BANK OF ENGLAND

Staff Working Paper No. 835

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December 2019

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Abstract

This paper examines whether monetary policy pass-through to mortgage rates affects household fertility decisions. Using administrative data on UK mortgages and births, our empirical strategy exploits variation in the timing of when families were eligible for a rate adjustment, coupled with the large reductions in interest rates that occurred during the Great Recession. We estimate that each 1 percentage point drop in the policy rate increased birth rates by 2%. In aggregate, this pass-through of accommodative monetary policy to mortgage rates was sufficiently large to outweigh the headwinds of the Great Recession and prevent a 'baby bust' in the UK, in contrast to the US. Our results provide new evidence on the nature of monetary policy transmission and suggest a new mechanism via which mortgage contract structures can affect aggregate demand and supply.

Key words: Mortgages, monetary policy, birth rates, fertility, natality, interest rates.

JEL classification: E43, E52, J13.

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ISSN 1749-9135 (on-line)

1 Introduction

Economists and policy-makers have long debated the question of how and to what degree monetary policy affects the real economy. The role of household decision-making is a central part of this debate. It has been recognized for some time that one of the most direct ways households are affected by monetary policy is through mortgage interest rates. Indeed, a number of recent papers have documented that when mortgage interest rates and scheduled mortgage payments fall, families increase their spending on durables and other consumer goods (Di Maggio et al., 2017; Flodén et al., 2017; La Cava et al., 2016). But we have a limited understanding of some of the broader effects monetary policy has on the real economy, despite standard economic models suggesting a plethora of household decisions might be affected by a decline in committed expenditures. We start to fill this gap by examining whether monetary policy influences one of the most important decisions a family will make: whether or not to have a baby.

In this paper, we employ administrative data covering the universe of births and mortgage originations in the UK to explore how the dramatic fall in policy interest rates in the Great Recession influenced household fertility decisions. We exploit unique institutional features of the UK mortgage market for identification. At the onset of the Great Recession, around half of UK families of child-bearing age were mortgaged home-owners. Of those, about half had mortgages that were directly tied to the policy rate. The other half had mortgages on an initial fixed-rate period, which would reset to an adjustable rate sometime over the next few years.[1] High pre-payment penalties made early refinance virtually non-existent. Thus, when the Bank of England lowered its policy rate 4.5 percentage points during 2008 and 2009, about a quarter of families' mortgage payments fell immediately, another quarter of families' payments would

[1] As we describe in detail in Section 3, the timing of when the initial fixed periods would reset was determined by both the date of origination and the length of initial period families chose (typical options ranged from two to five years). Mortgages with an adjustable and fixed rate carried roughly similar interest rates at origination, and the particular mortgage contract families chose was largely an artefact of which happened to be marginally cheaper on the day of origination. This price was determined by the slope of the yield curve, not borrower characteristics.

fall at some point over the next couple of years, and the other half of un-mortgaged families would never be affected. For families with an adjustable rate, interest rate pass-through was sizeable and swift, lowering their mortgage payments by over £1,000 a quarter (roughly 42 percent). Our identification strategy exploits these pre-determined, idiosyncratic differences in mortgage contract choice to estimate how the large, unexpected decline in the monetary policy rate in 2008-2009 affected families' fertility decisions over the next three years.

We implement this identification strategy by constructing birth rates at the local authority unit (LAU)-age-group level, dated to the quarter of conception, and merge that with a quarterly measure of simulated "exposure" to monetary policy at the LAU-age-group level.[2] Our exposure measure captures the share of families in a LAU-age-group on an adjustable rate in each quarter, and grows over time as fixed initial periods expire and mortgages reset to an adjustable rate.[3] We interact this quarterly measure of exposure with the cumulative decline in the policy interest rate up to that point, and employ a fixed effects design that controls for level differences in birth rates across groups and over time. Our main coefficient of interest thus describes how declining interest rates affect conception rates as the share of families who have reset to a lower rate increases. In this setting, identification arises from variation in the timing of resets across LAU-age groups.

Our results indicate that a 1 percentage point reduction in the monetary policy rate - which decreased mortgage payments by 12 percent on average - leads to a 5 percent increase in the birth rate among families on an adjustable rate. At the mean adjustable rate share, this is equivalent to a 2 percent increase in the UK birth rate. In aggregate, our estimates imply that accommodative monetary policy in late 2008 and 2009 led to 14,500 additional babies being born in 2009, and increased birth rates by 7.5 percent over the following three years. Heterogeneity analysis on subsamples indicates the effects are larger for groups with higher

[2]Local authority units are similar in size to US counties.

[3]Our measure is simulated because it uses only mortgages that existed as of 2008Q2, and how those contracts evolved over the next three years. We do this primarily so that our measure is explicitly stripped of any endogenous home-buying or refinancing in response to changing rates. We describe this in more detail in Section 4.

loan-to-incomes (LTIs), higher loan-to-values (LTVs) and lower average incomes. This suggests liquidity constraints play a role in explaining the fertility response to mortgage rate changes. Our results are robust to a number of robustness checks on the data construction and empirical specification, and we confirm the implied elasticities we estimate are in line with previous estimates of how changes in current-period liquidity affect fertility choices.

Aggregate birth rates grew in the UK over the period we study, but other countries - notably, the US - experienced a Great Recession "baby bust".[4] Figure 1 shows time trends in quarterly birth rates in the US and UK, with the period in which unemployment grew from its trough to peak highlighted by the grey bar, and the path of monetary policy noted by the dashed black line.[5] In both countries, birth rates begin to fall almost as soon as the unemployment rate begins to rise, but in the UK that trend is reversed once the policy rate (Bank Rate) begins to drop. In the US, the downward trend continues through the recession. We conduct counterfactual simulations based on our estimates and find that in the absence of monetary policy, declining employment and house prices during this time period would have otherwise led to a decline in birth rates in the UK, consistent with previous literature which has demonstrated that fertility is pro-cyclical (e.g., Schaller (2016)). In other words, the fertility stimulus effects of UK monetary policy were sufficiently large to outweigh the headwinds of the recession. We also conduct a simulation based on levels of interest rate exposure, and find that once 30 percent of mortgages have an adjustable rate, the change in birth rates over the recession becomes positive. Though only suggestive, we note that this threshold is well above the US adjustable rate share.[6]

Of course, other factors might confound our interpretation that the drop in rates *caused* a change in UK fertility decisions, particularly since our estimates are set in the context of the Great Recession. To this end, it is crucial that our analysis controls for quarter fixed effects, so that our estimates are net of any changes in economic conditions that affect all

[4]This was widely covered in the media, see, for example, https://www.theatlantic.com/business/archive/2014/09/the-recessions-baby-bust/380909/.

[5]The US series was constructed to be directly comparable to the UK series. More details on the US data can be found in Section 5.3.3. UK and US unemployment rates peaked at 8.4 and 9.5 percent, respectively.

[6]According to the Survey of Consumer Finances, the share of mortgaged families with a fully floating adjustable rate was 6 percent in 2007. Authors' calculations from the US Survey of Consumer Finances.

families, regardless of their mortgage type (or lack thereof). We also control for local house prices and unemployment rates to allow for spatial differences in economic conditions. In some specifications, we further employ two-way interactions between the group and time fixed effects, allowing, for example, different LAUs or age-groups to be on flexible fertility trends. Essentially, our strategy leverages the fact that all families in particular age-group and LAU (e.g., with adjustable rate, fixed rate, or no mortgage at all) are similarly exposed to changing economic conditions, but only families who transition onto an adjustable rate experience a change in their mortgage payment.

Another potential threat to identification is the possibility that pre-determined exposure rates were related to families' future fertility intentions. Survey evidence from the summer of 2008 indicates that just 10 percent of households expected rates to fall at all in the coming year (Bank of England, 2018). Thus, it seems very unlikely that families would have been motivated by any kind of strategic, anticipatory behavior. Still, it could be that couples planning to have children were more likely to choose a particular contract, or move at a particular time, causing a spurious correlation between reset timing and fertility decisions. To allow for this possibility, our analysis includes a host of controls for families' mortgage contract terms, including whether the contract originated with an adjustable or fixed rate and tenure. We also control for a host of characteristics that might be related to group-level fertility intentions, such as home ownership rates, educational attainment, household income and housing LTVs. We also present estimates from an alternate event study-style analysis, which uncovers no evidence of differential fertility pre-trends in the three years prior to monetary easing across groups of families of differing levels of exposure.

An important question that arises from our analysis is whether the effects we estimate represent a shift in the timing of births, or in the number of children ever born to a woman (completed fertility). Given the recentness of the natural experiment we study, we cannot empirically answer this question.[7] However, there is some suggestive evidence in favor of at

[7]We would need to wait for all women who were of child-bearing age during the Great Recession to complete their child-bearing years in order to conduct such an analysis.

least some change in completed fertility. First, survey evidence on interest rate expectations, combined with the ultimate length of the low interest rate environment, suggests the shock we study was perceived to be permanent. Standard models suggest this should lead to a change in completed fertility (Hotz et al., 1997). Second, time series evidence does not reveal a decline in birth rates among older women following the monetary easing period we study, which might be expected if women were bringing forward their child-bearing plans (see Figure 8). Third, there is evidence that decisions that begin as changes in timing ultimately lead to changes in completed fertility (Sommer, 2016). Still, changes in timing that lead to cyclical fluctuations in birth rates can have important effects on the economy. For example, fluctuations in cohort and class sizes have meaningful effects on children's educational attainment, human capital investment and future labor market outcomes (e.g., Angrist and Lavy (1999); Stapleton and Young (1988); Korenman and Neumark (2000)).

Our paper provides new evidence on the nature of monetary policy transmission to the real economy. Children are expensive, so a change in birth rates plausibly has spillover effects on consumer spending. In addition to food, clothing, and other daily necessities, many consumer durables purchases (such as a larger vehicle) are prompted by the addition of a child.[8] Indeed, estimates indicate that the average cost of raising a child during their first year in the UK is almost £11,000.[9] If we make the strong assumption that families previously saved this money, a simple back-of-the-envelope suggests that the additional 14,500 babies implied by our point estimates could have led to up to £130 million in additional spending in 2009 alone. And although this is surely an upper bound, it does not factor in the costs of raising children beyond their first year of life (the total cost of raising a child is around £230,000), nor any additional births that occurred due to the low interest rate environment in the years that followed 2009. On the whole, we view our results as shedding new light on a mechanism underlying previous

[8]Using data from the UK Living Cost and Food Survey, we find that mortgaged families with children under 2 are 4.1 points more likely to have recently purchased a vehicle than similar families without children (see Appendix Table **??**).

[9]Estimate based on the 2014 Center for Business and Economic Research and Liverpool Victoria Cost of a Child Survey (Liverpool Victoria, 2014).

estimates of mortgage rate pass-through to aggregate consumer spending (Di Maggio et al., 2017; Flodén et al., 2017; La Cava et al., 2016). But in contrast to that work, the outcome we study implies not only a short-term change in spending patterns, but also suggests monetary policy can have effects on aggregate demand that last a lifetime.

Our work is related to a growing literature on the importance of contractual rigidities in the mortgage market for monetary policy transmission during economic downturns (Rubio, 2011; Calza et al., 2013; Auclert, 2019; Cumming, 2018). These papers have shown that monetary policy is more effective as an automatic stabilizer in recessions when mortgage contracts have fewer rigidities and rate pass-through is quicker. We provide direct estimates of how one such rigidity - the share of fixed-rate mortgages - affects the demand for children (which, like the demand for consumer goods, falls in recessions).[10] For example, our estimates imply that monetary policy has three times the stimulus effect on birth rates when 75 percent of families have an adjustable rate compared to when 25 percent of families have an adjustable rate. To the extent that birth rates have spill-over effects on consumption, this confirms the notion that a higher prevalence of adjustable-rate mortgages can increase the spending response to expansionary monetary policy (Auclert, 2019; Guren et al., 2018; Rubio, 2011).

Though our paper uncovers a direct effect through the mortgage market, there are many ways that monetary policy indirectly affects birth rates. There is ample evidence that monetary policy affects house prices (Ahearne et al., 2005), which have been shown to positively affect fertility decisions (Dettling and Kearney, 2014; Lovenheim and Mumford, 2013). There is also evidence that lower mortgage rates positively affect home-buying (Bhutta et al., 2017) and household formation (Martins and Villanueva, 2009), which are often viewed as pre-cursors to child-bearing. And accomodative monetary policy increases labor demand and employment (Cumming, 2018), which also positively affects birth rates (Schaller, 2016). By design, our empirical strategy isolates the direct effect through the mortgage market so that our estimates are net of any of these general equilibrium effects. But once we consider all of the ways that

[10] See, for example, Schaller (2016); Dettling and Kearney (2014).

monetary policy might affect birth rates in general equilibrium, it becomes clear that our estimates are likely a lower bound on the total effect of monetary policy on birth rates.

Our results have important implications for monetary policymakers, and speak to a mechanism via which monetary policy can affect the supply side of the economy. Parenthood affects labor supply decisions (Angrist and Evans, 1998), which directly affects measurement of the unemployment rate, and could have knock-on effects for household income and productivity. Changes in birth rates also feed into population growth and dependency ratios, which affect the transmission of monetary policy (Berg et al., 2019). And there is evidence that changes in dependency ratios can alter the natural rate of interest (Lisack et al., 2017; Rachel and Smith, 2017), which suggests the assumed exogeneity of the natural interest rate might need re-examining. Overall, our results highlight several otherwise unexplored ways that monetary policy can influence aggregate demand and supply in the short and medium run.

2 Conceptual Framework

In this short section, we briefly outline how a change in mortgage payments might affect household fertility decisions. Beginning with the seminal work of Becker (1960), economists have modeled fertility behavior within the neoclassical choice-theoretic framework. In the simplest static models, children are treated like durable goods and parents are consumers who choose the quantity of children that maximizes lifetime utility subject to the price of children and their budget constraint. In this framework, a reduction in a family's scheduled mortgage payments can be thought of as either: (1) a reduction in committed expenditures which increases disposable income; or, if families view housing as an input in child-rearing, (2) a reduction in the price of child-rearing. In either case, theory predicts that reducing scheduled mortgage payments will increase the demand for children, increasing the number of children born.[11] Con-

[11] Becker and Lewis (1973) proposed that parents have preferences for both the quantity and quality of their children, and face a trade-off between the two. Thus, any increase in the demand for children might plausibly lead to an increase in the number of children, or in investment per child. Our paper will ignore the latter channel and focus on whether the *quantity* of children responds to changes in mortgage interest rates. Though

sistent with the predictions of these models, there is growing empirical evidence using credible, quasi-experimental methods that changes in income and prices have tangible effects on current-period fertility (see, for example, Black et al. (2013); Kearney and Wilson (2018); Autor et al. (2018) on income effects and Milligan (2005); Cohen et al. (2013) on price effects).

In dynamic, life-cycle models of fertility, families not only choose their desired family size, but also time their child-bearing throughout their life-course (see Hotz, Klerman and Willis (1997) for a review). In these models, transitory changes in prices over the life-cycle can affect the optimal timing of child-bearing without affecting the total number of children that will be born to a woman. If capital markets are imperfect, and families cannot borrow or save, transitory changes in income also affect the timing of child-bearing. Thus, whether a change in income or prices affects completed fertility (a so-called *quantum* effect) or the timing of fertility (a so-called *tempo* effect) depends on whether the shock is viewed to be permanent or transitory, as well as the extent to which families are liquidity or borrowing constrained.[12]

Interest rates are generally understood to be cyclical, thus, we might model a change in mortgage payments due to interest rates as a transitory shock. Still, what matters in these models is what households *believe* about the nature of the shock. To that end, it is useful to examine survey evidence on interest rate expectations to better gauge families' beliefs. In the summer of 2009, 70 percent of households expected rates to either stay the same or rise only a little.[13] This suggests most families perceived the changes to their mortgage payments to be at least somewhat permanent. And this expectation of permanence proved to be fairly accurate: rates have remained low for the 10 years since 2009, ultimately encompassing a large portion of many women's child-bearing years. These patterns would suggest the change in mortgage

we do not study this in our paper, it is clear that parents might also adjust the *quality* of their children in response to a change in mortgage interest rates, for example, by investing more in their children's education. We leave the investigation of such a possibility to future work.

[12]In these models, monetary policy can affect the optimal timing of child-bearing by affecting intertemporal allocation via the real rate of interest. We will ignore that dimension of monetary policy in our analysis for two reasons. First, because the variation in the real rate in the Great Recession was substantially less than the nominal rate, and second, because changes in the real rate would affect all families and not just mortgage-holders. Our empirical strategy will abstract away from those effects by design.

[13]Source is the *Inflation Attitudes Survey*, which is available at https://www.bankofengland.co.uk/statistics/research-datasets

payments we observe may have been perceived as closer to a permanent shock.

Before moving on, we note that for exposition we will discuss fertility choice in our paper as though it is a simple decision. Of course, in reality it is a complex decision with a stochastic outcome, and families' child-bearing goals will not always be exactly realized. Thus, any monetary policy pass-through to birth rates that we observe is likely to be a muted reflection of a family's latent fertility preferences.

3 Background on UK Mortgage Market

Prior to the onset of the Great Recession, the vast majority of UK mortgages featured a short initial period with either an adjustable rate or fixed rate. The interest rate on the former was tied one-for-one to Bank Rate, while the interest rate on the latter was typically fixed for 2-5 years. Only 3 percent of families obtained initial fixed-rate periods of 10 years or more.[14] Following the end of the initial fixed or adjustable period, all UK mortgages revert to the Standard Variable Rate (SVR), which is an adjustable rate. Henceforth, we will refer to all mortgages on an adjustable rate (either initial period or having reset to the SVR) as an ARM.[15]

All UK mortgages carried high pre-payment penalties during the initial period. Typically, these fees ranged between 2 and 5 percent of the loan balance outstanding (where the fees increased with time left in the initial period). Thus, it was rarely beneficial to refinance into a new mortgage rate before the end of the initial period (even if rates fell substantially).[16] After the end of the initial period when the mortgage reverted to the SVR, these fees were lifted. And because the SVR was typically several hundred basis points above prevailing refinancing offer rates (see Figure 2), the majority of mortgagors found it beneficial to refinance their contracts

[14] Authors' calculations based on the data used in this paper.

[15] Conceptually, UK mortgage contracts are similar to the short-run hybrid mortgage product in the US that is commonly referred to as an adjustable rate mortgage. As is the case in the US, UK mortgages typically feature a 20 or 30 year term. However, in contrast to the US, virtually no UK mortgages will include a fixed rate for the entire 20 or 30 year term. Thus, the most common mortgage product in the US -the 30 year fixed rate mortgage- is virtually non-existent in the UK.

[16] This contrasts with most fixed rate mortgages in the US, where it is possible to pre-pay (and thus, refinance) during the fixed rate period without penalty.

upon reset when they reverted to the SVR. As a result, most mortgagers in the UK refinanced into a new mortgage precisely at the time each initial period expired (Cloyne et al., 2019). In practice, this implies that most families with a mortgage had obtained that mortgage in the past two to three years, and tenure in the mortgage was often disconnected from the year of home purchase.

Because of these short initial periods and the stable economic environment in the early 2000s, the choice between an adjustable or fixed initial period was viewed to have little effect on the lifetime cost of the loan. Many families switched between an fixed and adjustable contracts over time as they refinanced: between 2005 and 2008, around 40 percent of households chose the opposite contract when they refinanced, providing *prima facie* evidence that contract choice was largely unrelated to fixed family preferences. Rather, Cumming (2018) shows that relative prices at the time the borrower happened to originate or be eligible to refinance a mortgage are highly predictive of product choice. These price differences were induced by the slope of the yield curve, rather than individual borrower characteristics, and varied over time (see Figure 2).

Between October 2008 and March 2009, Figure 2 shows that Bank Rate fell from 5 percent to 0.5 percent. Families with an ARM at this time experienced a substantial, unexpected decline in their monthly mortgage payment. Table 1 displays information on the distribution of the change in quarterly ARM payments in our data.[17] The average family with an ARM experienced a decline in quarterly payments of £1130, representing 42 percent of their initial mortgage payment, or 7.5 percent of their gross income. There is also considerable variation in the data in the size of payment decline, ranging from £447 at the 25th percentile to £1228 at the 75th percentile. Across age-groups, older families experienced the largest average drop in terms of pounds sterling (£1208), and families aged 16-24 experienced the largest drop relative to their initial income (8.5 percent).

[17]Note that families who were on initial adjustable period saw their rate fall one-for-one with Bank Rate. Families on the SVR (having reset from either an adjustable or fixed rate) experienced a smaller decline in their rate. Table 1 displays the average payment drop pooling both types of families. Families on adjustable initial periods are 33 percent of the sample.

For families with fixed initial periods, high pre-payment fees (combined with falling house prices and tight credit conditions) meant that it was cost-prohibitive (or impossible) to refinance into a lower rate. Rather, those families had to wait for their fixed term to expire before they would automatically reset to the SVR. For some families, this was a couple of days, but for others it was up to 5 years. The timing of the reset depended on a combination of when they had last refinanced (or originated) their current mortgage and the fixed term length they had chosen. Consider, for example, two families who refinanced into a fixed rate mortgage in October 2006, where the first chose a 2 year initial period and the second chose a 3 year initial period. The thought experiment motivating our empirical approach is to compare how the 4.5 percentage point decline in Bank Rate affected the first family (whose fixed term ended in October 2008), with the second family (whose fixed term would not end until October 2009). Although both families opted for a fixed rate in October 2006, the first family received a large reduction in their monthly mortgage payment between October 2008 and March 2009, while the other family did not. And a family who had chosen an adjustable initial period in October 2006 would have received a large payment reduction even sooner, beginning in September 2008. This sort of pre-determined, idiosyncratic variation in mortgage contract terms is the natural experiment we exploit in this paper.

4 Data and Empirical Approach

4.1 Data

We obtained birth data from the Office for National Statistics (ONS). These data are based on *UK Vital Statistics* and represent a count of virtually all births in England and Wales.[18] We refer to our analysis as covering the United Kingdom for exposition only. The data includes the exact date of birth and conception and the mother and father's (when present) age and location of residence. The data do not include information on home ownership or mortgage characteristics,

[18]The data do not include Scotland and Northern Ireland so we will not examine those areas in our analysis.

so in order to match to the relevant independent variables of interest we aggregate births by LAU, age-group and quarter of conception. We use the date of conception since that is the time period in which a family is making the decision to get pregnant, and thus, the economic conditions at that time would be the most relevant in the decision-making process.

We construct quarterly conception rates at the LAU age-group and quarter level by matching the aggregated cell-level births to annual female population counts, also obtained from the ONS. The age-groups we use are 16-24, 25-35, and 35-44 because those are the groups available across all of our datasets. The time period we study are the three years (12 quarters) from the third quarter of 2008 through the second quarter of 2011. We begin in the third quarter of 2008 because it is just before the 4.5 percentage point drop in the policy rate occurred. We end our analysis in 2011 because by that point more than 80 percent of the fixed terms originated before the third quarter of 2008 had already expired, which means we no longer have a clean source of identification as families would have been able to choose a new mortgage. Figure 3 provides more details on the timeline of policy, our data and our analysis.

The mortgage data is derived from administrative data on the universe of new and refinanced mortgages issued by UK lenders from 2005 through 2009, which is collected by the Financial Conduct Authority and distributed in the Product Sales Database (PSD). Because households in the UK rarely obtain fixed rate terms longer than five years and there is an active refinancing market, we estimate that by June 2008 this count of originations represents at least 80 percent of the stock of all mortgages outstanding at that time.[19] The mortgage data includes information on the home's location (local authority), purchase price, loan value, initial period length, term, whether there is a fixed or adjustable rate, whether the mortgage was a purchase or refinance, whether the purchase was a first home purchase, and the borrowers' gross annual income and

[19]There are no good estimates for the UK of the stock of all mortgages during this time period. However, data from 2015 on the stock suggest an estimate of 80-85 percent. Since there are almost no long term fixed contracts issued in the UK, the missing mortgages would be all be on the SVR. So unless these missing mortgages are unevenly distributed across the UK, it should have little impact on the relative proportions on an adjustable rate. In the robustness checks in section 5, we implement a procedure to impute missing mortgages where we age backwards the stock from 2015 that we do not observe refinancing from 2005-2015, as in Cumming (2018).

age.[20] We describe this data in more detail in the Appendix.

To measure mortgage interest rate exposure we *simulate* the share of families on an adjustable rate at the LAU by age-group by quarter level. We use a simulated measure because home-buying or refinancing decisions during the period in which interest rates were falling could be endogenous to fertility choice. Therefore, we construct our measure of exposure using baseline characteristics of mortgages that existed as of June 2008. In particular, we use information on the origination date and initial period length to estimate the expiration date of the mortgages that had fixed terms. We use this to construct the share of *mortgagers* on an adjustable rate in each LAU, age-group and quarter (which we define as simply 1 minus the imputed share still on a fixed rate).

Because the mortgage data does not include information on those without a mortgage and we are interested in the exposure rate among all households in a LAU-age group, we supplement the mortgage data with data on home ownership rates. In particular, we interact the *mortgager* adjustable-rate share with LAU-age group home ownership rates, which we obtained from the 2001 UK Census.[21] To be precise, we estimate Equation 1 for each local authority l, age-group a and quarter t:

$$exposure_{l,a,t} = (1 - \frac{fixedrate_{l,a,t}}{mortgagers_{l,a,t}}) \times (\frac{owners_{l,a,2001}}{households_{l,a,2001}}) \quad (1)$$

In practice, there is considerable variation in this simulated measure of exposure across local authorities and over time within the UK. Figure 4 shows this geographic dispersion in ARM shares across England and Wales as of June 2008. ARM shares ranged from 15 percent to 43 percent across LAUs, and there are areas of relatively high and low ARM shares throughout the

[20] The mortgage data has information on the "lead borrowers" age, but not sex. In our main specification we assume that is the mother's age and match accordingly, but in robustness checks we will instead assume that is the father's age, when it is available.

[21] We use 2001 data because it is the most recent year available, but even if we had contemporaneous data we might prefer at least some lag since recent home-buying could be endogenous to fertility intentions. Our measure will ignore families who are outright owners, however, this is a very small share of owners in the age-groups we study. For example, the UK housing Survey shows that in 2009 outright owners were 1.1 percent of 16-24 year olds, 2.7 percent of 25-34 year olds and 7.5 percent of 35-44 year olds. See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/6695/1750765.pdf.

country, even, for example, within London. There is also considerable variation in ARM shares over time (top panel, Table 2): on average 21 percent of households were on an adjustable rate in the third quarter of 2008 (with a standard deviation of 8.7 percent across LAUs), and this increases to 34 percent a year later (with a standard deviation of 12.5 percent across LAUs) and 43 percent by 2010 (with a standard deviation of 14.9).

4.2 Empirical Specification

Our main analysis will consist of a series of ordinary least squares regression models of the following form:

$$\begin{aligned}\ln(birthrate_{l,a,t+3}) = \beta_1 exposure_{l,a,t} \times \Delta bankrate_{2008Q2,t} \\ + \beta_2 \mathbf{E}_{l,t} + \beta_3 \mathbf{X}_{l,a} + \gamma_a + \alpha_l + \theta_t + \epsilon_{l,a,t} \end{aligned} \quad (2)$$

Where the level of analysis is the local authority (l) age-group (a) quarter (t) cell. In these specifications we match all relevant time-varying independent variables of interest to the quarter of conception (notated here for exposition as three quarters after the measurement of economic variables, although we use the actual date of conception in our data construction). Note that LAUs in which any cell has fewer than ten observations in any of our datasets are dropped. Because there are 12 quarters of data, three age groups, and 343 local authorities, our analysis sample will have up to 12,348 observations. All regressions are weighted by the total number of births in each cell, and standard errors are adjusted for clustering at the LAU level.

The coefficient of interest β_1 captures the interaction between $exposure_{lat}$ and $\Delta bankrate_{2008Q2,t}$, which describes how an increase in the share of households on an adjustable rate affects the relationship between the cumulative decline in Bank Rate since the second quarter of 2008 and the log of birth rates three quarters later.[22] In other words, β_1 captures the extent of monetary policy-pass through, since the interaction between $exposure_{lat}$ and $\Delta bankrate_{2008Q2,t}$ will be

[22]The cumulative decline in Bank Rate is defined as the average decline over the quarter, where the average is based on the daily value of Bank Rate.

larger when there are larger changes in Bank Rate and more families are exposed to those changes. If monetary policy pass-through affects birth rates, we would expect β_1 to be positive.

The vectors γ_a, α_l, θ_t represent a full set of age-group, quarter and local-authority fixed effects to account for fixed differences across local authorities, time and age-groups in birth rates and mortgage rate exposure. Because $\Delta bankrate_{2008Q2,t}$ only varies over time, θ_t nets out any differences in birth rates induced by monetary policy that affect families who do not have an ARM. Similarly, α_l nets out any time-invariant differences across local authorities in preferences for children which might be correlated with $exposure_{lat}$. So, if families in Manchester have more children on average than families in London, and also are more likely to have an ARM, α_l captures those differences.

The vector $\mathbf{X}_{la}$ represents a vector of age-group by local authority controls. Importantly, this includes characteristics of the mortgage contracts chosen by families in each age-group and local authority. This includes the home ownership rate and the share of families who initially chose an ARM for their current mortgage contract. We include these variables to facilitate a casual interpretation of β_1, in case groups with different fertility preferences might have different propensities to choose an ARM or own a home. We also control for the number of years since the mortgage was originated (in year-groups), the number of years before the loan will be paid off (in year-groups), whether the mortgage was used for a refinance or a purchase, and if it was a purchase, whether the buyer was a first time home owner. We include these variables to allow for the possibility that families with fertility intentions may have different rates of exposure because of different lengths of tenure in their homes. All of the mortgage variables are measured in the June 2008, just like $exposure_{lat}$.

The vector $\mathbf{X}_{la}$ also includes age-group by local authority measures of educational attainment, income, and wealth. Educational attainment is measured as the share of women in each group who have a higher-education qualification and is obtained from the 2001 Census. To capture incomes, we use the 5th, 25th, 50th, and 75th percentile of gross annual incomes, which we collect from the mortgage data. We include the bottom of the distribution to better capture

non-owners.[23] We also control for differences in wealth and leverage using loan-to-values and loan-to-incomes at origination, which are discretized into 10 and 6 categories (plus non-owners), respectively.

Our analysis also includes a number of time-varying characteristics of local authorities which the previous literature has shown have an impact on fertility choice. In particular, the vector $\mathbf{E}_{lt}$ includes controls for the quarterly unemployment rate at the local authority level and home prices, both obtained from the ONS.[24] Since owners and non-owners will react differently to changes in house prices, we also interact house prices with the aforementioned LAU-age group home ownership rate.

Tables 2 and 3 provide descriptive statistics of the data we use in our analysis. On average, there about 21 births per 1,000 women in each LAU-age-group quarter; across age-groups, the means range from 9.7 for 35-44 year olds to 28 for 25-34 year olds. 53 percent of women in each LAU-age-group are home owners and 36.2 percent of were on an adjustable rate during our analysis period. Across age-groups, adjustable rates shares range from 17 percent of 16-24 year olds to 49 percent for 35-44 year olds, which mostly reflects the fact the ownership rates increase as women get older. Median gross annual income for mortgagers at origination was £27,850. Most families had mortgage LTVs at origination above 85 percent. About 18 percent of families are in the first year of their mortgage, another 20 percent in the second, 13 percent in the third, and under 2 percent in the third or later year. 14 percent of families chose an ARM at origination, 22 percent of families had a refinanced mortgage and 31 percent had a purchase mortgage. House prices during this time averaged £180,460 and the unemployment rate averaged 7.9 percent.

Our main identification assumption is that group-level exposure interacted with changes in the monetary policy rate is conditionally exogenous to birth rates. Violations to this assumption would arise if there are omitted variables that coincide with the path of monetary policy and

[23] Incomes are calculated per capita by dividing by 2 when there is a joint mortgage. We convert gross incomes into 2008Q2 .

[24] The unemployment rate we use are the model-based estimates of unemployment based on the Annual Population Survey. The house price index we use is the UK HPI. Both were obtained from the ONS.

differentially affect the demand for children among groups with higher exposure rates. We probe the sensitivity of our results to this assumption by conducting a number of alternative specifications, such as replacing $\mathbf{X}_{la}$ with LAU-by-Age-group fixed effects and $\mathbf{E}_{lt}$ with LAU-by-quarter fixed effects. We also present results from an event study analysis which does not uncover any evidence of a difference in pre-period birth rate trends by exposure level.

A final threat to identification is possibility of reverse causality, wherein families who wish to have children manipulate their own exposure in anticipation of monetary policy. Recall that we construct our measure of $exposure_{lat}$ at the baseline to remove the possibility of endogenous home-buying or refinancing, and that we control for initial adjustable or fixed rate choice, home-ownership rates, and housing and mortgage tenure. Thus, the story of reverse causality is one in which families anticipate policy several years in advance and time the expiration of their fixed terms accordingly. Given that survey evidence suggests that less than 10 percent of families expected rates to fall in the months preceding the Great Recession, widespread behavior of this nature appears implausible.

5 Results

5.1 Main Results

Table 4 presents the results of estimating Equation 2.[25] Column 1 is the main specification. The coefficient of interest, β_1 which is the interaction between $exposure_{lat}$ and $\Delta bankrate_{2008Q2,t}$ displays a point estimate of 0.0513, which is statistically significant at the 0.1 percent level. This implies that for family-groups with a 100 percent exposure rate (henceforth, families on an adjustable rate), a 1 percentage point decline in Bank Rate increases birth rates by 5 percent.[26] At the mean exposure rate for the UK, this is equivalent to a 2 percent increase in birth rates.

[25] Coefficients on the control variables in the model are displayed in appendix table A1.

[26] Note that a 100 percent exposure rate is out of sample. Still, it is instructive to think about what this implies at the individual-level for families on an adjustable rate. This suggests that a 1 percentage point drop in the policy rate would increase the probability of conceiving a baby by 5 percent, or 0.1 percentage points at the mean birth rate of 2 percent.

Or, put differently, moving from a group in which 25 percent of families are on an adjustable rate to a group where 75 percent of families are on an adjustable rate increases the responsiveness of the birth rate to Bank Rate by 300 percent.

The next two columns of Table 4 tests the robustness of those results to more flexible specifications of $\mathbf{X}_{la}$ and $\mathbf{E}_{lt}$. Column 2 of Table 4 adds LAU by age-group fixed effects to Equation 1. This allows for the possibility that there is some omitted variable that is correlated with differences across groups in exposure rates and birth rates. For example, if older families in Manchester had higher exposure rates than younger families in London, and older families in Manchester had higher latent fertility rates than younger families in London for reasons not captured by $\mathbf{X}_{la}$, this specification would allow for that possibility. Column 2 shows the point estimates are little changed.[27]

Column 3 adds LAU by quarter fixed effects to Equation 2. These specification allows for the possibility that different LAUs might have been on different fertility trends over the quarters we study. In other words, this allows for the possibility of omitted variable bias arising from changes in some aspects of the local economy that are correlated with the path of monetary policy and fertility trends. However, column 3 show our point estimates are little changed when we include these controls.

Finally, column 4 restricts the time period over which we estimate equation 2 to the six quarters from 2008Q3 to 2009Q4. As shown in Figure 4, all of the changes to Bank Rate occured between October 2008 and March 2009, at which point rates remained fixed at 0.5 percent. One motivation of our study is to identify how the initial monetary easing period affected birth rates in the short term. The specification in column 4 addresses that question. The coefficient on β_1 is slightly attenuated from the estimate derived from the larger time frame in column 1, but remains statistically significant at the 0.1 percent level. At the mean exposure

[27] Another possibility is owners and renters are differentially affected by monetary policy and our measure of exposure is capturing that effect. To allow for this, we ran a specification where we included an interaction term between $bankrate_{2008Q2,t}$ and the LAU-age-group home ownership rate in addition all of the variables in equation 2. The coefficient on this term was small and insignificant, and the coefficient on our main point estimate was virtually unchanged. Results available upon request.

rate for that time period, the estimate in column 4 implies that the 4.5 percentage point drop in the policy rate led to a 6.8 percent increase in the birth rate.

The effects we estimate are comparable to effects estimated in the literature on the effects of changes in income or prices on fertility. Our results imply that among families with an adjustable rate mortgage, a one percentage point decline in mortgage interest rates (which increases birth rates by 5 percent) reduces their mortgage payments £258 per quarter on average, equivalent to 1.7 percent their household income (see Table 1). For comparison, Milligan (2005) finds that a £900 (inflated to today's dollars, and at the current CAD-GBP exchange rate) child tax incentive leads to a 17 percent increase in birth rates, and Cohen et al. (2013) find that a 2 percent decline in income from a child tax benefit decreases the birth rate 10 percent. Kearney and Wilson (2018) find that a 3.8 percent increase in earnings associated with fracking in the U.S. increased the birth rate by 6 percent and Black et al. (2013) find that a 10 percent increase in income associated with Appalachian coal mining earnings due to changes in world energy prices led to a 7 percent increase in birth rates.

In Section 2, we noted that whether a transitory shock will affect the timing of fertility depends on the extent to which families are able to borrow or save. Thus, we would expect the effects we estimate to vary depending on the extent to which families are liquidity constrained. In our data, we can proxy for liquidity constraints in a couple of ways, such as using income, loan-to-incomes (LTIs), and LTVs, since families who have lower incomes, or are more highly leveraged, are typically less able to borrow and save. Table 5 displays the results of splitting our sample according whether a group has above or below median income, LTIs or LTVs. The results of Table 5 indicate that indeed, families who are lower income, or had higher LTIs or LTVs are more responsive to a change in monetary policy. For example, columns 3 and 4 indicates that a 1 percentage point drop in Bank Rate leads to a 5 percent increase in births for families on an adjustable rate in the high LTI group, compared to a 2.7 percent increase for families in the low LTI group. Overall, this suggests liquidity constraints play an important role in explaining why families' fertilty decisions are sensitive to changes in mortgage rates.

5.2 Robustness Checks

We conduct a number of robustness checks on the sample construction and empirical specification, displayed in Table 6. The mortgage data includes information on the "lead borrower's" age but not their sex. In our main specification we simply assume that is the mother's age. But in practice it is likely to often be the father's age if men are often listed as the lead borrower. Thus, column 1 presents the results where we match the mortgage information by the father's age. In our data, around 94 percent of birth certificates list the father's age, so this procedure should yield accurate results. The point estimates are slightly larger than the original point estimate, which could reflect attenuation bias in our original measure although it is well within the confidence interval of the original estimate.

Column 2-3 presents estimates in which we conduct some alternative imputations of missing information in the mortgage data, described in more detail in the Appendix. In column 2 we present estimates where we impute the number of age-group by LAU mortgages that are missing because they did not transact (either purchase or refinance) between 2005 and 2008. Recall these mortgages would virtually all be on an adjustable rate because their fixed periods (if present) would have mostly expired. We do this by isolating mortgages originated prior to 2005 from information on the stock of mortgages, which is available beginning in 2015. In this case, the point estimate is slightly smaller, but again well within the confidence interval of our original estimate.

Column 3 present results where we vary how we impute information on the length of the initial period when that information is missing. As discussed in the appendix, in the main results we use a model to impute this information when it was not reported by the lender. In column 3 we instead simply drop all mortgages with missing initial periods and use a subsample of mortgages with known initial periods to calculate quarterly ARM shares.[28] Columns

[28] As described in the appendix, omission of this information appears to lender-specific. The demographic characteristics of borrowers who used these lenders are very similar to those who did not, and the geographic distribution of those lenders is very similar to others. Thus, the subsample of borrowers without terms appears to be similar to what might be achieved from a random sample.

3 shows the results are robust to these changes. Finally, columns 4-5 present results estimating the model in levels and unweighted. Again, the results are not sensitive to these changes in the specification.

5.3 Event Study Design

The identification assumption underlying our empirical strategy is that in the absence of monetary policy, family-groups of varying levels of exposure would not have had different birth rates. To comprehensively examine pre-trends as well as dynamics over estimation period, we can estimate an alternative event-study style version of our estimating equation. To do so, we focus on exposure rates as of 2008Q2 (just prior to the beginning of our sample) and estimate the following regression for the time period 2005Q1 through 2011Q4:

$$\begin{aligned} birthrate_{l,a,t+3} = \beta_{\mathbf{t}} exposure_{l,a,2008Q2} \times \theta_t \\ + \beta_2 \mathbf{E}_{l,t} + \beta_3 \mathbf{X}_{l,a} + \gamma_a + \alpha_l + \theta_t + \epsilon_{l,a,t} \end{aligned} \tag{3}$$

where the left-out category of θ_t is 2008Q2. In this specification, $\mathbf{X}_{l,a}$ includes $exposure_{l,a,2008Q2}$. Figure 5 plots the coefficients on β_1 and 99 percent confidence intervals, where the coefficients can be interpreted as the conditional difference in trends in birth rates for LAU-age-groups with 100 percent exposure, relative to LAU-age-groups with no exposure.[29] The coefficients on the pre-trends for 2005Q1 through 2008Q1 indicate that prior to the onset of monetary easing, there was essentially no difference in birth rate trends across exposure rates, and only 2 of the 12 coefficients are statistically different from zero. After monetary easing begins, however, there is a strong divergence in trends by exposure from the end of 2008 through to the end of 2013. This gap grows throughout the time period examined, presumably due to the fact that actual exposure rates are increasing (recall this measure is frozen in time, and actual exposure can only increase from there). The gap between groups with 100 percent and zero percent exposure

[29] We estimated this model in levels because it is easier to interpret the magnitude of the coefficients. For comparison, our main specification in levels is in column 5 of Table 5.

(as of 2008) grows from essentially zero in 2005-2008 to 15 additional births per 1000 women by 2011.[30] Overall, Figure 5 provides no evidence that we can reject parallel trends by exposure rate in the three years leading up to monetary easing.

5.4 Extensions and Policy Implications

5.4.1 Would the UK have experienced a Great Recession "Baby Bust" without Mortgage Interest Rate Pass-through?

Our results indicate that monetary policy increased the birth rate in the UK, but what might have occurred in the absence of monetary policy? There is a long literature examining how birth rates evolve over business cycles, which has tended to find that birth rates fall in recessions and rise during expansions. But as evidenced by Table 2, birth rates in the UK *rose* over the recessionary period we study. Although they are not our variables of interest in our main analysis, we control for unemployment and house prices. Thus, we can conduct a similar exercise to the recent empirical US literature which examines cross-sectional variation over time to study the cyclicality of fertility (e.g., Dehejia and Lleras-Muney (2004); Dettling and Kearney (2014); Schaller (2016); Buckles et al. (2018)). To our knowledge, ours is the first study to do so for birth rates over the Great Recession in the UK.

Column 1 of Table 7 estimates a modified version of Equation 2, where we omit the monetary policy and mortgage variables and estimate how local economic conditions correlate with birth rates in UK over the time period of our analysis. This specification is very close to Dettling and Kearney (2014). Column 1 of Table 6 displays the results of this analysis. The coefficients on economic conditions confirm the effects for the US housing boom period hold in the UK: local house price gains increase birth rates for owners and decrease birth rates for renters, and there is a negative but statistically insignificant effect of local unemployment rates on birth rates.[31]

[30] Of course, 100 percent exposure is out of sample as no group in our data has 100 percent exposure. At the mean exposure rate, the magnitude is 3.6 births per 1000 women.

[31] The estimates indicate that a £10,000 decrease in house prices leads to 15 percent decrease in births for owners, and a 7 percent increase for non-owners. At the USD-GBP exchange rate at that time, (Dettling and Kearney, 2014) find that a £10,000 increase in house prices lead to a 7.5 percent increase in births among

The second column of Table 7 adds the control variables available in our mortgage to the specification. To our knowledge, ours is the first paper to include as extensive a set of controls as we use here in an examination of the cyclicality of fertility. Of particular note are the controls for housing tenure and leverage, which might bias previous estimates of the effects of economic conditions on birth rates if families who have been in their home longer or are more leveraged are more responsive to changes in house prices or unemployment. Still, column 2 confirms a sizable and statistically significant effect of house prices, though the effects on both owners and non-owners are attenuated from column 1. As before, unemployment rates do not enter significantly.

There were large national changes in economic conditions during the period we study, which may swamp local changes, particularly relative to studies of larger and more heterogeneous countries like the US. Thus, the coefficients on θ_t, which can be interpreted as the national change in birth rates (where the left out category is the third quarter of 2008), may be a better test of whether fertility is cyclical with national economic conditions. Columns 1 and 2, however, confirm that birth rates increased during the recession. The point estimates indicate birth rates were a statistically significant 2-6 percent higher in late 2008 through mid 2011 than in 2008Q3. Thus, without controlling for monetary policy, birth rates were strongly *counter-cyclical* at the national level over this time period of deteriorating economic conditions.

Finally, in column 3 of Table 7 we add in our coefficient of interest on the effects of monetary policy. The coefficients on local house prices are essentially unchanged by the inclusion of the monetary policy exposure measure, indicating those variables have independent effects on birth rates. However, unlike column 1, the coefficients on θ_t have reversed sign and are now negative, and statistically significant from late 2008 through mid 2011. In other words, controlling for the positive monetary policy effect on birth rates, the prevailing national trend during this period is that fertility rates would have been *pro-cyclical*.

Next, we conduct a counterfactual analysis that investigates this notion more formally. In

owners and a 3.6 percent decline among renters. We have also examined a longer time series of data spanning 2005-2013 in the UK and found similar results, which are available upon request.

particular, we use the parameters from column 1 of Table 4 and quarterly means of all of our variables to predict the path of birth rates if monetary policy was unchanged. The solid line of Figure 6 indicates that birth rates are considerably lower in the counterfactual throughout the sample period and indeed appear to fall during the Great Recession period.[32] In sum, this analysis appear to confirms the previous literature on pro-cyclical fertility, and suggests a Great Recession "baby bust" in the UK in the absence of monetary policy.

5.4.2 Mortgage Contract Flexibility and Monetary Policy Transmission to Birth Rates

Across developed countries, there is considerable variation in mortgage contracts, with countries like the US, Germany, and France tending to have more fixed rate mortgages (FRMs) and countries like the UK, Australia, and Spain tending to have more ARMs. As we have discussed, our point estimates imply that the reason monetary policy has a positive stimulus effect on fertility is that a relatively large share of UK borrowers have ARMs. In this section, we use our model to consider how birth rates might have evolved if the share of borrowers with ARMs was lower (or higher) prior to monetary easing. To implement this, we distribute alternative baseline mean ARM shares across groups and over time using the distributions we view in our data, restricting the ARM share to be between 0 and 100 percent and the mean ARM share to line up with our alternative scenario.[33]

Figure 7 displays the results of this exercise. The vertical axis displays the change in the birth rate between the third quarter of 2008 and the third quarter of 2009 (we chose the same quarter of the year since birth rates display seasonality), and the horizontal access displays

[32] Of course, monetary policy also has an effect on economic conditions, and a more realistic simulation of the overall path of birth rates in the absence of monetary policy might be one in which we also factor in the general equilibrium effects of policy on house prices and unemployment. Because national changes in house prices and unemployment are absorbed in the θ_t terms, it is not obvious how we would implement this exercise. One option might be to adjust the path of local house prices and unemployment rates only. In the Appendix we present the results of this exercise where we adjust each using the Bank of England's forecasting model (as in (Pugh et al., 2018)) as inputs in our model. We distribute these across LAUs using the observed distribution of changes in house prices and unemployment rates. This does little to impact the time trend.

[33] We also adjust the initial contract choice to in a similar fashion.

the hypothetical share of mortgages which are ARMs as of the third quarter 2008 (holding the home ownership rate constant). The dashed line presents 95 percent bootstrapped confidence intervals. We can see that an increase in the ARM share is associated with an increase in the birth rate. Once about 25 percent of mortgages are ARMs, the change in the birth rate becomes positive. Once around 70 percent of mortgagers have ARMs, the birth rate rises nearly 5 percent.[34]

5.4.3 Comparing UK and US Birth Rates over the Great Recession

The transmission of monetary policy is very different in the US and UK. In the US, more than 80 percent of mortgages are fixed rate mortgages (FRMs) with fixed terms of over 10 years, and the most popular mortgage is the 30 year FRM. In 2007, the share of mortgages with a fully floating rate was under 6 percent.[35] There are limited pre-payment penalties, however, and the primary transmission mechanisms is voluntary refinance. In contrast, fewer than 5 percent of mortgages in the UK feature fixed terms longer than 10 years and refinance prior to the end of a fixed term is very costly, so the primary transmission mechanism is through ARMs.[36] We can use these differences as an illustrative example of how differences in the transmission mechanism can affect birth rate trends across groups.

As a case study, a comparison between the US and UK is particularly interesting because the countries faced reasonably similarly sized down-turns and the path of the central bank policy response was similar. For example, from trough-to-peak the US unemployment rate rose from 4.4 percent in 2007 to 9.5 percent in 2010, whereas the UK rate rose from 5.2 percent in 2007 to 8.4 percent in 2011. The Bank of England lowered interest rates 4.5 percentage points in late 2008 and early 2009, and the Federal Reserve Board lowered interest rates by the same amount in late 2007 and early 2008.

[34] Note that once we reach about 70 percent of mortgages being ARMs the line flattens out because age groups cannot have an arm share over 100 percent and few mortgages will have fixed terms which expire over the course of that year.

[35] Authors' calculation from the 2007 Survey of Consumer Finances.

[36] Authors' calculations based on 2007 Survey of Consumer Finances for the US and UK PSD data.

To examine trends in birth rates between the two countries we compiled data on quarterly birth rates by age-group in the US and UK from 2002-2015. The UK trends are based on the same data we used for our main analysis, but including additional years. The US trend data were obtained from microdata on conceptions resulting in live births for 2002-2015 from the *US Vital Statistics* Natality files, which was matched that to population data from the CDC SEER program.[37] The gray connected lines in Figure 8 are seasonally adjusted quarterly birth rates in the US and UK over time for the same three age groups we used in our empirical analyses. As in Figure 1, for context, the shaded gray areas indicate the time period in which unemployment increased from its trough-to-peak and the dashed black line is the path of each country's policy rate.

A couple of baseline characteristics of different age-groups lead to predictions about the relative differences in the birth rates across the two countries. First, as indicated by Table 2, 16-24 year olds in the UK have relatively low rates of exposure because home ownership rates are low. This suggests that fertility rates among 16-24 year olds should be similar across the two countries. Second, although 25-34 year olds and 35-44 year olds have relatively higher exposure rates in both countries, 25-34 year olds tend to be more leveraged than 35-44 year olds in both countries.[38] As evidenced by Table 1, in the UK this led to a larger relative drop in mortgage payments (as a share of the mortgage payment or as a share of income) for 25-34 year olds. In the US, higher loan-to-value ratios imply there is a higher propensity to become underwater when house prices fall, which would have restricted active refinancing into a lower mortgage rate. This suggests the trends in the two countries should diverge for both age-groups, but more so for 25-34 year olds.

Figure 8 indicates the predictions above are born out in the data and different age-groups had differing fertility patterns during the recessions in the US and UK. The middle panel of Figure 8 is the most striking: 25-34 year olds initially had similar trends in the two countries.

[37] Data was downloaded from www.nber.org

[38] For example, the 2007 US Survey of Consumer Finances indicates that 50 percent of 25-34 year olds are home owners, with an average LTV of 67. Among 16-24 year olds, only 12 percent are owners and among 35-44 year olds, 83 percent are owners, with an average LTV of 55. Authors' calculations.

However, in the UK that trend reverses once monetary easing begins, at which point the birth rate subsequently rises. In the US, the downward trend continues. As predicted above, the pattern for 35-44 year olds is similar to 25-34 year olds, albeit somewhat more muted, and the broad pattern for 16-24 year olds is nearly identical in both countries. This highlights how differences in mortgage contract design can lead to differences in the economic incidence of monetary policy across groups.

6 Conclusion

This paper has examined how monetary policy affects fertility decisions. We exploit variation across groups and over time in the share of families whose mortgages were eligible for a rate adjustment, and find that every 1 percentage point decline in the policy rate increases birth rates by 5 percent for families with an adjustable-rate mortgage. On average for the UK, a 1 percentage point decline in the policy rate increases birth rates by 2 percent. Overall, our paper deepens our understanding of the transmission mechanism of monetary policy to household behavior and the role of mortgage-structure rigidities for the macroeconomy.

We have focused on differences across space and time in the share of mortgages with an adjustable rate in order to estimate the size of mortgage rate pass-through. But in other countries, there are other aspects of mortgage contracts that allow for interest rate pass-through, for example, lower pre-payment penalties on fixed rate mortgages so that borrowers can refinance (Beraja et al., 2018; Wong, 2016). That said, when mortgage refinance is the main transmission mechanism an asymmetry can arise between housing boom and bust cycles, since in order to refinance, the borrower must have sufficient equity to be approved for a new mortgage. With adjustable rate resets, re-approval is not necessary to obtain a lower mortgage rate. At face value, it is plausible then that the prevalence of fixed rate mortgages and negative equity in the US could offer one explanation for the divergence in birth rate trends between the US and UK (Figure 1). Though we leave a formal analysis of whether our results might hold in other

countries and time periods to future work, our descriptive comparisons with the US suggest that if more families had been able to obtain a lower interest rate, the U.S. might not have experienced as severe of a "baby bust" in the Great Recession.

Our paper is written within the paradigm of an active literature on the cyclicality of fertility, which is a literature about the timing of fertility decisions. Ultimately, the recentness of the episode we study makes it difficult to ascertain with certainty whether the effects we have estimated represent changes in the timing of births or changes in the number of births a woman will have over the course of her life. However, there is suggestive evidence based on interest rate expectations and time trends in older women's birth rates supporting the plausibility of a change in completed fertility. Birth rates feature prominently in standard models of economic growth. Thus, a change in completed fertility due to rate pass-through would imply a new supply-side mechanism via which monetary policy can affect long run economic outcomes.

Still, short-term fluctuations in birth rates can also have important effects on the economy. Families who move forward their child-bearing plans will also move forward any associated consumer spending. And year-to-year fluctuations in cohorts and class sizes can have important implications for educational attainment and future labor market outcomes. Overall, our paper suggests monetary policy can have spillover effects on a host of economic and social outcomes.

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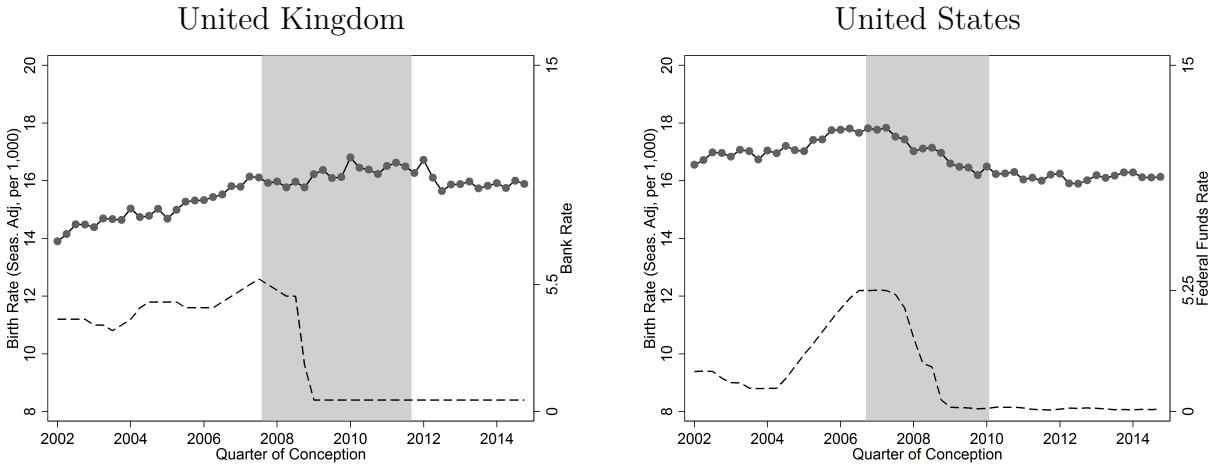
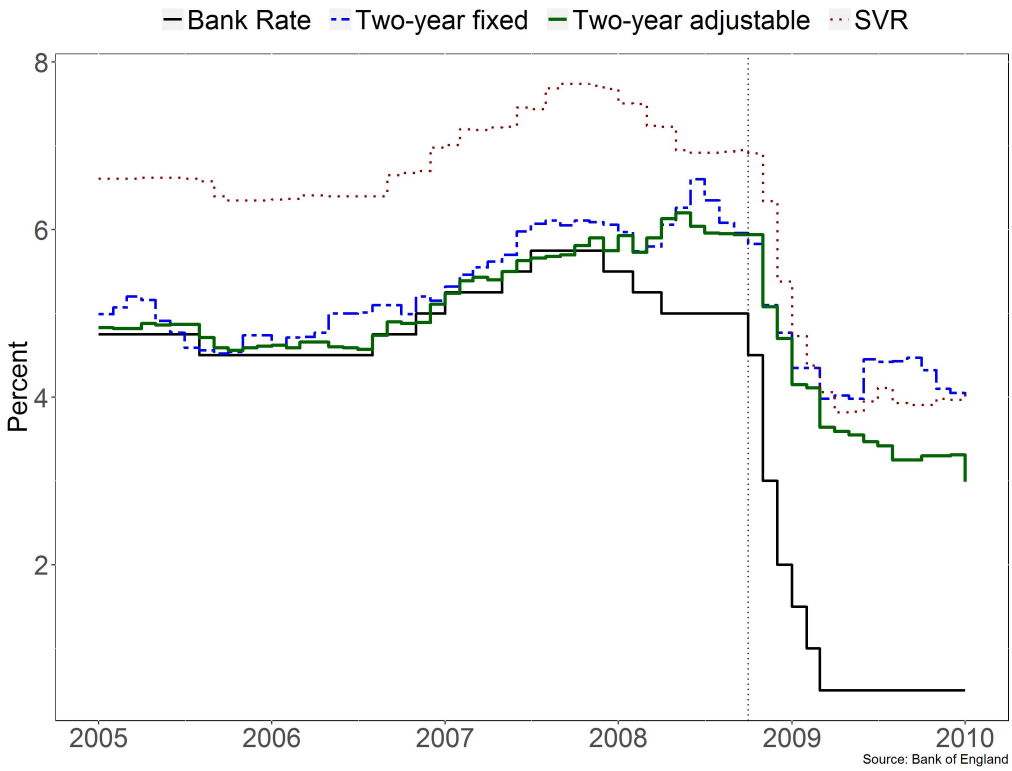
Figures and Tables

Figure 1: Trends in Birth Rates and Monetary Policy in the UK and US



Solid lines are seasonally adjusted quarterly birth rates by age-group dated to the quarter of conception and expressed per 1,000 women. The dashed line shows the path of Bank rate (left column) and the Federal Funds Rate (right column). The gray bar indicates the period in which unemployment increased from its trough to its peak in each country during the Great Recession. Sources: ONS and Bank of England (left column) and NCHS, Census, BLS, and Federal Reserve Board (right column).

Figure 2: The Path of Interest Rates



Source: Bank of England and own calculations.

Figure 3: Data and Empirical Strategy Timeline

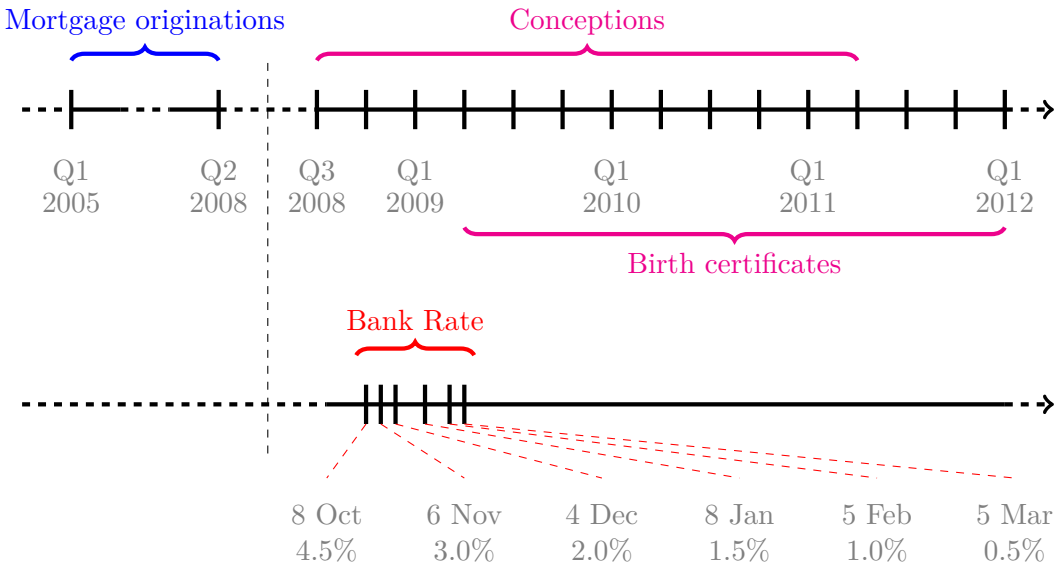


Figure shows the time-line for the data and central specification. We construct an estimate of the stock of mortgages using the flow of new loans between April 2005 and June 2008. The experiment begins in 2008Q3 when Bank Rate is reduced from 4.5% to 0.5% over the next five months. We measure the number of conceptions in each quarter from 2008Q3 to 2011Q2, which appear in the birth registry around nine months later.

Figure 4: Exposure Rates as of July 2008

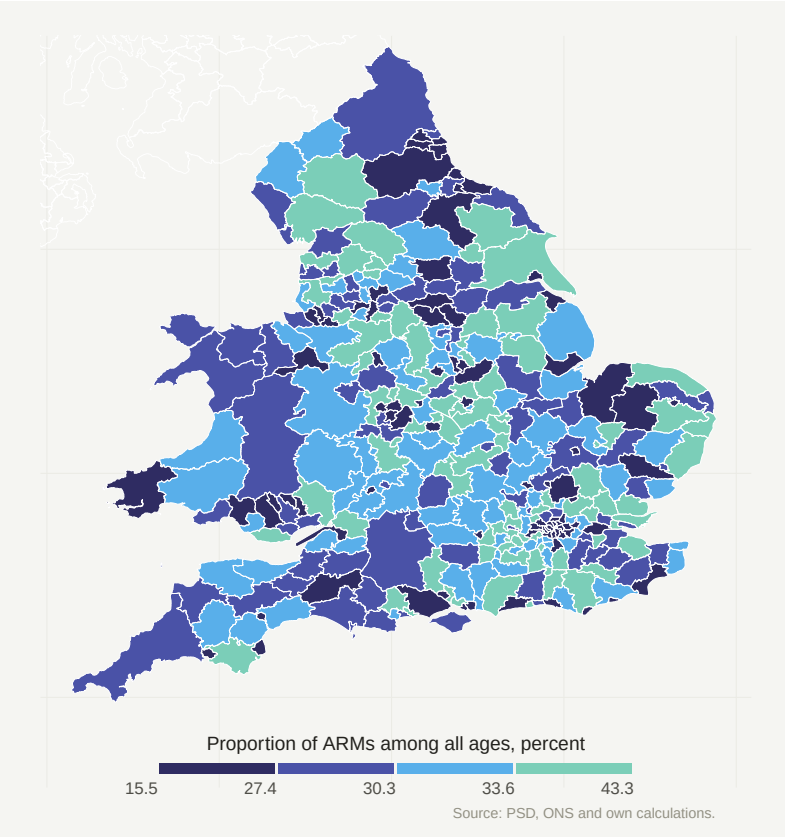


Figure shows proportion of families in each LAU with adjustable-rate mortgages as of July 2008. Color breaks denote quartiles and 343 local authorities are shown.

Figure 5: Event Study

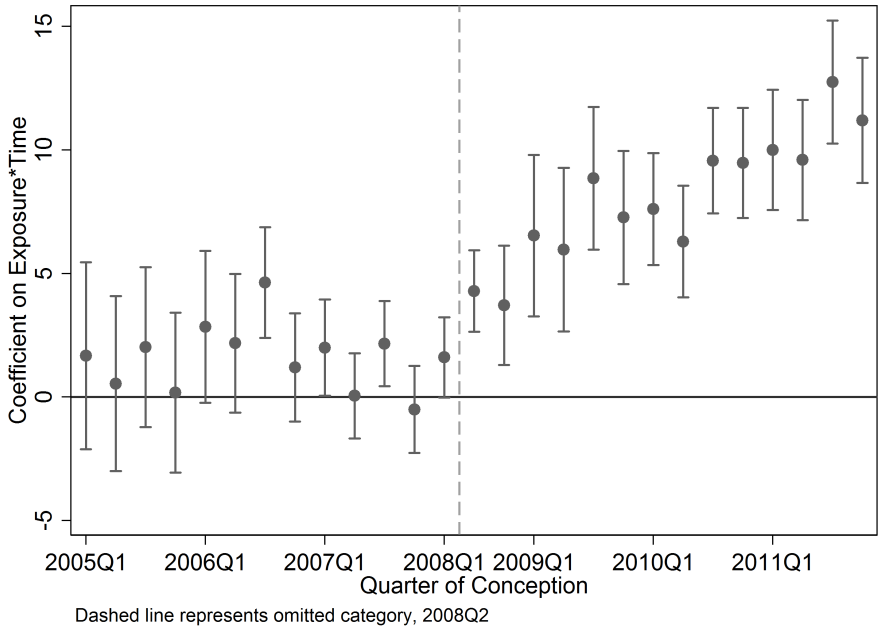
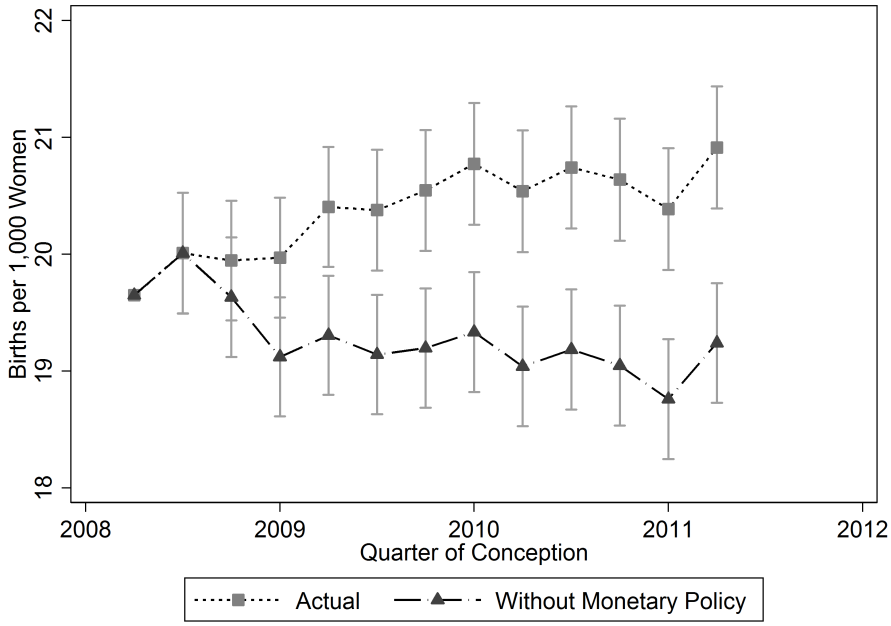


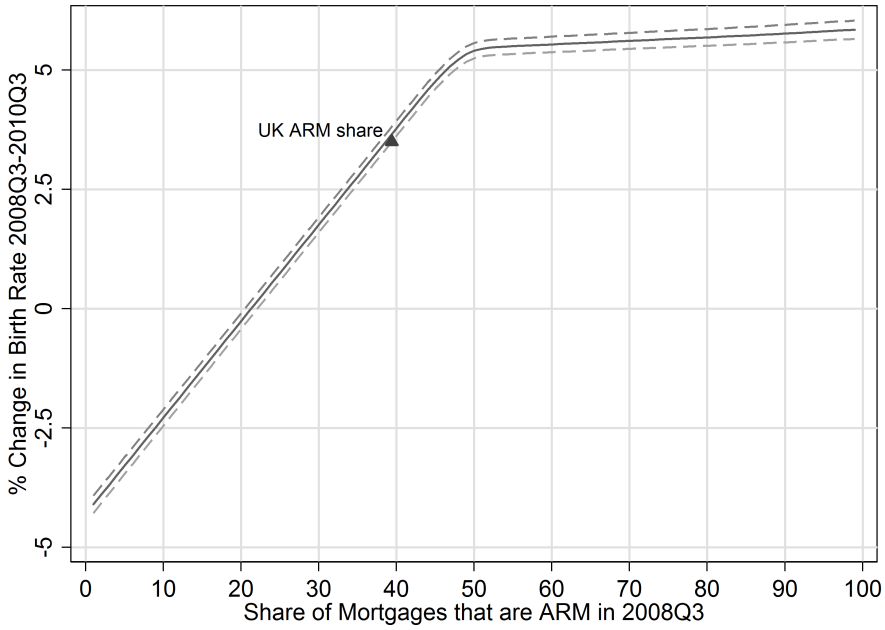
Figure plots coefficients and 99 percent confidence intervals on $\beta_{\mathbf{t}}$ based on estimating equation 3.

Figure 6: Counterfactual Simulation of Birth Rates with and without Monetary Policy



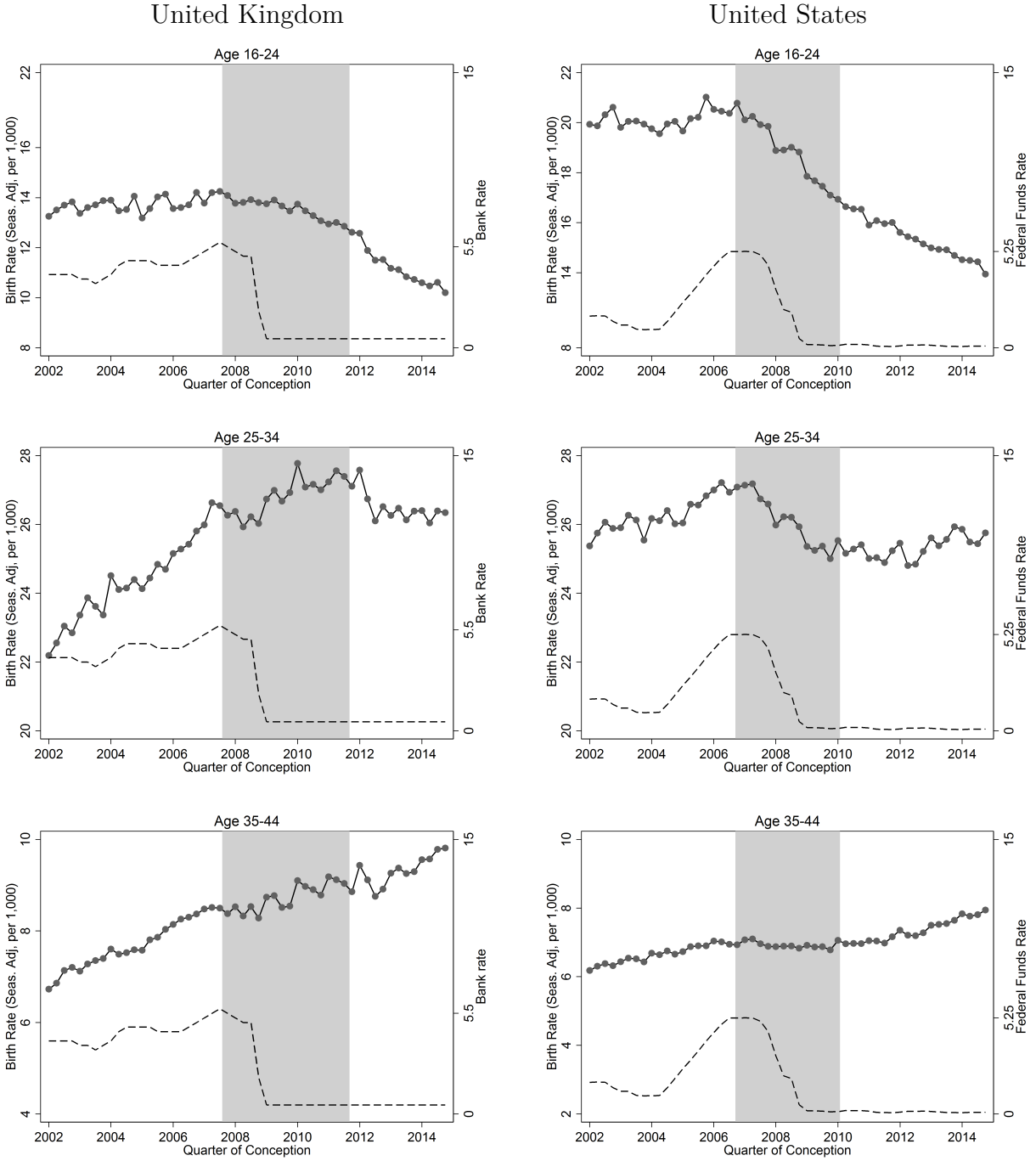
The dotted lines show the actual path of birth rates and the dashed line shows the predicted path with no change in Bank Rate based on estimates in Table 4. The capped bars indicate 95 percent confidence intervals. Birth rates are seasonally adjusted.

Figure 7: Counterfactual Simulation of Birth Rates by Share of Mortgages that are ARMs



The black line shows the predicted change in conceptions between the third quarter of 2008 and the third quarter of 2009 based on the results in Table 4. The horizontal axis displays the assumption about the share of mortgages that were an ARM at the end of the second quarter of 2008, which we use to simulate the change in birth rates, as described in the text. The dashed lines show bootstrapped 95 percent confidence intervals.

Figure 8: Trends in Birth Rates and Monetary Policy in the UK and US by Age-Group



Solid lines are seasonally adjusted quarterly birth rates by age-group dated to the quarter of conception and expressed per 1,000 women. The dashed line shows the path of Bank rate (left column) and the Federal Funds Rate (right column). The gray bar indicates the period in which unemployment increased from its trough to its peak in each country during the Great Recession. Sources: ONS and Bank of England (left column) and NCHS, CDC, BLS, and Federal Reserve Board (right column).

Table 1: Simulated Payment Changes for families with an Adjustable Rate

Variable	Mean	Median	SD	p25	p75
Panel 1: Impact of a 100bp fall in mortgage interest rates					
Quarterly payment decrease (£)	257.93	178.53	313.11	103.75	306.25
Change relative to payment (%)	9.50	8.08	5.14	5.58	12.50
Change relative to income (%)	1.72	1.53	1.02	1.05	2.20
Age group 16-24					
Quarterly payment decrease (£)	185.76	155.25	140.92	109.14	224.69
Change relative to payment (%)	9.77	8.74	4.05	6.57	11.71
Change relative to income (%)	1.97	1.74	1.02	1.33	2.39
Age group 25-34					
Quarterly payment decrease (£)	242.77	190.16	223.67	123.75	294.76
Change relative to payment (%)	9.61	8.57	4.40	6.37	11.46
Change relative to income (%)	1.85	1.66	0.94	1.22	2.29
Age group 35-44					
Quarterly payment decrease (£)	276.45	188.42	338.30	108.69	328.76
Change relative to payment (%)	9.34	8.00	4.94	5.60	11.50
Change relative to income (%)	1.70	1.52	0.98	1.05	2.17
Panel 2: Impact of a 450bp fall in mortgage interest rates					
Quarterly payment decrease (£)	1130.31	765.55	1406.39	446.78	1228.28
Change relative to payment (%)	41.63	33.58	23.59	24.01	56.71
Change relative to income (%)	7.51	6.60	4.53	4.50	9.52
Age group 16-24					
Quarterly payment decrease (£)	806.12	662.22	630.80	464.60	970.91
Change relative to payment (%)	42.39	36.62	18.72	27.93	50.08
Change relative to income (%)	8.51	7.52	4.49	5.69	10.67
Age group 25-34					
Quarterly payment decrease (£)	1053.56	810.25	1001.81	526.33	1275.00
Change relative to payment (%)	41.72	35.40	20.36	27.20	47.46
Change relative to income (%)	7.97	7.09	4.16	5.22	9.83
Age group 35-44					
Quarterly payment decrease (£)	1208.29	804.77	1518.59	464.24	1425.00
Change relative to payment (%)	40.79	33.06	22.74	24.07	51.51
Change relative to income (%)	7.40	6.50	4.38	4.49	9.32

Data Source is PSD. Simulation considers families on the initial period of an adjustable-rate mortgage (full interest rate pass-through) or on the SVR (two thirds pass-through).

Table 2: Summary Statistics by Quarter and Age

Variable	Mean	SD	Min	Max
Panel 1: Birth and exposure rates over time				
2008Q3				
Birth rate (per 1,000 women)	20.5	8.39	2.79	39.1
Exposure (% households)	20.9	8.65	3.06	44.4
2009Q3				
Birth rate (per 1,000 women)	20.9	8.62	3.08	37.1
Exposure (% households)	34.2	12.5	5.34	61.0
2010Q3				
Birth rate (per 1,000 women)	21.3	8.83	2.86	37.0
Exposure (% households)	43.1	14.9	7.11	73.1
Panel 2: Birth, ownership and exposure rates across age groups				
Age group 16-24				
Birth rate (per 1,000 women)	14.7	4.03	3.08	28.2
Ownership rate (% households)	27.1	8.20	8.31	56.0
Exposure (% households)	17.4	7.05	3.06	50.4
Age group 25-34				
Birth rate (per 1,000 women)	27.9	3.74	14.0	39.5
Ownership rate (% households)	58.3	10.7	29.0	85.3
Exposure (% households)	39.8	11.6	12.8	74.0
Age group 35-44				
Birth rate (per 1,000 women)	9.70	3.01	2.44	19.4
Ownership rate (% households)	70.3	11.2	33.8	90.7
Exposure (% households)	49.2	12.5	16.9	77.1

Data Sources are ONS, PSD and 2001 Census. Statistics are weighted by the number of births in each cell.

Table 3: Summary Statistics

Variable	Mean	SD	Variable	Mean	SD
Mortgage Variables (PSD)					
Interest Rate Pass-through			*Loan to Value Ratio (% households)*		
Exposure (%)	36.2	15.7	Under 60%	13.7	10.2
Exposure (%) x Bank Rate (%)	1.48	0.86	60-65%	2.87	1.63
			65-70%	3.18	1.63
Type of Mortgage (% households)			70-75%	4.18	1.96
ARM at Origination	14.3	7.16	75-80%	4.11	1.69
First Time Buyer	14.6	5.44	80-85%	4.62	1.75
Re-mortgager	21.6	13.3	85-90%	6.30	2.02
Mover	16.9	8.08	90-95%	7.70	2.43
Years since origination (% households)			95-100%	5.39	2.37
Less than 1 year	17.7	6.64	Over 100%	1.16	0.63
1-2 years	20.0	7.10	*Mortgagers' personal income (£1,000s)*		
2-3 years	13.1	4.51	5th percentile	14.7	3.64
More than 3 years	2.21	0.72	25th percentile	21.0	6.27
Loan to Income Ratio (% households)			50th percentile	27.8	9.99
Under 200%	7.02	4.90	75th percentile	38.7	17.5
200-250%	6.93	3.45	*Years until loan paid off (% households)*		
250-300%	10.4	3.98	Under 15 years	2.81	3.30
300-350%	11.3	3.72	15-20 years	6.99	6.37
350-400%	8.91	3.04	20-25 years	28.8	10.9
Over 400%	8.54	3.15	More than 25 years	14.5	7.31
Other Variables (ONS and Census)					
Birth rate (per 1,000 women)	21.1	8.65	Median House Price (£1000s)	18.46	8.15
Female higher qualification (%)	23.4	12.3	Unemployment Rate (%)	7.91	2.46
Ownership rate (%)	53.1	18.5			

Data Sources are ONS, PSD and 2001 Census. Stastistics are weighted by the number of births in each cell.

Table 4: Monetary Policy and Birth Rates

	(1)	(2)	(3)	(4)
Dep Var: ln(birth rate$_{lat+3}$)				
Exposure$_{lat}$ x Bank Rate$_{2008Q2,t}$	0.0513***	0.0517***	0.0637***	0.0493***
	(0.0042)	(0.0042)	(0.0056)	(0.0082)
LAU Fixed Effects	x			x
Age Fixed Effects	x		x	x
Quarter Fixed Effects	x	x		x
LAU-Age Controls (X$_{la}$)	x		x	
LAU-Quarter Controls (E$_{lt}$)	x	x		x
LAU x Age Fixed Effects		x		
LAU x Quarter Fixed Effects			x	
Only 2008q3-2009q4				x
N	12,348	12,348	12,348	6,174

Estimated according to Equation 2, as described in the text. Data Sources are ONS, PSD and 2001 Census. Standards errors adjusted for clustering at LAU level. Regressions are weighted by the number of births in each cell. * p<0.05 ** p<0.01 *** p<0.001.

Table 5: Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	Below	Above	Above	Below	Above	Below
	Median income	Median income	Median LTI	Median LTI	Median LTV	Median LTV
Dep Var: ln(birth rate$_{lat+3}$)						
Exposure$_{lat}$ x Bank Rate$_{2008Q2,t}$	0.0708***	0.0557***	0.0514***	0.0267***	0.0585***	0.0433***
	(0.0072)	(0.0077)	(0.0056)	(0.0075)	(0.0055)	(0.0116)
N	6,180	6,168	6,180	6,168	6,180	6,168

Data Sources are ONS, PSD and 2001 Census. Standards errors adjusted for clustering at LAU level. Regressions are weighted by the number of births in each cell. * p<0.05 ** p<0.01 *** p<0.001.

Table 6: Robustness Checks

	(1) Father's Mortgage	(2) Impute Missing Stock	(3) Exclude Missing Periods	(4) Levels	(5) Unweighted
Dep Var: ln(birth rate$_{lat+3}$)					
Exposure$_{lat}$ x Bank Rate$_{2008Q2,t}$	0.0525***	0.0513***	0.0449***	0.8063***	0.0473***
	(0.0042)	(0.0042)	(0.0038)	(0.0734)	(0.0047)
N	12,348	12,348	12,348	12,348	12,348

Estimated according to Equation 2, as described in the text. Data Sources are ONS, PSD and 2001 Census. Standards errors adjusted for clustering at LAU level. Regressions are weighted by the number of births in each cell. * p<0.05 ** p<0.01 *** p<0.001.

Table 7: Effect of Unemployment Rates and House Prices on Birth Rates

	(1)	(2)	(2)
Dep Var: ln(birth rate$_{lat+3}$)			
House price$_{lt}$ x Own$_{la}$	0.1113***	0.0579***	0.0576***
	(0.0100)	(0.0112)	(0.0113)
House price$_{lt}$	-0.0506***	-0.0272***	-0.0262***
	(0.0053)	(0.0052)	(0.0054)
Unemployment rate$_{lt}$	-0.0008	-0.0002	0.0014
	(0.0019)	(0.0020)	(0.0021)
Exposure$_{lat}$ x Bank Rate$_{2008Q2,t}$			0.0513***
			(0.0042)
2008Q4	0.0348***	0.0278***	0.0072
	(0.0049)	(0.0046)	(0.0049)
2009Q1	0.0257***	0.0138*	-0.0408***
	(0.0074)	(0.0065)	(0.0080)
2009Q2	0.0157	0.0030	-0.0681***
	(0.0080)	(0.0068)	(0.0091)
2009Q3	0.0215**	0.0109	-0.0692***
	(0.0069)	(0.0063)	(0.0092)
2009Q4	0.0532***	0.0453***	-0.0424***
	(0.0056)	(0.0053)	(0.0089)
2010Q1	0.0454***	0.0388***	-0.0548***
	(0.0055)	(0.0052)	(0.0092)
2010Q2	0.0023	-0.0036	-0.1012***
	(0.0050)	(0.0048)	(0.0090)
2010Q3	0.0222***	0.0181***	-0.0828***
	(0.0049)	(0.0048)	(0.0099)
2010Q4	0.0474***	0.0425***	-0.0609***
	(0.0051)	(0.0048)	(0.0097)
2011Q1	0.0227***	0.0157**	-0.0899***
	(0.0057)	(0.0056)	(0.0104)
2011Q2	0.0100	0.0022	-0.1066***
	(0.0058)	(0.0057)	(0.0104)
LAU Fixed Effects	x	x	x
Age Fixed Effects	x	x	x
Education and Income	x	x	x
Housing Tenure and Leverage		x	x
N	12,348	12,348	12,348

Estimated according to Equation 2, as described in the text. Data Sources are ONS, PSD and 2001 Census. Standards errors adjusted for clustering at LAU level. Regressions are weighted by the number of births in each cell. * p<0.05 ** p<0.01 *** p<0.001.