Helping the Middle-Class: How Interest Rates Affect the Distribution of Housing Wealth*

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Abstract

This paper documents that economy-wide declines in interest rates cause middle-priced neighborhoods to experience large gains in house prices, while high- and low-priced neighborhoods experience no gains. I develop a novel identification strategy that exploits minor incidental differences in the distribution of the metropolitan population to estimate a measure of latent demand for small neighborhoods. I show that a 1.2% decline in mortgage interest rates from July 2000 to December 2001 leads to an average increase of 7% to 8.5% in house prices for middle-priced neighborhoods, which translates to an average monetary increase of $11,000 to $12,000 in housing wealth for homeowners who live in these neighborhoods. Credit constraints for low-income households and high transaction costs—i.e., realtor fees—together with minimal dependence on mortgage financing for high-income households might explain the low sensitivity to interest rate of households at both ends of the income distribution, and consequently the lack of price effects in low- and high-priced neighborhoods.

JEL Codes: E52; D14; D31; E21; R21; R31

Keywords: Interest rates; housing wealth; mortgage rates; house prices; housing demand; cost of capital; monetary policy

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1. INTRODUCTION

The long period of low interest rates that followed the 2008 financial crisis originated an extensive debate on who benefits from monetary policy interventions. Economists have since started to document the effect of interest rates on the distribution of income and wealth (Doepke and Schneider (2006); Coibion, Gorodnichenko, Kueng, and Silvia (2012); Di Maggio, Kermani, and Ramcharan (2014); Keys, Piskorski, Seru, and Yao (2014); Auclert (2015); Sterk and Tenreyro (2015); and Agarwal, Chomsisengphet, Mahoney, and Stroebel (2015)). Nonetheless, one potentially significant effect remains largely unstudied: the effect of interest rates on the distribution of housing wealth. The largest asset that most U.S. households hold on their balance sheet is their home; thus, interest rates may plausibly have large effects on household wealth by impacting housing demand.

This paper aims to fill this gap in the literature by documenting the distributional effects of interest rates on house prices at the neighborhood level.[1] This effect on housing wealth is important for the real economy since homeowners are likely to fund consumption and investment by borrowing against gains in home equity (Mian and Sufi (2011); Adelino, Schoar, and Severino (2015); and DeFusco (2015)). I find that, after economy-wide changes in interest rates, homeowners who live in middle-priced neighborhoods experience considerable gains in housing wealth, while homeowners who live in low- and high-priced neighborhoods experience no gains in housing wealth.

Standard neoclassical models of investment assume that the cost of capital is a key determinant of the demand for capital. In the housing market, a decline in mortgage interest rates might shift the demand schedule since households may be able to afford mortgage payments on homes that they could not afford otherwise. If the supply of housing is not perfectly elastic, this shift in housing demand might have significant effects on house prices.[2] In the first part of the paper, using a novel identification strategy that estimates *latent demand* of interest rate-sensitive buyers for neighborhoods in a quasi-experimental fashion, I estimate the average effect of changes in interest rates on housing demand and house prices. Existing homeowners who live in neighborhoods that are targeted by interest rate-sensitive buyers will then experience gains in housing wealth. However, not all buyers are sensitive to changes in interest rates. Some home buyers face credit constraints (usually, low-income households), while others are less dependent on mortgage financing to pur-

[1] Following zillow.com, I define a neighborhood as one of the terciles of the zip code in price. A neighborhood is then the collection of non-contiguous houses in the zip code that have similar house prices. This proves advantageous for the purposes of this analysis because it makes the neighborhoods homogeneous despite the fact that the houses might not be contiguous. A neighborhood contains on average 3,500 households.

[2] The mechanism through which changes in interest rates affect house prices growth involves three types of agents. The first two are existing homeowners and renters who might be sensitive to changes in the cost of capital. These two agents may become home buyers if interest rates decline sufficiently. An existing homeowner who does not become a home buyer even after a decline in interest rates is the third type of agent. She might experience gains in housing wealth if interest rate-sensitive buyers increase housing demand in the neighborhood where she lives.

chase a home[3] (usually, high-income households) or might face large transaction costs in the form of Realtors' fees. Thus, the average effect of interest rates on house prices might mask large distributional effects. In the second part of the paper, I take advantage of the small size and homogeneity of neighborhoods to document the distributional effects of interest rates on housing wealth.

It is, however, non-trivial to identify the effect of changes in interest rates on house prices. First, mortgage interest rates are driven, among other factors, by the future expectations of inflation and output. Second, interest rates tend to change simultaneously for the entire economy, making it difficult to find credible contemporaneous counterfactuals. To address these endogeneity issues, this paper introduces a novel empirical design that exploits incidental differences in the distribution of the metropolitan population around pre-determined affordability income thresholds.

The key intuition of the empirical design is the concept of the minimum income required to afford mortgage payments on an average house in a small and homogenous neighborhood; the reduction in interest rates will then allow marginal households to overcome the affordability barrier. The crucial ingredient of the identification strategy is the *neighborhood affordability threshold*, which is defined prior to the interest rate change as the income level below which households cannot afford to make mortgage payments on the average house in the neighborhood.[4] The paper refers to the fraction of metropolitan households below this threshold as *mortgaged-out*. When interest rates decline, households with income immediately to the left of a neighborhood affordability threshold can afford to make mortgage payments in that neighborhood. This fraction of households represents the measure of *latent demand*[5] for the neighborhood. The identification strategy relies on the comparison of latent demand in neighborhoods in different metropolitan areas in the same U.S. state, holding constant the fraction of mortgaged-out households and the level of house prices in the neighborhood prior to the interest rate change.[6]

The identification assumption is that, after controlling for the fraction of mortgaged-out households and the level of house prices, the source of variation for latent demand stems from small incidental differences in the distribution of the metropolitan population, which are plausibly exogenous to house price growth. The metropolitan areas of Cleveland, OH, and Cincinnati, OH,

[3]The independence here refers to timing and amount. Some households might only require a small loan amount (i.e. high-wealth households). Others might need a mortgage to purchase a home but are less concerned with timing, since they can afford to make the mortgage payments at high interest rates and then refinance at low interest rates (i.e. low-wealth but high-income households).

[4]Section 2.3.1 discusses in detail the computation of the affordability threshold.

[5]Latent demand varies with the size of the interest rate change. Throughout the the paper the term latent demand is associated with a specific interest rate change from July 2000 and December 2001. Below, I explain the choice of this time period.

[6]Other demographics at the neighborhood, zip code, and metropolitan level are also held constant; namely, income level, income growth, past house price growth, unemployment, age, population size, race, immigration, and education levels.

provide one good example of this concept. Figure 1 reports the income distribution of households for these two metropolitan areas in 2000.[7]

Except for minor differences, the two distributions are remarkably similar. The empirical design of this paper exploits these relatively minor differences to causally estimate the effect of changes in interest rates on house price growth. To see this, consider two hypothetical neighborhoods in each metro area: Neighborhood A in Cleveland and Neighborhood B in Cincinnati, depicted at the bottom of Figure 1. Both neighborhoods have the same house price level and the same fraction of mortgaged-out households in July 2000 (light blue area). Neighborhoods A and B appear to be subject to similar metro-level housing demand; however, the fraction of the population in Cleveland that is immediately to the left (following income bin) of the affordability threshold for Neighborhood A in Cleveland is larger than its counterpart fraction for Neighborhood B in Cincinnati. If interest rates decline just enough, the new fraction of households in Cleveland, OH, that can afford to make mortgage payments in Neighborhood A is larger than the new fraction of households in Cincinnati, OH, that can afford to make mortgage payments in Neighborhood B. That is, latent demand for Neighborhood A is larger than latent demand for Neighborhood B. If the supply of housing is not perfectly elastic, Neighborhood A in Cleveland will experience a larger increase in house prices when interest rates decline.

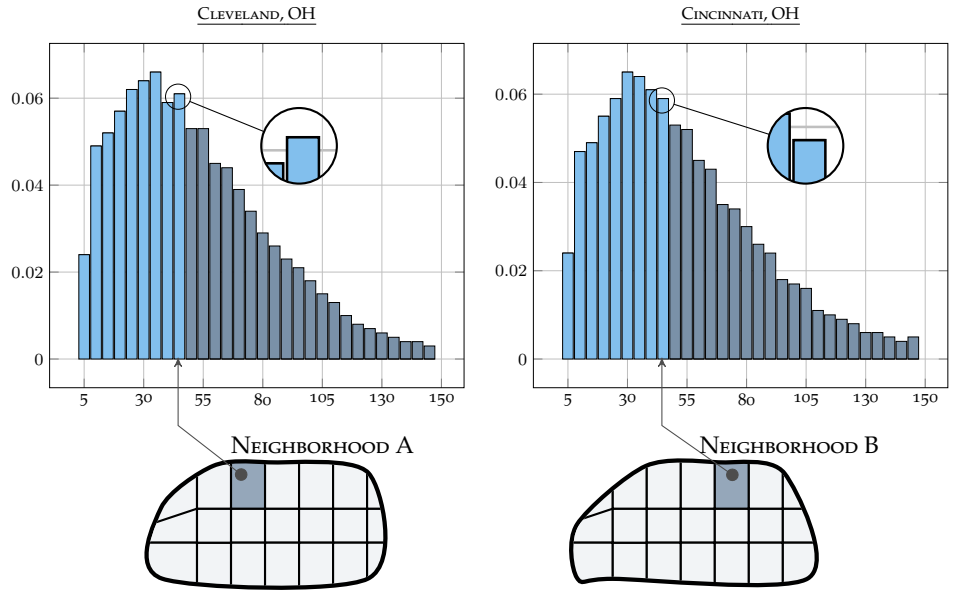
Latent demand may seem to be always larger for neighborhoods in Cleveland than neighborhoods in Cincinnati; that is, systemic differences between Cleveland and Cincinnati might cause neighborhoods in Cleveland to consistently experience higher demand shifts after changes in interest rates. These systemic differences could pose a critical threat to the identification strategy. However, it requires little effort to find another example in which latent demand is larger for a neighborhood in Cincinnati than one in Cleveland. For instance, if one chooses a neighborhood with an income affordability threshold further to the left than the above example, latent demand would be larger for the neighborhood in Cincinnati. Section 2.2 discusses these two examples in detail.

The empirical design of this paper can theoretically be applied to any macro interest rate decline, as long as the interest rate change is unrelated to the housing market. Between July 2000 and December 2001, the Federal Reserve Board introduced an expansionary monetary policy intervention, primarily motivated by the burst of the dot-com bubble and the geopolitical uncertainty brought about by the 9/11 terrorist attacks. During this 17-month period, the Fed funds rate dropped from 6.5% to 1.7%, and the 30-year mortgage fixed rate dropped by 1.2%, from 8.3% to 7.1%. Employing the novel empirical methodology of this paper, I use the mortgage interest rate

[7] This income distribution is obtained from the 2000 decennial census.

FIGURE 1: SOURCE OF VARIATION FOR CLEVELAND, OH, VERSUS CINCINNATI, OH

The figure below presents the distribution of income for all households of Cleveland, OH, and Cincinnati, OH metropolitan areas. The income information is from the 2000 decennial census and downloaded from IPUMS.org. Data was obtained at the household level and aggregated into bins of $5,000. The y-axis reports the fraction (in decimals) of households that fall in each income bin, while the x-axis reports the total household income in thousands of dollars.



change during this period to examine the effect of interest rate changes on housing wealth.[8]

To validate the methodology of this paper, it is first necessary to estimate the correlation between latent demand for a neighborhood and the growth in mortgage applications for home purchase in that neighborhood. Neighborhoods that have higher latent demand should experience an increase in mortgage applications. Indeed, a decline of 1.2% in the 30-year mortgage rates between July 2000 and December 2001 is associated with an increase of almost 10% in mortgage applications for home purchase from applicants. This jump in mortgage applications might seem unreasonably large, but since neighborhoods are fairly small, the sizable percentage increase translates to a small absolute number of mortgage applications for home purchase.

Next, I turn to the effect on prices. The estimated effect of interest rates on average home prices is also economically large. The contemporaneous average effect of the change in mortgage interest rates from July 2000 to December 2001 on home price growth is approximately 2.7%. On the one hand, the effect on the sub-sample of neighborhoods located in metropolitan areas with high

[8]This interest rate intervention is also ideal for this study because, coincidentally, the decennial census of 2000 provides a comprehensive metropolitan level income distribution in 2000, the year of the monetary policy intervention.

housing supply elasticity[9] is statistically zero. The economic effect is half the size of the average effect. In these cities, new residential construction compensates for the demand shock due to the abundance of space, preventing home prices from adjusting upward. On the other hand, in neighborhoods located in metro areas with low housing supply elasticity the effect of interest rates on home price growth is economically large and statistically significant. For the most part, interest rates only impact house price growth in metropolitan areas with low housing supply elasticity, since the supply of housing cannot adjust to the shift in demand.

Since current homeowners and renters can both be potentially sensitive to changes in interest rates, I estimate separately the effects of renters' and homeowners' latent demand on house price growth. The results show that average effects are mostly driven by renters' latent demand. Homeowners' latent demand has the right direction but it is economically and statistically insignificant. This difference is plausibly related to the large transaction costs faced by existing homeowners. In the U.S., sellers bear the Realtors' fees, which are usually between 5% and 6% of the home value. This large transaction fee may deter existing homeowners from adjusting housing consumption as interest rates decline.

After establishing that changes in interest rates shift the schedule of housing demand and affect house prices, the paper turns to the distributional effects to shed light on what neighborhoods gain from changes in interest rates. I separate neighborhoods by quartiles of houses prices by metropolitan area, and then estimate the effect of interest rates on house prices for each quartile.[10] The results vary by a striking amount. Homeowners who live in middle-priced neighborhoods (second and third quartile) experience large gains in housing wealth after a decline in mortgage interest rates. In contrast, homeowners in low- and high-priced neighborhoods (first and fourth quartiles) experience no gains in housing wealth. A 1.2% decline in mortgage interest rates leads to an average increase of between 7% and 8.5% in housing wealth for the second and third quartiles of house prices; in monetary terms, this is an average increase of $11,000-$12,000 in housing wealth.

Given that households have high marginal propensities of consumption out of their housing wealth (Mian and Sufi (2011), DeFusco (2015)), these results suggest that the housing market might represent a relevant transmission mechanism of interest rates to the real economy. Di Maggio, Kermani, and Ramcharan (2014) and Keys, Piskorski, Seru, and Yao (2014) have documented evidence

[9] Housing supply elasticity is from Saiz (2010)

[10] The house price quartiles are computed within a metropolitan area. For the whole sample of U.S. neighborhoods, the average house price in July 2000 was $92,484 in the lowest quartile, $131,363 in the second quartile, $174,211 in the third quartile, and $272,880 in the highest quartile. There is, however, a fair amount of heterogeneity across metropolitan areas. For example, in San Francisco, CA, the average house price in July 2000 was $228,509 in the lowest quartile, $351,787 in the second quartile, $446,961 in the third quartile, and $712,923 in the highest quartile; while in Cleveland, OH, the average house price in July 2000 was $71,807 in the lowest quartile, $104,786 in the second quartile, $134,726 in the third quartile, and $207,770 in the highest quartile.

that supports this claim by showing that households increase their consumption and reduce default rates after declines in mortgage payments resulting from mortgage rate adjustments in their loans.

The distributional results documented here are also useful to potentially help us understand the micro foundations behind the house price contagion during the 2000s housing boom recently documented in the urban economics literature (Glaeser, Gottlieb, and Tobio (2012); DeFusco, Ding, and Ferreira (2015); Landvoigt, Piazzesi, and Schneider (2015); and Kleiner (2015)). The results presented in this paper suggest a possible connection between the increase in house prices in middle-income neighborhoods and the subsequent house price growth in low-income neighborhoods, perhaps through a gentrification mechanism (Guerrieri, Hartley, and Hurst (2013)).

The remainder of this paper is organized as follows: the rest of this section reviews related literature; the following section describes the economic mechanism, explains in detail the empirical design, and reviews the monetary policy intervention in the 2000s; section 3 outlines the regression methodology; section 4 presents the micro data and the construction of the dataset used in the analysis; section 5 reports the results and robustness tests; and section 6 concludes the paper.

1.1. Related Literature

This paper relates closely to three strands of literature. First, it relates to recent literature that investigates the impact of monetary policy shocks on wealth, income, and consumption inequality (Doepke and Schneider (2006);Coibion, Gorodnichenko, Kueng, and Silvia (2012);Di Maggio, Kermani, and Ramcharan (2014); Keys, Piskorski, Seru, and Yao (2014); Auclert (2015); Sterk and Tenreyro (2015); and Agarwal, Chomsisengphet, Mahoney, and Stroebel (2015)). Coibion, Gorodnichenko, Kueng, and Silvia (2012) use the Consumer Expenditure Survey and find that expansionary monetary policy shocks lower income and consumption inequality.[11] Auclert (2015) shows that lower-income agents, who maintain higher margins of propensities of consumption, may increase aggregate demand following falls in interest rates. Using the Survey of Consumer Finances, Doepke and Schneider (2006) estimate the wealth redistribution caused by a moderate inflation episode through changes in the value of nominal assets. They show that the main losers from inflation are rich and old households, and that the main winners are young middle-class households with fixed-rate mortgage debt.

Others have studied how monetary policy shocks affect households' saving and consumption behavior (Di Maggio, Kermani, and Ramcharan (2014) and Bhutta and Keys (2014)). Bhutta and Keys (2014) show that policy-driven short-term mortgage rates significantly impact home equity–

[11] Coibion, Gorodnichenko, Kueng, and Silvia (2012) consider five channels through which monetary policy may affect income and consumption inequality.

based borrowing because homeowners take advantage of low interest rates to refinance their mortgages. Di Maggio, Kermani, and Ramcharan (2014) investigate how indebted households' consumption and saving decisions are affected by anticipated changes in monthly interest payments. Keys, Piskorski, Seru, and Yao (2014) claim that borrowers with lower housing wealth are more sensitive to mortgage payment reduction relative to wealthier households and, as a result, respond more to new financing of durable consumption. Agarwal, Chomsisengphet, Mahoney, and Stroebel (2015) find that consumers' short-term marginal propensity to borrow is declining in creditworthiness, and they claim that banks' marginal propensity to lend is lowest for consumers with the highest-margin propensity to borrow. This paper is the first to study the role of monetary policy in redistributing housing wealth through the household cost of capital channel. The results of this paper are consistent with those of Doepke and Schneider (2006), Auclert (2015), and Di Maggio, Kermani, and Ramcharan (2014), since here middle-income homeowners are the major winners of expansionary monetary policies.

Second, this paper establishes a causal effect of interest rates on home prices and housing demand, a link to which macroeconomists and policy-makers have given considerable attention (Christiano, Eichenbaum, and Evans (1996); Glaeser, Gottlieb, and Gyourko (2010); Del Negro and Otrok (2007)). After the housing boom and subsequent financial crisis of the 2000s, interest in how monetary policy affects home prices has heightened. Iacoviello and Neri (2010) develop and estimate a DSGE model to show that monetary factors explain less than 20% of the volatility of housing investment and housing prices but played a more significant role in the housing cycle at the turn of the century. Jiménez, Ongena, Peydró, and Saurina (2014) show that a lower overnight interest rate induces low-capitalized banks to grant more loan applications to ex-ante risky firms and to commit larger loan volumes with fewer collateral requirements to these firms despite the higher ex-post likelihood of default. DeFusco and Paciorek (2014) estimate the interest rate elasticity of mortgage demand, and find that a 1% point increase in the rate on a 30-year fixed-rate mortgage reduces first mortgage demand by between 2% and 3%. This paper complements the existing literature by providing additional evidence that changes in interest rates affect housing demand and home prices, but it is the first to do so using a micro geographical cross-sectional and a quasi-experimental setting that allows for a focus on a single monetary policy intervention.

Finally, this paper contributes to the literature that studies the causes of the early 2000s housing boom. The seminal works of Mian and Sufi (2009) and Keys, Mukherjee, Seru, and Vig (2010) show that in the beginning of the 2000s, the U.S. economy experienced an outward shift in the supply of credit. Mian and Sufi (2009) document that less-creditworthy borrowers experienced easier access to mortgage credit between 2002 and 2005 despite their negative income growth. Keys, Mukherjee, Seru, and Vig (2010) suggest that existing securitization practices adversely affected the screening

incentives of subprime lenders. Adelino, Schoar, and Severino (2012) use exogenous changes in the conforming loan limit as an instrument for lower cost of financing and higher supply to show that easier access to credit significantly increases home prices. Agarwal and Ben-David (2014) show that changing loan officers' compensation structure from fixed to volume-based pay leads to more and larger loan originations despite resulting increases in default rates. Nadauld and Sherlund (2013) show that investment banks' increased securitization activity lowered lenders' incentives to carefully screen borrowers. This paper shows that the low-interest rate environment explains part of the home price growth in middle-priced neighborhoods between July 2000 and December 2001, the very beginning of the housing boom.

2. EMPIRICAL DESIGN

2.1. Mechanism

2.1.1. Average Effects

Standard neoclassical models of investment assume that the *cost of capital* is a key determinant of the demand for capital. When interest rates decline, the user cost of capital declines, and the demand for capital assets increases. In the housing market, the change in mortgage rates might shift the demand schedule, since buyers who are more sensitive to changes in the cost of capital may be able to afford mortgage payments after a decline in mortgage interest rates. This shift in the demand schedule might affect home prices if the supply of housing is not perfectly elastic. Consequently, existing homeowners might experience increases in housing wealth that are indirectly subsidized by buyers who can afford better homes due to the decline in their user cost of capital.

The mechanism through which changes in interest rates affect house prices growth entails three types of economic agents. The first two are existing homeowners and renters who might be sensitive to changes in interest rates. These two agents may demand more housing after declines in interest rates. An existing homeowner who does not become a home buyer even after a decline in interest rates is the third type of agent. She might experience gains in housing wealth if interest rate-sensitive buyers increase housing demand in the neighborhood where she lives.

The economic mechanism that underlines this hypothesis is best described if one assumes that households maximize their preferences and choose to allocate c_H of their disposable income to housing consumption. Given their cost of capital, they can then maximize the home value that they can purchase. Assume that r represents the mortgage interest rate, D represents the down payment, T represents the maturity of the mortgage loan, and $HV(r)$ represents the home value.

$HV(r)$ is then equal to:

$$HV(r) = \frac{\overline{c_H}}{r} \times \left(1 - \frac{1}{(1+r)^T}\right) + D.$$

If mortgage interest rates were to fall from r_{before} to r_{after}, households could purchase more expensive homes up to a value equal to $HV(r_{after})$. Homeowners with home values between $HV(r_{before})$ and $HV(r_{after})$ could then experience gains in housing wealth if the supply of these houses is relatively inelastic.

2.1.2. Distributional Effects

The mechanism described above justifies a channel through which changes in interest rates might lead to average effects on house price growth. However, it is nontrivial to consider why a decline in interest rates should have heterogenous effects on house price growth. There are two frictions that can create distributional effects.

Low-income households are likely to be credit-constrained (Hall and Mishkin (1982); Zeldes (1989); Jappelli (1990); Johnson, Parker, and Souleles (2006)) and thus less likely to be sensitive to changes in interest rates. Since low-income households are likely to shift housing demand in low-income neighborhoods, it is likely that a decline in interest rates might not cause house prices to change in these neighborhoods.

High-income households are likely to be homeowners and have low marginal utility of housing consumption. In the U.S., homeowners face high moving costs due to Realtors' fees of 5%- 6%. It is thus likely that, for high-income households, transaction costs outweigh the benefits of adjusting housing consumption as interest rates fall, diminishing the potential effects of interest rates on house prices in high-priced neighborhoods. High-income households are, however, more likely to refinance their mortgages as interest rates fall (Bhutta and Keys (2014)), allowing them to benefit from declines in interest rates, albeit not through the housing demand channel.

2.2. Empirical Design

Interest rates incorporate a significant amount of future expectations about the economy, mostly because the Federal Reserve invests a substantial amount of resources in forecasting the likely behavior of output and prices. Subsequently, movements in mortgage interest rates are likely to be a

response to future outcomes of the economy.[12]

Furthermore, most interest rate shocks affect the whole economy, making it difficult to find contemporaneous counterfactuals. As a result, it is challenging to identify the effect of changes in interest rates on house prices. When studying distributional effects on housing wealth, the characteristics of the homeowners and the neighborhoods might change over time, presenting an additional challenge. Thus, the ideal experiment to study distributional effects of interest rate changes on housing wealth exploits the effect of one interest rate shock on a rich cross section of small geographic units in which the units of observation are subject to different intensities of interest rate shock due to relatively random reasons.[13] This is the spirit of the identification strategy of this paper.

The unit of observation in this paper is a *neighborhood*, defined as one third of a zip code in size. The empirical design uses a macro interest rate shock to identify *latent demand* for each neighborhood based on an incidental distribution of the metropolitan population around a pre-determined *neighborhood affordability threshold*. The affordability thresholds represent a key concept of the empirical design. A neighborhood affordability threshold is defined as the income level below which households cannot afford to make mortgage payments on the average house in the neighborhood at the current interest rate and house price level. The affordability assumption is that the annual mortgage payments must be lower than 40% of the annual household income. This affordability assumption follows a rule of thumb in the lending industry and the revealed preference that is observed in the data. Section 2.3.1 presents detailed reasoning on the validity of this assumption.

When interest rates decline, the neighborhood affordability threshold shifts to the left, and households immediately to the left of the affordability threshold are able to afford to make mortgage payments in that neighborhood. The fraction of households in the metropolitan area that can afford to make mortgage payments only after the decline in interest rates is the measure of *latent demand* for each neighborhood. The fraction of the metropolitan households whose income

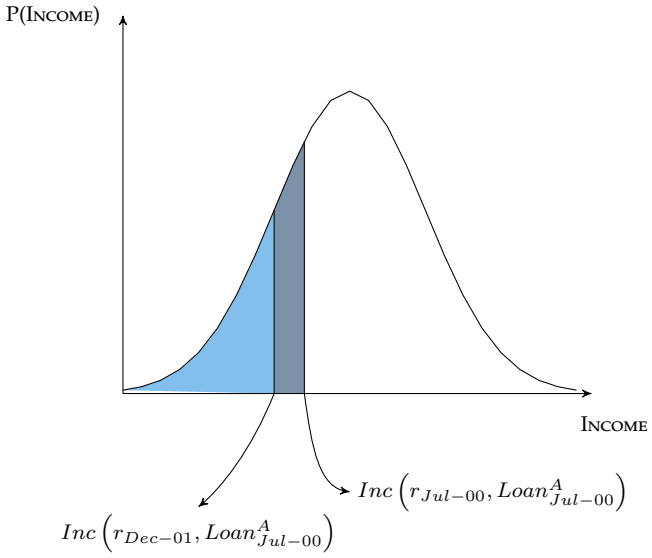
[12] Romer and Romer (2004) address the time-varying endogeneity problem by developing a time series measure of U.S. monetary policy shocks from 1969 to 1996 that is relatively free of anticipatory movements. Their methodology could have been used in this paper; however, it is not feasible because in order to measure changes in house prices, the units of observation must be small geographical areas. These areas may have substantially changed between 1969 and 1996. These changes would not be problematic if suitable data at the micro level existed during these years. However, that is not the case: for instance, house price data is only available at a granular level starting in the mid-1990s. Therefore, the ideal experiment to study distributional effects exploits one policy intervention, possibly unanticipated, across a rich cross section of micro geographical units.

[13] Other fields, particularly labor economics, have successfully found ways of exploiting geographical variation to causally identify the impact of macroeconomic shocks on labor outcomes. Most notably, Card (1992) studies the effect of changes in the federal minimum wage on the labor supply of teenagers, and Bartik (1991) proposes an instrument for local labor demand based on national labor demand. The empirical design proposed in this paper is close to that of Card (1992) and Bartik (1991) in spirit, but the methodology used to create the cross-sectional variation is novel and varies greatly from theirs.

lies below the neighborhood affordability threshold prior to the interest rate change is referred throughout the paper as *mortgaged-out*.

FIGURE 2: REPRESENTATION OF LATENT DEMAND AND THE INCOME DISTRIBUTION

This figure sketches the main intuition of how latent demand is computed. Consider that P is the probability distribution of income at the metropolitan level; r_i is the interest rate level in period i; and $Loan_i^A$ is the average loan that a household requires to purchase an average home in a neighborhood A inside the metropolitan area. The dark blue area is the measure of latent demand after interest rates fall from r_{Jul-00} to r_{Dec-01}.



One could derive the intuition of the empirical design from a theoretical income distribution. Figure 2 depicts this hypothetical income distribution. Consider that P represents the probability distribution of income for a metropolitan area in 1999, r_{Jul-00} represents the interest rate level in July 2000, and r_{Dec-01} represents the interest rate level in December 2001. $Loan^A_{Jul-00}$ represents the average loan that a household needs to purchase a house in neighborhood A in July 2000.[14] $Inc\left(r_{Dec-01}, Loan^A_{Jul-00}\right)$ represents the income threshold below which a household cannot afford to make the mortgage payments of an average house in neighborhood A at the interest rate and price level of July 2000. If interest rates decline to r_{Dec-01}, the affordability threshold, $Inc\left(r_{Dec-01}, Loan^A_{Jul-00}\right)$, moves to the left. The dark blue area in Figure 2 represents the measure

[14]The loan to purchase a house in neighborhood A is a function of the house price level in neighborhood A and the down payment amount. For the sake of this example, assume that the down payment is constant across neighborhoods.

of latent demand that is sensitive to the interest rate change. Formally, latent demand is defined as:

$$P\left(Inc\left(r_{Jul-01}, Loan^{A}_{Jul-00}\right) < Income < Inc\left(r_{Dec-01}, Loan^{A}_{Jul-00}\right)\right).$$

The light blue area combined with the dark blue area represent the fraction of households mortgaged-out in July 2000. The empirical design compares two neighborhoods with the same level of mortgaged-out households, same house price level, but different latent demand.[15]

The identification assumption is that the relative differences in the fraction of the population right around the affordability threshold are exogenous to house price growth. That is, the exclusion restriction is guaranteed if the slope of the metropolitan income distribution around the neighborhood affordability threshold is exogenous to house price growth. Take the example of an important alternative explanation: the shock in the lending standards due to securitization. If the increase in securitization is a credible alternative, securitization must be more intense when the slope of the county income distribution is higher around the neighborhood affordability threshold. This sounds implausible.[16]

The empirical design uses real income distributions, thus it is best described through an example. Consider the metropolitan areas of Cleveland, OH, and Cincinnati, OH. Figure 3 presents the income distributions for these two metropolitan areas. Except for minor differences, the two distributions are remarkably similar. The empirical design of this study exploits these minor differences to causally estimate the effect of changes in interest rates on house prices. Consider Neighborhood A in Cleveland and Neighborhood B in Cincinnati, which have the same house price level and the same fraction of mortgaged-out households in July 2000 (light blue area); that is, the light blue areas are equal, as are the affordability thresholds. However, the fraction of the population in Cleveland that is immediately to the left of the affordability threshold in Neighborhood A is larger than the counterpart fraction of the population in Cincinnati; that is, latent demand for Neighborhood A is larger than latent demand for Neighborhood B. When interest rates fall by a sufficiently small amount, Neighborhood A in Cleveland will experience a larger demand shock than Neighborhood B in Cincinnati, despite the similarities between the two neighborhoods. If the housing supply is not perfectly elastic, Neighborhood A in Cleveland will experience a larger increase in house prices.

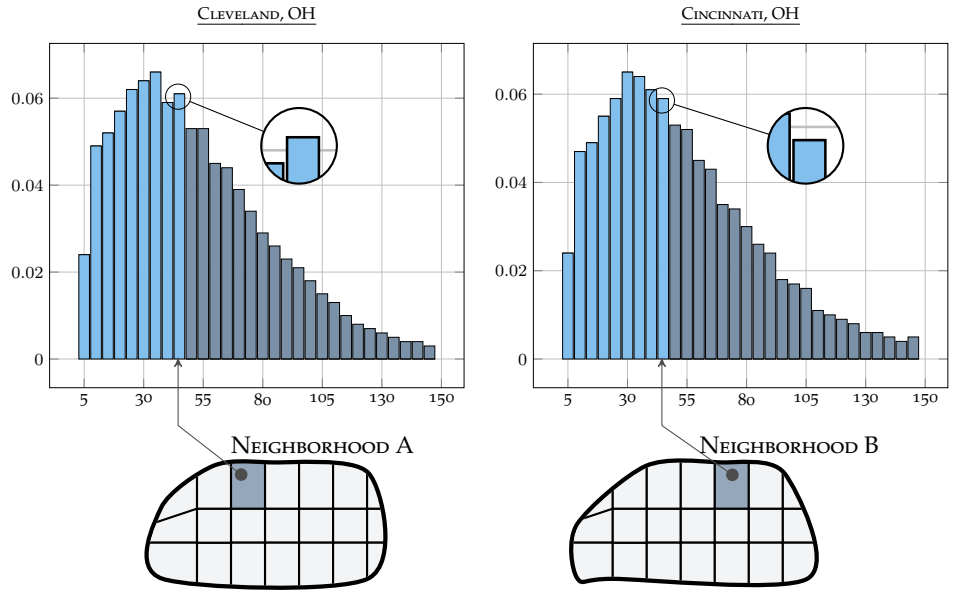
From this example, one might think that latent demand is always larger for neighborhoods

[15] The regression models also include a long list of controls at the neighborhood-, zip code-, and metropolitan-level.

[16] To further emphasize that this alternative is unlikely, I show that neighborhoods that experienced large demand shocks due to changes in interest rates, as measured by latent demand, exhibit no difference between the growth of loans that were that were originated and sold to third parties, in particular sold to be securitized. In contrast, neighborhoods with large latent demand are associated with an increase in mortgages that are kept on the lender's balance sheet.

Figure 3: Cleveland, OH, Versus Cincinnati, OH—Example 1

The figure below presents the distribution of income for all households of Cleveland, OH, and Cincinnati, OH metropolitan areas. The income information is from the 2000 decennial census and downloaded from IPUMS.org. Data was obtained at the household level and aggregated into bins of $5,000. The y-axis reports the fraction (in decimals) of households that fall in each income bin, while the x-axis reports the total household income in thousands of dollars.



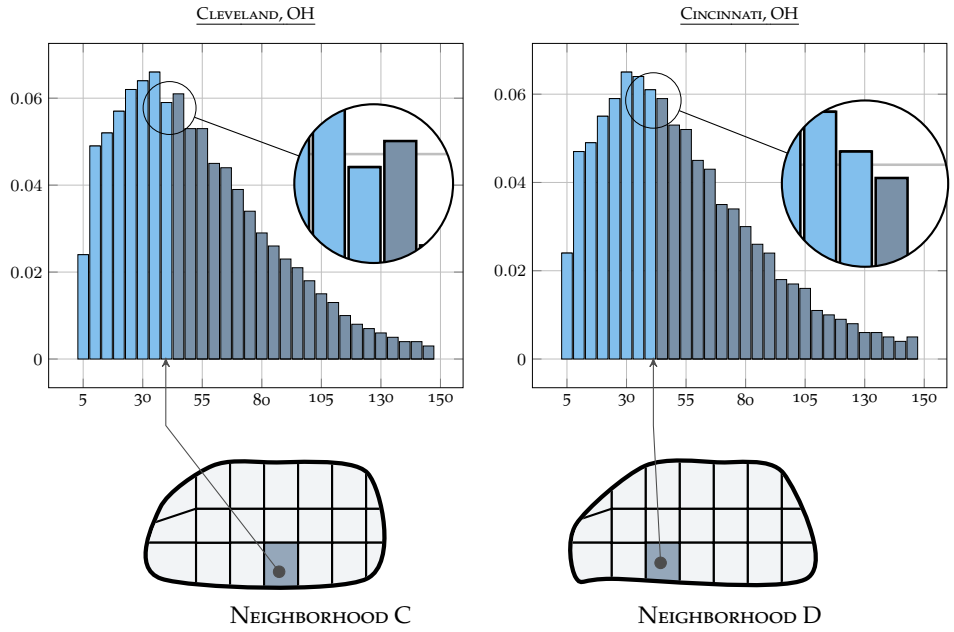
in Cleveland than for neighborhoods in Cincinnati. This could pose a critical threat to the exclusion restriction, as systematic differences between metropolitan areas confound the identification strategy. However, Figure 4 shows that this is not possible.

Figure 4 introduces Neighborhood C in Cleveland and Neighborhood D in Cincinnati. They differ from Neighborhoods A and B because the affordability threshold is one income bin to the left. The house price level and the fraction of mortgaged-out households in July 2000 are identical for C and D, but, in this case, latent demand is larger for Neighborhood D in Cincinnati than in Neighborhood C in Cleveland. This is because the fraction of the population immediately to the left of the affordability threshold is larger in Neighborhood D. This second example demonstrates that it is very unlikely that the identification of this paper is driven by systemic differences between metropolitan areas.

This paper studies the effects of the expansionary intervention between July 2000 and December 2001. I use this intervention because the methodology described above requires a detailed income distribution at the metropolitan level. The decennial census of 2000, which provides a comprehensive metropolitan-level income distribution from 1999, makes the study of this policy intervention

FIGURE 4: CLEVELAND, OH, VERSUS CINCINNATI, OH—EXAMPLE 2

The figure below presents the distribution of income for all households of Cleveland, OH, and Cincinnati, OH metropolitan areas. The income information is from the 2000 decennial census and downloaded from IPUMS.org. Data was obtained at the household level and aggregated into bins of $5,000. The y-axis reports the fraction (in decimals) of households that fall in each income bin, while the x-axis reports the total household income in thousands of dollars.



feasible.[17] Moreover, this intervention is suitable for my analysis because of its association with the dot-com bubble, the geopolitical uncertainty brought about by the 9/11 terrorist attacks, and the mild recession in the second half of 2001; even more importantly, this intervention was not associated with outcomes in the housing market.

One possible immediate concern with this identification strategy is that between July 2000 and December 2001 the income distributions across metropolitan areas shifted due to changing economic conditions; that is, systemic shifts in the distribution of income may create a confounding mechanism. For example, if income grows equally in all metro areas, neighborhoods for which the county income slope is steeper on the affordability threshold might experience a higher latent demand because of income reasons, not changes in interest rates. However, since my analysis exploits a decline in interest rates, income shocks are only considered confounding if the shock is large and

[17] I assume that the change in mortgage rates from July 2000 to December 2001 was due to the increase in money supply (Romer and Romer (2000); Bernanke and Blinder (1992); Kashyap and Stein (2000); Rudebusch (1995); Cook and Hahn (1989); Ang, Boivin, Dong, and Loo-Kung (2011)). Figure 5 suggests that the relationship between the Fed funds rate and the two most important mortgage rates is very strong, especially around the 2000 monetary policy intervention.

positive.[18] Between 2000 and 2001, the average metropolitan income growth was -3.0%, while the median metropolitan income growth was -2.5%.[19] These income changes are not only negative but also too small in magnitude to be considered confounding. Section 4 shows that an interest rate shock generates a change in the income affordability threshold of approximately 11%. To further alleviate any identification concern associated with shifts in the income distribution, I control for a battery of metropolitan-level characteristics, including the metropolitan income growth.[20]

2.3. Monetary Policy Intervention in the 2000s

In the late 1990s, the stock markets in industrialized countries experienced rapid growth in equity valuations, particularly in the Internet sector and related fields. This rapid growth in equity prices is commonly referred to as the *dot-com bubble*. The climax of the dot-com bubble occurred on March 10, 2000, with the NASDAQ peaking at 5,132.52 in intraday trading; the burst of the stock market bubble transpired in the form of the NASDAQ crash in March 2000. Growth in gross domestic product slowed considerably in the third quarter of 2000 to the lowest rate since a contraction in the first quarter of 1991. Nonetheless, the 2001 recession was the mildest in post-war history; i.e., one of the shortest recessions with the smallest real GDP declines.[21] According to the National Bureau of Economic Research (NBER), the U.S. economy was in recession from March 2001 to November 2001. Unemployment rose from 4.2% in February 2001 to 5.5% in November 2001 but did not peak until June 2003 at 6.3%, after which it declined to 5% by mid-2005. The economic situation in the early 2000s was further clouded by the geopolitical uncertainty associated with the terrorist attacks of September 11, 2001. As a result, the target federal funds rate was quickly lowered from 6.5% in late 2000 to 1.75% in December 2001.[22]

[18] The average income affordability threshold was $34,757 before the monetary policy intervention in July 2000, and $29,409 after the monetary intervention in December 2001. This is a drop of 15.5% in the required income to afford to make mortgages payments in an average U.S. neighborhood. Below, I present more details.

[19] The negative income growth is due to the 2001 economic recession.

[20] Also note that all regression specifications include state fixed effects; therefore, I only compare neighborhoods between counties in the same state.

[21] "The U.S. economy suffered a moderate recession between March and November 2001, largely traceable to the ending of the dot-com boom and the resulting sharp decline in stock prices" (Bernanke (2010)).

[22] "The aggressive monetary policy response in 2002 and 2003 was motivated by two principal factors. First, although the recession technically ended in late 2001, the recovery remained quite weak and "jobless" into the latter part of 2003. Real gross domestic product (GDP), which normally grows above trend in the early stages of an economic expansion, rose at an average pace just above 2% in 2002 and the first half of 2003, a rate insufficient to halt continued increases in the unemployment rate, which peaked above 6% in the first half of 2003. Second, the FOMC's policy response also reflected concerns about a possible unwelcome decline in inflation. Taking note of the painful experience of Japan, policymakers worried that the United States might sink into deflation and that, as one consequence, the FOMC's target interest rate might hit its zero lower bound, limiting the scope for further monetary accommodation" (Bernanke (2010)).

FIGURE 5: MORTGAGE RATES AND FED FUNDS RATE FROM 1997 TO 2013

This chart depicts the Fed funds rate (light blue), the 1-year adjustable mortgage rate (dark blue), and the 30-year fixed mortgage rate (brown). The mortgage rates are from the Freddie Mac website. The gray areas highlight the monetary policy intervention in the beginning of the 2000s. The intervention started in the summer of 2000 and lasted until the end of 2001—during which time the Fed funds rate decreased from 6.5% to 1.75%.

Figure 5 reports the time series of the 1-year adjustable mortgage, 30-year fixed mortgage, and the Fed funds rates. Between the summer of 2000 and the end of 2001, the 30-year fixed rate fell by approximately 1.2%, and the 1-year adjustable rate fell by a little over 2%. It is important to note that this monetary policy intervention was not driven by economic events in the housing market. It is then plausible that a large fraction of this decline in the mortgage interest rates was driven by the Fed funds rate. To estimate the empirical results below, I will use the 1.2% change in 30-year mortgage rate under the assumption that this change was mostly driven by the rapid decline in the Fed funds rate.

2.3.1. AFFORDABILITY

An important assumption of the empirical design is the affordability assumption. It is common practice in the lending industry to require borrowers to keep their mortgage payments below 30% of their annual salary. This affordability assumption is often self-imposed by borrowers, since it becomes significantly harder for a household to manage a monthly budget when housing costs are substantially larger than disposable income. Lenders often recommend a 30% limit on mortgage payments because homeowners have more housing expenses, namely maintenance costs, property taxes, and insurance. These non-mortgage housing-related costs may account for 10% of disposable

income. Under this lenders' rule of thumb, total housing costs (mortgage plus non-mortgage) should remain under 40% of the household income. In practice, it is possible to verify if this rule of thumb is followed by households and lenders in equilibrium, since several surveys, including the American Community Survey (ACS), collect information on household income and mortgage payments. Figure 6 depicts the box plot of the distribution of the ratio of mortgage payments to household income from the ACS for all households who moved in the year of 2000 and 2001 and purchased a home with a mortgage. There are 16,269, 15,476, and 36,112 households in the 2000, 2001, and 2005 samples, respectively.

FIGURE 6: DISTRIBUTION OF MORTGAGE PAYMENTS TO HOUSEHOLD INCOME RATIO

The figure below depicts the box plot of the ratio of mortgage payments to total household income. The data is from the 2001, 2002, and 2006 American Community Survey, and it was downloaded from IPUMS.org. The box plots only include households who moved in the year prior to the survey (as depicted in the y-axis) and purchased their home with a mortgage.

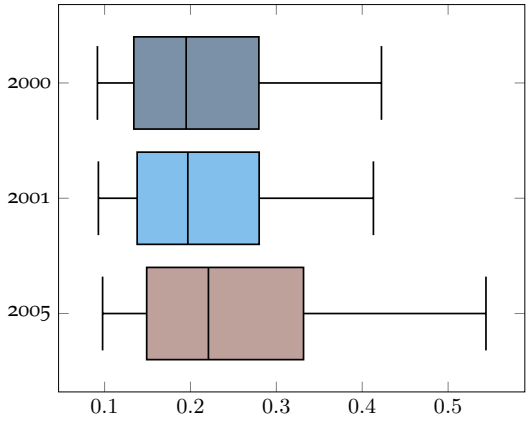


Figure 6 shows two relevant facts. First, the distributions of the ratio of mortgage payments to household income are remarkably similar for households who purchased a home in 2000 and 2001. Second, the majority of households who purchased a home in 2000 and 2001 have mortgage payments lower than 40% of their household income—in both years, the 75^{th} and the 90^{th} percentile of the distribution of the ratio of mortgage payments to household income is 28% and 41%, respectively. The fact that the distributions are almost equal in 2000 and 2001 is critical to verify that neither U.S. households nor lenders changed their behavior with respect to the level of mortgage payments relative to the level of household income from 2000 to 2001. Since several innovations in lending standards occurred during the 2000s housing boom, this indicates that lending innovations did not affect the affordability threshold in 2000 and 2001. In contrast, households who moved in 2005 and purchased a home with a mortgage were significantly more likely to have

higher mortgage payments relative to their income. This is consistent with most of the literature on the expansion of the credit supply, which documents that most innovations in lending standards occurred between 2002 and 2006 (Mian and Sufi (2009) and Nadauld and Sherlund (2013)). Consistent with the lender's rule of thumb and the evidence observed in the data, I will assume that the affordability threshold is that mortgage payments should not exceed 40% of the household's total income.

The position of the neighborhood affordability thresholds depends on the specific mortgage characteristics chosen by homebuyers. In this paper, I do not observe these choices. Instead, I rely on the most common choices made between 2000 and 2001. The three major choices in a mortgage contract are the maturity of the mortgage, the level of down payment, and the type of mortgage contract (adjustable- or fixed-rate). In 2001, the most common mortgage contract was a 30-year fixed-rate;[23] and the down payment ranged from 5% to 20%, with an average payment of 10%.[24] As such, the baseline model is that households contract a 30-year fixed-rate mortgage with a 10% down payment. Given these assumptions, the definition of the income affordability threshold for neighborhood i is as follows:

$$Inc_i\left(r_t, \overline{L}_{i,t}\right) = \frac{1}{40\%} \times 12 \times \underbrace{\frac{r_t \times \overline{L}_{i,t}}{1 - \left(\frac{1}{1+r_t}\right)^{30\times 12}}}_{Monthly\ Payments} \tag{1}$$

where r_t represents the mortgage interest rate in monthly terms; $\overline{L}_{i,t}$ represents the loan amount necessary to purchase the average home in neighborhood i; and t corresponds to July 2000 or December 2001. Given the assumption on the amount of down payment, $\overline{L}_{i,t}$ is a linear function of the house price level in July 2000 in neighborhood i. The definition of mortgaged-out households in July 2000 is:

$$\text{Mortgaged-out}_{\ Jul-00,i} = P_j\Big\{Income < Inc_i\left(r_{Jul-00}, \overline{L}_{i,Jul-00}\right)\Big\} \tag{2}$$

where P_j is the probability distribution of income for metropolitan area j where neighborhood i is located. The definition of latent demand in July 2000:

$$\text{Latent Demand}_{\ Jul-00,i} = P_j\Big\{Inc_i\left(r_{Dec-01}, \overline{L}_{i,Jul-00}\right) < Income < Inc_i\left(r_{Jul-00}, \overline{L}_{i,Jul-00}\right)\Big\} \tag{3}$$

[23] According to Pafenberg (2005), in 2001, 85% of the loan origination was fixed-rate mortgages, while only 15% were adjustable rate mortgages. In contrast, in 2004, only 64% of the mortgage loans were fixed-rate.

[24] Figure 1 of Duca, Muellbauer, and Murphy (2011) shows that the average down payment for mortgage loans originated in 2001 varied between 88% and 90%

Section 4.4 explains the numerical computation of mortgaged-out households and latent demand.

3. REGRESSION SPECIFICATION

3.1. Average Effects

Using the empirical design from the previous section, I first estimate the contemporaneous effect of a monetary policy intervention on home prices, mortgage applications, and mortgage originations. I use a cross-sectional Ordinary Least Squares (OLS) model to regress changes in housing outcomes on the *latent demand* in July 2000, the level of *mortgaged-out households* in July 2000, and other control variables, which include the level of house prices in the neighborhood in July 2000 and the income level in 1998.[25] Below, I discuss all control variables used in the model. All regression models include state-fixed effects, unless noted otherwise. All standard errors are clustered at the metropolitan level and robust. Equation (4) summarizes the baseline regression model:

$$\begin{aligned} \text{Y}_{\,2000\rightarrow 2001,i} &= \theta_0 + \theta_1 \times \text{Latent Demand}_{\,Jul/00,i} + \theta_2 \times \text{Mortgaged-out}_{\,Jul/00,i} \\ &+ \theta_3 \times \text{House Prices}_{\,Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i \end{aligned} \tag{4}$$

where $\text{Y}_{\,2000\rightarrow 2001}$ is either the home price growth from *July 2000* to *December 2001* or the growth in mortgage applications from 2000 to 2001.[26] This model specification estimates the average treatment effects of mortgage interest rates on housing outcomes during the monetary policy intervention.

3.2. Measuring the Size of the Effect

To measure the interest rate effect on house prices, one needs to consider that house prices are a function of latent demand, and that latent demand, in turn, is a function of interest rates; that is:

$$\text{House Prices} = f(\text{Latent Demand}(r)).$$

[25] The Internal Revenue Service only provided zip code–level income for 1998 and 2001. In the baseline model, I use the income level in 1998; in robustness tests, I also use the income level in 2001. The results remain unchanged.

[26] HMDA, the provider of the loan application data, aggregates the data at the annual level; as a result, I can only compute the annual growth from 2000 to 2001.

Thus, when measuring the impact of changes in interest rates on house prices, one needs to take into account that:

$$\frac{\partial \text{House Prices}}{\partial r} = \underbrace{\frac{\partial \text{House Prices}}{\partial \text{Latent Demand}}}_{\theta_1} \times \underbrace{\frac{\partial \text{Latent Demand}}{\partial r}}_{\text{Average Latent Demand}}.$$

θ_1 from model (4) is an estimator for the partial derivative of house prices with respect to latent demand, while the average of latent demand across neighborhoods is a good estimator for the partial derivative of housing demand with respect to interest rates.

3.3. Low Versus High Supply of Housing

The effect of interest rates on house prices only exists if the supply of housing does not fully adjust to the shift in housing demand. Thus, no effect should exist if the supply of housing is perfectly elastic, and we should observe a large price effect if the supply of housing is inelastic. Using the topology-based measure of housing supply elasticity developed by Saiz (2010), one can test this prediction. To this end, I estimate the model (4) in two sub-samples: high- and low-housing supply elasticity metropolitan areas. The threshold of housing supply elasticity for the two sub-samples is 1.5, the median elasticity in my sample of neighborhoods.

3.4. Distributional Effects

After establishing the average effects of interest rates on house prices, the paper turns to the distributional effects. Ultimately, the paper aims to document which neighborhoods benefit from declines in interest rates. Zillow provides monthly house price indexes for terciles of zip codes. I use each tercile as a small neighborhood. There is, however, one shortcoming in using zip code terciles as neighborhoods. Since the houses have to fall into one of the zip code terciles, they might not be adjacent. This might sound counterintuitive to the definition of a neighborhood. However, in the context of the analysis in the paper, this price uniformity among the houses might be a great advantage, since the neighborhood becomes exceptionally homogenous. The homeowners are likely to have similar characteristics since they live in similarly priced homes in the same zip code.

To study the distributional effects, I separate the neighborhoods by house price quartiles within the same metropolitan area. The empirical exercise is then equivalent to estimating the interest rate effect on house prices by comparing two neighborhoods located in different metropolitan areas but positioned in the same house price quartile. The regression specification is the same as (4), but the

model is estimated for four subsamples of house price quartiles. For the whole sample of U.S. neighborhoods, the average house price in July 2000 is $92,484 in the lowest quartile, $131,363 in the second quartile, $174,211 in the third quartile, and $272,880 in the highest quartile.

3.5. Controls

The vector X_i in regression model (4) includes several controls of levels and changes at the neighborhood, zip code, and metropolitan level. In an ideal randomized experiment the control and treatment groups are balanced on all covariates besides the treatment; as a result, the addition of control variables does not affect the estimated treatment effect. The empirical design presented in this paper tries to separate neighborhoods by latent demand that is fairly random and exogenous to growth in house prices. It is then useful to verify that the addition of several controls at the neighborhood, zip code, and metropolitan level does not impact the effect of interest rates on house prices.

Neighborhood-level controls. I observe home prices and loan outcomes at the neighborhood level. In the context of the identification presented in this paper, it is important to control for past house price growth since it is likely to drive future home price growth. Borrowers and lenders could base their beliefs about future changes in house prices on past house price growth, leading to an increase in the willingness to enter into a mortgage contract on both sides (Foote, Gerardi, and Willen (2012)). In this case, the relationship between latent demand and house price growth would have been driven by the expectations of house price growth. To test that this alternative does not drive the results, I control for past home price growth and show that the effect of the interest rate on house prices and mortgage applications remains unchanged with the addition of several controls representing past house prices, including the house price growth from December 1999 to July 2000—the seven months prior to the monetary policy intervention. Moreover, the house price growth between July 2000 and December 2001 is uncorrelated with house price growth between December 1999 and July 2000.

I also control for the level of denial rate for home purchase in 2000 at the neighborhood level. Lenders lowered credit standards in the beginning of the 2000s and extended credit to less creditworthy borrowers (Mian and Sufi (2009) and Nadauld and Sherlund (2013)). Controlling for the level of denial rates is a cheap way to rule out the alternative hypothesis based on the expansion of credit supply to subprime borrowers. Mian and Sufi (2009) show that the zip code level of denial rates prior to the 2000s housing boom is strongly correlated with the zip code fraction of subprime borrowers. Even though it is not a conclusive test, controlling for the level of denial rates sheds

light on the extent to which the credit supply hypothesis is an plausible alternative.[27]

Zip code–level controls. At the zip code level, it is possible to observe the average income from the IRS; and from the 2000 decennial census, it is possible to observe the median income, median age, fraction of renters, immigration, fraction of Blacks, and fraction of the population with a college degree. Although it is unclear through which mechanism the income level of the residents in the neighborhood could affect the fraction of the total population in the metro area that is at the margin of being able to afford a house in the neighborhood, I control for the income at the zip code level to attempt to hold income constant when comparing neighborhoods. Controlling for the fraction of renters is useful to ensure that the possible supply of houses for sale is equivalent between two neighborhoods. It is relevant to control for the immigration flow in the year prior to the interest rate change because it proxies for the demand for the zip code where the neighborhood is located. Finally, the fraction of college-educated individuals and fraction of non-Whites are important controls because these summary statistics have been shown to be determinants for zip code–level housing demand. They are also alternative proxies for the level of income and house prices.

MSA-level controls Since the identification of the interest rate effect on house prices relies on comparing neighborhoods across metropolitan areas in the same state, systemic differences between metro areas might explain the dependent and independent variables simultaneously. As stressed in section 2.2, the construction of the empirical design in itself makes it unlikely that systemic differences between metropolitan areas might confound the identification. Nonetheless, to ensure that this is unlikely, I control for several metropolitan area variables such as: median age, fraction of non-Whites, fraction of college-educated individuals, unemployment rate, and flows of immigration in the year prior to the interest rate change.

4. DATA

4.1. Data Sources

Home prices are publicly available on the Zillow Real Estate Research website.[28] Zillow provides a home price index for the bottom, middle, and top terciles of house price for a zip code as long as there is a sufficient volume of transactions. I use this division to form the unit of observation

[27] I conduct an additional series of tests to show that the credit expansion hypothesis does not explain the effect of interest rates documented in this paper. These tests are presented in the results and robustness sections

[28] http://www.zillow.com/research/data/.

in the paper: a *neighborhood*. A neighborhood is roughly one third the size of a zip code. This is not a neighborhood in the common sense. Although the houses are in the same zip code, they are grouped by price level rather than exact location; as a result, the unit of observation might be dispersed within the zip code. As explained above, this peculiar definition of *neighborhood* is an advantage in the context of the analysis of the paper, since it creates an exceptional level of homogeneity among houses and households within the same neighborhood. Each Zillow Home Value Index (ZHVI) is a time series tracking the monthly median home value. In general, each ZHVI time series begins in April 1996, but for some newer zip codes, data is only available starting at the beginning of the 2000s. Instead of using a repeat sales methodology, Zillow uses the same underlying deed data as the Case-Shiller index but creates a hedonically adjusted price index. The Zillow index uses detailed information on properties collected from county public records, including the size of the house, the number of bedrooms, and the number of bathrooms.[29] To assess the quality of the ZHVI, Guerrieri, Hartley, and Hurst (2013) show that the zip code–level correlation between the Case-Shiller Index and the Zillow Index where the two samples overlap is equal to 94%. Monthly home prices are available from 1996 to 2012 for 10,187 zip codes.

Loan-level data is provided by the Home Mortgage Disclosure Act (HMDA). Application-level data is available from all lenders that meet one or more disclosure criteria defined by the HMDA.[30] Each loan application provides information on *year* of application; *lender*; *type of loan*; *loan amount*; *action taken* by the lender; *reason for denial*, if the loan is denied; *race*, *sex* and *income* of the applicant and co-applicant; *census tract*, *county FIPS*, and *state FIPS* where the loan was originated; *owner occupancy*; and *purpose*. Loans have four types of purpose: *home purchase*, *home improvement*, *refinancing*, and *multifamily dwelling*. I only use loans that are originated for home purchase and are owner-occupied as a principal dwelling.

The Internal Revenue Service (IRS) makes zip code–level income data publicly available on their website.[31] Income data is available for the years 1998 and 2001, and from 2004 to 2012. The IRS uses tax returns to create the zip code-level data. Several income items are available, including the adjusted gross income, number of returns, and wage income. Throughout the paper, income per capita represents the ratio of adjusted gross income to number of returns.

Finally, I use the 2000 Decennial Census to estimate several demographics at the zip code and metropolitan level, namely: population, median age, fraction of non-Whites, fraction of college-educated individuals, fraction of renters, unemployment rate, and flows of immigration in the year prior to the interest rate change.

[29] More information about the computation methodology of the Zillow home price index can be found here at http://www.zillow.com/research/zhvi-methodology-6032/.

[30] More details can be found at the following weblink: http://www.goo.gl/oRm0KQ.

[31] http://www.irs.gov/uac/SOI-Tax-Stats-Individual-Income-Tax-Statistics-ZIP-Code-Data-(SOI).

4.2. Construction of the Dataset

I start with the Zillow home price dataset and create three units of observation for each zip code, corresponding to the bottom, middle, and top tercile of the zip code. The paper refers to these units of observation as *neighborhoods*. For each neighborhood, as long as enough transaction data exists, Zillow provides a monthly home price index from 1996 to 2014. There are 24,146 data points in 1996, 27,310 in 2000, and 29,056 in 2010. Next, I use loan-level data from HMDA to compute the number of annual applications, originations, and denial rates for mortgage loans for home purchase. HMDA provides the census tract for each loan application. Using this identifier, I match each loan to a zip code using a crosswalk provided by the Census Bureau. I then match the loan application to a neighborhood within the zip code using the loan amount from the application. To perform this match, I must determine the home price associated with the loan application. This information is not directly provided by HMDA. If the loan is marked as conventional, I assume that the borrowers made a 20% down payment, and if the loan is marked as FHA, I assume that the borrowers made a 5% down payment. I then match each neighborhood to the income data provided by the IRS using the zip code identifier. This assumes that the IRS income data is the same across neighborhoods in the same zip code. Finally, I match each neighborhood to a metropolitan area from the 2000 decennial census.

4.3. Metropolitan Income Distribution: Computation

I use the individual public records from census data to compute the income distribution for homeowners and renters at the metropolitan level. To compute the income distribution at the metropolitan level, I use the household-level Public Use Micro Data from the 2000 census found on the IPUMS-USA website. I download all data entries for heads of household and drop all households that do not live in a metropolitan area, as well as all households in which the head is older than 75.[32] I then form income bins of $5,000 and assign households to each bin. The process is repeated separately for renters and homeowners. To compute the frequency in each income bin, I aggregate all households in each bin using the census household weight from the decennial census. The fractions of renters and homeowners are based on the total number of households in the metropolitan area.

[32] It should not be a concern that I drop households outside of metropolitan areas. House price data from Zillow is only available for zip codes in metropolitan areas. Thus, there is no selection bias by dropping non-metropolitan households at this point.

4.4. Latent Demand and Mortgaged-Out: Numerical Details

The computation of latent demand and mortgaged-out households require several steps reported in section 2.2 and 2.3.1. To compute these two variables, I start by computing the *neighborhood affordability thresholds*. In the baseline specification, a household obtains a 30-year fixed rate mortgage, providing a 10% down payment; therefore, to purchase a house in a given neighborhood, it needs to obtain a loan equal to 90% of the average price level in that neighborhood. The 30-year fixed rate was 8.3% in July 2000 and 7.1% in December 2001. I use these mortgage rates to compute the income affordability threshold in July 2000 and December 2001, respectively. Using the definitions presented in section 2.3.1, the average income affordability threshold across all neighborhoods was $34,034 in July 2000, before the monetary policy intervention, and $30,211 in December 2001, after the monetary intervention. This is a drop of 11% in the required income to afford to make mortgage payments in an average U.S. neighborhood. Using the income threshold for each neighborhood in July 2000, I compute for each neighborhood the fraction of the metropolitan households whose income is below this income level; this fraction is the measure of households *mortgaged-out* in July 2000. Then, using the two income thresholds for each neighborhood, I compute the measure of *latent demand* for each neighborhood; this is the fraction of the metropolitan households whose total income falls between the two income thresholds.

4.5. Summary of Statistics

Tables 1.1 to 1.3 report the summary statistics for neighborhood, zip code, and metropolitan level variables, respectively. Given the interest rate level in July 2000, the average ratio of renters who cannot afford to make mortgage payments in the average neighborhood (as a fraction of the total metropolitan population) is 14%. After the mortgage interest rate change from July 2000 to December 2001, on average, this percentage decreases to 12.5% on average. That is, after the change in interest rates, the latent demand for an average neighborhood is equal to 1.5% of total households in the metropolitan area. For an average neighborhood in a metropolitan area with 1 million households[33], the average latent demand is equal to 15,000. Thus, latent demand in absolute terms equals an average of 15,000 households who can afford mortgage payments in an average neighborhood after the decline in interest rates. This can potentially represent a large demand shock since an average neighborhood has approximately 3,500 households.

Table 1.1 also shows that home price growth was positive before, during, and after the monetary policy intervention. From 2000 to 2001, mortgage applications experience zero average growth, but the standard deviation is significantly large—approximately 33%. Since this period overlapped

[33]The median metropolitan area in the sample has approximately one million households.

with an economic recession, it is natural that mortgage applications did not grow in the aggregate. Under the hypothesis of this paper, mortgage applications would have grown less—that is, declined—during this period if interest rates had not declined. Mortgage origination grew by 7.9%, with a very large standard deviation as well—45%. The median housing supply elasticity is 1.5; this is the threshold used to divide the low- and high-housing elasticity neighborhoods.

5. RESULTS

5.1. Latent Demand and Mortgage Applications

As explained previously, homeowners and renters have different sensitivities to changes in interest rates due to disparities in transaction costs. Because of this fundamental difference between renters and homeowners, I compute latent demand for these two groups separately and estimate every regression in this section separately. Because the documented effects of interest rates on housing wealth mostly stem from renters' latent demand, this paper focuses on these results; regression results based on homeowners' latent demand are available in the online appendix.

The first set of results validates the measure of latent demand constructed in the paper by estimating the correlation between latent demand and the change in housing demand. Using HMDA data, I first compute, for each neighborhood, the growth in mortgage applications for home purchase from 2000 to 2001.[34] As opposed to house price data, mortgage data is only available annually; thus, one can only compute the annual change between 2000 and 2001, while, with house price data, one can compute the change in house prices between July 2000 and December 2001.

Table 2 reports the estimated coefficients of the regression model (4), in which the outcome variable is the growth in mortgage applications for home purchase between 2000 and 2001. Table 2 confirms that neighborhoods with higher renter latent demand experienced a larger growth in mortgage applications for home purchase. To understand the importance of latent demand in explaining growth in mortgage applications, Table 2 estimates several variations of the model (4). Column (1) presents the regression model (4) with latent demand for renters and only state fixed effects. This estimation allows us to understand the total variability of mortgage growth that is explained by renters' latent demand. The estimated coefficient on latent demand is statistically

[34]Matching each loan to a neighborhood is non-trivial. In this paper, neighborhoods are defined as zip code terciles based on house prices. One can think of a neighborhood as a set of houses within the same zip code that have similar prices. To map each mortgage application to a neighborhood, I use three pieces of information: the loan amount specified in each loan application, the type of loan (conventional or FHA), and the census tract of the house to be purchased. With this information, I estimate the house price associated with the loan application. The census tract allows me to pin down the zip code. With the loan amount and type of mortgage, I estimate the house price. With the estimated house price and the zip code, I can then associate the mortgage application to a tercile of the zip code and, therefore, to a neighborhood. The Online Appendix provides more details on the mapping of mortgage applications to neighborhoods.

different than zero at the 1% level and is economically large. The estimated coefficient is equal to -6.82, which implies, as explained in section 3.2, that a decline in interest rates of 1.2% leads to an average additional growth in mortgage applications for home purchase of 10% ($=-6.82 \times -0.015$). The regression models of column (2) to (4) add several control variables to the model reported in column (1). The model in column (2) adds the following neighborhood-level control variables: mortgaged-out renter households, the level of house prices in July 2000, and the level of denial rates in 2000. The model in column (3) adds the neighborhood-level house price growth from December 1999 to July 2000, zip code–level income controls, and the measure of housing supply elasticity from Saiz (2010). Column (4) adds a long list of controls at the zip code and metropolitan level; namely, the log of population, the flow of immigration, the medium household age, the fraction of renters, the fraction of non-Whites, the fraction of college-educated individuals, and the level of unemployment.

Remarkably, the coefficient on renters' latent demand hardly changes across specifications. The addition of neighborhood-level controls on the fraction of mortgaged-out households, house price level, and the level of denial rates on mortgages for home purchase leads to a change in the estimated coefficient on latent demand to -6.07. In other words, the addition of the most important neighborhood-level determinants of housing demand only leads to a drop in approximately 10% on the coefficient of interest. Further, the inclusion of a long list of zip code-level controls and metropolitan level controls only changes the estimated coefficient of interest to -5.94. There are two important conclusions from the first four columns of Table 2. First, the measure of latent demand constructed in this paper is associated with a demand shock. Second, a change in mortgage interest rates leads to a shift in the housing demand schedule driven by renters who experience a fall in their cost of capital.

Columns (5) and (6) of Table 2 report the regression model (4), with the growth in mortgage applications for home purchase between 2000 and 2001 as the outcome variable and homeowners' latent demand as the explanatory variable. Without any controls, the estimated coefficient on homeowners' latent demand of homeowners, but it is almost three times smaller than the coefficient on renters' latent demand; that is, the sensitivity of homeowners to interest rates is significantly smaller than that of renters. This is consistent with the large transaction costs of moving for current homeowners as compared to renters (primarily Realtors' fees). Unsurprisingly , after the addition of the full set of controls, which are reported in column (6), the coefficient on homeowners' latent demand becomes statistically insignificant.

The last column reports a regression with both measures of latent demand and the full set of controls. The estimated coefficients on latent demand are consistent with results reported in the rest of Table 2. The coefficient on renters' latent demand hardly changes, while the coefficient on

homeowners' latent demand remains statistically insignificant and its economic significance falls by one third.

5.2. Average Effects on House Prices: Renters

After validating the measure of latent demand, the paper investigates the average effect of changes in mortgage interest rates on home price growth between July 2000 and December 2001, a period during which the Fed funds rate dropped from 6.5% to 1.7% and the 30-year mortgage fixed rate dropped from 8.3% to 7.07%.[35] Latent demand is constructed separately for renters and homeowners, and the results are also presented separately.

Table 3 reports the estimated coefficients of the regression model (4) for renters' latent demand. Column (1) of Table 3 presents the estimated coefficients of model (4) without controls, but including state-fixed effects, which leads to a comparison of neighborhoods within the same U.S. state. The coefficient on renters' latent demand is -2.170 and statistically different from zero at the 1% level. This coefficient implies that, as explained in section 3.2, a decline in interest rates of 1.2% leads to an average increase in the growth of house prices of 3.2% (=-2.17×-0.015).

The rest of Table 3 reports variations of the model presented in column (1) that increasingly include a larger number of controls. The model in column (2) includes two important neighborhood-level determinants of house price growth: the house price level in July 2000 and the fraction of households which were mortgaged-out in July 2000. The model in column (3) controls for the house price growth between December 1999 and July 2000 to exclude an alternative hypothesis - the idea that future house price growth is driven by past house price growth. The estimated coefficients in column (2) and (3) imply that a change of 1.2% in interest rates leads to an increase in the growth of house prices of 3.3%-3.4%. Relative to the model without controls, there is no change in the estimated effect of renters' latent demand on house price growth. This evidence is reassuring of the orthogonality of renters' latent demand with respect to these three important neighborhood controls.

Next, the model in column (4) controls for income growth at the zip code level between 1998 and 2001, income at the zip code level in 1998, the income at the neighborhood level in 2000, the level of denial rates for home purchase in 2000s, and the housing supply elasticity from Saiz (2010). The estimated coefficient on renters' latent demand hardly changes from the model without controls. The inclusion of a measure of elasticity is central to guarantee that we strip out equilibrium housing supply adjustments from the demand shock driven by interest rate-sensitive households.

The model in column (5), in addition to the controls of the model in column (4), controls for

[35] This change in mortgage interest rates is used to construct a measure of latent demand that is plausibly exogenous to house price growth, as explained in section 2.2.

several demographic variables at the zip code level; namely, population size, median age of the population, fraction of the population with a college degree, fraction of the non-White population, fraction of the population who immigrated into the zip code in the previous year, and fraction of households who are renters. Using the coefficient on latent demand from column (4), the effect of a 1.2% decline in interest rates leads to an average increase in house prices of 3.1%. The model in column (6), in addition to the controls of the model in column (5), controls for several demographic variables at the metropolitan level; namely, median age of the population, fraction of the population who has a college degree, fraction of the non-White population, fraction of the population who immigrated into the zip code in the previous year, and the unemployment rate in 2000. Using the coefficient on latent demand from column (6), the effect of a 1.2% decline in interest rates leads to an average increase in house prices of 2.9%.

Across the board, the coefficient on renters' latent demand remains between -1.914 and -2.296, and is always statistically different than zero at the 1% level. These estimates suggest that house prices grow by 2.9%-3.2% on average when interest rates decline by 1.2%. This is a very large economic effect that shows the importance of interest rates in establishing house prices.

Given the time period used in this analysis, one might be concerned that the effect of interest rates on house prices documented in the paper might be confounded by the two leading hypotheses that have been put forward to explain the housing boom in the beginning of the 2000s. One hypothesis is that lenders relaxed their credit standards and expanded the supply of credit to less creditworthy borrowers (Mian and Sufi (2009); Di Maggio and Kermani (2015); Kleiner (2014)). The other hypothesis is that borrowers and lenders had expectations of house price growth that were higher than homes' fundamental values (Foote, Gerardi, and Willen (2012); Cheng, Raina, and Xiong (2014); Shiller (2014); and Glaeser and Nathanson (2015)). It is then important to guarantee that the effects presented here are not confounded by these two hypotheses. Table 3 shows that the house price growth between July 2000 and December 2001 is unrelated to the level of house price growth in July 2000, and the house price growth between December 1999 and July 2000. Also, after controlling for the level of denial rates for home purchase in 2000, the coefficient on renters' latent demand hardly changes. Furthermore, the correlation between the level of denial rates in 2000 and the house price growth between July 2000 and December 2001 is zero.[36] The results reported in Table 3 help alleviate potential concerns that the two leading hypotheses for the 2000s housing boom might explain the documented effect of mortgage interest rates on house price growth.

It is noteworthy to point out that the 1998 income by zip code is positively correlated with house price growth between July 2000 and December 2001. Income growth between 1998 and

[36] Previous work by Mian and Sufi (2009) has shown that the level of denial rates before the housing boom is a good proxy for the level of subprime borrowers.

2001 is also positively correlated with the house price growth during this period. The highest house price growth between July 2000 and December 2001 happened in metropolitan areas with smaller fractions of Blacks. These correlations are additional evidence that the expansion of credit supply to low income borrowers did not occur during this period, which is consistent with the results found in Mian and Sufi (2009) and Adelino, Schoar, and Severino (2015). Finally, the house price growth from July 2000 and December 2001 was larger in zip codes that have higher fractions of renters, which is consistent with the hypothesis that renters are more sensitive to interest rate changes than homeowners.

5.3. Average Effects on House Prices: Homeowners

As mentioned above, homeowners and renters might have different sensitivities to changes in interest rates. The previous section confirmed part of this hypothesis by showing that housing demand and house price growth is strongly correlated with renters' latent demand, and that housing demand is not associated with homeowners' latent demand. This section shows that homeowners' latent demand is not correlated with house price growth from July 2000 to December 2001, which is consistent with the previous results. Table 4 reports the estimated coefficients of the model (4), in which the outcome variable is the house price growth from July 2000 to December 2001 and the main explanatory variable is the measure of latent demand for homeowners. Across all specifications, which are all equal to the ones from Table 3, the coefficient on homeowners' latent demand is statistically and economically zero. The fact that homeowners face larger transaction costs than renters does not imply that the sensitivity of homeowners to changes in interest rate is zero. In this case, it must mean that the potential housing consumption benefits stemming from the change in mortgage interest rates were not sufficient to counterbalance the transaction costs that homeowners face when selling their home.

5.4. High Versus Low Supply of Housing

The home price effect reported in the previous section only exists if the supply of housing does not fully adjust to the shift in demand driven by the decline in interest rates. To test this, I estimate the effect of changes in mortgages' interest rates on home prices in two sub-samples: high- and low-housing supply elasticity metropolitan areas.[37] Table 5 reports the results of this estimation. Columns (1) and (3) report the estimation when the neighborhood is located in a metropolitan area with low elasticity of housing supply, while columns (4) and (6) report the estimation when the neighborhood is located in a metropolitan area with low elasticity of housing supply. The

[37] I use the housing supply elasticity from Saiz (2010).

median housing supply elasticity in the sample is used to separate the two sub-samples. For the working sample, the median elasticity is 1.5. Table 5 presents two reassuring facts. The effect on the sub-sample of neighborhoods located in metropolitan areas with high housing supply elasticity is weak. The coefficient is barely statistically significant at the 10% level and is economically small—less than half relative to the average effect. Cities with high elasticity of housing supply construction can adjust to the demand shock because there is space for construction. On the other hand, in neighborhoods located in low-housing supply elasticity areas, the effect of a decline in mortgage interest rates on home price growth is economically large and statistically different from zero. This is because, due to geographical constraints such as bodies of water and mountains, the supply of housing cannot fully adjust to the demand shock, and, as a result, home prices adjust upward.

5.5. Distributional Effects on Housing Wealth: Renters

After establishing the average effects, this paper analyzes the distributional effects of interest rates on house prices, aiming to shed light on which neighborhoods, and consequently which homeowners, benefit from the increase in home prices caused by the decline in interest rates. Each neighborhood in the sample is a small geographical unit—approximately three times smaller than a zip code. This is because the definition of a neighborhood follows the zip code terciles in house prices, as defined by Zillow. While there is a shortcoming with this definition of *neighborhood* because the houses are not adjacent, it is advantageous in studying distributional effects because the house prices are homogenous within the neighborhood. Neighborhoods are then organized into quartiles of house price of July 2000 within the same metropolitan area. For the whole sample of U.S. neighborhoods, the average house price in July 2000 was $92,484 in the lowest quartile, $131,363 in the second quartile, $174,211 in the third quartile, and $272,880 in the highest quartile. There is, however, a fair amount of heterogeneity across metropolitan areas. For example, in San Francisco, CA, the average house price in July 2000 was $228,509 in the lowest quartile, $351,787 in the second quartile, $446,961 in the third quartile, and $712,923 in the highest quartile; while in Cleveland, OH, the average house price in July 2000 was $71,807 in the lowest quartile, $104,786 in the second quartile, $134,726 in the third quartile, and $207,770 in the highest quartile. I estimate the effect of changes in mortgage interest rates on house price growth for each subsample of house price quartile.

Table 6 reports the effect of changes in mortgage interest rates on house prices for each quartile of house prices. The regression specification in each column includes state fixed effects, and all the neighborhood-, zip code–, and metropolitan-level controls found in Table 3. This is the most

restrictive specification. The effects on housing wealth for a decline in mortgage interest rates of 1.2% are remarkably different across quartiles. Neighborhoods in the lowest house price quartile in a given metropolitan area experience no growth in house prices after a decline in mortgage interest rates. Neighborhoods in the second and third house price quartile experience the highest increase in house prices, 8.5% and 7%, respectively. This growth translates into a monetary increase of $11,000 to $12,000. Homeowners who live in these middle-priced neighborhoods experience a significant increase in housing wealth. Neighborhoods in the highest quartile of house prices in the metropolitan area experience no gains in house price after a decline of mortgage interest rates.

Households who desire to purchase a house in the lowest priced neighborhoods in the metropolitan area are likely to be credit-constrained. Mian and Sufi (2009), Nadauld and Sherlund (2013), and Keys, Mukherjee, Seru, and Vig (2010) document that in the beginning of the 2000s, especially around 2002, the lending industry in the U.S. shifted their lending standards, implying that low-income households who previously were credit-constrained now had access to credit. This same evidence suggests that a large fraction of low-income households were credit constrained before 2002. This might be the leading explanation of why the cheapest neighborhoods in a metropolitan area do not experience house price growth after a decline in interest rates.

Homebuyers in the highest priced neighborhoods are likely to have high incomes and be current homeowners; consequently, there are two explanations for why mortgage interest rates do not affect house prices in the highest-priced neighborhoods in the metropolitan area. First, households with high incomes are less likely to time mortgage interest rates. They are likely to purchase their house based on their life-cycle preferences or tax benefits associated with mortgage deduction (Rosen, Rosen, and Holtz-Eakin (1984), Henderson and Ioannides (1983)), which are likely the highest for high-income households. These households are then likely to refinance their mortgage loans when interest rates fall significantly. Second, if potential homebuyers in the highest priced quartile are more likely to be current homeowners, then potential homebuyers will face a large transaction cost in the form of Realtors' fees.

5.6. Distributional Effects on Housing Wealth: Homeowners

As documented above, the average effects of homeowners' latent demand on house price growth are statistically and economically zero. However, the average effects might mask some cross-sectional heterogeneous effects. Table 7 confirms that there are almost no effects of latent demand of homeowners on house prices in differently priced neighborhoods. The only exception is the third quartile. Homeowners in neighborhoods in this quartile experience an economically small positive house price effect due to homeowners who are sensitive to changes in interest rates.

6. ROBUSTNESS TESTS

6.1. Is the Effect Explained by the Expansion of Credit Supply?

In the beginning of the 2000s, the U.S. economy experienced an outward shift in the supply of credit (Mian and Sufi (2009); Keys, Mukherjee, Seru, and Vig (2010); Adelino, Schoar, and Severino (2012); and Agarwal and Ben-David (2014)). One potential identification concern is that the effect documented in this paper is picking up the credit supply shock. To show that the credit supply hypothesis does not drive my results, I estimate the effect of changes in interest rates on mortgage applications kept on the lender's balance sheet as compared to the effect on mortgage applications sold off the lender's balance sheet,mainly through securitization. If the effect documented in this paper is driven by the credit supply shock in the early 2000s, the latter effect must be significantly larger than the former (i.e. the number of loans destined for securitization should grow at higher rates than the number of loans kept by the lender). Table 8 shows that the estimated effect is, in fact, larger for loans that were kept on the lender's balance sheet. This provides reassuring evidence that the securitization hypothesis is unlikely to drive the effect of interest rate changes on housing wealth.

6.2. Placebo Test from December 1999 to July 2000

An alternative way to test the validity of the paper's empirical design is to run a placebo test. That is, one can simulate that the decline in mortgage interest rates from July 2000 to December 2001 during a different time frame, namely December 1999-July 2000. To this end, one needs to reconstruct latent demand using house price level in December 1999 and assume that the 1.2% decline in interest rates occurred between December 1999 and July 2000. In this test, I continue to use the same metro-level income distribution from the 2000 census because the analysis period is mostly in the year 2000. I regress the house price growth between December 1999 and July 2000 on the reconstructed measure of latent demand. Table 9 reports the results of this estimation. The regression model is similar in controls and fixed effects to that of Table 6. The house price controls are different. The placebo regression model controls for the house price level in December 1999, and also controls for house price growth between December 1998 and December 1999. The reported results show that there are no effects in this placebo test. The estimated coefficients are insignificant both statistically and economically, except in the first quartile, in which there is a negative effect on house prices. This is reassuring evidence that omitted variables are unlikely to drive the results reported in this paper, and that the identification strategy is well designed to capture the effect of mortgage interest rates on house prices at the neighborhood level.

7. CONCLUSIONS

Economists have become increasingly interested in documenting the effect of interest rates on the distribution of income and wealth (Coibion, Gorodnichenko, Kueng, and Silvia (2012); Auclert (2015); Sterk and Tenreyro (2015); Di Maggio, Kermani, and Ramcharan (2014); Keys, Piskorski, Seru, and Yao (2014); and Agarwal, Chomsisengphet, Mahoney, and Stroebel (2015)). Understanding these effects can help unravel how interest rate policy affects the real economy, and who, ultimately, benefits from monetary policy interventions. Since the largest asset that most U.S. households hold on their balance sheet is their home, interest rates can have a significant effect on a household's wealth if changes in interest rates significantly affect house prices. This effect on housing wealth can prove particularly important for the real economy because, after increases in house prices, homeowners are more likely to borrow against home equity to fund consumption and investment (Mian and Sufi (2011), Adelino, Schoar, and Severino (2015)). This paper shows significant distributional effects of interest rates on housing wealth. Homeowners who live in middle-priced neighborhoods experience large gains in housing wealth after economy-wide changes in interest rates; homeowners who live in low- and high-priced neighborhoods experience no gains in housing wealth.

In the first part of this paper, using a novel identification strategy that estimates *latent demand* for neighborhoods in a quasi-experimental fashion, I estimate the average effect of changes in interest rates on housing demand and house prices. In the second part of the paper, I exploit the small size and homogeneity of neighborhoods to document the distributional effects of interest rates on housing wealth. It is non-trivial to isolate these effects, since mortgage interest rates are driven, among other factors, by future expectations of inflation and output. Moreover, interest rates tend to change simultaneously for the whole economy, making it difficult to find credible contemporaneous counterfactuals. To address these endogeneity issues, this paper introduces a novel empirical design that exploits the incidental differences in the distribution of the metropolitan population around pre-determined a ffordability income thresholds.

This paper shows that a 1.2% decline in mortgage interest rates leads to an average increase from 7% to 8.5% in housing wealth for the second and third income quartiles; in monetary terms, this is an average increase of $11,000-$12,000 in housing wealth. Given that households have high marginal propensities of consumption out of their housing wealth (Mian and Sufi (2011), DeFusco (2015)), these results suggest that the housing market represents a relevant transmission mechanism of interest rates to the real economy. Di Maggio, Kermani, and Ramcharan (2014) and Keys, Piskorski, Seru, and Yao (2014) have documented evidence that supports this claim by showing that households increase their consumption and reduce default rates after declines in mortgage

payments that are induced by mortgage rate adjustments in their loans. An interesting line of future research is to show that the effect of interest rates on housing wealth spills over to the real economy.

The distributional results documented here are also useful to potentially help us understand the micro foundations behind the house price contagion during the 2000s housing boom recently documented in the urban economics literature (DeFusco, Ding, and Ferreira (2015); Glaeser, Gottlieb, and Tobio (2012); Landvoigt, Piazzesi, and Schneider (2015); and Kleiner (2015)). The results presented in this paper suggest a possible connection between the increase in house prices in middle-income neighborhoods and the subsequent house price growth in low-income neighborhoods, perhaps through a gentrification mechanism. (Guerrieri, Hartley, and Hurst (2013)). Linking the documented effect of interest rates on house prices with the house price contagion literature might also be a fruitful line of future research.

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Table 1.1: Summary of Statistics: Neighborhood Level

Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. The homeowners' latent demand is computed similarly to the renters' later demand, but using the fraction of homeowners instead of renters. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Population is measured using the 2000 decennial census. It is measured at the zip code level and divided by three, since each neighborhood represents a zip code tercile. All fractions are presented in decimals.

	N	Mean	Std	10th	90th
Renters Latent Demand $_{\text{Jul/00}}$	19577	-0.015	0.0057	-0.023	-0.0073
Renters Mortgaged-out $_{\text{Jul/00}}$	19577	0.15	0.083	0.055	0.27
Homeowners Latent Demand $_{\text{Jul/00}}$	19577	-0.022	0.011	-0.038	-0.0089
Homeowners Mortgaged-out $_{\text{Jul/00}}$	19577	0.15	0.097	0.048	0.28
Mortgage Applications Growth $_{00\to01}$	19577	0.0035	0.33	-0.32	0.32
Mortgage Origination Growth $_{00\to01}$	19570	0.059	0.37	-0.29	0.40
Denial Rate $_{2000}$	19577	0.17	0.13	0.050	0.36
HP Growth $_{\text{Jul/01}\to\text{Dec/02}}$	19577	0.079	0.063	0.010	0.16
HP Growth $_{\text{Jul/00}\to\text{Dec/01}}$	19577	0.11	0.083	0.021	0.22
HP Growth $_{\text{Dec/96}\to\text{Jul/00}}$	17903	0.25	0.17	0.081	0.46
HP Growth $_{\text{Dec/98}\to\text{Jul/00}}$	19498	0.13	0.094	0.032	0.24
House Price (in 10,000) $_{\text{Jul/00}}$	19577	16.7	11.3	6.92	29.1
Population (in thds.) $_{2000}$	19577	7.09	5.15	1.49	14.1

Table 1.2: Summary of Statistics: Zip code Level

This table reports the summary of statistics of zip code-level variables used in this paper. Given the construction of the dataset (explained in section 4.2), the sample has 7,600 unique zip codes. All variables in this table, except for Income, are obtained from the 2000 decennial census. Fraction of College is the fraction of population that a college degree. Median Age is the median age of the population that lives in the zip code. Immigration Outside County is the fraction of immigration into the zip code from outside the county in the last 5 years. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. All fractions are presented in decimals.

	N	Mean	Std	10th	90th
ZIP Median Age $_{2000}$	19577	36.7	4.97	31	41.5
ZIP Fraction of Black $_{2000}$	19577	0.098	0.17	0.0036	0.28
ZIP Fraction of College $_{2000}$	19577	0.55	0.16	0.34	0.77
ZIP Immigration Outside County $_{2000}$	19577	0.18	0.090	0.077	0.30
ZIP Fraction of Renters $_{2000}$	19577	0.30	0.17	0.12	0.53
ZIP IRS Income Growth $_{98\rightarrow01}$	19577	0.10	0.37	0.019	0.18
IRS Income (in thousands) $_{1998}$	19577	47.4	27.4	27.8	70.7

Table 1.3: Summary of Statistics: MSA Level

This table reports the summary of statistics of metropolitan-level variables used in this paper. Given the construction of the dataset (explained in section 4.2), the sample has 268 unique metropolitan areas. Except for the Elasticity Saiz, all variables in this table are obtained from the 2000 decennial census. Median Age is the median age of the population that lives in the metropolitan area. Immigration is the fraction of immigration into the metropolitan from outside the metropolitan in the last 5 years. Fraction of College is the fraction of population that a college degree. Elasticity Saiz is the measure of housing supply elasticity from Saiz (2010). All fractions are presented in decimals.

	N	Mean	Std	10th	90th
Elasticity Saiz $_{2000}$	19577	1.63	0.87	0.76	2.79
MSA Population $_{2000}$	19577	5241935.9	6388785.2	341851	16373645
MSA Median Age $_{2000}$	19577	35.0	4.29	32.3	38.2
MSA Fraction of Black $_{2000}$	19577	0.13	0.087	0.037	0.26
MSA Fraction of College $_{2000}$	19577	0.54	0.067	0.46	0.65
MSA Unemployment Rate $_{2000}$	19577	0.056	0.014	0.042	0.069
MSA Immigration $_{2000}$	19577	0.18	0.055	0.11	0.26

Table 2: Latent Demand and Mortgage Applications

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned}\text{Mortgage Applications}_{2000\to2001,i} &= \theta_0 + \theta_1 \times \text{Renters Latent Demand}_{Jul/00,i} \\ &+ \theta_2 \times \text{Renters Mortgaged-out}_{Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i\end{aligned}$$

Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. The homeowners' latent demand is computed similarly to the renters' later demand, but using the fraction of homeowners instead of renters. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Elasticity Saiz is the measure of housing supply elasticity from Saiz (2010). Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, fraction of renters, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, fraction of college educated, fraction of Black, and size of the population. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	Growth in Mortgage Applications: 2000 to 2001						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Renters Latent Demand $_{Jul/00}$	-6.820***	-6.065***	-6.143***	-5.937***			-5.369***
	(-4.66)	(-2.97)	(-3.17)	(-3.22)			(-3.79)
Renters Mortgaged-out $_{Jul/00}$		-0.313*	-0.356**	-0.362***			-0.435***
		(-1.78)	(-2.22)	(-3.12)			(-2.97)
Homeowners Latent Demand $_{Jul/00}$					-2.679***	-3.172	-1.302
					(-3.48)	(-1.58)	(-0.62)
Homeowners Mortgaged-out $_{Jul/00}$						-0.384	-0.081
						(-1.41)	(-0.28)
House Price (in 10,000) $_{Jul/00}$		-0.001*	0.000	0.000		-0.001	0.001
		(-1.76)	(0.55)	(0.54)		(-0.55)	(0.61)
Denial Rate $_{2000}$		-0.611***	-0.662***	-0.686***		-0.714***	-0.674***
		(-14.14)	(-14.41)	(-14.89)		(-14.16)	(-13.18)
HP Growth $_{Dec/99 \to Jul/00}$			-0.243*	-0.132		-0.103	-0.136
			(-1.97)	(-1.40)		(-1.05)	(-1.43)
ZIP IRS Income Growth $_{98\to01}$			0.022	0.023		0.024	0.023
			(1.04)	(1.08)		(1.15)	(1.09)
Income $_{1998}$			-0.059***	-0.031		-0.023	-0.029
			(-3.96)	(-1.42)		(-0.93)	(-1.21)
Elasticity Saiz $_{2000}$			0.001	-0.007		-0.006	-0.006
			(0.26)	(-1.11)		(-0.93)	(-0.90)
State Fixed Effects	No	Yes	Yes	Yes	Yes	Yes	Yes
Zip Controls	No	No	No	Yes	No	Yes	Yes
MSA Controls	No	No	No	Yes	No	Yes	Yes
#Neighborhoods	19577	19577	19577	19577	19577	19577	19577
R-squared	0.014	0.076	0.081	0.088	0.008	0.086	0.088

Table 3: Effect of Interest Rates on Home Prices: Renters Demand

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned} \text{House Price}_{\,Jul/00 \to Dec/01,i} &= \theta_0 + \theta_1 \times \text{Renters Latent Demand}_{\,Jul/00,i} \\ &+ \theta_2 \times \text{Renters Mortgaged-out}_{\,Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i \end{aligned}$$

Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Elasticity Saiz is the measure of housing supply elasticity from Saiz (2010). Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, and fraction of college educated. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	House Price Growth from Jul-2001 to Dec-2001					
	(1)	(2)	(3)	(4)	(5)	(6)
Renters Latent Demand $_{Jul/00}$	-2.170***	-2.296***	-2.225***	-2.027***	-2.103***	-1.914***
	(-3.34)	(-4.31)	(-4.02)	(-3.44)	(-4.03)	(-3.82)
Renters Mortgaged-out $_{Jul/00}$		-0.014	-0.005	-0.012	-0.017	-0.078
		(-0.15)	(-0.07)	(-0.17)	(-0.22)	(-1.09)
House Price (in 10,000) $_{Jul/00}$		-0.000	-0.000	-0.001	-0.001	-0.000
		(-0.17)	(-0.37)	(-1.22)	(-1.17)	(-0.50)
HP Growth $_{Dec/99 \to Jul/00}$			0.047	0.007	-0.031	-0.021
			(0.44)	(0.07)	(-0.30)	(-0.25)
ZIP IRS Income Growth $_{98 \to 01}$				0.003	0.005*	0.003
				(1.48)	(1.82)	(1.48)
Income $_{1998}$				0.016***	0.025***	0.018***
				(3.49)	(3.32)	(3.03)
Denial Rate $_{2000}$				0.010	0.011	0.010
				(0.60)	(0.76)	(0.82)
Elasticity Saiz $_{2000}$				-0.019***	-0.018***	-0.009
				(-4.14)	(-3.98)	(-1.57)
ZIP Fraction of Renters $_{2000}$					0.051***	0.048***
					(4.95)	(4.77)
MSA Fraction of Black $_{2000}$						-0.102*
						(-1.97)
Log MSA Population $_{2000}$						0.011***
						(2.73)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Zip Controls	No	No	No	No	Yes	Yes
MSA Controls	No	No	No	No	No	Yes
#Neighborhoods	19577	19577	19577	19577	19577	19577
R-squared	0.413	0.414	0.414	0.436	0.445	0.462

Table 4: Effect of Interest Rates on Home Prices: Homeowners Demand

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned} \text{Mortgage Applications}_{\,2000\to2001,i} &= \theta_0 + \theta_1 \times \text{Homeowners Latent Demand}_{\,Jul/00,i} \\ &+ \theta_2 \times \text{Homeowners Mortgaged-out}_{\,Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i \end{aligned}$$

Homeowners' latent demand is a neighborhood-specific variable that measures the fraction of household homeowners in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Elasticity Saiz is the measure of housing supply elasticity from Saiz (2010). Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, and fraction of college educated. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	House Price Growth from Jul-2001 to Dec-2001					
	(1)	(2)	(3)	(4)	(5)	(6)
Homeowners Latent Demand $_{Jul/00}$	-0.033	-0.585	-0.542	-0.111	-0.222	0.038
	(-0.13)	(-1.17)	(-1.05)	(-0.23)	(-0.49)	(0.09)
Homeowners Mortgaged-out $_{Jul/00}$		-0.087	-0.076	-0.015	-0.018	0.064
		(-0.82)	(-0.74)	(-0.16)	(-0.19)	(0.82)
House Price (in 10,000) $_{Jul/00}$		0.000	0.000	-0.001	-0.001	-0.001**
		(0.18)	(0.07)	(-0.91)	(-1.00)	(-2.03)
HP Growth $_{Dec/99 \to Jul/00}$			0.061	0.022	-0.014	-0.007
			(0.54)	(0.20)	(-0.13)	(-0.09)
ZIP IRS Income Growth $_{98\to01}$				0.003	0.005*	0.003
				(1.32)	(1.86)	(1.55)
Income $_{1998}$				0.014***	0.024***	0.018***
				(2.83)	(3.19)	(2.62)
Denial Rate $_{2000}$				-0.023**	-0.020*	-0.008
				(-2.21)	(-1.90)	(-0.79)
Elasticity Saiz $_{2000}$				-0.021***	-0.020***	-0.009
				(-3.96)	(-3.82)	(-1.48)
ZIP Fraction of Renters $_{2000}$					0.047***	0.046***
					(4.58)	(4.59)
MSA Fraction of Black $_{2000}$						-0.098*
						(-1.88)
Log MSA Population $_{2000}$						0.013***
						(3.24)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Zip Controls	No	No	No	No	Yes	Yes
MSA Controls	No	No	No	No	No	Yes
#Neighborhoods	19577	19577	19577	19577	19577	19577
R-squared	0.398	0.399	0.399	0.426	0.435	0.457

Table 5: Effects on High and Low Housing Supply Elasticity Areas

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned} \text{House Price}_{\,Jul/00 \to Dec/01,i} &= \theta_0 + \theta_1 \times \text{Renters Latent Demand}_{\,Jul/00,i} \\ &+ \theta_2 \times \text{Renters Mortgaged-out}_{\,Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i \end{aligned}$$

The regression model is estimated for a sub-sample of low housing supply elasticity (Elasticity of (Saiz)<1.5) and for a sub-sample of high housing supply elasticity (Elasticity of (Saiz)>1.5). Elasticity (Saiz) is the measure of housing supply elasticity from Saiz (2010). Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, fraction of renters, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, fraction of college educated, fraction of Black, and size of the population. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	Elasticity Saiz(2010)<1.5			Elasticity Saiz(2010)>1.5		
	(1)	(2)	(3)	(4)	(5)	(6)
Renters Latent Demand $_{Jul/00}$	-2.034***	-2.194***	-1.986***	-0.774	-0.914*	-0.871
	(-3.06)	(-3.21)	(-2.88)	(-1.33)	(-1.66)	(-1.59)
Renters Mortgaged-out $_{Jul/00}$	-0.155***	-0.156***	-0.176***	-0.267**	-0.264**	-0.238**
	(-3.45)	(-3.02)	(-3.70)	(-2.41)	(-2.32)	(-1.99)
House Price (in 10,000) $_{Jul/00}$	0.000	-0.000	-0.000	0.003***	0.002**	0.002**
	(0.30)	(-0.00)	(-0.03)	(2.93)	(2.38)	(2.06)
HP Growth $_{Dec/99 \to Jul/00}$		-0.075	-0.098		-0.013	-0.015
		(-0.70)	(-1.01)		(-0.14)	(-0.18)
ZIP IRS Income Growth $_{98 \to 01}$		0.001	0.001		0.004	0.004
		(0.40)	(0.23)		(1.05)	(1.06)
Income $_{1998}$		0.015*	0.011		0.016	0.016
		(1.90)	(1.50)		(1.50)	(1.52)
Denial Rate Change $_{00 \to 01}$		-0.006	-0.003		-0.006	-0.005
		(-0.54)	(-0.31)		(-0.60)	(-0.54)
Elasticity Saiz $_{2000}$			-0.068			-0.007
			(-1.18)			(-1.16)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Zip Controls	No	Yes	Yes	No	Yes	Yes
MSA Controls	Yes	Yes	Yes	Yes	Yes	Yes
#Neighborhoods	9748	9748	9748	9829	9829	9829
R-squared	0.466	0.478	0.484	0.431	0.441	0.442

Table 6: Distributional Effects on Home Prices: Renters Demand

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned}\text{House Price}_{\,Jul/00 \to Dec/01,i} &= \theta_0 + \theta_1 \times \text{Renters Latent Demand}_{\,Jul/00,i} \\ &+ \theta_2 \times \text{Renters Mortgaged-out}_{\,Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i\end{aligned}$$

The regression model is estimated for each sub-sample of house price quartile. The average house price in July 2000 was $92,484 in the lowest quartile, $131,363 in the second quartile, $174,211 in the third quartile, and $272,880 in the highest quartile. Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, fraction of renters, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, fraction of college educated, fraction of Black, and size of the population. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	House Price Growth from Jul-2000 to Dec-2001			
	(1) Q1	(2) Q2	(3) Q3	(4) Q4
Renters Latent Demand $_{Jul/00}$	-1.142	-5.435***	-4.843***	-0.608
	(-0.31)	(-3.17)	(-3.34)	(-0.64)
Renters Mortgaged-out $_{Jul/00}$	-0.186	-0.134	-0.076	0.164*
	(-0.38)	(-0.54)	(-0.39)	(1.74)
House Price (in 10,000) $_{Jul/00}$	0.002	0.002	0.001	-0.000
	(0.83)	(0.75)	(0.88)	(-0.59)
HP Growth $_{Dec/99 \to Jul/00}$	0.010	-0.089	-0.181**	-0.107
	(0.15)	(-0.97)	(-2.21)	(-1.04)
ZIP IRS Income Growth $_{98 \to 01}$	0.002	0.003	0.014	0.047**
	(1.20)	(1.00)	(0.90)	(2.17)
Income $_{1998}$	0.027**	0.011	-0.001	0.017*
	(2.38)	(1.07)	(-0.10)	(1.80)
Denial Rate $_{2000}$	-0.027	-0.020	0.010	0.024
	(-1.61)	(-1.54)	(0.63)	(1.32)
Elasticity Saiz $_{2000}$	-0.010*	-0.008	-0.008	-0.005
	(-1.84)	(-1.44)	(-1.42)	(-0.82)
State Fixed Effects	Yes	Yes	Yes	Yes
Zip Controls	Yes	Yes	Yes	Yes
MSA Controls	Yes	Yes	Yes	Yes
#Neighborhoods	4978	4876	4912	4811
R-squared	0.483	0.532	0.505	0.495

Table 7: Distributional Effects on Home Prices: Homeowners Demand

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned}\text{House Price}_{Jul/00 \to Dec/01,i} &= \theta_0 + \theta_1 \times \text{Homeowners Latent Demand}_{Jul/00,i} \\ &+ \theta_2 \times \text{Homeowners Mortgaged-out}_{Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i\end{aligned}$$

The regression model is estimated for each sub-sample of house price quartile. The average house price in July 2000 was $92,484 in the lowest quartile, $131,363 in the second quartile, $174,211 in the third quartile, and $272,880 in the highest quartile. Homeowners' latent demand is a neighborhood-specific variable that measures the fraction of household homeonwners in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, fraction of renters, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, fraction of college educated, fraction of Black, and size of the population. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	House Price Growth from Jul-2000 to Dec-2001			
	(1) Q1	(2) Q2	(3) Q3	(4) Q4
Homeowners Latent Demand $_{Jul/00}$	2.886	-0.729	-2.510*	-0.339
	(1.17)	(-0.39)	(-1.73)	(-0.73)
Homeowners Mortgaged-out $_{Jul/00}$	0.281	-0.063	-0.036	0.142***
	(0.49)	(-0.18)	(-0.16)	(2.68)
House Price (in 10,000) $_{Jul/00}$	0.003	0.003	-0.001	-0.001
	(0.86)	(0.95)	(-0.29)	(-1.58)
HP Growth $_{Dec/99 \to Jul/00}$	0.010	-0.119	-0.179**	-0.129
	(0.14)	(-1.23)	(-1.99)	(-1.20)
ZIP IRS Income Growth $_{98 \to 01}$	0.002	0.002	0.018	0.043*
	(1.28)	(0.95)	(1.15)	(1.95)
Income $_{1998}$	0.027**	0.011	0.002	0.010
	(2.30)	(1.08)	(0.23)	(1.18)
Denial Rate $_{2000}$	-0.030*	-0.034**	0.003	0.023
	(-1.82)	(-2.34)	(0.19)	(1.14)
Elasticity Saiz $_{2000}$	-0.012**	-0.008	-0.005	-0.001
	(-2.07)	(-1.19)	(-0.94)	(-0.19)
State Fixed Effects	Yes	Yes	Yes	Yes
Zip Controls	Yes	Yes	Yes	Yes
MSA Controls	Yes	Yes	Yes	Yes
#Neighborhoods	4978	4876	4912	4811
R-squared	0.485	0.514	0.496	0.499

Table 8: Effect on Applications Kept in the Balance Sheet versus Loans Sold

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned} \text{Mortgage Applications}_{\,2000\to2001,i} &= \theta_0 + \theta_1 \times \text{Renters Latent Demand}_{\,Jul/00,i} \\ &+ \theta_2 \times \text{Renters Mortgaged-out}_{\,Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i \end{aligned}$$

Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	Mortgage Applications from 2000 to 2001		
	(1) All	(2) Kept	(3) Not-Kept
Renters Latent Demand $_{Jul/00}$	-12.039***	-13.284***	-7.875***
	(-4.85)	(-4.95)	(-2.85)
Renters Mortgaged-out $_{Jul/00}$	-0.384	-0.924***	0.531*
	(-1.50)	(-3.13)	(1.76)
House Price (in 10,000) $_{Jul/00}$	0.001	0.002	-0.003
	(1.08)	(1.65)	(-1.61)
State Fixed Effects	Yes	Yes	Yes
Zip Controls	No	No	No
MSA Controls	No	No	No
#Zip codes	19577	19544	19411
R-squared	0.038	0.037	0.034

Table 9: Placebo Test between December 1999 and July 2000

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned} \text{House Price}_{Dec/99 \to Jul/00,i} &= \theta_0 + \theta_1 \times \text{Renters Latent Demand}_{Dec/99,i} \\ &+ \theta_2 \times \text{Renters Mortgaged-out}_{Dec/99,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i \end{aligned}$$

The regression model is estimated for each sub-sample of house price quartile. The average house price in December 1999 was $87,666 in the lowest quartile, $123,996 in the second quartile, $164,532 in the third quartile, and $256,107 in the highest quartile. Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in December 1999 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from December 1999 to July 2000—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in December 1999. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, fraction of renters, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, fraction of college educated, fraction of Black, and size of the population. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	House Price Growth from Dec-1999 to Jul-2001			
	(1) Inc Q1	(2) Inc Q2	(3) Inc Q3	(4) Inc Q4
Renters Latent Demand $_{Dec/99}$	3.011*	1.190	-0.666	-0.835
	(1.74)	(1.42)	(-1.15)	(-1.36)
Renters Mortgaged-out $_{Dec/99}$	-0.121	-0.073	-0.203**	-0.035
	(-0.50)	(-0.73)	(-2.57)	(-0.62)
House Price (in tens of thousands) $_{Dec/99}$	0.008***	0.006***	0.005***	0.001***
	(4.48)	(8.09)	(7.57)	(3.82)
HP Growth $_{Dec/98 \to Dec/99}$	-0.027	-0.000	-0.022	0.046**
	(-1.04)	(-0.00)	(-0.95)	(2.09)
Income $_{1998}$	0.009**	0.009*	0.005	0.005
	(2.20)	(1.78)	(1.20)	(0.75)
ZIP IRS Income Growth $_{98 \to 01}$	0.001**	0.003*	0.017*	0.054***
	(2.07)	(1.68)	(1.82)	(3.01)
Denial Rate $_{2000}$	0.001	0.011*	0.019**	0.006
	(0.10)	(1.86)	(2.38)	(0.58)
Elasticity Saiz $_{2000}$	-0.002	-0.000	-0.002	-0.004
	(-0.82)	(-0.03)	(-1.19)	(-1.46)
State Fixed Effects	Yes	Yes	Yes	Yes
Zip Controls	Yes	Yes	Yes	Yes
MSA Controls	Yes	Yes	Yes	Yes
#Zip codes	4957	4853	4893	4795
R-squared	0.416	0.505	0.504	0.473

ONLINE APPENDIX

Table A.1: Complete version of Table 3

The Table below reports the estimated coefficients for the following regression specification at the neighborhood level:

$$\begin{aligned} \text{House Price}_{\,Jul/00 \to Dec/01,i} &= \theta_0 + \theta_1 \times \text{Renters Latent Demand}_{\,Jul/00,i} \\ &+ \theta_2 \times \text{Renters Mortgaged-out}_{\,Jul/00,i} + \Delta \times X_i + \text{State-Fixed-Effects} + \varepsilon_i \end{aligned}$$

Renters' latent demand is a neighborhood-specific variable that measures the fraction of household renters in July 2000 (out of all households in the metropolitan area) that could afford to make mortgage payments after the decline in interest rates from July 2000 to December 2001—the theoretical details are explained in section 2.2, and the numerical details are presented in section 4.4. A neighborhood is defined by the house price terciles for a zip code, as defined by Zillow. Mortgage applications, originations, and denial rates are for home purchase and are measured using HMDA loan data. HP Growth is the growth in the Zillow price index for all houses in the neighborhood. House Price is the Zillow price index for all houses in the neighborhood in July 2000. Income is obtained from the Internal Revenue Service (IRS), and is defined as the gross adjusted income divided by the number of returns. Elasticity Saiz is the measure of housing supply elasticity from Saiz (2010). Zip controls include zip code-level controls for median age, fraction of college educated, fraction of Black, size of the population, and immigration from outside the county. MSA controls include metropolitan-level controls for immigration from outside the metro area, and fraction of college educated. Standard errors are heteroskedastically robust, and are clustered at the metropolitan level. t-statistics are in parentheses. Statistic significance: ***=1%; **=5%; and *=10%.

	House Price Growth from Jul-2000 to Dec-2001					
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Renters Latent Demand $_{Jul/00}$	-2.170***	-2.296***	-2.225***	-2.027***	-2.103***	-1.914***
	(-3.34)	(-4.31)	(-4.02)	(-3.44)	(-4.03)	(-3.82)
Renters Mortgaged-out $_{Jul/00}$		-0.014	-0.005	-0.012	-0.017	-0.078
		(-0.15)	(-0.07)	(-0.17)	(-0.22)	(-1.09)
HP Growth $_{Dec/99 \to Jul/00}$			0.047	0.007	-0.031	-0.021
			(0.44)	(0.07)	(-0.30)	(-0.25)
ZIP IRS Income Growth $_{98 \to 01}$				0.003	0.005*	0.003
				(1.48)	(1.82)	(1.48)
Income $_{1998}$				0.016***	0.025***	0.018***
				(3.49)	(3.32)	(3.03)
Denial Rate $_{2000}$				0.010	0.011	0.010
				(0.60)	(0.76)	(0.82)
Elasticity Saiz $_{2000}$				-0.019***	-0.018***	-0.009
				(-4.14)	(-3.98)	(-1.57)
House Price (in 10,000) $_{Jul/00}$		-0.000	-0.000	-0.001	-0.001	-0.000
		(-0.17)	(-0.37)	(-1.22)	(-1.17)	(-0.50)
ZIP Fraction of Renters $_{2000}$					0.051***	0.048***
					(4.95)	(4.77)
MSA Fraction of Black $_{2000}$						-0.102*
						(-1.97)
Log MSA Population $_{2000}$						0.011***
						(2.73)
ZIP Median Age $_{2000}$					0.000	0.001*
					(1.05)	(1.79)
ZIP Immigration Outside County $_{2000}$					0.022	0.021
					(0.86)	(0.87)
ZIP Fraction of Black $_{2000}$					0.001	-0.002
					(0.07)	(-0.18)
ZIP Fraction of College $_{2000}$					-0.009	-0.005
					(-0.39)	(-0.28)
ZIP Population $_{2000}$					0.000*	0.000
					(1.80)	(1.45)
MSA Median Age $_{2000}$						-0.000
						(-0.44)
MSA Fraction of College Education $_{2000}$						0.093
						(1.04)
MSA Unemployment Rate $_{2000}$						1.042**
						(2.55)
MSA Immigration $_{2000}$						0.084
						(0.58)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
#Neighborhoods	19577	19577	19577	19577	19577	19577
R-squared	0.413	0.414	0.414	0.436	0.445	0.462