NBER WORKING PAPER SERIES

WHAT CALLS TO ARMS? INTERNATIONAL EVIDENCE ON INTEREST RATES AND THE CHOICE OF ADJUSTABLE-RATE MORTGAGES

Cristian Badarinza
John Y. Campbell
Tarun Ramadorai

Working Paper 20408
http://www.nber.org/papers/w20408

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2014

We gratefully acknowledge the Sloan Foundation for financial support. We thank Gene Amromin, Ralph Koijen, Stijn van Nieuwerburgh, and participants at the European Conference on Household Finance for many useful comments, and Joshua Abel and Gaurav Kankanhalli for excellent research assistance. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

What Calls to ARMs? International Evidence on Interest Rates and the Choice of Adjustable-Rate Mortgages
Cristian Badarinza, John Y. Campbell, and Tarun Ramadorai
NBER Working Paper No. 20408
August 2014
JEL No. D14,E43,G21

ABSTRACT

The relative popularity of adjustable-rate mortgages (ARMs) and fixed-rate mortgages (FRMs) varies considerably both across countries and over time. We ask how movements in current and expected future interest rates affect the share of ARMs in total mortgage issuance. Using a nine-country panel and instrumental variables methods, we present evidence that near-term (one-year) rational expectations of future movements in ARM rates do affect mortgage choice, particularly in more recent data since 2001. However longer-term (three-year) rational forecasts of ARM rates have a weaker effect, and the current spread between FRM and ARM rates also matters, suggesting that households are concerned with current interest costs as well as with lifetime cost minimization. These conclusions are robust to alternative (adaptive and survey-based) models of household expectations.

Cristian Badarinza
Said Business School
University of Oxford
Park End Street
Oxford, OX1 1HP
UK
cristian.badarinza@sbs.ox.ac.uk

John Y. Campbell
Morton L. and Carole S.
Olshan Professor of Economics
Department of Economics
Harvard University
Littauer Center 213
Cambridge, MA 02138
and NBER
john_campbell@harvard.edu

Tarun Ramadorai
University of Oxford
Said Business School
Park End St.
Oxford OX1 1HP
United Kingdom
tarun.ramadorai@sbs.ox.ac.uk

An online appendix is available at:
http://www.nber.org/data-appendix/w20408

1 Introduction

The structure of housing finance is highly variable both across countries and over time. One of the most important aspects of this structure from the perspective of macroeconomics is the interest rate schedule applicable over the life of a mortgage loan. Mortgage rate provisions can broadly be categorized into two groups. Fixed-rate mortgages (FRMs) entail a constant nominal interest rate throughout the life of the mortgage. Adjustable-rate mortgages (ARMs) have an interest rate that varies over the life of the contract in relation to market conditions. The share of mortgages issued that are ARMs (the "ARM share") exhibits significant cross-country and time-series variation. In the US, for example, the dominant mortgage form is normally a 30 year fixed rate mortgage, but ARMs were unusually popular in the late 1980s, mid 1990s, and mid 2000s; whereas in the UK, it is difficult to find an interest rate fixation period that is much above 5 years.

These differences in the structure of housing finance influence the monetary policy transmission mechanism (Bernanke and Gertler 1995), as movements in short-term market interest rates directly affect the budgets of all ARM borrowers, while FRM borrowers are only affected by long-term interest rates, and then only if rates fall and these borrowers are able to refinance their mortgages (Taylor 1995, Miles 2003). Our goal in this paper is to understand the determinants of the cross- and within-country variation in the ARM share, with an emphasis on households' reactions to movements in interest rates. Our analysis also sheds light on the extent to which households are forward-looking when choosing the form of their mortgages. This question of households' forward-looking behaviour has been studied extensively in macroeconomics, often in relation to consumption-smoothing (e.g. Souleles 1999, Agarwal, Liu, and Souleles 2007, and Parker 2014).

Theory and prior empirical work offer some guidance about the likely determinants of household mortgage choice between ARMs and FRMs. Absent borrowing constraints, the rational decision between fixed- and variable-rate mortgages depends on the expected future costs borne by the borrower over the life of the loan, in relation to the risks that these costs will be higher or lower than expected. If the relative risks of ARMs and FRMs are relatively stable, the primary determinant of variation in the ARM share over time should be the spread between the current fixed rate and the expectation of the average adjustable rate over the life of the mortgage.

Koijen, Van Hemert, and Van Nieuwerburgh (KVHVN 2009) argue that households estimate the future path of adjustable rates, and posit that they do this using a simple rule of thumb which is well approximated by a backward moving average of realized ARM rates. They find evidence using US data that appears consistent with this hypothesis. On the other hand, Campbell and Cocco (2003, 2014) suggest that the spread between the FRM rate and the current ARM rate may be the relevant variable for determining mortgage choice, given that borrowing-constrained households care about current interest costs and are particularly likely to choose ARMs in order to reduce those costs. Households may also focus on the current rate spread if they are constrained in the size of house they can buy by bank limitations on the maximum interest-payment-to-income ratio at the origination of the mortgage.[1]

It is difficult to distinguish between these two explanations using time-series data from a single country, because interest rates are persistent and the available time-series on the ARM share is relatively short. This problem may be exacerbated by inertia among market participants. For example, it may take time for banks to shift their marketing strategies gradually towards mortgage forms that they think will have greater customer appeal in current market conditions. In turn, households may be slow to respond to movements in rates if they tend to copy other households who have taken out mortgages recently, or simply if their expectations adjust gradually over time.

To surmount these obstacles, we compile panel data on the ARM share, ARM and FRM rates, interbank rates, government bond yields, and survey forecasts of interest rates from nine countries. This helps to alleviate the constraints imposed by a single country study, and allows us to bring more statistical power to bear on the problem. While there are numerous comparative studies of mortgage market structure across countries (for example, Lea 2011, Lea and Sanders 2011, IMF 2011, Bardhan, Edelstein, and Kroll 2012), we are unaware of

[1]Consistent with this, empirical papers by Brueckner and Follain (1988), Coulibaly and Li (2009), and Dhillon, Shilling, and Sirmans (1987) use household-level data on mortgage choice and include the current interest spread as an explanatory variable. Johnson and Li (2011) use data from the US Consumer Expenditure Survey to argue that adjustable-rate mortgage borrowers appear particularly likely to be borrowing-constrained.

any study that uses cross-country data to study time-variation in the ARM share.

Using our nine-country panel, we estimate a series of models that discriminate between current cost minimization and longer-term cost minimization as determinants of the ARM share. Each model allows both the spread of the FRM over the current ARM rate, and the spread of the FRM rate over average expected future ARM rates to influence the current ARM share. The models differ in the way they model household expectations of future ARM rates.

Our first approach assumes that households have rational expectations. Using a panel instrumental variables (IV) method, we instrument realized future ARM rates with current and past mortgage rates and government bond yields. This setup allows us to test both the hypothesis that expected future changes in ARM rates have no influence on current mortgage choice (as implied by current cost minimization) and the hypothesis that the current spread correlates with the ARM share only to the extent that it predicts future ARM rates (as implied by longer-term cost minimization). We vary the horizon over which households are assumed to forecast mortgage rates between one and three years, and consider both stationary and first-order integrated (I(1)) interest-rate processes.

In our full sample, the results of this approach generally support the hypothesis of current cost minimization as the proximate driver of household mortgage choice, although we do find some evidence that households anticipate movements in ARM rates within the first year after mortgage origination. Within the last decade there is somewhat more evidence for the relevance of longer-term cost minimization.

Our second approach follows KVHVN (2009) and assumes that households have adaptive expectations, forecasting average future ARM rates with a backwards moving average of ARM rates. We find little evidence that a backwards moving average of ARM rates helps determine the ARM share outside the US data studied by KVHVN.

Our third approach uses one-year ahead survey forecasts of short-term nominal interest rates. These interest rates influence ARM rates both directly (for tracker or index-linked mortgages) and indirectly (through the cost structure of banks), so their future path is a substantial determinant of the expected relative costs of FRM and ARM contracts over the life of the mortgage. We use survey forecasts both as additional instruments in our basic rational expectations model, and as additional explanatory variables that may directly affect household mortgage choice if households' expectations are irrational but well proxied by survey forecasts.

We show that the survey forecast data do contain relevant information about near-term movements in interest rates. In a model where households are assumed to look forward one year, survey forecasts correlate with the ARM share only because they can predict movements in future ARM rates over the next year. In a longer-term forecasting model, however, the correlation between survey forecasts and the ARM share cannot be explained by the predictive power of the survey forecasts for future ARM rates. Instead, they seem to have a direct influence on mortgage choice, as would be the case if households respond to irrational expectations of longer-term ARM rates that are correlated with survey forecasts.

Our nine-country panel analysis allows us to better understand time-series variation in the ARM share. However there are likely broader macroeconomic determinants of preferred mortgage form across countries. If a fixed mortgage cannot be prepaid without penalties, as in Germany, then a FRM is risky to the extent that inflation is volatile and persistent. If it can be prepaid without penalties, as in the US, then inflation volatility increases the FRM rate that banks will want to charge. On the other hand, real interest rate volatility makes an ARM risky for any borrower, while inflation volatility makes an ARM risky for a borrowing-constrained household, because it makes the timing of required payments more volatile in real terms. Using 14 countries including the nine countries in our panel analysis, we also uncover suggestive cross-sectional evidence that the country-average ARM share is well-explained by historical country-specific inflation volatility.

The organization of the paper is as follows. Section 2 describes the cross-country data that we compile and employ in our study. Section 3 describes the econometric methodology that we use to distinguish between current cost minimization and longer-term cost minimization in household mortgage choice. Section 4 estimates these models. Section 5 explores robustness and presents cross-country evidence on the role of historical inflation volatility in explaining the cross-country average ARM share. Section 6 concludes. An online appendix, Badarinza, Campbell, and Ramadorai (2014), provides additional details about our data sources and econometric procedures, and additional empirical results.

2 Data

Our panel analysis covers nine countries: Australia, Belgium, Denmark, Greece, Ireland, Italy, Netherlands, Sweden, and the United States. For the countries which are part of the Eurozone, we obtain aggregate monthly data on volumes and interest rates on new mortgage loans from the statistical repositories of respective national central banks. These data are part of the harmonized system, introduced by the European Central Bank in 2003, which reports and aggregates credit volumes from country-level mortgage finance institutions. For Sweden, we use the Swedish statistical agency's Financial Market Statistics report, which contains monthly series of volumes and interest rates on new housing credit agreements, and goes back to 1996. For Australia, we use data released by the Australian Bureau of Statistics, which covers the period from 1991 to the present. For Denmark, we use the historical time series of financial statistics reported by the Danmarks Nationalbank, which begins in 2003.

Our mortgage data for the US is from the Monthly Interest Rate Survey, collected since 1985 by the Federal Housing Financing Board. Towards the end of the sample, the share of adjustable-rate mortgages becomes very low in the US market and we therefore impute values for the corresponding interest rates, in order to insure representativeness and time series comparability. We verify that our results are not driven by this imputation of rates, and give further details of this procedure in the online appendix.

In order to insure comparability across countries, we classify any mortgage loan which either pays a variable interest rate until it matures, or has an initial fixation period of below one year as an ARM. This includes "tracker" contracts with interest rates which are linked to underlying indices or benchmark interest rates. As measures of the nominal short- and long-term costs of lending, we use the 3-month interbank rate and the 5-year sovereign bond yield in all countries. We measure the inflation rate as the monthly year-on-year change of the consumer price index (CPI). The data source for both interest rates and CPI statistics is Datastream.

The ARM share and inflation data for countries which are not part of our panel analysis (but are included in our pure cross-country analysis) are derived from national central banks and Datastream. Additional details about all data employed in the paper are provided in the online appendix. We also present broader institutional information about these mortgage markets in a separate institutional appendix, Badarinza et al. (2014), also available online.

Finally, we obtain data on interest rate expectations from Consensus Economics, as reported in their "Consensus Forecasts Report". The Report is based on surveys of local economists, primarily employed by large financial institutions. These economists predict the evolution of nominal 3-month interest rates over the 12-month period following the survey date. We compute country-level monthly time series by cross-sectionally averaging forecasts across the set of respondents in each country. The disaggregated data are not available for Denmark, Belgium, Ireland and Greece. We therefore drop Denmark from the analysis which uses survey forecast data. For Belgium, Ireland, and Greece, we use data on survey forecasts for the Eurozone.

2.1 Cross-sectional and time-series variation in the ARM share

Table 1 reports summary statistics on the ARM share—that is, the percentage share of adjustable-rate mortgages in the total volume of new mortgage loans issued to households—and, for countries where the data are available, the average period of initial interest rate fixation in years. We divide our countries into two groups, using the following algorithm. If the volatility (time-series standard deviation) of the ARM share exceeds five percentage points, and if the volatility of the average initial interest rate fixation period is either unmeasured or exceeds 2 years, then we classify the country as one with significant time-series variation in the ARM share.

The top panel of the table shows the nine countries that satisfy both of these conditions, and which we include in our panel estimation: Australia, Belgium, Denmark, Greece, Ireland, Italy, the Netherlands, Sweden, and the USA. The bottom panel of the table shows countries that do not satisfy these conditions, in other words countries where there is a dominant mortgage form with minimal time-variation: Finland, Germany, Portugal, Spain, and the

UK. Most of these countries have mortgage systems dominated by ARMs, but the mortgage system in Germany is dominated by FRMs. The UK and Spain are two countries where the ARM share does vary through time, but in a fashion that is not economically meaningful because mortgage loans in these countries have very low average fixation periods which hardly vary over time. In other words, "fixed-rate" mortgages in these countries have such short fixation periods that they are barely distinguishable from "adjustable-rate" mortgages.

Table 1 documents considerable time-series variation in the ARM share within the countries selected by our algorithm. The time-series standard deviation of the ARM share ranges from roughly 60% of the mean ARM share in the US to roughly 6% of the mean in Australia. Figure 1 plots the history of the ARM share in each of these nine countries, along with the contemporaneous spread between FRM and ARM rates. The figure shows both temporary fluctuations in the ARM share that are typically correlated with the FRM-ARM spread, and some longer-term movements that vary across countries. For example Sweden moves towards a greater average ARM share over the sample period, whereas the US moves towards a lower average ARM share.

2.2 Survey forecasts of interest rates

In Table 2, we assess the information contained in Consensus Economics survey forecasts for future realizations of interest rates using the following regression specification, which we estimate both country-by-country and in a panel with fixed effects:

$$R^f_{i,t+12} - R^f_{i,t} = \alpha_i + \beta_i (R^{f,CF}_{i,t,t+12} - R^f_{i,t}) + \varepsilon_{i,t+12}. \quad (1)$$

Here, $R^f_{i,t}$ is the 3-month interest rate in country i in period t and $R^{f,CF}_{i,t,t+12}$ is the 12-month ahead average consensus forecast in country i in period t. The hypothesis that the survey forecasts are rational expectations of future interest rates in country i implies that we should estimate an intercept $\alpha_i = 0$ and a slope coefficient $\beta_i = 1$. More generally, if the survey forecasts contain relevant information about future interest rate changes but are not fully rational, then we should find $\beta_i > 0$ even if $\alpha_i \neq 0$ and $\beta_i \neq 1$.

Table 2 estimates equation (1) for each country separately, and then for the panel as a whole. The first column of Panel A of the table reports uniformly negative intercepts that are statistically significant in Sweden, the Netherlands and the Eurozone. In other words, survey responds tend to predict slightly higher changes in interest rates than the ones that actually materialize one year later. The second column of Panel A reports uniformly positive slope coefficients that are significantly different from zero in all countries except Australia, and insignificantly different from one in all countries except the Eurozone.[2] The third column of Panel A shows that the rational expectations hypothesis that the intercept and slope coefficients equal zero and one, respectively, can be rejected at the 5% level or better for all countries except the US and Italy.

Panel B of Table 2 imposes a common slope across countries but allows country-specific fixed effects, and shows that the estimated slope is 1.02, insignificantly different from one. For the purposes of our analysis, the slight upwards bias in the forecasts observed in Panel A appears not to be particularly important, only affecting the estimated regression constants and country fixed effects. We conclude that the survey-based one-year ahead expectations contain relevant information about the path of future interest rates.

3 Methodology

In this section we present the methodology that we use to discover whether the positive correlation between the ARM share and the spread between FRM and ARM rates, illustrated in Figure 1, is driven by short-term cost minimization, or by rational forecasts of future ARM rates.

We propose a simple model to distinguish between alternative explanations for variation

[2] The data sample for short-term interest rate forecasts at the level of the Eurozone only covers the period after 2005, as indicated in Table 1. In this case, the rapid decline of interest rates during the financial crisis leads us to observe a slope coefficient higher than one.

in the ARM share across countries i and months t:

$$\begin{aligned} ARMSHARE_{i,t} = \mu_i + \rho ARMSHARE_{i,t-1} + \beta_1(FRM_{i,t} - ARM_{i,t}) \\ + \beta_2\left(FRM_{i,t} - \hat{\mathrm{E}}_{i,t}[\overline{ARM}_{i,t,t+T}]\right) + \nu_{i,t}. \end{aligned} \tag{2}$$

In this equation, $ARMSHARE_{i,t}$ is the percent share of ARMs in total mortgage issuance (i.e., total ARM issuance divided by the sum of total ARM issuance and total FRM issuance) in each month, and $ARM_{i,t}$ and $FRM_{i,t}$ are country-specific monthly mortgage interest rates on ARMs and FRMs respectively. $\overline{ARM}_{i,t,t+T}$ is the forward-looking simple moving average of the ARM rate in country i, evaluated between time t and time $t+T$, where T is measured in calendar years.[3]

In our panel estimation, we allow for country-specific intercept terms μ_i, which control for the possibility that there may be pure time-invariant cross-country variation in the ARM share. We also include the lagged dependent variable $ARMSHARE_{i,t-1}$, in order to capture the effect of inertia on the part of households or mortgage providers. As mentioned earlier, it may take time for banks to shift their marketing strategies gradually towards mortgage forms that they think will work better, or for households to respond to movements in rates.

Our setup requires us to estimate household expectations of future average ARM rates, $\hat{\mathrm{E}}_{i,t}[\overline{ARM}_{i,t,t+T}]$. We consider three alternative models for household expectations—rational expectations, adaptive expectations, and survey proxies for expectations—each of which leads to its own empirical specification.

3.1 Rational household expectations

If household expectations are rational, we can use a panel instrumental variables approach, replacing expected future ARM rates in equation (2) with realized future ARM rates, and then instrumenting these future rates with current and lagged interest rates. This approach can be described as a two-stage procedure.

[3]The horizon T at which future payment streams are evaluated should, in theory, correspond to the average fixation period for fixed-rate mortgages in each country. However, as Table 1 shows, we have relatively short sample periods so we do not extend T beyond 3 years as doing so would leave us with a remaining sample which is too short for accurate estimation.

The first-stage regression uses current and past mortgage rates, as well as nominal short-term interest rates and government bond yields, to predict $\overline{ARM}_{i,t,t+T}$:

$$\overline{ARM}_{i,t,t+T} = \alpha_i + \gamma_1 ARM_{i,t} + \gamma_2 FRM_{i,t} + \gamma_3 \overline{ARM}_{i,t-K,t} + \gamma_4 B^5_{i,t} + \gamma_5 R^f_{i,t} + \varepsilon_{i,t}. \qquad (3)$$

Employing the same notation as earlier, $\overline{ARM}_{i,t,t-K}$ is the *backward*-looking moving average of the ARM rate in country i, evaluated between time t and time $t-K$, where K is once again measured in calendar years. We also include the 3-month interest rate $R^f_{i,t}$ and the 5-year government bond yield $B^5_{i,t}$ as explanatory variables. Their separate inclusion allows for benchmark rates and the excess of the ARM or FRM rates over these benchmark rates to forecast future ARM rates with different coefficients.

A variant of this approach modifies equation (3) to account for potential non-stationarity in interest rates. We assume that in the case of such non-stationarity, all interest rates are cointegrated, with a coefficient of cointegration equal to 1 for any given pair of interest rates. Campbell and Shiller (1987) show that such cointegration arises if there is a unit root in the short-term interest rate and the expectations hypothesis holds; the same will be true in the presence of time-varying risk premia, provided that risk premia follow a stationary process. Under this set of assumptions, in order to forecast $\overline{ARM}_{i,t,t+T}$ we estimate the following equation in which both right- and left-hand-side variables are stationary:

$$\begin{aligned} \overline{ARM}_{i,t,t+T} - ARM_{i,t} \;&=\; \varphi_i + \phi_1(FRM_{i,t} - ARM_{i,t}) + \phi_2(\overline{ARM}_{i,t-K,t} - ARM_{i,t}) \\ &\quad + \phi_3(B^5_{i,t} - R^f_{i,t}) + \xi_{i,t}. \qquad (4) \end{aligned}$$

In the second stage, $\hat{\mathrm{E}}_{i,t}[\overline{ARM}_{i,t,t+T}]$ is the fitted value from estimation of (3) or (4), which is then substituted back into equation (2).

Our identification strategy is straightforward. If the current spread between FRM and ARM rates, $(FRM_{i,t} - ARM_{i,t})$, is useful at predicting $ARMSHARE_{i,t}$ only to the extent that the spread forecasts $\overline{ARM}_{i,t,t+T}$, this will "knock out" any role for β_1 equation (2) given our instrumental variables approach. However if current cost minimization drives the ARM share, then β_1 will continue to be important. The relative significance of the two coefficients β_1 and β_2 in equation (2) allows us to measure the relative importance of current and longer-term cost minimization in household mortgage choice.

A few notes on our estimation procedure and results: First, in our estimation, we consider values of $T = 1, 2, 3$ and $K = 1, 2, 3$ years, and show results in the paper for $T = 1, 3$, and $K = 1, 3$, in the interest of preserving clarity of exposition. The results for $K = 2$ and $T = 2$ are available in the online appendix.

Second, estimation of equation (3) requires measuring a backward moving average of ARM rates. Since our sample periods are quite short for many countries, we wish to avoid shortening them further for models with a high K. For this reason, when $K > 1$, we impute ("back-cast") ARM rates prior to the beginning of our sample using nominal short-term interest rates, which are available earlier than ARM rates, and provide details of this procedure in the online appendix. This allows us to present all results for a common sample period. Our results are very similar if we shorten the sample as K increases rather than using this imputation approach.

Third, we calculate standard errors for all coefficients using a non-parametric bootstrap procedure, along the lines of Politis and Romano (1994), and as employed by Ramadorai (2012). Details are provided in the online appendix.

3.2 Adaptive household expectations

An alternative approach follows Koijen et al. (2009) in assuming that household expectations follow a simple adaptive process, $\hat{\mathrm{E}}_{i,t}[\overline{ARM}_{i,t,t+T}] = \overline{ARM}_{i,t-K,t}$, which we again substitute back into equation (2). In this case we use OLS to estimate either

$$\begin{aligned} ARMSHARE_{i,t} = \mu_i &+ \beta_1(FRM_{i,t} - ARM_{i,t}) \\ &+ \beta_2 \left(FRM_{i,t} - \overline{ARM}_{i,t-K,t}\right) + \nu_{i,t}, \end{aligned} \tag{5}$$

which excludes the lagged ARM share, or

$$ARMSHARE_{i,t} = \mu_i + \rho ARMSHARE_{i,t-1} + \beta_1(FRM_{i,t} - ARM_{i,t}) + \beta_2\left(FRM_{i,t} - \overline{ARM}_{i,t-K,t}\right) + \nu_{i,t}, \qquad (6)$$

which includes it. Current cost minimization implies that $\beta_1 > 0$ and $\beta_2 = 0$, while Koijen et al.'s adaptive forward-looking cost minimization implies that $\beta_1 = 0$ and $\beta_2 > 0$.

3.3 Survey proxies for household expectations

Finally, we consider survey-based data on actual interest rate forecasts. These direct measures of agents' expectations are well suited to serve as instruments for expected future ARM rates, as they are forward-looking in nature, and potentially reflect more relevant information than current realizations of term structure variables. We also allow for the possibility that the survey-based interest rate forecasts influence mortgage choice directly—a possibility if household expectations are not fully rational, but are correlated with survey forecasts.

We alter our first-stage regressions to include survey forecasts:

$$\overline{ARM}_{i,t,t+T} = \alpha_i + \gamma_1 ARM_{i,t} + \gamma_2 FRM_{i,t} + \gamma_3 \overline{ARM}_{i,t-K,t} + \gamma_4 B^5_{i,t} + \gamma_5 R^f_{i,t} + \gamma_6 R^{f,CF}_{i,t,t+12} + \varepsilon_{i,t}, \qquad (7)$$

and:

$$\overline{ARM}_{i,t,t+T} - ARM_{i,t} = \varphi_i + \phi_1(FRM_{i,t} - ARM_{i,t}) + \phi_2(\overline{ARM}_{i,t-K,t} - ARM_{i,t}) + \phi_3(B^5_{i,t} - R^f_{i,t}) + \phi_4(R^{f,CF}_{i,t,t+12} - R^f_{i,t}) + \xi_{i,t}. \qquad (8)$$

Similarly, we alter our main regression to include the survey forecast of the future change in the short-term interest rate:

$$ARMSHARE_{i,t} = \mu_i + \rho ARMSHARE_{i,t-1} + \beta_1(FRM_{i,t} - ARM_{i,t}) + \beta_2(FRM_{i,t} - \overline{ARM}_{i,t,t+T}) + \beta_3(R^f_{i,t} - R^{f,CF}_{i,t,t+12}) + \nu_{i,t}, \qquad (9)$$

To the extent that households have rational expectations of future interest rates, the survey forecasts should only be useful instruments in the first-stage regressions and should have no additional explanatory power for the ARM share when included directly in equation (9). That is, we should find $\beta_3 = 0$. We test this exclusion restriction in both the stationary and the unit-root panel models. Alternatively, a positive and statistically significant coefficient β_3 implies that a survey forecast of increasing short-term interest rates over the course of the next year leads to a decrease in the ARM share, beyond any information that the one-year forecasts may contain about the levels of future ARM rates.

4 Estimation of mortgage choice models

4.1 Rational expectations

Table 3 asks whether the ARM share is driven by the current FRM-ARM spread or by the spread of the FRM rate over rational expectations of an average of future ARM rates. We estimate equation (2) by instrumental variables, where equation (3) is our first-stage regression, assuming that interest rates are stationary.[4]

The table is divided into two sets of rows, each corresponding to a different sample: the full sample, and a sample beginning in 2001. We also differentiate across two sets of columns, between panel regressions that do and do not include the US. The exclusion of the US is intended to provide an "out-of-sample" evaluation of the model—several studies including Brueckner and Follain (1988), Koijen et al. (2009), and Moench et al. (2010) have attempted to explain the ARM share in the US, but to our knowledge, ours is the first academic study attempting to explain such variation in the additional 8 countries in our panel.

Within each sample we vary the parameter K that governs the number of past years over which we average ARM rates, from one to three. We also vary the parameter T, that governs the number of future years over which we are forecasting future ARM rates, from one to three. For these four combinations of K and T we show the estimated coefficients

[4] In the online appendix, we also report panel estimation results assuming that interest rates have a common unique unit root. In this case, we estimate equation (2) by instrumental variables, where equation (4) is our first-stage regression.

β_1 and β_2. The coefficient β_1 measures the impact of the current spread between FRM and ARM rates on the ARM share, while the coefficient β_2 measures the impact of the spread between the current FRM rate and the average of expected future ARM rates on the ARM share.

Most of our results are robust to the choice of K, the backward window for averaging ARM rates. However the choice of T, the forward window over which we calculate average future ARM rates, is quite important. When $T = 1$, we compare a FRM-ARM spread that includes the current ARM rate with a near-term alternative that includes an average expected ARM rate over the next year. As T increases, the alternative model requires longer-term forecasts that are more relevant for lifetime mortgage cost comparisons, but also may be more difficult for households to make.

When $T = 1$, we obtain mixed results in the full sample (this is one of the few cases where the choice of K affects the results). In a sample that starts in 2001, however, we typically obtain a small and statistically insignificant coefficient β_1 and a larger coefficient β_2 that is significant at the 10%, 5%, or even 1% level. This provides some evidence for near-term forward-looking behavior on the part of households, at least in recent data.

When $T = 3$, however, we obtain a large coefficient β_1 that is always significant at the 1% level. In the full sample there is almost no evidence for forward-looking behavior: the coefficient β_2 is small (typically about one-fifth the size of β_1) and statistically insignificant. If we shorten the sample to start in 2001, however, we estimate β_2 to be statistically significant and one-half to three-quarters the magnitude of β_1.

The results assuming a unit-root interest rate process, which we report in the online appendix, are broadly consistent with those discussed above. The coefficients are less stable in the case $T = 1$, probably reflecting the fact that fewer instruments are available in the first-stage regression for the unit-root case, so the fitted forward-looking FRM-ARM spread is more highly correlated with the current FRM-ARM spread in the second stage. In the case $T = 3$, the coefficient β_1 on the current spread remains strongly statistically significant whenever the US is included, and for the post-2001 sample, while the coefficient β_2 on the forward-looking spread is variable in magnitude and statistical significance.

In summary, there is some evidence that household mortgage choice responds to rational forecasts of future ARM rates. This evidence is stronger for near-term forecasts of rates within the next year than for longer-term three-year forecasts, and stronger in recent data since 2001. However there is also evidence that the current FRM-ARM spread influences mortgage choice, and in most of our specifications the current spread has a greater influence than the anticipated future spread.

Table 4 estimates country-specific regressions and provides more details about the underlying coefficients from equations (2) and (3) when $K = 1$ year and $T = 3$ years. The first-stage regressions generate relatively consistent results across countries—γ_1 is positive on average, which indicates that mortgage rates are persistent over the short-run. However, γ_3 is negative, which suggests that controlling for short-run continuation, there is a tendency for ARM rates to reverse over the longer run. The table makes clear that the magnitude of this reversal is small and statistically insignificant for the US when estimated over the whole sample, however it is quite pronounced in the more recent sample period. In the online appendix , we repeat this exercise under the assumption of a unit root in interest rates. We generally find evidence that long-short spreads, both of FRM rates over ARM rates and of longer-term government bond yields over short-term rates, tend to predict increases in ARM rates, and there is some evidence of mean-reversion in changes in ARM rates.

Our analysis also reveals that in the second stage regression, i.e., equation (2), the coefficient on the lagged ARM share is high and statistically significant. This is consistent with a high degree of inertia in mortgage markets in every country in our sample. This inertia could arise from sluggishness in the sales effort of mortgage providers, in the sense that they only gradually shift towards selling products that households are interested in buying. It could also capture households' sluggish adjustment to interest rate movements, or spillovers within the household sector—with households' mortgage decisions strongly influenced by other households' recent choices.

4.2 Adaptive expectations

In Table 5, we drop the assumption of rational forecasting and instead estimate rule-of-thumb models as suggested by Koijen, Van Hemert, and Van Nieuwerburgh (KVHVN 2009).

The left-hand side of the table estimates (2) with the simple rule of thumb adaptive expectations assumption, but omitting the lagged ARM share. This specification does result in a statistically significant and economically large coefficient on the spread of the FRM rate over the moving average of past ARM rates for a maximum of five of the countries in our nine-country panel, one of which is always the US. However the sign is negative in two of these countries and positive in three of them. In our four panel specifications (including and excluding the US, and data from before 2001), we obtain relatively small β_2 coefficients whose sign is unstable across specifications.

The right-hand side of the table shows what happens when we include the lagged dependent variable in these regressions. We find that the relative magnitude of β_2 is further reduced even for the US. This suggests that inertia in mortgage choice may be partly responsible for the results reported in KVHVN. Overall this table supports the hypothesis of current cost minimization against the alternative that households minimize longer-term costs but have adaptive interest-rate expectations.

4.3 Survey expectations

In Table 6, we add survey forecasts of near-term interest rate movements to our analysis. This table repeats the rational-expectations analysis of Table 3, but includes the forecasted one-year change of the nominal 3-month interest rate both as an additional explanatory variable, with coefficient β_3, and as an additional instrument for future average ARM rates. We again report results for forecasting horizons $T = 1$ year and $T = 3$ years, but to save space we fix the parameter $K = 1$ year.

Once again the results are sensitive to the forecasting horizon that we consider. In the case $T = 1$, survey forecasts strengthen the evidence that rational near-term interest-rate forecasts affect mortgage choice. The current FRM-ARM spread is never significant, while the rationally anticipated future spread is significant in three out of four specifications. The survey forecasts also enter directly when we exclude US data.

For longer-term forecasting horizons, the results are very different. Here the current FRM-ARM spread is always significant and the survey forecast of interest rate changes enters the regression directly in three out of four specifications, while the rationally anticipated future spread only enters in one. These two variables appear to drive out the rational forecast of future ARM rates in determining household mortgage choice. Thus, while households may be forward-looking in the sense that they are responsive to survey expectations of future interest-rate movements, this forward-looking behavior is not consistent with rational cost minimization over horizons longer than one year. The evidence can only be reconciled with longer-term cost minimization if households have irrational expectations of longer-term movements in ARM rates that are correlated with survey forecasts of near-term movements in short rates.

5 Robustness and further analysis

5.1 Interest rate fixation periods

In most European countries and differently from the US, fixed-rate mortgages are offered for a variety of initial fixation periods. As mentioned above, FRM contracts entail very different repayment streams in Spain and Germany, with short-term fixation (below 5 years) more common in the former and long-term fixation (above 10 years) typical for the latter.

It is also interesting to note that in the nine countries constituting our estimation sample (where the overall share of adjustable- vs. fixed-rate mortgages varies through time), we observe substantial time-variation in the market share of mortgages corresponding to different initial fixation periods.[5]

For example, in the Netherlands, households increasingly opted for long-term FRMs during the years preceding the financial crisis. More recently however, long-term FRMs have virtually disappeared from the Dutch market, whereas the transaction volumes of FRMs

[5]In the appendix, we illustrate the dynamics of the monthly transaction volumes for residential fixed-rate mortgage contracts with different initial fixation periods, grouped in three sub-categories: 1 to 5 years, 5 to 10 years and above 10 years.

with lower fixation periods have remained broadly unchanged throughout the decade. In contrast, the increase in FRM volumes in Greece between 2006 and 2008 is associated with an increased preference for relatively shorter-duration FRMs.

As a robustness exercise, we repeat our instrumental-variables panel analysis, replacing the ARM share with the country-level overall average fixation period.[6] Our set of countries is substantially reduced, since disaggregated data on mortgage transaction volumes are only available for Denmark and the euro zone countries (see Table 1). For the United States, we approximate the long-term fixation period by 25 years. In the online appendix , we show that the results reported in Table 3 carry through in this setup. In particular, households exhibit short-term forward looking behaviour, while time- variation in the current FRM-ARM spread still explains a significant portion of the dynamics of average fixation periods.

5.2 Cross-country identification: time fixed effects

Our panel estimation approach relies on cross-country differences in ARM share dynamics as a way to distinguish between alternative theories. Of course, the power of this identification method depends on whether mortgage interest rates and yield curve data exhibit sufficient cross-sectional heterogeneity.

For instance, Figure 1 shows that the financial crisis affected the terms of mortgage loans in a broadly similar fashion: the FRM-ARM spread declines at first, picks up during 2009, and then declines again. The ARM share mirrors these dynamics, with fixed-rate mortgages being relatively more desirable before the onset of the crisis and the share of adjustable-rate mortgages picking up thereafter.

We control for the possibility that common shocks may be responsible for driving the co-movement between mortgage product choice and term structure variables, by including time fixed effects in our benchmark specifications. The results, reported in the online appendix, confirm the dominant role of the contemporaneous spread. In the full sample of countries, the estimated coefficients β_1 are barely affected by the inclusion of the time fixed effects

[6] In this context, it is no longer appropriate to compute the FRM-ARM spread as a weighted average of rates across fixation periods, as this would, by construction, introduce a simultaneity bias. We therefore construct our right-hand side explanatory variables in this robustness exercise using the interest rates on contracts with fixation periods above 10 years.

and remain statistically significant at a 1% confidence level. Interestingly, the role of the forward-looking component also remains robust in terms of estimated magnitudes, especially for the post-2001 period, despite this coefficient being less precisely estimated.

5.3 Cross-sectional patterns

Having explored the determinants of pure time-series variation in the shares of ARMs, we conclude with a simple cross-country analysis of the determinants of the time-series average ARM shares.

In the top two panels of Figure 2, we plot the country-level average ARM shares and interest rate fixation periods against the average FRM-ARM rate spread over the sample. The very strong relationship between interest rate spreads and ARM shares which we documented in the time series dimension seems to not hold when we analyze the cross section of countries. If anything, higher spreads tend to be weakly associated with a lower share of ARMs.

We do not find this surprising, though, given that the institutional structures of the different international mortgage markets are likely to be affected by numerous legal and regulatory factors, foreclosure and bankruptcy rules, different prepayment penalty regimes, as well as supply-side constraints referring to the cost structure of banks. We review these factors in detail in a separate institutional appendix,[7] and highlight the challenges involved in generating comparable mortgage market statistics across countries.

Following Campbell (2013), the bottom part of Figure 2 plots the average ARM share and average interest rate fixation period versus the historical level of inflation volatility in each country. The figure shows that there is a strong positive cross-sectional relationship between the average ARM share and the historical level of inflation volatility, and a negative relationship between the average fixation period and historical inflation volatility. This suggests that there is a significant role for household perceptions of inflation risk in determining household mortgage choice in the long run, consistent with the findings of Malmendier and Nagel (2011) in the context of stock market participation. Viewed through this lens, the

[7] The web version of the institutional appendix is available through the following URL: `http://hhf.oxford-man.ox.ac.uk/node/804`.

striking cross-country differences in the structure of mortgage markets seems plausible: in most of Northern and Western Europe and the US, inflation has been contained over the last decade and fixed-rate mortgages are more prevalent. In contrast, in Southern Europe and Australia inflation has been more volatile, and higher ARM shares and lower fixation periods are more prevalent.

6 Conclusion

Mortgage markets are remarkably heterogeneous across countries, and also vary considerably over time. In a number of countries, including the US, the market share of adjustable-rate mortgages (the ARM share) co-moves with interest rates. In this paper we ask whether households choose the form of their mortgages in response to current interest rates, or also in anticipation of future interest rates.

We uncover some evidence that households are forward-looking over relatively short periods of time. The spread between the fixed-rate mortgage (FRM) rate and the average rationally expected ARM rate over the next year is often a better predictor of the ARM share than is the spread between the FRM rate and the current ARM rate. The evidence for forward-looking behavior is particularly strong in more recent data since 2001.

Over a longer three-year horizon, however, the current rate spread tends to have a larger influence on the ARM share than the rate spread involving rationally expected future rates. Thus households do not seem to anticipate longer-term rate movements in the manner that would be required to minimize the lifetime costs of their mortgages. Instead the current rate spread is an important influence on mortgage choice, as would be implied by a model in which borrowing-constrained households seek low rates in order to maintain the level of current consumption, or to increase the size of the house they can buy when constrained by bank limitations on mortgage interest-to-income ratios.

We find that a model in which households use an adaptive rule of thumb for forecasting future ARM rates generally performs poorly in our international dataset. This does not imply that households are fully informed about the process driving interest rates, or manage their mortgages optimally. On the contrary, there is evidence that ARM borrowers in the

US do not understand the extent to which ARM rates can vary (Bucks and Pence 2008), and evidence for suboptimal mortgage refinancing in Denmark, the US, and the UK (Andersen et al. 2014, Campbell 2006, Miles 2003). We interpret this finding as suggesting that mechanical forecasting rules do not adequately capture household expectations about future interest rates.

We also bring survey data on interest rate forecasts into our analysis and find that the ARM share tends to increase when professional forecasters expect short-term interest rates to decrease during the next year. We test and reject the hypothesis that the effect of survey forecasts is due to their ability to predict longer-term movements in ARM rates. Instead, survey forecasts seem to have a direct effect on mortgage choice, as would be implied by a model in which households have irrational expectations of longer-term movements in interest rates that are correlated with near-term professional forecasts.

Our analysis of time-series variation in the ARM share concentrates on interest rate movements, but it is equally interesting to ask what drives persistent cross-country variation in this share. We have presented evidence that historical volatility in inflation is associated with a high ARM share. This makes sense since inflation volatility makes long-term nominal contracts risky for both borrowers and lenders, or risky for lenders and correspondingly expensive for borrowers in the case where FRMs can be refinanced with minimal prepayment penalties. There are of course many other variables that should help to determine mortgage choice, including for example the cost of default and the prevalence of borrowing constraints, and some of these may vary both over time and across countries. These questions remain to be explored in future research.

References

Agarwal, S., C. Liu, and N. Souleles, 2007, Reaction of consumer spending and debt to tax rebates: Evidence from consumer credit data, *Journal of Political Economy* 115, 986–1019

Andersen, S., J.Y. Campbell, K.M. Nielsen, and T. Ramadorai, 2014, Inattention and inertia in household finance: Evidence from the Danish mortgage market, unpublished paper.

Badarinza, C., J.Y. Campbell, G. Kankanhalli, and T. Ramadorai, 2014, Institutional appendix to What calls to ARMs?, http://hhf.oxford-man.ox.ac.uk/node/804.

Badarinza, C., J.Y. Campbell, and T. Ramadorai, 2014, Online appendix to What calls to ARMs?, http://hhf.oxford-man.ox.ac.uk/node/804.

Bardhan, A., R.H. Edelstein, and C.A. Kroll (eds.), 2012, *Global Housing Markets: Crises, Policies, and Institutions*, John Wiley.

Bernanke, B. S., and M. Gertler, 1995, Inside the black box: The credit channel of monetary policy transmission, *Journal of Economic Perspectives* 9, 27–48.

Brueckner, J.K. and J.R. Follain, 1988, The rise and fall of the ARM: An econometric analysis of mortgage choice, *Review of Economics and Statistics* 70, 93–102.

Bucks, B., and K. Pence, 2008, Do borrowers know their mortgage terms?, *Journal of Urban Economics* 64, 218–233.

Campbell, J.Y., 2006, Household finance, *Journal of Finance* 61, 1553–1604.

Campbell, J.Y., 2013, Mortgage market design, *Review of Finance* 17, 1–33.

Campbell, J.Y. and J.F. Cocco, 2003, Household risk management and optimal mortgage choice, *Quarterly Journal of Economics*, 118(4), 1449–1494.

Campbell, J.Y. and J.F. Cocco, 2014, A model of mortgage default, forthcoming *Journal of Finance*.

Campbell, J.Y. and R.J. Shiller, 1987, Cointegration and tests of present value models, *Journal of Political Economy* 95, 1062–1088.

Coulibaly, B. and G. Li, 2009, Choice of mortgage contracts: Evidence from the Survey of Consumer Finances, *Real Estate Economics* 37, 659–673.

Dhillon, U.S., J.D. Shilling, and C.F. Sirmans, 1987, Choosing between fixed and adjustable rate mortgages: Note, *Journal of Money, Credit, and Banking*, 19, 260–267.

International Monetary Fund, 2011, Housing finance and financial stability – back to basics?, in: *Global Financial Stability Report, April 2011: Durable Financial Stability – Getting There from Here*, International Monetary Fund, Washington, DC, pp. 111–142.

Johnson, K., and G. Li, 2011, Are adjustable-rate mortgage borrowers borrowing constrained?, FEDS Working Paper 2011-21, Federal Reserve Board, Washington, DC.

Koijen, R.S.J., Van Hemert, Otto and Stijn Van Nieuwerburgh, 2009, Mortgage timing, *Journal of Financial Economics*, 93(2), 292–324.

Lea, M., 2011, Alternative forms of mortgage finance: what can we learn from other countries?, in: N. Retsinas and E. Belsky (eds.), *Moving Forward: The Future of Consumer Credit and Mortgage Finance*, Joint Center for Housing Studies, Harvard University, Cambridge, MA, and Brookings Institution Press, Washington, DC, pp. 118–149.

Lea, M., and A. Sanders, 2011, Government policy and the fixed-rate mortgage, *Annual Reviews of Financial Economics* 3, 223–234.

Malmendier, U. and Nagel, S., 2011, Depression babies: do macroeconomic experiences affect risk taking?, *Quarterly Journal of Economics*, 126(1), 373-416.

Miles, D., 2003, *The UK Mortgage Market: Taking A Longer-Term View, Interim Report: Information, Incentives, and Pricing*, HM Treasury, London.

Moench, E., J. Vickery, and D. Aragon, 2010, Why is the market share of adjustable rate mortgages so low? *Federal Reserve Bank of New York: Current Issues in Economics and Finance*, 16(8), 1–11.

Parker, J., 2014, Why don't households smooth consumption? Evidence from a 25 million dollar experiment, unpublished paper.

Politis, D. N., and Joseph P. Romano, 1994, The stationary bootstrap, *Journal of the American Statistical Association*, 89, 1303–1313.

Ramadorai, T., 2012, The secondary market for hedge funds and the closed hedge fund premium, *Journal of Finance*, 67, 479-512.

Souleles, N., 1999, The response of household consumption to income tax refunds, *American Economic Review* 89, 947-958.

Taylor, J. B., 1995, The monetary transmission mechanism: An empirical framework, *Journal of Economic Perspectives*, 9, 11–26.

Table 1
Summary statistics

In Panel A, the table reports summary statistics on the share of adjustable-rate mortgages in percent of the total volume of new loans to households, as well as the average period of initial interest rate fixation (in years). Under the heading *S.d.*, we report time series volatility, measured by the realized standard deviation. Average fixation periods are derived based on the market share of mortgages falling within three different fixation period categories: 1 to 5 years, 5 to 10 years and above 10 years. We calculate the average fixation periods as weighted averages of interval means, considering a 1-year fixation for ARMs, and 3, 7 and 25 years for FRMs, respectively. The data for Australia, Ireland and Sweden does not allow the computation of these series. The sample coverage coincides with the one for the share of ARMs. Overall, three groups of countries are identifiable: ones in which ARMs predominate throughout the sample and the fixation periods of FRMs is low (Portugal, Finland, Spain), ones in which FRMs predominate (Germany) and ones in which the market structure varies through time. The top panel contains the countries from this latter category, which we also include in the panel analysis. The case of the UK is special in that the ARM share is varying through time, but an average interest rate fixation period of around 2 years is inconsistent with our understanding of the more medium- to long-run nature of a FRM. In Panel B, the table reports selected moments of the time series of 3-month nominal interest rates, as well as corresponding one-year ahead consensus forecasts. Disaggregated forecast data are not available for Denmark, Belgium, Greece and Ireland. In our panel estimation, we use forecasts at the level of the Eurozone for the latter three of these countries.

Panel A
Mortgage market data

	Share of ARMs				Interest rate fixation period				Sample
	Mean	S.d.	Min	Max	Mean	S.d.	Min	Max	coverage
Australia	88.25	5.06	74.50	97.80					1991-2013
Belgium	23.15	17.02	5.34	61.86	11.78	3.70	4.13	16.31	2003-2013
Denmark	44.59	13.17	13.88	73.25	8.69	2.86	2.99	14.96	2003-2013
Greece	63.14	23.25	20.55	93.12	3.38	1.00	1.84	5.57	2003-2010
Ireland	81.55	9.14	52.91	94.17					2003-2013
Italy	70.66	16.82	28.94	88.56	5.78	3.22	2.34	13.68	2003-2013
Netherlands	24.30	7.43	11.27	47.26	6.37	1.95	4.07	11.49	2003-2013
Sweden	53.62	17.67	14.47	90.76					1996-2013
USA	22.62	14.22	0.81	69.00	19.57	3.41	8.44	24.81	1986-2013
Finland	96.11	2.53	89.59	99.32					2005-2013
Germany	15.88	2.20	12.14	25.25	9.08	0.68	7.32	10.33	2003-2013
Portugal	97.16	2.98	85.91	99.51					2003-2013
Spain	85.32	7.81	64.62	94.16	1.54	0.23	1.20	2.07	2003-2013
UK	46.93	15.32	15.48	83.11	2.22	0.32	1.42	2.77	2004-2013

Panel B
Realizations and forecasts of 3-month nominal interest rates

	Short-term interest rates				Consensus forecasts				Sample
	Mean	S.d.	Min	Max	Mean	S.d.	Min	Max	coverage
Australia	5.69	1.86	2.58	15.81	6.05	1.94	2.56	15.10	1990-2013
Eurozone	2.04	1.57	0.19	5.28	2.19	1.35	0.27	4.57	2005-2013
Italy	5.25	4.11	0.19	18.22	5.04	3.66	0.22	13.27	1990-2013
Netherlands	3.80	2.55	0.19	9.82	3.83	2.17	0.30	8.66	1990-2013
Sweden	5.02	3.76	0.48	20.00	5.01	3.08	0.88	14.25	1990-2013
USA	3.68	2.36	0.24	8.57	3.65	2.11	0.12	7.79	1990-2013

Table 2

Rationality of one-year ahead interest rate forecasts

The table reports estimation results from regressions of the form:

$$R^f_{i,t+12} - R^f_{i,t} = \alpha_i + \beta_i(R^{f,CF}_{i,t,t+12} - R^f_{i,t}) + \varepsilon_{i,t+12}.$$

In this specification, $R^f_{i,t}$ is the 3-month interest rate in country i in period t and $R^{f,CF}_{i,t,t+12}$ is the one-year ahead average consensus forecast in country i in period t. Disaggregated forecast data are not available for Denmark, Belgium, Greece and Ireland. In our panel estimation, we use forecasts at the level of the Eurozone for the latter three of these countries. In Panel A, we estimate the coefficients unrestricted country-by-country. In Panel B, we consider the Eurozone to be a single unit and restrict the slope coefficients β to be identical across i. Standard errors are reported in parentheses below the coefficients. Statistical significance is indicated through at most three stars, referring to confidence levels of 10%, 5% and 1% respectively.

Panel A

Country-by-country estimation

	Intercept α_i	Slope β_i	p-Value $\beta_i = 1$	p-Value $\alpha_i = 0$ and $\beta_i = 1$
Australia	-0.55	0.55	0.34	0.01
	(0.34)	(0.47)		
Eurozone	-0.60**	2.30***	0.01	0.01
	(0.27)	(0.51)		
Italy	-0.25	1.36***	0.14	0.24
	(0.23)	(0.24)		
Netherlands	-0.45**	0.98***	0.96	0.05
	(0.19)	(0.31)		
Sweden	-0.50*	0.82***	0.56	0.03
	(0.28)	(0.31)		
USA	-0.28	1.16***	0.69	0.51
	(0.25)	(0.40)		

Panel B

Panel estimation with fixed effects

	Slope β	p-Value $\beta = 1$
Panel	1.02***	0.92
	(0.20)	

Table 3

Determinants of the ARM share in a cross-country panel:
Current mortgage rates vs. rational expectations of future rates

The table reports estimation results from panel instrumental-variables regressions of the form:

$$ARMSHARE_{i,t} = \mu_i + \rho ARMSHARE_{i,t-1} + \beta_1(FRM_{i,t} - ARM_{i,t}) + \beta_2(FRM_{i,t} - \overline{ARM}_{i,t,t+T}) + \nu_{i,t},$$

where μ_i are country-specific fixed effects. $ARM_{i,t}$, $FRM_{i,t}$ and $\overline{ARM}_{i,t-K,t}$ are used as instruments for $\overline{ARM}_{i,t,t+T}$, with T and K varying as indicated (in years). The first-stage model specification is given by:

$$\overline{ARM}_{i,t,t+T} = \alpha_i + \gamma_1 ARM_{i,t} + \gamma_2 FRM_{i,t} + \gamma_3 \overline{ARM}_{i,t-K,t} + \gamma_4 B^5_{i,t} + \gamma_5 R^f_{i,t} + \varepsilon_{i,t}.$$

All estimations cover the same sample as the one with $T = 3$ years. When $K = 3$ years, extrapolated values are calculated for the part of the sample where $\overline{ARM}_{i,t-K,t}$ is missing. We report bootstrap standard errors in parentheses. Statistical significance is indicated through at most three stars, referring to confidence levels of 10%, 5% and 1% respectively.

		Panel		Panel (excl. USA)	
		$T = 1$	$T = 3$	$T = 1$	$T = 3$
Full sample					
β_1	$K = 1$	0.61	1.18***	-0.11	0.87***
		(0.41)	(0.25)	(0.41)	(0.27)
	$K = 3$	1.14**	1.19***	0.48	0.91***
		(0.52)	(0.24)	(0.52)	(0.27)
β_2	$K = 1$	0.84**	0.30	1.53***	0.46*
		(0.40)	(0.21)	(0.40)	(0.24)
	$K = 3$	0.12	0.24	0.66	0.24
		(0.50)	(0.20)	(0.54)	(0.24)
Post-2001					
β_1	$K = 1$	-0.13	1.09***	-0.22	1.05***
		(0.48)	(0.29)	(0.49)	(0.32)
	$K = 3$	0.40	1.09***	0.26	1.04***
		(0.56)	(0.30)	(0.59)	(0.33)
β_2	$K = 1$	1.70***	0.76***	1.85***	0.74***
		(0.42)	(0.26)	(0.43)	(0.27)
	$K = 3$	0.94*	0.52**	1.13**	0.54**
		(0.50)	(0.26)	(0.54)	(0.27)

Table 4
Determinants of the ARM share at the country level:
Current mortgage rates vs. rational expectations of future rates

The table reports estimation results from country-by-country and panel instrumental-variables regressions where $ARM_{i,t}$, $FRM_{i,t}$ and $\overline{ARM}_{i,t-K,t}$ are used as instruments for $\overline{ARM}_{i,t,t+T}$, with $T = 3$ years and $K = 1$ year:

$$\overline{ARM}_{i,t,t+T} = \alpha_i + \gamma_{i,1} ARM_{i,t} + \gamma_{i,2} FRM_{i,t} + \gamma_{i,3} \overline{ARM}_{i,t-K,t} + \gamma_{i,4} B^5_{i,t} + \gamma_{i,5} R^f_{i,t} + \varepsilon_{i,t}.$$

The second-stage model specification is given by:

$$\begin{aligned} ARMSHARE_{i,t} &= \mu_i + \rho_i ARMSHARE_{i,t-1} + \beta_{i,1}(FRM_{i,t} - ARM_{i,t}) \\ &\quad + \beta_{i,2}(FRM_{i,t} - \overline{ARM}_{i,t,t+T}) + \nu_{i,t}, \end{aligned}$$

Correlation coefficients among regressors are reported under the column heading Γ. Statistical significance is reported through at most three stars, referring to confidence levels of 10%, 5% and 1% respectively, based on bootstrap standard errors.

First-stage estimation							
	γ_1	γ_2	γ_3	$\Gamma_{\gamma_1,\gamma_2}$	$\Gamma_{\gamma_1,\gamma_3}$	$\bar{R}^2$	obs.
Full sample							
Australia	0.89***	0.12	-0.19***	0.91	0.84	0.66	222
Belgium	-0.77***	-0.37*	-0.17**	0.87	0.75	0.83	72
Denmark	-0.27	-0.44	-0.97***	0.95	0.77	0.61	83
Greece	-0.05*	0.03	-1.01***	-0.14	0.48	0.96	47
Ireland	-0.55*	-0.58*	-0.42***	0.94	0.75	0.77	84
Italy	1.06	-1.04***	-0.56**	0.83	0.80	0.61	84
Netherlands	0.81***	-1.57***	0.05	0.71	0.79	0.76	84
Sweden	-0.01	1.28***	-0.33***	0.94	0.83	0.67	166
USA	-0.09	0.39**	-0.13	0.95	0.95	0.80	288
Panel	0.00	0.50***	-0.24***	0.94	0.95	0.86	1130
Panel (excl. USA)	0.62***	0.19***	-0.34***	0.95	0.94	0.87	842
Post-2001							
Australia	-0.06	-0.07	-0.18***	0.82	0.58	0.17	120
Sweden	0.75***	0.07	-0.36***	0.96	0.80	0.36	120
USA	-0.21	0.90***	-0.71***	0.91	0.88	0.63	120
Panel	0.15**	0.03	-0.43***	0.93	0.91	0.85	814
Panel (excl. USA)	0.31***	-0.12*	-0.43***	0.93	0.90	0.87	694

Table 4

Determinants of the ARM share at the country level:
Current mortgage rates vs. rational expectations of future rates
(continued)

Second-stage estimation						
	ρ	β_1	β_2	$\Gamma_{\widehat{\beta_1,\beta_2}}$	$\bar{R}^2$	obs.
Full sample						
Australia	0.90***	0.41	-0.05	0.22	0.84	222
Belgium	0.84***	3.47***	2.43***	-0.11	0.97	72
Denmark	0.81***	-0.41	-0.06	-0.47	0.63	83
Greece	0.97***	1.04	2.66	0.69	0.98	47
Ireland	0.88***	0.75	0.39	0.11	0.74	84
Italy	0.96***	2.02**	0.05	0.09	0.99	84
Netherlands	0.92***	1.32**	0.49	0.22	0.93	84
Sweden	0.96***	0.64	0.53	-0.56	0.93	166
USA	0.93***	2.79***	-1.08*	0.58	0.95	288
Panel	0.94***	1.18***	0.30	0.44	0.98	1130
Panel (excl. USA)	0.95***	0.87***	0.46*	0.29	0.98	842
Post-2001						
Australia	0.99***	-0.04	0.70**	0.22	0.92	120
Sweden	0.95***	-0.11	0.12	-0.67	0.89	120
USA	0.95***	2.21***	-0.98	0.06	0.95	120
Panel	0.95***	1.09***	0.76***	0.27	0.98	814
Panel (excl. USA)	0.95***	1.05***	0.74***	0.27	0.98	694

Table 5

Determinants of the ARM share at the country level:
Current mortgage rates vs. adaptive expectations of future rates

The table reports estimation results from running the two regressions:

$$\begin{aligned} ARMSHARE_{i,t} =& \mu_i + \beta_{i,1}(FRM_{i,t} - ARM_{i,t}) + \beta_{i,2}(FRM_{i,t} - \overline{ARM}_{i,t-K,t}) + \nu_{i,t}, \\ ARMSHARE_{i,t} =& \mu_i + \rho_i ARMSHARE_{i,t-1} + \beta_{i,1}(FRM_{i,t} - ARM_{i,t}) \\ & + \beta_{i,2}(FRM_{i,t} - \overline{ARM}_{i,t-K,t}) + \nu_{i,t}, \end{aligned}$$

for each country separately and in a pooled panel setup with country-specific fixed effects. Statistical significance is reported through at most three stars, referring to confidence levels of 10%, 5% and 1% respectively, based on bootstrap standard errors.

	Excluding lagged term				Including lagged term			
	β_1		β_2		β_1		β_2	
	$K=1$	$K=3$	$K=1$	$K=3$	$K=1$	$K=3$	$K=1$	$K=3$
Full sample								
Australia	3.56***	2.59***	-1.09**	-0.13	0.33	0.40	0.05	0.17
Belgium	21.15***	20.45***	0.67	-1.48	1.94**	1.02	-3.46***	-1.84
Denmark	5.51***	-0.41	-6.58***	-3.79***	0.50	-0.97	-1.62*	-0.83
Greece	34.35***	43.79***	8.52	-17.37	6.61*	3.94	-4.83	0.47
Ireland	-0.01	-15.01***	-12.94***	-10.75***	0.81	1.15	-2.62**	0.21
Italy	8.58***	9.78**	15.87***	-7.70	2.59***	0.55	-2.83***	-2.64***
Netherlands	7.10***	13.66***	6.08***	11.65***	1.80***	3.74***	-0.44	3.66***
Sweden	10.94**	16.95***	-1.24	6.87***	0.56	0.42	-0.95*	0.14
USA	-1.20	11.61***	18.35***	10.04***	1.14	2.42***	1.97***	0.64
Panel	11.43***	12.97***	1.37	2.91***	1.42***	1.32***	-0.34	0.24*
Panel (excl. USA)	11.68***	10.98***	-1.72***	0.34**	1.27***	1.02***	-0.61***	0.15
Post-2001								
Australia	6.82***	4.30***	-2.52***	-4.00***	0.22	0.25	0.13	0.44
Sweden	17.04***	18.29***	-3.76*	1.51	0.13	-0.75	-1.37***	-0.38
USA	-7.15***	12.03***	24.68***	13.05***	0.97	2.37***	2.39**	0.57
Panel	13.59***	13.13***	-1.07*	-0.01	1.42***	1.23***	-0.67***	0.19
Panel (excl. USA)	14.45***	12.53***	-2.37***	-1.70***	1.48***	1.16***	-0.80***	0.12

Table 6

Determinants of the ARM share in a cross-country panel:
Current mortgage rates vs. survey-based expectations of future rates

The table reports estimation results from panel regressions of the form:

$$ARMSHARE_{i,t} = \mu_i + \rho ARMSHARE_{i,t-1} + \beta_1(FRM_{i,t} - ARM_{i,t}) + \beta_2(FRM_{i,t} - \overline{ARM}_{i,t,t+T}) + \beta_3(R^f_{i,t} - R^{f,CF}_{i,t,t+12}) + \nu_{i,t},$$

where μ_i are country-specific fixed effects and $R^{f,CF}_{i,t,t+12}$ is the consensus forecast of the one-year ahead nominal interest rate. The first-stage model specification is given by:

$$\overline{ARM}_{i,t,t+T} = \alpha_i + \gamma_1 ARM_{i,t} + \gamma_2 FRM_{i,t} + \gamma_3 \overline{ARM}_{i,t-K,t} + \gamma_4 B^5_{i,t} + \gamma_5 R^f_{i,t} + \gamma_6 R^{f,CF}_{i,t,t+12} + \varepsilon_{i,t}.$$

We show the results for the case $K = 1$ year. We report bootstrap standard errors in parentheses. Statistical significance is indicated through at most three stars, referring to confidence levels of 10%, 5% and 1% respectively.

	Panel		Panel (excl. USA)	
	$T = 1$	$T = 3$	$T = 1$	$T = 3$
Full sample				
β_1	0.62	1.31***	0.66	1.59***
	(0.42)	(0.27)	(0.44)	(0.30)
β_2	0.83**	0.15	1.07***	0.22
	(0.36)	(0.18)	(0.37)	(0.21)
β_3	0.36	0.56**	0.86**	1.32***
	(0.23)	(0.24)	(0.37)	(0.35)
Post-2001				
β_1	0.18	1.44***	1.23	2.11***
	(0.61)	(0.39)	(0.82)	(0.47)
β_2	1.44***	0.53**	0.85	0.15
	(0.46)	(0.27)	(0.61)	(0.32)
β_3	0.17	0.54	1.21*	1.76***
	(0.40)	(0.39)	(0.73)	(0.61)

Figure 1

Time series of ARM share and FRM-ARM spread at the country level

The figure illustrates the dynamics of the share of adjustable-rate mortgages in percent of the total volume of new loans to households (on the left axis) and the contemporaneous spread between the FRM and ARM rates (on the right axis). For the US, imputed values are used for the ARM rate during the periods November 2008 to March 2009, August 2011 to November 2011 and October 2012 to April 2013. Details of the imputation method are given in the online appendix . Mortgage interest rates correspond to volume-weighted averages of new loans advanced during the respective month, in domestic currency and to domestic households.

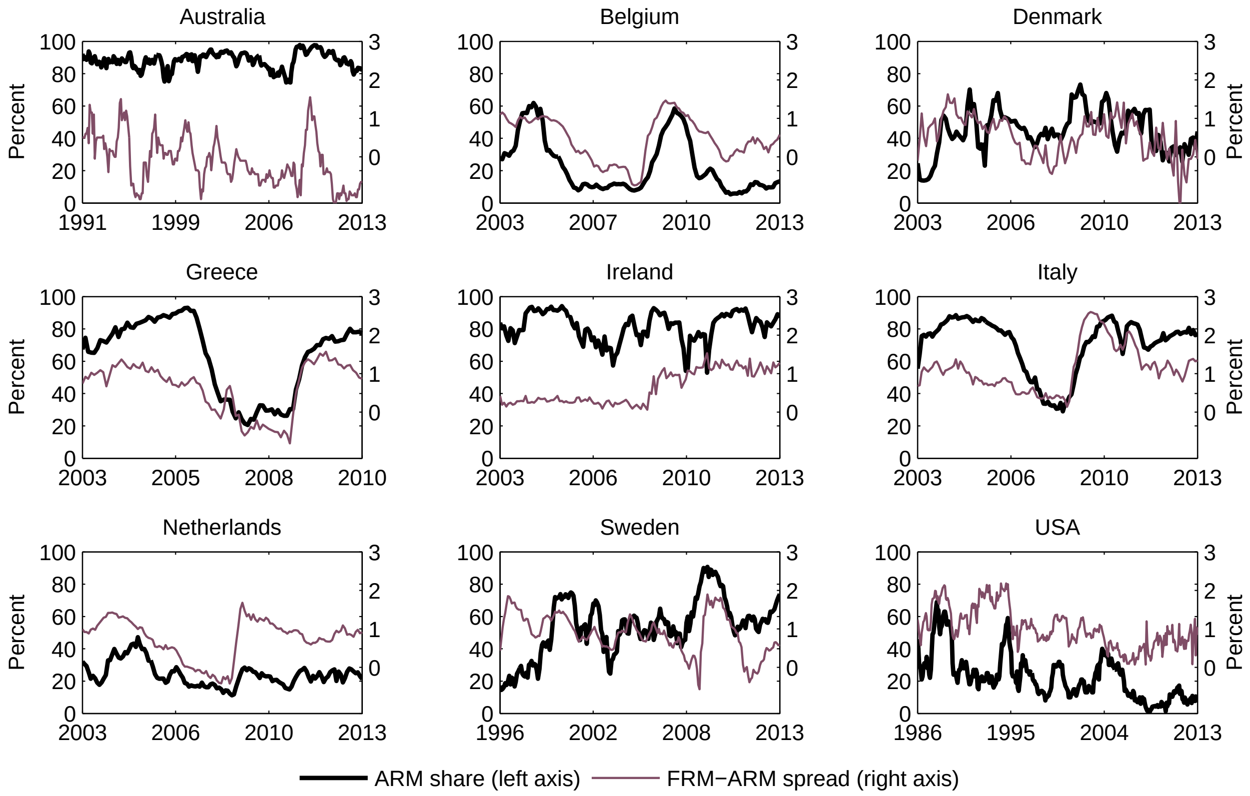

Figure 2

Cross-country patterns in mortgage market structure and historical inflation volatility

Inflation volatility is measured as the realized standard deviation of the monthly year-on-year inflation rate during the entire available sample period. For Australia, Belgium, Germany, Spain and the US, the series starts in 1956, Italy in 1958, Greece in 1960, Finland, the Netherlands, Portugal and Sweden in 1961, Ireland in 1970, Denmark in 1981 and the UK in 1989. Average fixation periods are derived based on the market share of mortgages falling within different fixation period categories. The green dots are distinguishing countries which are not included in the panel analysis. The FRM-ARM spread refers to the difference between the volume-weighted averages of interest rates on fixed-rate (FRM) versus adjustable-rate (ARM) mortgage loans advanced during the respective month.