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The Intertemporal Marginal Propensity to Consume out of Future Persistent Cash-Flows

Evidence from Transaction Data*

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Abstract

To analyze the effectiveness of stabilization policies which includes effects on households future income it is central to account for anticipation effects on consumption. We investigate this using high-frequency spending and balance sheet data from a major Danish bank. We examine the behavior of borrowers with adjustable rate mortgages, and exploit that the bank sends a letter before the annual reset containing advance information on the expected change in mortgage payments. We find that unconstrained households respond immediately, while liquidity constrained households instead wait and respond around the time the cash-flow-arrives. The cumulative response is similar across the liquidity distribution. This is in line with a standard buffer-stock consumption model, and implies that it is less effective to target stimulus to low liquidity households when the effect on household income is partly in the future.

Keywords: Consumption, anticipation effects, intertemporal MPC, persistent shocks, mortgages, monetary policy, heterogeneous agent models.

JEL Codes: D12, D14, D91, E21, E44, E52, G21.

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1 Introduction

A central feature in work horse macro models of consumption and saving is that agents are forward-looking (Deaton, 1991; Browning and Lusardi, 1996; Carroll, 1997). In such models unconstrained consumers adjust spending when they receive new information about changes to their future budget rather than at the time the cash-flow arrives, and only liquidity constrained consumers adjust spending when the cash-flow actually arrives. It is not new that policy changes can affect economic outcomes from the point of announcement and ahead of the actual implementation (e.g., House and Shapiro, 2006; Ramey, 2011a). In some contexts, policy makers even rely on anticipation effects; central banks, e.g., engage in forward guidance, i.e., advance notice about interest rate changes, to stimulate or contract the economy (e.g., Campbell et al., 2012). For modern Heterogeneous Agent New Keynesian (HANK) models, recent results furthermore show that the anticipation effect of future cash-flows on current consumption is central for the effectiveness of both monetary policy (Kaplan et al., 2018; Auclert, 2019) and fiscal policy (Hagedorn et al., 2019; Auclert et al., 2018). Hagedorn et al. (2019) show that the presence of strong anticipation effects of future cash-flows is a central difference between Two Agent New Keynesian (TANK) models and HANK models. Auclert et al. (2018) even propose that the intertemporal marginal propensities to consume , i.e., the marginal propensity to consume out of future, current and past innovations to income provide sufficient statistics for understanding the transmission of a wide range of shocks.

From an empirical perspective, it is a challenge to measure the marginal propensity to consume out of future shocks to the household budget as this requires precise knowledge about the point in time that information about expected changes to the

future budget arrives as well as data on income, consumption and balance sheets. Furthermore, both the budget change and the timing of the advance notice must be exogenous to avoid selection effects confounding the response. In this paper, we present a setting where all these challenges are addressed. We quantify the direct effect of the automatic interest rate resets of 1-year Adjustable Rate Mortgage Loans (ARM) on the budget of each household in our sample and measure its impact on their spending. This effect is sometimes referred to as the "borrower cash-flow channel" (La Cava et al., 2016) or as the "unhedged interest rate exposure" (Auclert, 2019). To quantify the response to a future expected change in mortgage payments, we lever a natural experiment where a major Danish mortgage bank, Nykredit, sends out a letter with a notice about the expected change in mortgage payments six months ahead of the actual mortgage rate reset. To document how the reset affects the household budget and spending, we collect transaction level data from the bank. The records document actual transactions, i.e., there are no reporting errors. The combination of the advance notice and the high frequency data with information about income, spending and balance sheets put us in a unique position to cleanly identify the effect of a drop in the debt service as well as to map the intertemporal MPCs over the relevant part of the mortgage reset cycle, i.e., the spending response to a change in future, current and past changes in mortgage payments. Additionally, the change in mortgage payments is persistent lasting for at least a year and likely longer, making it more salient and comparable to actual changes in monetary and fiscal policy.

We exploit the rich Danish research data infrastructure that allows us to combine transaction level data at the person level with administrative tax records and other public administrative registries for the customers of the bank as well as for a random sample from the population. This gives several advantages. First, the population

registers allow us to determine who lives together in a household. Next, the income-tax data enable us to identify whether the Nykredit bank customers have other bank connections, and if so how large the balances in other banks are, something which has been difficult to document in other transaction level data sets. This enables us to compare total wealth as recorded in the tax registries (see Leth-Petersen (2010) and Chetty et al. (2014) for a description of the wealth data from the tax authorities) with wealth recorded by the bank to make sure that we cover all wealth held by the household. Finally, since we have access to population data, we are able to assess how the Nykredit bank customers differ from the population at large.

Our data includes about 10,500 households who hold an ARM loan with one-year resets and who are exposed to at least one mortgage rate reset during the observation period. We observe all transactions for these households over the period 2011-2013. In order to identify the effect of the mortgage rate reset on the household budget and on spending, we exploit two types of variation. First, we exploit that households' budgets are differentially impacted by the reset because they hold mortgages that differ in size relative to their budget. Many households experience only minor changes to their budget, but about a third of the resets generate changes in mortgage payments that exceed 2.5 percent of the household's disposable income.[1] We also exploit that there are four 1-year ARM resets every year and that borrowers are allocated to these resets depending on the time of the year that the loan was originally established. The high frequency data is critical for our analysis because they allow us to document spending at the frequency that the information treatment takes place.

We find significant spending responses, both at the time of the announcement

[1]The change in mortgage rates might also affect the marginal interest rate that households face, implying a substitution effect. This effect would be similar across households, and thus independent of the size of the change in mortgage payment we use for identification.

and at the time the cash-flow hits the household budget. Households that are unlikely to be affected by liquidity constraints increase spending when the letter arrives but not when the cash-flow hits the household budget. Households that are likely to be affected by liquidity constraints also increase their spending, but they do thislater when the cash-flow hits, and not when the advance news about the payments arrives.[2] For all groups, the spending increase is concentrated on discretionary non-food spending, a category including durable and luxury goods. For the unconstrained households, the spending response remains significant at all levels of liquid asset holdings, and seems, if anything, to be increasing in the level of liquid assets.

One mechanism that could potentially confound our estimates is when income from other assets is correlated with changes in mortgage payments. The leading candidates for this are returns to bonds, stocks and changes in home values. First, financial assets and deposit account balances are dwarfed by the the size of mortgage loans. Moreover, the interest rate on deposits is close to zero throughout the sample period, which implies a weak lender cash-flow channel thatcannot substantially affect our results. Second, we show that similar results are obtained in a sub-sample of households not holding bonds or stocks. Third, our results are robust to controlling for municipality-month fixed effects, suggesting that house price movements are not an important confounding factor.

We rationalize our findings within a buffer-stock consumption model (Deaton, 1991; Carroll, 1997) augmented with an extra income component, which is zero today, but which the household anticipates to be positive starting from a period in the future and onwards. We are able to replicate the main features from the empirical analysis, in particular, the response to the future change in the cash-flow by

[2]We only observe reductions in mortgage repayments and, thus cannot investigate whether responses are asymmetric to gains and losses.

unconstrained households and the response to the realized cash-flow by liquidity constrained households. As in the empirical analysis, we also find a significant response among high (liquid) wealth households. The model can explain this as long as the impact of the mortgage rate reset on the household budget is modeled as persistent. For the initially constrained households, we show that the theoretical response in the anticipation period depends on the strength of the precautionary saving motive. If the precautionary saving motive is strong, the household will be moving away from the borrowing constraint in the anticipation period and, therefore, willbegin to respond during the anticipation period (but still later than the unconstrained households). In models with less or no income uncertainty, the household stays at the borrowing constraint throughout the whole anticipation period, and there is no response in the anticipation period, which is close to what we observe empirically.

Our findings have wide implications. Our paper is among the first to document the intertemporal MPCs related to pre-announced mortgage rate changes and the associated changes in disposable income. We document that anticipation effects are significant and that mortgage rate changes can have significant effects when they are announced but not yet put in place. More generally, our results show that pre-announced and salient changes to the household budget can have significant and lasting effects on household savings decisions. Such changes can arguably also be brought about by other policies, for example, through tax reforms or other fiscal reforms that directly target the household budget.

Our analysis contributes to several different literatures. First, we document the importance of quantifying the intertemporal MPCs and not merely current responses to realized changes to the household budget. This generally speaks to the recent macroeconomic literature emphasizing the importance of the household budget channel (e.g., Kaplan and Violante, 2018; Auclert et al., 2018; Hagedorn et al.,

2019) for understanding the impact of fiscal and monetary policy.[3] Most directly, our findings speak to the branch within this literature dealing with the effect of monetary policy.

Second, our study contributes to a small empirical literature studying how changes in interest rates affect household spending through adjustments of mortgage payments. Di Maggio et al. (2017) focus on US households with ARMs originated between 2005 and 2007. They find that, on average, consumers increase their car purchases by 40 percent when mortgage payments declined at the reset due to the prolonged low interest rates. Jappelli and Scognamiglio (2018) compare Italian ARM and fixed rate mortgage (FRM) borrowers following the Great Recession, and find that the decline in mortgage payments for ARM borrowers did not lead to a change in spending. La Cava et al. (2016) use a similar design for Australia and find that a change in mortgage payments impacts spending. Cloyne et al. (2020) show that the aggregate response of consumption to interest rate changes is driven by households with a mortgage, and Flodén et al. (2020) also find a positive spending response to changes in mortgage payments associated with ARM resets. These studies investigate responses at the annual frequency and focus on responses to the actual cash-flow changes arising from interest rate resets.[4] Agarwal et al. (2020) measure the effect of a universal Chinese policy that reduced debt service by lowering the mortgage payments. Comparing borrowers to non-borrowers over time, they find a spending response through credit card spending and a decrease in the credit card delinquency rate. The policy was announced 4 months before its implementation. As them, we document a response to the announcement. We directly measure the

[3]Kaplan and Violante (2018) provide a recent review of this emerging literature. Additional references include, among others, .Oh and Reis (2012); McKay and Reis (2016); Guerrieri and Lorenzoni (2017); Den Haan et al. (2018); Bayer et al. (2019); Luetticke (2020); Ravn and Sterk (2020).

[4]Di Maggio et al. (2017, p. 3566) finds some suggestive evidence of an anticipation effect, but cannot quantify it due to the lack of a sudden and salient information treatment.

announcement shock at the household level and quantify the intertemporal MPCs, i.e., the responses to future, current and past changes in mortgage payments. We show that the spending response is concentrated on non-food spending, that non-constrained households respond when they are informed about the change in mortgage payments and that constrained households increase spending around the time the cash-flow hits. An important new insight from our study is that high liquid wealth households adjust spending at least as much as low wealth households. We show that the patterns documented in the data are broadly consistent with standard consumption-saving theory. In particular, the standard consumption-saving model is able to rationalize the cash flow effect among constrained households and the significant response among high liquid wealth households at the time of the announcement. Simulating different policy scenarios, we show that the significant propensity to spend at the point of the information treatment of high liquid wealth households is likely due to the fact that ARM resets are perceived to be a persistent change to the household budget.

Third, our paper relates to a large body of empirical work studying the effect of anticipated and unanticipated income changes, including the effect of stimulus and fiscal policies. This literature also measures the effect of changes in the household budget, but it examines changes arising from different sources than studied here. Recent examples are Johnson et al. (2006), Agarwal and Souleles (2007), Parker et al. (2013), Misra and Surico (2014), Jappelli and Pistaferri (2014), Kreiner et al. (2019) and Fagereng et al. (2020). Most of this literature focuses on estimating the effect of anticipated or unanticipated payments, typically stimulus payments or other windfalls, but is primarily concerned with estimating the response to the arrival of the cash-flow.

Fourth, a few micro based studies are also concerned with anticipation effects of

future cash-flows[5], but find very mixed results. Agarwal and Qian (2014) study the effect of a Singaporean stimulus payment based on credit and debit card data. They find that consumers already increase spending at the point that the stimulus payment is announced. Likewise, Kueng (2020) finds that household spending adjusts to news about future after-tax income changes. Heim (2007) studies data from the Consumer Expenditure Survey and tests for announcement effects of state tax rebates, but finds no significant response to rebate announcements. Using information about tax filing dates, Baugh et al. (2018) find no anticipation effect of either future tax payments or tax rebates. Kueng (2018) finds limited evidence of anticipation effects from Alaska Permanent Fund news. Using survey questions about spending in hypothetical scenarios, Fuster et al. (2020) find some evidence of reaction to news about future income losses, but not to income gains. These studies, with the exception of Kueng (2020), focus on news about transitory shocks, while we focus on a salient persistent shock. Additionally, we are able to study the heterogeneity in responses not only across unconstrained and constrained households, but also across unconstrained household with less and more liquid assets.

Finally, our study is related to a recent literature based on transaction level data (see, e.g., Gelman et al., 2014; Kueng, 2018; Ganong and Noel, 2019; Baker, 2018; Olafsson and Pagel, 2018). While transaction level data opens up the possibility of analyzing consumer responses in much more detail and with much more precision than in previous data sets, they are not without shortcomings. Our data contains the same level of granularity as the data previously used in the literature, but we

[5]There is also a literature trying to identify announcement effects of fiscal policies based on aggregate data, Poterba (1988); Mertens and Ravn (2012); Ramey (2011b). They find mixed evidence. Poterba (1988) does not find any announcement effects of tax reforms, while Mertens and Ravn (2012) do. Ramey (2011b) studies the impact of government spending shocks and finds support for anticipation. This literature is, however, by nature, not informative about household level heterogeneity and, thus, does not speak to the question about the household interest rate exposure channel.

are able to link the individuals to population and tax records, and this allows us to assess the extent to which the transaction level data capture the entire budget set of the household and to assess the representativeness of our sample in terms of the population.

The next section provides a description of the institutional setting and the information treatment. Section 3 presents the data and documents how the interest rate resets impact the household budget. Section 4 presents the results of the analysis of how a (future) change to the household budget affects spending, both with respect to the timing of spending adjustments, and the magnitude and the type of spending that is adjusted. We first present bi-variate regression results and then a full multivariate analysis. Section 5 presents the model, and simulation results are compared to the results from the empirical analysis. Section 6 sums up and outlines implications of our findings.

2 Institutional setting and the information treatment

More than half of the adult population in Denmark are home owners at any given point in time, and many more are home owners at some point during their life time. Only a relatively small fraction hold financial assets, such as stocks and bonds, outright, and even for owners of such financial assets, the value of these assets constitutes a relatively small fraction of their total assets. For most home owners the housing asset and the mortgage loan make up the two dominant portfolio components. Housing is financed primarily through mortgage banks, which are financial intermediaries specialized in the provision of mortgage loans. Mortgage loans are match-funded, i.e., when granting a mortgage loan the mortgage bank issues bonds that are sold on the stock exchange to investors and the mortgage bank then pays

out the proceeds to the mortgage borrower. A basic principle underlying the design of the Danish mortgage market is the balance-principle, whereby total payments from the borrower, i.e., mortgage payments, installments and fees, and total payments from mortgage banks to mortgage bond holders must be in balance, except for fees which are paid by the borrower and kept by the mortgage bank. Match funding and the balance principle provides price transparency, where the interest on the loan corresponds to the capital market rate, except for fees. Consequently, once the bank has screened potential borrowers based on the valuation of their property at the time of the loan origination and on their ability to service the loan, i.e., their income, all borrowers who are granted a loan of a given type at a given point in time face the same interest rate, which is determined by the market. In this way, the Danish mortgage system is affected directly when the central bank implements monetary policy initiatives affecting the market interest rate.

Mortgage banks offer both fixed rate and adjustable rate mortgage loans. Loans can be of varying maturity up to 30 years, and they can be issued up to a legally defined threshold of 80 percent of the value of the home at loan origination. A significant fraction of mortgage loans are adjustable rate loans, and they come in varieties, for example, with interest rate resets every 6 months or every 1, 3, or 5 years. All types of mortgage loans can be combined with an interest only option for up to ten years.

Borrowers have the right to prepay their loan. However, prepayment options depend on the characteristics of the underlying bonds. In all cases, the borrower has the option to buy the bonds in the market and return them to the mortgage bank. If the underlying bonds are callable, then the loan can typically be prepaid at par. This is the case for FRMs. ARMs can also be prepaid, except for the last two months before the automatic interest rate reset. However, ARMs are based on

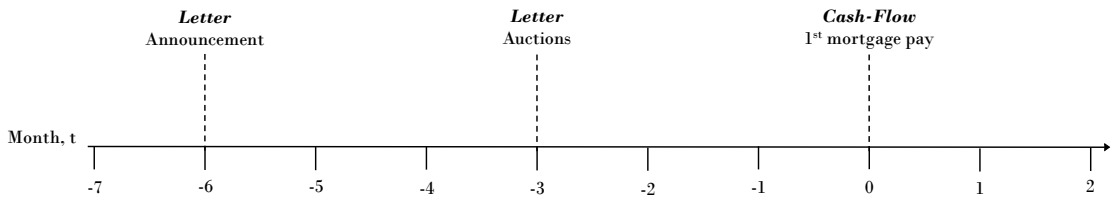
non-callable bonds and this implies that refinancing outside of the time of automatic refinancing requires the borrower to buy back mortgage bonds matching the loan, i.e., at the given market rate. In connection with the interest rate reset, ARMs can be prepaid at par.

Here we focus on ARMs for two reasons. First, for ARMs the exposure to and the timing of the the interest rate reset is set according to a plan that is determined at the origination of the loan, and there is thus no issue relating to active and passive behavior in the propensity to refinance (Andersen et al., 2019). Second, Nykredit, the mortgage bank, we have acquired data from, has implemented a particular information cycle where they inform their ARM borrowers about the expected change to the borrowers' mortgage payments ahead of the actual reset. This allows us to test whether the information treatment has an impact on household spending at the time the letter arrives rather than when the actual cash-flow change hits the household balance sheet.

Figure 1 shows the 1-year ARM reset cycle. We define $t = 0$ as the month that the first mortgage payment at the reset rate is due. Six months ahead of this (in $t = -6$) Nykredit sends out a letter informing the customer about the imminent mortgage rate reset, and how the bank expects the reset to affect total mortgage payments of the household. In Appendix A, we have reproduced such a sample letter. The letter explicitly states total mortgage payments for the household before and after the reset, i.e., how Nykredit expects that the reset will affect the household budget is very salient. As we will show below, the bank's stated expectation is highly correlated with the ex post change in mortgage payments. In month $t = -5$ the household must commit to continuing with its current loan or prepay it.[6] In month $t = -4$, the bonds that are going to finance the loans after the reset are auctioned,

[6]We exclude all observations from a reset cycle where a household chooses to prepay their current mortgage and take out another one.

Figure 1: ARM reset cycle



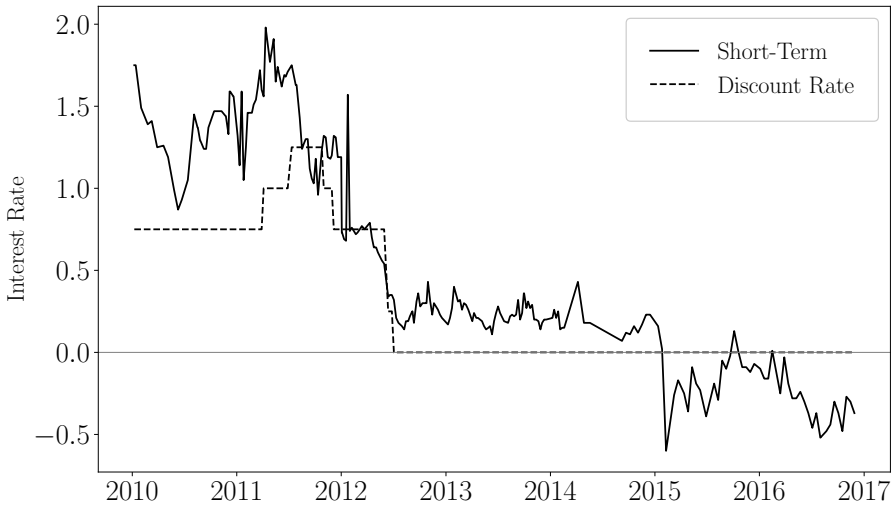
and two weeks later, i.e., in month $t = -3$, a second letter is sent to the households informing them about what their exact mortgage payments will be after the reset. Payments on one-year ARMs are made quarterly. By the end of months $t = -6$ and $t = -3$ payments at the old rate are due, and the first payment at the new rate is due in month $t = 0$.

The objective of this study is to measure the impact of mortgage payments on spending. As will be outlined in detail in the next section, we have spending data available from 2011. Figure 2 shows the evolution of effective interest rates on short-term mortgages, i.e., ARMs, as well as the "Discount Rate", which is one of the leading interest rates of the Danish central bank, Danmarks Nationalbank. Figure 2 shows that short-term mortgage rates dropped significantly over the period 2010-2013. After 2013 the short-term mortgage rate is very close to zero and varies very little. Furthermore, the short-term mortgage rate co-moves relatively closely with the "Discount Rate". This follows from the mortgage market structure where mortgage bonds are traded on the stock exchange

3 Data

The empirical analysis is based on transaction level data regarding mortgages, financial assets and spending made available to us by Nykredit. The bank data are combined at the individual level with third-party reported administrative register

Figure 2: Interest Rates



Notes: The figure plots the discount rate of the Danmarks Nationalbank and the weekly average effective interest rate on short term mortgage bonds. This is the weighted average of newly issued 1 and 2 year mortgage bonds used for financing 1 year and 2 year ARMs where weights are determined by the relative volume of issues of 1 and 2 year bonds. The ticks on the x-axis mark the beginning of the year. Data are from Finance Denmark (see financedenmark.dk).

data for the entire Danish population. The population data enable us to identify household units, and to assess how the customers of Nykredit compare to the population at large. Besides information about the population, the administrative data includes data from the Danish Tax Agency (SKAT) that includesinformation about all assets and liabilities for the entire population. This enables us to asses whether the detailed financial information that we observe in the Nykredit data cover the entire balance sheet of the households included in our sample.

3.1 Transaction level data

Nykredit is the largest Danish mortgage bank and is responsible for about 40 percent of all mortgage loans issued in Denmark. Besides the mortgage bank, Nykredit also has a retail bank which includes among its customers about 12 percent of the Danish population. For the purpose of this analysis we focus on households who

hold a mortgage with Nykredit and who are also customers of the retail bank, i.e., the intersection of customers in the two branches.

Nykredit has provided us with data on all mortgage loans as well as transaction level data for all their retail bank customers for the period 2011-2016. The data contain information about account types which we can classify into categories such as deposits, savings, pensions, housing loans, stock/bond holdings, etc. Furthermore, based on internal banking classifications, we can classify the transactions into income, payment service contracts (automatic bill payment services), transfers to/from other accounts, cash withdrawals, credit/debit card spending including payments made using mobile phones, and pension payments. Based on the Merchant Category Codes of retailers, an international standard for classifying merchants by the type of goods and services they provide, credit/debit card spending can be assigned to types of spending based on the type of outlet, for example grocery shops, clothes shops, transportation, restaurants, automobile sellers, subscriptions/memberships, mobile services, internet, television, etc. Based on this information we construct a measure of total monthly spending.

Nykredit offers both FRMs and ARMs. Our focus is on households with at least one 1-year ARM. As we want to measure spending responses to the automatic mortgage rate reset, we limit the sample to include only observations for households that are customers of both the mortgage and the retail bank branches of Nykredit. Next, we restrict the sample to include only households that have their salary paid into a Nykreditaccount. This is to minimize the risk that the customers included in the sample have significant activities in other banks. Figure 2 shows that there is only relevant variation in the short-term mortgage rate up to an including 2013; therefore, we include in the estimation sample only household units holding ARMs that were automatically refinanced at least one time during the period April 2011 to

September 2013. The final sample includes 10,579 households for whom we observe spending and at least one interest rate reset.

Based on the bank data we define gross spending as consisting of bill payments and cash-withdrawals, non-food spending and spending on food. Non-food spending includes spending on the home, spending on transportation, clothing, spending in health stores, spending in other outlets and spending on vacations. Food spending includes grocery and supermarket spending. Annual average gross household spending in our sample was approximately 500,000 DKK in 2011. This matches the level of spending stated in the Danish Family Expenditure Survey for people with a similar level of income as the households in our sample,[7] and it suggests that our spending data have a high level of coverage.

Our analysis will focus on the categories of spending that are easy to adjust, i.e., non-food and food spending, which make up 23 and 13 percent of the household budget. Cash withdrawals make up 7 percent of the transaction flows in our sample. Cash withdrawals are not easily allocated to spending purposes; they arguably facilitate discrete spending, but they could also be made to facilitate transfers. Generally, cash-use is low in Denmark covering just 16 percent of the total value of retail transactions (Smestad, 2017). This is considerably lower than in the US where cash transactions make up 39 percent of the value of transactions (Greene and Stavins, 2018). Bill payments make up a large fraction of the household budget for the households in our sample. However, we cannot see what types of payments are made; therefore, we omit bill payments from the analysis.[8]

We will later consider sub-samples where we split the sample according to the amount of liquid assets the households hold. We define liquid assets as deposits

[7]See summary statistics by level of income from the Danish Consumer Expenditure Survey at http://www.statistikbanken.dk/10082.

[8]We also performed the analysis including bill payments. The results were less clear than the results reported here, but all pointed in the same direction.

measured just after the household receives its monthly income.

3.2 Administrative data

Using data from a single bank is potentially problematic because customers may have accounts in other banks which are then not observed (Baker, 2018). In our context, we can link the bank data from public administrative data for the entire population. These data enable us learn whether the customers that we see in the bank data also have accounts elsewhere. Moreover, the administrative data allows us assess how the characteristics of the customers in the bank sample compare to the characteristics of the general population.

We use register data made available by Statistics Denmark from three different sources. First, we use a standard battery of merged administrative register data compiled by Statistics Denmark. These data include standard demographic information, such as age, sex, education, household composition, and data about income and wealth collected through income-tax returns. The latter gives information about disposable income during the year and about wealth, which can be broken into a number of subcategories. This information allows us to construct asset classes, such as net bank deposits, including deposits as well as bank loans and any other type of loan not secured by real estate, and financial assets, including the market value of stocks and bonds. The wealth data are measured as their market value on the last day of the year. Because these data are collected annually for the entire Danish population they are longitudinal by nature; for this study we make use of data covering the same period as the bank data. The tax return data are known to be of high quality (Kleven et al., 2011) and have been used extensively in previous studies of savings behavior, see for example, Browning et al. (2013), Leth-Petersen (2010), and Chetty et al. (2014).

The second type of register data are also obtained from the tax authorities. They include account level information, both deposit and loan accounts, recorded at the annual level, and they document the balance of the account as well as incurred mortgage payments over the past year. They also include information about the bank at which the account is held. This is valuable to us because it allows us to identify whether the individuals observed in the data provided by Nykredit have accounts outside of Nykredit. These data are available up to 2013, and they enable us to construct a sub-sample consisting of Nykredit customers who are unlikely to have major banking activities outside of Nykredit.

The third type of register data includes detailed information about mortgage loans. These data cover the same period as the bank data and include information about the terms of the mortgage, i.e., the principal, the size of the outstanding debt, the coupon rate and the issue date. The data are collected by Finance Denmark, which is the business association for all banks in Denmark. They cover the five largest mortgage banks, which represents a total market share of 94.2 percent (Andersen et al., 2020). In combination with the income-tax return data we then have an almost complete picture of the balance sheet for all individuals in the Danish population.[9]

3.3 Summary statistics

In Table 1 we present summary statistics for our sample of bank customers as well as for the general population of mortgage holders and the population of ARM1 holders in Denmark in 2011-2013.

[9]We do not have information about informal borrowing and transfers outside the formal banking system, and we do not have information about unlisted stocks and high value items such as paintings and boats.

Table 1: Summary Statistics for sample, population of mortgage holders and population of ARM1 holders

Sample	Population	All ARM1	Sample
Demographics			
Age	51.73	49.41	47.88
#children	0.79	0.96	1.22
#banks	1.83	2.00	2.45
Singles, %	0.22	0.19	0.160
Primary school, %	0.48	0.42	0.48
High school, %	0.03	0.03	0.04
Short higher education, %	0.12	0.12	0.13
Medium higher education, %	0.14	0.14	0.19
Long higher education, %	0.07	0.08	0.11
Research degree, %	0.01	0.01	0.01
Income			
Gross income	599,368.00	675,710.00	801,528.00
Disposable income	417,141.00	460,712.00	530,692.00
Deposits			
Deposits	99,822.00	103,630.00	89,924.00
Deposits / Gross income, %	0.20	0.20	0.13
Mortgage Loan			
Remaining maturity, years	27.70	28.70	28.33
Mortgage debt	1,013,547.00	1,440,995.00	1,800,340.00
Mortgage debt / Gross income	2.08	2.55	2.54
Interest-only loans, %	0.47	0.68	0.63
Stocks			
Stock-holding households, %	0.35	0.36	0.33
Stock holdings	24,073.00	34,828.00	31,237.00
Stock holdings / Gross income, %	0.04	0.06	0.04
Bonds			
Bond-holding households, %	0.13	0.13	0.16
Bond holdings	74,104.00	76,161.00	60,512.00
Bond holdings / Gross income, %	0.09	0.09	0.06
Debt			
Non-mortgage debt	157,454.00	216,875.00	147,663.00
Non-mortgage debt / Gross income, %	0.32	0.39	0.22
Households	1,148,923	352,639	10,579

Notes: Statistics on demographic variables and gross and disposable income measures are based on data from the Danish administrative population registers. The cross-bank data on debt and stock and bond-holdings are collected from the Danish tax records, with variables measuring end-of-year balances of households. The population-wide mortgage data are made available by Finance Denmark, which is the business association for all banks in Denmark. For share variables (%), we report mean values, while for level variables, to comply with data discretion, we report averages of the binned 50th percentiles in the sample as a measure of the median. All statistics are computed for the years 2011-2013, and monetary values are measured in DKK.

Column 1 shows summary statistics for the general population of mortgage holders, while column 2 narrows the sample to include only holders of 1-year adjustable rate mortgage (ARM1) loans in the population. Column 3 shows summary statistics for the sample of ARM1-holders who are customers of the bank in 2011-2013. The table shows that ARM1 holders are, in general, slightly better educated, have higher incomes and higher mortgage debt as a fraction of their income. They hold more debt, but they are also slightly more likely to hold financial assets and have more funds in their deposit accounts. Fewer than half of the households in the ARM1 sample hold stocks and bonds, and the median amounts to 6 percent of annual gross income for shares and 8 percent for bonds, which is modest compared to deposits, which make up about 18 percent of annual income, and dwarfed by mortgages, which are 2.5 times annual income. The bank sample of ARM1 borrowers differs slightly from the general population of ARM1 holders in that they tend to be slightly younger, less likely to be single, have higher incomes, hold less non-collateralized debt, but also slightly lower deposit balances and financial assets. However, the deviations are not massive, and for some key variables, such as the mortgage to income ratio, they look quite similar to the general population of ARM1 holders.

The households in our bank sample have, on average, 2.5 bank connections. This could suggest that we do not capture the entire household budget. In a robustness check presented in Section 4, we restrict our sample to a sub-sample consisting of households that have no bank connections outside of Nykredit. This reduces the sample size, leading the parameters to be less precisely estimated, but it renders the estimates practically unchanged.

4 Results

This section presents the empirical results. We start out documenting how the automatic mortgage rate resets impact the household budget. We then go on to show bi-variate graphical evidence documenting how changes in mortgage payments correlate with changes in household spending. Next, we introduce a full multivariate analysis and document how the timing of the response varies across levels of liquid assets. In the final subsection, we provide an estimate of the effect of the interest rate reset on the level of household spending.

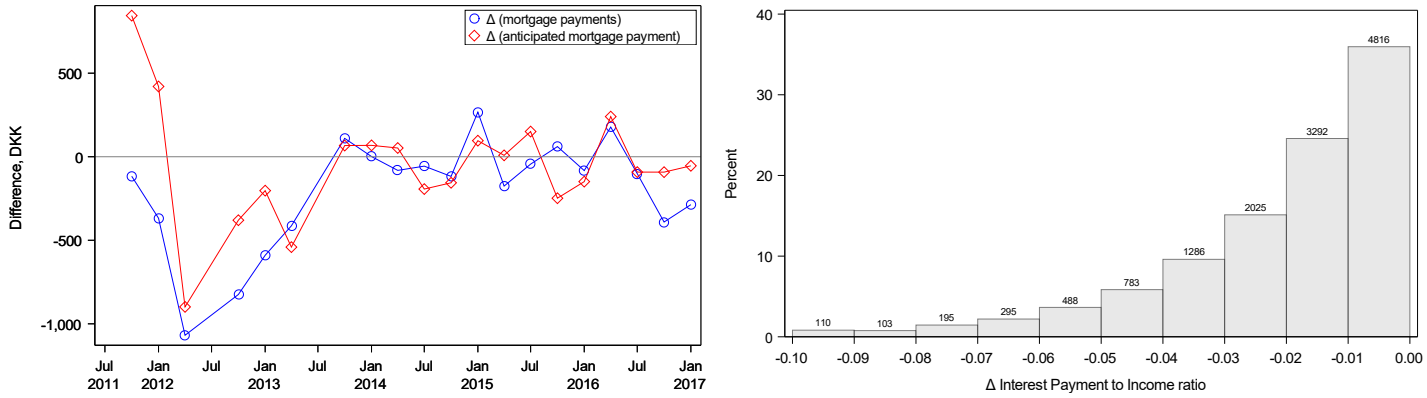
4.1 How does the mortgage rate reset affect the household budget?

The ARM rate reset primarily impacts the household budget through the so-called borrower cash-flow channel, i.e., through its impact on the debt service. Rate resets can impact households differently, both because the size of the loan differs across households and because interest rate resets differ in impact across time due the development of the market interest rate, cf. Figure 2. Figure 3 shows how ARM resets develop across time and how they impact across households in our sample. The left panel shows the average change in mortgage payments in terms of both the actual change and the expected change, which are conveyed by letter to the borrowers six months in advance of the actual change. The graph shows that resets in the period considered generally lead to lower mortgage payments, and that the announced and actual changes are closely correlated The right panel shows how the resets affect mortgage payments measured relative to average disposable income, where disposable income is averaged across the reset cycle, i.e., $t \in [-8; 3]$. For most households the resets have only minor consequences for the household budget, but

Figure 3: Impact of ARM resets on mortgage payments across time (left) and across households (right)

(a) Mortgage payment changes, average

(b) Mortgage payment changes, distribution



Notes: In the left panel, the blue line shows the average change in mortgage payments. The red line shows the average change in mortgage payments calculated according to the announcement letter. Our empirical analysis is based on the period April 2011 to September 2013. The right panel shows the distribution of mortgage payment changes, relative to the disposable income of the household, across this period of time.

for those with large loans relative to their income, the reset impacts the household budget significantly. According to the graph, about 1/3 of the resets impact the household budget by more than 2.5 percent of household disposable income.

4.2 How does the announcement and implementation of the mortgage rate reset affect spending?

The previous section documented how resets impact the household budget through the borrower cash-flow channel. We now investigate the impact of the mortgage rate reset on household spending.

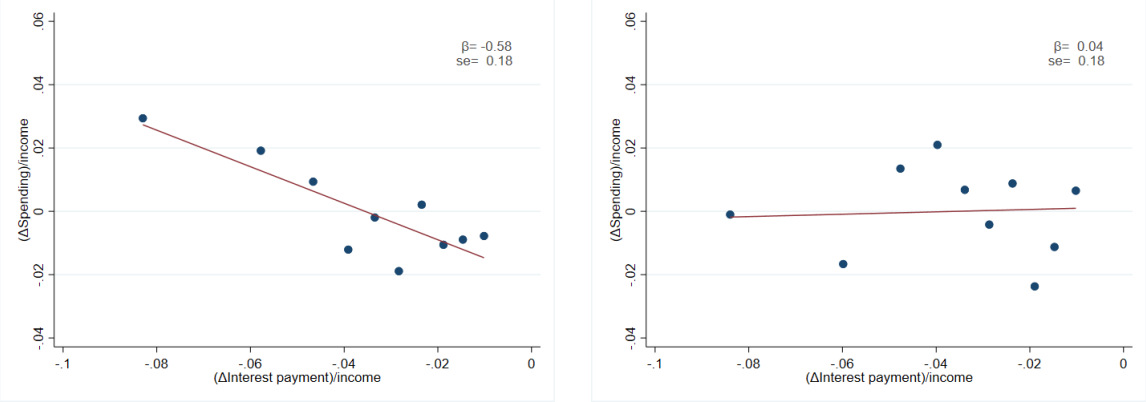
We start by presenting bi-variate graphs of the propensity to spend out of the change in mortgage payments for the subset of households who receive the 30 percent largest reductions in mortgage payments relative to disposable income in the sample.

Initially, we focus on the response six months ahead of the actual change in mortgage payments ($t = -6$), when the borrower receives the letter from Nykredit about the expected change in mortgage payments, and on the cash-flow period ($t = 0$), when the first payment on the loan is made following the reset. If consumers respond based on the announcement of the expected change in their mortgage payments rather than when the cash flow hits their budget, we would expect to see a response in the announcement month, and not in the month when the cash-flow is affected. The result is shown in Figure 4. The two panels show the relationship between $\frac{\triangle spending}{disposable\ income}$ and $\frac{\triangle mortgage\ payments}{disposable\ income}$ where all variables are measured at the monthly frequency, and disposable income is averaged over $t \in [-8; 3]$. The left panel shows the relationship for $t = -6$, i.e., at the time of the advance notice, and the right panel shows the relationship for period $t = 0$, i.e., the month when the cash-flow effect of the reset is realized. Both panels show a binned scatterplot based on deciles as well as a linear regression line through the underlying micro data. The slope of the regression line is (the negative of) the marginal propensity to spend out of the future cash-flow (left) and out of the actual cash-flow. $MPC(t = -6) = -0.58$, which means that a 1 DKK reduction in mortgage payments is associated with a 0.58DKK increase in spending at the time the household receives the letter with the advance notice. Considering the right hand-side panel, the estimated association is $MPC(t = 0) = 0.04$, but this parameter is imprecisely estimated and the null hypothesis that it is distinguishable from zero cannot be rejected at conventional levels of statistical significance. These graphs suggests that there is a significant spending response at the time the borrowers receive the letter with the advance notice, but not when the cash-flow actually hits their budget.

We now turn to a full multivariate analysis where we can explore the complete dynamic response pattern. To do this, consider the following regression setup

Figure 4: The propensity to spend out of the change in mortgage payments six months before(left) and when the cash-flow is affected(right).

(a) $t = -6$ (b) $t = 0$



Notes: The two panels show the relationship between spending adjustments and changes in mortgage payments for the one third of the sample with the largest reductions in interest payments in the sample. Spending includes non-food and food spending. The change in spending and the change in mortgage payments are both measured relative to average disposable income calculated over $t \in [-8; 3]$. The left panel shows the relationship for $t = -6$, i.e., the point of time of the advance notice, and the right panel shows the relationship for period $t = 0$, i.e., the month when the cash-flow effect of the reset is first realized. Both panels show a binned scatterplot based on deciles as well as a linear regression line through the underlying micro data. Before plotting the graphs, spending has been regressed on a constant. The dependent variable is censored at p2/p98 calendar-month-by-calendar-month. The change in mortgage payments is truncated at -0.11.

$$\Delta c_{it} = \sum_{j=-7}^{3} \gamma_j 1\{t = j\} \Delta R_{it} + \Gamma X_{it} + d_{it} + \varepsilon_{it}, \tag{1}$$

where i denotes the household, t denotes time in months relative to the first mortgage payment at the new rate after the reset, and $1\{t = j\}$ is the indicator function, which takes the value 1 if $t = j$. Δc_{it} is the first difference of spending divided by disposable income averaged over $t \in [-8; 3]$. ΔR_{it} is the change in the household's mortgage payments relative to disposable income, which in period $t \leq -2$ is proxied by the change announced by Nykredit, i.e.,

$$\Delta R_{it} = \begin{cases} \textit{announced} \text{ change in monthly mortage payment} & \text{if } t \leq -2 \\ \textit{actual} \text{ change in monthly mortgage payment} & \text{if } t > -2. \end{cases}$$

Recall that the cash-flow does not hit the household budget until $t = 0$. The coefficients γ_{-6} to γ_1 are thus the MPCs out of the future cash-flow, γ_0 is the MPC out of the realized cash-flow when it arrives, and γ_1 to γ_3 are MPCs out of the past realized cash-flow. X_{it} is a vector of control variables including the change in disposable income as well as mortgage and household size. d_{it} includes calendar-month×year fixed effects, and ε_{it} is an idiosyncratic error term.

Table 2 presents results from implementing eq. (1), where the dependent variable is the change in total spending, which is defined as the sum of food and non-food spending. Column 1 shows estimation results for the full sample. Results show that at $t = -7$ there is no significant response to the future change in mortgage payments. However, at $t = -6$, the period in which the borrower receives the letter about the expected future change in mortgage payments, the MPC out of the future change in mortgage payments is 31 percent and the effect is precisely estimated. In $t = -5$ and $t = -4$ there is some indication that spending reverts

back and it appears to be in roughly the same amount as the increase in $t = -6$. In period $t = -3$, which is the period in which the borrower receives the letter stating the result of the mortgage bond auction, and thus the point in time where the actual change in mortgage payments is known with certainty, spending increases again by about 15 cents for each DKK reduction of mortgage payments at the reset and the effect is precisely estimated. Spending keeps increasing in $t = -2$ and the effect is of the same magnitude. In none the of following periods do we find any significant spending effect. The pattern displayed here indicates that borrowers increase spending in response to a future reduction in their mortgage payments and that spending is not adjusted when the cash-flow actually hits the household budget.

In columns 2-5 we explore the heterogeneity by stratifying the sample into subgroups. In column 2, we single out households who, as an average over period $t = -7$ and $t = -8$, hold liquid assets, defined as deposits, corresponding to less than one month's disposable income. Holding a low level of liquid assets relative to disposable income has been been widely used as a marker for being affected by liquidity constraints (Zeldes, 1989; Johnson et al, 2006; Leth-Petersen, 2010). For this subgroup, the estimation results indicate no spending response at the time of the announcement, i.e., at $t = -6$, but rather a significant spending response in period $t = 0$ when the cash-flow effect of the mortgage rate reset arrives. The lack of a spending response at the time of the announcement is consistent with these households being affected by constraints and not having the means to increase spending until later in the ARM cycle. Column 3 presents the estimates on the subsample of individuals with liquid assets worth more than one month of disposable income. The results for this subsample resemble the results for the overall sample, cf. column 1, reflecting that this group makes up the vast majority of the overall sample. In column 4, the estimates on the subset of households who receive the 30 percent

Table 2: Dynamic responses to mortgage rate resets, total spending

Dependent variable: *total spending*	(1)	(2)	(3)	(4)	(5)
Announced change, $t = -7$	0.108	0.467	0.077	−0.100	−0.249
	(0.094)	(0.290)	(0.098)	(0.155)	(0.198)
Announced change, $t = -6$	−0.309***	−0.014	−0.327***	−0.623***	−0.514***
Letter: Announced change, MPCF	(0.086)	(0.274)	(0.089)	(0.151)	(0.186)
Announced change, $t = -5$	0.160*	−0.131	0.174*	0.573***	0.461**
	(0.095)	(0.305)	(0.098)	(0.159)	(0.188)
Announced change, $t = -4$	0.178**	0.002	0.187**	0.175	0.123
	(0.085)	(0.207)	(0.090)	(0.129)	(0.156)
Actual change, $t = -3$	−0.149**	−0.244	−0.144**	−0.199*	−0.260**
Letter: Auction, MPCF	(0.069)	(0.218)	(0.072)	(0.102)	(0.118)
Actual change, $t = -2$	−0.173**	−0.023	−0.187**	−0.254**	−0.172
	(0.075)	(0.223)	(0.079)	(0.111)	(0.149)
Actual change, $t = -1$	0.064	0.422*	0.040	−0.030	−0.015
	(0.068)	(0.223)	(0.070)	(0.082)	(0.104)
Actual change, $t = 0$	−0.091	−0.453**	−0.065	−0.097	−0.241*
First payment: Cash-flow effect, MPC	(0.074)	(0.209)	(0.078)	(0.114)	(0.136)
Actual change, $t = 1$	−0.016	−0.086	−0.018	0.046	0.104
	(0.076)	(0.244)	(0.079)	(0.096)	(0.119)
Actual change, $t = 2$	−0.022	0.355	−0.046	−0.052	0.013
	(0.069)	(0.255)	(0.071)	(0.094)	(0.119)
Actual change, $t = 3$	0.037	0.069	0.033	−0.013	−0.004
	(0.068)	(0.213)	(0.071)	(0.087)	(0.113)
Calendar month fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	0.040***	0.009	0.046***	0.037***	−0.048***
	(0.006)	(0.013)	(0.006)	(0.006)	(0.011)
Sample restrictions	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Credit constrained	-	*Yes*	*No*	*No*	*No*
Largest announcements at $t = -6$	-	-	-	*Yes*	*Yes*
Most wealth, liquidity $\geq 8 \times$ income	-	-	-	-	*Yes*
Observations	206,968	26,673	180,295	59,396	21,469
R^2	0.071	0.072	0.071	0.068	0.070

Notes: The dependent variable is the change in total spending normalized by disposable income averaged over $t \in [-8, 3]$, and it has been censored at p1/p99 calendar-month-by-calendar-month. Control variables include the month-by-month change in income as well as mortgage and household sizes. Column 1 includes the full sample. Column 2 is based on people who, on average, over periods $t = -7$ and $t = -8$ hold liquid assets, defined as deposits, corresponding to at most one month of disposable income. Column 3 is based on the subsample of individuals with liquid assets worth more than one month of disposable income. Column 4 includes the subset of households who received the third largest reductions in mortgage payments relative to disposable income according to the announcement. Column 5 is based on a subsample of the households in column 4 with large reductions in mortgage payments, where we require that they also hold liquid asset corresponding to at least eight months of disposable income. *MPCF* is the marginal propensity to consume out of the future cash-flow. *MPC* is the marginal propensity to consume out of the realized cash-flow. Standard errors are clustered at the household level, * indicates signficance at the 10 percent level, ** significance at the 5 percent level and *** significance at the 1 percent level.

largest reductions in mortgage payments relative to disposable income according to the announcement are presented. This is the sample used in Figure 4. In this case, the timing of responses resembles that shown in column 1, but the magnitude of the response is about double the size at the time of the announcement ($t = -6$). Finally, in column 5 we show results based on a subsample of the households in column 4 with large reductions in mortgage payments, where we require that they also hold liquid asset corresponding to at least eight months of disposable income, i.e., a group that received significant treatment and that is almost certainly not affected by liquidity constraints. Interestingly, the response profile is quite similar to the profile in column 4, but since these households have abundant financial wealth, it suggests that the change in mortgage payments may be perceived as a persistent change. In the Appendix, we show results where the dependent variable includes only non-food spending. For this outcome the response pattern is very similar to the response pattern documented in Table 2.

One mechanism that could potentially confound our estimates is if returns to other assets are correlated with the mortgage rate reset. The leading candidates for this are returns to bonds, shares and changes in home values. In Appendix Table 5, we have re-estimated the specification in Table 2 for the subsample of individuals not holding stocks or bonds. The sample is smaller and, consequently, the parameters are estimated less precisely. However, the overall pattern is the same as in Table 2, and we take this as evidence that our results are not driven by returns on financial assets. This is also in line with the observation that the value of financial assets the households hold is dwarfed by the the size of their mortgage loans, cf. Table 1. In the Appendix Table 6, we also report estimates where we control for municipality×month fixed effects. This effectively wipes out any variation moving within and across municipalities and hence also price variation at the municipal

level.[10] The results are also robust to this. Finally, Table 1 previously illustrated that households in the sample have an average of 2.5 bank connections. This could mean that we do not see activities outside of the bank that we have data for. In order to check for the importance of this, we have re-estimated the main specification for a subsample where the households only have one bank connection. The results are reported in Appendix Table 7 and they are also robust to this sample selection.

Overall, the results so far show evidence of a significant spending response at the point in time where borrowers receive the advance notice about the change in their mortgage payments. We show evidence that the anticipation effect is driven by households not affected by liquidity constraints and that the response is also strong for people holding substantial levels of liquid wealth. As opposed to this, people who are likely affected by liquidity constraints adjust spending several months after the announcement letter is sent out and around the time that the first payment at the new rate is to be made. These findings are consistent with basic insights from standard models of consumption and savings, as we will shown in Section 5. The analysis so far has focused on documenting the timing of responses based on high frequency measurements of spending adjustments. In the next section, we assess how the change in mortgage payments affects the level of spending across the ARM cycle.

4.3 The level effect of the reset on spending

In order to assess whether the mortgage rate reset shifts the overall level of spending and does not just affect the timing of spending, we collapse the data into a lower frequency. Specifically, we calculate average spending in the pre-announcement period, $c_{pre} = \frac{1}{2}\sum_{t=-8}^{t=-7} \widehat{c}_{it}$, and the post-announcement period, $c_{post} = \frac{1}{10}\sum_{t=-6}^{t=3} \widehat{c}_{it}$,

[10] Municipalities represent the lowest level of aggregation at which house price indices are published.

where $\widehat{c}_{it}$ is consumption after cleaning for calendar month effects. We calculate the average post-announcement spending over the periods $t \in [-6; 3]$ because the analysis in the previous section showed that spending responses are spread across most of this period. We then estimate the following regression

$$\Delta c_i = \beta_0 + \beta_1 \Delta R_i + \varepsilon_i, \tag{2}$$

where $\Delta c_i = c_{post} - c_{pre}$ is the change in average monthly consumption from the pre-announcement period to the post-announcement period, ΔR_i is the actual change in mortgage payments, and ε_{it} is an idiosyncratic error term.

The coefficient β_1 provides an estimate of the level shift in spending that is related to the mortgage rate reset that occurs from before to after the announcement letter arrives. The results from this regression are presented in Table 3, which includes estimates based on the same (sub-) samples as in Table 2. In column 1 we show the estimate for the overall sample. The estimated average MPC out of the change in mortgage payments is 41 percent, but the effect is not very precisely estimated. In column 2, we consider the subsample of households who are observed with liquid assets corresponding to less than one month's disposable income before the announcement, i.e., the subsample that is arguably affected by liquidity constraints. For this subsample, we estimate an MPC of the same magnitude as for the overall sample, but given the limited sample size, the effect is not precisely estimated. In column 3 we look at the subsample with liquid assets corresponding to more than one month's disposable income, and we confirm the result from column 1. Column 4 shows estimates for the subset of households that are not affected by the liquidity constraint and that experienced the third largest (announced) changes in mortgage payments. For this group we identify an average MPC of 64 percent. Finally, in

Table 3: Level effect of mortgage rate reset on total spending

Dependent variable: Δc_i	(1)	(2)	(3)	(4)	(5)
ΔR_i	-0.408^{*}	-0.403	-0.417^{*}	-0.641^{**}	-0.873^{*}
	(0.225)	(0.260)	(0.240)	(0.309)	(0.455)
Constant	-0.025^{***}	-0.004	-0.028^{***}	-0.033^{***}	-0.040^{***}
	(0.005)	(0.006)	(0.005)	(0.011)	(0.020)
Sample restrictions	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Credit constrained	-	*Yes*	*No*	*No*	*No*
Largest announcements at $t = -6$	-	-	-	*Yes*	*Yes*
Most wealth, liquidity $\geq 8 \times$ income	-	-	-	-	*Yes*
Observations	18,219	2,368	15,851	5,232	1,893
R^2	0.004	0.014	0.004	0.013	0.024

Notes: The dependent variable, $\Delta c_i = c_{post} - c_{pre}$, is calculated as the average change in spending from the pre-announcement period, $c_{pre} = \frac{1}{2}\sum_{t=-8}^{t=-7} \widehat{c}_{it}$, to the the post-announcement period, $c_{post} = \frac{1}{10}\sum_{t=-6}^{t=3} \widehat{c}_{it}$.The dependent variable is normalized by disposable income averaged over $t \in [-8, 3]$, and it has been censored at p1/p99. Column 1 includes the full sample. Column 2 is based on people who on average over period $t = -7$ and $t = -8$ hold liquid assets, defined as deposits, corresponding to at most one month of disposable income. Column 3 is based on the subsample of individuals with liquid assets worth more than one month of disposable income. Column 4 includes the subset of households who received the third largest reductions in mortgage payments relative to disposable income according to the announcement. Column 5 is based on a subsample of the households in column 4 with large reductions in mortgage payments, where we require that they also hold liquid assets corresponding to at least eight months of disposable income. Standard errors are clustered at the household level, * indicates signficance at the 10 percent level, ** significance at the 5 percent level and *** significance at the 1 percent level.

column 5, we narrow the sample further to include only households with abundant liquid asset holdings corresponding to more than eight months of disposable income and find an average MPC of 87 percent.

Mortgage rate resets constitute a more persistent shock for people with interest-only loans, all else being equal. In Appendix Table 8, we re-estimate the specification from Table 3 but we split the sample according to whether households have interest-only loans. The results suggest that interest-only mortgage holders have bigger responses to the mortgage rate reset than holders of principal and interest loans. However, the sample split leaves the parameters less precisely estimated, and these results are, therefore, only suggestive.

5 Model

This section explains our empirical findings through the lens of standard consumption-saving theory. We extend the canonical buffer-stock consumption model with an extra income component, which is zero today, but which the household (correctly) anticipates to be non-zero in a future period and onward. This is designed to mimic the natural experiment from the empirical section, but also covers the response to anticipated future income shocks more generally. Specifically, the extra component can be interpreted as the reduction in mortgage payments that the household gets advance notice about when it receives the announcement letter.

We show that our empirical results are broadly in line with the theoretical implications of standard consumption-saving theory. In the theoretical model the anticipation effect is, as in the data, driven by households that are not affected by liquidity constraints, and the response remains strong for wealthy households, while initially liquidity constrained households only respond when the cash-flow arrives or when the liquidity constraint stops being binding.

5.1 Buffer-stock consumption model

We consider a household with constant relative risk aversion (CRRA) utility over consumption, C_t, solving an infinite horizon problem defined by the objective,

$$\max_{\{C_{t+k}\}_{k=0}^{\infty}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \frac{C_{t+k}^{1-\rho}}{1-\rho}, \tag{3}$$

where β is the discount factor, ρ is the CRRA coefficient, and $\mathbb{E}_t$ is the expectation operator.

The household receives regular income, Y_t, according to a standard permanent-

transitory stochastic process with mean-one shocks,

$$Y_t = P_t \xi_t, \ \log \xi_t \sim \mathcal{N}(-0.5\sigma_\xi^2, \sigma_\xi^2) \tag{4}$$

$$P_t = G P_{t-1} \psi_t, \ \log \psi_t \sim \mathcal{N}(-0.5\sigma_\psi^2, \sigma_\psi^2), \tag{5}$$

where G is the growth factor of permanent income, P_t, σ_ψ^2 is the variance of the permanent shocks and σ_ξ^2 is the variance of the transitory shocks.

The household also knows that it will get access to an extra source of income after a τ_t period long anticipation horizon. In relation to the empirical section, the anticipation horizon, τ_t, thus represents the time from when the household receives the announcement letter to when its cash-flow is affected by the reduced mortgage payments. This extra income will initially, starting in period $t + \tau_t$, be equal to Δ_t, but will afterwards gradually deteriorate with a persistence factor of $\zeta \in (0, 1)$. $\zeta = 1$ implies a fully permanent cash-flow effect. $\zeta < 1$ implies a less-than-fully permanent cash-flow-effect, which might be relevant in our empirical setting both because the mortgage rate might revert back to the previously anticipated path, and because the effect on the future cash-flows, for a fixed change in the mortgage rate, might diminish over time as the mortgage debt is paid down.[11]

[11] In reality, the persistence process is more complex due to uncertainty and infrequent mortgage rate adjustments. We abstract from these issues here.

Taken together, the household's dynamic budget constraint is given by

$$\begin{aligned}
\tau_t &= \max\{\tau_{t-1} - 1, 0\} && (6)\\
\Delta_t &= \mathbf{1}\{\tau_{t-1} > 0\}\Delta_{t-1} + \mathbf{1}\{\tau_{t-1} = 0\}\zeta\Delta_{t-1} && (7)\\
A_t &= M_t + \mathbf{1}\{\tau_t = 0\}\Delta_t - C_t && (8)\\
B_t &= RA_{t-1} && (9)\\
M_t &= B_t + Y_t, && (10)
\end{aligned}$$

where A_t is end-of-period assets earning the gross return R, B_t is beginning-of-period bank balances, and M_t is cash-on-hand before extra income. We assume no borrowing in liquid assets, $A_t \geq 0$.

We denote the optimal consumption function by $C^\star(P_t, M_t, \tau_t, \Delta_t)$, and define the *marginal propensity to consume* as the derivative wrt. cash-on-hand

$$MPC = \frac{\partial C^\star(P_t, M_t, \tau_t, 0)}{\partial M_t}, \tag{11}$$

taken when no future extra income is expected, $\Delta_t = 0$.

Similarly, we define the marginal propensity to consume out of a *future* shock as the derivative wrt. the expected future income component

$$MPCF = \frac{\partial C^\star(P_t, M_t, \tau_t, 0)}{\partial_+ \Delta_t},\ \tau_t > 0,$$

taken when no future extra income is expected, $\Delta_t = 0$.

5.2 Permanent income hypothesis (PIH)

To gain some intuition, consider the permanent income hypothesis (PIH) version of the model with no income uncertainty, $\sigma_\psi^2 = \sigma_\xi^2 = 0$, and no borrowing constraints. The consumption function is then given by[12]

$$\begin{aligned} C^{PIH}(P_t, M_t, \tau_t, \Delta_t) &= \kappa\left[B_t + H_t\right] = \kappa\left[M_t - P_t + H_t\right] \\ &\kappa \equiv 1 - \left[R^{-1}(\beta R)^{1/\rho}\right] \\ &H_t \equiv \frac{1}{1 - G/R^{-1}} P_t + \frac{R^{-\tau_t}}{1 - \zeta/R}\Delta_t, \end{aligned} \tag{12}$$

where κ is the average propensity to consume out of total wealth and H_t is human wealth, i.e., the present discounted value of future income. As in the standard permanent income hypothesis model, we have that $MPC = \kappa$. More interestingly, we have that the marginal propensity to consume out of a shock with anticipation horizon τ_t and persistence ζ is given by

$$MPCF = \kappa \frac{\partial H_t}{\partial \Delta_t} = \kappa \frac{R^{-\tau_t}}{1 - \zeta R^{-1}}. \tag{13}$$

The $MPCF$ is thus the product of the MPC and the effect on human wealth, $\partial H_t / \partial \Delta_t$. The $MPCF$ is decreasing in τ_t because the effect on human wealth is smaller if the extra income is received later. The $MPCF$ is increasing in ζ because a higher persistence of the extra income component increases the human wealth effect. The MPC and $MPCF$ do not vary with cash-on-hand in this simple model because the consumption function is linear when there is neither income uncertainty nor any borrowing constraints.

[12] Assuming $R > G \geq 1$, and $R^{-1}(\beta R)^{1/\rho} < 1$.

5.3 Bellman equation

The Bellman equation for the full model can be written in ratio-form as,

$$
\begin{aligned}
v(m_t,\tau_t,\delta_t) &= \max_{c_t} \frac{c_t^{1-\rho}}{1-\rho} + \beta \mathbb{E}_t[(G\psi_{t+1})^{1-\rho} v(m_t,\tau_t,\delta_t)] \qquad (14)\\
&\text{s.t.} \\
a_t &= m_t + \mathbf{1}\{\tau_t = 0\}\delta_t - c_t \\
m_{t+1} &= \frac{R}{G\psi_{t+1}} a_t + \xi_{t+1} \\
\delta_{t+1} &= \frac{1}{G\psi_{t+1}} \left[\mathbf{1}\{\tau_t > 0\}\delta_t + \mathbf{1}\{\tau_t = 0\}\zeta\Delta_t\right] \\
\tau_{t+1} &= \max\{\tau_t - 1, 0\},
\end{aligned}
$$

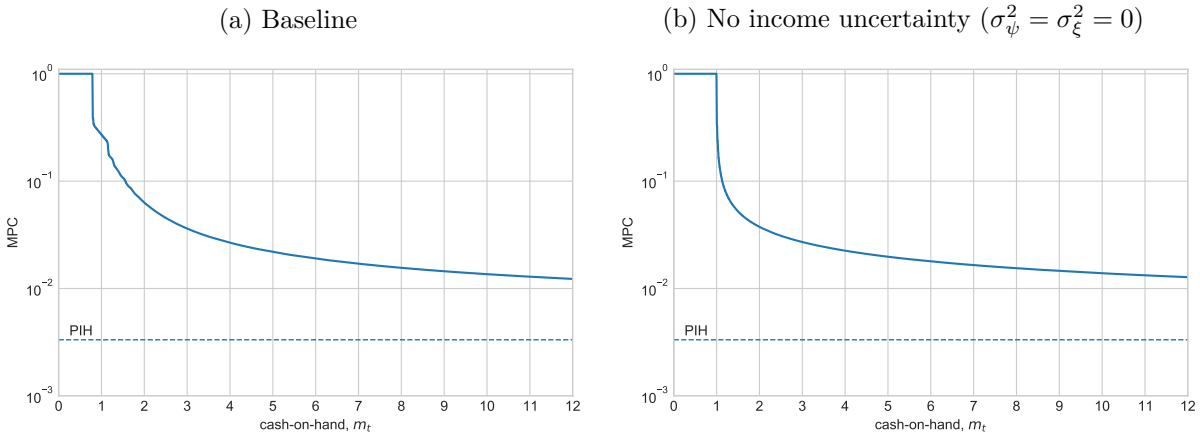
where all lowercase variables are the corresponding uppercase variables divided by permanent income. δ_t is thus the extra income relative to permanent income, Δ_t/P_t.

This model cannot be solved analytically. Instead, we turn to a numerical solution.[13] Our focus is on the qualitative implications of the model, and we therefore make standard parameter choices and explore alternatives in Appendix C.2. We choose the preferences and the return and growth rates converting the annual calibration in Carroll (2020) to an monthly frequency; $\beta = 0.96^{\frac{1}{12}}$, $\rho = 2$, $R = 1.04^{\frac{1}{12}}$, $G = 1.03^{\frac{1}{12}}$. For the income uncertainty, in our baseline calibration, we choose the variances of the permanent and transitory shocks to match the annual variances estimated by Jørgensen (2017) on Danish data; this implies $\sigma_\psi^2 = 0.00045$, and $\sigma_\xi^2 = 0.09283$.[14] The resulting transitory income shock variance is rather high. Consequently, we also consider an alternative where we disregard income uncertainty

[13] The model is solved with the endogenous grid method developed in Carroll (2006) using the efficient linear interpolation approach proposed in Druedahl (2020). The code for solving the model is available online at https://github.com/NumEconCopenhagen/ConsumptionSavingNotebooks/MPCF.

[14] Details are provided in Appendix C.1.

Figure 5: MPC



Notes: The baseline calibration is $\beta = 0.96^{\frac{1}{12}}$, $\rho = 2$, $R = 1.04^{\frac{1}{12}}$, $G = 1.03^{\frac{1}{12}}$, $\sigma^2_\psi = 0.00045$, and $\sigma^2_\xi = 0.09283$. The dashed lines are the analytical results from the PIH model in sub-section 5.2.

completely and set $\sigma^2_\psi = \sigma^2_\xi = 0$. In Appendix C.2 we consider additional alternative calibrations of the transitory income shock variance.

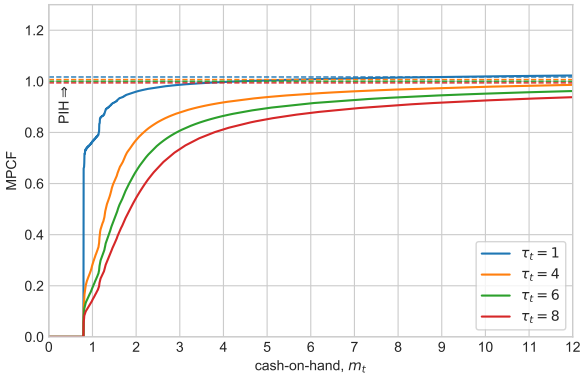
5.4 Theoretical results

Figure 5 shows the well-known result that the MPC is unity for those at the borrowing constraint, and otherwise falling in cash-on-hand. It drops substantially once the borrowing constraint stops being binding and then gradually converges to the PIH value. The results are similar for the calibrations with and without income uncertainty.

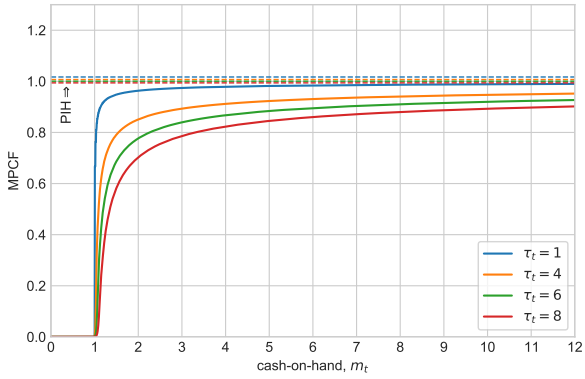
Figure 6 shows how the $MPCF$ varies with cash-on-hand for various anticipation horizons, τ_t. The first central difference to the standard MPC results is that the $MPCF$ is not unity for households at the borrowing constraint; on the contrary, the $MPCF$ is zero at the borrowing constraint. The second central difference is that the $MPCF$ is not monotonically decreasing in cash-on-hand. Conversely, it is increasing in cash-on-hand. Both of these observations are in line with our empirical

Figure 6: MPCF

(a) Baseline



(b) No income uncertainty ($\sigma^2_\psi = \sigma^2_\xi = 0$)



Notes: See Figure 5.

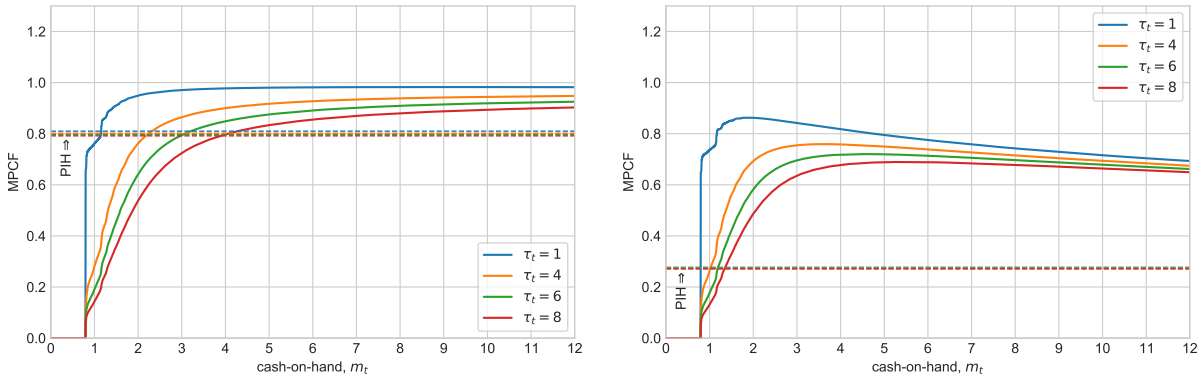
results. The $MPCF$ is zero for liquidity constrained households, and remains high for wealthy households.

To understand these results, it is useful to look back at the PIH solution in eq. (13), where the $MPCF$ was written as the product of the MPC and the effect on human wealth (i.e., the effect on the present discounted value of future income). As the MPC varies negatively with cash-on-hand, it seems as if the $MPCF$ should be *decreasing* in cash-on-hand. The human wealth effect, however, also varies with cash-on-hand because the *effective* discount rate differs from the interest rate in the presence of uncertainty and borrowing constraints. The stronger a precautionary motive a household has, the more heavily future income is discounted. A household with low cash-on-hand dares not spend out of anticipated future income because it makes their buffer-stock savings drop further below their target. If they are then hit by a series of bad income shocks, they might be forced to cut back heavily on consumption. Future binding liquidity constraints likewise also increase the effective discount rates.[15] In total, this discounting effect implies that the $MPCF$ is

[15]This is yet another example of the claim in Carroll (2001) that "for many purposes the be-

Figure 7: MPCF: Varying persistence (ζ)

(a) $\zeta = 0.99^{\frac{1}{12}}$ (b) $\zeta = 0.90^{\frac{1}{12}}$



Notes: See Figure 5.

initially *increasing* in cash-on-hand because when cash-on-hand increases, the precautionary motive is dampened and the time when the borrowing constraint will become binding is pushed further into the future. Appendix Figure 12 shows that the $MPCF$ eventually reaches a maximum as the MPC effect becomes dominating and the $MPCF$ begins to fall with cash-on-hand and gradually converges to the PIH solution.

Figure 7 shows that these observations are also true when varying the persistence of the shock, ζ. When persistence is reduced, the level of the $MPCF$ decreases, and the MPC effect begins to dominate earlier. The $MPCF$ does, however, remain high for wealthy households.

Appendix Figures 13 and 14 show that the main qualitative results are robust to varying risk-aversion, ρ, and patience, β.[16]

havior of constrained consumers is virtually indistinguishable from the behavior of unconstrained consumers with a precautionary motive".

[16]Appendix Figure 17 shows that similar results are also reached for an annual calibration, though the minimum anticipation horizon in this case is naturally one year.

5.5 Dynamic MPCF

To illustrate the dynamics of consumption when households receive information about future income, we simulate consumption for a panel of N households starting from some initial cash-on-hand level, M_0, and with some anticipation horizon, τ_0, and extra income Δ_0.

Specifically, we compute the average difference between consumption in a simulation where $\Delta_0 = 0.05$, denoted $C_{t\,|\Delta_0=0.05}$, and a simulation where $\Delta_0 = 0$, denoted $C_{t\,|\Delta_0=0}$. We then compute the *dynamic* marginal propensity to consume out of future income, $DMPCF_t$, as,

$$DMPCF_t = \frac{C_{t\,|\Delta_0=0.05} - C_{t\,|\Delta_0=0}}{\Delta_0}. \tag{15}$$

The result is shown in Figure 8a for an anticipation horizon of six months, $\tau_0 = 6$, as in our empirical setting. We see that households with high initial cash-on-hand respond in full immediately. Liquidity constrained households with low initial cash-on-hand, on the other hand, do not respond immediately, but only respond once they receive the actual cash-flow or the borrowing constraint unbinds. In the baseline calibration, the buffer-stock saving motive is, furthermore, rather strong, and being liquidity constrained is thus a short-term experience.[17] This explains why households that are initially liquidity constrained have a sizable consumption response already in the anticipation period in the baseline calibration. In the alternative calibration without income uncertainty, being liquidity constrained is an absorbing state, and initially liquidity constrained households never respond before the actual cash-flow is received. This is shown in Figure 8b. In our empirical results, we found no anticipation effect for liquidity constrained households, which is more

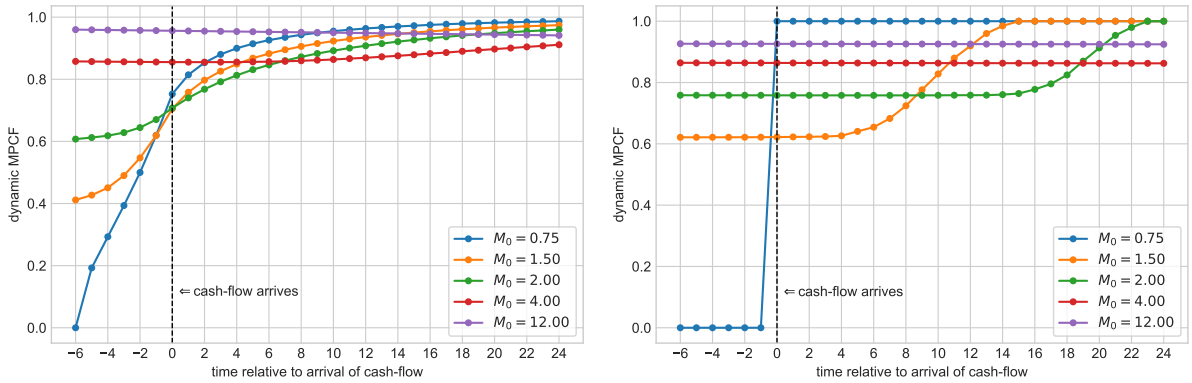
[17] See Appendix Figure 15.

in line with calibrations where the buffer-stock saving motive is not too strong, or, more generally speaking, models where being liquidity constrained is a persistent characteristic. Appendix Figure 16 shows that the size of the anticipation effect is strongly positively correlated with the variance of the transitory shock.

Figure 8: Simulation: Dynamic $MPCF$

(a) Baseline

(b) No income uncertainty ($\sigma^2_\psi = \sigma^2_\xi = 0$)



Notes: For each initial value of M_0, we simulate a panel of $N = 100,000$ households with $P_0 = 1$ and either $\Delta_0 = 0$ or $\Delta_0 = 0.05$. The anticipation horizon is $\tau_0 = 6$. The dynamic $MPCF$ is computed as in eq. (15).

6 Summary and conclusion

In this paper we study forward looking behavior of households. We leverage a unique combination of an information treatment, consisting of a letter from a bank to their customers giving advance notice about the expected impact of interest rate resets of their 1-year ARM on mortgage payments six months ahead of the rate reset, and high frequency spending data documenting household spending around the time of the information treatment as well as at the time that the rate reset is actually implemented.

We show that households are forward looking in a way that is consistent with standard consumption-saving theory. Specifically, we find that households that are

unlikely to be affected by constraints because they hold ample liquid assets respond to the advance notice about reductions in mortgage payments six months ahead by increasing spending. Our results indicate that the spending response is, if anything, increasing in the amount of liquid resources held by the household. This is consistent with consumption-saving theory where households with a large buffer-stock of savings discount future income less and perceive the change in mortgage payments as a persistent shock affecting disposable income for at least a year and probably even longer. In contrast to this, we find that households that are likely affected by liquidity constraints, because they hold very little in liquid assets, adjust their spending around the time that disposable income is actually affected by the reduced mortgage payments, i.e., when the first payment after the reset is made.

Our findings also have implications for understanding the consequences of monetary policy. Monetary policy affects the household budget through mortgage interest payments. We show that a salient advance notice of future changes in mortgage interest payments brought about by changes in the interest rate can have significant and lasting effects on household savings decisions. According to recent heterogeneous agent models, anticipation effects of future cash-flows on current consumption is key for assessing the effectiveness of both monetary policy and fiscal policy. In the context of interest rate resets of 1-year Adjustable Rate Mortgage Loans (ARM), we confirm that such anticipation effects are empirically important. Thus, this study provides a first attempt at quantifying the marginal propensity to consume out of future expected cash-flows which can be used for calibrating such models.

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A Letter from the bank to a customer

Figure 9: Letter from Nykredit to customer

Nykredit

Date 6. September 2011
Account No.
Loan type F1
Principal 1,057,807
Location

New interest rate on your adjustable-rate mortgage loan

We write to you because a new interest rate will soon apply your adjustable-rate mortgage loan. This change automatically takes effect on 1 January 2012. By then, you will have received a letter specifying your future mortgage payments.

What should you do?

If we do not hear from you, a new interest rate will automatically apply to your adjustable-rate mortgage loan. However, there may be attractive alternatives to your current loan type, which may be worth considering, as many things have changed since you took out your loan. Maybe another interest period or another type of mortgage loan would be more favorable for you today. Your Nykredit adviser can guide you through the choices available.

Contact your adviser well before the end of October 2011. This will leave you with enough time to change your loan if this is your decision.

If you keep your adjustable-rate mortgage loan

The table shows your payment today and our current expectations of your future payments:

		Today		As from 1 January 2012
Principal payment (interest-only until 31 December 2012)[1)]		0 euro		0 euro
Cash loan rate[2)] (interest rate incl price spread[3)])	2% =	5,289 euro	1.5% =	3,967 euro
Administration margin[4)]	0.72% =	1,785 euro	0.72% =	1,785 euro
Mortgage payments (interest + administration margin) before tax, quarterly		6,753 euro		5,431 euro

[1)] When your interest-only period expires, you start repaying your loan. This means that your mortgage payments will change.
[2)] Calculations are based on the debt outstanding as at 1 January 2012 of 991,452 and the current interest rate level. The interest rate – and consequently the new mortgage payments – may thus change. If you want to see whether this is the case, you can calculate your mortgage payments based on the interest rate- applicable today at any time in Nykredit's online banking service.
[3)] In connection with the interest rate adjustment, a price spread of 0.10 point will be payable. The amount is included in your interest payments over the next year.
[4)] The administration margin is variable and may thus change.

Nykredit Realkredit A/S
CVR no 12 71 92 80

Nykredit Realkredit A/S
Kalvebod Brygge 1-3
DK-1780 Copenhagen
www.nykredit.com

B Additional analyses

Table 4: Baseline specification, non-food spending

Dependent variable: *Non-Food*	(1)	(2)	(3)	(4)	(5)
Announced change, $t = -7$	0.060	0.394	0.033	−0.096	−0.244
	(0.078)	(0.259)	(0.081)	(0.144)	(0.184)
Announced change, $t = -6$	−0.259***	0.027	−0.278***	−0.474***	−0.343**
Letter: Announced change, MPCF	(0.075)	(0.229)	(0.078)	(0.126)	(0.158)
Announced change, $t = -5$	0.168**	−0.336	0.198**	0.535***	0.432***
	(0.079)	(0.242)	(0.081)	(0.127)	(0.145)
Announced change, $t = -4$	0.116	0.001	0.120	0.185	0.164
	(0.072)	(0.177)	(0.076)	(0.117)	(0.140)
Actual change, $t = -3$	−0.148**	−0.178	−0.147**	−0.192**	−0.244**
Letter: Auction, MPCF	(0.058)	(0.190)	(0.061)	(0.087)	(0.101)
Actual change, $t = -2$	−0.119*	0.017	−0.131*	−0.203**	−0.103
	(0.065)	(0.187)	(0.068)	(0.096)	(0.123)
Actual change, $t = -1$	−0.006	0.212	−0.021	−0.069	−0.071
	(0.060)	(0.203)	(0.062)	(0.076)	(0.096)
Actual change, $t = 0$	−0.081	−0.394**	−0.058	−0.075	−0.168
First payment: Cash-flow effect, MPC	(0.066)	(0.182)	(0.069)	(0.100)	(0.120)
Actual change, $t = 1$	0.024	−0.018	0.022	0.058	0.114
	(0.062)	(0.206)	(0.064)	(0.079)	(0.096)
Actual change, $t = 2$	−0.078	0.175	−0.096	−0.058	−0.007
	(0.060)	(0.230)	(0.062)	(0.078)	(0.101)
Actual change, $t = 3$	0.041	−0.003	0.044	−0.009	0.010
	(0.060)	(0.178)	(0.063)	(0.078)	(0.103)
Calendar month fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	0.023***	−0.007	0.029***	0.029***	−0.041***
	(0.005)	(0.011)	(0.006)	(0.005)	(0.009)
Sample restrictions	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Credit constrained	-	*Yes*	*No*	*No*	*No*
Largest announcements at $t = -4$	-	-	-	*Yes*	*Yes*
Most wealth, liquidity $\geq 8 \times$ income	-	-	-	-	*Yes*
Observations	206,968	26,673	180,295	59,396	21,469
R^2	0.046	0.047	0.047	0.047	0.051

Notes: See notes to Table 2. * significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

Table 5: Baseline specification, excluding stock and bond holders (by end of previous year)

Dependent variable: *total spending*	(1)	(2)	(3)	(4)	(5)
Announced change, $t = -7$	0.167	0.594	0.121	0.241	0.111
	(0.125)	(0.404)	(0.134)	(0.210)	(0.286)
Announced change, $t = -6$	-0.224^{*}	-0.009	-0.243^{*}	-0.659^{***}	-0.533^{***}
Letter: Announced change, MPCF	(0.129)	(0.351)	(0.136)	(0.181)	(0.215)
Announced change, $t = -5$	0.187	0.134	0.178	0.831^{***}	0.883^{***}
	(0.145)	(0.405)	(0.152)	(0.199)	(0.234)
Announced change, $t = -4$	0.175	-0.209	0.205^{*}	0.270	0.064
	(0.109)	(0.284)	(0.117)	(0.189)	(0.213)
Actual change, $t = -3$	-0.150	-0.417	-0.135	-0.139	-0.166
Letter: Auction, MPCF	(0.097)	(0.301)	(0.103)	(0.143)	(0.176)
Actual change, $t = -2$	-0.200^{*}	-0.010	-0.220^{*}	-0.233	0.010
	(0.118)	(0.312)	(0.126)	(0.178)	(0.204)
Actual change, $t = -1$	0.026	0.547	-0.020	-0.084	-0.007
	(0.096)	(0.343)	(0.097)	(0.109)	(0.131)
Actual change, $t = 0$	-0.035	-0.138	-0.023	-0.002	-0.054
First payment: Cash-flow effect, MPC	(0.109)	(0.281)	(0.117)	(0.158)	(0.190)
Actual change, $t = 1$	0.020	-0.110	0.019	0.185	0.223
	(0.114)	(0.331)	(0.119)	(0.132)	(0.167)
Actual change, $t = 2$	0.047	0.517	0.008	0.116	0.162
	(0.092)	(0.371)	(0.094)	(0.134)	(0.156)
Actual change, $t = 3$	-0.088	-0.007	-0.098	-0.065	-0.039
	(0.097)	(0.292)	(0.102)	(0.129)	(0.156)
Calendar month fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	0.034^{***}	0.015	0.038^{***}	-0.057^{***}	0.043^{***}
	(0.008)	(0.016)	(0.009)	(0.008)	(0.016)
Sample restrictions	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Credit constrained	-	*Yes*	*No*	*No*	*No*
Largest announcements at $t = -4$	-	-	-	*Yes*	*Yes*
Most wealth, liquidity $\geq 8 \times$ income	-	-	-	-	*Yes*
No stock/bond-holdings	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	110,241	16,628	93,613	29,932	9,540
R^2	0.072	0.074	0.073	0.071	0.072

Notes: see notes to Table 2. * significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

Table 6: Baseline specification, controlling for municipality×month fixed effects

Dependent variable: *total spending*	(1)	(2)	(3)	(4)	(5)
Announced change, $t = -7$	0.098	0.537*	0.068	−0.094	−0.229
	(0.092)	(0.313)	(0.095)	(0.155)	(0.202)
Announced change, $t = -6$	−0.279***	−0.161	−0.288***	−0.557***	−0.472**
Letter: Announced change, MPCF	(0.087)	(0.282)	(0.091)	(0.156)	(0.194)
Announced change, $t = -5$	0.160*	−0.077	0.171*	0.551***	0.444**
	(0.094)	(0.296)	(0.097)	(0.160)	(0.188)
Announced change, $t = -4$	0.186**	−0.042	0.191**	0.215	0.191
	(0.084)	(0.210)	(0.089)	(0.133)	(0.159)
Actual change, $t = -3$	−0.136**	−0.270	−0.127*	−0.176*	−0.226*
Letter: Auction, MPCF	(0.069)	(0.224)	(0.073)	(0.104)	(0.120)
Actual change, $t = -2$	−0.172**	−0.015	−0.182**	−0.249**	−0.158
	(0.076)	(0.241)	(0.080)	(0.114)	(0.151)
Actual change, $t = -1$	0.051	0.376*	0.021	−0.033	−0.011
	(0.068)	(0.228)	(0.070)	(0.085)	(0.108)
Actual change, $t = 0$	−0.082	−0.475**	−0.051	−0.078	−0.222
First payment: Cash-flow effect, MPC	(0.075)	(0.231)	(0.080)	(0.117)	(0.142)
Actual change, $t = 1$	−0.018	−0.090	−0.019	0.038	0.087
	(0.076)	(0.243)	(0.079)	(0.098)	(0.125)
Actual change, $t = 2$	−0.033	0.361	−0.056	−0.044	0.053
	(0.069)	(0.256)	(0.071)	(0.095)	(0.120)
Actual change, $t = 3$	0.053	0.053	0.052	−0.006	0.013
	(0.069)	(0.217)	(0.072)	(0.088)	(0.119)
Calendar month fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Municipality × *month* fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	0.002	−0.111**	0.023	−0.012	0.041***
	(0.020)	(0.053)	(0.021)	(0.049)	(0.004)
Sample restrictions	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Credit constrained	-	*Yes*	*No*	*No*	*No*
Largest announcements at $t = -4$	-	-	-	*Yes*	*Yes*
Most wealth, liquidity $\geq 8 \times$ income	-	-	-	-	*Yes*
Observations	206,968	26,673	180,295	59,396	21,469
R^2	0.086	0.185	0.088	0.103	0.161

Notes: See notes to Table 2. * significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

Table 7: Baseline specification, including households with Nykredit as only bank connection

Dependent variable: *total spending*	(1)	(2)	(3)	(4)	(5)
Announced change, $t = -7$	0.148	0.221	0.140	−0.040	−0.101
	(0.122)	(0.382)	(0.129)	(0.251)	(0.358)
Announced change, $t = -6$	−0.302***	0.526*	−0.352***	−0.702***	−0.608***
Letter: Announced change, MPCF	(0.113)	(0.307)	(0.116)	(0.173)	(0.215)
Announced change, $t = -5$	0.196	−0.531	0.247*	0.901***	1.066***
	(0.144)	(0.340)	(0.149)	(0.198)	(0.242)
Announced change, $t = -4$	0.318***	0.338	0.312**	0.273	0.179
	(0.100)	(0.265)	(0.106)	(0.175)	(0.196)
Actual change, $t = -3$	−0.203**	−0.145	−0.201**	−0.216	−0.187
Letter: Auction, MPCF	(0.090)	(0.315)	(0.094)	(0.139)	(0.179)
Actual change, $t = -2$	−0.153	−0.240	−0.151	−0.105	0.125
	(0.119)	(0.375)	(0.124)	(0.153)	(0.175)
Actual change, $t = -1$	−0.056	0.316	−0.077	−0.208**	−0.215*
	(0.089)	(0.313)	(0.092)	(0.100)	(0.124)
Actual change, $t = 0$	0.039	−0.512	0.076	0.082	0.086
First payment: Cash-flow effect, MPC	(0.116)	(0.331)	(0.124)	(0.169)	(0.208)
Actual change, $t = 1$	−0.049	−0.022	−0.054	0.007	0.097
	(0.122)	(0.413)	(0.128)	(0.152)	(0.193)
Actual change, $t = 2$	−0.093	0.127	−0.105	−0.091	0.024
	(0.095)	(0.383)	(0.098)	(0.138)	(0.177)
Actual change, $t = 3$	0.139	0.265	0.133	0.145	0.179
	(0.112)	(0.370)	(0.116)	(0.145)	(0.184)
Calendar month fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	0.029***	0.019	0.032***	−0.002***	−0.059***
	(0.007)	(0.016)	(0.008)	(0.007)	(0.015)
Sample restrictions	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Credit constrained	-	*Yes*	*No*	*No*	*No*
Largest announcements at $t = -4$	-	-	-	*Yes*	*Yes*
Most wealth, liquidity $\geq 8 \times$ income	-	-	-	-	*Yes*
Nykredit as only bank	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	105,817	14,024	91,793	31,772	10,880
R^2	0.075	0.076	0.075	0.075	0.079

Notes: See notes to Table 2. * significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

Table 8: Level effect of mortgage rate reset on total spending - splitting by interest-only

Dependent variable: Δc_i	(1)	(2)	(3)	(4)	(5)
	Interest-only loans				
ΔR_i	-0.787^{*}	-0.802	-0.803^{**}	-0.964^{**}	-1.154^{**}
	(0.310)	(0.487)	(0.326)	(0.421)	(0.574)
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	-0.033^{***}	-0.010	-0.038^{***}	-0.048^{***}	-0.054^{***}
	(0.009)	(0.013)	(0.009)	(0.018)	(0.029)
Observations	10,418	1,456	8,962	3,488	1,278
R^2	0.008	0.011	0.008	0.025	0.046
	Repayment on loans				
ΔR_i	0.122	-2.328	0.302	-1.318^{**}	-1.403^{*}
	(1.608)	(2.332)	(1.732)	(0.603)	(0.837)
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	-0.022^{*}	-0.024	-0.023	-0.045^{***}	-0.051^{**}
	(0.013)	(0.016)	(0.015)	(0.014)	(0.025)
Observations	7,328	845	6,483	1,565	553
R^2	0.004	0.030	0.003	0.011	0.006
Sample restrictions	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Credit constrained	-	*Yes*	*No*	*No*	*No*
Largest announcements at $t = -4$	-	-	-	*Yes*	*Yes*
Most wealth, liquidity $\geq 8 \times$ income	-	-	-	-	*Yes*

Notes: See notes to Table 2. * significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

C Details of the model

C.1 Calibration of income shock variances

Using Danish data on annual income, Jørgensen (2017) estimates the variances of the permanent and transitory income shocks by

$$\hat{\sigma}^2_\psi = \text{cov}(\Delta y_t, y_{t+1} - y_{t-2}) = 0.054 \tag{16}$$

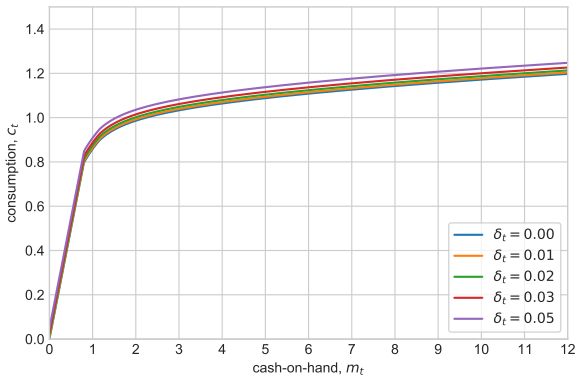
$$\hat{\sigma}^2_\xi = \text{cov}(\Delta y_t, -\Delta y_{t+1}) = 0.072 \tag{17}$$

We calibrate σ^2_ψ and σ^2_ξ in our monthly income process such that when we simulate and aggregate to an annual frequency and then apply the estimator in eqs. (16)-(17), it implies the same estimates as in Jørgensen (2017).

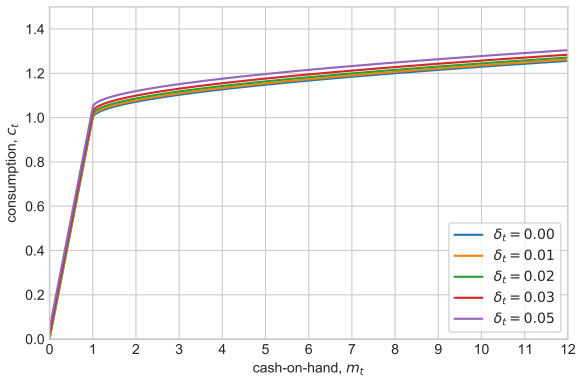
C.2 Robustness

Figure 10: Consumption function

(a) Baseline



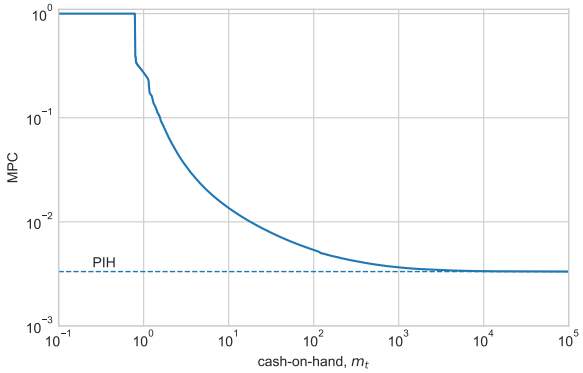
(b) No income uncertainty ($\sigma^2_\psi = \sigma^2_\xi = 0$)



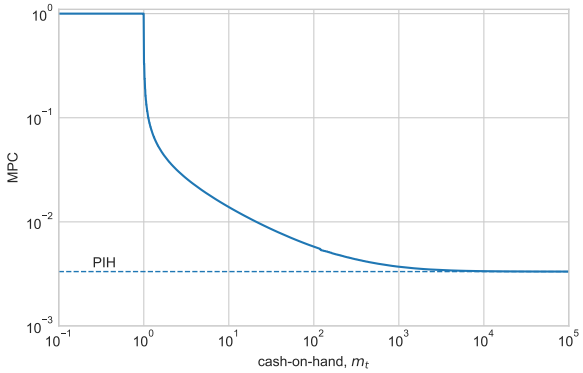
Notes: See Figure 5.

Figure 11: MPC - convergence to PIH

(a) Baseline



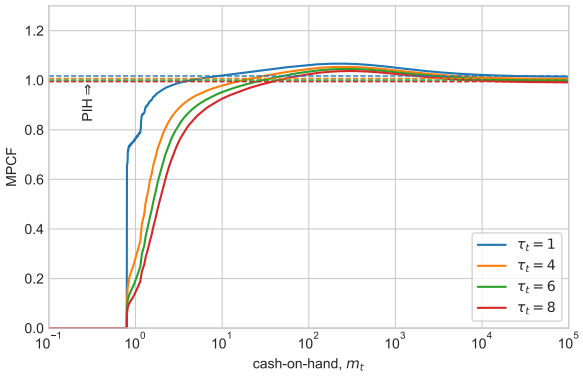
(b) No income uncertainty ($\sigma^2_\psi = \sigma^2_\xi = 0$)



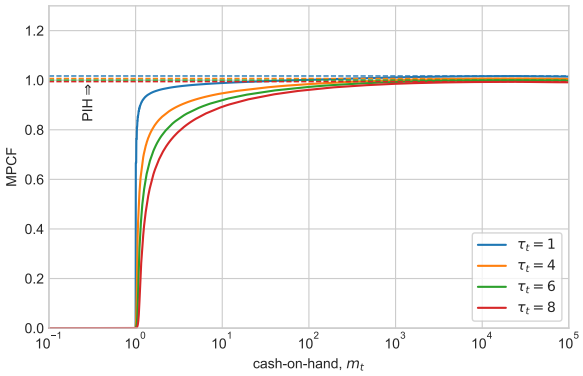
Notes: See Figure 5.

Figure 12: MPCF - convergence to PIH

(a) Baseline



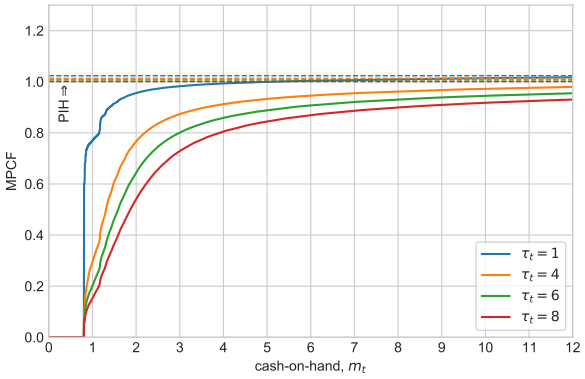
(b) No income uncertainty ($\sigma^2_\psi = \sigma^2_\xi = 0$)



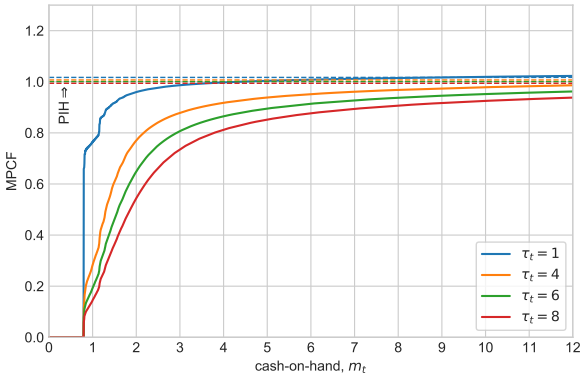
Notes: See Figure 5.

Figure 13: MPCF: Varying risk-aversion (ρ)

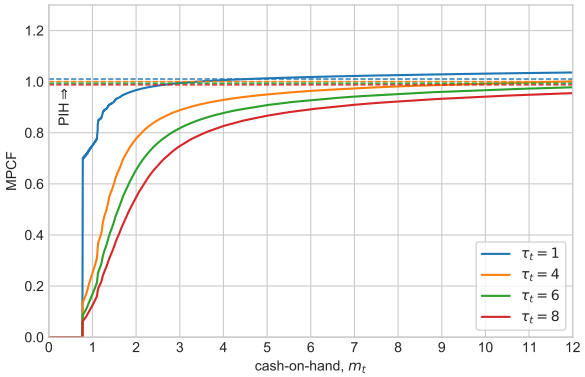
(a) $\rho = 1.5$



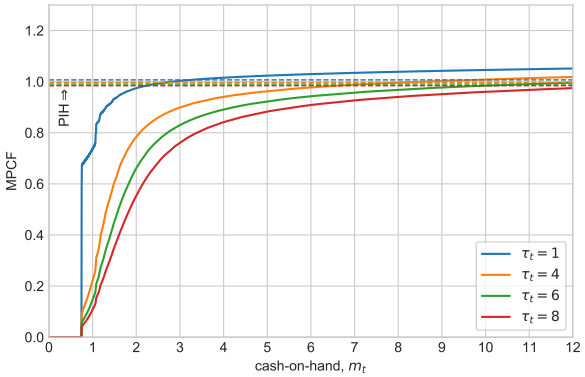
(b) $\rho = 2$



(c) $\rho = 3$



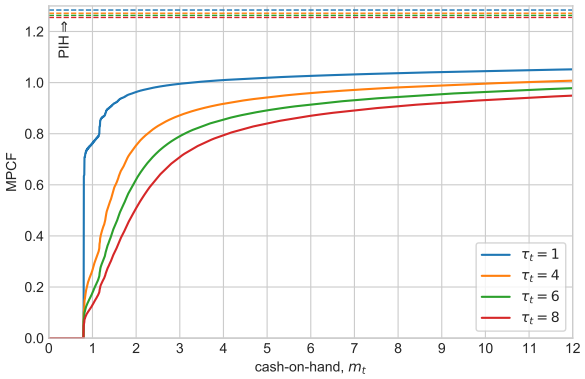
(d) $\rho = 4$



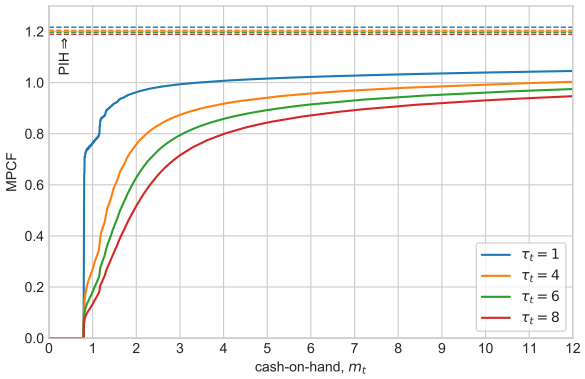
Notes: See Figure 5.

Figure 14: MPCF: Varying patience (β)

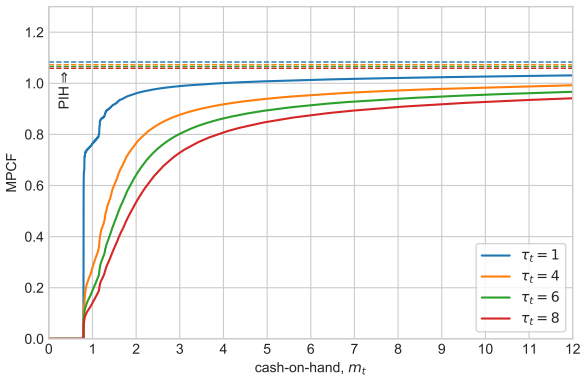
(a) $\beta = 0.93^{\frac{1}{12}}$



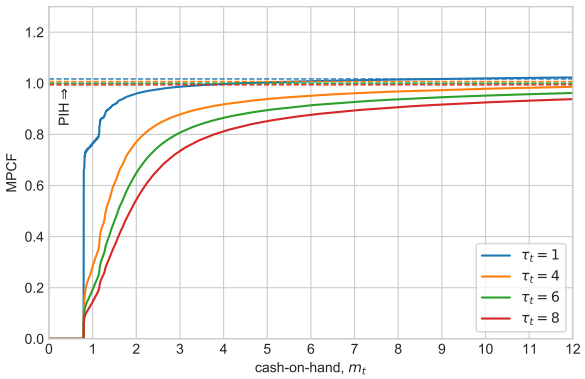
(b) $\beta = 0.94^{\frac{1}{12}}$



(c) $\beta = 0.95^{\frac{1}{12}}$



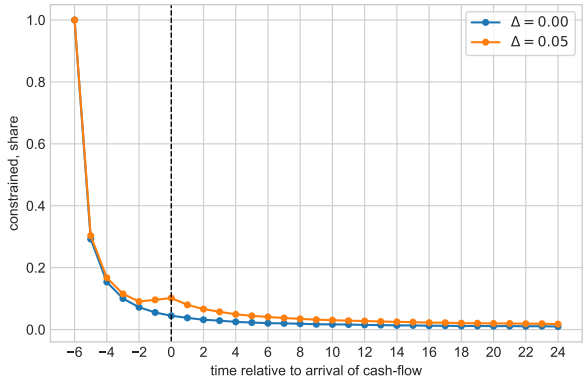
(d) $\beta = 0.96^{\frac{1}{12}}$



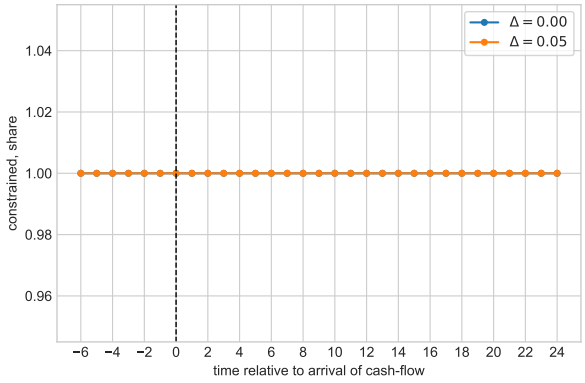
Notes: See Figure 5.

Figure 15: Simulation: Share of constrained households given $M_0 = 0.75$

(a) Baseline



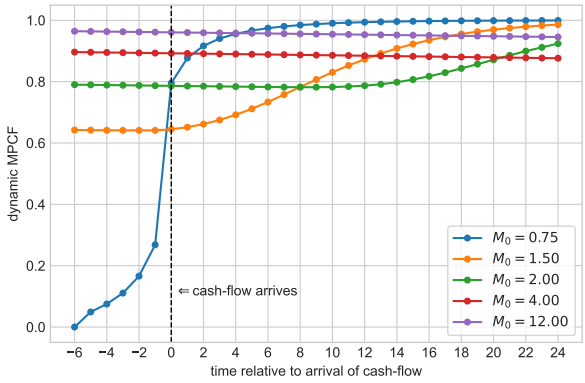
(b) No income uncertainty ($\sigma_\psi^2 = \sigma_\xi^2 = 0$)



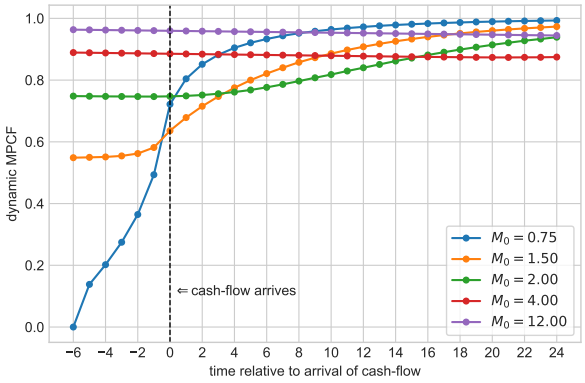
Notes: See Figure 8.

Figure 16: $DMPCF_t$: Varying transitory risk (σ^2_ξ)

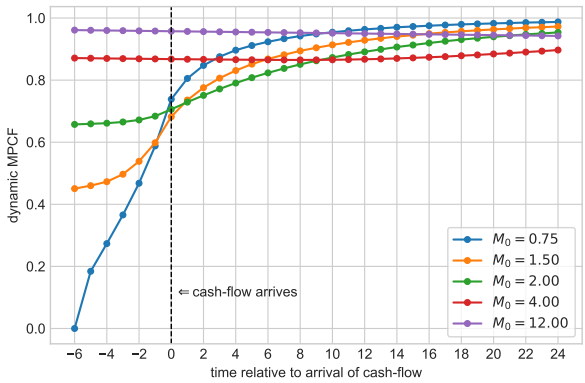
(a) $\sigma^2_\xi = 0.001$



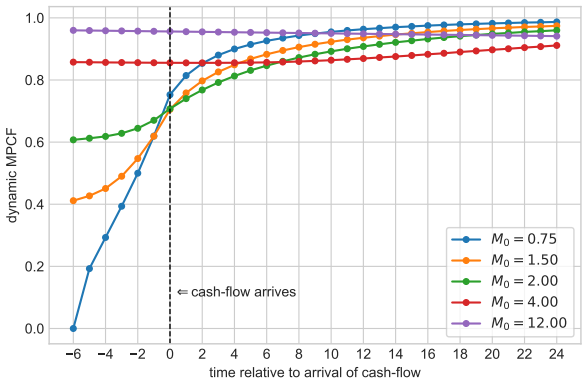
(b) $\sigma^2_\xi = 0.01$



(c) $\sigma^2_\xi = 0.05$



(d) $\sigma^2_\xi = 0.09283$

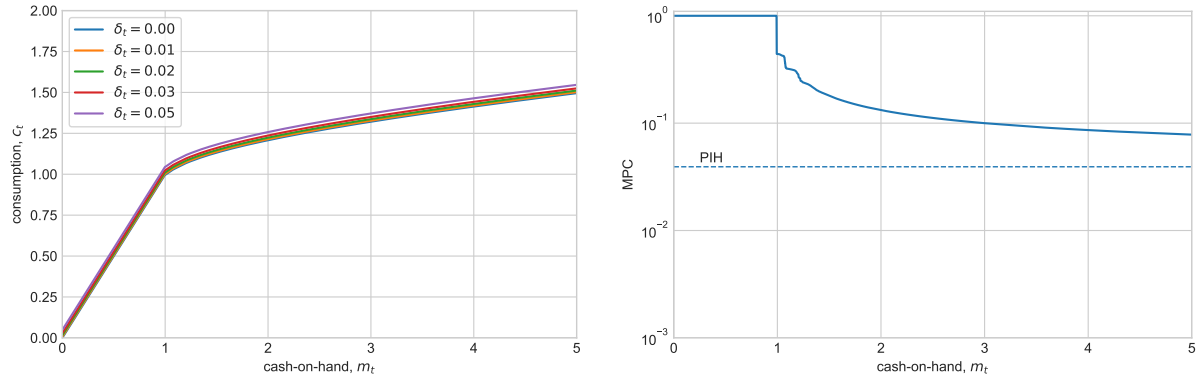


Notes: See Figure 8.

Figure 17: Annual calibration: MPC and MPCF

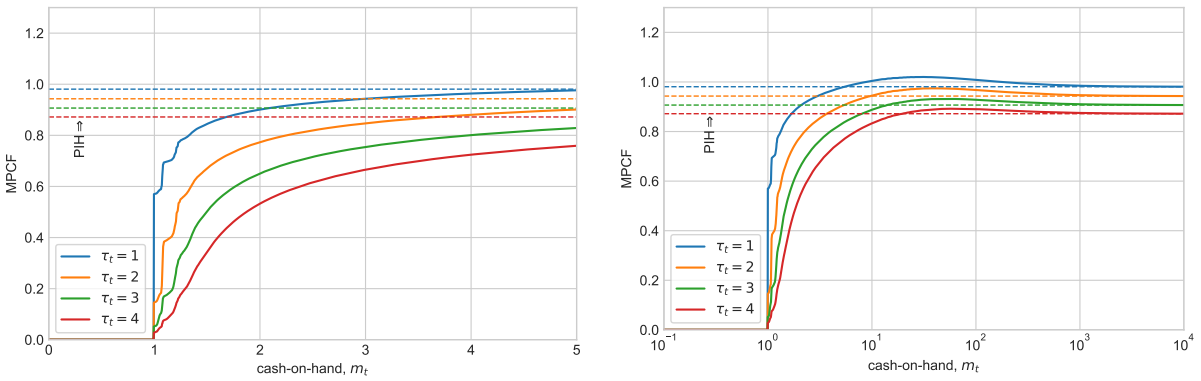
(a) Consumption function

(b) MPC



(c) MPCF (low m_t)

(d) MPCF (high m_t)



Notes: $\beta = 0.96$, $\rho = 2$, $R = 1.04$, $G = 1.03$, $\sigma^2_\psi = 0.0052$ and $\sigma^2_\xi = 0.0072$. All dashed lines correspond to the analytically derived results from the perfect foresight model without constraints.