The Environmental Cost of Easy Credit: The Housing Channel*

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Abstract

Heating, cooling, and powering the residential housing stock accounts for about one-fifth of total annual greenhouse gas emissions in the US. House size is a key determinant of the energy intensity of housing, and the average single-family home in the US has grown by about 50% in living area since the 1950s. Using distinct identification strategies spanning the last four decades of banking history, this paper shows that easier access to credit affects residential energy use through increases in average home size. While easier credit is associated with larger new construction, it does not generally produce offsetting increases in the quality or durability of structures. These results highlight potential policy levers for mitigating the carbon effects of expanded access to credit.

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Environmental concerns and the need to take collective action to curb global greenhouse gas (GHG) emissions sit at the forefront of public debate throughout the world. In the United States, which is second only to China in the global league tables of CO2 emitting countries, the residential housing stock is an important contributor to GHG emissions. As of 2019, as much as 20% of all carbon emissions in the US stem from heating, cooling and powering residential households (US Energy Information Administration, 2019). Because the US is both a populous and a wealthy country, the aggregate carbon emissions of the US housing stock is greater than the overall carbon emissions of all but a few countries—Japan, Russia, India, and China.

In this paper, we consider how changes in the supply of credit affect the carbon intensity of the aggregate housing stock. How does greater availability of credit change the size, quality and durability of the housing stock and, consequently, its carbon footprint? This question connects monetary policy and financial market conditions to the environment through a real-asset channel by studying the way in which financial markets literally shape the supply of the US housing stock.

Changes in the credit supply could either improve or worsen the carbon footprint of the housing stock through a complex series of channels that reflect the aggregate effects of individual household optimization decisions. Existing research has found a wide range of estimates for the elasticity of housing expenditure to income (see, e.g., Piazzesi, Schneider, Tuzel, 2007; Davidoff and Yoshida, 2013), but less is known about both the role of credit and how expenditure is split across house characteristics as credit conditions change. On the intensive margin, easier credit may induce changes in different (environmentally related) hedonic dimensions—the same household may respond by expanding home size, increasing new house quality or durability, or choosing different locations. But easier credit may also have compositional effects on the pool of borrowers (Adelino, Schoar and Severino, 2016) and, consequently, the buyers of new construction. Easier credit may induce existing homeowners to build larger new homes, or they may instead purchase older, more expensive homes in more established neighborhoods, leaving the new construction to respond to the influx of new, first-time buyers purchasing smaller, cheaper homes.

Changes in housing *quality* could improve or worsen the carbon footprint of the housing stock depending on the complementarity between energy conservation and the quality of other household amenities. The *durability* channel is equally ambiguous. On the one hand, building costs represent between 26 and 50% of the total energy use over the life of a home (Stephan, Crawford and Myttenaere, 2012; Stephan and Crawford, 2016). With more durable homes, these fixed environmental costs are amortized over a longer period, ceteris paribus. On the other hand, higher quality and more durable homes are also more likely to have more powerful air conditioning and heating systems, and generally contain more and larger appliances (American Housing Survey, 2013).

The impact of home *size* on energy consumption is straightforward—larger homes have a bigger carbon footprint than smaller homes of the same vintage. This comes not only from the fact that they require more material to build (recall from above that as much as half the total carbon load of a home occurs in the building process), but because larger homes require more energy to operate on a day-to-day basis (Wilson and Boehland, 2005; Larson, Liu, Yezer, 2012; Goldstein, Gounaridis, and Newell, 2020).[1] Our own results using Census data show that households in a 1% larger home spend between 0.3 and 0.4% more on their total energy bill, with little variation across homes of different vintages and after controlling for income, household size and geography.

Ultimately the aggregate net effect of these forces, and hence the overall impact of easier credit on the environmental cost of housing, is an empirical question. To connect changing home size and quality to credit conditions, we focus on three natural experiments covering four decades between the 1970s and the 2000s that have been shown to affect the local supply of credit. Our central result is that easier credit makes for larger homes, but generally not better or more durable homes. These findings are especially pronounced in low housing supply elasticity areas (Saiz, 2010).

The first empirical setting we consider is the wave of banking deregulation that occurred beginning in the 1970s through the mid-1990s, culminating in the Riegle-Neal Interstate Banking and Branching Efficiency Act (IBBEA) of 1994. Banking deregulation brought about profound changes in the scope and operation of banks, with sharp increases in bank acquisitions (Jayaratne

[1] Evidence outside the US shows similar patterns. Yohanis et al (2008) find similar patterns in Northern Ireland, Paulsen and Sposto (2013) find similar patterns in Brazil, while Santin et al (2009) report evidence from the Netherlands and Clune et al (2012) find similar evidence in Australia.

and Strahan, 1998; Berger, Kashyap, Scalise, Gertler, and Friedman, 1995; Strahan, 2002; Stiroh and Strahan, 2003, provide an overview of the changes to the banking industry structure and Kroszner and Strahan, 2014, survey the literature) and evidence of economic growth (Jayaratne and Strahan, 1996; Mian, Sufi and Verner, 2020 show that higher growth is followed by more severe recessions), firm entry and exit (Black and Strahan, 2002; Kerr and Nanda, 2009) and innovation (Chava, Oettl, Subramanian and Subramanian, 2013, and Amore, Schneider and Zaldokas, 2013). We exploit the staggered introduction of banking deregulations that allowed banks to expand within states (intrastate deregulation), resulting in a significant reduction in the importance of small banks, and across states (interstate deregulation) that allowed acquisitions by out-of-state banks. We use the dates identified in the literature (see, e.g., Kroszner and Strahan, 1999) to compare housing composition in treated and non-treated states around the time of deregulation.

As a second test, we draw on recent work by Mian and Sufi (2019), who show that regions with higher fractions of mortgage originators that relied primarily on non-core deposit financing (or non-core liabilities, NCL) experienced looser mortgage credit conditions in the 2001-2006 housing boom. Motivated by this observation, we consider variation in the cross-section of non-core liabilities in different Zip codes during the housing boom of the 2000s as a source of credit supply variation and examine how the flow of new homes in Zip codes exposed to higher NCL ratios differs from new construction in Zip codes with lower exposure.

Finally, to fill the gap between the two periods we use the introduction of state-level restrictions to interstate banking that arose following the Riegle-Neal IBBEA Act of 1994. We follow Rice and Strahan (2010) classification of each state's restrictions to both *de novo* branches by out-of-state banks, and restrictions to acquisitions of in-state institutions by out-of-state banks, including minimum age of the target institutions, whether banks allow partial acquisitions, and size caps of acquisitions. These restrictions have been associated with the cost of financing for small firms (Rice and Strahan, 2010), increased housing credit supply (Favara and Imbs, 2015), and increases in innovation by private firms (Cornaggia, Mao, Tian, and Wolfe, 2015).

The magnitudes of the effects we measure are economically and environmentally important. For example, depending on the specification, we find that interstate banking deregulation pre-1994 causes a permanent increase in new house size of between 1 and 2%--five percentage points in areas with below-median housing supply elasticity.[2] To put this in perspective, consider long-run changes in average home size. A new home built in 1965 was around 1600 square feet on average; today new homes average around 2,400 square feet. This amounts to a 7-10% per decade increase from the 1960s to the decade ending with the Global Financial Crisis, which implies that our (cross-sectional) coefficients are about one-third of the magnitude of the average house size increase per decade over the last few decades.

The macro-environmental implications of credit supply are not just a function of the size of any given house, but rather the total square footage of the overall housing stock and its condition. Here it is important to note that pre-1994 interstate banking deregulation did not only create bigger homes on average, but it also increased the number of new homes. The flow of newly built single-family houses built per year is 15-20% larger in Zip codes located in states treated by interstate banking deregulation than in non-treated states, with an economically smaller effect in areas where it is harder to build (although the difference is not statistically significant).

The effects we identify are important not only because they are large in magnitude, but because they are long-lasting. Houses in the US have an average lifespan of 40 years (Goldstein, Gounaridis, and Newell, 2020). This means the extra square footage built today will most likely be heated and cooled well into the second half of this century, with potentially large consequences for carbon emissions. Replacing these structures with more environmentally efficient ones introduces a heavy toll in terms of the upfront environmental cost of teardown and new construction. And while retrofitting modern energy-saving innovations into older homes may provide some relief, we show using the AHS that the marginal energy operating costs of an additional square foot of home built up to the 2010s are similar to those of a home built in the 1960s. Thus, long-run trends in the per square foot consumption of energy are unlikely to dominate the overall trend in home size.

[2] These results control for large remodeling, renovation or new construction on the same land parcel, as well as for changes in state-level income and population.

This paper connects distinct literatures in banking, climate finance, and the effects of credit supply on real outcomes. Our empirical setting builds on important work in banking deregulation, including Jayaratne and Strahan (1996, 1998), Rice and Strahan (2010), Favara and Imbs (2015), Brook, Hendershott, and Lee, (1998); Kerr and Nanda (2009) consider firm entry and exit, and Chava, Oettl, Subramanian, and Subramanian (2013), and Amore, Schneider, Žaldokas (2013) study deregulation and firm innovation. Recent work by Mian and Sufi (2019) and Griffin, Kruger and Maturana (2021) motivate the increase of non-core liabilities as a shock to mortgage credit in the 2000s. Kacperczyk and Peydro (2021) show that bank-level commitments to carbon neutrality affect loan supply to green and brown firms and, consequently, these firms' investment activity.

Our work is part of growing interest in the effects of climate change risk on different dimensions of housing finance. Flood risk has received particular attention given the predicted increase in this type of risk for coastal regions in the US over the coming decades. The effect of flood risk on house prices is explored in Murfin and Spiegel (2020), Baldauf, Garlappi and Yannelis (2020), Bernstein, Gustafson and Lewis (2021) and Giglio, Maggiori, Rao, Stroebel, and Weber (2021). Keys and Mulder (2020) explores the relation between flood risk and transaction volume. Flood risk affects sorting of homeowners (Bakkensen and Barrage, 2021; Billings, Bernstein, Gustafson and Lewis, 2022) as well as insurance uptake (Wagner, 2019). Recent work by Sastry (2021) explores how the banking sector attenuates the moral hazard associated with subsidized insurance through changes in equilibrium loan-to-value ratios.[3] Bolton and Kacperczyk (2020) and Giglio, Kelly, and Stroebel (2021) provide excellent recent surveys of climate finance. Finally, the paper is related to Shapiro (2021) who uncovers an environmental bias in trade policy, whereas we consider indirect consequences of changes in credit supply.

[3] Additional work includes that examining flood damage and securitization (Ouazad and Kahn, 2021), origination behavior (Cortés and Strahan, 2017), household finance and delinquencies (Gallagher and Hartley, 2017; Kousky, Palim, and Pan, 2020; Issler, Stanton, Vergara-Alert and Wallace, 2021). For work on climate change, the price of risk and hedging see Arrow (1995), Bansal, Kiku and Ochoa (2016), Barnett, Brock and Hansen, (2020), Krueger, Sautner, and Starks (2020), and Engle, Giglio, Kelly, Lee, and Stroebel (2020).

The remainder of the paper is organized as follows. In Section 1, we describe the Zillow Transaction and Assessment Dataset (ZTRAX) housing data that allow us to measure the key properties of the housing stock over time and relate it to other key variables in our analysis. Sections 2-4 relate credit shocks to changes in the composition of the housing stock using each of the empirical specifications discussed above. Section 5 offers a calibration exercise to quantify the carbon costs of easier credit by first connecting home size to energy costs, and then tying this back to changes in credit conditions. Section 6 concludes.

1. Housing Data

Our primary source of data for analyzing housing characteristics is the ZTRAX Assessor files pulled in Oct-2021. The Assessor files contain information on a variety of house characteristics, including the year a house was built (or, more precisely, the year a house was finished and included in the local county assessor files), as well as the living area and two other variables of interest for our analysis, an index for the quality of the structure and another index for the current condition of the house (as of October of 2021). For all of our analysis we aggregate the house-level data down to the (Zip code)-by-(year built)-by-(house type) level.

We start with approximately 1.5 million observations pertaining to single-family homes. Multi-family structures such as duplexes, condominiums and townhouses are excluded. For the square footage analysis, we drop 382,831 observations in which the average living area in new homes in the Zip code are missing, less than100 square feet, or above 10,000 square feet. Only about 2,500 of these excluded observations are flagged for square footage; almost all contain missing square footage data. The result is an unbalanced panel of 1.12 million Zip code – by - year built observations. To simplify the graphs and tables, we code homes built before 1930 as “1930”, those between 1931 and 1940 are coded as “1940”, and similarly homes built between 1941 and 1950 are coded as “1950”. All years 1951 and later are left unchanged.

Next we connect the housing data to each of the three identification strategies. For banking deregulation, we use intra- and interstate banking deregulation dates that pre-date the Riegel-Neal Interstate Banking and Branching Efficiency Act (IBBEA) of 1994 from the literature (see, for example, Kroszner and Strahan, 1999, or Kerr and Nanda, 2009). We code twelve states that had deregulated intrastate banking pre-1965 as “1965” so that they appear as always treated in the regressions.

For the second set of tests, we use the Zip code-level non-core deposit liability ratio in 2002 made available by Griffin, Kruger and Maturana (2021).[4] The NCL ratio is calculated as one minus the share of core deposits as a fraction of total liabilities for banks and thrifts using call report data and following Mian and Sufi (2019). Our third experiment uses the restrictiveness index developed by Rice and Strahan (2010), which measures the extent to which states restricted the ability of out-of-state banks and bank holding companies to expand across state lines following the IBBEA. Kroszner and Strahan (2014) provide a detailed overview of the changes in the banking industry that run through both sets of experiments used in this paper.

We explore the heterogeneity of our effects across three dimensions: housing supply elasticity (from Saiz, 2010), city-level building costs, and “degree days”. Building cost indices at the 3-digit Zip code level come from the 2003 RSMeans Residential Cost Report and provide a comparison of the cost of materials and labor for a standard structure across locations in the US (the RSMeans data covers virtually the whole US as of 2003). “Degree days” is a measure of how hot or cold a location is and it is defined as the sum of (absolute) deviations from a benchmark temperature of 65 degrees over a year at the state level (U.S. Energy Information Administration, 2021). Degree days data is available from the Environmental Protection Agency.[5] In many of our empirical specifications we weight the regressions using Zip code-level population data obtained from the Internal Revenue Service (IRS).

Insert Table 1 About Here

Summary statistics for the main variables are reported in Table 1. Panel A shows that the (population-weighted) average living area for the zip codes in our sample is approximately 1,950

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[4] Non-core deposit liabilities data available for Griffin, Kruger and Maturana (2021) from https://www.jfinec.com/data-and-code.

[5] https://www.epa.gov/climate-indicators/climate-change-indicators-heating-and-cooling-degree-days

square feet, and the standard deviation is approximately 800 square feet. Zip code weights are the 1998 Zip code population estimates from IRS data and we use these weights throughout the empirical analysis. Panel B of the same table shows the increase in living area over the last few decades. Average living area for new homes in our data was under 1,500 square feet before 1960 and rises to approximately 2,400 square feet by the last decade.

Figure 1 plots coefficients from a regression of average house living area for new homes built in a Zip code by year. The "*Year built*" variable corresponds to the first year a residential structure appears in the assessor records. Houses built before 1930 are about 100 square feet larger than those built in the 1940s and 1950s, up to about 1957. Then we see the start of a relatively rapid increase in home sizes up to 1970. By then, new single-family homes were larger on average than they were before 1930. The late 1980s and then again the 2000s are periods of rapid increase in new home size that then stabilizes by the peak of the housing boom and, in fact, shows a slight decrease over the last decade.

There are approximately 91 new single-family homes built in a Zip code each year, ranging from a minimum of 1 new house to maximum of over 13 thousand. We do not include Zip code-year observations without any new single-family homes built in the regressions.

Panels A and B of Table 1 also show the summary building quality and current building condition measures from the assessor files. We replace county-assigned building quality ratings with a numeric scale. Ratings range from a minimum of "D-" (replaced by a value of "1") to a maximum of "A+" (coded as "12"). Average quality in our data is 5.8, the equivalent of a "C+" rating. Figure A1 in the Online Appendix provides two examples from Durham County, NC of a high and a medium grade single family house, as well as the criteria used by the county to assign this grade. Panel B shows that average building quality has been steadily increasing throughout our sample period. Similarly, building condition is coded in the assessor files from a minimum of "Poor", which we replace with a numeric value of "1", to a maximum of "Excellent", replaced with a value of "5". The average building condition in our data receives a score of 4.1, the equivalent of an "Average" code in the assessor files.

Even though all our regressions are based on the year in which a residential structure first appears in the assessor records, we also have information on whether homes undergo new construction, significant renovations, or remodelings. This information is captured in the "*Effective year built*" and "*Year remodeled*" variables in ZTRAX. Panel A of the summary statistics shows that 12% of houses in the sample appear with a new effective year built in the data, and Panel B shows that this percentage is increasing every decade, as we would expect, from 20% of homes for the oldest homes in the sample to 4% for the most recent decade. There are fewer homes appearing as remodeled, probably because these capture smaller renovations that are less likely to require a permit. We see 4% of all records experiencing a remodeling, again with an increase over the decades (Panel B).

2. Banking deregulation and housing characteristics

The empirical methodology for our first natural experiment uses the staggered introduction of both intrastate and interstate deregulation pre-1994 at the state level to implement a differences-in-differences regression beginning in 1965.[6] Specifically, we run regressions of the form:

$$\text{Characteristic}_{\text{Zip},t} = \beta_1 Deregulated_s \times Post_t + \text{X}_{\text{Zip,t}} + \eta_{\text{Zip}} + \eta_{\text{t}} + \varepsilon_{\text{Zip},t} \tag{1}$$

The main characteristic of interest is the log average square feet in the Zip code for new homes in a given year. We also consider three other outcomes, namely the logarithm of the count of new homes built in a Zip code, the average quality of new homes (as included in the assessor deeds), converted into a rating scale (as described in the previous section) and the current condition of homes built in that year (as included in the assessor deeds and likewise converted to a rating scale).

The controls $X_{Zip,t}$ include state-level income and population and, importantly, the share of homes built in a given year that are remodeled or undergo new construction or substantial renovation after the initial "*Year built*". Even though we consider house quality and house condition separately,

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[6] Regulations started being relaxed in the 1970s. See Jayaratne and Strahan (1998) Table 1 for exact dates.

there might still be a concern that homes built during periods of looser credit might have later been more likely to undergo renovations and, consequently, changes in living area and quality that would be unobserved in the main regressions. By controlling directly for the share of homes that are renovated and considering how the main coefficients of interest change, we can assess whether this is likely to have a significant effect in our estimation.

The main variables of interest are the interactions *"$Deregulated_s$ x $Post_t$"*, where *Deregulated* is an indicator for years after intrastate or interstate deregulation in a state as defined in Jayaratne and Strahan (1996, 1998). All regressions include Zip code (η_{Zip}) and year of construction fixed effects (η_t). We cluster standard errors at the county code and year level, and weight regressions by the Zip code population as of 1998.

We now turn to the results when we estimate equation (1) in our data between 1965 and 1995. This period spans the whole experience of intrastate and interstate deregulation before the Riegle-Neal Act of 1994. Table 2 shows the results. We consider 4 outcomes in turn: the logarithm of the average Zip code-level new single-family house size, the (log) count of Zip code level new houses, a house quality index and a house condition index (both as raw indices, not in logs).

Insert Table 2 About Here

Panel A shows that interstate deregulation, i.e., the ability of banks to purchase branches out of their state, is associated with homes that are 1 to 2% larger, depending on whether we consider weighted or unweighted regressions. Columns 3 and 4 show that these effects are not sensitive to the inclusion of controls for state-level income and population, and for the share of homes that are renovated or remodeled. Figure 2 shows that this effect becomes positive and significant in the year after deregulation and is a permanent increase in house size that does not revert back several years after the deregulation happens.

We obtain different results when we consider intrastate banking deregulation, where the shock is associated with a negative change in living area, in particular when we add all of the controls to the regressions. This reversal is consistent with contrasting results in the broader literature for the two types of deregulation. For example, Kerr and Nanda (2009) and Chava, Oettl, Subramanian and Subramanian (2013) show sharply contrasting results for the two types of deregulation. Jayaratne and Strahan (1996) show no increase in the volume of bank lending following intrastate deregulation despite faster growth, and Jayaratne and Strahan (1998) show decreases in nonperforming loans only for intrastate banking, suggesting reductions in risk-taking and so possibly tighter, not looser credit conditions. Each is consistent with the direction of the coefficient in our tests.

Deregulation is also associated with more construction. We find that interstate deregulation leads to 15 to 18% higher number of new houses, while intrastate deregulation shows no impact on the number of new homes. This result is consistent with the finding in Favara and Imbs (2015), who find that increased credit supply due to inter-state restrictions implemented after 1995 is associated with more construction.

When we turn to measures of building quality and building condition, deregulation seems to have at most a muted effect. We do not find that building quality systematically changes after either type of deregulation and whether we weight the regressions or not. We do find a 0.02 increase in the building condition index after interstate deregulation, which represents a move of 1/50 of a point in our index (i.e., 1/50 of the distance between a rating of "Average" and a rating of "Good").[7] To put this number in perspective, the standard deviation of this measure in our data is 1.8 points on this scale. These results do not point to changes in building quality that would plausibly cancel out the change in house size we find after deregulation.

We next consider how the effect of deregulation changes across areas that we would expect ex ante to react differently to changes in the supply of mortgage credit. We first rely on the housing supply elasticity measure of Saiz (2010) to look at how house characteristics change in high and low house price areas. Then, we turn to a dataset Created by RSMeans (2003) and maintained over the last several decades that measures differences in the cost of labor and materials for building a standard residential structure in several cities across the United States. Table 3 includes the results

[7] Note that these regressions are run on the raw index values, not in logs, so the coefficients do not represent percent increases.

on the interaction of the interstate deregulation measure with indicators for whether a Zip code is above or below the median of each value.

Insert Table 3 About Here

In Panel A we obtain significant differences across areas when we split the data along these dimensions. We find that interstate deregulation affects house size much more in high price and in high construction cost areas. In fact, for areas below the median on either dimension we do not find any effect of deregulation on average square footage of single-family homes. In contrast, interstate deregulation dramatically increases the supply of new homes in high elasticity and low building cost areas.

Panel B of Table 3 shows the results based on intrastate deregulation. For the most part, we find very little difference in the results across areas split on the housing supply elasticity or the building cost dimensions. The one exception, and mirroring the results in Table 3, we find some significance for the effect of interstate banking deregulation, and the third column of the table shows that the significance is concentrated in low elasticity (high price) areas. The magnitude implies that after deregulation house quality is higher by 0.1 points on the rating scale in higher price areas.

3. Non-core liabilities and house characteristics in the 2000s boom

In our second set of tests, we exploit the non-core liability (NCL) measure introduced by Mian and Sufi (2019). Unlike deregulation, it is harder to define a precise timing where we expect the Zip code-level cross-section of non-core liability share to be associated with expanded credit and, consequently, changes in house characteristics. However, given the dynamics of the housing boom and the changes in private label securitization volume, as well as the timing of the changes in mortgage rate spreads (Justiniano, Primiceri and Tambalotti, 2022), we would expect this measure to matter primarily after 2001 and even more so after 2003. To capture this timing, we run cross-sectional regressions using long differences in the dependent variables. For this analysis we run regressions of the form:

$$\Delta_{2001-2006}\text{Log(Square feet)}_{\text{Zip}} = \beta_1 \textit{Non-core Liabilities}_{Zip} + \eta_{\text{State}} + \varepsilon_{\text{Zip}} \qquad (2)$$

Instead of outcomes in one specific year, the main outcome of interest for these regressions is the 5-year change in the logarithm of the average square footage in the Zip code for new homes between 2001 and 2006. As for the first empirical strategy, other outcomes include the 5-year change in the logarithm of the count of new homes, as well as 5-year changes in the quality index of new homes and the condition index of homes.

Non-core Liabilities is the non-core liability measure as of 2002 calculated at the Zip code level and described in more detail in Section 1.1. The variables η_{State} are state fixed effects. Standard errors are clustered at the county level, and regressions are weighted by Zip code population in line with the results in Table 2 and 3.

Insert Table 4 About Here

Table 4, Panel A shows that the non-core liability measure at the ZIP Code level is strongly associated with increases in average house size. This effect holds across a range of specifications. The estimate implies that a one standard deviation increase in the NCL measure is associated with 2% larger homes.

The number of new homes also changes, but this effect is sensitive to specification choice. In regressions without state fixed effects, we find a highly statistically significant effect of 0.33 on the log of new homes. The effect is imprecisely estimated, but similar in magnitude, when we include state fixed effects. This is consistent with the fact that the housing boom in the early 2000s was especially strong in a cluster of states in the Sunbelt region, which would lead to stronger identification across rather than within states; however, introducing controls for the fraction of houses in a zip code that were remodeled, the sign flips and the effect becomes negative but imprecisely estimated. This suggests that high NCL areas undergo both increases in the overall housing stock and a general renovation of the existing housing stock, yet the renovation of the existing stock is larger in magnitude.

Insert Figure 3 About Here

Figure 3 shows coefficients from a dynamic version of equation (2), where we consider multiple five-year periods starting with the period of 1986 through 1991 as the baseline and ending in 2011. The figure shows that the NCL variable does not affect house size during the 1990s and that this effect only appears for the 2001 through 2006 period. The effect again becomes null during the crisis period of 2006 through 2011.

Panel B shows that house quality is somewhat reduced by easier access to credit, with a magnitude that is somewhat larger than the effect in Table 3 regarding house condition grades. A one standard deviation change in the NCL variable is associated with a 0.06 point reduction in quality, which is meaningful when we consider that homes increased in quality, on average, by 0.3 points in the index between the 1990s and the 2000s. We do not find any effect on the condition of new homes today as a function of NCL. Table A2 of the Online Appendix shows that the effects on house size and house quality are close to monotonic in the NCL variable.

Table A3 of the Online Appendix shows that the effects of easier credit translate more into larger homes in high-priced and in high-building cost areas, mirroring the results in Table 4. We do not find significant differences across different areas in the drop in house quality we saw in Table 5, although we see that high NCL exposure is associated with worse building condition in high building cost areas.

Overall, there is no evidence that changes in quality (that could potentially be correlated with investments in energy conservation innovations) or increased durability that might have offset the energy use implications of the increase in house size we observe in high NCL areas.

4. Post-1994 interstate banking restrictions

Our final empirical strategy uses the state restrictiveness index post-IBBEA implemented by each state in a staggered fashion (following Rice and Strahan, 2010, and Favara and Imbs, 2015). We implement differences-in-differences regressions with the same outcomes as in equation (1) and our first empirical strategy. Outcomes are all in logs and the time period for these regressions spans 1994 (the year the IBBEA was implemented and the last year for our regressions using intrastate and interstate deregulation before this Act) to 2001 (the first year we use for the NCL regressions). Regressions are of the form:

$$\text{Log(Square feet)}_{\text{Zip},t} = \beta_1 Restrict\ Index_s \times Post_t + \eta_{\text{Zip}} + \eta_{\text{t}} + \varepsilon_{\text{Zip},t} \qquad (1)$$

The main variable of interest is the interaction *"Restriction Index$_s$ x Post$_t$"*, where *Restriction Index* enters the equation linearly and can have a maximum value of 4 and subtracts one for each of four possible restrictions put in place by the states. Those restrictions are listed in detail in Table I of Rice and Strahan (2010) and include both restrictions on *de novo* interstate branching and three possible restrictions on interstate bank acquisitions (minimum age of a target, the possibility of acquiring parts of another institution, and a cap on concentration of deposits in a single institution after a merger). All regressions include Zip code (η_{Zip}) and year of construction fixed effects (η_t), as well as controls for state-level income, population, and the Zip code share of remodeled and renovated homes ("*Effective year built*" and "*Remodeled*"). We cluster standard errors at the county code and year level, and weight regressions by the Zip code population as of 1998.

Insert Table 5 About Here

The results from this estimation are reported in Table 5. We find that lower restrictions following the passage of the IBBEA are only weakly related with changes in average home size. The effects are considerably stronger in regions characterized by low housing supply elasticity areas or high building costs. Here, we find that homes are larger by about one percentage point for every one-point increase in the index, which is equivalent to one fewer restriction to interstate banking expansion. We find no evidence that interstate post-1994 banking restrictions affect the supply or quality of homes.

5. Tallying the Environmental Cost of Easier Credit

In this section we draw together the work from the previous sections along with estimates from the existing literature to offer preliminary evidence on environmental magnitudes implied by the effects we have captured in the previous sections.

5.1 Bigger Homes Cost More to Heat and Cool

Understanding how home size is related to overall energy costs is an important first step in this calibration exercise. Even though the carbon intensity of larger homes has been studied extensively in the literature (see, for example, Goldstein, Gounaridis and Newell, 2020, or Streltsov, Malof, Huang, and Bradbury, 2020), our first step is both to confirm prior results and to measure how monthly energy costs and home size are related for homes of different vintages.

To establish the energy intensity of homes of different sizes and vintages, we rely on the American Housing Survey run by the Census Bureau. We use the National and Metropolitan files from 2005 to 2019 and the main variables of interest for our analysis are *HINCP* (household income), *ELECAMT* (monthly electricity costs), *GASAMT* (monthly gas costs), *OILAMT* (monthly oil costs) and *YRBUILT* (the year the house was built). The sample includes a total of 481 thousand observations at the household level across 8 biannual surveys.

Insert Figure 4 About Here

Figure 4 plots coefficients from a simple regression of all households in the AHS with information on the Core-based statistical area (CBSA) in which the house is located. The regressions include controls for the natural logarithm of household income, CBSA fixed effects and fixed effects for the decade in which the house was built (precise years are omitted for the sample of households with CBSA information to preserve anonymity). Energy costs are expressed in constant 2019 dollars. The figure shows an unambiguous increase in total monthly energy cost for bigger homes relative to smaller homes. In terms of magnitudes, the point estimates indicate that houses over 3000 square feet in area spend almost $100 more in energy then those that are around 1000 square feet.

Insert Table 6 About Here

Table 6 explores this in greater detail. In Panel A, the dependent variable is the 2019 constant-dollar energy cost. Each presents estimates based on Comparing point estimates across decades, we see that homes built more recently have higher additional energy cost per additional square foot than earlier vintages. One might naturally expect more recently built homes to be more efficient because they would incorporate more environmentally advanced technologies, and thus to display a lower sensitivity with respect to square footage, but this is not the case.

Panel B reports estimates from double-log specifications. Assume that the energy cost of a home can be described as

$$Total\ Cost_{ijt} = Unit\ Cost_{it} Usage_j,$$

for house *j* in region *i* at time *t*. If we assume that usage is a Cobb-Douglas function of home size and level of amenities (proxied by income), then in logs we have

$$\log Total\ Cost_{ijt} = \log Unit\ Cost_{it} + \alpha \log Size_j + \beta \log Income_{jt}.$$

This equation is estimated in Panel B of Table 2. The location fixed effects absorb the location-specific variation in average unit cost, leaving the α and β parameters to capture the effect of additional size and amenities in the home. These point estimates indicate that a ten percent increase in home size, holding constant income and hence the average level of amenities, raises energy costs by three to four percent. These effects are robust across time, and generally are higher for more recently built homes than older homes.

Next we combine the evidence from the cost/size relationship with estimates of the change in size with respect to a change in credit conditions in order to determine the overall carbon impact of easier mortgage credit.

5.2 Connecting Credit Conditions to Energy Costs

We first consider the banking deregulation tests and, specifically, the estimates in the fourth column of Table 2, where we show that interstate deregulation is associated with a 2% increase in average (single family) house size. Interstate deregulation took place primarily during the 1980s (Kroszner and Strahan, 1999), a period during which average new house size increased by 15% (from 1,866 square feet in 1980 to 2,141 square feet in 1990, unreported). This implies that over 13% of the increase in size during this period can be attributed to the deregulation episode. As we show in Table 3, this increase happens primarily in areas with low housing supply elasticity, where houses grew in size on average by slightly more during the 1980s (about 17%, unreported). Given that interstate deregulation accounts for an increase of 4.8% (Table 3, column 1), this means that over a quarter of the increase can be attributed to easier credit.

In order to relate the increase in home size to changes in credit, we turn to results in Mian and Sufi (2019), who show in Appendix Table IA.II that interstate deregulation is associated with a 3.3% increase in "household loans" per year.[8] The authors run the regression as of 1989, when the average distance (in years) to interstate deregulation was 2.94 (i.e., states had deregulated, on average, about 3 years before). If we scale the 3.3% estimate by the time since deregulation, this means that growth in household credit was close to 10% due to interstate deregulation. This produces an estimate for the elasticity of single-family house size to mortgage credit during this period of about 0.21.

We can translate the changes in house size into energy use by turning to the American Housing Survey data and the results in Panel B of Table 6. Across all house vintages, we find that the total monthly energy cost increases by 0.3 to 0.4% for every 1% increase in home size. Although these estimates represent an average across all regions and are based on energy *costs* rather than energy consumption, they are likely a conservative estimate. Goldstein, Gounaridis and Newell (2020) use data from the Energy Information Administration and obtain an elasticity estimate of energy consumption to house area of 0.29 for kilowatt hours (kWh) of electricity use (Tables SI-6 and SI-8 of the Online Appendix) and higher estimates for energy consumption of all other fuels (ranging from 0.5 to 0.8, Tables SI-8 through SI-17).

[8] Household loans include all real estate loans and loans to individuals and is the closest measure available in the literature to the growth in credit we are looking to capture in this context.

Taking 0.35 as the estimate of the elasticity of energy use to house size implies that banking deregulation contributed to an increase of 0.7% of energy use of all new single-family houses in the US. Single-family homes represented 62% of all housing units in the US in 1980 (1980 Census of Housing)[9], and housing represented about 20.2% of annual energy use in the US in that year (Energy Information Administration, 2022). In addition, we assume that the 2% increase in house size is permanent and would not take place in the absence of this deregulation. So, by 2022, 40% of the total stock of single-family homes (those built after 1980) is 2% larger due to this relaxation of credit. Taken together, this means that banking deregulation contributed to an increase of about 0.035% in total current US energy use through the house size channel. This is equivalent both in terms of energy use and greenhouse gas emissions to an additional 0.4-0.5 million passenger cars on the roads. If we scale this estimate by the change in credit, a permanent one percent expansion in credit to households translates to 0.35 basis points cumulative increase in total US energy consumption through the house size channel.

To offer a perspective on the relative importance of that number, consider the overall energy impact associated with the overall change in house size during our forty-year sample period. Homes are about 50% bigger now than they were at the beginning of the sample, so in a counterfactual world without home size expansion they would be two-thirds of their current size. We estimate the elasticity of energy use to size to be around 0.3 to 0.4 (estimates taken from Table 6). A one-third reduction in this number translates to a reduction of roughly one-ninth in the total energy output. Housing is around 20% of the total carbon footprint of the US, thus 20% * 1/9 amounts to about a 2.2% reduction in the total carbon footprint. Taking the 35 basis points in carbon consumption from credit expansion as the numerator, and 220 basis points as the total effect of the overall effect due to home expansion, a very rough estimate would attribute about 15% of the home-size channel's effect on the US carbon footprint to easier mortgage credit.

[9] https://www.census.gov/data/tables/time-series/dec/coh-units.html. We use the share of all housing units, which likely underestimates the contribution of single-family homes relative to other types of units, as these are generally smaller and less energy intensive.

6. Conclusion

There is significant academic and policy interest in understanding how environmental, social and governance (ESG) concerns affect the allocation of capital in financial markets, including how capital flows across ESG and non-ESG funds, companies and projects (Hartzmark and Sussman, 2019, Oehmke and Opp, 2020, Bolton and Kacperczyk, 2021, Pastor, Stambaugh and Taylor, 2021, among many others). However, even absent explicit ESG considerations, the expansion or contraction of availability of capital may have large carbon consequences that are rarely measured in the literature. This paper asks how variation in credit across regions affects the energy intensity of new single-family homes in the US.

We show that relaxing the supply of mortgage credit amplified the carbon footprint of the US residential housing stock by making homes larger, but not higher in quality or more durable. This shows that financial market conditions affect environmental outcomes not just through the pricing and sharing of environmental risk, but by literally shaping the carbon footprint of an important component of the real sector of the economy.

Policy interventions to relax credit constraints may want to consider the carbon impact of relaxed credit. Because the energy impact of easier credit is so directly tied to home size, it is easy to imagine straight-forward policy interventions, such as size-based carbon taxes on new construction, that achieve these goals. As energy grids become more efficient and operating costs drop, the salience of this concern grows, because more of the overall environmental weight of residential housing takes place during construction, which also scales with house size.

Our findings help to clarify the role of different policy tools on mitigating climate change. While policy makers across the globe scramble to find solutions to climate change, Hansen (2021) writes that "effective climate policy levers are in the fiscal but not in the monetary toolkit." Lagarde (2021) also acknowledges that "[it] is governments, not central banks, who are primarily responsible for facilitating an orderly transition" but also argues that central banks can "further incorporate climate considerations without prejudice to [their] primary mandate." Our results suggest there is a role of central bankers in this context. Given that easier monetary policy lowers interest rates, and that recent non-conventional monetary policy has explicitly targeted the home mortgage sector, we show that monetary policy has unintended environmental consequences through the house size channel.

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Figure 1: Evolution of average size of new homes, 1930-2019

Figure shows changes in average single-family house size by year of construction relative to the average size of homes completed during 1930-1939. Each point represents averages per year (except 1940, which includes 1940 through 1949), and standard errors are clustered at the county level. Data is from Zillow (ZTRAX Assessor files).

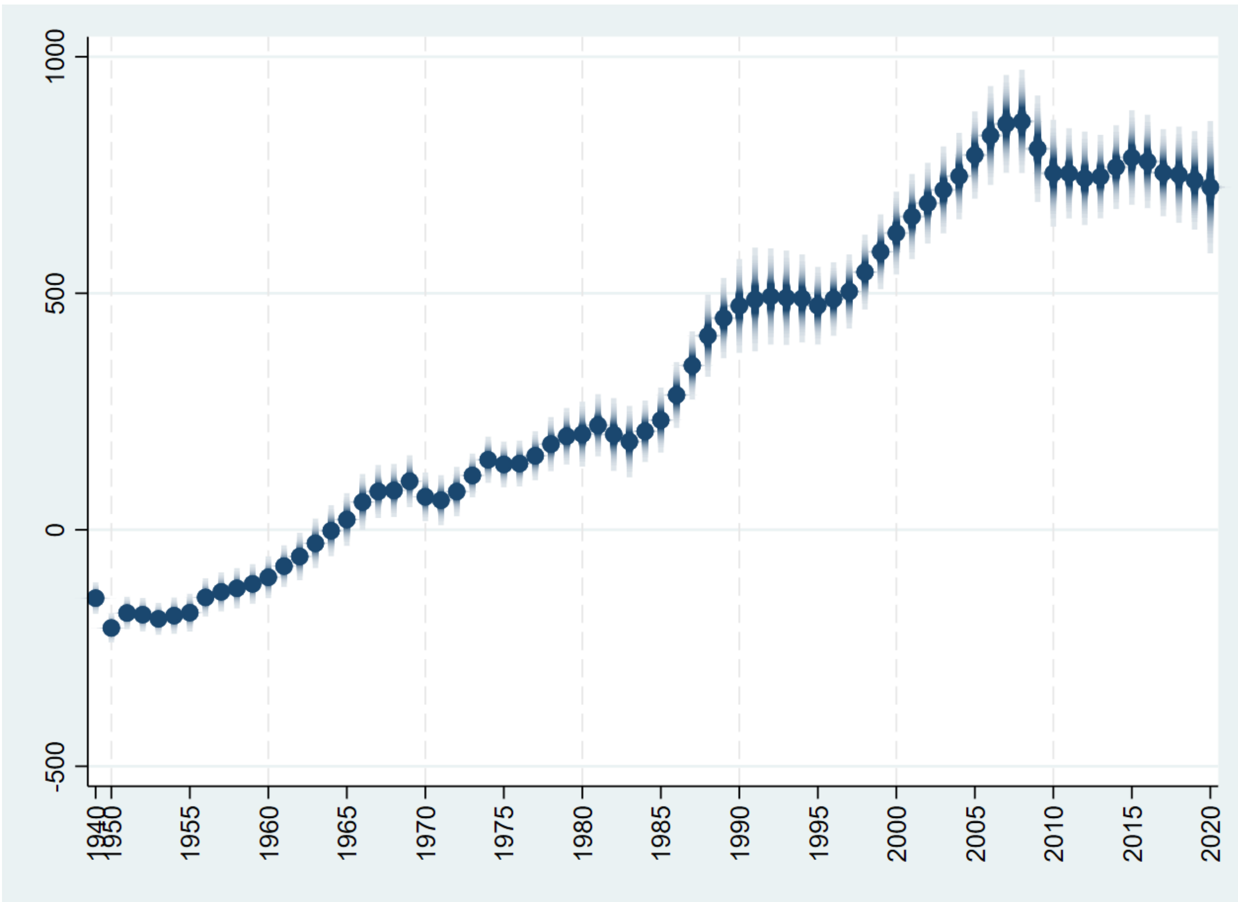

Figure 2: Dynamic effects of interstate banking deregulation on average house size

Figure shows coefficients from equation (1) where the "*Post*" coefficient is split into years before and after deregulation. All coefficients are shown relative to more than 3 years before interstate deregulation. Regressions control for Zip code and year built fixed effects and are weighted by Zip code population in 1998. Standard errors are clustered at the county and year level. Data is from Zillow (ZTRAX Assessor files).

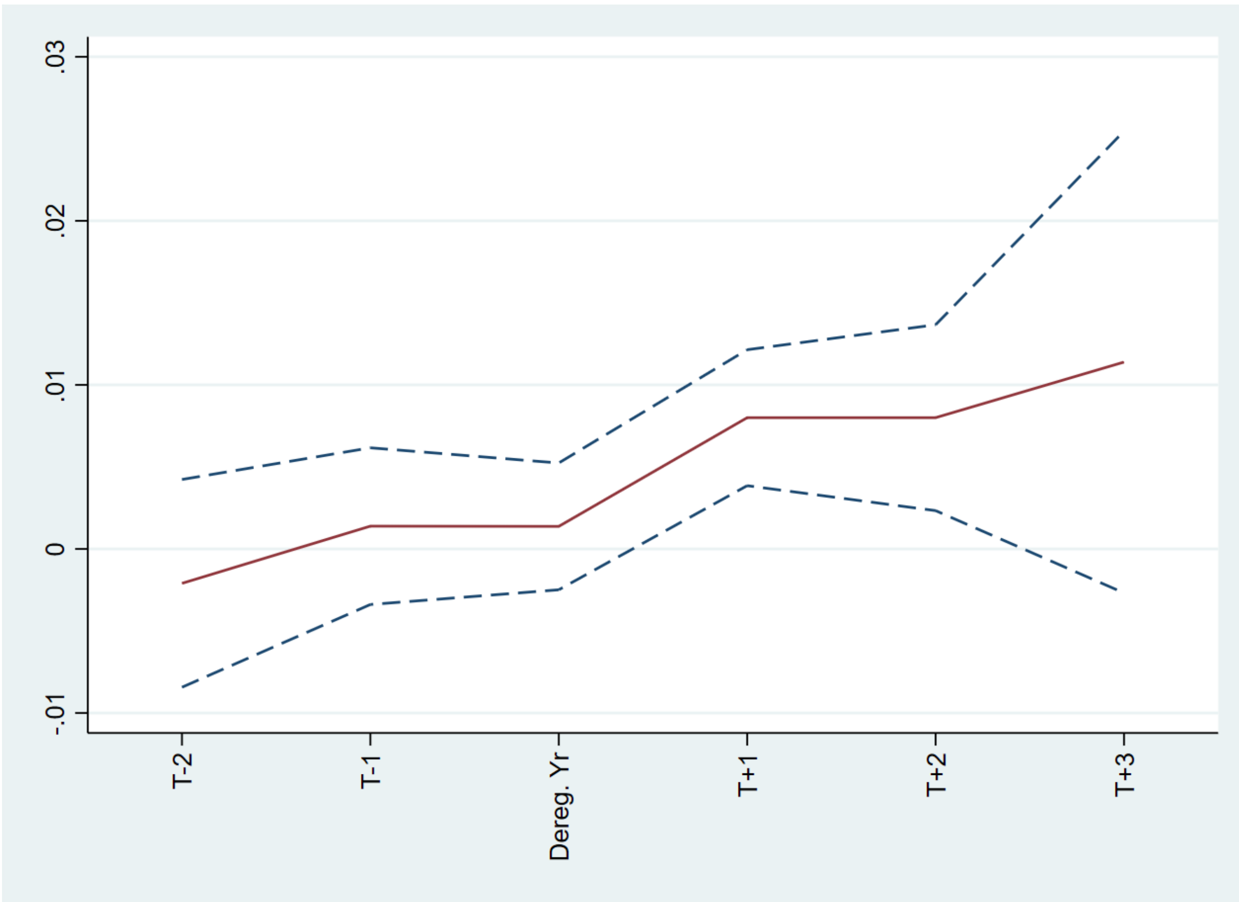

Figure 3: Non-core liabilities and average house size over

Figure shows coefficients from equation (2) and Table 5, but extending the sample to 1986 to 2011, split into 5 five-year periods interacted with the "*Non-core liabilities*" variable. The outcome is the 5-year change in the logarithm of average new house living area in a Zip code. "*Non-core liabilities*" are defined as the non-core liability ratio weighted by each institution's mortgage origination market share in a Zip code (as in Mian and Sufi, 2019). Coefficients are relative to the 1986-1991period. Regressions control for state-by-year fixed effects and are weighted by population in 1998. Standard errors are clustered at the county level. Data is from Zillow (ZTRAX Assessor files).

Figure 4: Total monthly energy costs by house size

Figure shows total monthly energy costs in US dollars (including electricity, gas and fuel costs) for households living in single-family homes included in the American Housing Survey run by the Census. Sample includes 2015, 2017 and 2019 Metro surveys. We plot differences for houses in each square footage bin relative to the smallest bin (houses less than 500 square feet). Regressions control for household income and fixed effects for CBSA and decade built. Standard errors are clustered at the Census division-by-survey year level.

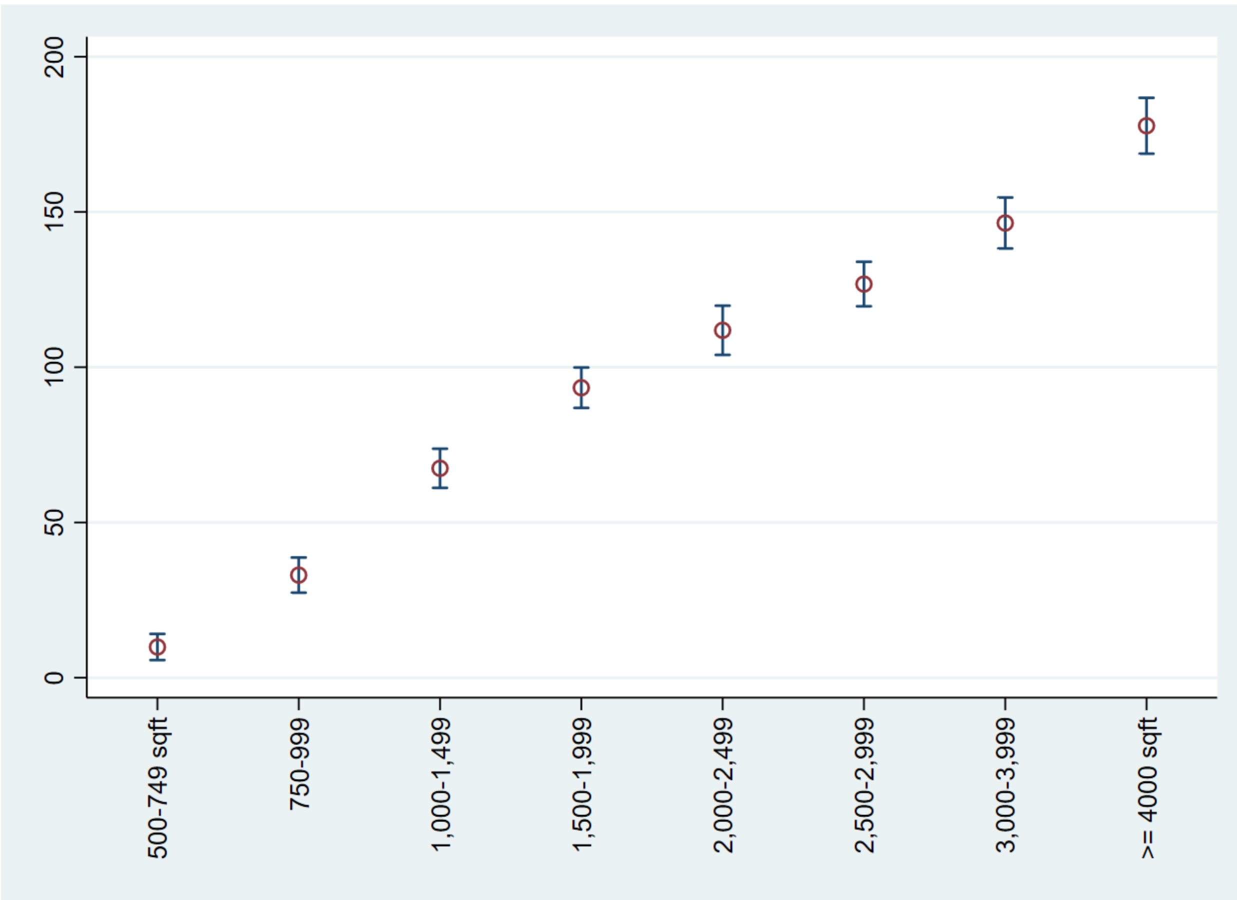

Table 1: Summary statistics

Table shows summary statistics for the variables used in the analysis. Living area is measured in square feet, and both building quality index and condition are converted into a numerical scale as described in the text. Quality ratings are converted to a numeric scale and they range from a minimum of "D-" (replaced by a value of "1") to a maximum of "A+" (coded as "12"). Building condition is coded in the assessor files from a minimum of "Poor", which we replace with a numeric value of "1", to a maximum of "Excellent", replaced with a value of "5". We show means weighted by 1998 Zip code population from the IRS. Data is from Zillow (ZTRAX Assessor files).

Panel A: Whole sample

	Mean	St. Dev.	Median	Min	Max	N. Obs
Living area (Sq. Feet)	1,976.0	790.5	1,784.8	102.0	10,000.0	1,108,902
Number of new houses	90.3	219.9	30.0	1.0	13,607.0	1,108,902
Year built	1982.9	21.5	1983.0	1930.0	2020.0	1,108,902
Building quality index	5.8	1.8	5.4	1.0	12.0	432,720
Building condition	4.1	0.6	4.0	1.0	6.0	646,156
New effective year built	0.12	0.27	0.00	0.00	1.00	1,108,641
Remodeled	0.04	0.14	0.00	0.00	1.00	1,108,859
Intrastate deregulation year	1979.8	9.3	1982.0	1965.0	1994.0	1,103,195
Interstate deregulation year	1986.0	2.0	1986.0	1978.0	1995.0	1,103,195
Non-core liabilities	0.74	0.06	0.74	0.53	0.95	280,216
Banking restriction index post-IBBEA	0.95	1.38	0.00	0.00	4.00	77,880
Supply elasticity (Saiz, 2010)	1.84	1.06	1.61	0.63	12.15	604,795

Panel B: Characteristics by decade

	Living area	Building quality	Building condition	Diff. effective year	Remodeled
1930-1939	1,653.0	4.7	3.9	0.20	0.08
1940-1949	1,506.5	4.8	3.9	0.18	0.07
1950-1959	1,486.2	4.9	4.0	0.17	0.06
1960-1969	1,654.7	5.3	4.0	0.16	0.05
1970-1979	1,781.8	5.5	4.1	0.15	0.05
1980-1989	1,921.7	5.7	4.1	0.12	0.04
1990-1999	2,161.0	6.1	4.2	0.10	0.03
2000-2009	2,428.1	6.4	4.3	0.07	0.02
2010-2019	2,441.3	6.6	4.4	0.04	0.01
Total	1,965.5	5.7	4.1	0.12	0.04

Table 2: Banking deregulation and the characteristics of new homes

Table shows the results from equation (1). The outcomes are year-by-Zip code averages of each variable and control for Zip code and year built fixed effects. Income per capita and population are at the state level and lagged by one year. "Different Effective Year Built" and "Remodeled" capture the average share of homes in a year that undergo new construction, major rehabilitation, or remodeling. Weights are Zip code population in 1998. Standard errors are clustered at the county and year level. Data is from Zillow (ZTRAX Assessor files).

Panel A: Living area and number of new homes

	Log(Living area in sq. ft)				Log(Number of new houses)			
Intrastate Deregulation	-0.012*	-0.012	-0.015**	-0.015**	-0.070	-0.026	0.037	0.036
	0.006	0.009	0.008	0.007	0.044	0.067	0.048	0.048
Interstate Deregulation	0.010**	0.021***	0.021***	0.020***	0.188***	0.165***	0.151***	0.151***
	0.004	0.005	0.006	0.006	0.041	0.051	0.048	0.048
Log(Income per Capita)			-0.024	-0.022			3.073***	3.069***
			0.052	0.051			0.460	0.459
Log(State Population)			-0.035	-0.034			0.905***	0.917***
			0.025	0.025			0.216	0.218
Diff. Effective Year Built				0.047***				0.079
				0.010				0.085
Remodeled				0.068***				-0.308***
				0.022				0.101
Weighted by Zip Population		Y	Y	Y		Y	Y	Y
Year	Y	Y	Y	Y	Y	Y	Y	Y
Zip Code	Y	Y	Y	Y	Y	Y	Y	Y
N	440,139	434,641	434,641	434,641	440,139	434,641	434,641	434,641
r2	0.62	0.71	0.71	0.71	0.74	0.66	0.67	0.67

Panel B: Quality and condition

	Building Quality Index			Building Condition (Latest)			Diff. Eff. Year Built	Remodeled
Intrastate Deregulation	0.046	0.088***	0.090***	-0.008	0.002	0.005	-0.005	-0.005**
	0.034	0.029	0.030	0.014	0.014	0.014	0.007	0.002
Interstate Deregulation	0.028	0.044	0.043	0.023*	0.022*	0.021*	0.004	0.002
	0.027	0.027	0.027	0.012	0.011	0.011	0.007	0.002
Effective year built and remodeled			Y			Y		
Income and Population Controls		Y	Y		Y	Y	Y	Y
Weighted by Zip Population		Y	Y		Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y	Y	Y
Zip Code	Y	Y	Y	Y	Y	Y	Y	Y
N	171,047	171,047	171,033	171,033	254,576	254,536	434,571	434,571
r2	0.78	0.78	0.78	0.78	0.75	0.75	0.89	0.89

Table 3: Banking deregulation across cheap and expensive areas

Table shows the results form equation (1), interacted with indicator variables for areas with low housing supply elasticity (as in Saiz (2010)) and high building costs (as measured by RS Means (2003)). The outcomes are year-by-Zip code averages of each variable and control for Zip code and year built fixed effects. Weights are Zip code population in 1998. Standard errors are clustered at the county and year level. Data is from Zillow (ZTRAX Assessor files).

Panel A: Interstate deregulation

	Log(Living area in sq. ft)		Log(Number of new houses)	
Interstate Deregulation	-0.007	0.001	0.234***	0.169***
	0.008	0.007	0.071	0.063
Interstate Deregulation x Low Elasticity	0.055***		-0.134	
	0.010		0.086	
Interstate Deregulation x High Building Costs		0.034***		-0.012
		0.010		0.078
Controls	Y	Y	Y	Y
Weighted by Population	Y	Y	Y	Y
Year	Y	Y	Y	Y
Zip Code	Y	Y	Y	Y
N	236,734	415,983	236,734	415,983
r2	0.72	0.71	0.64	0.66

Panel B: Intrastate deregulation

	Log(Living area in sq. ft)		Log(Number of new houses)	
Intrastate Deregulation	-0.033***	-0.023**	0.122	0.055
	0.009	0.009	0.076	0.063
Intrastate Deregulation x Low Elasticity	0.052***		-0.156**	
	0.010		0.069	
Intrastate Deregulation x High Building Costs		0.024***		-0.012
		0.008		0.057
Controls	Y	Y	Y	Y
Weighted by Population	Y	Y	Y	Y
Year	Y	Y	Y	Y
Zip Code	Y	Y	Y	Y
N	236,734	415,983	236,734	415,983
r2	0.72	0.71	0.64	0.66

Table 4: Non-core liabilities and the characteristics of new homes

Table shows coefficients from equation (2) for the period 2001 through 2006. The outcomes in Panel A is the 5-year change in the logarithm of average new house living area in a Zip code or the number of new single-family homes in a Zip code. Panel B considers the 5-year change in building quality index and building condition, both from the ZTRAX assessor files. "*Non-core liabilities*" are defined as the non-core liability ratio weighted by each institution's mortgage origination market share in a Zip code (as in Mian and Sufi, 2019). Regressions control for state fixed effects and are weighted by population in 1998. Standard errors are clustered at the county level. Data is from Zillow (ZTRAX Assessor files).

Panel A: Living area and count of new single-family houses

	Δ_5 Log(Living area in sq. ft)			Δ_5 Log(Number of new houses)		
Non-core liabilities	0.269***	0.324***	0.330***	0.330***	0.332	-0.362
	0.090	0.101	0.101	0.101	0.470	0.615
Remodel Controls			Y			Y
Weighted by Population	Y	Y	Y	Y	Y	Y
State FE		Y	Y		Y	Y
N	3,797	3,795	3,795	3,795	3,797	3,795
r2	0.00	0.04	0.04	0.04	0.00	0.05

Panel B: Quality and condition

	Δ_5 (Building quality)			Δ_5 (Building condition)		
Non-core liabilities	-1.724*	-0.952	-0.923	-0.923	-0.157	-0.217
	0.939	0.963	0.933	0.933	0.186	0.244
Remodel Controls			Y			Y
Weighted by Population	Y	Y	Y	Y	Y	Y
State FE		Y	Y		Y	Y
N	1,241	1,238	1,238	1,238	1,991	1,987
r2	0.01	0.03	0.03	0.03	0.00	0.05

Table 5: Post-1994 interstate banking restrictions and new construction

Table shows coefficients from equation (3) for the period 1994 through 2001. The outcomes in Panel A is the logarithm of average new house living area in a Zip code and in Panel B it is the logarithm of the number of new single-family homes in a Zip code. "*Low Restrictions Index*" is the interstate banking restriction index from Rice and Strahan (2010) and Favara and Imbs (2015). Regressions control for Zip code and year fixed effects and are weighted by population in 1998. Standard errors are clustered at the county and year level. Data is from Zillow (ZTRAX Assessor files).

Panel A: Living area of new single-family houses

	Log(Living area in sq. ft)					
Low Restrictions Index	0.002	0.003*	-0.002	0.000	-0.002	0.000
	0.002	0.002	0.002	0.002	0.002	0.002
Low Restrictions Index x			0.009***	0.008***		
Low Elasticity			0.003	0.002		
Low Restrictions Index x					0.006**	0.006**
High Building Costs					0.002	0.002
Controls		Y		Y		Y
Weighted by Population	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
Zip Code	Y	Y	Y	Y	Y	Y
N	77,153	71,984	60,276	57,565	73,798	70,133
r2	0.80	0.82	0.81	0.82	0.81	0.82

Panel B: Count of new single-family houses

	Log(Number of new houses)					
Low Restrictions Index	-0.018*	-0.011	-0.019	-0.007	-0.026**	-0.016
	0.010	0.010	0.013	0.013	0.012	0.012
Low Restrictions Index x			-0.008	-0.015		
Low Elasticity			0.016	0.017		
Low Restrictions Index x					0.012	0.008
High Building Costs					0.015	0.015
Controls		Y		Y		Y
Weighted by Population	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
Zip Code	Y	Y	Y	Y	Y	Y
N	77,153	71,984	60,276	57,565	73,798	70,133
r2	0.86	0.86	0.86	0.86	0.86	0.86

Table 6: Energy costs and house size

Table shows OLS regressions of monthly total energy costs (Panel A), and the logarithm of total energy costs (Panel B) on the logarithm of square footage and household income from the American Housing Survey administered by the Census. Sample includes all National and Metro surveys between 2005 and 2019. Regressions control for city / suburban status, as well as Census division-by-survey year fixed effects. Costs are all adjusted to 2019 constant dollars. Standard errors are clustered at the Census division-by-survey year level.

Panel A: Total energy costs

	Year Built				
	<= 1939	1940-1959	1960-1979	1980-1999	2000-2019
Log(Square Feet)	58.29***	58.53***	67.60***	67.40***	81.12***
	3.15	4.13	3.44	4.49	6.33
Log(Income)	16.75***	13.68***	17.10***	14.97***	11.76***
	1.74	1.77	1.64	1.17	1.65
City/Suburban FE	Y	Y	Y	Y	Y
Division x Survey Yr FE	Y	Y	Y	Y	Y
N	13,478	15,525	28,974	24,515	12,900
r2	0.23	0.22	0.27	0.30	0.31

Panel B: Log(Total energy costs)

	Year Built				
	<= 1939	1940-1959	1960-1979	1980-1999	2000-2019
Log(Square Feet)	0.30***	0.31***	0.40***	0.36***	0.40***
	0.03	0.03	0.04	0.03	0.03
Log(Income)	0.08***	0.07***	0.09***	0.08***	0.06***
	0.01	0.01	0.01	0.01	0.01
City/Suburban FE	Y	Y	Y	Y	Y
Division x Survey Yr FE	Y	Y	Y	Y	Y
N	12,741	14,739	26,773	23,437	12,545
r2	0.24	0.26	0.30	0.31	0.32

Online Appendix for:

The Environmental Cost of Easy Credit: The Housing Channel

Manuel Adelino, Duke University, CEPR and NBER

David Robinson, Duke and NBER

Table A1: Banking deregulation analysis including lagged dependent variable as a control

Table shows coefficients from equation (2) for the period 2001 through 2006, with non-core liabilities split into (population-weighted) quartiles. The outcomes are the same as Table 5: 5-year change in the logarithm of average new house living area in a Zip code, the number of new single-family homes, building quality index and building condition. "*Non-core liabilities*" are defined as the non-core liability ratio weighted by each institution's mortgage origination market share in a Zip code (as in Mian and Sufi, 2019). Regressions control for state fixed effects and are weighted by population in 1998. Standard errors are clustered at the Zip code level. Data is from Zillow (ZTRAX Assessor files).

	Log(Living area in sq. ft)	Log(Number of new houses)	Building Quality Index	Building Condition (Latest)
Intrastate Deregulation	-0.011**	0.057*	0.063***	0.004
	0.006	0.031	0.020	0.010
Interstate Deregulation	0.016***	0.098**	0.031*	0.015*
	0.004	0.038	0.016	0.009
Log(Income per Capita)	-0.014	0.954***	0.723***	0.215***
	0.039	0.294	0.255	0.062
Log(State Population)	-0.026	0.245**	0.219*	0.108
	0.019	0.113	0.130	0.079
Diff. Effective Year Built	0.040***	0.041	0.051	-0.024
	0.008	0.045	0.046	0.049
Remodeled	0.070***	-0.157***	0.164**	0.319**
	0.019	0.050	0.080	0.151
Lagged Dependent Variable	Y	Y	Y	Y
Weighted by Zip Population	Y	Y	Y	Y
Year	Y	Y	Y	Y
Zip Code	Y	Y	Y	Y
N	440,139	434,641	434,641	434,641
r2	0.62	0.71	0.71	0.71

Table A2: Quartiles of non-core liabilities

Table shows coefficients from equation (2) for the period 2001 through 2006, with non-core liabilities split into (population-weighted) quartiles. The outcomes are the same as Table 5: 5-year change in the logarithm of average new house living area in a Zip code, the number of new single-family homes, building quality index and building condition. "*Non-core liabilities*" are defined as the non-core liability ratio weighted by each institution's mortgage origination market share in a Zip code (as in Mian and Sufi, 2019). Regressions control for state fixed effects and are weighted by population in 1998. Standard errors are clustered at the Zip code level. Data is from Zillow (ZTRAX Assessor files).

	Δ_5 Log(Square feet)	Δ_5 Log(Number of new houses)	Δ_5(Building quality)	Δ_5(Building condition)
Q2.Non-core liabilities	0.025*	-0.015	-0.130	-0.005
	0.015	0.057	0.120	0.024
Q3.Non-core liabilities	0.029	0.077	-0.362**	-0.066*
	0.018	0.087	0.146	0.037
Q4.Non-core liabilities	0.069***	-0.013	-0.264*	-0.003
	0.021	0.126	0.147	0.060
Remodel Controls	Y	Y	Y	Y
Weighted by Population	Y	Y	Y	Y
State FE	Y	Y	Y	Y
N	3,738	3,738	1,224	1,962
r2	0.04	0.06	0.04	0.06

Table A3: Effect of NCL in cheap and expensive areas

Table shows the results form equation (2), interacted with indicator variables for areas with low housing supply elasticity (as in Saiz (2010)) and high building costs (as measured by RS Means (2003)). The outcomes are the 5-year change in the logarithm of average new house living area in a Zip code, the number of new single-family homes in a Zip code, the building quality index and the building condition. "*Non-core liabilities*" are defined as the non-core liability ratio weighted by each institution's mortgage origination market share in a Zip code (as in Mian and Sufi, 2019). Weights are Zip code population in 1998. Standard errors are clustered at the county level. Data is from Zillow (ZTRAX Assessor files).

	Δ_5 Log(Square feet)		Δ_5 Log(Number of new houses)		Δ5 (Building quality)		Δ5 (Building condition)	
Non-core liabilities	0.124	0.121	-1.094	-1.838***	-1.793**	-0.747	-0.099	0.530
	0.098	0.119	0.699	0.679	0.852	1.117	0.302	0.393
Low Elasticity	-0.245*		-0.748		-0.083		-0.168	
	0.146		0.679		1.244		0.328	
Non-core liabilities	0.330		0.954		0.076		0.171	
x Low Elasticity	0.202		0.970		1.724		0.471	
High building costs		-0.231*		-1.730**		-0.156		0.767**
		0.134		0.702		1.141		0.311
Non-core liabilities		0.327*		2.513**		0.038		-1.194***
x High building costs		0.186		1.030		1.599		0.435
Remodel Controls	Y	Y	Y	Y	Y	Y	Y	Y
Weighted by Population	Y	Y	Y	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y	Y	Y
N	3,161	3,727	3,161	3,727	1,003	1,212	1,651	1,952
r2	0.04	0.04	0.06	0.05	0.04	0.03	0.07	0.06

Figure A1: Example of high and medium quality grade structures

Figure is from the Uniform Schedules of Values, Standards, and Rules for Single Family Residences (Volume 3, January 2016) for Durham County produced by the Office of Tax Administration. Below are examples of a "Grade A" and "Grade C" residence, as well as descriptions of the typical characteristics of homes of these grades.

A Quality Dwellings

These homes are architecturally designed and custom built by contractors who specialize in good quality construction. Extensive detail is given to ornamentation with the use of good grade materials and skilled craftsmanship. Homes of this type are located in areas that are specifically developed for this level of quality.

BASE SPECIFICATIONS

FOUNDATION: Brick or reinforced concrete foundation walls on concrete footings with interior piers.

EXTERIOR WALLS: Stone, brick veneer, stucco, log, or frame siding. All exterior walls will be of good quality and constructed with detail and workmanship. Ample insulation and adequate openings for windows and doors is typical.

ROOF: Slate, tile, cedar shake, or architecture asphalt shingles on quality sheathing with well braced rafters having various slopes and ridges.

INTERIOR FINISH: The interior of these homes is of good design and good construction with much attention given to detail and good quality craftsmanship.

FLOORS: Heavy construction utilizing wood or steel joists and sub floor with a good quality combination of hardwoods, ceramic tile, marble or granite tile, vinyl, or good quality carpeting.

PLUMBING: A combination of good quality fixtures, good quality materials, and skilled workmanship; considered typical and adequate for the type of construction, generally exceeds a total of twelve fixtures.

CLIMATE CONTROL: A heating system equal to forced air with ample capacity and insulated ductwork throughout. Air conditioning is included as a part of the specifications; however, this item is considered an add-on item and is excluded from base pricing.

ELECTRICAL: Good quality wiring, maximum electrical outlets and expensive light fixtures.

C Quality Dwellings

These homes are designed and built by contractors who specialize in average quality construction. Adequate detail is given to ornamentation with the use of average grade materials and typical workmanship. Homes of this type are located in areas that are specifically developed for this level of quality. These homes represent the prevalent quality.

BASE SPECIFICATIONS

FOUNDATION: Brick or reinforced concrete foundation walls on concrete footings with interior piers.

EXTERIOR WALLS: Stone, brick veneer, stucco, log, or frame siding. All exterior walls will be average quality and constructed with detail and workmanship. Ample insulation and adequate openings for windows and doors is typical.

ROOF: Tile, cedar shake, or asphalt shingles on average quality sheathing with frame trusses and having typical slopes.

INTERIOR FINISH: The interior of these homes is of average design and average construction with attention given to detail and average quality workmanship.

FLOORS: Moderate construction utilizing wood or steel joists and sub floor with an average combination of hardwoods, ceramic tile, vinyl, or average quality carpeting.

PLUMBING: A combination of average quality fixtures, average quality materials, and workmanship; considered typical and adequate for the type of construction, generally does not exceed a total of ten fixtures.

CLIMATE CONTROL: A heating system equal to forced air with ample capacity and insulated ductwork throughout. Air conditioning is included as a part of the specifications; however, this item is considered an add-on item and is excluded from base pricing.

ELECTRICAL: Average quality wiring, adequate electrical outlets and average light fixtures from base pricing.