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Measuring household interest-rate sensitivity in Denmark

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Abstract
In this paper, we evaluate Danish homeowners' interest-rate sensitivity in terms of the partial effect of a 1 percentage point increase in interest rates on homeowners cash flows and balance sheets. We construct two measures to quantify the effect of an increase in interest rates on homeowners. The effect on homeowners' cash flow is measured as the change in the debt service-to-income ratio, i.e. the change in interest and amortisation in per cent of income. The effect on balance sheets is measured as the change in the debt-to-assets ratio, where we model the change in the two primary elements of homeowners' balance sheets: mortgage debt and housing wealth. Overall, the interest-rate sensitivity is limited. Cash-flow sensitivity fell during the 2009-19 period, coinciding with the fall in the aggregate share of outstanding adjustable-rate mortgages, and the fall in outstanding bank loans. The median and upper tails of the distribution of balance-sheet sensitivity fell as well. However, for a non-negligible share of homeowners, an increase in interest rates will have a substantial effect on their cash flows and balance sheets.

Resume
I dette papir evaluerer vi danske boligejeres renteføl somhed i form af den partielle effekt af en stigning på et procentpoint i renterne på husejernes cash flow og balancer. Vi konstruerer to mål til at kvantificere effekten af en stigning i renten på boligejernes økonomi. Effekten på boligejernes cash flow måles som ændringen i gældsserviceringsgraden, dvs. ændringen i rentebetalinger og afdrag som en procentdel af indkomsten. Virkningen på balancerne måles som ændringen i gælden sat i forhold til formuen, hvor vi modellerer ændringen i de to primære elementer i boligejernes balancer: realkreditgæld og boligformue. Overordnet set, så er renteføl somheden blandt husholdnignerne begrænset. Følsomheden i cash flowet er faldet i perioden 2009-19, hvilket er sammenfaldende med reduktionen af den samlede andel af udestående variabelt forrentede realkreditlån og faldet i udestående banklån. Medianen og de øvre haler af fordelingen af balancens følsomhed er også faldet. For en ikke ubetydelig andel af boligejerneejere vil en stigning i renterne imidlertid have en betydelig effekt på deres cash flows og balancer.

Key words
Financial stability; household balance sheets; housing finance.

JEL classification
D14; G21; E21.

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Abstract

In this paper, we evaluate Danish homeowners' interest-rate sensitivity in terms of the partial effect of a 1 percentage point increase in interest rates on homeowners cash flows and balance sheets. We construct two measures to quantify the effect of an increase in interest rates on homeowners. The effect on homeowners' cash flow is measured as the change in the debt service-to-income ratio, i.e. the change in interest and amortisation in per cent of income. The effect on balance sheets is measured as the change in the debt-to-assets ratio, where we model the change in the two primary elements of homeowners' balance sheets: mortgage debt and housing wealth. Overall, the interest-rate sensitivity is limited. Cash-flow sensitivity fell during the 2009-2019 period, coinciding with the fall in the aggregate share of outstanding adjustable-rate mortgages, and the fall in outstanding bank loans. The median and upper tails of the distribution of balance-sheet sensitivity fell as well. However, for a non-negligible share of homeowners, an increase in interest rates will have a substantial effect on their cash flows and balance sheets.

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1 Introduction

In recent years, interest rates have declined, which has supported house price growth and household borrowing. Housing is by far the largest asset of the household sector, and mortgages are similarly the largest liability. Consequently, much literature has focused on the interaction between household consumption, wealth, and debt, which has shown that household housing wealth and debt may play an important role for macroeconomic and financial stability.

Today, nominal house prices are above the levels during the house price bubble seen in the years preceding the recent financial crisis, see Hviid (2017), and aggregate household (mortgage) borrowing is rising, albeit at modest rates. The decline in interest rates has contributed to the inflation of household balance sheets, although previous studies have shown that the low interest-rate environment has also aided leveraged households in deleveraging, see Hviid and Kuchler (2017). A reversal of the decline in interest rates in recent years could potentially have severe consequences for parts of the household sector through primarily two channels: the cash-flow channel and the balance-sheet channel.

In this paper, we evaluate Danish homeowners' interest-rate sensitivity in terms of the effect on cash flows – interest and amortisation payments – and the effect on debt-to-asset ratios. We consider a 1 percentage points parallel upwards shift of the mortgage yield curve as a stylized and interpretable scenario on which to assess homeowners' interest-rate sensitivity. We focus on the short-term effect of an increase in interest rates, and it is thus a partial assessment of the effect on households' cash flows and balance sheets. In the short term, an increase in interest rates will affect the cash-flows of households through increasing payments on their adjustable-rate bank and mortgage loans. Payments on fixed-rate mortgages will not increase in the event of an increase in interest rates. As mortgages constitutes by far the largest share of household debt, homeowners' choice of fixed vs. adjustable-rate loans will to a large extent determine their cash-flow sensitivity. We measure the cash-flow sensitivity as the change in the Debt service-to-income ratio ($DSTI$), i.e. the interest and principal payments on homeowners' loans in per cent of disposable income.

The effect on households' balance sheets is measured as the change in the debt-to-assets ratio (DTA). We consider changes in the value of the two primary elements of homeowners' balance sheets: mortgage debt and house prices. Increasing rates will affect the market value of homeowners' mortgages as mortgage takers have the option of prepaying their loans by buying back the underlying bonds at face value. An interest-rate increase will lead to lower market prices on the bonds backing the mortgages, and house prices would expectedly fall too, thus partially protecting the balance sheets of homeowners from interest-rate increases. However, the duration, and hence interest-rate sensitivity, of bonds differ markedly between bonds financing fixed and adjustable-rate loans, and the choice of mortgage for households thus has a large effect on their balance-sheet sensitivity. Increasing interest rates is also expected

to lead to lower house prices, as increasing user costs of housing in per cent of disposable income, should lead to a downwards pressure on house prices if house buyers are not willing or able to increase the share of income devoted to housing. We model this short-term demand effect by assuming that house buyers will devote a fixed share of income to housing, and that lower demand will affect prices. Differences in user costs due to different effective tax rates on housing and differences in choices of financing leads to different house price effects across municipalities.

To the best of our knowledge, no one has previously addressed the implications of the balance-sheet channel across the distribution of households. The cash-flow channel has been the main focus in previous studies, finding that the household sector is generally robust to a modest interest-rate increase (See e.g. Hviid and Kuchler (2017)). Despite some investigations, little is known about the distribution of cash-flow risk across individual households, and in particular about the interaction of the cash-flow channel and the balance-sheet channel with one another. The cash-flow and balance-sheet channels affect aggregate demand through changes in the disposable income of homeowners and through the wealth and/or collateral effect. Assessing the heterogeneity of interest-rate sensitivity across households contributes to understanding the effect of increasing interest rates on aggregate demand. Additionally, the balance-sheet channel has implication for the mortgage institutions and banks. In case of an interest-rate increase and subsequent house price depreciation, lenders have to set aside supplementary capital and in the case of household default, financial institutions can expect a larger loss on the loans. In this way, an interest-rate increase has first order implications for the performance of financial institutions through write-offs and losses.

We use the rich Danish register data coving the 2009-2019 period to assess the implications of a 1 percentage point increase in the entire yield curve on individual household's DSTI and DTA. The rich data in the mortgage registry allows us to assess the effects of an interest-rate increase on interest payments, amortisations, and the market value of every outstanding mortgage. In particular, it allows us to distinguish between the effects on adjustable-rate mortgages (ARMs) and fixed-rate mortgages (FRMs) together with the interest-only (IO) version of the two, which has sizeable implications for the interest-rate sensitivity of cash flows and balance sheets.

Our findings confirm previous results that overall interest-rate sensitivity seems to be modest. However, 10 per cent of households have a cash-flow sensitivity of over 2.5 per cent of income, over 7 times as high as the median household. Additionally, we also find that there are non-trivial differences between ARM and FRM borrowers, with ARM borrowers being much more exposed to interest-rate increases both in terms of DTA and DSTI. In particular, we find that the sensitivity of the cash-flow and balance-sheet channels complement each other in that certain types of highly leveraged households are severely exposed to increasing interest rates. In addition, we find that interest-only mortgages too contribute to higher cash-flow sensitivity. In general, we find that cash-flow sensitivity is decreasing with income and increasing with

debt. When looking at balance-sheet sensitivity for house buyers, we find that the risk is centred around the larger cities, which is primarily explained by two factors: relatively more appetite for adjustable-rate mortgages and interest-only mortgages, and greater interest-rate sensitivity of housing assets in these areas.

Our approach is partial and focused on the very short term, meaning that extrapolation of our results to a long period of higher interest rates should be done with caution. In the longer run, higher interest rates would affect economic activity, giving rise to general equilibrium effects from which we abstract. Additionally, we do not address the causes of the interest-rate movement, which in itself might have adverse effects on economic activity, nor do we provide measures of the probabilities that such a scenario would arise. Our results should be interpreted as the first-order effect on households' cash flows and balance sheets from an exogenous shift of the yield curve.

The results presented here relate to several other strands of the literature. First and foremost they relate to work adressing the cash-flow sensitivity of housholds, which is directly adressed in Hviid and Kuchler (2017), finding that the effect of the cash-flow channel is modest for most households, but larger for at-risk households with higher debt and adjustable-rate mortgages in particular, which we confirm. Similarly, Andersen et al. (2012) find that Danish households are robust to an increase in the interest rate and periods of unemployment, which for most households would constitute an even larger shock to the cash flow than an interest-rate increase. As an extension, Andersen and Duus (2013) provide evidence that the probability of Danish households falling into arrears is very low, and even severe shocks, including a substantial increase in the interest-rate level, would seem to have only a limited impact on the probability of families falling into arrears. Using Swiss loan-application data, Brown and Guin (2015) find limited risk in the short term from an interest-rate increase, but find some risks in the longer term.

More generally this paper relates to the consumption decission of households, for which Ganong and Noel (2020) show that changes in household liquidity have a significant impact on household consumption (and default risk), whereas wealth itself has little or no effect, while both Andersen and Leth-Petersen (2021) and Stefani and Hviid (2019) show that (unexpected) house price changes have a significant impact on household consumption in Denmark. This paper also relates to the household decissions about mortgage choice addressed in many papers following Campbell and Cocco (2003) with regard to interest-rate risk specifically in Coulibaly and Li (2009) and Badarinza et al. (2018). Although we do not address consumption/saving decisions in this paper specifically, we point to important channels through which increasing interest rates can impact consumption/saving over the distribution of households.

Another strand of the literature that this paper is related to is the rapidly developing one of HANK models addressing the effects of monetary policy with heterogeneous agents, see e.g. Kaplan and Violante (2018) for an overview, and Kaplan et al. (2018) for a specific model

addressing monetary policy. We illustrate some of the key dimensions in which interest-rate changes would affect households' intertemporal optimisation problem, which we hope can guide future research into heterogeneous agent modelling. Crawley and Kuchler (2020) go a bit further in this respect, using Danish microdata where they estimate the marginal propensity to consume and find that given a 1 percentage point increase in the interest-rate level, an interest-rate exposure channel leads households with higher levels of cash-flow risk to adjust consumption relatively more.

The remainder of this paper is organised as follows. Section 2 describes the institutional setting of the Danish mortgage system. Section 3 describes the data used. Section 4 then introduces our measures of the financial stance of households, on which section 5 provides descriptive statistics. Section 6 develops the interest-rate sensitivity measures, which are presented in section 7. Section 8 concludes.

2 Overview of the Danish mortgage system

House purchases in Denmark are primarily financed with mortgages. Households usually obtain a mortgage through contact with their bank, as most Danish mortgage credit institutions are part of groups comprising both a bank and the mortgage credit institution.[1] Households can finance up to 80 per cent of the property value through mortgages, and any remaining financing must be obtained with other types of financing, most typically bank loans. The Danish mortgage system is well-established, large, and is considered to be relatively efficient as mortgage financing is relatively cheap in an international comparison. The Danish mortgage credit institutions only offer loans secured against real estate and work as financial intermediaries between investors and borrowers in a pass-through system. Credit mortgage institutions are non-deposit takers meaning that all loans are financed through the issuance of covered bonds. When households are granted a mortgage loan, the mortgage credit institution issues bonds that are sold to investors. The Danish mortgage system is characterised by a large number of long-term, fixed-rate loans and the use of the balance principle and match-funding. This means that a loan is matched by the issuance of a bond, and that households have the option of prepaying fixed-rate loans without penalties by rebuying the bond at face or par value at any time up until maturity. If the market rate has risen since the origination of the mortgage, the market value of the debt thus decreases. Falling interest rates do not lead to increasing debt for households with fixed-rate mortgages, as the mortgages can be prepaid at par value. The value of this option is embedded in the effective interest payments of the mortgage borrower.

[1] The largest Danish mortgage credit institution, Nykredit, has a partnership with several banks that are not part of groups comprising both a bank and a mortgage credit institution. Through the partnership agreements, these banks offer mortgage loans to their customers. The credit assessment of customers is done by partnership banks under some general guidelines from the mortgage credit institution.

Most mortgages have an original maturity of 30 years, but can have different characteristics. The majority of Danish households can chose from mortgages with fixed or adjustable interest rates, with or without amortisation. However, some households that are relatively highly leveraged have been subject to various restrictions in recent years.[2] Fixed-rate mortgages (FRM) have a fixed interest rate until maturity, i.e. up to 30 years. Depending on the type of adjustable-rate mortgage (ARM), loans can have interest rates that are adjusted every three months and up to every ten years. For ARMs with interest rates adjusted more than once a year, the interest rate follows the CITA[3] rate with a surcharge, and the loans are financed with bonds with longer time to maturity than the loans - in contrast to all other mortgages. For ARMs with interest rates adjusted yearly or at longer intervals, the underlying bonds reach price 100 at the time of refinancing. Furthermore, mortgages can be without amortisation for up to ten years. Household wanting another period with an interest-only loan (IO) then needs to refinance the mortgage.[4] Interest payments go directly to the bond holder, and households pay an administration fee (bidrag) to the mortgage credit institution, which is a percentage of the outstanding debt and depends on type of loan and Loan-to-Value (LTV). Overall, the Danish mortgage system is unique in an international comparison, but does share some similarities to the US system, see Campbell (2013). It is noteworthy that there is no credit scoring used when the administration fee is determined, which is one of the main differences compared to e.g. the US mortgage system, and the administration fee is thus unrelated to the creditworthiness of the household beyond what is captured in the LTV.

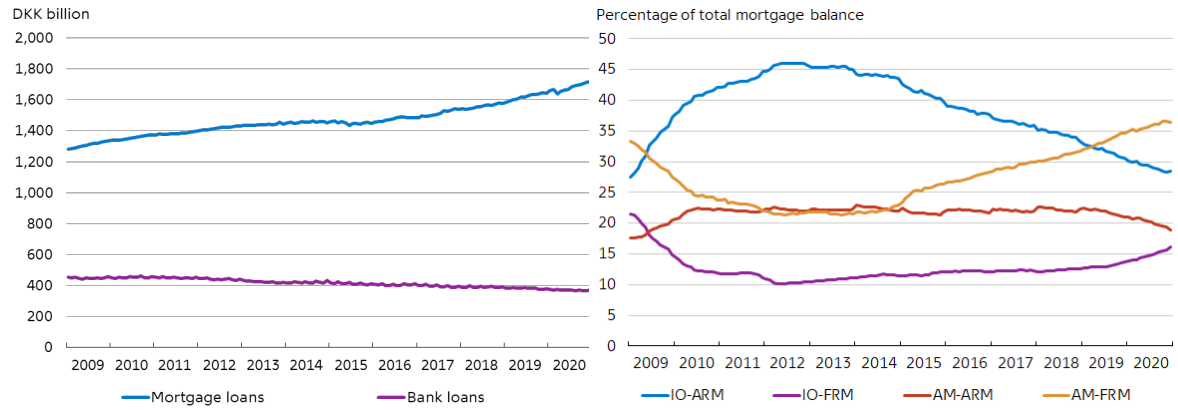
Mortgage debt for households generally rose between 2009 and 2020, cf. Figure 1 (a). The rate of growth of mortgage debt fell until 2014, after which it started to increase, albeit at modest rates. Bank debt of households generally fell since 2009, and in 2020 the amount of bank debt was 20 per cent lower than in 2009. A similar development can be seen at the household level (see Appendix A, Figure 3). The share of household debt which is banks loans has thus been decreasing, which ceteris paribus has contributed to less cash-flow sensitivity over the sample period, as bank debt is primarily adjustable-rate loans. Total debt has been rising at a slower pace than house prices since 2013, and the household sector has thus experienced a decline in DTAs.

[2]For an overview of borrower-based macroprudential measures introduced in Denmark, see Mogensen and Bohn-Jespersen (2018)

[3]Copenhagen Interbank Tomorrow/Next Average.

[4]Recently, Danish mortgage credit institutions started to offer mortgages without amortisation for up 30 years. The possibility of paying interest only for up to 30 years is only offered to households with an LTV below 75 per cent subject to a requirement of reducing it to below 60 before interest-onlyness applies.

Figure 1: Household mortgage and bank debt and distribution of mortgage debt across loan types

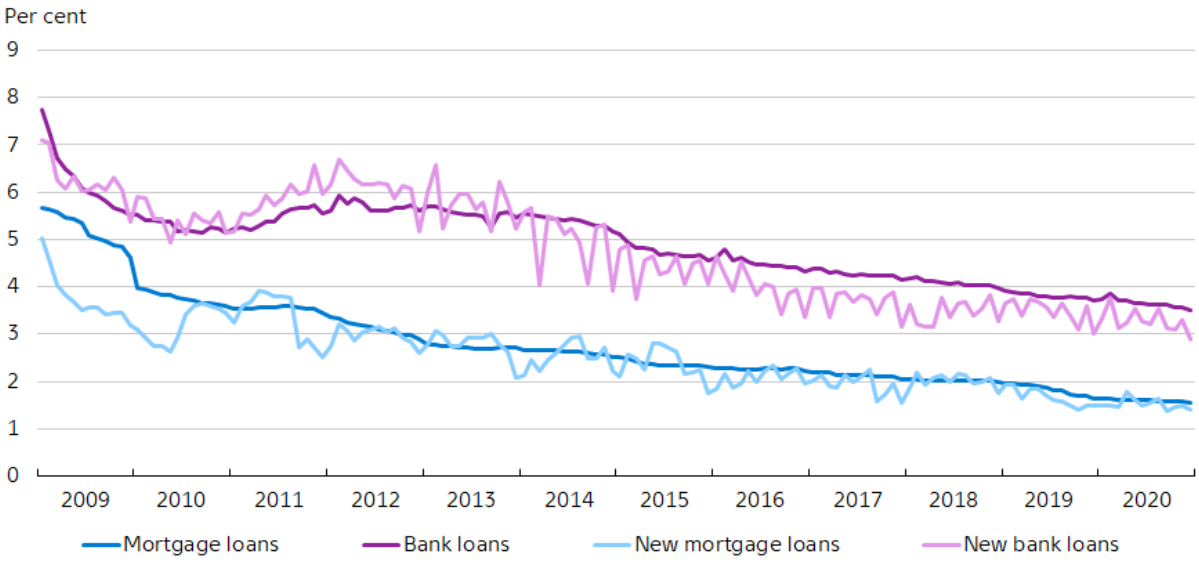


(a) Outstanding mortgage and bank debt (b) Outstanding mortgage debt across loan types

Notes: Mortgage and bank debt of households (a). Bank debt is lending to Danish employees, pensioners etc., i.e. excluding self-employed individuals. Mortgages debt is lending from mortgage credit institutions to Danish households for owner-occupied homes and summer cottages. Distribution of mortgage types for households (b) as percentages of outstanding mortgage debt. IO refers to interest-only mortgages, AM refers to mortgages with amortisation, FRM refers to fixed-rate mortgages, and ARM refers to adjustable-rate mortgage. Data is from Danmarks Nationalbank's MFI statistics.

The share of outstanding adjustable-rate mortgages increased from 2009 to 2012 as interest rates on adjustable-rate mortgages fell, cf. Figure 1 (b). Interest rates on fixed-rate mortgages fell as well, but to a lesser extent than for adjustable-rate mortgages. Beginning in 2013, the share of adjustable-rate mortgages started to fall. The flattening of the yield curve is expected to have contributed to the movement into fixed-rate mortgages. As the difference in the effective rate between fixed and adjustable-rate mortgages has narrowed, an increasing number of homeowners have opted to insure themselves against increasing interest rates by choosing fixed-rate mortgages – either by refinancing of their existing mortgages or through their choice of mortgage in connection with housing purchases. The increasing share of fixed-rate mortgages since 2013 has contributed to lowering the cash-flow sensitivity of households, which we will show later. In 2020, the share of FRMs exceeded ARMs for the first time since 2009.

Figure 2: Rates on bank and mortgage loans for households



Notes: Average annual effective interests rate on bank and mortgage loans to households. For mortgage loans, the effective interest rate includes administration fees. Data is from Danmarks Nationalbank's MFI statistics.

In just over a decade, households borrowing costs have decreased substantially, cf. Figure 2. The effective interest rate on new mortgages fell substantially in 2009 and at the beginning of 2010, which should be seen in light of the increasing share of adjustable-rate mortgages taken up in this period. The effective rate declined continually over the sample period as both long and short rates declined. However, the fall is counteracted somewhat by a general increase in administration fees on mortgages introduced by mortgage banks since 2011. The effective rate on bank loans has fallen as well since 2013.

3 Data description and sample selection

We use Danish register data from Statistics Denmark covering the full population of households in the 2009-2019 period. The registers are primarily administrative datasets containing third-party reported data to the tax authorities. Data on individuals is aggregated to household level using Statistics Denmark's family identifier.[5] We define our sample based on the

[5] A family consists of either one or two adults plus any co-habiting children. Two adults are considered to be a family if they live together, and i) are spouses or registered partners, ii) have one or more joint children registered in the Civil Register (CPR), or iii) are of opposite sexes and with an age difference of less than 15 years, are not close relatives and live in a household with no other adults. Adults living at the same address who do not meet at least one of the above criteria are counted as members of different families. Children living at home are counted as members of their parents' family if they are under the age of 25, live at the same address as at least one of their parents, have never been married or in registered partnership and have no children registered in CPR. Given these criteria, a family may consist of two generations only. If more than two generations are living at the same address, the youngest family consists of the two youngest generations.

population register (BEF), which has information about age, gender, family and residence of every individual living in Denmark at the beginning of each year. This data is merged with the income registry (IND) and the wealth and debt register (FORMGELD) to obtain information on the households' income, wealth, and debt components.

To identify a household's loans and the composition thereof, we use two different data sources. We rely on the register mortgages (REAL) to give us information on all mortgage loans held by a household. We can identify both the household that holds the mortgage but also the property that has been used as collateral for a particular mortgage. The REAL register covers all mortgage loans to Danish households. The register contains information on loan characteristics such as interest, amortisation profile, maturity and outstanding debt. For 2019, the REAL register is constructed on the basis on the Danish credit register. This can cause minor differences in some variable definitions compared to previous years. Administration fees are reported differently, however. For 2019, only the administration fees for the fourth quarter are reported in the register, while for previous years, the administration fee for the entire year was reported. Consequently, a level shift is seen in the distribution of administration fees in 2019, and thus also in DSTI. For bank loans, we rely on the income register (IND), which contains information on outstanding debt to banks and the interest payments made during a given year.

We supplement the register data with data coming from the Danish Collateral Registry, *Tingbogen*. Data from the Danish Collateral Registry provides information on all loans secured against property both inside and outside financial institutions. The data is at the property level, and can be merged with other administrative data based on a unique property identification number. The Danish Collateral Registry is a public register containing information about ownership of a given property and collateral in that property. When a property changes ownership, the new owner must be registered in the Danish Collateral Registry, and all loans secured against the property are also contained in that register. The data enables us to separate a household's debt into loans that are either secured or not against the household's property. We use this distinction when modelling how house prices are affected by a change in interest rates.

We focus on households that own at least one house and are residing in Denmark. We exclude households in which at least one member is not fully taxable in Denmark and households with after-tax income of less than DKK 2,000. Self-employed households are excluded as their income and wealth information is measured imprecisely. Finally, we exclude households with properties worth less than DKK 5,000. After these exclusions, our sample consists of roughly 1.3 million households each year.

4 Measures of household financial stance

We construct two measures to evaluate the financial stance of Danish households. First, we use the debt service-to-income (DSTI) measure to evaluate the households' ability to service their debt. This measure is closely related to the housing burden, as debt service costs makes up a large part of the housing burden. Second, we apply the debt-to-asset (DTA) ratio to evaluate the ability of the households to absorb shocks to their balance sheet, specifically outstanding mortgage debt and housing assets. Based on register data at the end of year t, we calculate the interest and amortisation payments to be made in the coming year relative to income, DSTI. We refer to variables taken from the register data for a given year with a subscript t, and calculations based on these variables regarding interest-rate sensitivity in the coming year with a subscript $t+1$.

4.1 Cash flow of households

We define DSTI as the interest, administration fees, and amortisation payments to be paid on bank and mortgage debt in the coming year as a percentage of household income after tax, net of tax deductions due to interest payments. We calculate DSTI_{t+1} as:

$$DSTI_{t+1} = 100\frac{Amortisation_{t+1} + (Int_{t+1} + Adm_{t+1})(1-\tau_{t+1})}{Income\ after\ tax_t + (Int_{t+1} + Adm_{t+1})\tau_{t+1}} \tag{1}$$

where $Amortisation_{t+1} = Amortisation^{bank}_{t+1} + Amortisation^{mort}_{t+1}$ is amortisation payments on bank and mortgage debt in year $t+1$, and $Int_{t+1} = Int^{bank}_{t+1} + Int^{mort}_{t+1}$ is interest payments on bank and mortgage debt. Adm_{t+1} is the administration fee paid to the mortgage institution. Interest and administration expenses are eligible for tax deductions, and thus reduce taxable income. We measure expenses after taxes. The after-tax value of interest and administration expenses differs from municipality to municipality due to different marginal tax rates, τ_{t+1}, in the municipalities.[6] We control for these differences in the calculations. The income register data contains data on household income after tax as assessed by the Danish Tax Agency in the yearly tax assessments, and is thus net of tax deductions due to interest expenses. We add the tax value of these expenses to the income measure. We implicitly assume that household income is unchanged over the coming year, as we take the income from register data.

The mortgage loan register has information on the current interest rate on the mortgage, the amount of outstanding debt, the original and remaining times to maturity, the number

[6]For households with one adult, 33.6 per cent of interest expenses up to DKK 50,000 can be deducted from taxable income, and 25.6 per cent of expenses above DKK 50,000 can be deducted. For households with two adults, the limit is DKK 100,000. The deduction rate for interest expenses exceeding DKK 50,000 (DKK 100,000 for two adults) has been gradually reduced from 33.7 per cent in 2010 to 25.6 per cent in 2019.

of payments during a year, and whether the household is currently making amortisation payments or not. Using this information, we calculate the interest and amortisation payments of an annuity using the mortgage level information to obtain $Amortisation_{t+1}^{mort}$ and Int_{t+1}^{mort}. The administration fee Adm_{t+1} is obtained directly from the register data. For interest-only mortgages, interest payments are calculated as the interest rate multiplied by the amount of outstanding debt. Some mortgages have a negative interest rates. For these loans, the negative interest payments are assumed not to reduce the amount of outstanding debt. Some mortgage institutions offer ARM with fixed-term payments where the remaining maturity is adjusted to reflect changes in the interest rate. These mortgages can be identified in the register data, and for these mortgages, an interest-rate increase results in a longer maturity unless the original maturity increases to more than 30 years.

For bank debt, we only have information about the amount of outstanding debt and interest payments made during a given year and must thus make a number of assumptions about interest rates and amortisation payments. We calculate the interest rate as $i_{t+1}^{bank} = \frac{interest\ payments_{t+1}}{\frac{1}{2}(Bank\ debt_{t+1}+Bank\ debt_t)}$ where $Interest\ payments_t$ are interest payments paid in year t, and $Bank\ debt_t$ is outstanding debt at the end of year t. For households without bank debt at $t-1$, we calculate the interest rate as interest payments divided by outstanding bank debt at the end of year t. In order to calculate amortisation payments, we take different approaches for households that have reduced and increased the amount of outstanding bank debt, respectively. For households that have reduced their outstanding debt, we assume that they make the same amount of amortisation payments in the coming year, $amortisation_{t+1}^{bank} = \Delta bank\ debt_t$. For households that have increased the amount of debt, we calculate amortisation payments as the amortisation part of an annuity payment based on the calculated interest rate i_t^{bank} and the average maturity of new bank loans. The average maturity of bank loans is calculated on the basis of information from *Raad Til Penge*[7], which has information on original time to maturity of bank loans secured against real estate. We assume that bank loans not secured against real estate have an original time to maturity of five years. To get the average maturity of all bank loans, we weigh information on maturity with average of outstanding debt in the MFI statistics. The average maturity is 15 years. Interest payments in the coming year are calculated as:

$$int_{t+1}^{bank} = i_{t+1}^{bank}\frac{1}{2}(Bank\ debt_t + Bank\ debt_{t+1} - Amortisation_{t+1}^{bank}) \tag{2}$$

The calculation of interest rates on bank loans naturally leads to approximation errors for some of the households. However, the impact on the DSTI is limited, as most household debt is mortgage debt, for which we have access to the exact interest rates.

[7]The information is retrieved from raadtilpenge.dk/Gode-raad/boliglaan/tjekboliglaan.

4.2 Balance sheets of households

DTA is defined as total household debt as a percentage of total household assets. Total household debt consists primarily of mortgage and bank debt, but also includes other types of debt reported to the tax authorities. Mortgage debt is always secured against real estate. Debt to commercial and savings banks may or may not be secured against real estate. Total household assets include both financial assets and real estate, where the property value is measured by the current market price as reported by mortgage institution implicitly via LTVs in the mortgage registry. Financial assets included are deposits, bonds, mortgage deeds, and stocks. Pension wealth is not included in total assets. Neither are cash, art, or cars. The DTA is calculated as:

$$DTA_t^i = 100\frac{Debt_t}{Assets_t}. \tag{3}$$

We measure the level of debt net of amortisation payments in the coming year, hence $Debt_t = Debt_{t-1} - amortisation_t$ is debt at the end of year t less amortisation payments during year $t+1$. Except for amortisation payments, all information used for DTA is taken directly from the register data.

5 Financial stance of Danish households

Table 1 reports summary statistics of the types of debt of homeowners. Of the 1.3 million homeowners in our sample for 2019, 88 per cent have outstanding debt. We exclude families without debt from the analysis as they have no interest-rate sensitivity in terms of the two measures we are considering in this paper. This results in 1.1 million homeowners being potentially exposed to interest-rate increases. Of these families, 81 per cent have bank debt. These families will experience an increase in DSTI as we assume all bank debt to be variable-rate loans. 85 per cent of families with debt have one or more mortgages, equating to just under one million homeowners. In the third column of Table 1, these families are sorted according to the type of mortgage loan they have. Just half of homeowners with mortgage debt have mortgages with fixed rates only. 39 per cent pay adjustable rates on all their mortgage debt. 29 per cent are paying interest only on their mortgage debt, and 13 per cent of homeowners have multiple types of mortgages.

The last four rows sort homeowners with mortgages according to their largest mortgage (in case they have more than one type of mortgage). Roughly half of homeowners have fixed-rate mortgages as their primary mortgage type, and the other half of homeowners have adjustable-rate mortgages.

Table 1: Types of debt of homeowners

	All	- with debt	- with mortgage debt
Share of households with debt	0.88		
- of which have			
Bank debt		0.81	
Mortgage debt		0.85	
- of which have			
AM-FRM only			0.38
AM-ARM only			0.20
IO-FRM only			0.10
IO-ARM only			0.19
Multiple mortgages types			0.13
- primary mortgage type			
IO-ARM			0.24
AM-ARM			0.23
IO-FRM			0.12
AM-FRM			0.41
Observations	1,301,612	1,145,388	976,367

Notes: Summary statistics on types of debt of homeowners at the end of 2019. In the third column, households with mortgage debt are sorted according to mortgage types. AM-FRM covers families with fixed-rate mortgages with amortisation and no other types of mortgages. Multiple mortgage types covers families with more than one of the four main types of mortgages. The last four rows sorts homeowners according to their largest mortgages.

Table 2 shows summary statistics for homeowners with debt. Homeowners have average debt of DKK 1.6 million, with mortgage debt accounting for the majority of household debt. There is considerable variation in the amount of debt of households. The standard deviation is much larger than the mean, and the distribution is very right-skewed. Real estate is the largest asset of homeowners, and liquid assets (deposits, bonds and mortgage deeds) are the second-largest asset, with deposits being by far the largest component of liquid assets. On average, the net wealth of homeowners is positive, however the 10^{th} percentile have negative net wealth, which is also reflected in the 90^{th} percentile of the DTA distribution exceeding 100 per cent. Homeowners spend an average of 19 per cent of their after-tax income servicing debt, and more than 10 per cent of homeowners spend more than a third of their income. Table 3 in Appendix A shows median statistics for 2009-2019.

Table 2: Summary statistics for homeowners with debt

	mean	sd	p10	p50	p90
Total debt	1,596,642	2,101,224	318,000	1,257,116	3,086,881
Bank debt	340,712	1,434,396	0	120,520	796,952
Mortgage debt	1,250,518	1,408,595	0	984,008	2,646,962
Wealth	3,106,890	6,724,431	948,265	2,340,670	5,686,735
Real estate	2,518,197	2,252,013	805,860	1,973,400	4,676,100
Net wealth	1,510,248	6,421,328	-160,613	904,082	3,622,867
Deposits, bonds, mortgage deeds	329,596	855,768	24,469	151,183	768,232
Deposits	321,967	673,707	24,429	150,827	763,387
Income before tax	761,979	986,559	290,091	673,256	1,242,175
Income after tax	491,190	565,914	204,121	450,328	775,859
Age	56	15	35	55	76
DSTI	19	38	3	15	34
DTA	60	114	13	55	107

Notes: Summary statistics for homeowners with debt at the end of 2019. sd denotes standard deviation. p10, p50, and p90 are the 10^{th}, 50^{th}, and 90^{th} percentile, respectively. Households that are self-employed, not fully taxable in Denmark, have after-tax income less than DKK 25.000, or have housing wealth less than DKK 5.000 are excluded.

Looking back, the distribution of DSTI shifted downwards from 2009 to 2015, with both the median and the tails of the distribution falling, cf. Figure 3. Since 2015, the level of DSTI has been fairly stable, with only minor changes to the distribution. The DTA distribution generally shifted upwards until 2012. Since then, the median and upper tails have been falling, whereas the lower tail has not shown any significant change. The DTA distribution is to a large extent driven by house price developments as real estate is the largest component of household assets. The fall in house prices from 2010 to 2012 and the subsequent continued increase are reflected in the DTA distribution. Note that a debt-to-assets ratio of more than 100 per cent does not necessarily mean that households have more debt than assets, as the measure of assets does not include all real assets, most importantly cars.

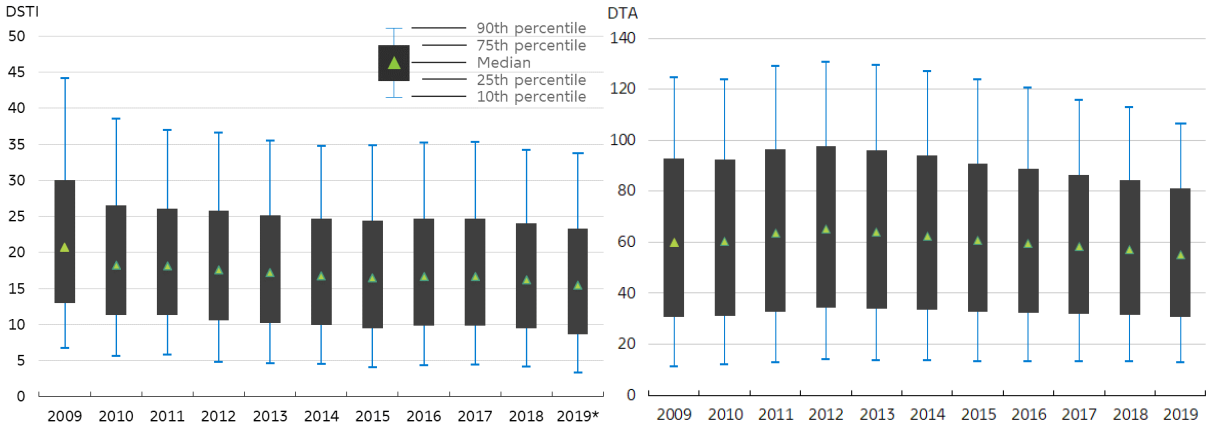
Whereas the distribution of DSTIs has changed very little, the composition of interest payments, amortisation payments, and administration fees has changed significantly, cf. Figure 4. Several developments affect the composition of debt service payments. Falling interest rates have contributed to a continued downward shift of the distribution of interest payments. In 2019, the median and upper tails of the distribution decreased noticeably, reflecting the large share of homeowners who chose to refinance their fixed-rate mortgages, resulting in lower interest payments. The level of outstanding bank debt has been trending downwards over the sample period, contributing to both lower interest payments as bank loans typically have a

higher interest rate than mortgages. However, the tax-deduction rate for interest expenses of more than DKK 50,000 (DKK 100,000 for two adults) has been gradually reduced, somewhat counteracting the reductions in interest rates, even though only 3 per cent of households have interest payments above this threshold. The median and upper tail of the distribution of amortisation payments have increased since 2011, both as a consequence of a smaller share of interest-only mortgages and because falling interest rates shifts the composition of annuity payments towards amortisation payments for flexible-rate mortgages. The lower tail of amortisation payments is close to zero for all years, as interest-only loans accounts for a substantial share of household mortgages for all years.

From 2009 to 2016, administration fees have been rising, somewhat counteracting the declining interest payments. Administration fees depend on the type of mortgage a household has. The administration fee paid to the mortgage credit institution is a percentage of the outstanding debt and is lowest for AM-FRMs. IO mortgages pay a higher percentage, as do ARMs, with IO-ARMs paying the highest percentage of outstanding debt as administration fees. All the mortgage credit institutions have increased administration fee percentages over the sample period. This has contributed to the upwards shift in the distribution. The increasing share of AM-FRMs and decreasing share of IO-ARMs have, however, counteracted this development, cf. Figure 1. The 10^{th} percentile is zero for all years, reflecting that more than 10 per cent of homeowners do not have any mortgage debt. It should be noted that the distribution of administration fees in 2019 is not directly comparable to previous years.

A particular group of households actively re-optimise their respective balance sheets, namely housing buyers. Typically, the housing investments of households come with a significant increase in balance sheets, which has long-term impacts on future interest-rate sensitivity. The DSTI and DTA distribution for house buyers, covering both first-time and repeat buyers, is presented in Figure 17 in Appendix C. House buyers have chosen to spend a fairly stable share of their income on servicing debt since 2014, with the median house buyer spending just below 20 per cent of income servicing debt. The upper tail of house buyers, however, spend over 40 per cent of income on debt service. The median, upper and lower tails of the DTA distribution for house buyers have been fairly stable over the sample period. The 75^{th} percentile has declined somewhat in recent years, falling to 95 per cent in 2016. This might reflect the fact that house buyers have been required to finance 5 per cent of house purchases with equity since 2015. The distribution of interest, amortisation payments and administration fees show similar developments for all homeowners, with all the components of the debt service payments constituting a larger share of disposable income for house buyers than for all homeowners, cf. Figure 18.

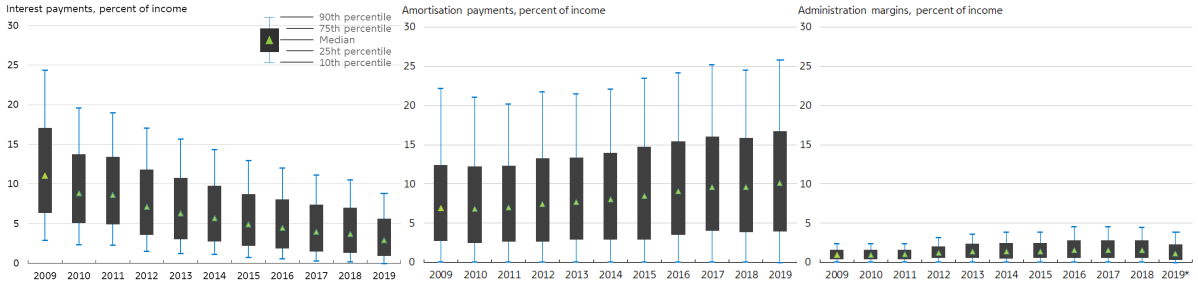
Figure 3: DSTI and DTA distribution for 2009-2019



(a) DSTI (b) DTA

Notes: Box plots of the debt service-to-income (a) and debt-to-assets (b) distributions for 2009-2019 for households with debt. (*) In 2019, the administration fees include only fees paid in the 4^th quarter of 2019. The distribution of DSTI in 2019 is thus not directly comparable to previous years.

Figure 4: Distribution of DSTI components for 2009-2019



(a) Interest payments (b) Amortisation payments (c) Administration fees

Notes: Box plots of the components of the debt service-to-income, distribution for 2009-2019, measured relative to after-tax income. (*) In 2019, the administration fees include only fees paid in the 4^th quarter of 2019. The distribution of administration fees in 2019 is thus not directly comparable to previous years.

6 Construction of interest-rate sensitivity measures

We use two measures, DSTI and DTA, to construct measures of interest-rate sensitivity in order to evaluate the exposure of households to interest-rate increases. We are considering a 1 percentage points upward shift of the yield curve as a stylised and interpretable scenario on which to assess homeowners' interest-rate sensitivity. The measures are intended to capture the short-term effects on households' cash flows and balance sheets households are facing over the coming year, and it is thus a partial assessment of the effect of an interest-rate increase on households. Section 6.1 presents the methodology for the effect on households' cash flows, which we measure by the change in the debt service-to-income ratio, $\Delta DSTI$. In section 6.2.1 we

present the method for calculating reductions in house prices at the municipal level. In section 6.2.2 we present the methodology for calculating the reduction in market prices of mortgage bonds.

6.1 Cash-flow effects on household budgets

The measure for the interest-rate sensitivity of house owners' cash flow is the change in the DSTI in percentage points:

$$\Delta DSTI_t^{i+1} = DSTI_t^{i+1} - DSTI_t^i. \tag{4}$$

We calculate the debt service-to-income ratio at a 1 percentage point higher interest rate, $DSTI_t^{i+1}$, in the same way as the $DSTI_t^i$ in section 4.1, but replace the actual interest rate with a 1 percentage point higher rate. All other variables are unchanged including with household borrowing behaviour. For households that will experience higher rates on their debt, interest and amortisation payments change, but administration fees are unchanged. Whether households will experience an increase in debt-service payments depends on their types of loans. Not all households with adjustable-rate mortgages will experience an immediate increase in their debt service ratio, as adjustable-rate mortgages are adjusted it intervals ranging from three months to ten years. The mortgage loan registers contains information about the rate adjustment intervals and the loan origination date of each single loan. We can therefore identify the adjustable-rate loans that are subject to a new interest-rate fixation in any given year, and we take this into account when calculating the change in the debt service. Administration fees are not affected by an interest-rate hike. For bank loans, we assume that all interest rates on all bank debt are adjusted. The interest and amortisation payments will thus be affected for all bank loans. The *change* in DSTI is much less sensitive to the potential approximation errors mentioned earlier in the interest-rates levels of bank debt. The change in DSTI for a 1 percentage point interest-rate increase should thus be a very precise measure of the cash-flow sensitivity of the households.

6.2 Balance-sheet effects of changing interest rates

We measure the effect on the balance sheets of homeowners of a 1 percentage point higher interest rate as the change in the DTAs in percentage points:

$$\Delta DTA_{t+1}^i = \frac{Debt_t + \Delta Mortage\ bonds\ price}{Assets_t + \Delta Property\ price} - \frac{Debt_t}{Assets_t} \tag{5}$$

The effect on the balance sheets of individual households will depend mainly on their type of debt. For households with fixed-rate mortgages, the market value of the mortgage debt will fall. The extent to which it falls depends primarily on the time to maturity of the loan and whether the loan has deferred amortisation. The value of bank loans is unaffected by changing interest rates. For households with mortgages of very limited duration, i.e. primarily households with flexible-rate loans, only the value of the assets will fall. For these households, the balance-sheet sensitivity is thus approximately $\Delta\text{DTA} = 100\frac{Debt_t}{Assets_t}\frac{1}{1+x}$, where $x = \frac{\Delta H_t}{H_t}$ is the change in the housing value, H_t, relative to the housing value. In this case, the percentage point change in the DTA ratio is thus roughly linear in the percentage change in house prices for small changes in housing values. For larger changes in the housing values, the change in the DTA is concave. Some households hold significant wealth in financial assets, however we do not know the composition of these assets, nor do we have a meaningful approach to addressing the interest-rate sensitivity of these assets, hence, we leave such assets aside as unchanged wealth components in the measurement of ΔDTA, but note that these households are concentrated in the highest percentiles of the wealth distribution.

6.2.1 Modelling changes in house prices

An increase in interest rates will, ceteris paribus, cause house prices to fall. As the payments on loans increase due to higher interest rates, the housing burden as a percentage of disposable income will increase. House buyers will be faced with higher financing costs, and if house buyers are not willing to spend a larger fraction of income on housing – or if the bank is not willing to allow it – there will be a downward pressure on house prices due to lower demand from house buyers. We model this demand-driven effect using the housing burden for all house buyers in a given year. We consider only the first-year housing burden for house buyers. Some households may be credit-constrained and find it easier to relate to the first-year housing burden than the housing burden over the entire lifetime of their housing investment, see e.g. discussions in Dam et al. (2011). Furthermore, households tend to focus on short-term costs and liquidity when choosing between different financing options of their house purchases (Badarinza and Ramadorai (2018)). The distribution of DSTI for house buyers, which is part of the housing burden, has been fairly stable in recent years, see Figure 17 in Appendix A, even though interest rates on both mortgages and bank loans have fallen. We therefore assume that potential house buyers will choose the same first-year housing burden as a percentage of disposable income for a given house purchase in the event of an 1 percentage point increase in interest rates. This assumption allows us to predict the effect of an interest-rate increase on house prices as the prices will have to adjust sufficiently for the housing burden to remain

unchanged:

$$\Delta Housing\ burden_{house\ buyers} = \frac{\Delta Debt\ service + \Delta Housing\ tax + \Delta Maintenance\ cost}{Disposable\ income} \equiv 0. \quad (6)$$

Implicitly, we hold the down payment of actual buyers constant, but acknowledge that repeat buyers could lose equity when selling their existing home, and which therefore cannot be transferred into the next. We do not include depreciation costs or expected capital gains or losses in the housing burden, as would be done when calculating conventional user costs of housing, see e.g. Bergman et al. (2015), since we are only considering the first-year payment. Furthermore, both depreciation costs and expected capital gains are subject to great uncertainty and hard to assess at the property level. Housing taxes will not be affected by increasing interest rates as they have been nominally frozen since 2001, hence they are unrelated to realised house price movements. We assume maintenance costs of 4 per cent of the public property values assessments, and that this rate does not change with rising interest rates. Only the effect of increasing interest rates on debt service payments will affect the demand and house prices in the short term..

The assumption that house buyers choose the same housing burden leads to a simple calculation of the house price effect of an increase in interest rates. Suppose a household buys a house at the price P_{pre} where the housing burden of the unit, c_{pre}, is measured in per cent of the house price. Then suppose that the interest rate was 1 percentage point higher with a corresponding housing burden denoted c_{post}. What would the price, denoted P_{post}, of the house be in this case, given that the household would prefer (or the bank would require) the same ratio of housing expenses to income, I? From the requirement of an unchanged housing burden-to-income ratio it follows that

$$\frac{c_{post}P_{post} - c_{pre}P_{pre}}{I} = 0 \quad \Leftrightarrow \quad \frac{P_{post}}{P_{pre}} = \frac{c_{pre}}{c_{post}}. \quad (7)$$

The house price effect of rising interest rates is thus the ratio of the actual housing burden of the property and the housing burden given a 1 percentage point higher interest rate. In this way, we assume that in the short term house prices are determined by the demand side and that the housing units sold are representative (in terms of potential buyers) of the housing stock within the municipality. The drop in house prices will thus be determined by the preferences of house buyers, i.e mainly their choice of mortgage type and loan-to-value. We assume that house buyers choose the same type of mortgage in the event of an increase in interest rates. Since we are considering a parallel shift in the yield curve, the incentives to choose flexible-rate

mortgages vs. fixed-rate mortgages are to a high extent unaffected. This leads to differences in the price effect at the municipal level as the distribution of mortgage types and housing burdens differs. Regional differences in house price developments have been documented by Dam (2014). The introduction of interest-only and adjustable-rate mortgages contributed to the boom in house prices leading up to the financial crises due to demand effects from credit-constrained households and short-sightedness, see Dam et al. (2011). Variations in the composition of mortgage types and housing burdens can thus be expected to affect housing demand at the municipal level.

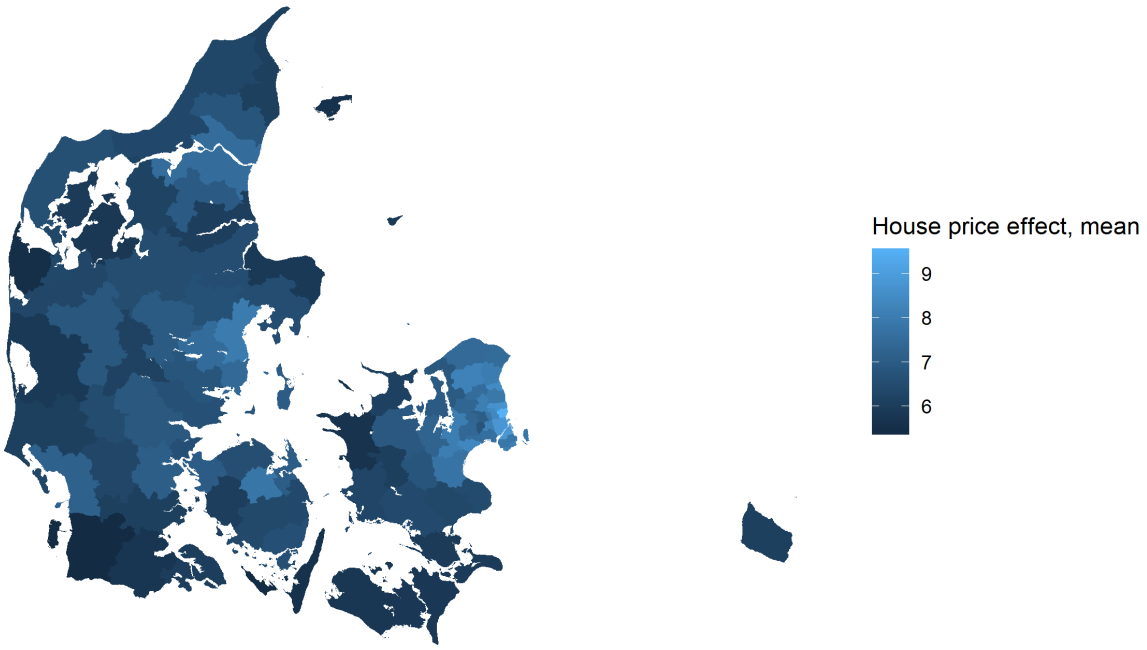
Utilising the rich micro-data information, we calculate the change in housing the burden for each single property sold on market terms in a given year. We calculate the average change in the property price for house buyers at the municipal level and assign this change to all housing units in that municipality. The change in debt service is done in same way as for the calculations for $\Delta DSTI$. However, we only include the part of the bank debt that is secured against real estate. To identify this, we utilise information from the Danish Collateral Registry (*Tingbogen*), which contains information on the amount of bank debt registered in each property. We compare this information to total bank debt in the income registers and use the lowest amount of the two as the measure of a household's bank debt that is secured against real estate. Housing taxes are taken from the register data from Statistics Denmark, which contains the public property-value assessments and the land tax (*grundskyld*) paid on each single property in a given year. For property taxes (*ejendomsværdiskat*), we calculate the tax as 1 per cent of the lowest of the public property-value assessments from 2001 plus 5 per cent, 2002 and 2011. Property values in excess of DKK 3,040,000 measured in 2001 are taxed an additional 2 per cent.

The resulting drop in house prices based on 2019 data is shown in Figure 5. The largest effect on house prices is found in the Copenhagen municipality, the Frederiksberg municipality, and the municipalities in the capital region, and more generally the largest price effects are found in the broader capital region and around the large cities. This pattern broadly corresponds to house price developments in recent years, where prices have surged in large towns and cities, especially Copenhagen, while price developments have been more modest in other parts of the country. The weighted average effect across municipalities is 6.7 per cent. It is natural to relate this number to findings in other work, where we will focus on MONA, Danmarks Nationalbank's model of the Danish economy. From the house price relation described in Dam et al. (2011), and most recently updated in Dam (2014), the effect on house prices of the minimum first-year burden – a measure that differs slightly from actual housing burden of buyers – is in the same ballpark as ours, however, it is slightly lower than the overall interest-rate effect on house prices in MONA. The nominal freeze on the property value tax introduced in 2002 and the cap on the year-on-year increase in the land tax affects the calculated price effects through the effective tax rate on housing. The effective tax rate is not the same across Denmark, as house prices generally have increased more in urban areas. As housing taxes

generally constitute a relatively smaller share of the housing burden in areas experiencing large increases in house prices, the increase in the housing burden as a result of higher interest rates has a larger effect in areas with a lower effective tax rate on housing. The housing burden will increase relatively more in areas where the tax is relatively lower. This contributes to the larger price fluctuations evident in Figure 5.[8] Higher price sensitivity to interest-rate changes in Copenhagen compared to the national level has also been shown by e.g. IMF (2016); Hviid (2016).

To reiterate, we do not think of the calculated effect on house prices from a general increase in interest rates as the general equilibrium effect on house prices, but only as a short term demand impact, which allows houses in different regions of the country to be affected differently based on e.g. the mortgage type chosen by the representative buyers. In the longer term, changes in disposable income, demographic developments and supply of housing will also affect the price effect of higher interest rates.

Figure 5: Reductions in house price given a 1 percentage point increase in interest rates



Notes: House-price effect of a 1 percentage point increase in interest rates at the municipal level in per cent.

[8]The link between the property tax rate and nominal house prices has been reintroduced by the agreement from 2018 on property taxes. However, the agreement does not come into effect until 2024 and thus does not affect the first-year housing burden used in our calculations.

6.2.2 Modelling price changes on mortgage bonds

Increasing interest rates will affect the value of the mortgage bonds used to finance homeowners' mortgage loans. Mortgage holders have the right to repay fixed-rate mortgages by buying back the underlying mortgage bonds. The market price of the bonds therefore affects homeowners balance sheet in the event that they sell their home, or if they choose to refinance their mortgage by buying back the mortgage bond financing the existing mortgage and taking up a new mortgage. In order to evaluate the price effect on mortgage bonds, we estimate a yield curve for each given year and price the individual mortgage bonds using the estimated yield curve.

In order to evaluate the effect of a shift in the yield curve on the market value of outstanding mortgage bonds, we need a good measure of the yield curve to begin with. We follow Svensson (1994) and estimate an extended Nielson-Siegel model for the forward rate function of the form

$$f(m) = z_0 + z_1 e^{\frac{-m}{\tau_1}} + z_2 \frac{m}{\tau_1} e^{\frac{-m}{\tau_1}} + z_3 \frac{m}{\tau_2} e^{\frac{-m}{\tau_2}}, \tag{8}$$

where time subscripts have been suppressed for simplicity. Here $f(m)$ is the forward rate where m is time to payment and $z = (z_0, z_1, z_2, z_3, z_4, \tau_1, \tau_2)\prime$ is a vector of parameters, which will be estimated. From this estimated curve it is relatively straightforward to back out the yield curve and the discount rates for every given future point in time, which is outlined in Svensson (1994). In order to do this, we need to have a set of prices for traded mortgage bonds that are reasonably representative of the market at various maturities. In practice, we select bonds based on the following selection criteria.[9]

- The bond must be issued in DKK.
- The coupon rate must be between 0 and 10.
- The bond must have a minimum of 6 months to maturity.
- The volume should exceed DKK 3 billion.
- Only bonds from capital centres E and H to ensure comparable risk premia.
- Only mortgages with a fixed rate until maturity are included (i.e. conventional mortgage bonds, including ARMs).
- The bond must be traded every day.
- For callable bonds:
  - The bond is traded at prices between 90 and 105.
  - The two bonds nearest price 97 is chosen for each time to maturity.

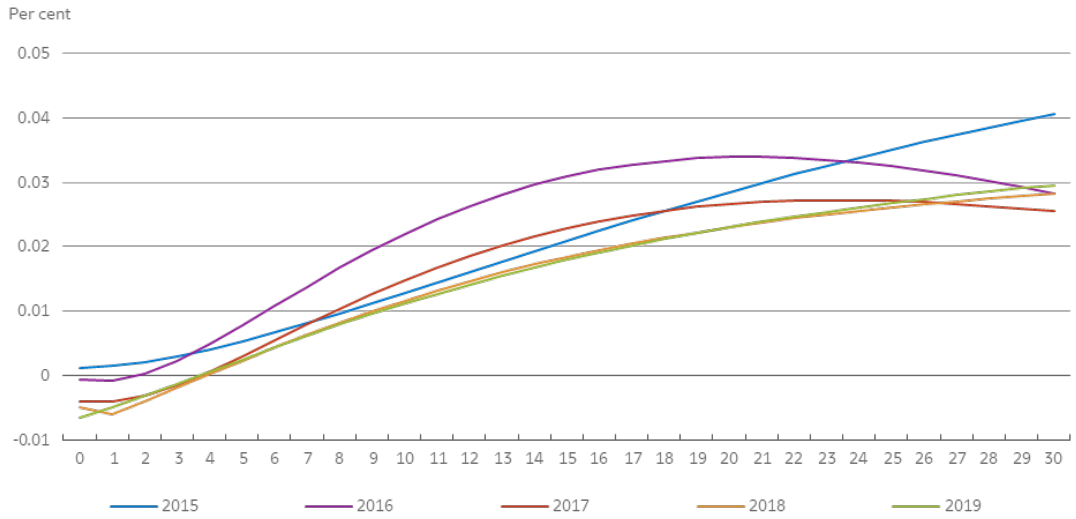
[9] The data are collected through ScanRate/Rio.

– Only bonds with amortisations and time to maturity above 28 years.

In order to align the mortgage yield curves with the administrative data, which are measured around the turn of a calendar year, we limit the data to the five trading days of the first full week in the new year. The resulting estimated yield curves are presented in Figure 6.

We use these estimated yield curves to calculate a theoretical price, i.e. the present value of the cash flow, of each individual loan. We then calculate the theoretical price in the scenario where the entire yield curves are shifted upwards by a 1 percentage point, in order to measure the change in the market value of the outstanding mortgage debt of a household. Obviously, we might get the particular yield curve slightly wrong for a number of reasons, e.g. due to mis-measurement of market expectations of refinancing probabilities, however, as it is the relative change that we are interested in and not the level in itself, such uncertainties are of minor importance as the pricing error should be comparable between the two scenarios for the yield curve. Because of the option of prepaying fixed-rate mortgages by buying back the underlying bonds at face or par value, the value of the debt reduction depends on the coupon rate of their loan relative to the current interest rate. For mortgage bonds that have a coupon rate much higher than the prevailing level of interest rates, the price of these bonds will only react very little to an increase in interest rates. We therefore set the price change for bonds with a coupon rate at least 1 percentage point higher than the prevailing rate to zero. For mortgages with a coupon rate higher than the prevailing rate, but less than 1 percentage point higher, we use the relative difference of the theoretical price change as the impact on the bond price.

Figure 6: Yield curves of the mortgage market.



Notes: Estimated yield curves for 2016-2019.

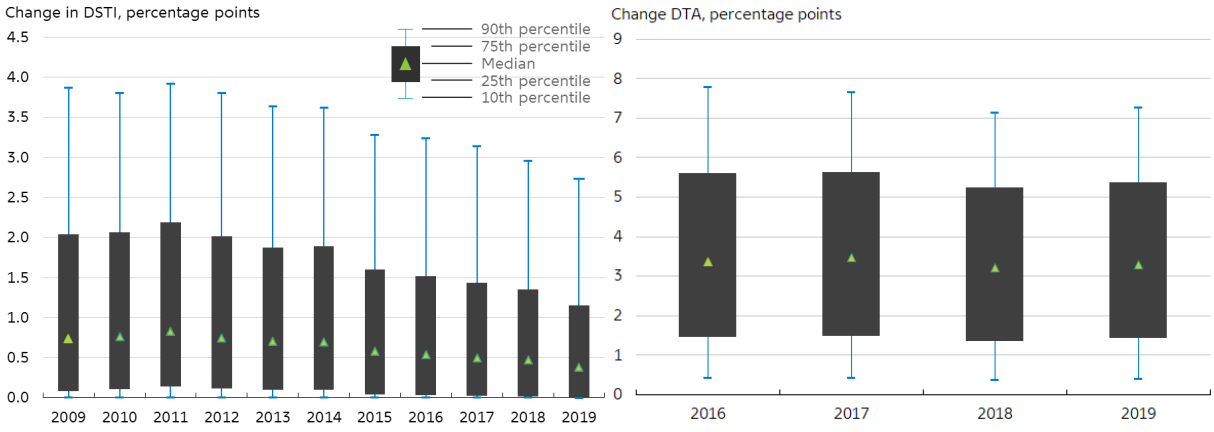
7 Distribution of interest-rate sensitivity

In this section, we present the distributions for the changes in the debt service-to-income and debt-to-assets ratios for homeowners. Effects on the cash flow, ΔDSTI, can be calculated for all years in the sample. Balance-sheet effects, ΔDTA, can only be calculated beginning from 2016. Despite being a long-standing registry, the data from the Danish Collateral Registry are only available for us from 2016 onwards, which limits the beginning of our sample period.

Over time, cash-flow sensitivity has generally been falling since since 2011, cf. Figure 7 (a). The distribution has shifted downwards with the median ΔDSTI falling from 0.8 percentage points of income at the end of 2011 to 0.5 percentage points at the end of 2019. The cash-flow sensitivity in the tails of the distribution has fallen as well, with the 90^{th}, 75^{th}, and 25^{th} percentiles all being the lowest in 2019. The lower tail is, however, zero for all years, reflecting households with only FRMs and no bank debt. The fall in cash-flow sensitivity should be seen in the light of the development in the aggregate share of outstanding fixed-rate mortgages, as well as the fall in outstanding bank loans. Cash-flow sensitivity does, however, differ markedly between households. 10 per cent of households have a sensitivity of over 2.5 per cent of income, over 7 times as high as the median household. For a median income households this equates to extra yearly payments of DKK 12,300 or more in the event of a 1 percentage point increase in interest rates.

Turning to the distribution of balance-sheet sensitivity, the median and upper tails of the distribution shifted downwards in 2018, while the lower tails of the distribution were at similar levels as in previous years, cf. Figure 7 (b). The fall in balance-sheet sensitivity for the upper tails of the distribution can be attributed to the increased share of households with fixed-rate mortgages, since fixed-rate mortgages partly insure households against increasing rates as the market value of their mortgage debt falls if rates increase. The lower share of bank debt on households' balance sheets also contributes to lower balance-sheet sensitivity. However, a substantial share of homeowners are exposed to increasing rates, as over a quarter of homeowners with debt will experience a worsening of their debt-to-assets ratio of 5 per cent or more if rates increase. For a first-time buyer with a little down payment who is amortising, this is more than the typical amount amortised in any one year.

Figure 7: Distribution of cash-flow and balance-sheet sensitivity



(a) ΔDSTI (b) ΔDTA

Notes: Box plots of the cash-flow sensitivity (ΔDSTI) distribution for 2009-2019 and the balance-sheet sensitivity (ΔDTA) for 2016-2019 from a 1 percentage points upward shift int the yield-curve.

7.1 Debt service-to-income sensitivity

Zooming in on the ditributions of the level of DSTI in the most recent year in the data, 75 per cent of households spend less than a quarter of their income on servicing debt, cf. Figure 8. There is, however, a tail of households spending a substantial amount of income paying interest and amortisation payments. 4 per cent have DSTI below 1 per cent, which represents households that are close to paying out their debt in the coming year or that only have minor financing needs. The distribution of DSTIs is somewhat similar for groups of households with different mortgages types. Households with IO-ARMs, however, generally have lower DSTIs, but the upper tail of the distribution of these households is similar to the distribution of the groups of households with other types of mortgages. Households with IO-ARMs do to some extent use the lower mortgage repayments to amortise more expensive debt, but not exclusively, see Kuchler (2015).

As argued previously, the main interest of this paper lies in the distribution of cash-flow sensitivity, ΔDSTI, which is shown in Figure 9. Over a third of homeowners would have to spend close to zero per cent more of income servicing debt if interest rates rise, and most households are only subject to low levels of cash-flow sensitivity. The distribution does, however, have a long right tail, with 10 per cent of households having ΔDSTIs of around 2.5 per cent or more. Households with FRMs naturally have the lowest cash-flow sensitivity. The CDFs for households with AM-FRMs and IO-FRMs are fairly similar, with IO-FRM households having slightly higher sensitivity as they tend to have more bank debt on which they pay interest. Households with IO-ARMs, which account for 24 per cent of households with mortgage debt, are most sensitive to interest-rate increases on their cash flows.

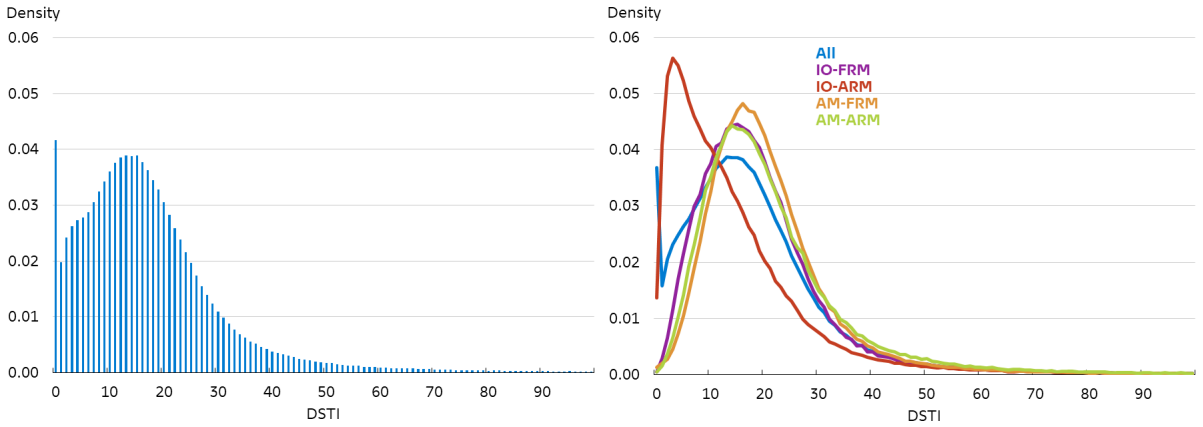
Whether high cash-flow sensitivity represents a challenge for a household depends on the amount of income it spends on servicing debt. Households spending a relatively small fraction of income servicing debt are likely to be more robust to interest-rate increases, whereas households already spending a large amount of income might be challenged by higher interest rates. The distribution of cash-flow sensitivity for each DSTI percentile has a clear hump at the lower DSTI percentiles, cf. Figure 10 (a). The median and upper tail sensitivities of these households are relative high. As these households spend a relatively low fraction of income servicing debt, they are likely to be robust to increases in interest rates. From DSTI levels of around 20 per cent and higher, cash-flow sensitivity is increasing in DSTI levels. A possible explanation could be that highly indebted households choose adjustable-rate loans in order to amortise more of their debt and thus reduce debt levels. There are, however, relatively few households with both high DSTI levels and high cash-flow sensitivity. The relationship between cash-flow sensitivity and debt-to-assets ratio (Figure 10 (b)) is more or less monotonically increasing in DTA levels. To some extent, this is a result of households only being able to finance up to 80 per cent of the housing value with mortgages, which can be fixed-rate loans. The 10^{th} percentile of ΔDSTI is more than zero for DTA levels of around 80 and higher, as debt in excess of 80 per cent of the housing value has to be financed with adjustable-rate bank debt.

It is also relevant to investigate distributions over other co-variates, which are shown in Figure 15 in Appendix B. The median, 25^{th}, and 10^{th} percentiles of ΔDSTI are flat over income distribution, but the upper tails are higher for income levels below DKK 500,000 (median income is DKK 450,000). Increasing interest rates thus have a larger effect on aggregate demand than the median cash-flow sensitivity would indicate as lower-income households have a larger propensity to consume. The distribution of cash-flow sensitivity is at higher levels for households with deposits below the median (DKK 150,000), showing that households with lower deposits than the median are more exposed to interest-rate increases. Households with negative net wealth have higher cash-flow sensitivity, but otherwise there is no relation between net wealth and ΔDSTI, except for the 90^{th} percentile of ΔDSTI, which increased with net wealth. The distribution of ΔDSTI is more dispersed for older households. The upper tails increase from the age of 60, which is the age range when some households retire. This suggests that a larger share of retired households have adjustable-rate debt. The lower tail for the retired households is, however, lower. The 25^{th} percentile is zero for all 60+ age groups. The median cash-flow sensitivity is fairly flat across the age distribution.

Again, house buyers are of particular interest as they actively choose their interest-rate exposure. The distribution of DSTI levels for house buyers exhibits a (surprisingly) similar development to the distribution for all homeowners, see Appendix C. The levels are, however, 3-5 percentage points higher as income levels for homeowners typically increase over the maturity of the loans. Debt service payments change only very slowly over the maturity of the loans, as most household debt is 30-year mortgages. The distribution of cash-flow sensitivity is

also fairly similar for homeowners and home buyers. There are, however, a somewhat larger share of buyers who are sensitive to interest-rate changes. As buyers generally have higher DTA levels compared to all homeowners, this small difference can be explained by house buyers having relatively more bank debt in the form of adjustable-rate loans.

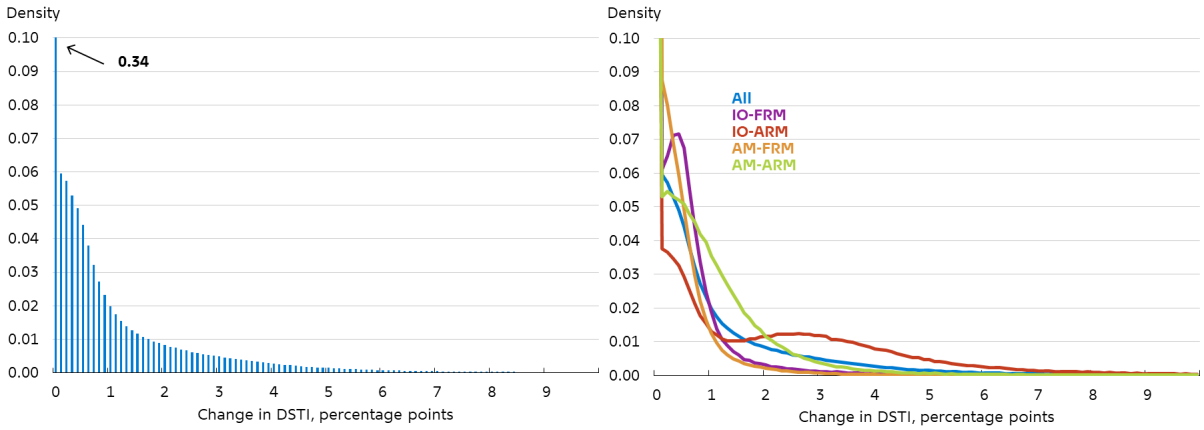
Figure 8: DSTI distribution for house owners



(a) Histogram (b) Density - primary mortgage type

Notes: Histogram (a) and density (b) of the DSTI distribution. The blue line in panel (b) shows the density for all homeowners with debt. The other lines show the density for groups of homeowners sorted according to their primary mortgage type.

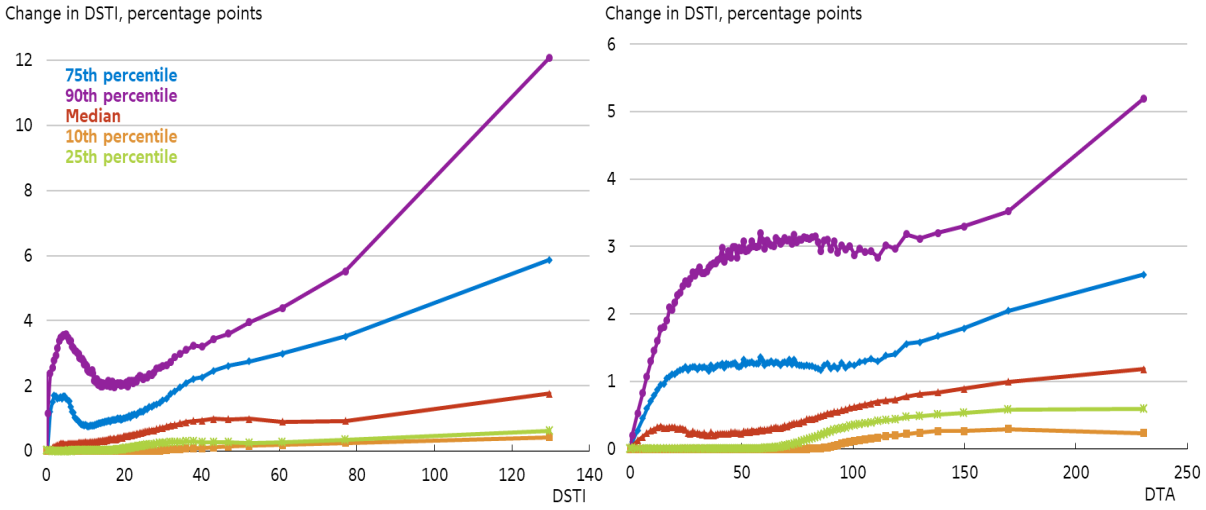
Figure 9: ΔDSTI distribution for house owners



(a) Histogram (b) Density - primary mortgage type

Notes: Histogram (a) and density (b) of the ΔDSTI distribution. The blue line in panel (b) shows the density for all homeowners with debt. The other lines show the density for groups of homeowners sorted according to their primary mortgage type.

Figure 10: Box plots for ΔDSTI for house owners for DSTI and DTA percentiles



(a) (b)

Notes: Percentiles of the ΔDSTI distribution for each DSTI percentile (a) and DTA percentile (b). The dots on the lines represent 1 per cent of homeowners over the DSTI and DTA distribution. E.g. the dots on the red line in (a) are the median ΔDSTIs for each percentile of homeowners sorted according to their DSTI.

7.2 Debt-to-assets sensitivity

Addressing the balance-sheet sensitivity of an increase in interest rates, we start by looking at the distributions of the DTA levels in the the last year of our sample in Figure 11. Most households (89 per cent) have less debt than assets, but there is a tail of households with substantially more debt than assets. The same 4 per cent from Figure 8 who are close to paying out are evident here as well. The distributions are fairly similar across mortgage types, but with IO households having higher DTA levels as they, all else being equal, have more debt. A takeaway is that there is considerable variation in DTA levels, and hence it is important how this interacts with the balance-sheet sensitivity. Starting with the distribution of balance-sheet sensitivity itself, the distribution has a large peak at zero, cf. Figure 12. For these households, the falls in the housing value and the market price of the mortgage bonds are of the same magnitude, which means that the debt-to-assets barely changes. Almost all households, roughly 98 per cent, will experience a worsening of their balance sheet in the event of interest-rate increases. The distribution of balance-sheet sensitivity differs markedly across mortgage types. Households with IO mortgages have the highest balance-sheet sensitivity as, all else being equal, they have a larger debt-to-asset ratio. Homeowners with AM-ARM mortgages have the lowest balance-sheet sensitivity as FRMs have a longer duration than ARMs and since amortisation brings the DTA level down.

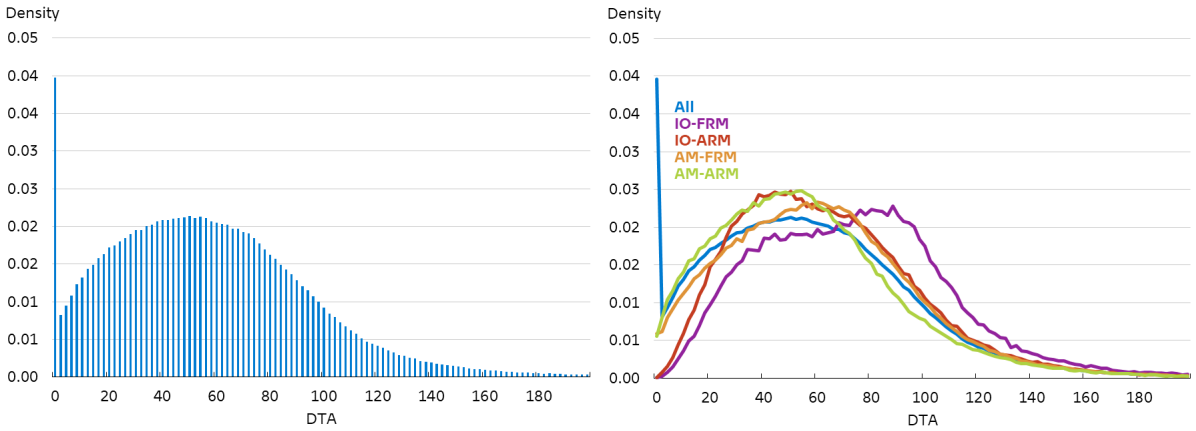
The distribution of balance-sheet sensitivity across the levels of DSTI and DTA percentiles is

in shown in Figure 13. The dispersion of the distribution of balance-sheet sensitivity is generally increasing with the level of DSTI up until a level of 40 per cent. For higher DSTI levels, there is no relation between balance-sheet sensitivity and the level of debt service-to-income. The level of the distribution of balance-sheet sensitivity is roughly linear with the level of DTA, as a higher debt-to-asset ratios, all else being equal, leads to a higher balance-sheet sensitivity.

As for the cash-flow sensitivity, it is important to know how the balance-sheet sensitivity correlates with the distribution of other relevant covariates, see Figure 16 in Appendix A. Balance-sheet sensitivity decreases with the level of wealth and increases with the level of debt. The balance-sheet sensitivity decreases with net wealth, with both the level and dispersion being much higher and larger for households with negative net wealth. As only the market price of mortgage debt can fall if interest rates increase, the price of all debt in excess of 80 per cent of the housing value will be the same. Hence, households with net wealth below or close to zero are more exposed to rate increases. Balance-sheet sensitivity is hump-shaped over the income distribution, peaking at income levels around DKK 600,000, which is roughly the 75^{th} percentile of after-tax income. Sensitivity decreases with levels of deposits, since deposits are a part of assets. Balance-sheet sensitivity has a hump-shaped behaviour over the age distribution, with sensitivity being highest around the age of 30, which is likely due to a relatively large share of relatively highly leveraged first-time buyers. Median sensitivity falls until retirement age, after which dispersion continues to fall.

Housing buyers, who typically increase the DTA level in relation to the housing purchase, might also be subject to highest balance-sheet sensitivity, as indicated by Figure 13 (b). The DTA levels and balance-sheet sensitivity measures for house buyers are shown in Appendix C. Buyers naturally have larger DTA levels compared to all homeowners, and distribution has two peaks just below 80 and 100 per cent DTA, corresponding to households that take up a mortgage up to the allowed 80 per cent of the house value, and household that are only able to make a small down payment. Compared to all homeowners, house buyers are characterized by higher balance-sheet sensitivity, as their debt-to-assets ratios are higher.

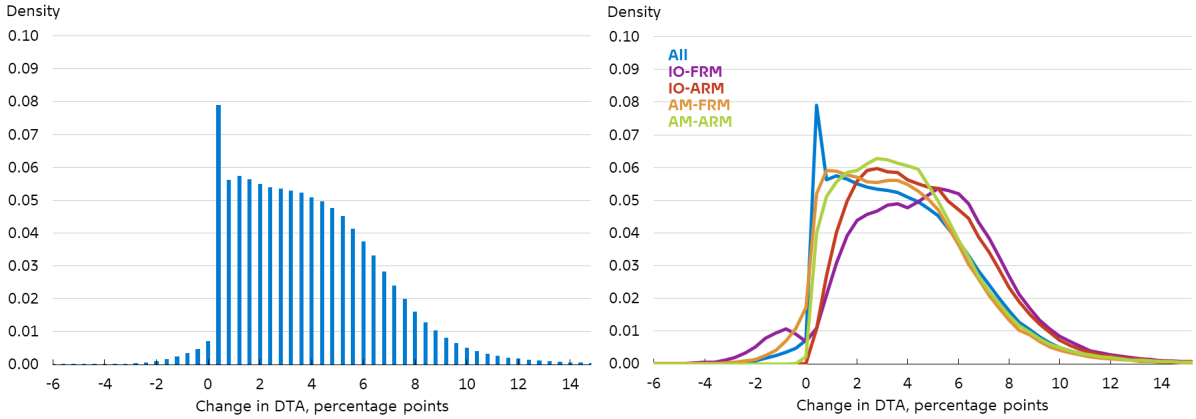
Figure 11: DTA distribution for house owners



(a) Histogram (b) Density - primary mortgage type

Notes: Histogram (a) and density (b) of the DTA distribution. The blue line in panel (b) shows the density for all homeowners with debt. The other lines show the density for groups of homeowners sorted according to their primary mortgage type.

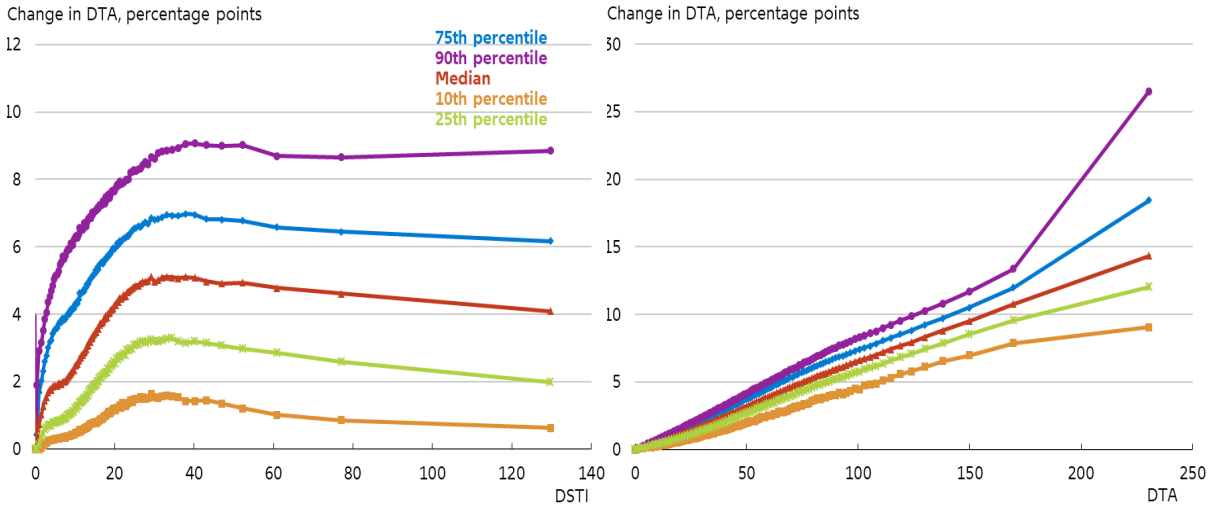
Figure 12: ΔDTA distribution for house owners



(a) Histogram (b) Density - primary mortgage type

Notes: Histogram (a) and density (b) of the ΔDTA distribution. The blue line in panel (b) shows the density for all homeowners with debt. The other lines show the density for groups of homeowners sorted according to their primary mortgage type.

Figure 13: Box plots for ΔDTA for house owners for DSTI and DTA percentiles



(a) (b)

Notes: Percentiles of the ΔDTA distribution for each DSTI percentile (a) and DTA percentile (b). The dots on the lines represent 1 per cent of homeowners over the DSTI and DTA distribution. E.g. the dots on the red line in (a) are the median ΔDTAs for each percentile of homeowners sorted according to their DSTI.

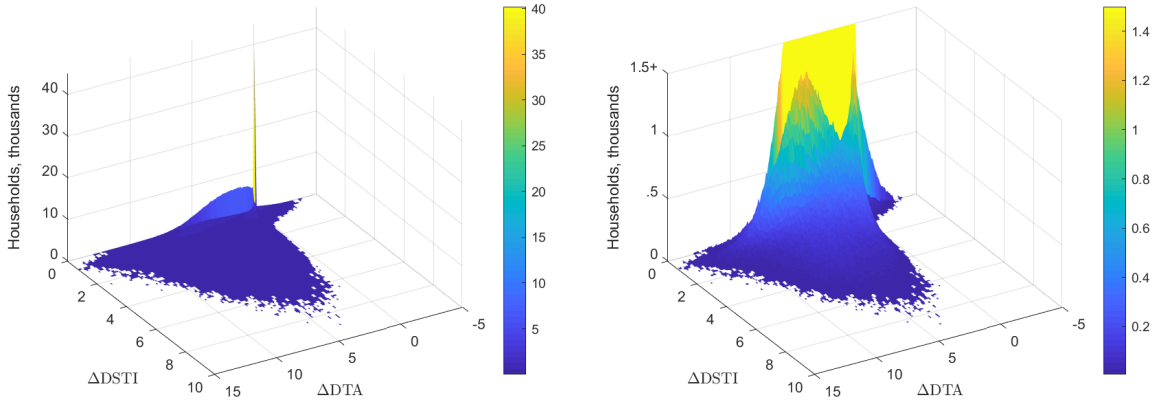
7.3 The joint distribution of balance-sheet and cash-flow sensitivity

Lastly, we turn to the joint distribution of balance-sheet and cash-flow sensitivity. There is a concentration of households with very limited cash-flow and balance-sheet sensitivity, as can be seen from the very large peak in the surface plot in Figure 14 (a). To enhance visibility of the remaining part of the distribution, Figure 14 (b) zooms in on the households that are more sensitive to interest-rate increases. Over half of the households have balance-sheet and cash-flow sensitivity larger than zero (62 per cent). The majority of these households do, however, have rather modest interest-rate sensitivity as most of the distribution is close to levels of zero. A small share of the households will experience a more substantial increase in debt service payments and worsening of their balance sheets if interest rates increase. This will typically be households with ARMs and/or bank debt combined with small or negative net wealth as this can result in fairly large increases in debt service payments and worsening of balance sheets simultaneously. It is important to take notice of this group of at-risk households, as some of them might be required to reduce consumption significantly if they do not go into arrears at the same time as they might go under water in the event of a large interest-rate increase. Such a combination can give rise to lock-in effects for some households.

A very small share of households will experience higher debt service payments combined with an improved balance sheet (1 per cent). These are households with FRMs as well as bank debt as this combination of debt can lead to increasing debt service payments and an improved

balance sheet (see also Figure 12). The increase in DSTI for this group of households is modest. All of these households have cash-flow sensitivity of less than 2 percentage points.

Figure 14: Surface plot of ΔDSTI and ΔDTA



(a) All households

(b) Z-axis capped at 1500

Notes: Surface of the joint distribution of ΔDSTI and ΔDTA. The left plot (a) shows the joint distribution for all households. In the right plot (b), the z-axis has been capped at 1500 households to enhance visibility of the surfaces.

8 Conclusions

In this paper we have addressed the interest-rate sensitivity of Danish households in recent years. In particular, we have focused on the distribution of household-level debt service-to-income and debt-to-assets ratios and how these distributions would be impacted by a 1 percentage point increase of the entire yield curve. Overall, Danish households are found to be fairly robust to such an interest-rate increase, however, choices of mortgage to a large extent determine homeowners' interest-rate sensitivity impacts households' cash-flows and balance sheets. In particular, adjustable-rate mortgages and interest-only mortgages substantially increase DSTI and DTA sensitivity to interest-rate increases, hence, some households are highly exposed in that case. We also find that the distribution of ΔDSTI has been falling from 2009 to 2019, where a third of households have ΔDSTI close to zero. Furthermore, the distribution of ΔDTA fell somewhat in 2018 due to a general movement into fixed-rate mortgages, which partly insure households' balance sheets against increasing interest rates.

Our analysis does not provide a comprehensive modelling of the general-equilibrium effects of a sudden interest-rate increase, nor the particular causes of such an event. We focus this paper on the direct implications for Danish households in order to provide a picture of the risks faced by the Danish economy, which can be taken into account in various risk scenarios, as the approach identifies segments of the homeowner distribution that are particularly vulnerable.

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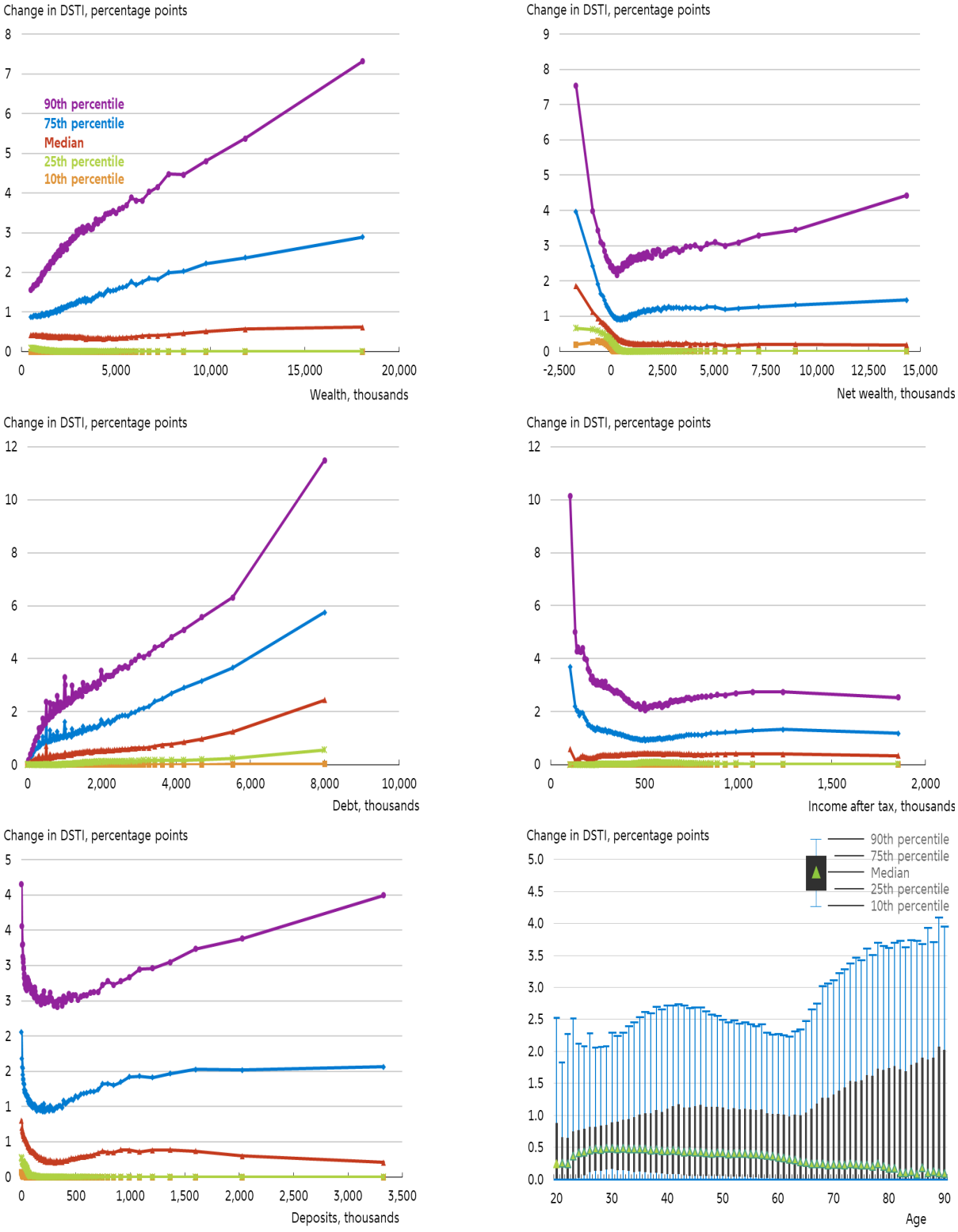
Table 3: Summary statistics for homeowners with debt 2009-2019

	2009 median	2010 median	2011 median	2012 median	2013 median	2014 median	2015 median	2016 median	2017 median	2018 median	2019 median
Total debt	1,098,262	1,134,514	1,160,868	1,189,374	1,189,158	1,202,239	1,196,090	1,216,308	1,224,997	1,239,412	1,257,116
Bank debt	152,811	157,408	165,346	158,744	153,421	158,788	150,167	148,610	145,452	141,792	120,520
Mortgage debt	838,390	875,596	900,000	935,490	936,748	931,874	916,064	923,714	931,486	944,000	984,008
Wealth	1,857,199	1,905,297	1,841,491	1,820,146	1,857,511	1,907,488	2,016,381	2,094,777	2,187,371	2,264,617	2,340,670
Real estate	1,621,962	1,651,410	1,593,800	1,566,000	1,581,250	1,618,500	1,705,100	1,771,987	1,853,550	1,923,384	1,973,400
Net wealth	635,224	647,510	558,905	509,641	546,475	581,214	685,579	732,702	799,121	855,294	904,082
Deposits, etc,	100,776	106,536	102,261	104,194	103,392	107,809	113,487	121,096	126,783	138,548	151,183
Deposits	87,476	93,228	89,958	99,990	100,374	106,202	112,766	120,564	126,301	138,048	150,827
Income, before tax	566,402	578,961	584,877	592,575	598,556	608,385	619,432	630,716	645,230	658,764	673,256
Income, after tax	376,514	394,690	398,533	400,873	406,286	412,408	418,324	424,885	433,806	446,160	450,328
Age	52	52	53	53	53	54	54	54	54	55	55
DSTI	21	18	18	18	17	17	16	17	17	16	15
DTA	60	60	63	65	64	63	61	59	58	57	55

Notes: Median statistics for homeowners with debt. Households that are self-employed, not fully taxable in Denmark, have after-tax income less than DKK 25,000, or have housing wealth of less than DKK 5,000 are excluded.

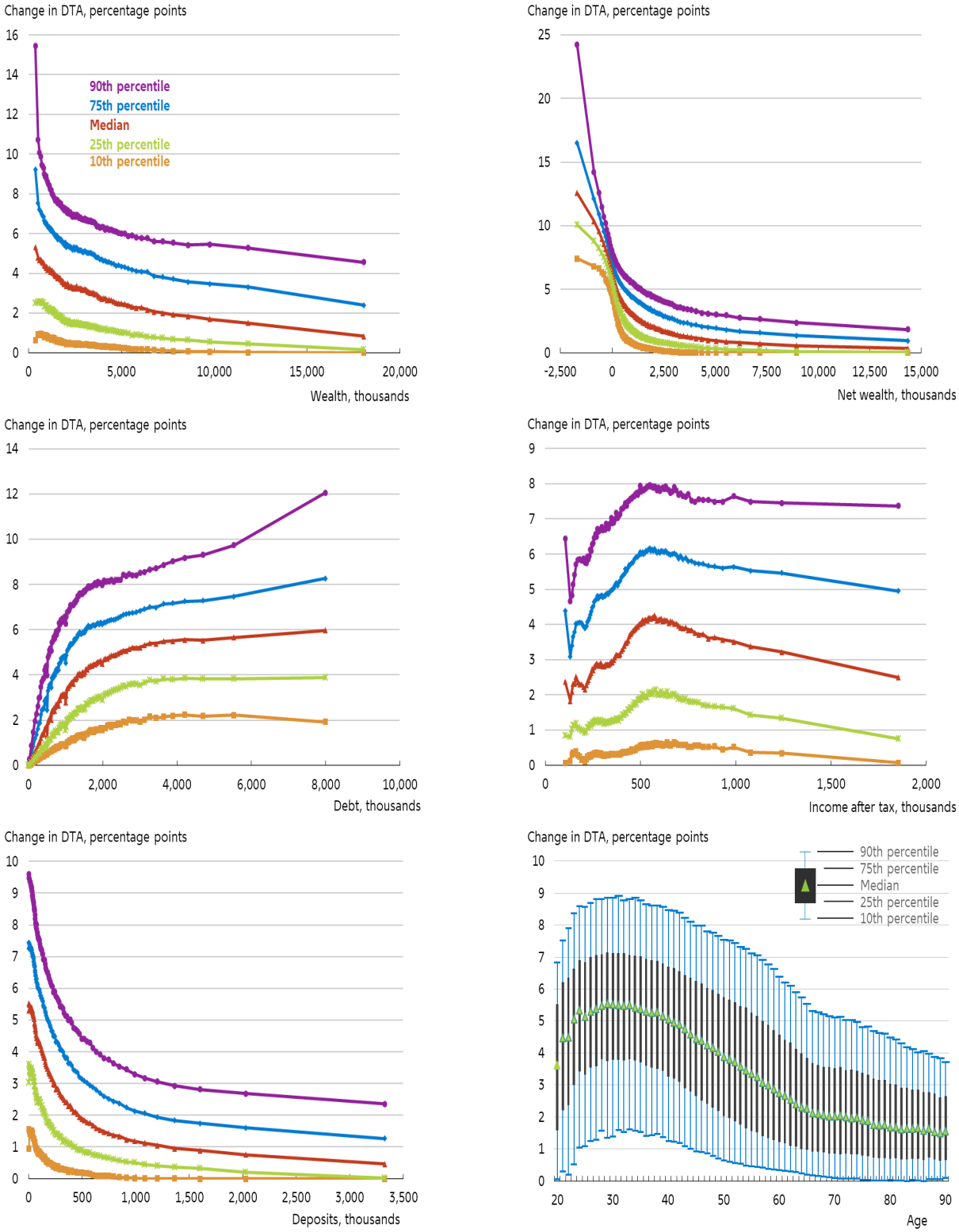
B Distribution of interest-rate sensitivity for homeowners

Figure 15: Box plots for ΔDSTI for house owners



Notes: Percentiles of the ΔDSTI distribution for each percentile of homeowners sorted according to wealth, net wealth, debt, income, and deposits. In the bottom-right panel, the distribution is plotted across the age profile of households.

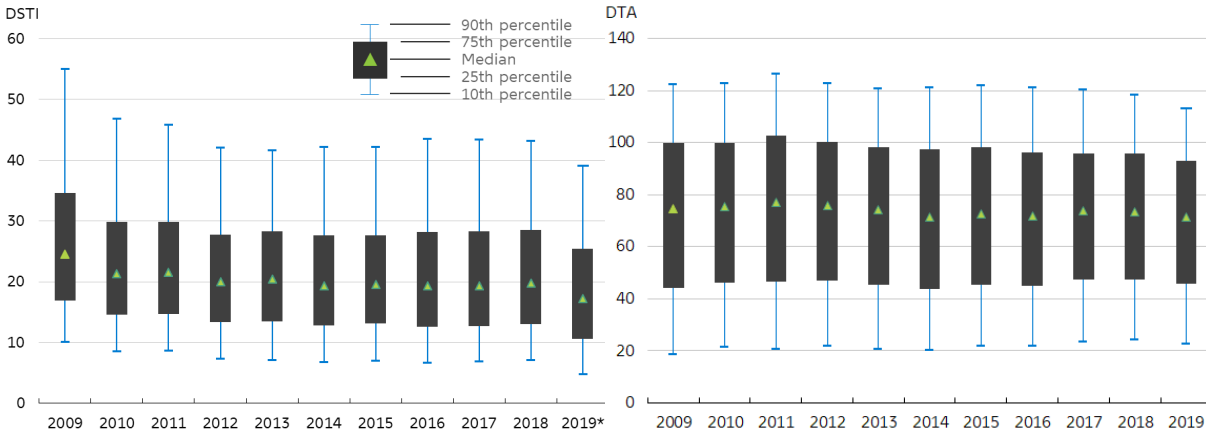
Figure 16: Box plots for ΔDTA for house owners



Notes: Percentiles of the ΔDTA distribution for each percentile of homeowners sorted according to wealth, net wealth, debt, income, and deposits. In the bottom-right panel, the distribution is plotted across the age profile of households.

C Results for house buyers

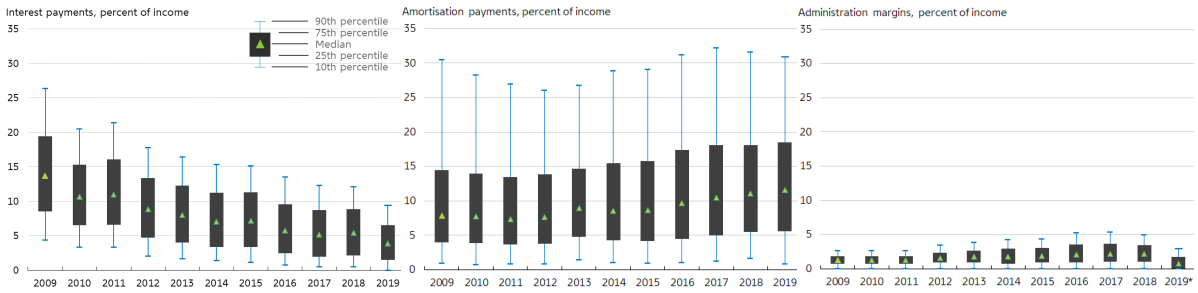
Figure 17: DSTI and DTA distribution for 2009-2019 for house buyers



(a) DSTI (b) DTA

Notes: Box plots of the debt service-to-income (a) and debt-to-assets (b) distribution for 2009-2019 for house buyers. (*) In 2019, the administration fees include only fees paid in the 4^{th} quarter of 2019. The debt service-to-income distribution in 2019 is thus not directly comparable to previous years.

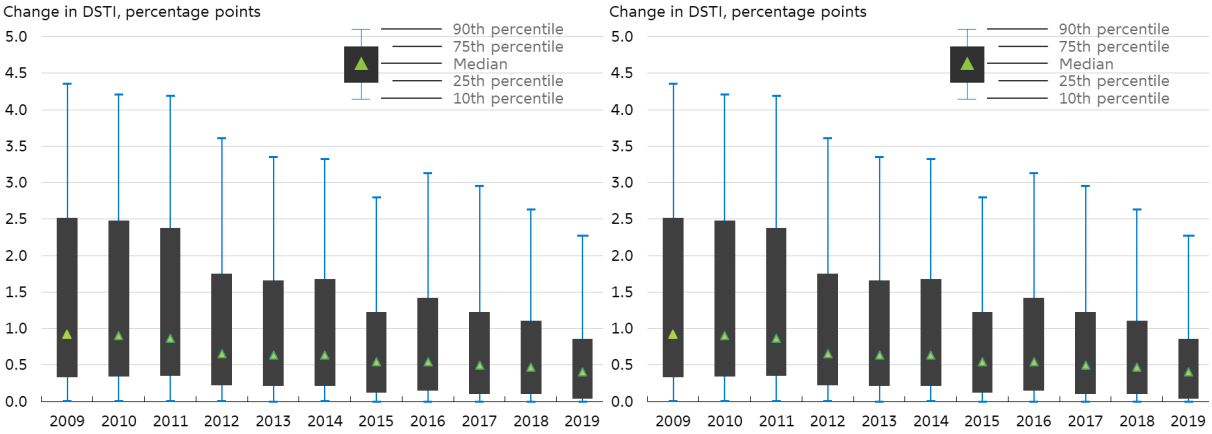
Figure 18: Distribution of DSTI components for 2009-2019 for house buyers



(a) Interest payments (b) amortisation payments (c) Administration fees

Notes: Box plots of the components of the debt service-to-income distribution for 2009-2019, measured relative to after-tax income for house buyers. (*) In 2019, the administration fees include only fees paid in the 4^{th} quarter of 2019. The distribution of administration fees in 2019 is thus not directly comparable to previous years.

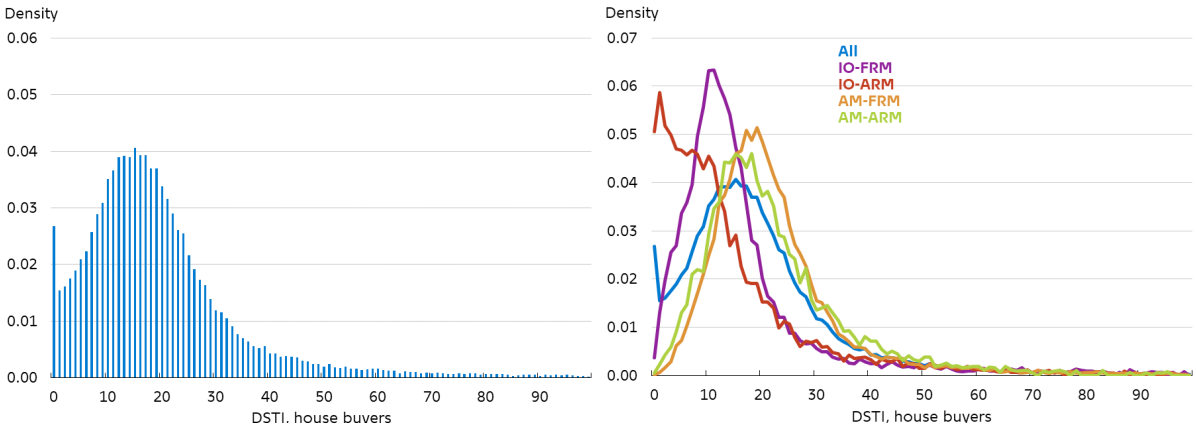
Figure 19: Distribution of cash-flow and balance-sheet sensitivity for house buyers



(a) ΔDSTI (b) ΔDTA

Notes: Box plots of the cash-flow sensitivity (ΔDSTI) distribution for 2009-2019 and the balance-sheet sensitivity (ΔDTA)for 2016-2019 for house buyers.

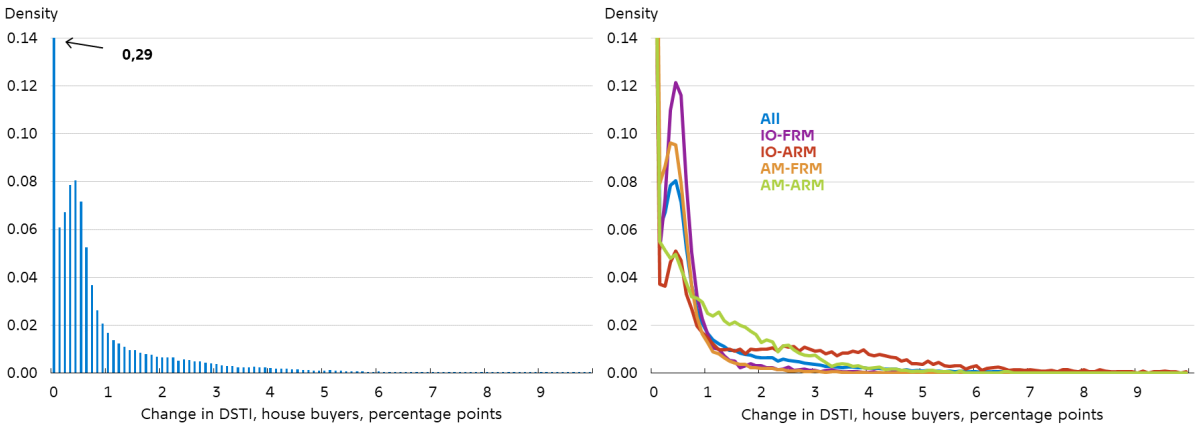
Figure 20: DSTI distribution for house buyers



(a) Histogram (b) Density - primary mortgage type

Notes: Histogram (a) and density (b) of the DSTI distribution for house buyers. The blue line in panel (b) shows the density for all house buyers with debt. The other lines show the density for groups of house buyers sorted according to their primary mortgage type.

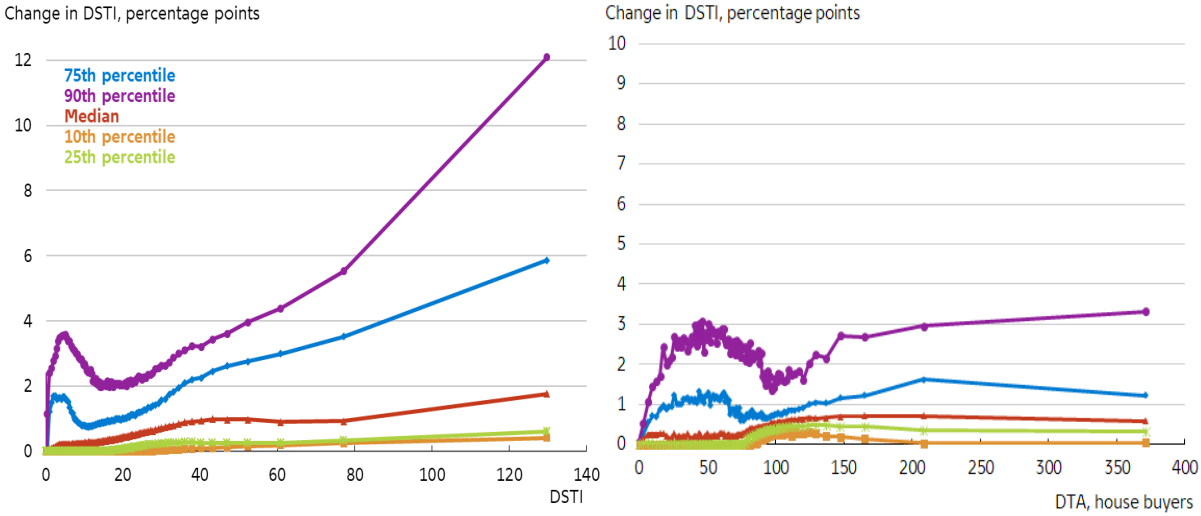
Figure 21: ΔDSTI distribution for house buyers



(a) Histogram (b) Density - primary mortgage type

Notes: Histogram (a) and density (b) of the ΔDSTI distribution for house buyers. The blue line in panel (b) shows the density for all house buyers with debt. The other lines show the density for groups of house buyers sorted according to their primary mortgage type.

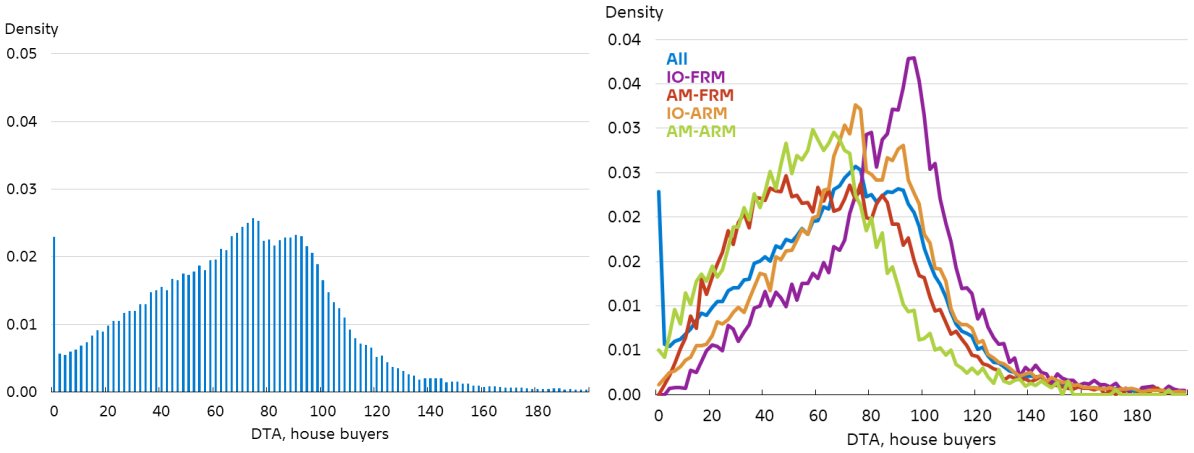
Figure 22: Box plots for ΔDSTI for DSTI and DTA percentiles for house buyers



(a) (b)

Notes: Percentiles of the ΔDSTI distribution for house buyers for each DSTI percentile (a) and DTA percentile (b). The dots on the lines represent 1 per cent of homeowners over the DSTI and DTA distribution. E.g. the dots on the red line in (a) are the median ΔDSTI for each percentile of homeowners sorted according to their DSTI.

Figure 23: DTA distribution for house buyers

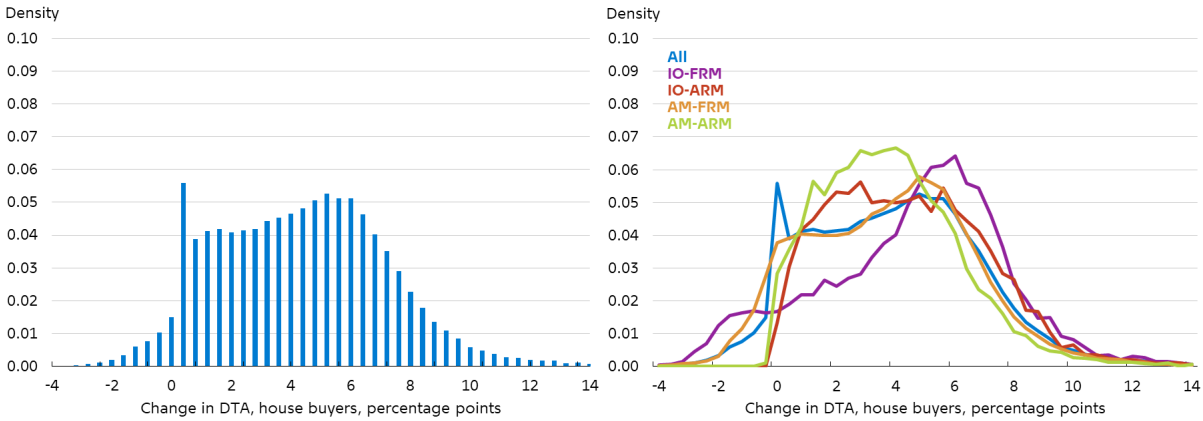


(a) Histogram

(b) Density - primary mortgage type

Notes: Histogram (a) and CDF (b) of the DTA distribution for house buyers. The red line in panel (b) shows the CDF for all house buyers with debt. The other lines show the CDF for groups of house buyers sorted according to their primary mortgage type.

Figure 24: ΔDTA distribution for house buyers

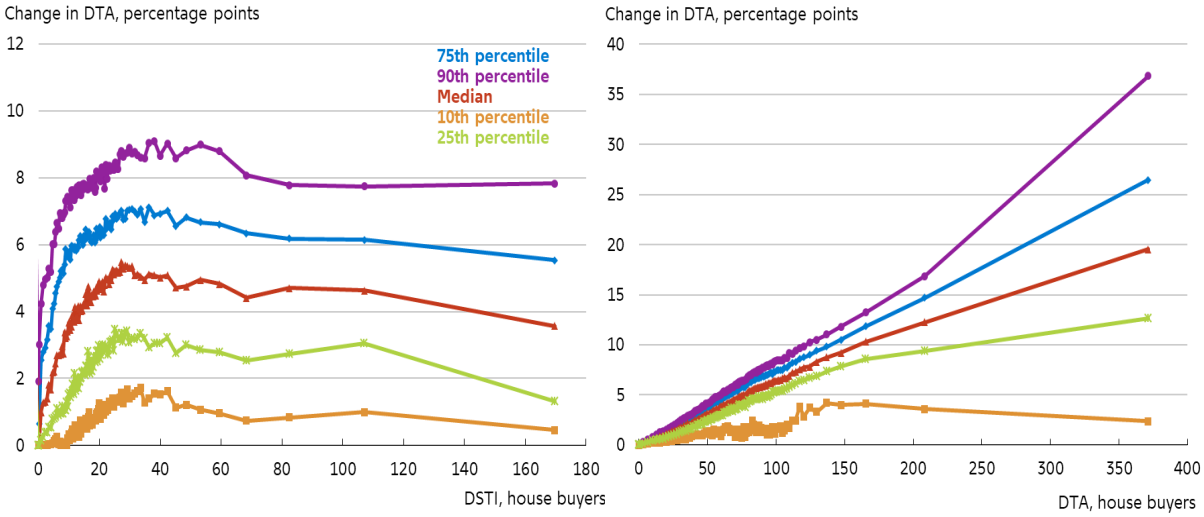


(a) Histogram

(b) Density - primary mortgage type

Notes: Histogram (a) and density (b) of the ΔDTA distribution for house buyers. The blue line in panel (b) shows the density for all house buyers with debt. The other lines show the density for groups of house buyers sorted according to their primary mortgage type.

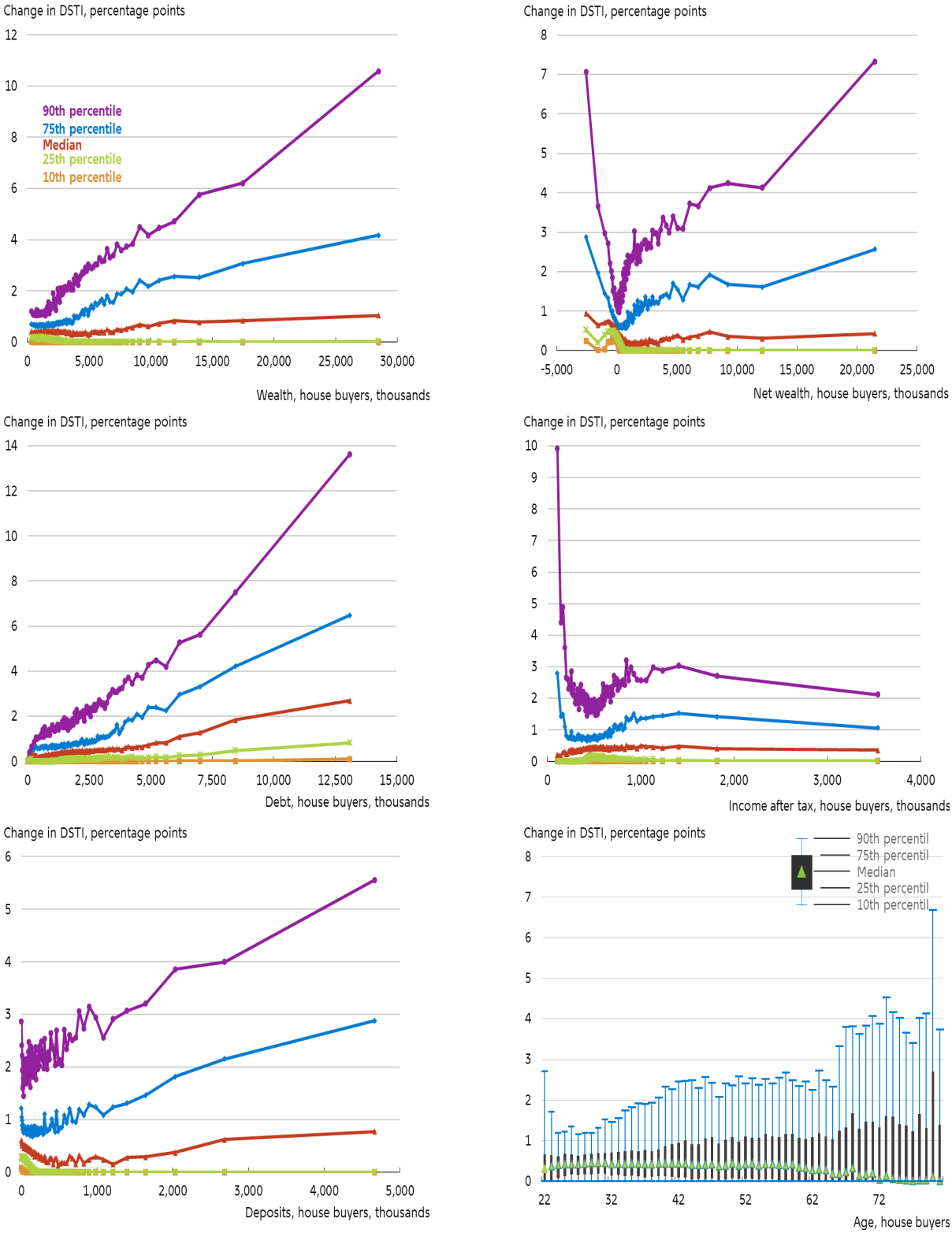
Figure 25: Box plots for ΔDTA for DSTI and DTA percentiles for house buyers



(a) (b)

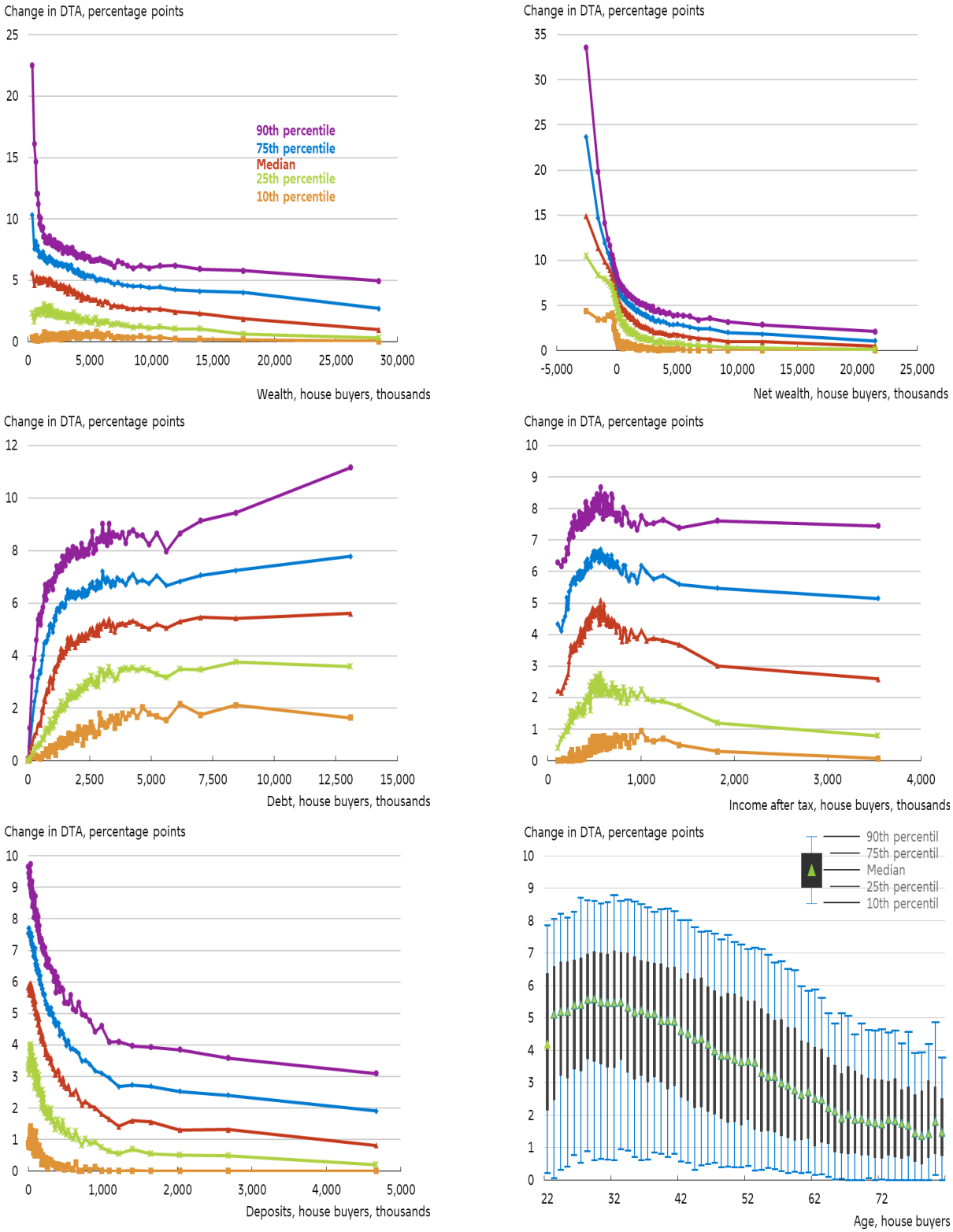
Notes: Percentiles of the ΔDTA distribution for house buyers for each DSTI percentile (a) and DTA percentile (b). The dots on the lines represent 1 per cent of homeowners across the DSTI and DTA distribution. E.g. the dots on the red line in (a) are the median ΔDTA for each percentile of homeowners sorted according to their DSTI.

Figure 26: Box plots for ΔDSTI for house buyers



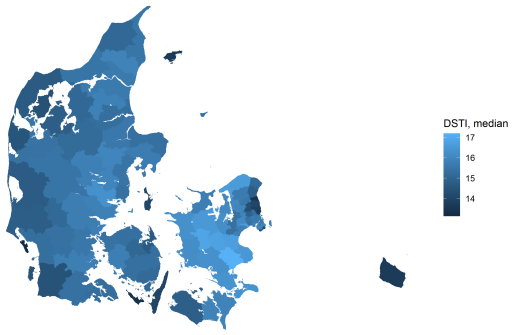
Notes: Percentiles of the ΔDSTI distribution for each percentile of house buyers sorted according to wealth, net wealth, debt, income, and deposits. In the bottom-right panel, the distribution is plotted across the age profile of households.

Figure 27: Box plots for ΔDTA for house buyers

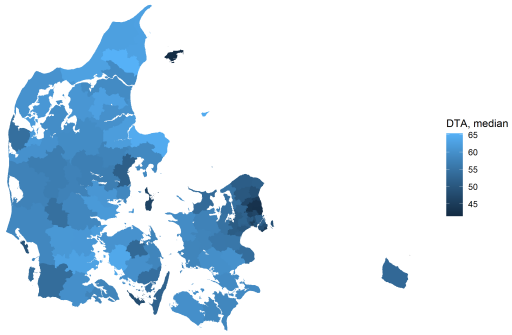


Notes: Percentiles of the ΔDTA distribution for each percentile of house buyers sorted according to wealth, net wealth, debt, income, and deposits. In the bottom-right panel, the distribution is plotted across the age profile of households.

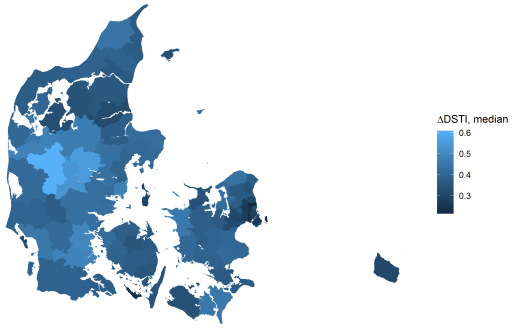
D Geographical distribution of interest-rate sensitivity



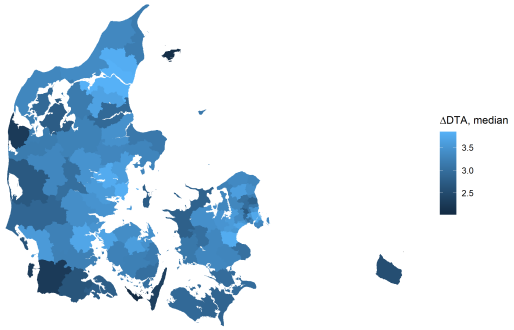
(a) DSTI



(b) DTA



(c) ΔDSTI



(d) ΔDTA

Notes: Median DSTI (a), median DTA (b), median ΔDSTI (c), and median ΔDTA (d) for homeowners with debt at the municipal level.

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