Macroprudential Policy, Mortgage Cycles and Distributional Effects: Evidence from the UK*

José-Luis Peydró   Francesc Rodriguez-Tous   Jagdish Tripathy   Arzu Uluc

Abstract

We analyse the distributional effects of macroprudential policy on mortgage and house-price cycles. For identification, we exploit the UK mortgage-register and a 15%-limit imposed in 2014 on lenders—not households—for high loan-to-income ratio (LTI) mortgages. Despite some regulatory arbitrage (e.g. increasing loan-to-value ratios), more-constrained lenders issue fewer and more expensive high-LTI mortgages. Partial substitution by less-constrained lenders leads to overall credit contraction to low-income borrowers in local-areas more exposed to constrained lenders, lowering house-price growth. Finally, exploiting the Brexit referendum (which led to house-price correction), the 2014-policy strongly implies better house prices and lower mortgage defaults during a bust.

JEL Classification: E5; G01; G21; G28; G51.

Key words: macroprudential policy; mortgages; credit cycles; inequality; house prices.

---

*This draft is from July 2020. We are thankful to David Aikman, João Cocco, Andy Haldane, David Jaume, Anil Kashyap, Benjamin Keys, Frederic Malherbe, Ricardo Reis, Sagar Shah, Vahid Saadi, Rhiannon Sowerbutts, Philip Strahan, Misa Tanaka, Neeltje Van Horen, Stijn Van Nieuwerburgh and John O. S. Wilson for insightful comments. We are also grateful to conference participants at the CEPR-Bank of Slovenia-European Central Banking Network Conference on Evaluating the Effectiveness of Macroprudential Policies 2017, RIDGE Finance Stability Forum 2017, EFA 2018, EEA 2018, Annual Workshop of ECB-ESCB at Bank of Greece 2018, 3rd Conference on Financial Stability at Banco de México 2019, Alternative Datasets Conference at Bocconi University 2019, FINEST Workshop at Bristol University 2019, Workshop on Banking and Financial Intermediation at Middlesex University 2020, and seminar participants at the Bank of England, Deutsche Bundesbank, Cass Business School, and CPB Netherlands Bureau for Economic Policy Analysis. The views expressed in this article are without exception those of the authors; they are not meant to represent the views of the Bank of England, members of its Financial or Monetary Policy Committee or any other institutions the authors are affiliated to. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 648398). Peydró acknowledges financial support from the ECO2015-68182-P (MINECO/FEDER, UE) grant and the Spanish Ministry of Economy and Competitiveness, through the Severo Ochoa Programme for Centres of Excellence in R&D (SEV-20150563) and a 2018 Leonardo Grant for Researchers and Cultural Creators, BBVA Foundation. José-Luis Peydró is with Imperial College London, UPF-CREi-ICREA-BarcelonaGSE, CEPR; Francesc Rodriguez-Tous is with Cass Business School; Jagdish Tripathy is with Bank of England (email: jagdish.tripathy@bankofengland.co.uk); Arzu Uluc is with Bank of England.

1 Introduction

Household leverage has received intense academic scrutiny as a source of financial instability, thereby causing long and deep recessions. The empirical literature provides evidence that strong mortgage expansion to households was the underlying cause of the 2007-09 US subprime/global financial crisis—as well as previous financial crises in history—with associated high mortgage defaults, house price contractions, and overall negative real effects (Schularick and Taylor (2012); Favara and Imbs (2015); Mian et al. (2017); Di Maggio and Kermani (2017); Piskorski and Seru (2018)). Theoretical literature shows settings in which unrestricted lending to households can lead to housing booms and to negative externalities during financial crises, with strong negative effects on house prices (fire sales) and bank defaults; thereby advocating macroprudential policies to limit pre-crisis household leverage (Lorenzoni (2008); Corbae and Quintin (2015); Farhi and Werning (2016); Korinek and Simsek (2016); Favilukis et al. (2017); Dávila and Korinek (2017); Greenwald (2017)). Consistent with this view, policymakers across the world have introduced macroprudential regulations on household leverage, especially after the global financial crisis.[1] Despite the academic and policy importance of macroprudential policy on household leverage, the empirical literature is scant—and particularly so in analyzing the effects during booms *and* busts.

In this paper, we analyse the distributional effects of macroprudential policy on mortgage and house price cycles. For empirical identification, we utilise the UK mortgage register in conjunction with a 15% cap on the proportion of new mortgages with high loan-to-income ratios (LTI $\geq$ 4.5) imposed in 2014 on UK mortgage lenders. These lenders are differentially affected based on their pre-policy share of high LTI loans in their mortgage portfolio. Moreover, we exploit the unexpected results of the Brexit referendum, which led to a house price correction across the UK, to analyse the effects of macroprudential policy implemented during booms in subsequent busts.

In brief, our robust results show that more-constrained lenders issue fewer and more expensive high-LTI mortgages, with stronger effects for low-income households (despite some regulatory arbitrage on unregulated loan-to-value ratios (LTV) of high LTI mortgages). Moreover, even though the regulation is on lenders (and not households), substitution by less-constrained lenders is only

[1] E.g., regulators in Denmark, Hong Kong, Ireland, Israel, Netherlands, Sweden, and the US (among others) have introduced restrictions on household leverage. A complete list of jurisdictions that have regulated household leverage is available in the iMaPP database (IMF). See Online Appendix A for a discussion.

partial and leads to strong overall credit contraction to low-income households in areas more exposed to the more-constrained lenders—with associated dampening of house price growth. Finally, our results suggest that the 2014 macroprudential policy leads to lower house price correction and mortgage default rates during the bust.

Our main contribution to the literature is to analyse the impact of household leverage regulation on credit and house price cycles, as well as its distributional effects (with respect to household income), thereby showing costs and benefits of macroprudential policy. To the best of our knowledge, there is currently no paper which studies the effects of changes in macroprudential policy on household leverage during both *boom and bust* periods. This is not only due to the scarcity of administrative data on mortgages, but also due to relative recency of such regulation because of which there have not been negative overall shocks to check the potential benefits of limiting household leverage during a boom.[2] However, the UK offers an ideal setting as it has administrative mortgage data, introduced macroprudential policy on LTI in 2014, and had a relative bust in house prices stemming from the unexpected result of the so-called Brexit referendum held in June 2016.[3] Our results show that the policy strongly restricts credit to low-income households in the boom even though the LTI regulation is on banks and not households. However, this distributional effect of the policy on leverage leads to lower mortgage defaults and substantially lower house price correction during the bust. In addition, we offer novel findings on regulatory arbitrage.

In the remainder of this Section, we provide a detailed preview of the paper and a detailed discussion of the literature and its contrast with our paper.

Preview of the paper. Mortgage defaults in the UK are highly correlated with household leverage, and strategic default (unlike the US) is a lesser concern since lenders have full recourse on all mortgages.[4] The macroprudential measure limiting high LTI lending was announced by the UK

[2]There has been the COVID-19 pandemic shock in 2020. However, many additional policy measures have been introduced concurrently in the UK during the COVID-19 episode. The additional measures include banking regulations (softening of capital, liquidity and provisioning requirements, short-sale restrictions), and fiscal measures (job retention schemes, freezing debt payments, tax deferment).

[3]See Figure 1 on house prices. Moreover, a growing literature on the effects of the Brexit referendum has shown a slowdown in UK growth and firm investment (Born et al. (2019), Faccini and Palombo (2019)), productivity (Bloom et al. (2019), Broadbent et al. (2019)), syndicated loan markets (Berg et al. (2019)), and stock returns (Davies and Studnicka (2018)) following the referendum.

[4]See Bank of England (2017a) for a discussion on the evidence (based on data from multiple surveys) linking household leverage with payment difficulties in the UK. Mortgage lenders in the UK have full recourse following a judicial foreclosure, an institutional framework shared with most other European economies (IMF (2013); Badarinza et al. (2016)).

regulator in June 2014. The measure imposed a 15% limit on the proportion of total number—not total £ amount—of new mortgages with LTI $\geq$ 4.5 that a UK lender could issue quarterly starting 2014Q4.[5] The regulation is applicable on residential mortgages issued by lenders, i.e. mortgages issued to first-time-buyers, home-movers and refinancers where the borrower lives in the underlying property.

We exploit the loan-level data on mortgages issued in the UK during 2012Q3-2016Q2 from the mortgage register in conjunction with the LTI regulation of June 2014. The loan-level data, reported quarterly, includes information on borrower characteristics such as income, age and employment status, on the issuing lender, and on characteristics of the loan itself, such as loan amount, interest rate, interest rate type (fixed or floating), mortgage term, property value and postcode. We merge the loan-level data with lenders' balance-sheet data on credit, size, funding, and liquidity status at a quarterly frequency. In addition, we match mortgage data with house price growth and mortgage non-performance rates (defaults) at a local-area level between 2012Q3 and 2018Q2 to exploit the unexpected outcome of the Brexit referendum in mid-2016. Therefore, we create a rich dataset that allows us to exploit time, borrower, lender, and location characteristics to study the effects of the policy.

In addition to exploiting the loan data before and after the LTI regulation, our research design hinges on the restriction on high LTI lending being binding at a lender level. This provides a variation across UK lenders based on the share of loans with LTI $\geq$ 4.5 in their mortgage portfolio a year before the announcement of the regulation (i.e. 2013Q3-2014Q2).[6] We use these shares to classify UK lenders into two groups of more-constrained and less-constrained lenders.[7] Constrained lenders issued roughly a third of all mortgages in our sample. The constrained and unconstrained lenders are similar across a range of balance sheet characteristics such as size, liquidity ratio, core funding ratio, return on assets, CET1 ratio, and share of household credit. We use a difference-in-differences specification to make causal inferences on the changes in the mortgage portfolio of the constrained lenders in response to the regulation.

[5] There was evidence of deteriorating underwriting standards in the UK mortgage market before 2014, with a sharp increase in highly leveraged mortgages. For instance, the share of mortgages with LTI $\geq$ 4.5 had been around 10% in 2013; the corresponding figure for the pre-crisis period (2005-2007) was just 6.5%.

[6] UK lenders under the purview of the regulation includes banks and building societies which account for 99% and 98% of the total number and total £ value of mortgage lending in the UK, respectively.

[7] Our baseline specification distinguishes more-constrained and less-constrained lenders using an indicator variable. We also refer to these groups as constrained and unconstrained groups, respectively, for brevity.

Our results show that the introduction of the regulation affects mortgage lending. First, after the macroprudential regulation and in comparison to unconstrained lenders, constrained lenders cut their share of mortgages with LTI $\geq$ 4.5 by 3.9%, and charge a higher loan rate (by 14 bp) for those loans, thereby suggesting credit supply restrictions due to the new policy. Moreover, the fewer high LTI loans issued by constrained lenders after the regulation contain 5.2% fewer loans issued to borrowers in the lowest income-quintile. That is, the policy doubly-affects low-income households through the reduction in high LTI loans (which they are more likely to borrow) *and* the drop in their presence *within* high LTI loans issued by constrained lenders.[8] Importantly, all the key effects happen *only after* the regulation is implemented and not before its announcement (i.e., parallel trends), which serves as a placebo test.

Second, we analyse credit substitution since the regulation is on UK lenders and not on households: borrowers who could not receive high LTI loans from constrained banks (i.e. low-income borrowers) could either receive a loan with LTI $<$ 4.5 from those banks or obtain a high LTI loan from an unconstrained bank. As these two substitution channels are statistically significant at the loan-level, we aggregate mortgage lending by time (quarterly), location (UK local areas equivalent to boroughs) and income-quintiles to study the combined effect of these substitution channels on overall lending to low-income borrowers. We use a triple difference-in-differences specification to check whether the regulation has an overall effect on lending (in total number and total £ value of loans) to borrowers in the lowest income-quantile in the UK, especially in local areas more exposed to constrained banks. Estimated coefficients show that borrowers in the bottom income-quintile in areas with an ex-ante one standard deviation higher exposure to constrained lenders (equivalent to a 6.6% higher share of those banks) experience a 9.0% decline in the total number of mortgages and a 11.4% decline in the total £ value of lending after the introduction of the regulation.[9] We estimate a lower-bound for these coefficients accounting for unobserved local-area heterogeneity using the techniques described in Altonji et al. (2005) and Oster (2019); the estimated lower-bounds

[8]Results are robust to alternate thresholds for low-income borrowers, for e.g., those based on income-quartiles or terciles. There is no concomitant drop in the share of high LTI loans issued to the lowest age-quintile, which shows that the contraction in high LTI loans by constrained lenders had a stronger effect on low-income households than for younger households.

[9]These effects are estimated controlling for local area$\times$time, income-band$\times$time and local area$\times$income-band fixed-effects. Therefore, the contraction in lending to low-income borrowers in high exposure areas is unlikely to be driven by demand shocks specific to local areas or low-income borrowers. Moreover, as the Oster (2019) test suggests, results are not driven by (other) unobservables.

are remarkably close to the actual coefficients.

Third, the contraction in high LTI lending due to the regulation affects house price dynamics. We use house prices from the universe housing transactions to show that the introduction of the regulation implies a drop in the growth rate of the 25th percentile of house price transactions in local areas more affected by the regulation (i.e., local areas more exposed to constrained lenders *and* with a higher concentration of low-income borrowers).

Fourth, we exploit the unexpected outcome of the Brexit referendum in June 2016 which led to a drop in house price growth across the UK. Figure 1 shows that growth in median house price in the UK fell from a peak of 7.5% annually just before the referendum to 2.7% two years after the referendum. We find that local areas more affected by the 2014-policy (i.e., local areas with a higher proportion of constrained lenders and low-income borrowers) have a relatively lower cooling in house price growth after the referendum. The relatively lower decline in house price growth post-Brexit referendum is stronger for lower quantiles of house price transactions.[10]

We provide evidence which suggest that these results do not capture differences in house price trends across types of houses or local areas, or differential responses across UK local areas to financial crises. We show that the house price results are robust to controlling for housing supply constraints across local areas measured by regulatory constraints, land availability and geographical constraints. The results also hold if we compare house-price trends for similar houses across local-areas, instead of comparing moments from the entire distribution which may conflate structural differences in housing markets—for e.g., house price trends for old houses, semi-detached, freehold, leasehold, etc. Moreover, we find that exposure to lenders constrained by the 2014 macroprudential policy and a higher concentration of low-income borrowers does not affect house price trends around the 2007-08 financial crisis, which suggests that our post-Brexit house price results are not driven by the effect of unobservable local area characteristics on local house price behaviour during busts.

[10] The house price trends are estimated in the presence of region×time fixed-effects and, therefore, do not result from regional house price trends unrelated to the regulation; i.e., the house price trends described are between local areas with different exposures to the 2014 regulation in the same region in the UK.

Figure 1: Median house-price growth

The above figure shows the annual growth rate of median house prices in England and Wales. The vertical dashed line denotes the date of the Brexit referendum. The data is from the House Price Statistics for Small Areas (HPSSAs) Dataset 9: Median price paid for administrative geographies.

Further, these local areas with relatively lower decline in house price growth post-Brexit referendum also experience relatively lower rates of mortgage defaults after the Brexit referendum. We measure mortgage defaults using the share of mortgages with a payment shortfall.[11] Banks must provision for these delinquencies, implying lower profits and a hit to their capital position. Mortgage non-performance, therefore, is costly for both banks and borrowers (due to worse rating and credit history for the latter), and we interpret the relatively lower mortgage default rates post-Brexit referendum as a positive effect of the 2014-policy in the more affected areas. In sum, better house price effects (with stronger effects on the lower percentiles of house price transactions) and lower default effects are consistent with the ex-ante (to the Brexit referendum) reduction in debt due to the 2014 policy. That is, the improvement during the bust is stronger for banks and households in local areas more exposed to the 2014 macroprudential policy.

Finally, we analyse regulatory arbitrage after the introduction of the regulation. First, as the regulation is on the proportion of loans and not the total value, the lower number of high LTI loans issued by the constrained lenders after the regulation are, on average, larger (by 7%) and with higher loan-to-value ratios (by 1.8 pp). The overall LTI distribution of mortgages issued by constrained banks moves significantly to the right after the regulation, with a marked increase in the mass of mortgages with LTI just below 4.5 (i.e. bunching). Moreover, following the counterfactual distribution estimation technique by Chernozhukov et al. (2013) and using the Oaxaca-Blinder decomposition, results suggest that the changes in the LTI distribution are driven by the regulation. The decomposition shows that while the rightward shift of the LTI distribution for constrained

[11] In general, mortgages with a payment shortfall have been under arrears for less than 6 months

banks is almost entirely attributable to the regulation, the more marginal changes in the LTI distribution for unconstrained banks is instead explained by changes in covariates.[12]

Literature Review. Our main contribution to the literature is to show the impact of household leverage regulation on boom/bust cycles and its distributional effects (with respect to household income), thereby showing costs and benefits of macroprudential policy. In addition, we also provide novel findings on regulatory arbitrage.

To the best of our knowledge, there is currently no paper which studies the effects of changes in macroprudential policy on household leverage during *both boom and bust periods*. This is not only due to scarcity of administrative data on mortgages (most credit registers are on corporate loans), but also due to relative recency of such regulation because of which there have not been negative overall shocks to check the potential benefits of limiting household leverage during a boom. The UK offers an ideal setting as it has a mortgage register, a macroprudential policy which restricted LTI in 2014, and a mild bust in house prices stemming from the unexpected result of the Brexit referendum. We find that the policy restricts credit to low-income households during the boom even though the LTI regulation is on banks and not households, an effect which leads to lower mortgage defaults and better house price correction during the bust. Other papers studying the effects of household leverage regulation introduced post-2008 financial crisis (e.g. DeFusco et al. (2020), Acharya et al. (2019), and Bekkum et al. (2019) based on regulations in the US, Ireland and Netherlands, respectively, and Benetton (2018) and Belgibayeva (2020) based on regulations in the UK) analyse the effects of the macroprudential policy only around its introduction and not during a bust.[13,14] Importantly, by showing the effects during the bust, we test a key prediction of the theoretical models highlighted in the first page of the Introduction, i.e., the reduction in

[12] In other words, while constrained banks issue a different LTI post-regulation controlling for borrower characteristics, unconstrained banks issue a similar LTI for those characteristics irrespective of the regulation.

[13] Benetton (2018) also studies the effect of leverage regulation on the UK mortgage market, although the focus of their paper is to estimate a structural model to investigate the equilibrium effects of alternate leverage regulations (e.g. bank capital requirements). Our paper, in comparison, is a comprehensive empirical assessment of the causal effects of the 2014 macroprudential regulation. Belgibayeva (2020) also reports a reduction in high LTI lending resulting from the policy. As compared to our paper, these papers do not study the effects of macroprudential regulation in terms of house prices and mortgage defaults, or the effect of macroprudential regulation on boom-bust dynamics. In addition, establishing extensive and intensive margin effects of macroprudential regulation on lending (because of partial substitution by unconstrained lenders) is also unique to our paper.

[14] Jiménez et al. (2017) study the impact of bank-based macroprudential regulation (countercyclical capital) on corporate loans during a full credit cycle and find no overall effects during boom periods. Our paper finds effects of the regulation during boom periods as well. There are also papers, for instance, Igan and Kang (2011) and Crowe et al. (2013), which use aggregate cross-country data to study effects of macroprudential regulation, with the usual limitations in identification.

pre-crisis leverage has an impact on house prices and defaults during a bust.

As compared to the regulations in other jurisdictions, measures in the UK set a cap on household leverage at a *lender* level. Our results, which show a reduction in household leverage resulting from the UK measures despite *no restriction at the borrower level*, suggest that there are important frictions in substituting credit across differently affected banks in a *boom* period. This feature also distinguishes our study from those by DeFusco et al. (2020), Acharya et al. (2019) and Bekkum et al. (2019). For instance, DeFusco et al. (2020) study the impact of "ability-to-pay" (or affordability) requirements introduced on large mortgages (*jumbo loans*) with debt-service-to-income ratios (DSTI) beyond a certain threshold, with other loans remaining unaffected by the regulation. In contrast to these papers, the key transmission mechanism to lending and house prices in our paper is via change in lender-behaviour (supply) following a macroprudential regulation.

We also contribute to the literature on credit and house prices. Household leverage closely interacts with house prices on the way to affecting the macroeconomy. The literature has emphasized the amplification loop that exists between loosening of lending standards, increase in household leverage and subsequent increases in house prices (Mayer et al. (2009); Mian and Sufi (2009); Favara and Imbs (2015); Jordà et al. (2015); Bhutta and Keys (2016); Di Maggio and Kermani (2017)). The LTI regulation in the UK, introduced in response to sharp increases in household leverage, resulted in cooling down of house prices in local areas with a higher exposure to lenders more constrained by the regulation and with a higher concentration of low-income borrowers.

Importantly, we show that the macroprudential policy yields benefits in house price dynamics and mortgage defaults after the Brexit referendum (which led to house price cooling across the UK). Lower house price drops can be beneficial given the evidence linking changes in house prices to mortgage default (Ghent and Kudlyak (2011); Mian and Sufi (2011); Guiso et al. (2013); Adelino et al. (2016); Fuster and Willen (2017); Bhutta et al. (2017)), household consumption (Campbell and Cocco (2007); Lustig and Van Nieuwerburgh (2010); Mian et al. (2013); Aladangady (2017); DeFusco (2018); Guren et al. (2018)), economic activity (Chaney et al. (2012)), and the aggregate demand externality that operates during a financial crisis concurrent with a house price correction (Mian and Sufi (2014)). Thus, our paper is unique in showing the effect of macroprudential policy on smoothing house price cycles, and localized benefits of restricting household leverage during boom periods, including lower loan defaults.

There is also a growing literature which has varyingly attributed the secular rise in income and wealth inequality to taxation (for instance, Piketty and Saez (2003)), globalization (Autor et al. (2013)) and automation (Autor and Dorn (2013)). Papers have also studied the redistributive effects of policies, such as those for monetary policy (Auclert (2019)) and for policies aimed at financial access (Rajan (2011); Agarwal et al. (2012)). We contribute to this literature by linking debt, inequality and macroprudential policies and showing an important trade-off. On the one hand, we find that macroprudential policies aimed at high leverage can disproportionately reduce lending to low-income borrowers (affecting their wealth dynamics since real estate is the key component of household wealth);[15] on the other hand, the macroprudential policy yields benefits—in terms of a lower house price correction and lower mortgage defaults in low-income areas—during a bust.

Regarding regulatory arbitrage, other papers on macroprudential policy have also reported unintended consequences (Acharya et al. (2019); Jiménez et al. (2017)). We find some novel findings given the distinct nature of the 2014-policy (on LTI and on banks). While lenders more-constrained by the regulation reduce their share of mortgages with LTI ≥ 4.5, they increase the (unregulated) loan-to-value ratios (LTV) and average loan-size of high LTI mortgages. They also disproportionately raise the mass of mortgages with LTI close to and below the 4.5 threshold, leading to an overall rightward shift in the LTI distribution of mortgages issued post-regulation.

Organization. The rest of the paper is organized as follows. Section 2 provides a background on the 2014 regulation. Section 3 discusses the data and empirical strategy. Section 4 presents the key results in different subsections. Section 5 concludes.

2 Institutional Background

Mortgages are one of the largest asset classes on the UK banks' balance sheets. Therefore, poorly performing mortgages can pose direct risks to the resilience of the UK banking system and to financial stability. Mortgages are also the largest liability on the UK household sector's balance sheet.[16] In the event of a fall in incomes or an increase in interest rates, households may cut

[15] Property wealth accounts for 60% of total household wealth in the UK. Source: Office of National Statistics, Wealth and Assets Survey 2018.

[16] Lending to households consistently accounts for roughly half of all the credit issued to the private non-financial sector by banks in the UK (Source: FRED Economic Data). In 2017Q2, mortgages (£1.3 trillion) made up more than 80% of the total stock of household debt (£1.6 trillion) (Bank of England (2017b)).

back consumption to keep paying their mortgages, which could have indirect effects on the rest of the economy. The macroprudential policy authority in the UK, the Bank of England's Financial Policy Committee (FPC), monitors developments in the housing and mortgage markets in order to mitigate these risks to financial and economic stability.

At its June 2014 meeting, the FPC assessed risks to lenders and the wider economy from an increase in UK household indebtedness. At that time, there were signs that the UK housing market was heating up. There was strong recovery in the housing market, and house prices were rising faster than household income. These developments were associated with a significant increase in the share of high leverage mortgages. For instance, the share of mortgages with loan-to-income ratios (LTI) at or greater than 4.5 rose from 6.5% in the immediate pre-crisis period during 2005-07 to 10% between 2013Q2-2014Q1 (see Online Appendix Figure A.2). Therefore, as insurance against the risk of a loosening in underwriting standards and a significant increase in the number of highly indebted households, the FPC recommended the Prudential Regulation Authority (PRA) and Financial Conduct Authority (FCA) to ensure that mortgage lenders do not extend more than 15% of their total number of new residential mortgages with loan-to-income ratios at or greater than 4.5.[17,18]

The PRA and the FCA implemented the FPC's recommendation as of 1 October 2014. The policy was implemented on a quarterly basis and excludes re-mortgages with no change to the outstanding principal, and lifetime mortgages. The policy applies to mortgage lenders whose annual residential mortgage lending is in excess of £100 million in value and 300 in number of mortgages. According to the policy, a mortgage lender part of a banking group is allowed to allocate all or part of its high LTI allowance to any other regulated entity within that group. When the rules applied as of 1 October 2014, there were 32 banking groups within the scope of the policy. During the period of interest of this study, mortgage lenders inside the scope of the policy account for 99% and 98% percentage of the total number and total £ value of mortgage lending, respectively.[19]

[17]The PRA is responsible for prudential regulation and supervision of banks, building societies, credit unions, insurers and major investment firms in the UK. The FCA is the conduct regulator for financial services firms and financial markets in the UK. Along with the cap on the proportion of mortgages with LTI ≥ 4.5, the FPC also introduced an affordability test that lenders had to conduct on each mortgage issued by them. See Footnote 24 for a discussion on the effects of the affordability tests.

[18]The 4.5 loan-to-income ratio is calibrated to ensure a cap on the mass of borrowers that may face stressed debt-servicing ratios of around 35-40%. This is an inflection point beyond which the proportion of borrowers experiencing repayment difficulties can rise sharply. See Bank of England (2017a), page 8 for details.

[19]Substitution by unregulated mortgage lenders is minimal since they have a small market share and risk coming

3 Data and Empirical Strategy

3.1 Data

We draw upon multiple data sources for our empirical analysis. These are: the PSD001 database which includes the universe of newly issued residential mortgages in the UK; the PSD007 database which includes the stock of mortgages in the UK; the balance sheet and income statement data from lenders; and the UK land registry for data on housing transactions.

PSD001 (Product Sales Database 001), updated quarterly by the FCA, contains information on the universe of newly issued residential mortgages in the UK.[20] These are the type of mortgages subject to the limit on high loan-to-income (LTI) lending. We exclude from our sample instances of external re-mortgaging without a change in the principal of the loan and life-time mortgages since these types of contracts are not in the scope of the policy. We report summary statistics of our sample in Table 1 (A). The data from PSD001 provides a wide range of borrower characteristics, such as borrower's gross income, age, employment status, and whether the borrower is a home-mover, first-time-buyer or re-mortgagor. Moreover, the database contains information on mortgage characteristics such as loan amount, interest rate, price of the property, LTI, loan-to-value (LTV), term, type of repayment, and location of the property. The data also includes the date of issuance and the issuing bank of the mortgage. Therefore, we can use this data to study changes in the mortgage portfolio of banking groups more constrained by the limit on high LTI lending, as well as whether some borrower cross-sections are disproportionally affected by the regulation.

PSD007 (Product Sales Database 007) contains information on the stock of UK mortgages. This data has been obtained by the Financial Conduct Authority bi-annually starting 2015. The stock data includes information on the performance of each extant mortgage in a given period,

under the purview of the policy if they cross the £100 million/300 mortgages portfolio threshold.

[20] The database includes the full set of mortgages that UK regulators use to assess compliance with the policy. PSD001 excludes loans such as second-charged, commercial, and buy-to-let mortgages, none of which are under the scope of the regulation. The database includes external remortgages (also known as external product transfers), but not internal ones—i.e., remortgaging/refinancing without changing lender and property. Importantly, the high-LTI limit does *not* apply to remortgages without a change in principal. Remortgages, both internal and external, should be less affected by the policy compared to other types of mortgages: borrowers remortgage their loans typically after the initial fixed-rate period (two or five years); as they have paid part of the mortgage for a period of time, they are likely to have lower loan-to-income ratios than when acquiring the initial mortgage. Consistent with this intuition, in unreported results, we find that external remortgagors, when compared with first time buyers, are significantly less affected by the policy.

such as whether the mortgage is in payment arrears or under forbearance; the latter refers to mortgages under re-payment difficulties which have received modified terms from lenders in the form of payment suspension, payment reduction, term extension etc. The stock data includes the date of origination, issuing bank, and location of the related property. We use this information to calculate rates of mortgages with payment arrears or mortgages under forbearance across UK local areas over time.

In addition, we have data on lenders' balance sheet position and income statement at a quarterly frequency reported by these institutions to the Bank of England. The data includes lender size, liquidity and core funding from balance sheets; return on assets from income statement; and share of household credit and capital ratio from other regulatory reports.

Finally, the HM Land Registry's Price Paid Data contains information on the price paid, date, and location of all residential housing transactions in England and Wales. We use this data to understand the effect of the policy on house prices, both immediately after its introduction as well as during the correction in housing market dynamics following the Brexit referendum. Therefore, we focus on the period between 2012 (two years before the introduction of the policy) and 2018 (two years after the referendum).

3.2 Empirical Strategy

Our empirical strategy exploits the variation in the exposure to the regulation across lenders for identification. In this section, we first define the criteria for classifying lenders into two groups: more-constrained (alternately "constrained") and less-constrained (alternately "unconstrained") lenders. We study the impact of the regulation on high LTI lending by differentially constrained lenders using loan-level data in Equations 1, 2 and 3. We use lending data aggregated at the quarterly$\times$local area$\times$borrower-income level in Equation 4 to study the effects of the regulation on lending to borrowers in the bottom income-quintile in local areas more exposed to constrained lenders. Finally, we study house price growth and mortgage performance in local areas with more constrained lenders *and* more low-income borrowers using Equation 5 and Equation 6, respectively.

Constrained and unconstrained lenders. The 2014 regulation set a 15% limit on the proportion of new residential mortgages that lenders could issue every quarter with loan-to-income ratios (LTI) at or greater than 4.5. We use the lenders' quarterly shares of high LTI loans in the run up to its announcement (from 2013Q3 to 2014Q2) to identify lenders more likely to be constrained by the regulation. There are 5 lenders, which issue a third of all mortgages in our sample, whose average level of high LTI loans is greater than (or very close to) 15%. We refer to these five lenders as "constrained" lenders. The remaining lenders are well within the 15% limit set by the regulation and hence less constrained by the regulation.[21] We refer to these lenders as "unconstrained" lenders. Apart from the shares of high LTI lending, constrained lenders do not significantly differ from unconstrained lenders in other key characteristics, such as size, liquidity, and capital ratio, as we show in Table A.3 in the Online Appendix.

We exploit the differential exposure to the regulation for constrained and unconstrained lenders as a quasi-experiment. Figure 2 shows the time frame. We use data on lending 2-years prior to and 2-years after the announcement of the regulation in 2014Q2, i.e. all the mortgages issued during 2012Q3-2016Q2. We drop all mortgages issued during 2014Q3 from our sample since the regulation came into effect only in 2014Q4. We restrict our study to mortgages issued until 2016Q2 when the UK held the so-called Brexit referendum.

Share and pricing of high LTI mortgages. The baseline specification described in Equation 1 is a standard difference-in-differences specification which uses loan-level data to test whether mortgages issued by constrained lenders are less likely to be high LTI loans (LTI $\geq$ 4.5). The treatment variable in this specification is $\text{Post}_t \times \text{Constrained}_b$ where Post_t and Constrained_b are dummies which indicate periods after the implementation of the regulation (2014Q4 onwards) and the constrained lenders, respectively. We regress a dummy $\mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t}$ indicating whether a loan issued to borrower i in local area l by bank b in quarter t has LTI $\geq$ 4.5 on Post_t interacted with Constrained_b, while controlling for borrower and loan characteristics ($X_{i,l,b,t}$), bank×time controls ($X_{b,t}$), local area×time fixed-effects ($f_{l,t}$), and local area×bank fixed-effects ($f_{l,b}$).[22] Local area l refers to the geographic location of the underlying property at the Local Administrative Unit Level 1 (LAU1) level based on the postcode reported in the loan-level PSD001 dataset.[23]

The coefficient β on $\text{Post}_t \times \text{Constrained}_b$ in this specification reflects the change in the share

[21] We cannot share the lender *specific* shares of high LTI loans because of data confidentiality requirements.

[22] Borrower controls include borrower type, employment status, age, and income. Loan controls include type of rate, term, type of repayment, loan value, and property value. Bank controls include size, liquidity and core funding ratios, return on assets, CET1 ratio, and share of household lending. These variables are described in Online Appendix B.

[23] The Office of National Statistics provides an overview of the administrative geographies for the United Kingdom at link. LAU1 is the second lowest level of administrative geography, followed by electoral wards. There are 415 LAU1 local areas in the UK with an average population of around 158,000 residents (2016).

of high LTI loans in the portfolio of constrained banks in Post_t periods.[24] The sample period for loan-level regressions is from 2012Q3 to 2016Q2. As mentioned before, we exclude loans issued in 2014Q3, but the results are robust to their inclusion.

$$\mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t} = \beta \cdot \text{Post}_t \times \text{Constrained}_b + \gamma_1 \cdot X_{b,t} + \gamma_2 \cdot X_{i,l,b,t} + f_{l,t} + f_{l,b} + \varepsilon_{i,l,b,t} \tag{1}$$

We use Equation 2 to test whether constrained banks charge different interest rates on high LTI loans after the introduction of the policy. The dependent variable is $\text{Rate}_{i,l,b,t}$, the interest rate of the mortgage issued to borrower i in local area l by bank b in quarter t. The coefficient β_{rate} on $\text{Post}_t \times \text{Constrained}_b \times \mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t}$ reflects the change in interest rate for high LTI loans issued by constrained banks after the policy. We repeat the same set of controls described in Equation 1 in this specification.

$$\text{Rate}_{i,l,b,t} = \beta_{rate} \cdot \text{Post}_t \times \text{Constrained}_b \times \mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t} + \gamma_1 \cdot X_{b,t} + \gamma_2 \cdot X_{i,l,b,t} + f_{l,t} + f_{l,b} + \varepsilon_{i,l,b,t} \tag{2}$$

Composition of high LTI mortgages. We use an analogue of the above specification to test whether the average size, LTV, and borrowers' income of the high LTI loans change differentially for the constrained banks after the regulation. For these regressions, the dependant variables ($\log(\text{Loan Size})_{i,l,b,t}$, $\text{LTV}_{i,l,b,t}$, and $\log(\text{Borrower Income})_{i,l,b,t}$) are regressed on $\text{Post}_t \times \text{Constrained}_b$ in the sub-sample of high LTI loans while including all the controls described in Equation 1.

Redistribution of high LTI loans across borrowers. We use Equation 3 to investigate the impact of the regulation on borrower income and age in the sub-sample of mortgages with $\text{LTI} \geq 4.5$. We classify mortgages into income- and age-quintiles based on the distribution of reported income and age of borrowers of all mortgages issued during 2012Q3-2014Q2 (i.e. before the introduction of the regulation) and assign them a dummy $\mathbb{D}(\text{Inc/Age} = j)$, where $j \in \{1, 2, 3, 4, 5\}$. For each individual i, we use information on the location of the underlying property to position them in

[24] The estimated coefficient does not confound the effects of 'affordability tests' implemented along with the lender-level restriction on high LTI lending. As per these tests, UK lenders must assess the affordability of each mortgage issued to ensure that borrowers could still afford the mortgage if the Bank rate were to increase by 300 basis points (stress rate) within 5 years of the origination of the mortgage. However, these tests had already been introduced by the FCA in 2012 and UK lenders were using stress tests of 250-300 basis points when the 2014 regulation were introduced. See Bank of England (2014), Box 5 for details.

their corresponding quintile j based on the income- or age-distribution of all mortgages issued at a regional level. We use a localized distribution, rather than say the national distribution, to account for regional differences across the UK.[25]

The estimated $\beta_{Inc/Age,j}$ reflects the change in the share of the borrower-quintile j (in income or age) in high LTI mortgages issued by constrained lenders in Post_t periods.

$$\mathbb{D}(\text{Inc/Age}=j)_{i,l,b,t} = \beta_{Inc/Age,j} \cdot \text{Post}_t \times \text{Constrained}_b + \gamma_1 \cdot X_{b,t} + \gamma_2 \cdot X_{i,l,b,t} + f_{l,t} + f_{l,b} + \varepsilon_{i,l,b,t} \quad (3)$$

To test the parallel-trends assumption underlying equations Equation 1 and Equation 3, we regress the dependant variables on Constrained_b interacted with the full set of time-dummies to test whether the estimated coefficients in periods *before* the introduction of the regulation are 0.

Extensive and intensive margin. We analyse credit substitution since the regulation is on UK lenders and not on households: borrowers who could not receive high LTI loans from more-constrained banks (i.e. low-income borrowers) could either receive a loan with LTI < 4.5 from those banks or obtain a loan from a less-constrained bank. To study the net effect of these two substitution channels, we aggregate lending data at a quarterly×local area×borrower-income level, and use a triple difference-in differences specification (Equation 4) to check whether the regulation has an overall effect on lending to low-income borrowers at the extensive (number of mortgages) and intensive (total £ value of mortgages) margins in local areas more exposed to the constrained lenders after the regulation.

First, we calculate the share of mortgages issued by the constrained lenders a year before the introduction of the regulation—i.e. during 2013Q3-2014Q2—in a given local area (ConstrShare_l, in percentages). Next, we aggregate lending by volume and value at a quarterly×local area×income-band (5 quintiles) level. We estimate Equation 4 regressing the total number (extensive margin) or total £ value (intensive margin) of mortgages aggregated by quarter×local area×income-quintile on $\text{Post}_t \times \text{ConstrShare}_l \times \mathbb{D}(\text{Inc}=1)$, where ConstrShare_l is as described earlier and $\mathbb{D}(\text{Inc}=1)$ is a dummy variable which indicates lending to low-income borrowers (i.e. borrowers in the bottom

[25]The income and age quintile classification is based on all mortgages issued at the Local Administrative Unit 2 (LAU2) level. There are 40 LAU2 regions in the UK. LAU2 is at a higher level than LAU1, the level at which we aggregate lending data in Section 4.3. The main reason for using LAU2 instead of the more granular LAU1 level to classify borrowers into their income- or age-quintiles is the presence of very few mortgages for some local areas at the LAU1 level in Pre_t periods to generate reliable quintile thresholds.

income-quintile).

$$\log(\mathbb{L}_{l,j,t}) = \beta_{Inc} \cdot \text{Post}_t \times \text{ConstrShare}_l \times \mathbb{D}(\text{Inc=1}) + f_{l,j} + f_{j,t} + f_{l,t} + \varepsilon_{l,j,t} \tag{4}$$

The coefficient β_{Inc} reflects the impact of the regulation on lending to borrowers in the bottom income-quintile in local areas with a higher exposure to constrained banks. We saturate the specification with local area×time ($f_{l,t}$), local area×income-quintile ($f_{l,j}$), and income-quintile×time ($f_{j,t}$) fixed-effects. This allows for strong identification since we control for factors that may impact borrowers in a specific income group or specific local areas at a given time, such as a demand shock common to low-income groups or local areas in Post_t periods. We report standard errors clustered at the local-area level.

To test the parallel-trends assumption underlying Equation 4, we regress the lending data on $\text{ConstrShare}_l \times \mathbb{D}(\text{Inc=1})$ interacted with the full set of time-dummies to test whether exposure to the constrained lenders explains lending to low-income borrowers only in periods after the introduction of the regulation.

House price growth. We use the specification described in Equation 5 to analyse the effect of the policy on house prices. The dependent variable is the annual change in the logarithm of house prices in local area l at *half-year* t. Local house prices are based on the 25th, 50th (median), and 75th percentile of all housing transactions in local area l at time t. We use half-years, rather than quarters, in order to reduce noise since some local areas have a limited number of transactions in a given quarter. We study the period from 2012H2 to 2018H1.

$$\begin{aligned}\Delta \log(\text{P}_{l,t}) = \beta_{pol} \cdot \text{Post}_t \times \text{Constr}_l \times \text{LowInc}_l + \beta_{ref} \cdot \text{BrexitRef}_t \times \text{Constr}_l \times \text{LowInc}_l \\ + \gamma_1 \cdot \text{Post}_t \times \text{Constr}_l + \gamma_2 \cdot \text{Post}_t \times \text{LowInc}_l + \gamma_3 \cdot \text{BrexitRef}_t \times \text{Constr}_l \\ + \gamma_4 \cdot \text{BrexitRef}_t \times \text{LowInc}_l + f_l + f_{r,t} + \varepsilon_{l,t}\end{aligned} \tag{5}$$

We regress the dependent variable on two triple-interaction terms. The first is $\text{Post}_t \times \text{Constr}_l \times \text{LowInc}_l$, where Post_t is a dummy variable which indicates periods from 2014H2 onwards, Constr_l indicates local areas where the market share of constrained lenders before the policy (i.e. ConstrShare_l described in Equation 4) is greater than the median share, and LowInc_l indicates local areas where the share of mortgages received by low-income borrowers is above the 75th percentile.[26] The interaction between Constr_l and LowInc_l captures local areas more affected by the regulation, i.e. those with a higher share of constrained lenders *and* a substantial number of low-income borrowers. Figure 6 shows the spatial distribution of the affected local areas in a map of the UK; the affected local areas are not concentrated in a specific region of the UK. The coefficient β_{pol} reflects whether house price growth changes in local areas more affected by the regulation.

The second triple-interaction is $\text{BrexitRef}_t \times \text{Constr}_l \times \text{LowInc}_l$, where BrexitRef_t indicates periods after the Brexit referendum in the UK, i.e. from 2016H2 onwards. The coefficient β_{ref} reflects whether house price growth is different in local areas more affected by the policy after the Brexit referendum.

We add local area (f_l) and region×time ($f_{r,t}$) fixed-effects in the specification. Local area fixed-effects control for time-invariant heterogeneity across local areas that could affect house prices. Region×time fixed-effects control for shocks to the housing market specific to the regions in the UK—i.e., we compare local areas with different exposures to constrained lenders within a particular region. This means that our results cannot be driven by, for instance, a differential impact of the referendum on housing markets in London vs. Wales.

Robustness of house price growth. We explore the robustness of the house price results in three different ways. First, our dependent variable is constructed from the distribution of all housing transactions in a given local area at a given period, and thus compares different types of properties. In particular, certain types of properties might be more exposed to the cycle and, at the same time, be correlated with the income level of borrowers and banks' market share. For instance, the price of new houses might be more volatile and, since it tends to be higher than the price of old houses, new houses might be more common in higher-income local areas (and this could be different for constrained banks). To tackle this issue, we run Equation 5 but taking the prices from housing transactions of similar types of houses.

We employ eight different types (disjoint sets are separated by commas; different categories by semi-colons): semi-detached, terraced, detached, flats; old and new; freehold and leasehold. Semi-

[26] Results reported in Table 7 and Table 11 are significant when we classify local areas in the top tercile or the top 2-quantile of the share of mortgages received by low-income borrowers as LowInc_l. Online Appendix Figure A.3 shows that there is sufficient cross-variation between share of mortgages issued by constrained UK lenders and the share of mortgages issued to low-income borrowers across local areas—a factor essential for identification using the specification described in Equation 5.

detached houses share one common wall with a neighbouring house, terraced houses share two common walls with neighbouring houses, and detached houses do not share any common wall with other properties. Freehold transactions entail the ownership of both the property and the land, while leasehold transactions entail the ownership of the property only, with a lease of finite—but usually long—maturity for the land.

The second way we test the robustness of our results is by taking into account housing supply constraints in local areas. While we use local area and region x time fixed effects, local areas might differ in their geographical characteristics, making them more or less exposed to the housing cycle. Hilber and Vermeulen (2016) show that regulatory constraints in terms of new developments and geography play a role in the elasticity of house prices with respect to income, and this role varies through the cycle. In particular, house prices increase more following a positive income shock in areas with tighter housing supply constraints. In order to control for the possibility that our results are confounded by this effect, we interact the three supply constraint variables described in Hilber and Vermeulen (2016) with Post_t and BrexitRef_t, and include them as additional controls:[27] Refusal rate_l is the average refusal rate of major residential projects by the local authority during the years 1979-2008; % developed_l is the percentage of developable land that was developed by 1990; Range_l is the logarithm of the difference between the highest and lowest altitude, in meters. The first variable captures regulatory constraints to the expansion of housing supply; the second variable captures the amount of land available to increase housing supply; the third variable captures geographical constraints in terms of uneven topography.

The third way we test the robustness of our results is by running a placebo on the 2007-08 financial crisis. Even if we control for observable characteristics related to building regulatory constraints and geography, there could be unobservable local-area characteristics that make house prices behave differently in booms and busts. We run the specification described in Equation 5 using house price growth around the 2007-08 financial crisis (i.e., a different house price cycle) to test whether unobserved local-area characteristics might account for local house price behaviour during busts. As shown in Figure 10, there is a significant change in house price growth across the UK during that period. As shown by the verticle dashed lines, we define the boom period as 2005-06

[27] The sources and more information about the variables can be found in Hilber and Vermeulen (2016) Appendix A.

and the bust period as 2007-08 (Post_t) to mimic the 2-year length from the main regressions. The dummy variables identifying local areas with more constrained banks (by the 2014 macroprudential policy) and more low-income borrowers are identical to the main regression.

Mortgage performance. We also test whether there is a change in mortgage non-performance rates in affected local areas (those with ex-ante high exposure to constrained lenders and higher concentration of low-income borrowers) after the Brexit referendum.

We use the *stock* data on mortgages to create a database of the proportion of non-performing mortgages in a given local area in the UK over time. A mortgage is classified as being non-performing in case it has a payment shortfall, it is under forbearance, or if it has a possession order.[28] These three criteria form three disjoint sets which together form the set of distressed or non-performing loans.

Table 1 (A) shows the summary statistics of the proportion of mortgages with a payment shortfall, under forbearance, and with a possession order at a local-area level over time. UK local areas have roughly 1.8% of mortgages with a payment shortfall at any given point in time. The total share of non-performing loans is 4.8%. These summary statistics are based on such shares for six periods for each local area—2015Q2 (i.e., end of June 2015), 2015Q4 (i.e. end 2015), 2016Q2, 2016Q4, 2017Q2 and 2017Q4.[29] Thus we have 3 observations before the Brexit referendum result and 3 observations post-referendum for the 415 local areas in our sample.

We study the evolution of mortgage non-performance rates in the form of payment shortfalls and forbearance using a modified version of Equation 5 (described below) since, unlike the data for house price growth, we do not have data on mortgage performance at a local-area level before the introduction of the mortgage regulation.

$$\begin{aligned} \text{NP}_{l,t} &= \beta^{np}_{ref} \cdot \text{BrexitRef}_t \times \text{Constr}_l \times \text{LowInc}_l \\ &+ \gamma_1 \cdot \text{BrexitRef}_t \times \text{Constr}_l + \gamma_2 \cdot \text{BrexitRef}_t \times \text{LowInc}_l + f_l + f_{r,t} + \varepsilon_{l,t} \end{aligned} \tag{6}$$

[28] Forbearance refers to mortgages that have received modified terms from lenders after a long period of remaining under arrears. A mortgage under forbearance may have received one of 7 different types of modified terms—payment shortfall arrangement; payment shortfall capitalisation; switch to interest only; payment suspended; reduced payments; term extension; and other forbearance. In June 2016, mortgages with a payment shortfall are, on an average, under arrears for 6 months; mortgages under forbearance have been under arrears for, on an average, 22 months.

[29] PSD007 data—or the stock of mortgages in the UK—has been reported half-yearly since 2015. PSD007 is based on regulatory reports submitted to the Financial Conduct Authority by individual lenders.

$NP_{l,t}$ is the mortgage non-performance rate (payment shortfall or forbearance) in local area l at time t. The rest of the variables are as defined in Equation 5. β^{np}_{ref} reflects the differential rates of mortgage non-performance in the affected local areas (i.e. $\text{Constr}_l \times \text{LowInc}_l$) after the Brexit referendum.

4 Empirical Results

4.1 Share of high LTI mortgages

Table 2 (A) presents estimates of the coefficient β described in Equation 1 using loan-level data. The negative and significant estimate of the coefficient β suggests that constrained lenders reduce mortgages with high loan-to-income ratios (LTI) in the aftermath of the regulation. The coefficient is highly robust to the inclusion of different set of controls. In column 1, we use the full sample with no controls. In columns 2-6, we restrict the sample to those observations for which the full set of control variables contain non-missing values.[30] The coefficient is highly significant and stable as we add borrower and loan-controls (column 3), bank×time controls (column 4), local area×time FE (column 5), and local area×bank FE (column 6). In column 6, which includes all the controls mentioned earlier, the coefficient indicates that the share of high LTI mortgages in the portfolio of constrained lenders drops by roughly 3.9% in the aftermath of the regulation. We include Post_t and Constrained_b as standalone variables when they are not absorbed by fixed-effects; estimated coefficients for either variable is positive and smaller in magnitude than the coefficient estimated on $\text{Post}_t \times \text{Constrained}_b$.

Figure 3 plots the coefficients obtained by regressing the dependant variable on the dummy for constrained lenders interacted with the full set of time-dummies (except 2014Q2, the reference time period) and the controls described in Equation 1. The resulting coefficients are negative and significant *only* in periods after the introduction of the regulation. The coefficients in Pre_t periods are quantitatively and statistically not different from 0, consistent with the parallel-trends assumption underlying Equation 1.

Table 2 (B) shows the estimates of the coefficient β_{rate} described in Equation 2. As in Table

[30] The sample size decreases from 2.9 million to 1.8 million when all controls are included. This drop is primarily due to missing observations for loan-level controls described in Online Appendix A.1.

2 (A), we progressively saturate the specification with additional controls and fixed effects. In the most saturated specification, in column 6, β_{rate} is positive and significant, which shows that the constrained lenders charge a higher (on average, by 14 bp) interest rate for high LTI loans issued by them in periods after the introduction of the regulation.

4.2 Composition of high LTI mortgages

Next, we investigate whether constrained lenders change the composition of their high LTI mortgages in response to the regulation. First, we test whether there is a change in the unregulated size and loan-to-value ratio (LTV) of high LTI mortgages. Then, we check whether there is a change in the income or age composition of borrowers receiving high LTI mortgages. This latter point shows whether the contraction in high LTI lending by constrained lenders might disproportionately affect some borrower cross-sections.

Size, LTV, and income of high LTI mortgages. We use the regression specification described in Equation 1 with dependent variables log (Loan size), LTV, and log (Borrower Income) in a sub-sample of mortgages with LTI $\geq$ 4.5 (around 150 thousand mortgages). The estimate β shows changes in these alternate dependant variables in the portfolio of high LTI mortgages issued by the constrained lenders after the regulation.

As we see in Table 3 (A), average loan size of high LTI mortgages issued by constrained lenders is roughly 9% larger in periods after the introduction of the regulation. In a similar vein, constrained lenders issue high LTI mortgages with 1.8 percent point higher LTV ratio (Table 3 (B), column 6) in Post_t periods. Thus, while constrained lenders issue fewer high LTI mortgages after the introduction of the regulation, those loans are larger in size and have a higher LTV. These results suggest that lenders increase unregulated aspects of their high LTI mortgage portfolio after the regulation. We further elaborate on the effect of the regulation on the unregulated parts of the LTI distribution with a discussion on the overall changes in the LTI distribution of mortgages issued by constrained lenders in Section 4.5.

Table 3 (C) further shows that average borrower incomes are 11.5% higher in high LTI mortgages issued by constrained lenders in Post_t periods. These results lead us to investigate whether the contraction in high LTI lending by constrained lenders have a disproportionate impact on any specific borrower cross-sections such as low-income and/or younger borrowers.

The results presented so far use a specification which distinguishes more-constrained and less-constrained lenders using an indicator variable. Results are robust to directly interacting the lender-specific share of high LTI loans in the total mortgage portfolio with Post_t as an alternate, continuous explanatory variable (see Online Appendix E).

Redistribution of high LTI loans across borrowers. We regress dummies indicating borrowers in the lowest quintile in terms of income or age (as described in Section 3) on the set of controls described in Equation 3 in the sub-sample of loans with LTI ≥ 4.5. The coefficient β_j (on $\text{Post}_t \times \text{Constrained}_b$, where j refers to low-income or young borrowers) reflects the change in the share of the borrower-type j in the sub-sample of high LTI loans issued by constrained lenders in Post_t periods.

Table 4 (A) highlights a stark change in the distribution of borrower-incomes in high LTI loans issued by constrained lenders in Post_t periods. Column 1 shows that constrained lenders decrease the share of high LTI loans issued to borrowers in the lowest income-quintile by 5.2%. This decline is matched by an increase in the proportion of high LTI loans obtained by borrowers in the highest income-quintile (column 5). Interestingly, Table 4 (B) shows that there was no change in the age composition of high LTI mortgages issued by constrained lenders in Post_t periods. This shows that the contraction in high LTI loans by constrained lenders had a stronger effect on low-income borrowers. They are affected by both the reduction in the share of high LTI loans (which they are more likely to borrow) and the drop in their share *within* high LTI loans issued by constrained lenders after the regulation. This result is also consistent with the increase in the average size of high LTI loans issued by constrained lenders reported in Table 3 (A).

However, low-income borrowers receiving fewer high LTI loans from constrained lenders may not reflect an aggregate effect. For instance, such borrowers may receive smaller loans (with LTI<4.5) from the constrained lenders or obtain mortgages with high LTI from unconstrained lenders. We find some evidence of the former channel in the results reported in Table 5 (A). We regress the dummy indicating low-income borrowers ($\mathbb{D}(\text{Inc}=1)$) on $\text{Post}_t \times \text{Constrained}_b$ in different sub-samples of LTI groups. While the share of lowest income-quintile borrowers drops in the sample of high LTI loans issued by constrained lenders after the regulation (Table 5 (A), column 5),[31] it expands in the rest of the LTI groups (columns 1-4). In particular, the expansion is stronger in the

[31] This is the same regression as in Table 4 (A), column 1.

sample of mortgages with LTI just below the 4.5 threshold (Table 5 (A), column 4).[32]

Table 5 (B) further shows that unconstrained lenders also substitute for the contraction in high LTI lending to low-income borrowers by constrained lenders. We regress the dummy indicating low-income borrowers ($\mathbb{D}$(Inc=1)) on $\text{Post}_t \times \text{Unconstrained}_b \times \text{ConstrShare}_l$ in different sub-samples of LTI groups. Unconstrained_b is a dummy for the unconstrained lenders and ConstrShare_l is the market share of *constrained* lenders in the mortgage market in local area l. Column 5 in Table 5 (B) reports a positive and statistically significant coefficient on $\text{Post}_t \times \text{Unconstrained}_b \times \text{ConstrShare}_l$ in the sub-sample of loans with LTI ≥ 4.5. This shows that there is an increase in the proportion of loans obtained by low-income borrowers in high LTI loans issued by unconstrained lenders in Post_t periods in areas more exposed to *constrained* lenders.

4.3 Lending to low-income borrowers

What is the net effect on lending to low-income borrowers of the contraction in high LTI lending by constrained lenders and any possible substitution for this contraction by the two channels described above? To address this question, we aggregate lending by both constrained and unconstrained lenders at the local area×borrower income-quintile×quarter level. We use this aggregate data and the saturated regression specification described in Equation 4 to test whether low-income borrowers in local areas more exposed to the constrained lenders experience any change in lending at the extensive (number of loans) or the intensive (value of loans) margin after the regulation.

The coefficient β_{Inc} estimated for the total volume of lending in Table 6 (A) is negative and highly significant.[33] This suggests that there is a contraction in the volume of loans to borrowers in the lowest income-quintile in local areas more exposed to constrained banks in Post_t periods. Similarly, the estimated coefficient for the total value (or £ amount) of lending is -0.0173 (Table 6 (B)) and highly significant. The estimated coefficients are robust; a lower-bound for these coefficients calculated accounting for unobserved local-area heterogeneity—and using the technique described in Altonji et al. (2005) and Oster (2019)—is remarkably close to the actual coefficients.

[32] The coefficients in Table 5 (A) do not suggest that the increase in the share of loans with LTI < 4.5 going to low-income borrowers perfectly substitute for the drop in high LTI lending by constrained lenders. The reduction in high LTI lending to low-income borrowers by constrained lenders is driven by both the reduction in the share of such borrowers in their high LTI portfolio, *and* the drop in the size of this portfolio itself. We address the net effect on lending to low-income borrowers in Section 4.3.

[33] The lending data is aggregated at the level of 3-digit administrative units (LAU1). See Section 3.2, particularly *Extensive and intensive margin*, for details.

The estimated coefficients show that borrowers in the bottom income-quintile in local areas with a one standard deviation higher pre-shock share of constrained lenders experience a 9.0% drop in the number of mortgages and a 11.4% drop in the £ amount of mortgages in Post_t periods.

Figure 5 shows coefficients from regressing the aggregated lending data on $\text{ConstrShare}_l \times \mathbb{D}(\text{Inc=1})$ interacted with the full set of time-dummies. The estimated coefficients are zero in periods *before* 2014Q3 and show a contraction in the amount of lending to low-income borrowers only in periods *after* 2014 Q3. These time-varying coefficients are consistent with the parallel-trends assumption underlying Equation 4.

4.4 House prices and mortgage defaults in affected local areas

We explore whether the constraint on high LTI mortgage lending has an effect on house prices and mortgage performance. Macroprudential policy is a tool to "lean against the wind" in order to smooth the credit cycle. We investigate this hypothesis by studying whether the policy leads to lower house price growth during a boom and, consequently, lower house price correction during a bust.

The Brexit referendum in June 2016 allows us to examine the effect of a macroprudential policy during a bust period as there was a house price correction across the UK following the vote. We use this unexpected shock to test whether the policy had an effect on house prices and mortgage performance in local areas more affected by the regulation, potentially alleviating the effects of the mild bust in house prices following the referendum.

4.4.1 House price growth

The coefficients of interest—β_{pol} and β_{ref} in Equation 5—correspond to the triple interactions between Constr_l, LowInc_l, and the dummies for the post-policy (Post_t) and post-referendum (BrexitRef_t) periods. These interactions explore whether house prices of local areas with a high presence of constrained banks and low-income borrowers behave differently after the introduction of the policy and the Brexit referendum. To shut down other potential channels, we saturate the specification with local authority (f_l) and region×time ($f_{r,t}$) fixed effects.[34]

[34]These regions are: East, East Midlands, London, North East, North West, South East, South West, Wales, West Midlands, and Yorkshire and the Humber.

Figure 1 shows the actual aggregate trends for annual (median) house price growth for England and Wales during 2012Q3-2018Q1, the period relevant to our study. There is an increasing trend since 2013Q3, peaking at around 7.5% in the quarter before the EU referendum. After the referendum, however, the trend completely reverses and, in just one quarter, growth falls by 2 percentage points and continues to fall afterwards.

Table 7 reports results based on Equation 5. In columns 1-3, the dependent variable is the annual change in the 25th percentile of house price transactions at a local-area level. In column 1, we use only time fixed-effects. The coefficient β_{pol} is negative, as well as statistically and economically significant. After the policy is introduced, local areas with high shares of constrained banks and low-income borrowers ("affected local areas") experience a 1.5 percentage points lower house price growth. The average price growth during this period is 6.8%, so the effect is sizable. This result is consistent with our previous evidence that the limit to high-LTI mortgages leads to a decline in mortgage supply, particularly to low-income borrowers. This supply shock particularly affects the lower-end of housing transaction prices.

The coefficient β_{ref}, on the other hand, is positive, and statistically and economically significant. Post-referendum and in the middle of a correction in house price growth, affected local areas experience a higher growth in house prices. The magnitude of the effect—$\beta_{pol} + \beta_{ref}$—is 1.34% and statistically significant (p-value-6.9%). This result is consistent with the objective of such macroprudential interventions: restricting leverage during a boom leads to lower correction in price growth following a bust.

The coefficients of the triple interactions are fairly stable as we add local area and region×time fixed-effects in the second and third columns. In the most saturated specification (column 3), the coefficients imply a 1.35 percentage points lower growth post-policy, and a 1.26 percentage points higher growth after the referendum.

We test the timing of the changes by plotting the coefficient of the interaction between Constr_l and LowInc_l over time. To do so, we use the specification in column 3 but interact the two variables with time (half-year) dummies. The coefficients are plotted in Figure 7. Before the introduction of the policy (first vertical dotted line) the coefficients are centred around 0, which alleviates pre-trend concerns. After the policy is introduced, the coefficient becomes negative until the referendum (second vertical dotted line). After the referendum, the coefficients are positive.

We compare these results to those based on the middle- and upper-end of the distribution of house price transactions. We expect estimates of β_{ref} based on these alternate house prices to be weaker—consistent with the effect of the policy on lending to low-income borrowers and hence the lower-end of house prices. This analysis could also rule out the possibility that the shock to house price growth after the referendum is correlated with other shocks in affected local areas: if that were the case, estimates of β_{ref} would be similar irrespective of house prices being drawn from the lower, mid or upper-end of housing transactions.

Columns 4-6 of Table 7 show the results when using the change in the median price as our dependent variable. The magnitude of the coefficients is significantly lower, and in particular the effect of the policy is insignificant. In columns 7-9 of Table 7, we use the 75th percentile of the distribution of house prices to calculate the house price growth in each local area. The coefficient for the triple interaction during the period after the referendum is positive, although substantially smaller in size and not statistically significant.

4.4.2 House price growth: Robustness tests

We report multiple robustness tests for the house price results. The first test analyses house price growth for similar types of houses (results are shown in Table 8). The first four columns in Table 8 show the results of the most-saturated regression for the 25th percentile of local house prices for four different types of houses: semi-detached (27.1% of all transactions), terraced (28.6%), detached (24.9%), and flats (19.4%). Since we are using substantially fewer transactions to calculate the moments for local house prices for each house type separately, we expect the dependent variable to be more noisy.

The results for semi-detached and terraced houses (columns 1 and 2) are positive and significant, with an almost identical coefficient. The coefficients of the triple interaction with BrexitRef_t are quantitatively similar except for detached houses (column 3), where it is substantially smaller. The coefficient for flats (column 4) is positive but not significant, although this is mainly driven by much larger standard errors. These results are consistent with the policy affecting lower-income borrowers more, since, on average, the 25th percentile transaction price for detached houses is significantly higher than that for semi-detached and terraced houses.

We report separate estimated coefficients for old (used) and new properties in columns 5 and

6. Old properties comprise over 89% of all housing transactions. The coefficients for old houses in both triple interactions (bust and post-policy) are slightly stronger than in the main specification, thus suggesting that new properties are not driving the results. Differently, for new properties, the coefficients are not significant. All these results are therefore consistent with our interpretation since results are insignificant for more expensive houses (new and detached). Finally, in columns 7 and 8, we split the sample between freehold and leasehold transactions. Freehold properties comprise three-quarters of all transactions. The results are qualitatively similar to the main findings.

Further, we test the robustness of our results by taking into account housing supply constraints in local areas. The results are shown in Table 9. The results of the coefficients of interest are consistent with the main results; if anything, they are now stronger in magnitude.[35,36]

The third way we test the robustness of our results is by running a placebo on the 2007-08 financial crisis. The dummy variables identifying local areas with more constrained banks (by the 2014 policy) and more low-income borrowers are identical to the main regression. The results are presented in Table 10. We find no effect for this period, which suggests that the main results are not driven by unobserved local-area characteristics interacting with house price trends during busts. In particular, the coefficients for the 25th percentile are an order of magnitude smaller, and hence the non-significance is not driven by an increase in standard errors.

4.4.3 Mortgage performance

Columns 1-3 in Table 11 show that the coefficient on $\text{Ref}_t \times \text{Constr}_l \times \text{LowInc}_l$ using the data on proportion of mortgages with a payment shortfall at a local-area level is negative and significant. The estimated coefficient suggests that local areas with a higher share of constrained lenders *and* a higher share of low-income borrowers experienced a 0.064% lower rate of payment shortfall in the aftermath of the Brexit referendum. This is approximately a 4% decline from the average payment shortfall rate across UK local areas.

These results show that the affected local areas (i.e. local areas with greater presence of both

[35] The coefficient for the double interactions of Refusal rate_l are consistent with the previous literature: higher restrictions are associated with higher price volatility. In particular, prices grow by more during the boom phase (Post_t) and by less during the correction (BrexitRef_t).

[36] In unreported regressions, we also add triple interactions for each of the three housing supply constraint variables with LowInc_l and $\text{Post}_t/\text{BrexitRef}_t$; our coefficient of interest (the one estimated for $\text{BrexitRef}_t \times \text{Constr}_l \times \text{LowInc}_l$) remains positive and significant.

constrained lenders and low-income borrowers, which experience a contraction in lending as a result of the regulation) not only experience a relatively lower drop in house price growth post-Brexit referendum, but also relatively lower rates of mortgage non-performance rates. Figure 8 (A) shows that the estimated coefficient on the dummy for affected local areas ($\text{Constr}_l \times \text{LowInc}_l$) interacted with half-yearly time-dummies is significant *only* in periods after the Brexit-referendum, i.e. after 2016Q2.

However, we observe this lower mortgage non-performance rate primarily in terms of payment shortfall; the result showing changes in rates of mortgages under forbearance in affected local areas is less robust (columns 4-6 in Table 11). Figure 8 (B) shows that the proportion of mortgages under forbearance in affected local areas in periods after the Brexit-referendum are not statistically different from the proportion before 2016Q2. As noted earlier, mortgages undergo forbearance only after remaining under arrears for a long duration. It is possible that our sample on mortgage non-performance (until 2018Q2) is not long enough to pick up changes in forbearance rates in affected local areas after the Brexit referendum.[37]

4.5 Overall changes in the LTI distribution of lenders

We now discuss the effect of the regulation on the overall LTI distribution of mortgages issued by constrained and unconstrained lenders. Figure 9 (A) shows the LTI distribution of the mortgages in periods before (2012Q3 - 2014Q2) and after (2014Q4 - 2016Q2) the introduction of the regulation in colours blue and red for constrained (left panel) and unconstrained banks, respectively. The LTI distribution of mortgages issued by the constrained banks shows a clear shift to the right in Post_t periods, with an increase in the mass of mortgages with LTI close to and below 4.5. We use a counterfactual distribution estimation technique to provide a breakdown of the changes in the LTI distribution between Pre_t and Post_t periods attributable to the regulation and to changes in the underlying distribution of covariates plausibly unrelated to the regulation.

We use the technique described in Chernozhukov et al. (2013) to estimate a counterfactual LTI distribution for Post_t periods for the two lender groups. As per the technique, we take the distribution of covariates (bank×time, borrower, and loan controls described in Online Appendix

[37] This also applies to mortgages with a possession order; default rates using possession orders do not undergo a relative change in affected local areas after the Brexit referendum.

Table A.1) in periods after the introduction of the regulation (Post_t periods) and estimate a counterfactual LTI distribution based on the likelihood of obtaining a LTI for a given combination of covariates in periods before the introduction of the regulation (Pre_t periods). We use the estimated counterfactual to provide a breakdown of the changes in quantiles of the LTI distribution between Pre_t and Post_t periods attributable to changes in covariates and to the regulation, the so-called Oaxaca-Blinder decomposition (Figure 9 (B)).

Figures 9 (B) (i) and (ii) show the Oaxaca-Blinder decomposition for the constrained and unconstrained banks, respectively. The decomposition is based on a breakdown of the total change (solid line) in the quantiles of the LTI distribution into two driving forces—changes in underlying covariates (dotted line) and the effect of the regulation (dashed line).[38] Figure 9 (B) (i) shows that changes in LTI quantiles for the constrained banks in Post_t periods are largely attributable to the regulation; the changes driven by differences in underlying covariates is quantitatively a lot smaller, and consistently so across the different quantiles. On the other hand, changes in the quantiles of the LTI distribution for unconstrained banks in Figure 9 (B) (ii) are largely explained by the changes in underlying covariates. The effect of the regulation on the LTI quantiles of unconstrained banks is estimated to be close to 0.

5 Conclusion

We analyse the distributional effects of macroprudential policy on mortgage and house price cycles, thereby showing costs and benefits of macroprudential policy. To the best of our knowledge, this is the first paper which studies the effects of changes in macroprudential policy on household leverage during *both boom and bust periods*. For empirical identification, we use the UK mortgage register in conjunction with a 15% cap on the proportion of new mortgages with high loan-to-income ratios (LTI $\geq$ 4.5) imposed in 2014 on UK mortgage lenders. These lenders are differentially affected based on their pre-policy share of high LTI loans in their mortgage portfolio. Moreover, we exploit the unexpected outcome of the Brexit referendum, that led to a house price correction across the UK, to analyse the effects of macroprudential policy implemented during a boom in a subsequent

[38] A simple way to understand the decomposition is that the effect of changes in covariates is equal to the differences between the estimated counterfactual and the Pre_t period LTI distribution; differences between the Post_t period and the estimated counterfactual LTI distribution show the effect of the regulation.

bust.

Our robust results show that more-constrained lenders issue fewer and more expensive high-LTI mortgages. There is also regulatory arbitrage post-regulation as more-constrained lenders increase the unregulated loan-to-value ratios (LTV) and average loan size of high LTI mortgages, and disproportionately raise the mass of mortgages with LTI close to and below the 4.5 threshold. The regulation has a stronger effect on lending to low-income households who are affected by both the reduction in high LTI loans (which they are more likely to borrow) and the drop in their share *within* high LTI loans issued by constrained lenders after the regulation.

Even though the regulation is on lenders (and not households), substitution by less-constrained lenders is partial and leads to overall credit contraction to low-income households in areas more exposed to the more-constrained lenders. This implies dampening of house price growth in local areas with a higher share of these constrained lenders *and* a higher share of low-income borrowers in periods after the introduction of the regulation, but before the Brexit referendum. Finally, our robust results suggest that the 2014 macroprudential policy leads to significantly lower house price correction and mortgage default rates during the bust.

References

Acharya, Viral V, Katharina Bergant, Matteo Crosignani, Tim Eisert, and Fergal McCann (2019). "The Anatomy of the Transmission of Macroprudential Policies: Evidence from Ireland". *NBER Working Paper No. 27292*.

Adelino, Manuel, Antoinette Schoar, and Felipe Severino (2016). "Loan originations and defaults in the mortgage crisis: The role of the middle class". *Review of Financial Studies* 29.7.

Agarwal, Sumit, Efraim Benmelech, Nittai Bergman, and Amit Seru (2012). "Did the Community Reinvestment Act (CRA) lead to risky lending?" *NBER Working Paper No. 18609*.

Aladangady, Aditya (2017). "Housing wealth and consumption: Evidence from geographically-linked microdata". *American Economic Review* 107.11.

Altonji, Joseph G, Todd E Elder, and Christopher R Taber (2005). "Selection on observed and unobserved variables: Assessing the effectiveness of Catholic schools". *Journal of Political Economy* 113.1, pp. 151–184.

Auclert, Adrien (2019). "Monetary policy and the redistribution channel". *American Economic Review* 109.6.

Autor, David H and David Dorn (2013). "The growth of low-skill service jobs and the polarization of the US labor market". *American Economic Review* 103.5.

Autor, David H, David Dorn, and Gordon H Hanson (2013). "The China syndrome: Local labor market effects of import competition in the United States". *American Economic Review* 103.6.

Badarinza, Cristian, John Y Campbell, and Tarun Ramadorai (2016). "International comparative household finance". *Annual Review of Economics*.

Bank of England (2014). "Financial Stability Report (June)".

— (2017a). "Financial Stability Report (June)".

— (2017b). "Financial Stability Report (November)".

Bekkum, Sjoerd van, Marc Gabarro, Rustom M Irani, and José-Luis Peydró (2019). "Macroprudential policy and household leverage: Evidence from administrative household-level data". *CEPR Discussion Paper No. 13503*.

Belgibayeva, Adiya (2020). "Changes in the mortgage market post 4.5 limit on loan to income ratios". *FCA Occasional Paper*.

Benetton, Matteo (2018). "Leverage regulation and market structure: An empirical model of the uk mortgage market". *SSRN Working Paper No. 3247956*.

Berg, Tobias, Anthony Saunders, Larissa Schafer, and Sascha Steffen (2019). "Brexit and the contraction of syndicated lending". *SSRN Working Paper No. 2874724*.

Bhutta, Neil and Benjamin J Keys (2016). "Interest rates and equity extraction during the housing boom". *American Economic Review* 106.7.

Bhutta, Neil, Jane Dokko, and Hui Shan (2017). "Consumer ruthlessness and mortgage default during the 2007 to 2009 housing bust". *Journal of Finance* 72.6.

Bloom, Nicholas, Philip Bunn, Scarlet Chen, Paul Mizen, Pawel Smietanka, and Gregory Thwaites (2019). "The impact of Brexit on UK firms". *NBER Working Paper No. 26218*.

Born, B, GJ Muller, M Schularick, and P Sedlacek (2019). "The costs of economic nationalism: Evidence from the Brexit experiment". *Economic Journal* 129.623.

Broadbent, Ben, Federico Di Pace, Thomas Drechsel, Richard Harrison, and Silvana Tenreyro (2019). "The Brexit vote, productivity growth and macroeconomic adjustments in the United Kingdom". *External MPC Unit Discussion Paper no. 51*.

Campbell, John Y and João F Cocco (2007). "How do house prices affect consumption? Evidence from micro data". *Journal of Monetary Economics* 54.3.

Chaney, Thomas, David Sraer, and David Thesmar (2012). "The collateral channel: How real estate shocks affect corporate investment". *American Economic Review* 102.6.

Chernozhukov, Victor, Iván Fernandez-Val, and Blaise Melly (2013). "Inference on counterfactual distributions". *Econometrica* 81.6.

Corbae, Dean and Erwan Quintin (2015). "Leverage and the foreclosure crisis". *Journal of Political Economy* 123.1.

Crowe, Christopher, Giovanni Dell'Ariccia, Deniz Igan, and Pau Rabanal (2013). "How to deal with real estate booms: Lessons from country experiences". *Journal of Financial Stability* 9.3.

Davies, Ronald B. and Zuzanna Studnicka (2018). "The heterogeneous impact of Brexit: Early indications from the FTSE". *European Economic Review* 110.C.

Dávila, Eduardo and Anton Korinek (2017). "Pecuniary externalities in economies with financial frictions". *Review of Economic Studies* 84.4.

DeFusco, Anthony, Stephanie Johnson, and John Mondragon (2020). "Regulating household leverage". *Review of Economic Studies* 87.2.

DeFusco, Anthony A (2018). "Homeowner borrowing and housing collateral: New evidence from expiring price controls". *Journal of Finance* 73.2.

Di Maggio, Marco and Amir Kermani (2017). "Credit-induced boom and bust". *Review of Financial Studies* 30.11.

Faccini, Renato and Edoardo Palombo (2019). "News uncertainty in Brexit UK". *Working Paper.*

Farhi, Emmanuel and Iván Werning (2016). "A theory of macroprudential policies in the presence of nominal rigidities". *Econometrica* 84.5.

Favara, Giovanni and Jean Imbs (2015). "Credit supply and the price of housing". *American Economic Review* 105.3.

Favilukis, Jack, Sydney C Ludvigson, and Stijn Van Nieuwerburgh (2017). "The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium". *Journal of Political Economy* 125.1.

Fuster, Andreas and Paul S Willen (2017). "Payment size, negative equity, and mortgage default". *American Economic Journal: Economic Policy* 9.4.

Ghent, Andra C and Marianna Kudlyak (2011). "Recourse and residential mortgage default: Evidence from US states". *Review of Financial Studies* 24.9.

Greenwald, Daniel (2017). "The mortgage credit channel of macroeconomic transmission".

Guiso, Luigi, Paola Sapienza, and Luigi Zingales (2013). "The determinants of attitudes toward strategic default on mortgages". *Journal of Finance* 68.4.

Guren, Adam M, Alisdair McKay, Emi Nakamura, and Jón Steinsson (2018). "Housing wealth effects: The long view". *NBER Working Paper No. 24729.*

Hilber, Christian A. L. and Wouter Vermeulen (2016). "The Impact of Supply Constraints on House Prices in England". *Economic Journal* 126.591, pp. 358–405.

Igan, Deniz O and Heedon Kang (2011). "Do loan-to-value and debt-to-income limits work? Evidence from Korea". *IMF Working Paper No. 11/297.*

IMF (2013). "Chapter 22. Mortgage Markets and Foreclosure Processes in Europe and the United States". *From Fragmentation to Financial Integration in Europe.* International Monetary Fund.

Jiménez, Gabriel, Steven Ongena, José-Luis Peydró, and Jesús Saurina (2017). "Macroprudential policy, countercyclical bank capital buffers, and credit supply: Evidence from the Spanish dynamic provisioning experiments". *Journal of Political Economy* 125.6.

Jordà, Òscar, Moritz Schularick, and Alan M Taylor (2015). "Betting the house". *Journal of International Economics* 96.

Korinek, Anton and Alp Simsek (2016). "Liquidity trap and excessive leverage". *American Economic Review* 106.3.

Lorenzoni, Guido (2008). "Inefficient credit booms". *Review of Economic Studies* 75.3.

Lustig, Hanno and Stijn Van Nieuwerburgh (2010). "How much does household collateral constrain regional risk sharing?" *Review of Economic Dynamics* 13.2.

Mayer, Christopher, Karen Pence, and Shane M. Sherlund (2009). "The Rise in Mortgage Defaults". *Journal of Economic Perspectives* 23.1.

Mian, Atif and Amir Sufi (2009). "The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis". *Quarterly Journal of Economics* 124.4.

— (2011). "House prices, home equity-based borrowing, and the US household leverage crisis". *American Economic Review* 101.5.

— (2014). *House of debt: How they (and you) caused the Great Recession, and how we can prevent it from happening again.* University of Chicago Press.

Mian, Atif, Kamalesh Rao, and Amir Sufi (2013). "Household balance sheets, consumption, and the economic slump". *Quarterly Journal of Economics* 128.4.

Mian, Atif, Amir Sufi, and Emil Verner (2017). "Household debt and business cycles worldwide". *Quarterly Journal of Economics* 132.4.

Oster, Emily (2019). "Unobservable selection and coefficient stability: Theory and evidence". *Journal of Business & Economic Statistics*, pp. 1–18.

Piketty, Thomas and Emmanuel Saez (2003). "Income inequality in the United States, 1913–1998". *Quarterly Journal of economics* 118.1.

Piskorski, Tomasz and Amit Seru (2018). "Debt relief and slow recovery: A decade after Lehman". *NBER Working Paper No. 25403.*

Rajan, Raghuram G (2011). *Fault lines: How hidden fractures still threaten the world economy.* Princeton University press.

Schularick, Moritz and Alan M Taylor (2012). “Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008”. *American Economic Review* 102.2.

Table 1 (A): Summary statistics of loan level data

Total sample of mortgages						
Variable	count	mean	sd	p25	p50	p75
Loan Value	1,849,952	165,138	119,625	90,000	136,093	202,995
Property Value	1,849,952	270,612	215,928	145,000	210,000	318,000
Mortgage Term	1,849,952	23.44	7.75	18.00	25.00	30.00
LTI	1,849,952	3.00	1.10	2.23	3.05	3.82
LTV	1,849,952	66.0	22.3	51.9	73.1	84.9
Borrower Income	1,849,952	58,535	45,396	33,000	46,706	68,001
Borrower Age	1,849,952	38.21	9.80	30.00	37.00	45.00

Sample of high LTI mortgages						
Variable	count	mean	sd	p25	p50	p75
Loan Value	149,709	235,786	140,768	142,400	200,000	285,000
Property Value	149,709	362,452	259,608	202,000	287,000	427,000
Mortgage Term	149,709	28.16	6.16	25.00	30.00	34.00
LTI	149,709	4.85	0.30	4.63	4.77	4.99
LTV	149,709	69.8	15.5	60.3	73.5	80.6
Borrower Income	149,709	48,803	31,646	29,308	41,014	58,765
Borrower Age	149,709	35.00	8.24	29.00	34.00	40.00

The above shows summary statistics based on loan- and borrower-level data of residential mortgages issued in the UK during 2012Q3-2016Q2 that were under the purview of the 2014 regulation.

Table 1 (B): Summary statistics of local-area level data

House price growth						
Variable	count	Mean	SD	p25	p50	p75
Δ log(p25 price)	4,176	0.051	0.047	0.021	0.048	0.079
Δ log(p50 price)	4,176	0.051	0.046	0.021	0.048	0.079
Δ log(p75 price)	4,176	0.050	0.050	0.017	0.047	0.082

Mortgage non-performance rates						
Variable: Mortgages...	count	Mean	SD	p25	p50	p75
with payment shortfall (%)	2,361	1.84	0.74	1.30	1.71	2.28
under forbearance (%)	2,361	2.69	0.94	1.98	2.55	3.26
with possession order (%)	2,361	0.45	0.28	0.23	0.39	0.64

The above shows summary statistics based on data available for house price growth and mortgage distress rates for local areas in the UK (LAU1 (lower local administrative units), or equivalently boroughs or counties). House price growth is calculated as the annual change in the logarithm of the corresponding price level (25th, 50th, or 75th percentile) paid in local area l.

Table 2 (A): Loan level: Share of loans with high LTI (LTI $\geq$ 4.5)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	← Dummy for high LTI loans ($\mathbb{D}$(LTI $\geq$ 4.5)) →					
Post$_t$×Constrained$_b$	-0.0295**	-0.0474***	-0.0394***	-0.0513***	-0.0566***	-0.0388***
	(0.0118)	(0.0116)	(0.0099)	(0.0093)	(0.0089)	(0.0076)
Bank×Time Controls			Yes	Yes	Yes	Yes
Borrower and Loan Controls				Yes	Yes	Yes
Local Area×Time FE					Yes	Yes
Local Area×Bank FE						Yes
Observations	2,907,529	1,849,952	1,849,952	1,849,952	1,849,952	1,849,952
R^2	0.005	0.012	0.014	0.066	0.103	0.121

The dependent variable in this table is $\mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t}$, a binary variable that equals 1 if the mortgage granted by lender b to borrower i in quarter t in local area l has a loan-to-income ratio (LTI) equal or above 4.5, and 0 otherwise. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. Column (1) includes all observations; columns (2)-(6) include only observations for which the full set of control variables contain non-missing values. Post$_t$ is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. Constrained$_b$ is a binary variable that equals 1 if lender b is at or very close to the limit of 15% share of high LTI mortgages in the four quarters before the announcement of the policy (2013Q3-2014Q2), 0 otherwise. All regressions are estimated using ordinary least squares. Borrower, loan, and bank controls, as well as fixed-effects are either included ("Yes") or not included. Online Appendix Section B shows the definition of the main controls. Post$_t$ and Constrained$_b$ are included as standalone variables when they are not absorbed by fixed-effects; the coefficients are reported in Table A.5. Robust standard errors double-clustered at bank-quarter and local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 2 (B): Loan level: Pricing of high LTI loans

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
			← Interest rate →			
$\text{Post}_t \times \text{Constrained}_b \times \mathbb{D}(\text{LTI} \geq 4.5)$	0.0311	0.0715	0.0477	0.130**	0.153***	0.136***
	0.072	(0.0850)	(0.0829)	(0.0629)	(0.0526)	(0.0449)
Bank×Time Controls			Yes	Yes	Yes	Yes
Borrower and Loan Controls				Yes	Yes	Yes
Local Area×Time FE					Yes	Yes
Local Area×Bank FE						Yes
Observations	2,907,529	1,849,952	1,849,952	1,849,952	1,849,952	1,849,952
R^2	0.106	0.096	0.111	0.292	0.395	0.431

The dependent variable in this table is the interest rate charged on a mortgage by lender b to borrower i in quarter t in local area l. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. Columns (2)-(6) include only observations for which the full set of control variables contain non-missing values, equivalent to the sample used for Tables 2-6. Post_t is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. Constrained_b is a binary variable that equals 1 if lender b is at or very close to the limit of 15% share of high LTI mortgages in the four quarters before the announcement of the policy (2013Q3-2014Q2), 0 otherwise. $\mathbb{D}\text{LTI} \geq 4.5$ is a binary variables which equals 1 for mortgages with a loan-to-income ratio (LTI) equal to or above 4.5, and 0 otherwise. All regressions are estimated using ordinary least squares. Borrower, loan, and bank controls, as well as fixed-effects are either included ("Yes") or not included. Online Appendix Section B shows the definition of the main controls. Post_t and Constrained_b are included as standalone variables when they are not absorbed by fixed-effects. Robust standard errors double-clustered at bank-quarter and local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 3: Loan level: Size, LTV and borrower income of high LTI loans

(A) Size

VARIABLES	(1)	(2)	(3) ← log(Loan Size) →	(4)	(5)	(6)
$Post_t \times Constrained_b$	0.116*	0.208***	0.230***	0.217***	0.0929***	0.0898***
	(0.0624)	(0.0562)	(0.0412)	(0.0368)	(0.0214)	(0.0198)
Bank×Time Controls			Yes	Yes	Yes	Yes
Borrower and Loan Controls				Yes	Yes	Yes
Local Area×Time FE					Yes	Yes
Local Area×Bank FE						Yes
Observations	252,547	149,709	149,709	149,709	149,709	149,709
R^2	0.077	0.059	0.088	0.315	0.603	0.627

(B) LTV

VARIABLES	(1)	(2)	(3) ← LTV →	(4)	(5)	(6)
$Post_t \times Constrained_b$	0.0552	0.667	-0.892	0.788	2.408***	1.796***
	(1.102)	(1.371)	(0.953)	(0.746)	(0.661)	(0.567)
Bank×Time Controls			Yes	Yes	Yes	Yes
Borrower and Loan Controls				Yes	Yes	Yes
Local Area×Time FE					Yes	Yes
Local Area×Bank FE						Yes
Observations	252,542	149,709	149,709	149,709	149,709	149,709
R^2	0.021	0.021	0.037	0.277	0.349	0.376

(C) Borrower income

VARIABLES	(1)	(2)	(3) ← log (Borrower Income) →	(4)	(5)	(6)
$Post_t \times Constrained_b$	0.115*	0.223***	0.250***	0.241***	0.116***	0.115***
	(0.0687)	(0.0601)	(0.0438)	(0.0396)	(0.0236)	(0.0223)
Bank×Time Controls			Yes	Yes	Yes	Yes
Borrower and Loan Controls				Yes	Yes	Yes
Local Area×Time FE					Yes	Yes
Local Area×Bank FE						Yes
Observations	252,547	149,709	149,709	149,709	149,709	149,709
R^2	0.081	0.059	0.092	0.306	0.581	0.607

The dependent variables are: in Panel A ($\log(\text{Loan Value}_{i,l,b,t})$), the (log of the) value of the mortgage granted by lender b to borrower i in quarter t in local area l; in Panel B ($LTV_{i,l,b,t}$), the loan-to-value ratio (in percentage points) of the mortgage granted by lender b to borrower i in quarter t in local area l; and in Panel C ($\log(\text{Income}_{i,l,b,t})$), the (log of the) annual gross income of borrower(s) i associated to a mortgage granted by lender b in quarter t in local area l. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. The sample is restricted to mortgages with a loan-to-income ratio (LTI) $\geq$ 4.5. Column (1) includes all observations; columns (2)-(6) include only observations for which the full set of control variables contain non-missing values. $Post_t$ is a binary variable that equals 1 for quarters after 2014Q3, 0 before. $Constrained_b$ is a binary variable that equals 1 if lender b is at or very close to the limit of 15% share of high LTI mortgages in the four quarters before the announcement of the policy (2013Q3-2014Q2), 0 otherwise. All regressions are estimated using ordinary least squares. Borrower, loan, and bank controls, as well as fixed-effects are either included ("Yes") or not included. Online Appendix Section B shows the definition of the main controls. $Post_t$ and $Constrained_b$ are included as standalone variables when they are not absorbed by fixed-effects; we do not report their coefficients. Robust standard errors double-clustered at bank-quarter and local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 4: Loan level: Income and age quintiles in high LTI loans

(A) Income Quintiles

VARIABLES	(1)	(2)	(3)	(4)	(5)
	← Dummy for income quintiles ($\mathbb{D}(\text{Inc} = j)$) →				
	I	II	III	IV	V
$\text{Post}_t \times \text{Constrained}_b$	-0.0520***	-0.0154*	-0.0133	0.0235***	0.0572***
	(0.0153)	(0.0089)	(0.0093)	(0.0086)	(0.0150)
Borrower, Loan, Bank Controls	Yes	Yes	Yes	Yes	Yes
Local Area×Time FE	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes
Observations	149,709	149,709	149,709	149,709	149,709
R^2	0.366	0.102	0.110	0.168	0.236

(B) Age Quintiles

VARIABLES	(1)	(2)	(3)	(4)	(5)
	← Dummy for age quintiles ($\mathbb{D}(\text{Age} = j)$) →				
	I	II	III	IV	V
$\text{Post}_t \times \text{Constrained}_b$	-0.0058	-0.0012	-0.0013	0.0039	0.0044
	(0.0072)	(0.0069)	(0.0056)	(0.0054)	(0.0039)
Borrower, Loan, Bank Controls	Yes	Yes	Yes	Yes	Yes
Local Area×Time FE	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes
Observations	149,709	149,709	149,709	149,709	149,709
R^2	0.343	0.121	0.103	0.174	0.389

The dependent variables are binary variables indicating whether borrower(s) i associated to a mortgage granted by lender b in quarter t in local area l belongs to a particular quintile (1) or not (0). The dependent variables in Panel A (B) focus on income (age) quintiles: in each column, the dependent variable is a binary variable equal to 1 if the income (age) of the borrower(s) is in that particular quintile (with I being the bottom and V the top quintile) of the income (age) distribution. The quintiles are constructed using the sample from the pre-policy period. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3, and it is restricted to mortgages with a loan-to-income ratio (LTI) $\geq$ 4.5. Post_t is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. Constrained_b is a binary variable that equals 1 if lender b is at or very close to the limit of 15% share of high LTI mortgages before the announcement of the policy (2013Q3-2014Q2), 0 otherwise. All regressions are estimated using ordinary least squares. All regressions include borrower, loan, and bank controls, and local area × quarter and local area × bank fixed-effects. Online Appendix Section B shows the definition of the main controls. Robust standard errors double-clustered at bank-quarter and local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 5: Loan level: Substitution effects in lending to low-income borrowers

(A) Constrained lenders across LTI groups

VARIABLES	(1)	(2)	(3)	(4)	(5)
	← Dummy for low-income borrowers ($\mathbb{D}$(Inc=I)) →				
Sub-sample	LTI ∈ (0,2.09)	LTI ∈ [2.09,2.87)	LTI ∈ [2.87,3.57)	LTI ∈ [3.57,4.5)	LTI ≥ 4.5
$\text{Post}_t \times \text{Constrained}_b$	0.0136**	0.0236***	0.0244***	0.0321***	-0.0520***
	(0.0056)	(0.0072)	(0.0083)	(0.0079)	(0.0153)
Borrower, Loan, Bank Controls	Yes	Yes	Yes	Yes	Yes
Local Area×Time FE	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes
R^2	0.187	0.213	0.220	0.258	0.366

(B) Unconstrained lenders across LTI groups in high-exposure local areas

VARIABLES	(1)	(2)	(3)	(4)	(5)
	← Dummy for low-income borrowers ($\mathbb{D}$(Inc=I)) →				
Sub-sample	LTI ∈ (0,2.09)	LTI ∈ [2.09,2.87)	LTI ∈ [2.87,3.57)	LTI ∈ [3.57,4.5)	LTI ≥ 4.5
$\text{Post}_t \times \text{Unconst.}_b \times \text{ConstrShare}_l$	-0.000417**	-0.000831***	-0.000810**	-0.00102***	0.00147***
	(0.000204)	(0.000257)	(0.000355)	(0.000306)	(0.000499)
Borrower, Loan, Bank Controls	Yes	Yes	Yes	Yes	Yes
Local Area×Time FE	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes
Observations	404,337	417,771	427,980	445,284	149,709
R^2	0.187	0.213	0.220	0.258	0.366

The dependent variable, $\mathbb{D}$(Inc=I), is a binary variable indicating whether the income of borrower(s) i associated to the mortgage granted by lender b in quarter t in local area l is in the bottom quintile of the income distribution among borrowers. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. We calculate the quartiles of the loan-to-income distribution for LTI<4.5 in the pre-policy period. In each column (1)-(4), we restrict the sample to mortgages with an LTI inside that particular quartile. In column (5), we restrict the sample to mortgages with LTI≥4.5. Post_t is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. Constrained_b (Unconst._b) is a binary variable that equals 1 if lender b is at or very close to (below) the limit of 15% share of high LTI mortgages before the announcement of the policy (2013Q3-2014Q2), 0 otherwise. ConstrShare_l is a variable that equals the total share of lending by constrained lenders in local area l in the years before the announcement of the policy. All regressions are estimated using ordinary least squares. All regressions include borrower, loan, and bank controls, local area × quarter and local area × bank fixed-effects. Online Appendix Section B shows the definition of the main controls. Robust standard errors double-clustered at bank-quarter and local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 6: Local-area–income level: Overall lending to low-income borrowers

(A) Total number of loans (extensive margin)

VARIABLES	(1)	(2)	(3)	(4)	(5)
			← log(# of loans) →		
$\text{Post}_t \times \text{ConstrShare}_l \times \mathbb{D}(\text{Inc=I})_j$	-0.0125***	-0.0135***	-0.0137***	-0.0137***	-0.0137***
	(0.00335)	(0.00271)	(0.00279)	(0.00277)	(0.00479)
Lower-level interactions	Yes	Yes	Yes	-	-
Local Area×Income Quintile FE		Yes	Yes	Yes	Yes
Local Area×Time FE			Yes	Yes	Yes
Time×Income Quintile FE				Yes	Yes
Observations	31,043	31,043	31,043	31,043	31,043
R^2	0.029	0.869	0.896	0.902	0.902

(B) Total £ value of loans (intensive margin)

VARIABLES	(1)	(2)	(3)	(4)	(5)
			← log(£ of loans) →		
$\text{Post}_t \times \text{ConstrShare}_l \times \mathbb{D}(\text{Inc=I})_j$	-0.0157***	-0.0171***	-0.0173***	-0.0173***	-0.0173***
	(0.00351)	(0.00257)	(0.00265)	(0.00262)	(0.00462)
Lower-level interactions	Yes	Yes	Yes	-	-
Local Area×Income Quintile FE		Yes	Yes	Yes	Yes
Local Area×Time FE			Yes	Yes	Yes
Time×Income Quintile FE				Yes	Yes
Observations	31,043	31,043	31,043	31,043	31,043
R^2	0.141	0.838	0.857	0.861	0.861

The dependent variable in Panel A the logarithm of the total number of mortgages granted in quarter t in local area l to borrowers in the income quintile j. The dependent variable in Panel B is the logarithm of the total value (in GBP) of mortgages granted in quarter t in local area l to borrowers in the income quintile j. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. Post_t is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. ConstrShare_l is a variable that equals the total share of lending by constrained lenders in local area l in the years before the announcement of the policy. $\mathbb{D}(\text{Inc=I})_j$ is a binary variable that equals 1 for the bottom income quintile, 0 for the rest. All regressions are estimated using ordinary least squares. Fixed-effects and lower-level interactions are either included ("Yes"), spanned by other fixed-effects ("-"), or not included. Robust standard errors clustered at local-area (columns (1) to (4)) and at LAU2 (column (5)) level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 7: Local-area level: House price growth in affected local areas

VARIABLES	(1)	(2) 25th percentile	(3)	(4)	(5) 50th percentile	(6)	(7)	(8) 75th percentile	(9)
$BrexitRef_t \times Constr_l \times LowInc_l$	0.028***	0.027***	0.026***	0.017**	0.018**	0.017**	0.004	0.004	0.002
	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$Post_t \times Constr_l \times LowInc_l$	-0.015**	-0.012*	-0.014*	-0.003	-0.001	-0.001	0.009	0.012	0.010
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)
Lower-level interactions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	-	-	Yes	-	-	Yes	-	-
Region×Time FE		Yes	Yes		Yes	Yes		Yes	Yes
Local Area FE			Yes			Yes			Yes
Observations	4,176	4,176	4,176	4,176	4,176	4,176	4,176	4,176	4,176
R^2	0.327	0.389	0.441	0.336	0.407	0.453	0.237	0.301	0.347

The dependent variable for columns (1)-(3) is the change in the logarithm of the 25th percentile price paid at local area l. The dependent variable for columns (4)-(6) is the change in the logarithm of the median price paid at local area l. The dependent variable for columns (7)-(9) is the change in the logarithm of the 75th percentile price paid at local area l. The 25th, 50th, and 75th percentiles are calculated using all house transactions during a six-month period t. The change is calculated with respect to the same period in the year before. The sample spans from 2012H2 to 2018H1. $Post_t$ is a binary variable equal to 1 in the period 2014H2 - 2018H1, i.e. after the introduction of the policy, 0 before. $BrexitRef_t$ is a binary variable equal to 1 in the period 2016H2 - 2018H1, i.e. after the Brexit referendum, 0 before. $Constr_l$ is a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local area l is above the median before the announcement of the policy, 0 otherwise. $LowInc_l$ is a binary variable equal to 1 if the local area is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise. All regressions are estimated using ordinary least squares. Fixed-effects and lower level interactions are included ("Yes"), spanned by other fixed-effects ("-"), or not included. The full set of coefficients for lower level interactions are reported in Table A.6. Robust standard errors are clustered at local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 8: Local-area level: House price growth in affected local areas—property type

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Type of house				State		Ownership	
	Semi-det.	Terraced	Detached	Flat	Old	New	Freehold	Leasehold
$BrexitRef_t \times Constr_l \times LowInc_l$	0.021***	0.024***	0.009	0.016	0.030***	-0.028	0.019***	0.029*
	(0.008)	(0.008)	(0.010)	(0.021)	(0.007)	(0.035)	(0.007)	(0.018)
$Post_t \times Constr_l \times LowInc_l$	-0.001	-0.007	0.001	-0.034	-0.018**	0.013	-0.002	-0.040**
	(0.008)	(0.009)	(0.008)	(0.021)	(0.007)	(0.036)	(0.008)	(0.020)
Lower-level interactions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region×Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local Area FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,159	4,160	4,158	4,173	4,176	4,157	4,166	4,176
R^2	0.382	0.453	0.207	0.165	0.494	0.070	0.524	0.174

The dependent variable is the change in the logarithm of the 25th percentile price paid at local area l, calculated using house transactions during a six-month period t. The change is calculated with respect to the same period in the year before. The type transactions used to calculate the dependent variable is specified at the top of each column: semi-detached (1), terraced (2), detached (3) houses, flats (4), old (5) and new (6) properties, and properties with freehold (7) and leasehold (8).The sample spans from 2012H2 to 2018H1. $Post_t$ is a binary variable equal to 1 in the period 2014H2 - 2018H1, i.e. after the introduction of the policy, 0 before. $BrexitRef_t$ is a binary variable equal to 1 in the period 2016H2 - 2018H1, i.e. after the Brexit referendum, 0 before. $Constr_l$ is a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local area l is above the median before the announcement of the policy, 0 otherwise. $LowInc_l$ is a binary variable equal to 1 if the local area is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise. All regressions are estimated using ordinary least squares and include Region x Time and Local Area fixed-effects as well as all lower-level interactions. Robust standard errors are clustered at local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 9: Local-area level: House price growth in affected local areas—housing supply constraints

VARIABLES	(1)	(2) 25th percentile	(3)	(4)	(5) 50th percentile	(6)	(7)	(8) 75th percentile	(9)
$\text{BrexitRef}_t \times \text{Constr}_l \times \text{LowInc}_l$	0.032***	0.031***	0.031***	0.018**	0.018**	0.017**	0.008	0.007	0.006
	(0.009)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
$\text{Post}_t \times \text{Constr}_l \times \text{LowInc}_l$	-0.016*	-0.014	-0.016*	-0.001	0.001	-0.000	0.008	0.009	0.007
	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.008)
$\text{Post}_t \times \text{Refusal rate}_l$	0.113***	0.107***	0.107***	0.072**	0.058*	0.057*	0.036	0.035	0.034
	(0.030)	(0.034)	(0.031)	(0.028)	(0.031)	(0.030)	(0.031)	(0.036)	(0.034)
$\text{Post}_t \times \%\ \text{developed}_l$	0.004	-0.005	-0.006	-0.022**	-0.013	-0.013	-0.052***	-0.023	-0.024
	(0.010)	(0.012)	(0.012)	(0.011)	(0.013)	(0.013)	(0.010)	(0.016)	(0.016)
$\text{Post}_t \times \text{Range}_l$	-0.000	0.002	0.002	-0.005**	-0.001	-0.001	-0.009***	-0.006**	-0.006**
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$\text{BrexitRef}_t \times \text{Refusal rate}_l$	-0.107***	-0.084**	-0.073**	-0.088***	-0.064**	-0.056*	-0.063**	-0.060**	-0.049*
	(0.030)	(0.032)	(0.028)	(0.027)	(0.028)	(0.029)	(0.027)	(0.030)	(0.028)
$\text{BrexitRef}_t \times \%\ \text{developed}_l$	-0.068***	-0.012	-0.011	-0.060***	-0.023	-0.022	-0.032***	-0.011	-0.011
	(0.011)	(0.014)	(0.014)	(0.010)	(0.014)	(0.014)	(0.010)	(0.015)	(0.015)
$\text{BrexitRef}_t \times \text{Range}_l$	-0.004	-0.003	-0.003	-0.002	-0.002	-0.002	0.000	-0.002	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Lower-level interactions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	-	-	Yes	-	-	Yes	-	-
Region×Time FE		Yes	Yes		Yes	Yes		Yes	Yes
Local Area FE			Yes			Yes			Yes
Observations	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120
R^2	0.352	0.405	0.452	0.355	0.407	0.448	0.262	0.315	0.356

The dependent variable for columns (1)-(3) is the change in the logarithm of the 25th percentile price paid at local area l. The dependent variable for columns (4)-(6) is the change in the logarithm of the median price paid at local area l. The dependent variable for columns (7)-(9) is the change in the logarithm of the 75th percentile price paid at local area l. The 25th, 50th, and 75th percentiles are calculated using all house transactions during a six-month period t. The change is calculated with respect to the same period in the year before. The sample spans from 2012H2 to 2018H1. Post_t is a binary variable equal to 1 in the period 2014H2 - 2018H1, i.e. after the introduction of the policy, 0 before. BrexitRef_t is a binary variable equal to 1 in the period 2016H2 - 2018H1, i.e. after the Brexit referendum, 0 before. Constr_l is a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local area l is above the median before the announcement of the policy, 0 otherwise. LowInc_l is a binary variable equal to 1 if the local area is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise. Refusal rate_l is the average refusal rate of major residential projects between 1979 and 2008. $\%\ \text{developed}_l$ is the share of developable land developed in 1990. Range_l is the logarithm of 1 plus the range between the highest and lowest altitude in meters. Refusal rate_l, $\%\ \text{developed}_l$, and Range_l are obtained from Hilber and Vermeulen (2016). All regressions are estimated using ordinary least squares. Fixed-effects and lower level interactions are included ("Yes"), spanned by other fixed-effects ("-"), or not included. Robust standard errors are clustered at local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 10: Local-area level: House price growth in affected local areas—2007-08 financial crisis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES		25th percentile			50th percentile			75th percentile	
$Post_t \times Constr_l \times LowInc_l$	-0.013	0.003	0.002	0.000	0.011	0.011	-0.005	0.002	0.002
	(0.010)	(0.007)	(0.007)	(0.009)	(0.007)	(0.007)	(0.009)	(0.008)	(0.008)
Lower-level interactions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	-	-	Yes	-	-	Yes	-	-
Region×Time FE		Yes	Yes		Yes	Yes		Yes	Yes
Local Area FE			Yes			Yes			Yes
Observations	2,784	2,784	2,784	2,784	2,784	2,784	2,784	2,784	2,784
R^2	0.677	0.727	0.798	0.610	0.662	0.731	0.486	0.538	0.599

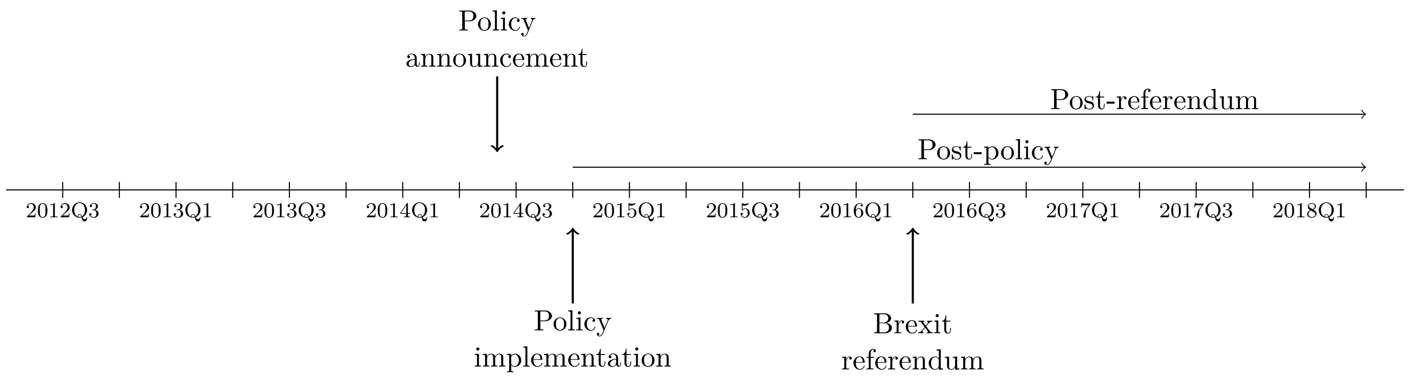
The dependent variable for columns (1)-(3) is the change in the logarithm of the 25th percentile price paid at local area l. The dependent variable for columns (4)-(6) is the change in the logarithm of the median price paid at local area l. The dependent variable for columns (7)-(9) is the change in the logarithm of the 75th percentile price paid at local area l. The 25th, 50th, and 75th percentiles are calculated using all house transactions during a six-month period t. The change is calculated with respect to the same period in the year before. The sample spans from 2005H1 to 2008H2. $Post_t$ is a binary variable equal to 1 in the period 2007H1 - 2008H2, 0 before. $Constr_l$ and $LowInc_l$ are defined as in previous tables (i.e., with data from the pre-policy period). $Constr_l$ is a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local area l is above the median before the announcement of the policy, 0 otherwise. $LowInc_l$ is a binary variable equal to 1 if the local area is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise. All regressions are estimated using ordinary least squares. Fixed-effects and lower level interactions are included ("Yes"), spanned by other fixed-effects ("-"), or not included. All lower-level interactions are included. Robust standard errors are clustered at local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table 11: Local-area level: Mortgage non-performance rates in affected local areas

VARIABLES	(1)	(2) Payment shortfall	(3)	(4)	(5) Forbearance	(6)
$\text{BrexitRef}_t \times \text{Constr}_l \times \text{LowInc}_l$	-0.057*	-0.072**	-0.064**	-0.146***	-0.102**	-0.096**
	(0.031)	(0.029)	(0.029)	(0.052)	(0.045)	(0.047)
Lower-level interactions	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	-	-	Yes	-	-
Region×Time FE		Yes	Yes		Yes	Yes
Local Area FE			Yes			Yes
Observations	2,361	2,361	2,361	2,361	2,361	2,361
R^2	0.661	0.667	0.982	0.627	0.634	0.975

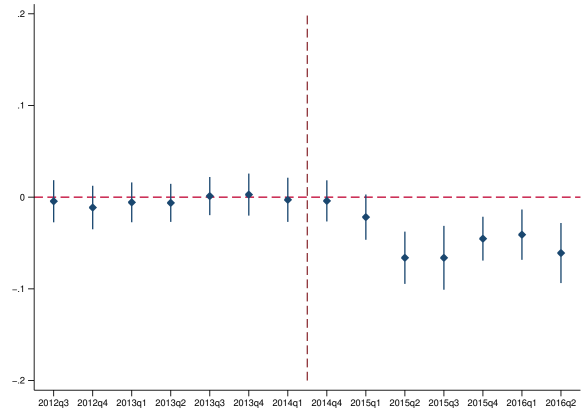
The dependent variable in (1)-(3) is the percentage of mortgages with payment shortfall in local area l at the end of the half-year t. The dependent variable in (4)-(6) is the percentage of mortgages under forbearance in local area l at the end of half-year t. The sample spans from 2015H1 to 2017H2. BrexitRef_t is a binary variable equal to 1 in the period 2016H2 - 2017H2, i.e. after the Brexit referendum, 0 before. Constr_l is a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local area l is above the median before the announcement of the policy, 0 otherwise. LowInc_l is a binary variable equal to 1 if the local area is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise. All regressions are estimated using ordinary least squares. Fixed-effects and lower level interactions are included ("Yes"), spanned by other fixed-effects ("-"), or not included. Robust standard errors are clustered at local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Figure 2: Timeline



The above figure shows the important dates for our analysis. The macroprudential policy was announced in 26th of June 2014, and it was implemented from 1st of October 2014. The Brexit referendum in the UK took place on the 23rd of June 2016. For the analysis on the impact of the macroprudential policy on credit availability, we focus on all mortgages issued between 2012Q3 and 2016Q2. We drop the mortgages issued in 2014Q3 since the policy had already been announced but not yet implemented during that quarter; we stop in 2016Q2 to avoid the possibility that our results on credit availability reflect some of the effects of the Brexit referendum. For the analysis on house price growth (non-performing mortgages), we study the period between 2012Q4-2018Q2 (2015Q2-2017Q4). We study the period after the Brexit referendum to understand whether the changes in credit availability have beneficial effects on house price dynamics and mortgage defaults following the referendum.

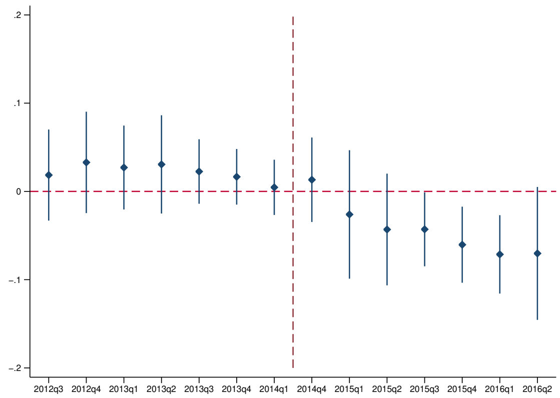
Figure 3: Loan level: Share of loans with high LTI (LTI ≥ 4.5)



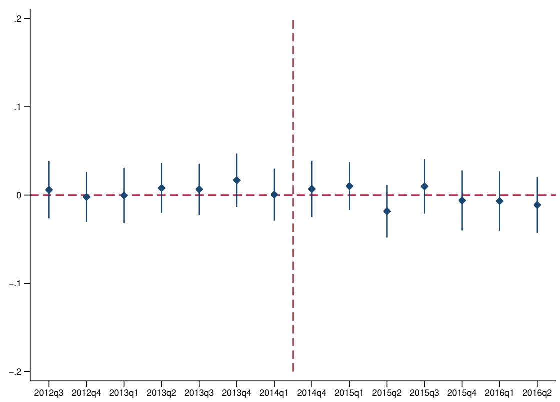
The figure above shows the estimated coefficients of the interaction of Constrained$_b$, a binary variable that equals 1 if lender b is at or very close to the limit of 15% share of high LTI mortgages in the four quarters before the announcement of the policy (2013Q3-2014Q2), 0 otherwise, and the full set of time(quarter)-dummies (excluding 2014Q2, the reference time-period). The dependent variable is $\mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t}$, which is a a binary variable that equals 1 if the mortgage granted by lender b to borrower i in quarter t in local area l has a loan-to-income ratio (LTI) equal or above 4.5. The bands represent the 95% confidence interval based on robust standard errors double-clustered at the bank×quarter and local-area level. The vertical dashed line shows the date of the introduction of the policy. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. The regression is estimated using ordinary least squares, and includes borrower, loan, and bank controls, as well as Local Area×Quarter and Local Area×Bank fixed-effects. The definition of the main independent variables can be found in Online Appendix Section B.

Figure 4: Loan level: Share of low-income and young borrowers in high LTI loans

(A) Low-income borrowers (regression results in Table 4 (A), column 1)



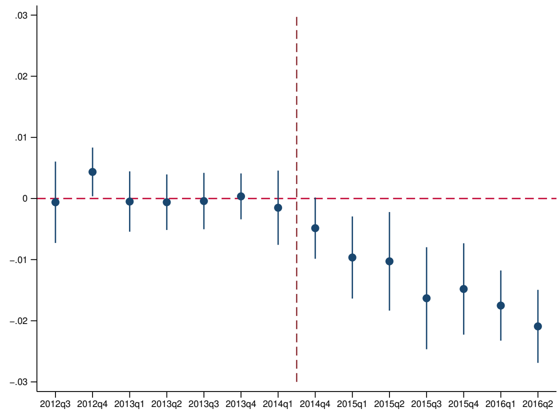
(B) Young borrowers (regression results in Table 4 (B), column 1)



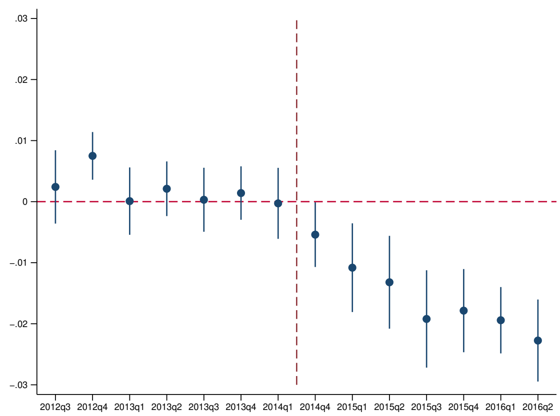
The figures above show the estimated coefficients of the interaction of Constrained_b, a binary variable that equals 1 if lender b is at or very close to the limit of 15% share of high LTI mortgages in the four quarters before the announcement of the policy (2013Q3-2014Q2), 0 otherwise, and the full set of time(quarter)-dummies (excluding 2014Q2, the reference time-period). The dependent variable in (A) is $\mathbb{D}$(Inc=I), which is a a binary variable that equals 1 if the income of the borrower is in the bottom quintile of the income distribution, 0 otherwise. The dependent variable in (B) is $\mathbb{D}$(Age=I), which is a binary variable that equals 1 if the age of the main borrower is in the bottom quintile of the age distribution, 0 otherwise. The bands represent the 95% confidence interval based on robust standard errors double-clustered at the bank×quarter and local-area level. The vertical dashed line shows the date of the introduction of the policy. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3, and it only includes mortgages with an LTI $\geq$ 4.5. The regressions are estimated using ordinary least squares, and include borrower, loan, and bank controls, as well as Local Area×Quarter and Local Area×Bank fixed-effects. The definition of the main independent variables can be found in Online Appendix Section B.

Figure 5: Local-area–income level: Overall lending to low-income borrowers

(A) Extensive margin effects (regression results in Table 6 (A), column 4)

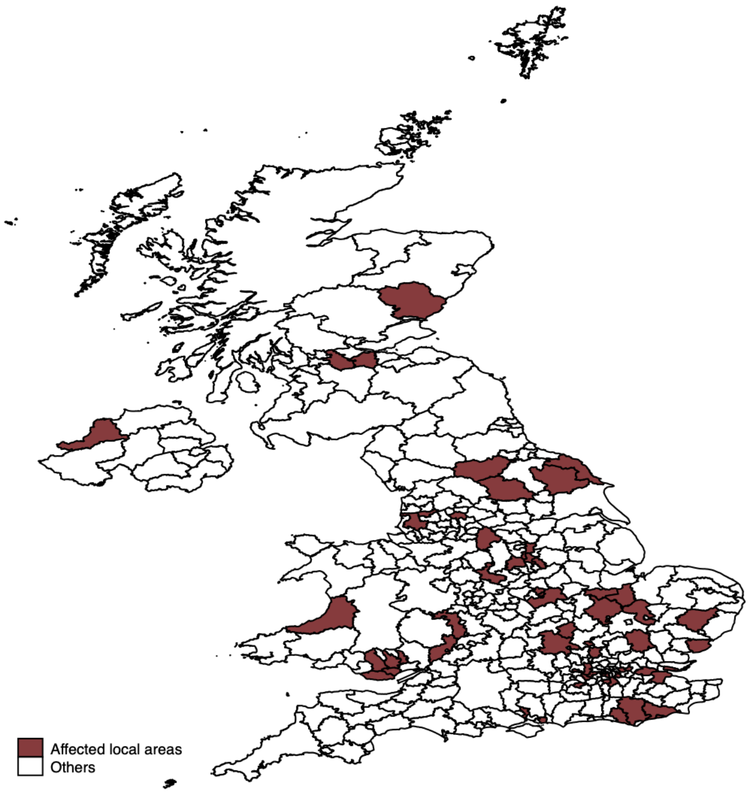


(B) Intensive margin effects (regression results in Table 6 (B), column 4)



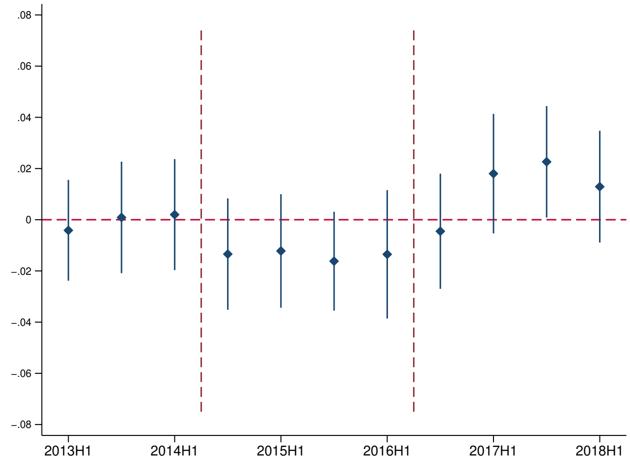
The figures above show the estimated coefficients of the interaction of ConstrShare_l (a variable that equals the total share of lending by constrained lenders in local area l in the years before the announcement of the policy), $\mathbb{D}$(Inc=I) (a binary variable that equals 1 for the bottom income quintile, 0 for the rest), and the full set of time(quarter)-dummies (excluding 2014Q2, the reference time-period). The dependent variable in Panel A the logarithm of the total number of mortgages granted in quarter t in local area l to borrowers in the income quintile j. The dependent variable in Panel B is the logarithm of the total value (in GBP) of mortgages granted in quarter t in local area l to borrowers in the income quintile j. The bands represent the 95% confidence interval based on robust standard errors clustered at local-area level. The vertical dashed line shows the date of the introduction of the policy. The sample period is from 2012Q3 to 2016Q2. The regressions are estimated using ordinary least squares and include Local Area×Time, Local Area×Income Quintile, and Time×Income Quintile fixed-effects.

Figure 6: Local-areas more affected by the policy



The figure above shows the spatial distribution of the local areas more affected by the policy. These are the local areas with an ex-ante higher exposure to constrained lenders *and* a higher proportion of low-income borrowers. The affected local areas are indicated by the interaction between Constr_l, which indicates local areas where the share of constrained lenders before the policy is greater than the median share, and LowInc_l, which indicates local areas where the share of loans received by low-income borrowers is above the 75th percentile. UK local areas (at the official Local Administrative Unit Level 1) are equivalent to counties/boroughs.

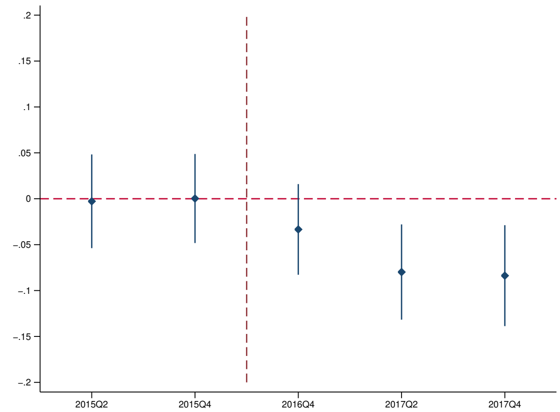
Figure 7: Local-area level: House price growth in affected local areas



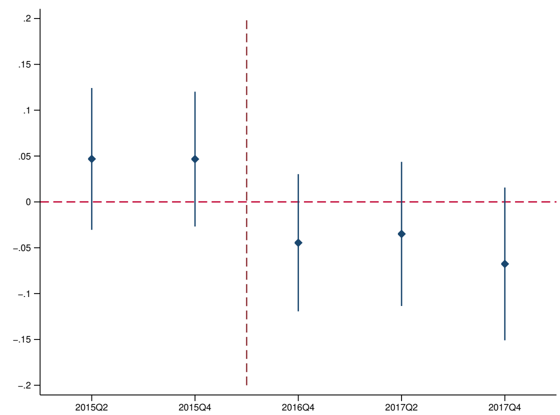
The figures above show the estimated coefficients of the interaction of Constr_l (a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local authority l is above the median before the announcement of the policy, 0 otherwise), LowInc_l (binary variable equal to 1 if the local authority is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise), and the full set of time(half-year)-dummies (excluding 2012H2, the reference time-period). The dependent variable is the annual change in the logarithm of the 25th percentile house price in local authority l in half-year t. The bands represent the 90% confidence interval based on robust standard errors clustered at local-area level. The vertical dashed lines show the date of the introduction of the policy and the Brexit referendum. The sample period is from 2012H2 to 2018H1. The regression is estimated using ordinary least squares and includes Local Area and Region×Time fixed-effects.

Figure 8: Local-area level: Mortgage non-performance in affected local areas

(A) Payment shortfall



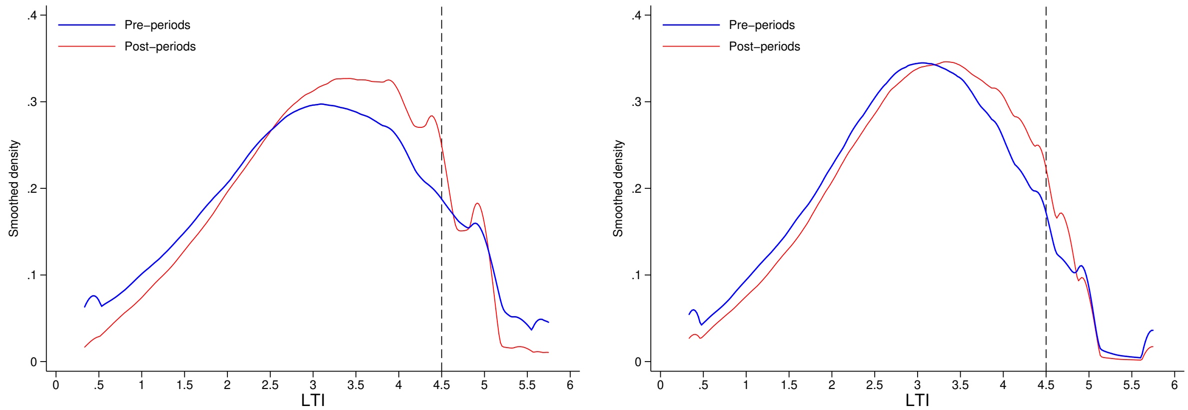
(B) Forbearance



The figures above show the estimated coefficients of the interaction of Constr_l (a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local authority l is above the median before the announcement of the policy, 0 otherwise), LowInc_l (binary variable equal to 1 if the local authority is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise), and the full set of time(half-year)-dummies (Q2 refers to the end of June of the corresponding year; Q4 refers to the end of the corresponding year). 2016Q2 is excluded as the reference time-period. The dependent variable in Panel (A) is the percentage of mortgages with payment shortfall in local area l at the end of the half-year t. The dependent variable in Panel (B) is the percentage of mortgages under forbearance in local area l at the end of the half-year t. The bands represent the 95% confidence interval based on robust standard errors clustered at local-area level. The vertical dashed line shows the date of the introduction of the Brexit referendum. The sample period is from 2015Q2 to 2017Q4. The regressions are estimated using ordinary least squares and include Local Area and Region×Time fixed-effects.

Figure 9 (A): Distribution of LTI for constrained and unconstrained lenders

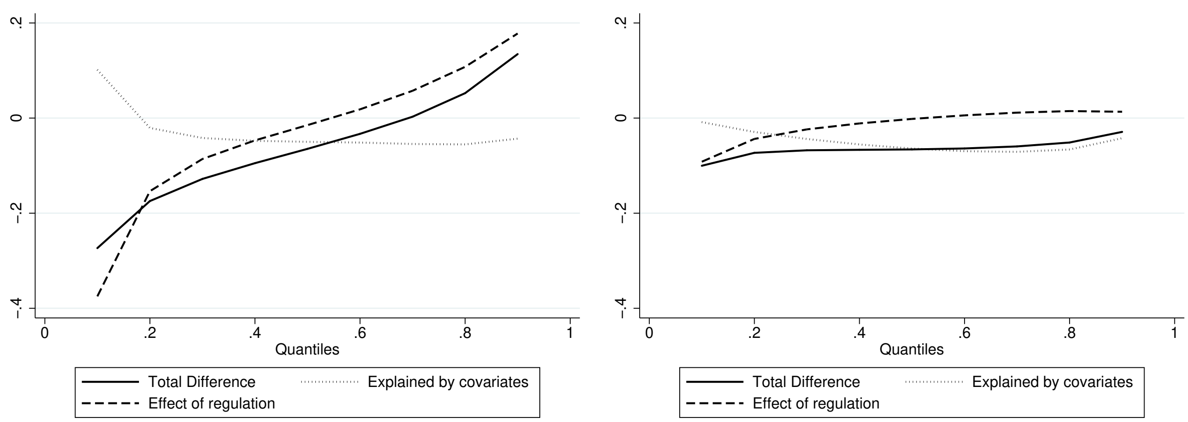
(i) Constrained lenders **(ii)** Unconstrained lenders



The above figures show a histogram of the loan-to-income ratios of mortgages issued by the constrained (left panel) and unconstrained lenders (right panel) in periods before (2012Q3-2014Q2; Pre-periods) and after (2014Q4-2016Q2; Post-periods) the introduction of the limit on high LTI lending by UK regulators. The underlying data is the universe of newly issued residential mortgages in the UK from PSD001.

Figure 9 (B): Oaxaca-Blinder decomposition for constrained and unconstrained lenders

(i) Constrained lenders **(ii)** Unconstrained lenders



The above figure shows the Oaxaca-Blinder decomposition for the change in the LTI distribution of mortgages issued by constrained (left panel) and unconstrained lenders (right panel) in Pre_t and Post_t periods. The decomposition is based on a counterfactual distribution estimated using the technique described in Chernozhukov et al. (2013). The technique uses a set of covariates for all mortgages issued in Post_t periods and estimates a counterfactual distribution based on the likelihood of obtaining a certain LTI for the set of covariates in Pre_t periods. The difference between the quantiles of the Post_t period LTI distribution and the counterfactual distribution is attributable to the regulation (dashed line); the difference between the quantiles of the counterfactual and Pre_t period LTI distribution is explained by changes in the distribution of covariates in the mortgages issued by the lender in Pre_t and Post_t periods (dotted line).

Figure 10: House price index growth - Financial Crisis

The above figure shows the annual growth rate of the UK house price index (UKHPI) during the years 2004 to 2009. The first dashed vertical line denotes the beginning of the "boom" phase; the second dashed vertical line denotes the end of the "boom" and the beginning of the "bust"; the third dashed vertical line denotes the end of the "bust." The data is from the HM Land Registry. It can be obtained in the following link: https://www.gov.uk/government/statistical-data-sets/uk-house-price-index-data-downloads-march-2020.

INTERNET APPENDIX

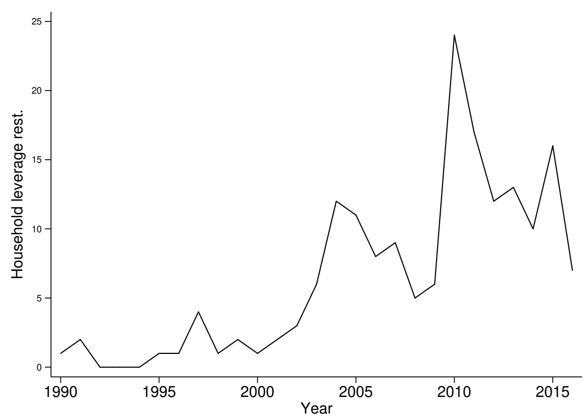
Macroprudential Policy, Mortgage Cycles and Distributional Effects:

Evidence from the UK

A Restrictions on household leverage introduced during 1990-2016

Figure A.1 shows the number of regulations introduced annually world-wide during 1990-2016 aimed at restricting household leverage by setting limits on loan-to-value (LTV) and debt-service-to-income (DSTI) ratios. The figure shows that most interventions to restrict household leverage have taken place after the 2008 financial crisis. The restriction on high LTI lending introduced in the UK was one of 10 regulations on household leverage introduced worldwide in 2014.

Figure A.1: Number of regulations restricting household leverage during 1990-2016



The above figure shows the number of regulations aimed at restricting household leverage introduced world-wide during 1990-2016. The underlying data used for the figure is obtained from the Integrated Macroprudential Policy (iMaPP) database collated by the IMF (link). The figure for each year sums the number of instances of regulations restricting loan-to-value and debt-service-to-income ratios, indicated by two separate variables in the database.

B Description of loan level and bank-time level controls

Table A.1: Loan level controls

Variable	Description
Borrower-type	Includes *first-time-buyers, home-movers, refinancers*
Ratetype	*Fixed* or *floating*
Dealtype	Duration of initial teaser rates
Employement	Employment status of the primary borrower
Age	Age of the primary borrower
Mortgage term	Duration of payment period
Repayment	Type of repayment, for e.g. *interest-only*
Loan value	Total loan amount issued to the borrower
Property value	£ value of the property evaluated by the lender

Source: PSD001

Table A.2: Bank-time level controls

Variable	Description
Size	Logarithm of total assets
Liquidity ratio	Cash and government bonds over total assets
Core funding ratio	Retail deposits over total assets
Return on assets	Profits over total assets
CET1 ratio	Common Equity Tier 1 capital over risk-weighted assets
Share of household credit	Household lending over total lending

Source: Statistical and regulatory data reported by financial institutions to the Bank of England (BT/PL/AL forms) and PRA.

Table A.3: Summary statistics for constrained and unconstrained lenders

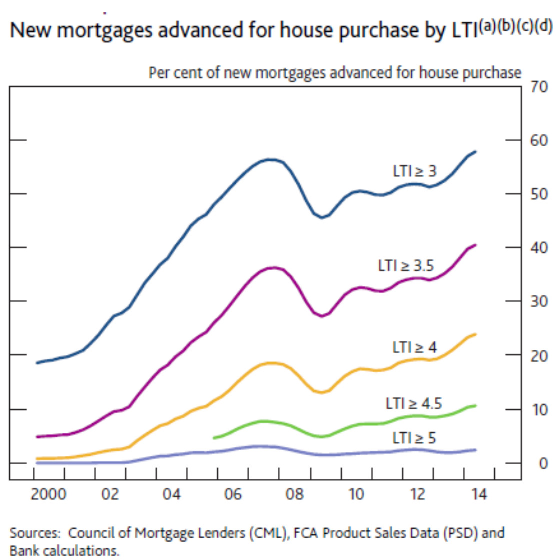
Statistic	$\mu_{Unconst.}$	$\mu_{Constrained}$	t	p
Size	9.94	10.54	-1.07	0.29
Liquidity (%)	9.95	9.33	0.47	0.64
Core funding (%)	73.3	66.3	1.31	0.19
Return on assets (%)	0.14	0.12	0.38	0.7
CET1 Ratio (%)	16.14	18.39	-1.4	0.17
Share of household credit (%)	71.88	65.36	1.04	0.3
Share of high LTI loans	0.05	0.18	-10.32	0.00

The above table shows the difference in the averages of the bank-level control variables for constrained and unconstrained lenders based on data at a quarterly level for the period 2013Q3 - 2014Q2. Column (1) shows the averages for unconstrained banks; column (2) shows the averages for constrained banks; column (3) provides the t-statistic for the null hypothesis of equal means, and column (4) provides the corresponding p-value. A constrained lender is defined as a lender that is at or very close to the 15% limit on the share of high LTI mortgages in the four quarters before the announcement of the policy (2013Q3-2014Q2). The definition of these variables can be found in Online Appendix Table A.2.

C Lending standards prior to the introduction of the 2014 regulation

Figure A.2 shares evidence on changes in lending standards in the UK mortgage market in the run up to the introduction of the 2014 restrictions on high LTI lending. The figure plots the share of mortgages above a given level of LTI, such as the share of mortgages with LTI $\geq$ 3, 4, and 5. The share of mortgages with these relatively high levels of borrower leverage had creeped up back to the pre-crisis levels by early-2014.

Figure A.2: Share of different LTI groups in new mortgages issued before the introduction of the limit on high LTI lending



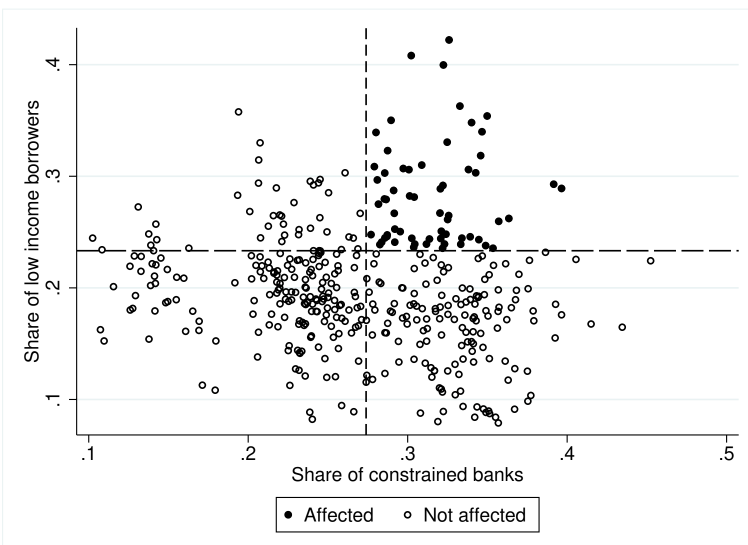
The above figure shows the share of different LTI groups in the new mortgages issued at a quarterly level between 2013Q2-2014Q1. During this period, around 10% of lending for house purchase was extended at an LTI at or above four and a half times income; this compares to 6.5% in the immediate pre-crisis period, 2005-07.

D Cross-variation across UK local-areas of exposure to constrained lenders and share of low-income borrowers

Section 4.4 show that (1) local-areas more affected by the regulation experienced a cooling down of house prices after the regulation, and (2) experienced relatively lower house price declines and mortgage non-performance rates during the house price correction in the UK following the so-called Brexit referendum. "Affected" local-areas are those with a higher share of constrained lenders and a higher share of low-income borrowers.

Figure A.3 shows the cross-variation between the share of constrained lenders and the share of mortgages (in Pre_t) periods received by low-income borrowers. Figure shows that there is a sufficient cross-variation between the two variables for identification using our empirical strategy; the "affected" local-areas are reflected as shaded dots in the figure.

Figure A.3: Cross-variation across UK local-areas of exposure to constrained lenders and low-income borrowers



The above figure shows the cross-variation between the share of constrained banking groups and the share of borrowers in the bottom income quintile across local areas in the United Kingdom. Share of borrowers in the bottom income quintile is based on thresholds defined using the income distribution of mortgages issues at a more aggregated NUTS2 level in periods before the introduction of the regulation (see Section 4.3). The above figure shows that the share of constrained banks and the share of low-income borrowers is not highly correlated. We study house price growth and mortgage arrears in local areas more exposed to constrained banks and with greater share of low-income borrowers in the aftermath of the Brexit referendum as compared to other local areas in Section 4.4.

E Supplementary results

Table A.4: Results with a continuous explanatory variable

(A) Share of loans with loan-to-income ratios $\geq$ 4.5; robustness result for Table 2 (A)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	← Dummy for high LTI loans ($\mathbb{D}$(LTI $\geq$ 4.5)) →					
Post$_t$×Share$_b$	-0.414***	-0.347***	-0.329***	-0.451***	-0.473***	-0.476***
	(0.0935)	(0.109)	(0.0969)	(0.0828)	(0.0748)	(0.0806)
Borrower and Loan Controls			Yes	Yes	Yes	Yes
Bank×time Controls				Yes	Yes	Yes
Local Area×Time FE					Yes	Yes
Local Area×Bank FE						Yes
Observations	2,907,529	1,849,952	1,849,952	1,849,952	1,849,952	1,849,952
R^2	0.013	0.015	0.016	0.068	0.106	0.121

(B) Composition of high LTI loans; robustness result for Table 3 and Table 4

	(1)	(2)	(3)	(4)	(5)
VARIABLES	log(Loan Size)	LTV	log(Income)	$\mathbb{D}$(Inc=I)	$\mathbb{D}$(Age=I)
Post$_t$×Share$_b$	0.862***	10.80†	1.049***	-0.308*	-0.0307
	(0.231)	(6.766)	(0.261)	(0.161)	(0.0709)
Controls and FE	Yes	Yes	Yes	Yes	Yes
Observations	149,709	149,705	149,709	149,709	149,709
R^2	0.627	0.376	0.607	0.366	0.578

The dependent variable in Panel (A) is $\mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t}$, a binary variable that equals 1 if the mortgage granted by lender b to borrower i in quarter t in local area l has an LTI $\geq$ 4.5, 0 otherwise. The dependent variables in Panel (B) are the following: (1) the (log of the) mortgage granted by lender b to borrower i in quarter t in local area l; (2) the LTV of the mortgage granted by lender b to borrower i in quarter t in local area l; (3) the logarithm of the annual gross income of borrower(s) i in the mortgage granted by lender b in quarter t in local area l; (4) a binary variable equal to 1 if the income of borrower i is in the bottom quintile of the distribution, 0 otherwise; and (5) a binary variable equal to 1 if the age of borrower i is in the bottom quintile of the distribution, 0 otherwise. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. Panel (A) includes all mortgages. Panel (B) include only LTI $\geq$ 4.5. Post$_t$ is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. Share$_b$ is the share of high LTI mortgages held by bank b in the quarters before the announcement of the policy. All regressions are estimated using ordinary least squares. Borrower, loan, and bank controls, as well as fixed-effects are either included ("Yes") or not included. Online Appendix Section B shows the definition of the main controls. Robust standard errors double-clustered at bank-quarter and local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level; †: significant at 11%.

Continuous explanatory variable. The baseline specification (Equation 1) is based on classifying UK lenders into two groups, "constrained" and "unconstrained", based on their share of high LTI loans in all mortgages issued during 2013Q3-2014Q2. In Table A.4 we show that the results are robust to using a continuous explanatory variable, i.e. Share$_b$, instead of using a dummy for constrained lenders as done for Table 2 (A), Table 3 and Table 4. Table A.4 (A) shows that this alternate treatment variable also highlights a contraction in the share of high LTI loans issued by the more-constrained lenders in Post_t periods. Table A.4 (B) shows increases in the loan size, LTV and borrower income, and a drop in the proportion of low-income borrowers in the fewer high LTI loans issued by the more-constrained lenders as estimated on the alternate continuous treatment variable.

Coefficients on low-level interactions. In the main text, we do not report the coefficients on the all levels and interaction of the main independent variables due to lack of space. We reproduce here the full set of levels from Table 2 (A) (in Table A.5) and Table 7 (in Table A.6).

Table A.5: Loan level: Share of loans with high loan-to-income ratios (LTI≥4.5)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	← Dummy for high LTI loans ($\mathbb{D}(\text{LTI} \geq 4.5)$) →					
$\text{Post}_t \times \text{Constrained}_b$	-0.0295**	-0.0474***	-0.0394***	-0.0513***	-0.0566***	-0.0388***
	(0.0118)	(0.0116)	(0.0099)	(0.0093)	(0.0089)	(0.0076)
Constrained_b	0.0599***	0.0836***	0.0779***	0.0706***	0.0647***	
	(0.00934)	(0.00827)	(0.00759)	(0.00690)	(0.00620)	
Post_t	0.00500	0.0219***	0.0130**	0.0215***		
	(0.00671)	(0.00661)	(0.00518)	(0.00745)		
Borrower and Loan Controls			Yes	Yes	Yes	Yes
Bank×time Controls				Yes	Yes	Yes
Local Area×Time FE					Yes	Yes
Local Area×Bank FE						Yes
Observations	2,907,529	1,849,952	1,849,952	1,849,952	1,849,952	1,849,952
R^2	0.005	0.012	0.014	0.066	0.103	0.121

The dependent variable in this table is $\mathbb{D}(\text{LTI} \geq 4.5)_{i,l,b,t}$, a binary variable that equals 1 if the mortgage granted by lender b to borrower i in quarter t in local area l has a loan-to-income ratio (LTI) equal or above 4.5, and 0 otherwise. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. Column (1) includes all observations; columns (2)-(6) include only observations for which the full set of control variables contain non-missing values. Post_t is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. Constrained_b is a binary variable that equals 1 if lender b is at or very close to the limit of 15% share of high LTI mortgages in the four quarters before the announcement of the policy (2013Q3-2014Q2), 0 otherwise. All regressions are estimated using ordinary least squares. Borrower, loan, and bank controls, as well as fixed-effects are either included ("Yes") or not included. Online Appendix Section B shows the definition of the main controls. Robust standard errors double-clustered at bank-quarter and local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.

Table A.6: Local-area level: House price growth

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	25th percentile			50th percentile			75th percentile		
$\text{BrexitRef}_t \times \text{Const}_l \times \text{LowInc}_l$	0.028***	0.027***	0.026***	0.017**	0.018**	0.017**	0.004	0.004	0.002
	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$\text{Post}_t \times \text{Const}_l \times \text{LowInc}_l$	-0.015**	-0.012*	-0.014*	-0.003	-0.001	-0.001	0.009	0.012	0.010
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)
Const_l	-0.011***	-0.007**		-0.005	-0.002		0.002	0.004	
	(0.003)	(0.003)		(0.003)	(0.004)		(0.003)	(0.004)	
LowInc_l	-0.005	-0.002		-0.003	-0.000		-0.003	-0.000	
	(0.004)	(0.004)		(0.003)	(0.003)		(0.004)	(0.004)	
$\text{Post}_t \times \text{Const}_l$	0.038***	0.016***	0.017***	0.027***	0.007	0.008	0.009**	-0.007	-0.007
	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.007)	(0.007)
$\text{Post}_t \times \text{LowInc}_l$	0.007	0.003	0.004	0.001	-0.003	-0.003	-0.000	-0.005	-0.004
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
$\text{BrexitRef}_t \times \text{Const}_l$	-0.039***	-0.008	-0.008	-0.038***	-0.008	-0.008	-0.025***	0.002	0.002
	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.007)	(0.007)
$\text{BrexitRef}_t \times \text{LowInc}_l$	-0.004	-0.005	-0.004	0.004	0.003	0.004	0.005	0.005	0.005
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)
$\text{Const}_l \times \text{LowInc}_l$	-0.001	-0.002		-0.003	-0.005		-0.005	-0.007	
	(0.005)	(0.005)		(0.004)	(0.004)		(0.005)	(0.005)	
Time FE	Yes	-	-	Yes	-	-	Yes	-	-
Region×Time FE		Yes	Yes		Yes	Yes		Yes	Yes
Local Area FE			Yes			Yes			Yes
Observations	4,176	4,176	4,176	4,176	4,176	4,176	4,176	4,176	4,176
R^2	0.327	0.389	0.441	0.336	0.407	0.453	0.237	0.301	0.347

The dependent variable for columns (1)-(3) is the change in the logarithm of the 25th percentile price paid at local area l. The dependent variable for columns (4)-(6) is the change in the logarithm of the median price paid at local area l. The dependent variable for columns (7)-(9) is the change in the logarithm of the 75th percentile price paid at local area l. The 25th, 50th, and 75th percentiles are calculated using all house transactions during a six-month period t. The change is calculated with respect to the same period in the year before. The sample spans from 2012H2 to 2018H1. Post_t is a binary variable equal to 1 in the period 2014H2 - 2018H1, i.e. after the introduction of the policy, 0 before. BrexitRef_t is a binary variable equal to 1 in the period 2016H2 - 2018H1, i.e. after the Brexit referendum, 0 before. Constr_l is a binary variable equal to 1 if the market share in mortgage lending by constrained lenders in the local area l is above the median before the announcement of the policy, 0 otherwise. LowInc_l is a binary variable equal to 1 if the local area is in the top quartile in terms of share of low income borrowers before the announcement of the policy, 0 otherwise. All regressions are estimated using ordinary least squares. Fixed-effects are included ("Yes"), spanned by other fixed-effects ("-"), or not included. Robust standard errors are clustered at local-area level are reported in parentheses. ***: Significant at 1% level; **: significant at 5% level; *: significant at 10% level.