mortgages from MCIs' net tax for the period.

One complication of fixing n at a constant value is that we do not account for the possibility that n varies over time. For example, according to Madsen and Rasmussen (2013), mortgage refinancing increased between 2003 and 2005, which implies that the mortgage stock could occasionally be younger than our estimate of 5.3 years. In addition, for annuity mortgages, repayments are lower in the beginning and will increase as the loan approaches maturity, which implies that if we overestimate n , we will also overestimate the counterfactual repayment rate. We thus check whether our estimate of the counterfactual repayment rate at least lies in the right interval. The counterfactual repayment rate should be higher than the actual repayment rates for the entire mortgage stock but lower than the repayment rate for the part of the mortgage stock that is still amortized.

Figure B.1 shows our estimated counterfactual repayment rates for mortgages granted by MCIs, actual repayment rates on total mortgages granted by MCIs and the repayment rates for MCIs mortgages that were still being amortized after 2003.

Because the average interest rate for the mortgage stock decreased after 2003, the counterfactual repayment rate has increased. In addition, the actual repayment rate for MCI mortgages that is being amortized has increased, which can be the result either of a reduced mortgage interest rate (assuming that the mortgages are designed as annuity mortgages) or of the age of the mortgage stock that is amortized having increased. An “age effect” may have been particularly prevalent in late 2005, when we can see that the counterfactual repayment rate on MCI mortgages exceeded the repayment rate for MCI mortgages that were still being amortized. One possible explanation is that the average age of the mortgage stock that was still being amortized (n) was temporarily lower than 5.3 years, due to a wave of refinancing that culminated in 2005 Madsen and Rasmussen (2013). When borrowers refinance their loans, it is expected that the average repayment rate for all mortgages will fall because mortgages are transformed to deferred amortization mortgages, and the maturity can be reset to full length for those loans that will still be designed as annuity mortgages. However, except for late 2005, the estimated counterfactual repayment rate lies within the given interval. As Figure B.1 shows, our calculations suggest that the mortgage repayment rate on all mortgages granted by MCIs would have been close to the repayment rate on those MCI mortgages that were still being amortized after 2003, had interest-only mortgages not been introduced in 2003.

Figure B.1. Actual and counterfactual repayment rates on mortgages granted by mortgage credit institutes 2003-2013.

Source: Denmark Statistics, and the authors' calculations.