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Macroprudential Policy, Mortgage Cycles, and Distributional Effects: Evidence from the United Kingdom

José-Luis Peydró
Imperial College London, CEPR, UK, and UPF-ICREA-BSE, Spain

Francesc Rodriguez-Tous
Bayes Business School, UK

Jagdish Tripathy
The Bank of England, UK

Arzu Uluc
The Bank of England, UK

We analyze the distributional effects of macroprudential policy on mortgage cycles by exploiting the U.K. mortgage register and a 2014 15% limit imposed on lenders' high loan-to-income (LTI) mortgages. Constrained lenders issue fewer and more expensive high-LTI mortgages, with stronger effects on low-income borrowers. Unconstrained lenders strongly substitute high-LTI loans in local areas with higher constrained lender presence, but not high-LTI loans to low-income borrowers—consistent with adverse selection problems—implying lower overall credit to low-income borrowers. Consistently, policy-affected areas experience lower house price growth postregulation and, following the Brexit referendum (negative aggregate shock), better house price growth and lower mortgage defaults for low-income borrowers. (*JEL* E5, G01, G21, G28, G51)

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Household leverage has received intense academic scrutiny as a source of financial instability. The empirical literature provides evidence that strong mortgage expansion to households was the underlying cause of the 2007–2009 U.S. financial crisis—as well as some previous financial crises—with associated high mortgage defaults, house price contractions, and overall negative real effects (Schularick and Taylor 2012; Favara and Imbs 2015; Adelino, Schoar, and Severino 2016; Mian, Sufi, and Verner 2017; Di Maggio and Kermani 2017; Piskorski and Seru 2021). The theoretical literature shows settings in which unrestricted lending to households can lead to housing booms and to negative externalities during periods of adverse macroeconomic conditions, with strong negative effects on house prices (fire sales) and bank loan defaults, thereby advocating macroprudential policies that limit household leverage during booms (Lorenzoni 2008; Corbae and Quintin 2015; Farhi and Werning 2016; Korinek and Simsek 2016; Favilukis, Ludvigson, and Van Nieuwerburgh 2017; Dávila and Korinek 2017; Greenwald 2018). Consistent with this view, policy makers 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, especially so in analyzing the effects during booms and adverse aggregate conditions.

In this paper, we analyze the distributional effects of macroprudential policy on mortgage cycles. For empirical identification, we utilize the U.K. mortgage register in conjunction with a 15% limit imposed on lenders' high loan-to-income (LTI) mortgages. These lenders are differentially affected based on their prepolicy share of high-LTI loans in their mortgage portfolio. Moreover, we exploit the unexpected outcome of the Brexit referendum, a negative aggregate shock that led to a strong house price growth correction

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[1] For example, regulators in many countries around the world, including the United States and some European and Asian countries, have introduced restrictions on household leverage. A complete list of jurisdictions that have regulated household leverage is available in the iMaPP database (IMF). Some of these policies are on debt/loan-to-income ratios or debt service-to-income ratios, which may affect low-income borrowers more; however, it is not clear that the so-called 2007–2008 U.S. subprime financial crisis was caused by the leverage of low-income as compared to middle-class borrowers (see Adelino, Schoar, and Severino 2016).

across the United Kingdom, to analyze the effects of macroprudential policies implemented during booms at times of negative aggregate shocks.

The macroprudential policy limiting high-LTI lending was announced by the U.K. regulator in June 2014. We exploit the loan-level data on mortgages issued in the United Kingdom during 2012Q3–2016Q2 from the mortgage register in conjunction with this LTI regulation. The loan-level data include information on borrower characteristics such as income, age, and employment status; on the issuing lender; and on characteristics of the loan itself, such as origination date, loan amount, interest rate, interest rate type (fixed or floating), mortgage term, property value, and full postcode. We merge the loan-level data with lenders' balance sheet data. We also match mortgage data with house price growth at the full postcode local area level for different house price quantiles between 2012Q3 and 2018Q2, and loan-level mortgage default status to exploit the unexpected outcome of the Brexit referendum in mid-2016. Therefore, we create a rich data set that allows us to exploit time, borrower, lender, and location characteristics to study the effects of the policy.

Our research design hinges on the restriction on high-LTI lending binding at the lender level for some lenders. At the time of the policy's introduction, the economy was performing well and, moreover, the overall lending of high-LTI loans was just 10%, that is, far from the 15% limit. However, there were differences in exposure across lenders. This provides a variation across U.K. lenders based on the share of high-LTI loans in their mortgage portfolio during the year before the policy's introduction. We use the high-LTI shares to classify U.K. lenders into two groups: constrained and unconstrained lenders. Constrained lenders issued just over a fifth of all mortgages in our sample. Constrained and unconstrained lenders are similar across a wide range of balance sheet characteristics (such as size, liquidity ratio, core funding ratio, return on assets, CET1 ratio, and share of household credit) and mortgage characteristics (such as volume, interest rate, rate type, loan-to-value (LTV), and maturity). We use both a specification without controls and a highly saturated specification to study changes in the mortgage portfolio of constrained lenders in response to the policy. We also test in all key results that there are no differential pretrends.

Our results show that the introduction of the macroprudential regulation affects mortgage lending. First, after the regulation, and compared to unconstrained lenders, constrained lenders cut their share of high-LTI mortgages (by 3.9%) and charge higher loan rates (by 13 basis points [bps], 4.5% higher) for those loans, thereby suggesting bank-driven (credit supply) restrictions due to the policy. Moreover, the fewer high-LTI loans issued by constrained lenders after the regulation contain 6.1% fewer loans to borrowers in the lowest income quintile. That is, the regulation affects low-income borrowers through two distinct channels: 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. Importantly, all the key effects happen only after the regulation is implemented (i.e., no pretrends, which serve as a placebo test).

Second, we analyze credit substitution since the regulation is on lenders (not on households) and is not binding at the aggregate (unconstrained lenders have substantial slack to substitute), and business cycle conditions are good around the policy's introduction. We find imperfect credit substitution.

We find evidence that low-income borrowers are more likely to receive loans with LTI lower than 4.5 from constrained (vs. unconstrained) lenders, leading to no change in the proportion of loans to low-income borrowers by constrained banks. However, this does not imply that intralender substitution is perfect, as the credit substitution is via lower-seized loans (e.g., weighting loans by their size, constrained banks cut the proportion of loans to low-income borrowers) and, in addition, constrained banks cut average loan volumes to low-income borrowers (by 3.7%).

Moreover, there is no substitution of high-LTI loans to low-income borrowers by unconstrained lenders, as these lenders reduce high-LTI loans to low-income borrowers and increase their loan price in areas with a higher prepolicy presence of constrained lenders (and hence with a higher cut in high-LTI loans to low-income borrowers).[2] This finding highlights a third channel through which the regulation negatively affects lending to low-income borrowers. Thus, low-income borrowers suffer a triple credit crunch since unconstrained lenders' substitution is strong for high-LTI loans in general, but nonexistent for high-LTI loans to low-income borrowers.

Furthermore, the cut in credit that we document (i.e., lack of substitution for high-LTI loans to low-income borrowers from unconstrained lenders) is consistent with adverse selection problems. The increases in loan prices for low-income borrowers in high-LTI loans are monotonically increasing for lenders that have more capacity to substitute and are the highest for the unconstrained lenders furthest away from the regulatory limit, that is, lenders with a lower prepolicy presence (proxying for less knowledge) in this market. These effects are even stronger in areas with a higher prepolicy presence of constrained lenders and hence higher substitution possibilities. These results are consistent with winner's curse problems for unconstrained lenders only in the substitution for the segment of low-income borrowers within high-LTI loans. Moreover, the increase in loan prices of high-LTI loans to low-income borrowers is strongest in areas with higher competition among unconstrained lenders (proxied by the Herfindahl-Hirschman Index [HHI]) and with higher potential for credit substitution (i.e., areas with a higher presence of constrained lenders). This result is consistent with theories of adverse selection under differential bank competition (e.g., Marquez 2002) in which higher bank

[2] Said differently, in areas with a higher prepolicy presence of constrained lenders (higher credit substitution possibilities), unconstrained lenders expand high-LTI loans in general and reduce their loan price (i.e., higher credit supply).

competition exacerbates adverse selection problems since lenders are afraid that available borrowers have been rejected by other lenders, thus raising loan prices due to winner's curse problems.

Since results suggest that credit substitution is imperfect, we analyze the overall lending to low-income borrowers stemming from the policy. We aggregate mortgage lending by time (quarterly), local areas (equivalent to boroughs), and income quintiles. Estimated coefficients show that low-income borrowers in areas with a prepolicy one standard deviation higher exposure to constrained lenders experience a 10.8% decline in the total value of lending (in £) after the introduction of the regulation. Consistently, after the regulation there is a drop in the growth rate of the 25th percentile of house price transactions (a quantile that is more linked to low-income borrowers) in local areas more affected by the regulation—that is, areas more exposed to constrained lenders and with a higher concentration of low-income borrowers.

Third, we exploit the unexpected outcome of the Brexit referendum in June 2016, which led to a strong drop in house price growth across the United Kingdom; for instance, growth in the 25th percentile of house prices in the United Kingdom fell from a peak of 11% annually just before the referendum to 2% 2 years later. Also, there was a substantial increase in the number of local areas with negative house price growth (from less than 9% in the 2 years before the referendum to 25% by 2018Q2). Our results suggest that local areas more affected by the 2014 macroprudential policy have a relatively lower cooling in house price growth after the referendum, especially for lower quantiles of house price transactions, consistent with the reduced lending to low-income borrowers postregulation. We also find that the areas more affected by the 2014 macroprudential policy do not respond differently to past negative aggregate shocks (2007–2008 financial crisis), which serves as a placebo test. Moreover, low-income borrowers in the more affected local areas experience relatively lower mortgage defaults after the Brexit referendum. This postreferendum positive effect from the 2014 macroprudential policy is consistent with the relatively lower decline in house price growth in those affected areas as well as the lower leverage due to the policy's introduction.

Literature Review. Our main contribution to the literature is to show the effects of macroprudential regulation of household leverage both during a boom and after a negative aggregate shock (cycle), including its distributional effects—for example, the triple credit crunch to low-income borrowers, including the lack of credit substitution from unconstrained lenders due to adverse selection problems, and the effects on lower defaults for low-income borrowers due to the policy—thereby showing costs and benefits of macroprudential policies on households.

To the best of our knowledge, there is currently no paper that studies the effects of macroprudential regulation of household leverage during periods of both booms and adverse aggregate conditions. This is not only due to scarcity of administrative data on mortgages (most credit registers are on corporate loans), but also to the 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.[3] The United Kingdom offers an ideal setting as it has a mortgage register, a macroprudential policy that restricted high-LTI lending, and a negative aggregate shock (with a strong reduction in house price growth) stemming from the unexpected result of the Brexit referendum. Even though the LTI regulation is on lenders and not on households, business cycle conditions were good when the policy was introduced, and the banking system was not constrained at all (constrained lenders represented only a fifth of lending and aggregate share of high-LTI loans was 10% as opposed to the 15% policy limit), we find that the policy restricts credit to low-income households during the boom, and consistently, lower mortgage defaults and better house price growth during adverse aggregate conditions.

Other papers studying the effects of household leverage regulation introduced after the 2008 financial crisis (e.g., DeFusco, Johnson, and Mondragon [2020]; van Bekkum et al. [2019] and Acharya et al. [2022] based on regulations in the United States, Netherlands, and Ireland, respectively, and Belgibayeva [2020] and Benetton [2021] based on regulations in the United Kingdom) have analyzed the effects of the macroprudential policy only around its introduction and not during an episode of negative aggregate shock. Importantly, by analyzing the beneficial effects during negative aggregate shocks, we provide suggestive evidence on a key prediction of the theoretical models highlighted in our introduction, that is, the reduction in leverage during booms can have an impact on house prices and loan defaults during adverse macroeconomic conditions. Our results, which show a reduction in household leverage resulting from the U.K. macroprudential policy despite no restriction at the borrower level, suggest that there are important frictions in substituting credit across differently affected lenders during a boom period. Our evidence is consistent with adverse selection problems in credit (mortgage) markets (e.g., Shaffer 1998; Marquez 2002; Freixas and Rochet 2008), which further distinguishes our study from the other papers analyzing macroprudential policy.[4]

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

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[3] There was the COVID-19 pandemic in 2020–2022. However, many different policy measures have been introduced in many countries around the world (including the United Kingdom) during the COVID-19 period, including strong expansive fiscal policies, as well as policies supporting lenders (liquidity facilities) and borrowers (loan moratoria).

[4] Our results on the absence of substitution of high-LTI loans to low-income borrowers by unconstrained lenders, despite the substantial capacity among unconstrained lenders to do so and mortgage lending being more transactional than SME lending, expands our understanding of credit frictions. On the transactional nature of mortgage lending, see, for example, Nguyen (2019), in which competitor banks are more likely to substitute mortgages than SME loans when faced with rival bank branch closures.

loop that exists between changes in lending standards or expectations, household leverage, and subsequent changes in house prices (Mayer, Pence, and Sherlund 2009; Mian and Sufi 2009; Favara and Imbs 2015; Jordà, Schularick, and Taylor 2015; Bhutta and Keys 2016; Di Maggio and Kermani 2017; Adelino, Schoar, and Severino 2017; Johnson 2020). Our results suggest that the macroprudential regulation (introduced during a boom in response to increases in household leverage) is associated with a subsequent reduction in house price growth in local areas more affected by the regulation, and importantly, with better house price dynamics and mortgage defaults after the Brexit referendum (a negative aggregate shock). That is, consistent with the reduction in lending to low-income borrowers due to the macroprudential policy, after the Brexit referendum and in areas affected by the 2014 policy, there are lower mortgage defaults (notably for low-income borrowers) and relatively better house price growth (especially stronger for houses in the 25th percentile).

There is also a growing literature that has varyingly attributed the secular rise in income and wealth inequality to taxation (Piketty and Saez 2003), globalization (Autor, Dorn, and Hanson 2013), and automation (Autor and Dorn 2013). Some papers have also studied the redistributive effects of policies, such as those for monetary policy (Auclert 2019; Andersen et al. Forthcoming) 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. Our results suggest that, on the one hand, macroprudential policies aimed at limiting high leverage can strongly reduce mortgage lending to low-income borrowers, but, on the other hand, such macroprudential policies are associated with benefits—in terms of a lower house price growth correction and lower mortgage defaults for low-income borrowers—during an episode of negative aggregate shock.

1. Institutional Background

Mortgages are one of the largest items on the balance sheets of both U.K. lenders and households; indeed, they are the largest liability for U.K. households.[5] Therefore, nonperforming mortgages can pose direct risks to the resilience of the U.K. banking system and to financial stability. In the event of a negative aggregate shock, households may increase loan defaults and/or adjust their real estate assets, which could have significant indirect effects on the rest of the economy. The macroprudential policy authority in the United Kingdom, 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.

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

At its June 2014 meeting, the FPC assessed risks to lenders and the wider economy from an increase in U.K. household indebtedness. At that time, there were signs that the U.K. 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 at or greater than 4.5 rose from 6.5% in the immediate precrisis period during 2005–2007 to 10% between 2013Q2 and 2014Q1. 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 that the Prudential Regulation Authority (PRA) and Financial Conduct Authority (FCA) ensure that mortgage lenders do not extend more than 15% of their new residential mortgages with LTI at or greater than 4.5.[6]

The PRA and the FCA implemented the FPC's recommendation as of October 1, 2014. The policy was implemented on a quarterly basis and excludes remortgages 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 came into effect on October 1, 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 accounted for 99% and 98% of the total number and total value of mortgage lending, respectively.

2. 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 United Kingdom; the PSD007 database, which includes the stock of mortgages in the United Kingdom; the balance sheet and income statement data from lenders; and the U.K. land registry for data on housing transactions.

[6] The PRA is responsible for prudential regulation and supervision of banks, building societies, credit unions, insurers, and major investment firms in the United Kingdom. The FCA is the conduct regulator for financial services firms and financial markets in the United Kingdom. Along with the cap on the proportion of mortgages with LTI ≥ 4.5, the FPC also introduced an affordability test for lenders with which they must assess the affordability of each mortgage issued to ensure that borrowers could still afford the mortgage if the Bank of England's base 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 U.K. lenders were using stress tests of 250–300 basis points when the 2014 regulation was introduced. See Bank of England (2014), Box 5, for details. The 4.5 LTI limit was calibrated to ensure a cap on the mass of borrowers who may face 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), p. 8 for details.

Table 1
Summary statistics of loan and borrower 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	23.4	7.7	18	25	30
Loan-to-Income	1,849,952	3.0	1.1	2.2	3.1	3.8
Loan-to-Value	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	9.8	30	37	45

Sample of high loan-to-income (LTI) mortgages

Variable	count	mean	sd	p25	p50	p75
Loan Value (£)	149,988	235,599	140,741	142,100	199,999	284,995
Property Value (£)	149,988	362,146	259,518	201,000	286,950	426,000
Mortgage Term	149,988	28.16	6.17	25	30	34
Loan-to-Income	149,988	4.85	0.30	4.63	4.77	4.99
Loan-to-Value	149,988	69.8	15.5	60.3	73.5	80.6
Borrower Income (£)	149,988	48,763	31,636	29,262	41,000	58,720
Borrower Age	149,988	35	8.24	29	34	40

This table shows summary statistics based on loan- and borrower-level data of residential mortgages issued in the United Kingdom during 2012Q3–2016Q2 that were under the purview of the 2014 regulation.

PSD001 (Product Sales Database 001), updated quarterly by the Financial Conduct Authority, contains information on the universe of newly issued residential mortgages subject to the limit on high loan-to-income lending introduced in 2014.[7] We exclude from our sample instances of external remortgaging without a change in the principal of the loan and lifetime mortgages since these types of contracts are not in the scope of the regulation. Our sample covers mortgages originated between 2012Q3 and 2016Q2, covering 2 years around the announcement of the regulation in June 2014. The data from PSD001 provide a wide range of borrower characteristics, such as the borrower's gross income, age, and employment status, and whether the borrower is a home-mover, first-time buyer or remortgagor. Moreover, the database contains information on mortgage characteristics such as loan amount, interest rate, the price of the property, LTI, loan-to-value, mortgage term, type of repayment, and the location of the property. We report summary statistics of our sample in Table 1.

The data set also includes the date of origination, the issuing lender, and highly disaggregated information on the property's location at the six-digit

[7] The database includes the full set of mortgages that U.K. regulators use to assess compliance with the regulation. 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—that is, 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 regulation compared to other types of mortgages: borrowers remortgage their loans typically after the initial fixed rate period (2 or 5 years); as they have paid part of the mortgage for a period of time, they are likely to have lower LTI 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 regulation.

postcode level. Therefore, we can use these data to study changes in the mortgage portfolio of lenders more, or less, constrained by the limit on high-LTI lending; test whether some borrower cross sections are disproportionately affected by the regulation; and also explore the geographic dimensions across which these adjustments take place following the regulation. Into this data set, we merge information on the sales channel (i.e., whether the mortgage is sold directly by the lender or via a mortgage broker), provided by the FCA.

PSD007 (Product Sales Database 007) contains information on the stock of U.K. mortgages. This data set has been obtained by the FCA biannually starting in 2015. It includes information on the performance of extant mortgages in a given period, such as whether the mortgage is in payment arrears or under forbearance; the latter refers to mortgages under repayment difficulties that have received modified terms from lenders in the form of payment suspension or reduction or term extension. The stock data set includes the date of origination, issuing lender, and the location of the related property. We use this information to track whether a mortgage in our original sample is under default (i.e., under payment arrear or forbearance or possession order) by the end of 2017. This allows us to study the impact of the 2014 LTI regulation on mortgage defaults (for loans issued before as opposed to after the policy) following the Brexit referendum, which led to a substantial house price correction in the United Kingdom.

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

Finally, the His Majesty's Land Registry's Price Paid Data contain information on the price paid, date, location (at the six-digit postcode level), and house type (flat, terraced, semidetached, or detached) of all residential housing transactions in England and Wales. We use this data set to study house prices dynamics immediately after the policy's introduction as well as during the correction in the housing market following the Brexit referendum, and focus on the period between the second half of 2012 (2 years before the introduction of the regulation) and the first half of 2018 (2 years after the referendum). The key feature of this data set—disaggregated location (six-digit postcodes) and house types—allows us to also create a house price index at a full postcode–house type level that we use to study changes in house price dynamics.

We construct a house price series that controls for the quality of the properties transacted while retaining a house price distribution within local areas.[8] The United Kingdom has approximately 1.75 million unique postcodes

[8] We expand on the construction of the index in Internet Appendix Section C.

at the most disaggregated level for a population of approximately 27.5 million households in 2018, with around 4,500 unique postcodes in each local area. This level of disaggregation is quite uncommon: for comparison, the United States only has 41,689 different Zip codes for a much bigger territory and population. For each period, we aggregate the data as postcode–house type pairs, while taking the average price in cases for which there is more than one transaction in a given period. We create a balanced panel of postcode–house type pairs that are transacted every period. We thus control for the quality (proxied by the full postcode–house type unit) of transacted houses in local areas over time, while retaining a house price distribution for each local area.

3. Empirical Strategy and Results

Lenders in the United Kingdom are differentially affected by the 2014 loan-to-income regulation based on their prepolicy share of high-LTI loans. We first define the criteria for classifying lenders into two groups: “constrained” and “unconstrained” lenders. We use this variation to analyze lending, both at the loan level as well as aggregated, and house prices and loan defaults.

The 2014 LTI regulation sets a 15% limit on the proportion of new residential mortgages that lenders could issue every quarter with 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 five lenders, which issue just over a fifth 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 below the 15% limit and hence less constrained by the regulation.[9] We refer to these lenders as “unconstrained” lenders. Apart from the shares of high-LTI lending (Figure 1), constrained lenders do not significantly differ from unconstrained lenders in other key characteristics of their balance sheets, such as size, liquidity, and capital ratio (Internet Appendix Table IA.4), or (apart from the average LTI) in the underlying characteristics of their mortgage portfolio, such as loan volume, loan interest rate, rate type, loan-to-value, or maturity (Internet Appendix Table IA.5).

Our empirical strategy relies on the differential exposure to the regulation for constrained and unconstrained lenders. We use data on lending 2 years prior to and 2 years after the announcement of the regulation at the end of 2014Q2, that is, all the mortgages issued during 2012Q3–2016Q2. We drop all mortgages issued during 2014Q3 from our sample since the regulation was announced towards the end of 2014Q2 but came into effect only in 2014Q4. We restrict our study to mortgages issued until 2016Q2, when the United Kingdom held

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

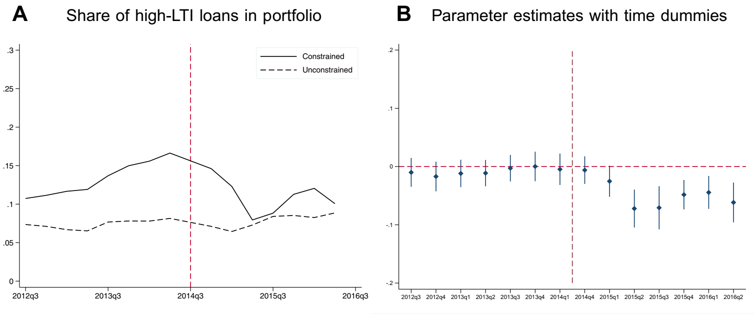

Figure 1
Loan level: Share of high-LTI loans
Panel (A) shows the quarterly share of the number of high loan-to-income mortgages for the period of 2012Q3 to 2016Q2 for constrained and unconstrained lenders. Panel (B) shows the estimated coefficients of the interaction of $Constrained_b$, a binary variable that equals 1 if lender b is at or very close to the limit of a 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 $HighLTI_{i,l,b,t}$, which is 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 equal to 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 announcement 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×bank and quarter fixed effects. The definitions of the main independent variables can be found in Internet Appendix Section A.

the so-called Brexit referendum to leave the European Union. Exploiting the Brexit referendum shock, we analyze house prices (with data until 2018Q2, i.e., 2 years after the referendum) and loan defaults in areas differentially affected by the regulation.

3.1 Loan-level analysis

3.1.1 Share, pricing, and redistribution of high-LTI mortgages. We study the differential impact of the regulation on high-LTI lending by constrained lenders using loan-level data in Equations (1), (2), and (3). The baseline specification (Equation (1)) tests whether mortgages issued by constrained lenders are less likely to be high-LTI loans (LTI $\geq$ 4.5) following the regulation. The outcome variable, $HighLTI_{i,l,b,t}$, indicates whether a loan issued to borrower i in local area l by bank b in quarter t has LTI $\geq$ 4.5; the key regressor is $Post_t \times Constrained_b$, where $Post_t$ and $Constrained_b$ are dummies that indicate periods after the implementation of the regulation (2014Q4 onwards) and constrained lenders, respectively. The controls in the highly saturated specification are borrower and loan characteristics ($X_{i,l,b,t}$), bank×time controls ($X_{b,t}$), local area×bank fixed effects ($f_{l,b}$) and time fixed effects (f_t).[10] l refers to the location of the underlying property at Local

[10] Borrower controls include borrower type, employment status, age, income and whether joint or sole applicant. Loan controls include type of rate, term, type of repayment, loan value, property value, and income verification.

Table 2 (A)
Loan level: Share of high-LTI loans (LTI ≥ 4.5)

Variable	←Dummy for high-LTI loans ($HighLTI_{i,l,b,t}$)→				
	(1)	(2)	(3)	(4)	(5)
$Post_t \times Constrained_b$	−0.0474***	−0.0578***	−0.0513***	−0.0401***	−0.0387***
	(0.0116)	(0.0102)	(0.0093)	(0.0087)	(0.0079)
Observations	1,849,952	1,849,952	1,849,952	1,849,952	1,849,952
R^2	0.0124	0.0641	0.0657	0.117	0.118
Borrower, Loan Controls		Yes	Yes	Yes	Yes
Bank Controls			Yes	Yes	Yes
Local Area×Bank FE				Yes	Yes
Time FE					Yes

The dependent variable in this table is $HighLTI_{i,l,b,t}$, 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 equal to or above 4.5, and 0 otherwise. 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. $Constrained_b$ 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. Internet Appendix Section A 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 the bank–quarter and local area level are reported in parentheses. * $p<.1$; ** $p<.05$; *** $p<.01$.

Administrative Unit Level 1 (LAU1).[11] The coefficient β reflects the change in the share of high-LTI loans in the portfolio of constrained lenders after the introduction of the policy.

$$HighLTI_{i,l,b,t} = \beta \cdot Post_t \times Constrained_b + \gamma_1 \cdot X_{i,l,b,t} + \gamma_2 \cdot X_{b,t} + f_{l,b} + f_t + \varepsilon_{i,l,b,t} \tag{1}$$

Table 2 (A) presents estimates of β (Equation (1)) based on our loan-level sample during 2012Q3–2016Q2.[12] The negative and significant estimate of β suggests that constrained lenders reduce high-LTI mortgages in the aftermath of the regulation. The coefficient is robust and highly significant as we add loan-level controls (column 2 (c.2)), bank×time controls (c.3), local area×bank fixed effects (c.4), and time fixed effects (c.5). In c.5, which includes all the controls, the coefficient indicates that the share of high-LTI mortgages in the portfolio of constrained lenders drops by roughly 3.9% following the regulation, down from 16.6% when the policy was introduced (2014Q2).

Bank controls include size, liquidity and core funding ratios, return on assets, provisions, and the share of household lending. These variables are described in Internet Appendix Tables IA.1 and IA.2. In unreported results, we also test for robustness to inclusion of local area×time fixed effects (throughout all tables and columns when possible); our results are qualitatively and quantitatively similar with these fixed effects.

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

12 Our loan-level data include 2.9 million mortgages issued during the period of our study; 1.8 million of these have information on all our controls and form the basis of our loan-level regressions. The drop is primarily due to missing observations for loan-level controls described in Internet Appendix Table IA.1. We include $Post_t$ and $Constrained_b$ as standalone variables when not absorbed by fixed effects; estimated coefficients for either variable are positive and smaller in magnitude than the one on $Post_t \times Constrained_b$.

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

Variable	←Interest rate($Rate_{i,l,b,t}$)→						
Subsample	Low-LTI	High-LTI	All				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Post_t \times Constrained_b$	−0.0068	0.0647	−0.0068	0.0433	−0.0055	0.0396	0.0597
	(0.130)	(0.151)	(0.130)	(0.132)	(0.130)	(0.127)	(0.0353)
$Post_t \times Const._b \times HighLTI_j$			0.0715	0.145**	0.131**	0.123**	0.128***
			(0.085)	(0.0643)	(0.0629)	(0.0517)	(0.0447)
Observations	1,694,823	150,845	1,845,668	1,845,668	1,845,668	1,845,668	1,845,668
R^2	0.0878	0.156	0.0964	0.281	0.292	0.356	0.428
Borrower, Loan Controls				Yes	Yes	Yes	Yes
Bank Controls					Yes	Yes	Yes
Local Area×Bank FE						Yes	Yes
Time FE							Yes

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. The sample is restricted to mortgages with a loan-to-income ratio less than (column 1) or greater than or equal to (column 2) 4.5, while columns 3–7 include the full sample. $Post_t$ 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 a 15% share of high-LTI mortgages in the four quarters before the announcement of the policy (2013Q3–2014Q2), 0 otherwise. $HighLTI_j$ is a binary variable that equals 1 for mortgages with LTI≥4.5, 0 for the rest. 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. Internet Appendix Section A shows the definition of the main controls. Lower-level interactions are included as standalone variables when they are not absorbed by fixed effects. Robust standard errors double-clustered at the bank–quarter and local area level are reported in parentheses. * $p<.1$; ** $p<.05$; *** $p<.01$.

Figure 1 (A) shows the share of high-LTI loans in the portfolio of constrained and unconstrained lenders, with a clear decline of high-LTI loans in the portfolio of constrained lenders following the regulation. Figure 1 (B) plots the coefficients obtained by regressing $Constrained_b$ 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 prepolicy coefficients are quantitatively and statistically not different from 0, consistent with the lack of pretrends.

Pricing of high-LTI loans. Columns 1 and 2 of Table 2 (B) show results from regressing $Rate_{i,l,b,t}$—interest rate of the mortgage issued to borrower i in local area l by bank b in quarter t—on $Post_t \times Constrained_b$ in subsamples of low-LTI (LTI<4.5) and high-LTI (LTI≥4.5) loans, respectively. The coefficient in the subsample of high-LTI loans is positive (6.5 bp), while that in the subsample of low-LTI loans is quantitatively insignificant (−0.7 bp).

$$Rate_{i,l,b,t} = \beta_{rate} \cdot Post_t \times Constrained_b \times HighLTI_{i,l,b,t} + \gamma_1 \cdot X_{i,l,b,t} + \gamma_2 \cdot X_{b,t} + f_{l,b} + f_t + \varepsilon_{i,l,b,t} \quad (2)$$

We further estimate β_{rate} using Equation (2) and our loan-level data to test whether constrained lenders charge different interest rates on high-LTI loans after the introduction of the regulation. Columns 3–7 show estimates of β_{rate}

on the triple interaction term first without any controls, and progressively with the controls used to saturate the specification (as in Equations (1) and (2)). β_{rate} is positive and robust to the inclusion of controls. Further, β_{rate} is statistically significant in columns 4–7 as the standard errors go down with the inclusion of controls that also substantially increase the R^2. The coefficient in c.7 shows a 4.5% increase in interest rates for high-LTI loans issued by constrained lenders, up 13 bp in comparison to the average interest rate of 290 bp for such loans at the policy's introduction. The results this far—lower volume and higher price—suggest that the drop in high-LTI lending in Table 2 (A) is lender-driven (credit supply).

Redistribution of high-LTI loans across borrowers. We use Equation (3) to investigate the impact of the regulation on borrower income in the subsample of high-LTI mortgages. We classify mortgages into income quintiles based on the distribution of the reported income of borrowers of all mortgages issued in periods before the introduction of the regulation and assign them a dummy $\mathbb{D}(Inc=j)$, where $j \in \{1,2,3,4,5\}$. For each borrower i, we use information on the location of the underlying property to position them in their corresponding quintile j based on the income distribution of all mortgages issued at a regional level.[13]

$$\mathbb{D}(Inc=j)_{i,l,b,t} \\ = \beta_j \cdot Post_t \times Constrained_b + \gamma_1 \cdot X_{i,l,b,t} + \gamma_2 \cdot X_{b,t} + f_{l,b} + f_t + \varepsilon_{i,l,b,t} \qquad (3)$$

The estimated β_j shown in Table 3 reflects a stark change in the distribution of borrower incomes in the high-LTI portfolio of constrained lenders following the policy. Column 1 shows that constrained lenders decrease the share of high-LTI loans issued to borrowers in the lowest income quintile by 6.1% (down from 30.5% at the policy's introduction). This decline is matched by an increase in the proportion of high-LTI loans obtained by borrowers in the higher income quintiles (c.4, c.5). Figure 2 shows a lack of pretrends in the share of low-income borrowers in high-LTI loans by constrained lenders, with the negative effect only coming after the introduction of the policy. Interestingly, in Internet Appendix Table IA.8, there is no change in the age composition of high-LTI mortgages issued by constrained lenders in $Post_t$ periods (also without pretrends, Internet Appendix Figure IA.4). Thus, the contraction in high-LTI loans by constrained lenders has a stronger effect on low-income borrowers. These households are negatively affected by both the reduction in

[13] We use a localized distribution, rather than the national distribution, to account for regional differences across the United Kingdom. The income quintile classification is based on all mortgages issued at the 40 Local Administrative Unit 2 (LAU2) level in the United Kingdom. LAU2 is at a higher level than LAU1, the level at which we aggregate lending data in Section 3.2. The main reason for using LAU2 instead of the more granular LAU1 to classify borrowers is the presence of very few mortgages for some LAU1 local areas in prepolicy periods to generate reliable quintile thresholds.

Table 3
Loan level: Income quintiles in high-LTI loans

Variable	←Dummy for income quintiles ($\mathbb{D}(Inc=j)_{i,l,b,t}$)→				
j =	I	II	III	IV	V
$Post_t \times Constrained_b$	−0.0608***	−0.0221*	−0.0069	0.0309***	0.0588***
	(0.0159)	(0.0096)	(0.0092)	(0.0089)	(0.0119)
Observations	149,988	149,988	149,988	149,988	149,988
R^2	0.338	0.0654	0.079	0.140	0.207
Borrower, Loan Controls	Yes	Yes	Yes	Yes	Yes
Bank Controls	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes

The dependent variables are binary variables indicating whether borrower i associated with a mortgage granted by lender b in quarter t in local area l belongs to a particular income quintile (1) or not (0). Each column corresponds to the binary variables for a specific quintile group, with I being the bottom and V the top quintile of the income distribution. The quintiles are constructed using the sample from the prepolicy period. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. The sample is restricted to mortgages with an 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 a 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, as well as fixed effects. Internet Appendix Section A shows the definition of the main controls. Robust standard errors double-clustered at the bank–quarter and local area level are reported in parentheses. * $p<.1$; ** $p<.05$; *** $p<.01$.

the share of high-LTI loans (which they are more likely to borrow) and the drop in their share within high-LTI loans.[14]

3.1.2 Substitution. We analyze credit substitution since the regulation applies to U.K. lenders and not households, and business cycle conditions were good around the policy's introduction: borrowers who could not receive high-LTI loans from constrained lenders (i.e., low-income borrowers) could either receive a loan with LTI < 4.5 from those lenders or obtain a (high-LTI) loan from an unconstrained lender.

We analyze the first possibility in Table 4. We regress the dummy indicating low-income borrowers ($LowInc_i$, which corresponds to $\mathbb{D}(Inc=1)$ in the previous table) on $Post_t \times Constrained_b$ in different subsamples of LTI bands (four bands in c.1–4 are based on quartiles for mortgages with LTI<4.5, LTI≥4.5 in c.5, and for all loans in c.6). Table 4 emphasizes the role of substitution by constrained lenders via smaller loans to low-income borrowers. Columns 1–4 of the table show a 2.2 percentage point (pp) increase (up from 15.1% at the policy's introduction) in the share of low-income borrowers in lower-LTI loans issued by constrained lenders after the regulation, while c.5 corresponds to a 6.1% reduction in the share of low-income borrowers in high-LTI loans.

14 In Internet Appendix Table IA.7, we find that constrained lenders increase average loan size, property value, and LTV of high-LTI loans after the policy; they also reduce the average LTI and increase borrower income (controlling for loan size). The increase in average borrower incomes is over and above any (mechanical) increase driven by the increase in loan size (reported in column 1 of the same table).

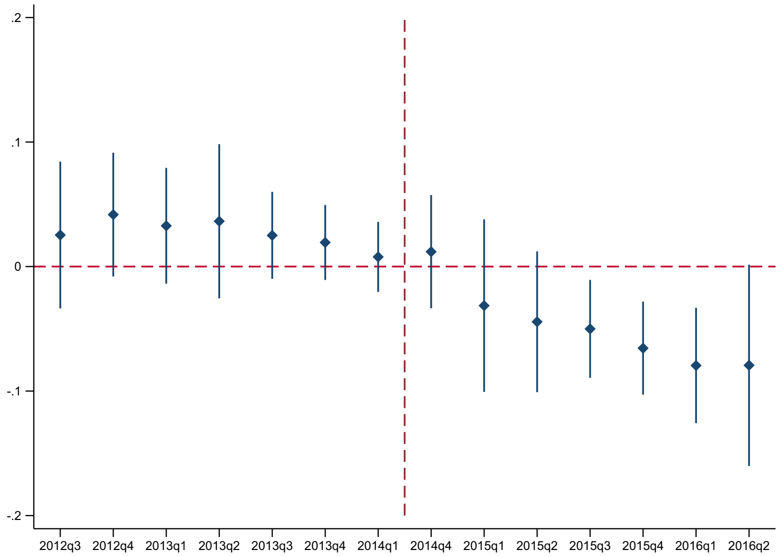

Figure 2
Loan level: Share of low-income borrowers in high-LTI loans
This figure shows the estimated coefficients of the interaction of $Constrained_b$, a binary variable that equals 1 if lender b is at or very close to the limit of a 15% share of high loan-to-income mortgages in the four quarters before 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 $\mathbb{D}(Inc$=I) ($LowInc_i$), which is a binary variable that equals 1 if the income of the borrower is in the bottom quintile of the income 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 announcement 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×bank and time fixed effects. The definitions of the main independent variables can be found in Internet Appendix Section A.

When combining the different LTI groups in c.6, there is a zero differential change in the share of loans to low-income borrowers between constrained and unconstrained lenders. However, this does not suggest that intralender substitution is perfect since substitution in c.1–4 is towards (on average) smaller low-LTI loans (within low-income borrowers), while the contraction in c.5 is in the larger high-LTI loans. Consistent with the shift towards smaller low-LTI loans for low-income borrowers, an estimate of c.6 using loan size as weights is negative and statistically significant at the 0.05 level. Further, c.7 shows a 3.7% reduction in the average size of loans to low-income borrowers following the regulation (while c.8 shows that there is no corresponding reduction in the average size of loans to borrowers with higher incomes).

Heterogeneous substitution of high-LTI loans. To further study substitution (given the substantial reduction in high-LTI loans (Table 2 (A)) and the disproportionate reduction of low-income borrowers receiving high-LTI loans (Table 3)), we focus on the behavior of unconstrained lenders who had substantial slack to substitute constrained lenders. We classify unconstrained

Table 4
Loan level: Substitution in lending to low-income borrowers

Variable	←Dummy for low-income borrowers ($\mathbb{D}(Inc=\mathrm{I})$)→						log(Loan Size)	
Subsample	LTI ∈ (0,2.09)	LTI ∈ [2.09,2.87)	LTI ∈ [2.87,3.57)	LTI ∈ [3.57,4.5)	LTI ≥ 4.5	All	Low Income	Non-low Income
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Post_t \times Constrained_b$	0.0128*	0.0243***	0.0249**	0.0313***	−0.0608***	0.0038	−0.0366*	−0.0094
	(0.0057)	(0.0071)	(0.0078)	(0.0073)	(0.0159)	(0.0058)	(0.0203)	(0.0149)
Observations	404,346	417,799	428,022	445,371	149,988	1,849,962	278,524	1,570,212
R^2	0.173	0.200	0.207	0.245	0.338	0.189	0.488	0.528
Borrower, Loan Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable in columns 1–6, $LowInc_{i,l,b,t}$, is a binary variable indicating whether the income of borrower i associated with a mortgage granted by lender b in quarter t in local area l is in the bottom quintile of the income distribution among borrowers. The dependent variable in columns 7–8, $\log(LoanSize_{i,l,b,t})$, is the logarithm of the total amount of mortgage granted by lender b to borrower i in quarter t in area l. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. The quartiles of the loan-to-income distribution are calculated based on the prepolicy period. In columns 1–4, the sample is restricted to mortgages with an LTI inside that particular quartile. In column 5, the sample is restricted to mortgages with LTI≥4.5. Column 6 includes the full sample. Column 7 (8) contains mortgages to low-income (non–low-income) borrowers only. $Post_t$ 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 a 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, as well as fixed effects. Internet Appendix Section A shows the definition of the main controls. Robust standard errors double-clustered at the bank–quarter and local area level are reported in parentheses. * $p<.1$; ** $p<.05$; *** $p<.01$.

lenders into three groups based on the share of high-LTI loans in their portfolio a year before the introduction of the regulation. $Least\_Unconstr._b$ is the group of lenders closest to the 15% limit (with a share of high-LTI loans around 10% before the regulation), $Mid\_Unconstr._b$ comprises lenders further away from the limit (share of high-LTI loans around 5% before the regulation), and $Most\_Unconstr._b$ are lenders furthest away from the limit (share of high-LTI loans around 1% before the regulation). We test whether these three lender groups substitute high-LTI loans, and particularly to low-income borrowers among the high-LTI loans, in areas with a higher exposure to constrained lenders (i.e., areas with a higher credit substitution potential), and whether they do so differentially with respect to their available slack.

$$HighLTI/LowInc_{i,l,b,t} = \beta_h \cdot Post_t \times ConstrShare_l + \gamma_1 \cdot X_{i,l,b,t} + \gamma_2 \cdot X_{b,t} + f_{l,b} + f_t + \varepsilon_{i,l,b,t} \qquad (4)$$

We estimate Equation (4) in the sample of loans issued by unconstrained lenders to study the substitution of high-LTI loans by these lenders. First, we regress a dummy for high-LTI loans ($HighLTI_{i,l,b,t}$) on the interaction between $Post_t$ and $ConstrShare_l$. $ConstrShare_l$ is the demeaned share of lending by constrained lenders in local area l in periods before the introduction of the regulation. β_h, if positive (negative), shows whether there is an overall expansion (contraction) in lending of high-LTI loans by unconstrained lenders

Table 5
Loan level: Substitution by unconstrained lenders

Variable	Dummy for high-LTI loans $\leftarrow (HighLTI_{i,l,b,t}) \rightarrow$		Dummy for low-income borrowers within high-LTI loans $\leftarrow (LowInc_{i,l,b,t}) \rightarrow$	
Subsample	All		High-LTI loans	
	(1)	(2)	(3)	(4)
$Post_t \times ConstrShare_l$	0.0007*		−0.0083***	
	(0.0004)		(0.0017)	
$Post_t \times ConstrShare_l \times Least\_Unconstr._b$		−0.0010**		−0.0056***
		(0.0004)		(0.0018)
$Post_t \times ConstrShare_l \times Mid\_Unconstr._b$		0.00134**		−0.0081***
		(0.0005)		(0.0022)
$Post_t \times ConstrShare_l \times Most\_Unconstr._b$		0.00144**		−0.001
		(0.0006)		(0.0244)
Observations	1,233,127	1,233,127	75,103	75,103
R^2	0.0942	0.0950	0.331	0.332
Borrower, Loan Controls	Yes	Yes	Yes	Yes
Bank Controls	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

The dependent variables are $HighLTI_{i,l,b,t}$ (c.1–2), a binary variable that equals 1 if a mortgage granted by lender b to borrower i in quarter t in local area l has a loan-to-income ratio equal to or above 4.5, and 0 otherwise; $LowInc_{i,l,b,t}$ (c.3–4), a binary variable indicating whether the income of borrower i associated with a 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 includes all mortgages issued by unconstrained lenders (c.1–2) and high-LTI mortgages issued by unconstrained lenders (c.3–4). Unconstrained lenders are classified into three groups—$Least\_Unconstr._b$ refers to unconstrained lenders whose share of loans with LTI≥4.5 in 2013Q3–2014Q2 is closest to the 15% limit, $Most\_Unconstr._b$ refers to unconstrained lenders furthest from the 15% limit, and $Mid\_Unconstr._b$ refers to unconstrained lenders with an intermediate share of high-LTI loans. $Post_t$ is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. $ConstrShare_l$ equals the demeaned share of lending by constrained lenders in local area l in periods before the announcement of the policy. All regressions are estimated using ordinary least squares. Lower-level interactions are included as standalone variables when they are not absorbed by fixed effects. Borrower, loan, and bank controls, as well as fixed effects, are included. Internet Appendix Section A shows the definition of the main controls. Robust standard errors double-clustered at the bank–quarter and local area level are reported in parentheses. * $p<.1$; ** $p<.05$; *** $p<.01$.

in areas with higher exposure to constrained lenders (and hence higher potential to substitute high-LTI loans in general or to low-income borrowers). We include lower-level interaction terms and controls described in Equation (1).

Table 5 c.1 shows that unconstrained lenders are more likely to provide high-LTI mortgages in areas with a higher prepolicy presence of constrained lenders after the policy is introduced (up by 0.5 pp in areas with one standard deviation higher exposure to constrained lenders). Further, in c.2, the triple-interaction among $Post_t$, $ConstrShare_l$, and the lender groups shows that this substitution of high-LTI loans is a lot stronger for the two lender groups further away from the 15% limit, $Mid\_Unconstrained_b$ and $Most\_Unconstrained_b$. This result is consistent with the residualized shares of high-LTI loans shown in Internet Appendix Figure IA.3, with a strong decline for constrained lenders, and an increase for unconstrained lenders following the regulation.

Yet, is this substitution of high-LTI loans homogeneous? We have seen that the reduction of high-LTI lending by constrained lenders (Table 2 (A)) affects low-income borrowers through two distinct channels: first because they are overrepresented in the high-LTI segment, and second because constrained lenders shift their high-LTI lending away from low-income borrowers (Table 3). Do unconstrained lenders substitute high-LTI mortgages to low-income borrowers? Or are there impediments that do not allow low-income borrowers to benefit from substitution?

Table 5 c.3–4 show estimates of β_h in Equation (4) by regressing the dummy for low-income borrowers ($LowInc_{i,l,b,t}$) in the subsample of high-LTI loans issued by unconstrained lenders. Column 3 shows that β_h for low-income borrowers is negative and statistically significant. That is, in their substitution of high-LTI loans, unconstrained lenders reduce lending to low-income borrowers in areas with a higher share of constrained lenders—areas with more possibilities for substitution. Local areas with a one standard deviation higher share of constrained lenders experience a 5.7-pp decline (down from 35.2%) in the share of low-income borrowers in high-LTI loans issued by unconstrained lenders. This lack of substitution of high-LTI loans for low-income borrowers is despite the reduction in lending of high-LTI loans to low-income borrowers by constrained (compared to unconstrained) lenders (Table 3), available slack, and overall good economic and financial conditions. Further, c.4 shows that this decline is driven by all three unconstrained lender groups.

Mechanisms underlying substitution pattern. We explore mechanisms behind the heterogeneous substitution pattern described above. First, we test whether unconstrained lenders adjust their pricing of high-LTI mortgages after the policy. We estimate Equation (5), where the dependent variable is the same as in Equation (2), but the sample is again restricted to loans issued by unconstrained lenders.

$$Rate_{i,l,b,t} = \beta^{s}_{rate} \cdot Post_t \times HighLTI_{i,l,b,t} + \gamma_1 \cdot X_{i,l,b,t} + \gamma_2 \cdot X_{b,t} + f_{l,b} + f_t + \varepsilon_{i,l,b,t} \tag{5}$$

The estimate of β^{s}_{rate} in Table 6 c.1 shows that unconstrained lenders reduce loan rates for high-LTI loans compared to other loans after the policy is introduced, consistent with a willingness to substitute for these loans. This 12-bp reduction in loan rates (against an average price of 315 bps for high-LTI loans by unconstrained lenders at the policy's introduction) is present for all three unconstrained lender groups (c.2) as well as in areas with high (c.3) and low (c.4) shares of constrained lenders before the policy. That is, results are consistent with a higher credit supply of high-LTI loans by unconstrained lenders after the regulation in areas with a higher prepolicy share of constrained lenders.

Given the heterogeneous substitution pattern of high-LTI loans by unconstrained lenders (i.e., not to low-income borrowers), we study whether these results are more consistent with borrower frictions or lender frictions by analyzing the pricing of this segment. We use Equation (6) for the subsample of high-LTI loans issued by unconstrained lenders: a negative $\beta^{s'}_{rate}$ would suggest that unconstrained lenders try to attract low-income borrowers in high-LTI

Table 6
Loan level: Pricing of high-LTI loans by unconstrained lenders

Variable	← Interest rate ($Rate_{i,l,b,t}$) →			
Subsample	All		High constr. share	Low constr. share
	(1)	(2)	(3)	(4)
$Post_t \times HighLTI_{i,l,b,t}$	−0.121***		−0.125***	−0.116***
	(0.0306)		(0.0260)	(0.0342)
$Post_t \times HighLTI_{i,l,b,t} \times Least\_Unconstr._b$		−0.131***		
		(0.0498)		
$Post_t \times HighLTI_{i,l,b,t} \times Mid\_Unconstr._b$		−0.050**		
		(0.0219)		
$Post_t \times HighLTI_{i,l,b,t} \times Most\_Unconstr._b$		−0.244**		
		(0.122)		
Observations	1,228,827	1,228,827	244,208	984,619
R^2	0.482	0.483	0.495	0.479
Borrower, Loan Controls	Yes	Yes	Yes	Yes
Bank Controls	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

The dependent variable is the interest charged on a mortgage at the time of origination. The sample includes mortgages issued by unconstrained lenders only. Unconstrained lenders are classified into three groups—$Least\_Unconstr._b$ refers to unconstrained lenders whose share of loans with an LTI≥4.5 in 2013Q3–2014Q2 is closest to the 15% limit, $Most\_Unconstr._b$ refers to unconstrained lenders furthest from the 15% limit, and $Mid\_Unconstr._b$ refers to unconstrained lenders with an intermediate share of high-LTI loans. $Post_t$ is a binary variable equal to 1 for quarters after 2014Q3, 0 for quarters before. $ConstrShare_l$ equals the demeaned share of lending by constrained lenders in local area l in periods before the announcement of the policy. The sample is restricted to areas with a $ConstrShare_l$ above (c.3) or below (c.4) the 75th percentile. All regressions are estimated using ordinary least squares. Lower-level interactions are included as standalone variables when not absorbed by fixed effects. Borrower, loan, and bank controls, as well as fixed effects, are included. Internet Appendix Section A shows the definition of the main controls. Robust standard errors double-clustered at the bank–quarter and local area level are reported in parentheses. * $p<.1$; ** $p<.05$; *** $p<.01$.

mortgages but, given the results in Table 5 (c.3–4), are unsuccessful because of borrower frictions; a positive $\beta^{s'}_{rate}$ would be more consistent with a restriction of credit supply driven by lender-side frictions.

$$Rate_{i,l,b,t} = \beta^{s'}_{rate} \cdot Post_t \times LowInc_{i,l,b,t} + \gamma_1 \cdot X_{i,l,b,t} + \gamma_2 \cdot X_{b,t} + f_{l,b} + f_t + \varepsilon_{i,l,b,t} \tag{6}$$

As shown in Table 7, the pricing of high-LTI loans to low-income borrowers experiences a very different pattern from the pricing of high-LTI loans in general. Column 1 shows that, on average, unconstrained lenders increase the price of high-LTI loans issued to low-income borrowers after the policy, while reducing loan volumes (as shown in Table 5 c.3–4). This increase in loan prices is significantly higher in areas with a higher prepolicy share of constrained lenders (c.3) compared to those with a lower share (c.4).[15] The coefficient in c.3 implies an increase in the loan interest rate of almost 15 basis

15 Note also that constrained lenders increase the loan price more than unconstrained lenders, as the regulation is binding for the former, but after the regulation, unconstrained lenders increase loan prices to low-income borrowers in areas with a higher prepolicy presence of constrained lenders (and hence where there are possibilities for credit substitution).

Table 7
Loan level: Pricing of high-LTI loans to low-income borrowers

Variable	←Interest rate ($Rate_{i,l,b,t}$)→				
Subsample	High-LTI loans		High constr. share	Low constr. share	High constr. share
	(1)	(2)	(3)	(4)	(5)
$Post_t \times LowInc_{i,l,b,t}$	0.105***		0.145***	0.0860***	
	(0.0325)		(0.0409)	(0.0322)	
$Post_t \times LowInc_{i,l,b,t} \times Least\_Unconstr._b$		0.0111			0.0365
		(0.0383)			(0.0565)
$Post_t \times LowInc_{i,l,b,t} \times Mid\_Unconstr._b$		0.0965***			0.113***
		(0.0323)			(0.0414)
$Post_t \times LowInc_{i,l,b,t} \times Most\_Unconstr._b$		0.272			0.705**
		(0.322)			(0.312)
Observations	75,008	75,008	25,444	49,564	25,444
R^2	0.536	0.537	0.556	0.525	0.558
Borrower, Loan Controls	Yes	Yes	Yes	Yes	Yes
Bank Controls	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes

The dependent variable is the interest charged on a mortgage at the time of origination. The sample includes high loan-to-income mortgages issued by unconstrained lenders only. Unconstrained lenders are classified into three groups—$Least\_Unconstr._b$ refers to unconstrained lenders whose share of loans with LTI≥4.5 in 2013Q3–2014Q2 is closest to the 15% limit, $Most\_Unconstr._b$ refers to unconstrained lenders furthest from the 15% limit, and $Mid\_Unconstr._b$ refers to unconstrained lenders with an intermediate share of high-LTI loans. $Post_t$ is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. $ConstrShare_l$ equals the demeaned share of lending by constrained lenders in local area l in periods before the announcement of the policy. The sample is restricted to areas with a $ConstrShare_l$ above (c.3 and c.5) or below (c.4) the 75th percentile. All regressions are estimated using ordinary least squares. Lower-level interactions are included as standalone variables when not absorbed by fixed effects. Borrower, loan, and bank controls, as well as fixed effects, are included. Internet Appendix Section A shows the definition of the main controls. Robust standard errors double-clustered at the bank–quarter and local area level are reported in parentheses. $^{*}p<.1$; $^{**}p<.05$; $^{***}p<.01$.

points.[16] Moreover, in c.2 and c.5, we find that the increase in loan interest rates of high-LTI loans to low-income borrowers monotonically increases with unconstrained lenders' pre-policy amount of slack to substitute—for the $Most\_Unconstrained_b$ group, the coefficient implies an increase of over 70 basis points, approximately 23% of the average loan interest rate in the quarter of the policy announcement.

These results suggest that lender-level frictions prevent low-income borrowers from substituting the drop in high-LTI lending from constrained lenders via unconstrained lenders. There are two types of frictions that are consistent with the results in Table 7: market power and adverse selection. This is because the increase in the pricing and the decrease in volume of high-LTI loans to low-income borrowers by unconstrained lenders could be explained by problems of adverse selection of low-income borrowers for unconstrained lenders, or by the higher market power acquired by unconstrained lenders postregulation.

First, for high-LTI loans in general, lenders with more available slack (i.e., $Most\_Unconstr._b$) are the ones with more aggressive cuts in loan prices

16 The average interest rate for such loans before the announcement of the policy was just above 3%.

and higher increases in loan volume (Table 5 c.2 and Table 6 c.2).[17] This is the exact opposite of what we find in the pricing for high-LTI loans to low-income borrowers. As shown in Table 7 c.2 and c.5, the increases in the prices of high-LTI loans to low-income borrowers are monotonically increasing for lenders that have more capacity to substitute, that is, lenders with less prepolicy presence (proxying for less prepolicy knowledge) in this market. The increase is also stronger in areas where there are more possibilities for substitution, that is, areas where constrained lenders have a higher prepolicy presence (Table 7 c.3 vs. c.4), while they cut loan volumes (Table 5 c.4). These results are consistent with winners' curse problems for unconstrained lenders only in the substitution for the segment of low-income borrowers within high-LTI loans.

Second, we compare the pricing of high-LTI loans to low-income borrowers in areas with different levels of competition (proxied by the Herfindahl-Hirschman Index based on the local area share of lending among unconstrained lenders) and higher substitution possibilities (i.e., a higher prepolicy share of constrained lenders). If market power is the main driver of the increase in pricing, we expect this increase to be the highest in areas with low competition. If adverse selection is driving the results, the result should be the opposite since winner's curse problems are theoretically more intense in higher competition areas (Marquez 2002). Higher bank competition exacerbates adverse selection problems since lenders are afraid that available borrowers have been rejected by other lenders, and raise loan prices and cut loan volumes due to winner's curse problems.

In c.1–2 of Table 8, we report that the increase in the price of high-LTI loans to low-income borrowers by unconstrained lenders is present in areas with high and low competition, although it is significantly larger in areas with higher competition. Importantly, as shown in columns 3–6, this increase in prices is the strongest (over 14 bps, a 4.5% increase vs. the average level for high-LTI loans at policy's introduction) in areas with higher bank competition among unconstrained lenders and a higher prepolicy share of lending by constrained lenders (and hence more possibilities for credit substitution).[18] We show in Internet Appendix Table IA.10 that the difference in the interest rate charged between high- and low-competition areas is statistically significant within areas with a higher prepolicy share of constrained lenders (c.2). These results further

[17] Note also that the results on the substitution of high-LTI loans in general are not consistent with market power playing a key role since there is a strong decrease, rather than increase, in the prices of high-LTI loans by unconstrained lenders after the regulation (Table 6). Moreover, this decrease is of similar magnitude precisely in areas where unconstrained lenders have acquired more market power to potentially increase loan prices, that is, those areas where constrained lenders have a higher prepolicy presence, and hence there is a higher cut in high-LTI loans by constrained lenders.

[18] High-competition areas are those where the Herfindahl-Hirschman Index based on the intra-unconstrained lender share of lending is in the bottom 50th percentile; high-share areas are those where the prepolicy share of lending by constrained lenders is greater than the 50th percentile. Results are qualitatively and quantitatively similar using the Herfindahl-Hirschman Index based on intra-unconstrained lender share specifically in the market segment of low-income borrowers receiving high-LTI loans (see Internet Appendix Table IA.11).

Table 8
Loan level: Competition and pricing of high-LTI loans to low-income borrowers by unconstrained lenders

Variable	←Interest rate ($Rate_{i,l,b,t}$)→					
Subsample	All		High Share		Low Share	
	High Comp	Low Comp	High Comp	Low Comp	High Comp	Low Comp
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_t \times LowInc_j$	0.126***	0.085**	0.142***	0.086*	0.0874**	0.0852**
	(0.0332)	(0.0383)	(0.0394)	(0.0465)	(0.0384)	(0.0409)
Observations	48,169	26,839	35,726	15,723	12,443	11,116
R^2	0.544	0.527	0.550	0.538	0.528	0.509
Borrower, Loan Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank Controls	Yes	Yes	Yes	Yes	Yes	Yes
Local Area×Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable is the interest charged on a mortgage at the time of origination. The sample includes high loan-to-income mortgages (LTI≥4.5) issued by unconstrained lenders only. Columns 1 and 2 include all observations. Columns 3 and 4 restrict the sample to areas with a higher share of constrained lenders (share above the median), while columns 5 and 6 focus on areas with a lower share of constrained lenders (below the median). Each sample is divided between high-competition (areas with a Herfindahl-Hirschman Index below the median) and low-competition (HHI above the median) areas, based on market shares among unconstrained lenders. $Post_t$ is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. $LowInc_j$, is a binary variable indicating whether the income of a borrower associated with a granted mortgage is in the bottom quintile of the income distribution among borrowers. All regressions are estimated using ordinary least squares. Lower-level interactions are included as standalone variables when they are not absorbed by fixed effects. All regressions include borrower, loan, and bank controls, as well as fixed effects. Internet Appendix Section A shows the definition of the main controls. Robust standard errors double-clustered at the bank–quarter and local area level are reported in parentheses. * $p < .1$; ** $p < .05$; *** $p < .01$.

suggest a key role of adverse selection in preventing the substitution of high-LTI loans to low-income borrowers.

Robustness of reported coefficients to substitution pattern. While the heterogeneous substitution patterns described above suggest that substitution for high-LTI loans is strong, we show that coefficients estimated in Section 3.1.1 are robust to the exclusion of the lenders further away from the LTI limit, which use their available slack to strongly substitute for high-LTI loans (Table 5 c.1–2). We replicate Tables 2 (A), 2 (B), and 3 after excluding mortgages issued by the $Mid\_Unconstrained_b$ and $Most\_Unconstrained_b$ lenders, and report results in Internet Appendix Table IA.9. The reported coefficient in Internet Appendix Table IA.9 (A) for the most saturated specification is negative, quantitative, and statistically significant, and somewhat smaller than the one reported in Table 2 (A), consistent with a stronger substitution of high-LTI loans by the excluded lender groups with substantial slack to substitute.[19] The results on high-LTI pricing and shifting away from low-income borrowers

19 This result is also consistent with the overall change and Oaxaca-Blinder decomposition of the LTI distribution for constrained and unconstrained lenders shown in Internet Appendix Figures IA.2 (I) and IA.2 (II), respectively. The decomposition shows that changes in LTI quantiles for constrained lenders are primarily attributable to the 2014 regulation, while those for unconstrained lenders are largely explained by underlying covariates (and hence can be controlled for in our saturated regression specifications).

by constrained banks (Internet Appendix Tables IA.9 (B) and (C)) are similar to the ones in the main tables, if anything somewhat stronger.

3.2 Overall lending to low-income borrowers

As credit substitution is imperfect, we now turn to the overall effect of these multiple channels on lending to low-income borrowers in areas with a higher prepolicy presence of constrained lenders.

To study the net effect of the aforementioned channels on lending to low-income borrowers, we combine lending by constrained and unconstrained lenders. We create a time series of aggregate lending volumes (in £) and use the specification described in Equation (7) to check whether the regulation has an overall effect on lending to low-income borrowers in local areas more exposed to constrained lenders after the regulation. In Equation (7), we regress the lending data aggregated by quarter×local area×income-quintile on $Post_t \times ConstrShare_l \times LowInc_j$, where $ConstrShare_l$ is the demeaned share of constrained lenders (described in Section 3.1.2 previously) and $LowInc_j$ is a dummy variable that indicates lending to low-income borrowers (i.e., borrowers in the bottom income quintile). β_{Inc} indicates whether there is a drop in lending to low-income borrowers after the regulation in areas with higher a prepolicy presence of constrained lenders.

$$\log(\mathbb{L}_{j,l,t}) = \beta_{Inc} \cdot Post_t \times ConstrShare_l \times LowInc_j + f_{j,l} + f_{j,t} + f_{l,t} + \varepsilon_{j,l,t} \quad (7)$$

We report the results on changes in lending volumes in Table 9. We start by splitting the sample into low-income (c.1) and higher-income (c.2) quintiles. Consistent with the loan-level evidence, the presence of constrained lenders is associated with a reduction in lending after the policy only for the lowest income quintile. In c.3–6 we test whether this difference is statistically significant using the triple interaction specified in Equation (7). The coefficient β_{Inc} is negative and significant, showing a contraction in total lending to borrowers in the lowest income quintile in local areas more exposed to constrained lenders after the regulation.[20] We gradually 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. These allow for strong identification since we control for factors that may impact borrowers in a specific income

[20] Internet Appendix Table IA.12 shows results by weighting each observation with the size of the local area's prepolicy total lending portfolio; that is, the effects are not driven by the relative size of local areas. Internet Appendix Table IA.13 shows that the contraction in lending for low-income borrowers in c.1 of Table 9 is particularly driven by constrained lenders, and is substantially weaker for unconstrained lenders. The strong contraction in lending to low-income borrowers is also present in the residualized shares of low-income borrowers in high-LTI loans shown in Internet Appendix Figure IA.5 with a strong decline for constrained lenders, which is not compensated by unconstrained lenders, following the regulation. Finally, the contraction in lending to low-income borrowers in areas more exposed to constrained lenders is ameliorated by the presence of brokers, and is stronger in their absence (Internet Appendix Table IA.15).

Table 9
Overall lending to low-income borrowers

Variable	←Total value (in £) of mortgages($\log(\mathbb{L}_{j,l,t})$)→					
Subsample	Low income	Non–low income	All			
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_t \times ConstrShare_l$	−0.0156***	0.0012	0.0012			
	(0.0024)	(0.0012)	(0.0012)			
$Post_t \times ConstrShare_l \times LowInc_j$			−0.0169***	−0.0168***	−0.0168***	−0.0168***
			(0.00252)	(0.00259)	(0.00260)	(0.00258)
Observations	6,200	24,852	31,045	31,045	31,043	31,043
R^2	0.958	0.813	0.841	0.841	0.863	0.864
Local Area FE	Yes	Yes	Yes	–	–	–
Time FE	Yes	Yes	Yes	–	–	–
Local Area×Time FE				Yes	Yes	Yes
Local Area×Income quintile FE					Yes	Yes
Time×Income quintile FE						Yes

The dependent variable is the logarithm of the total value (in £) 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. $ConstrShare_l$ equals the demeaned share of lending by constrained lenders in local area l in periods before the announcement of the policy. $LowInc_j$ indicates the bottom income quintile. Column 1 restricts the sample to lending to low-income borrowers (i.e., borrowers in the bottom income quintile), while column 2 restricts the sample to lending to the rest of the borrowers (i.e., 2nd–5th income quintiles). Columns 3–6 use the full sample. All regressions are estimated using ordinary least squares. Lower-level interactions are included as standalone variables when they are not absorbed by fixed effects. Fixed effects are either included ("Yes"), spanned by other fixed effects ("-"), or not included. Robust standard errors clustered at the local area level are reported in parentheses. $^{*}p<.1$; $^{**}p<.05$; $^{***}p<.01$.

group or a specific local area at a given time, such as a demand shock common to low-income borrowers or local areas following the regulation.[21]

The estimated coefficients show that borrowers in the bottom income quintile in local areas with a one standard deviation higher prepolicy share of constrained lenders experience a 10.8% drop in the total loan amount (in £) following the regulation. Similarly, these areas experience an 8.6% drop in the total number of loans (Internet Appendix Table IA.14), which shows that the overall drop in lending to low-income borrowers is driven by both a drop in the number of loans and the average size of loans. We also regress the aggregated lending data on $ConstrShare_l \times LowInc_j$ interacted with the full set of time dummies: Figure 3 shows that the resulting estimates are zero in periods before 2014Q2 and show a contraction in lending to low-income borrowers only in periods after the introduction of the regulation (showing a lack of pretrends). The strong contraction in lending to low-income borrowers is in contrast with the overall effect on high-LTI lending (Table IA.16), which, though negative, is economically a lot weaker and statistically insignificant.

21 In unreported results, we use the Oster (2019) test and find that our results are robust to concerns about selection and omitted variable biases (we find identical conclusions in the loan-level analysis, e.g., in Table 2 (A)). Moreover, the results are also robust to the inclusion of alternate controls, such as those based on the local area share of high-LTI loans and regional house price and GDP growth.

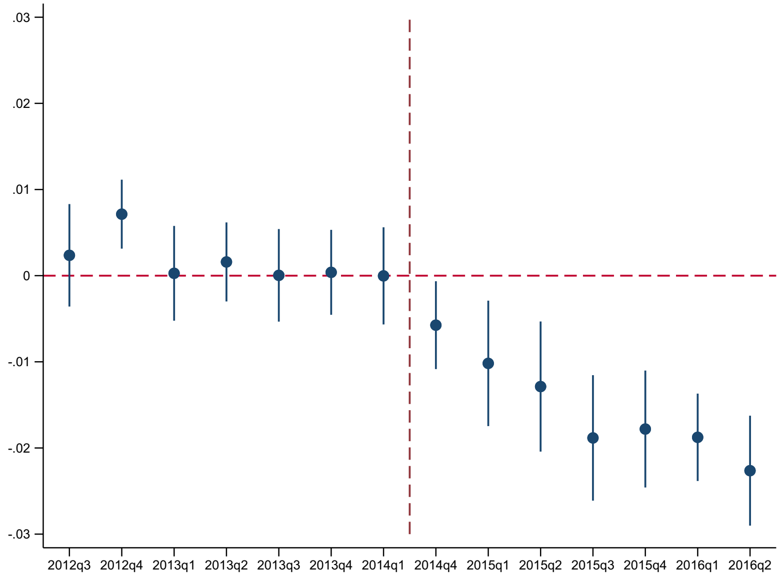

Figure 3
Lending to low-income borrowers in areas with more constrained lenders
This figure shows the estimated coefficients of the interaction of $ConstrShare_l$ (a variable that equals the total share of lending by constrained lenders in local area l in periods before the announcement of the policy), $LowInc_j$ (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 is the logarithm of the total value (in £) 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 announcement of the policy. The sample period is from 2012Q3 to 2016Q2, excluding 2014Q3. The regressions are estimated using ordinary least squares and include local area×time, local area×income quintile, and time×income quintile fixed effects.

3.3 House prices

In this section, we study the behavior of house prices after the introduction of the policy. While the policy was introduced during a housing boom, the Brexit referendum 2 years later (June 2016) was followed by a house price growth correction across the United Kingdom (Internet Appendix Figure IA.6 (A)). We analyze whether the areas more affected by the macroprudential policy are associated with lower house price growth during good times (as lending to low-income borrowers goes down) and higher house price growth during a negative aggregate shock (as low-income borrowers were less leveraged due to the 2014 policy).

We use Equation (8) to analyze house prices during 2012H2–2018H1 in more affected areas. We regress annual changes in the logarithm of house price indices in local area l at year t, on $Post_t \times Constr_l \times LowInc_l$ and $BrexitRef_t \times Constr_l \times LowInc_l$, where $Post_t$ indicates periods 2014H2 onwards, $BrexitRef_t$ indicates periods 2016H2 onwards, and $Constr_l \times LowInc_l$ indicates affected local areas with a high prepolicy share of constrained lenders (> median) and mortgages to low-income borrowers (>75th percentile). β_{pol} reflects trends in house price growth in affected areas postpolicy; β_{ref} reflects trends in house price growth in affected areas after the Brexit referendum. We include highly disaggregate fixed effects: for instance county×time fixed effects ($f_{c,t}$) compares trends across geographically proximate local areas with differential exposures to the regulation.

$$\Delta \log(P_{l,t}) = \beta_{pol} \cdot Post_t \times Constr_l \times LowInc_l + \beta_{ref} \cdot BrexitRef_t \times Constr_l \times LowInc_l + f_l + f_{r,t} + f_{c,t} + \varepsilon_{l,t} \quad (8)$$

Table 10 (A) shows that affected areas are associated with a drop in house price growth (−3 pp, c.1) at the lower end of the house price distribution after the policy. This trend reverses after the Brexit referendum (+5.9 pp, c.1) and holds for both the 25th percentile (c.1 and c.2) and the bottom tercile (c.4) of the distribution, irrespective of whether indices are based on all transactions (c.1) or repeat postcode–house type combinations that control for the mix of transacted houses (c.2 and c.4). These results are consistent with the credit reduction to low-income borrowers from the policy affecting house price growth at the lower end of the price distribution. Consistent with the lack of an effect on higher-income borrowers, the coefficients for the higher end of the price distribution (c.3 and c.5) are not statistically significant. A placebo test (c.6) shows that affected areas did not respond differentially in a separate episode of negative aggregate shock (2007–2008 financial crisis).[22]

These results suggest that the triple credit crunch on low-income borrowers following the regulation is associated with subsequent lower house price growth in the lower end of the house price distribution in policy-affected areas, and with a relatively lower drop in house price growth after a negative aggregate shock. While these results are consistent with previous contributions on interactions between house prices and household leverage, we note that the relatively short 2-year windows after the policy and after the Brexit referendum are limitations to making stronger claims on the effects of the 2014 regulation on house prices.

3.4 Defaults

Results suggest that the 2014 macroprudential policy leads to a contraction in lending to low-income borrowers (Table 9), and policy-affected areas (areas with higher prepolicy exposure to constrained lenders and higher concentration

[22] Internet Appendix Table IA.17 shows that results are not driven by Greater London, local area housing supply constraints, share of high-LTI mortgages, and differential exposures to the regional shocks. We run 1,048,575 different regressions to test the sensitivity of the estimated coefficients and their statistical significance to observed characteristics (as in Brodeur, Cook, and Heyes [2020] in Internet Appendix Figure IA.6 (C)) and results are robust. Our estimates are also robust to concerns about selection and omitted variable biases (i.e., unobservables) using the tests described in Oster (2019) and Altonji, Elder, and Taber (2005). Internet Appendix Figure IA.6 (B) shows a lack of pretrends in house price growth in affected local areas.

Table 10 (A)
House price growth in affected local areas

Variable	←House price growth (Δlog($House\ Price_{l,t}$))→					
Index	25th perc.	25th perc.	75th perc.	Bottom tercile	Top tercile	25th perc.
	(1)	(2)	(3)	(4)	(5)	(6)
$BrexitRef_t \times Constr_l \times LowInc_l$	0.059***	0.081***	−0.035	0.093***	0.007	
	(0.022)	(0.020)	(0.050)	(0.022)	(0.035)	
$Post_t \times Constr_l \times LowInc_l$	−0.030*	−0.059**	0.014	−0.073**	0.017	
	(0.016)	(0.027)	(0.043)	(0.031)	(0.042)	
$Fin.Crisis_t \times Constr_l \times LowInc_l$						0.005
						(0.023)
Observations	3,072	1,536	1,536	1,536	1,536	1,024
R^2	0.553	0.475	0.439	0.463	0.423	0.904
Local Area FE	Yes	Yes	Yes	Yes	Yes	Yes
Region×Constr×Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Region×LowInc×Time FE	Yes	Yes	Yes	Yes	Yes	Yes
County×Time FE	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable is the (annual) change in the logarithm of house price indices for local area l, calculated using all transactions (c.1) or repeat postcode–house type transactions (c.2–6). The indices are based on: 25th percentile (c.1, c.2, c.6), 75th percentile (c.3), and average price paid in bottom (c.4) and top (c.5) terciles of house transactions. The sample spans from 2012H2–2018H1 (c.1–5) and 2004H2–2009H1 (c.6). $Post_t$ indicates periods 2014H2–2018H1 (i.e., postpolicy); $BrexitRef_t$ indicates 2016H2–2018H1 (i.e., post–Brexit referendum). $Constr_l$ and $LowInc_l$ indicate affected local areas with a high prepolicy share of constrained lenders (>p50) and mortgages to low-income borrowers (>75th percentile), respectively. $Fin.Crisis_t$ indicates the period 2007H2–2009H1. All regressions are estimated using ordinary least squares. All lower-level interactions are included. Fixed effects are either included ("Yes"), spanned by other fixed effects ("-"), or not included. Robust standard errors clustered at the local area level are reported in parentheses. $^{*}p<.1$; $^{**}p<.05$; $^{***}p<.01$.

of low-income borrowers) experience a relatively lower house price drop following a negative aggregate shock (Table 10 (A)). We now test whether affected areas, consistent with a prereferendum reduction in leverage, are also associated with lower mortgage defaults following the negative aggregate shock (referendum).

We use the stock data on mortgages to track performance of the mortgages in our sample. A mortgage is classified as under default when it is under payment arrears (or shortfall), forbearance, or a possession order. We focus on mortgage performance in 2017H2 (18 months following the Brexit referendum)[23] and compare mortgages issued before (2012Q3–2014Q2) and after (2014Q4–2016Q2) the introduction of the policy to test whether mortgages issued postpolicy in affected areas experience relatively lower rates of defaults relative to other areas and, within affected areas, whether low-income borrowers experience lower defaults than other borrowers.

We use Equation (9) to estimate the effects of the 2014 LTI regulation on mortgage defaults using a Poisson model, that is, we assume that the number of defaults in a local area in a given quarter is Poisson distributed. We take loan-level data matched with mortgage performance in 2017H2 to

[23] Internet Appendix Figure IA.7 shows an increase in the default rate for mortgages in our sample with LTI≥4.5 and mortgages to low-income borrowers following the Brexit referendum.

Table 10 (B)
Mortgage defaults

Variable	←Number of mortgages under default ($ND_{j,l,t}$)→				
Subsample	Low income	Non–low income	All		
	(1)	(2)	(3)	(4)	(5)
$Post_t \times ConstrShare_l \times LowInc_l$	−0.24**	0.0245	0.0262	0.161	0.0473
	(0.0969)	(0.0568)	(0.0562)	(0.1)	(0.121)
$Post_t \times ConstrShare_l \times LowInc_l \times LowInc_j$			−0.265**	−0.259**	−0.408***
			(0.111)	(0.113)	(0.13)
Observations	3,599	5,615	9,214	9,214	5,868
Time FE	Yes	Yes	Yes	–	–
Local Area FE	Yes	Yes	Yes	Yes	Yes
Region×Constr×Time FE				Yes	Yes
Region×LowInc×Time FE				Yes	Yes
County×Time FE					Yes

The dependent variable is the total number of mortgages under default in December 2017 aggregated by borrower income quintile j, quarter t, and local area l. The sample includes existing mortgages in 2017H2 that were originated between 2012Q3 and 2016Q2, excluding 2014Q3. $Post_t$ is a binary variable that equals 1 for quarters after 2014Q3, 0 for quarters before. $Constr_l$ and $LowInc_l$ are local area level variables that indicate local areas with a higher share of constrained lenders (>p50) and a higher share of lending to low-income borrowers (>p75), respectively. $LowInc_j$ is a binary variable that equals 1 for the bottom income quintile, 0 for the rest. Column 1 restricts the sample to lending to low-income borrowers (i.e., borrowers in the bottom income quintile), while column 2 restricts the sample to lending to the rest of the borrowers (i.e., 2–5 income quintiles). Columns 3–4 include the full sample. Regressions are estimated using Poisson regression. Lower-level interactions are included as standalone variables when they are not absorbed by fixed effects. Fixed effects are either included ("Yes"), spanned by other fixed effects ("-"), or not included. Robust standard errors clustered at the local area level are reported in parentheses. $^{*}p<.1$; $^{**}p<.05$; $^{***}p<.01$.

create an aggregated data set of the number of mortgages under default ($ND_{j,l,t}$) for income-quintile j in local area l and period of mortgage origination t (quarter), and the total number of mortgages ($M_{l,t}$, i.e., the exposure variable) issued in local area l in quarter t. The Poisson model is appropriate to study the count of local area defaults given the low number of defaults at the level of disaggregation (income band×local area×time). We estimate the coefficient β_d^{ext} on $Post_t \times Constr_l \times LowInc_l \times LowInc_j$, where $Constr_l \times LowInc_l$ refers to policy-affected areas, and $LowInc_j$ refers to borrowers in the bottom income quintile, which shows differences in the relative risk of being under default by end-2017, conditioned on being issued to low-income borrowers in affected areas after the introduction of the policy. The equation is estimated in the presence of lower-level interaction terms, and the same set of fixed effects as Equation (8).[24]

$$\frac{ND_{j,l,t}}{M_{l,t}} = e^{-\lambda_{j,l,t}}, \text{ where } \lambda_{j,l,t} = \beta_d^{ext} \cdot Post_t \times Constr_l \times LowInc_l \times LowInc_j$$
$$+ f_l + f_{r,t} + f_{c,t} + \varepsilon_{j,l,t} \qquad (9)$$

In Table 10 (B), c.1–2, we report the coefficient on $Post_t \times Constr_l \times LowInc_l$ in split-samples by income quantile: c.1 shows the results for low-income borrowers (borrowers in the lowest income quintile); c.2 shows the

[24] We exclude local area×time fixed effects to report the coefficient on $Post_t \times Constr_l \times LowInc_l$.

results for the rest of the borrowers. We find that mortgages issued in affected areas after the introduction of the policy experience lower default only for low-income borrowers, not for the rest. This result is confirmed using the coefficient on the quadruple interaction shown in c.3–5, which suggests that areas affected by the 2014 macroprudential policy are associated with a lower number of mortgage defaults (relative less affected areas) following the Brexit referendum, driven by lower defaults for low-income (as opposed to higher-income) borrowers in those areas (again consistent with the macroprudential policy). The coefficient in c.5 shows a relative risk (of being under default) of 0.66 for low-income borrowers (i.e., 34% lower defaults) conditioned on their mortgage being issued after the policy in an affected area.

4. Conclusion

We analyze the distributional effects of macroprudential policy on mortgage cycles. To the best of our knowledge, this is the first paper to study the effects of macroprudential regulation of household leverage both during a boom and following a negative aggregate shock. For empirical identification, we use the U.K. mortgage register in conjunction with a 15% limit imposed on lenders' high loan-to-income mortgages. These lenders are differentially affected based on the prepolicy share of high-LTI loans in their mortgage portfolio. Moreover, we exploit the unexpected outcome of the Brexit referendum, which led to a strong house price growth correction across the United Kingdom, to analyze potential effects of macroprudential policies implemented during booms at times of negative aggregate shocks.

Our robust results show that constrained lenders issue fewer and more expensive high-LTI mortgages. This reduction affects low-income borrowers through two distinct channels: first, because they are overrepresented in the high-LTI segment, and second because constrained lenders shift their high-LTI lending towards higher-income borrowers; low-income borrowers, hence, suffer a double crunch. Credit substitution for low-income borrowers is imperfect. We find substitution towards smaller low-LTI loans to low-income borrowers when comparing constrained with unconstrained lenders. Furthermore, substitution by unconstrained lenders is heterogeneous: they strongly substitute high-LTI loans in general, but do not extend these loans to low-income borrowers. We document wide-ranging evidence that suggests that this heterogeneous substitution lending pattern is driven by lender-side frictions, in particular consistent with concerns around adverse selection of low-income borrowers. This highlights a third channel that negatively affects lending to low-income borrowers, that is, low-income borrowers suffer a triple crunch in lending resulting from the regulation. The net result of these multiple channels is that low-income borrowers experience a strong contraction in lending in areas more exposed to constrained lenders (i.e., lower loan volumes).

Our results show that market frictions are an important channel in the transmission of macroprudential regulations to credit markets. The lack of substitution by unconstrained lenders occurs despite the regulation being aimed at the lender (not household) level, despite multiple lenders (and an aggregate banking system) with sufficient slack to substitute constrained lenders, and despite good financial and economic conditions around the introduction of the regulation, which are all a testament to the strength of those market frictions. Consideration of these market frictions is a key implication of our results for both policy and theory concerning the effects of macroprudential policies on credit markets.

We document house price and default dynamics consistent with the contraction in lending to low-income borrowers. We find that local areas more affected by this contraction are associated with a dampening of house prices following the regulation. Our results suggest that during the strong drop in house price growth across the United Kingdom following the Brexit referendum, these affected areas experience relatively lower drops in house price growth; moreover, low-income borrowers in the affected areas experience relatively lower mortgage defaults concurrent with the better house price growth. These potential costs and benefits of macroprudential regulation are highly topical given the widespread interest in introducing such regulations as a way to ensure financial stability and potential implications for inequality due to their burden on low-income borrowers.

In sum, on the one hand, we document a triple credit crunch of mortgages to low-income borrowers in high-LTI loans, with imperfect credit substitution consistent with adverse selection problems, leading to an overall reduction in lending to low-income borrowers. But, on the other hand, following a negative aggregate shock and consistent with the drop in leverage for low-income borrowers, policy-affected areas are associated with relatively lower subsequent drops in house prices (particularly at the lower end of house price distribution) and lower loan defaults (particularly for low-income borrowers).

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