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Mortgage Lock-In, Mobility, and Labor Reallocation

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ABSTRACT

We study the impact of rising mortgage rates on mobility and labor reallocation. Using individual-level credit record data and variation in the timing of mortgage origination, we show that a 1 percentage point decline in the difference between mortgage rates locked in at origination and current rates reduces moving by 9% overall and 16% between 2022 and 2024, and this relationship is asymmetric. Mortgage lock-in also dampens flows in and out of self-employment and the responsiveness to shocks

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to nearby employment opportunities that require moving, measured as wage growth within a 50- to 150-mile ring and instrumented with a shift-share instrument.

MORTGAGE CONTRACTS IN THE UNITED States allow households to lock in interest rates for up to 30 years. After broadly declining for decades and hitting record lows at the end of 2020, mortgage rates rose sharply between 2022 and 2023 (Figure 1). As of March 2024, most U.S. mortgage borrowers had locked in a rate below 4%, compared to current mortgage rates of over 7%. For households who have locked in low mortgage rates, these rate increases add to the financial cost of moving, as moving requires prepaying the current mortgage balance and remortgaging at significantly higher rates. For instance, a 1 percentage point (p.p.) rise in rates increases annual mortgage payments for the median borrower by around 2,000 USD, which can raise the present value of future payments by up to 35,000 USD.[1]

This implicit financial cost might have unintended consequences for household mobility and labor reallocation. A widely cited concern is that it may "lock in" households, reducing housing market transactions and mobility (Quigley (1987), Ferreira, Gyourko, and Tracy (2010)).[2] But if this financial cost is small relative to the benefit of moving, the real effects on mobility may be relatively muted. This paper provides one of the first causal estimates of the effect of mortgage lock-in on mobility and labor reallocation. We do so by developing a simple theoretical framework that relates the difference between the mortgage rate locked in at origination and the prevailing market rate (henceforth, mortgage delta or Δr) to households' moving behavior, and deriving testable implications. We then take these predictions to the data using U.S. individual-level credit record data and exploiting plausibly exogenous variation in the timing of mortgage origination.

Mortgage lock-in occurs when the net cost of moving (inclusive of the cost of remortgaging at higher rates) prevents households from moving, even though the net benefit of moving—that is, the fundamental benefit of moving less a moving cost—is positive. Intuitively, these households would want to move if they did not have to remortgage, but this contractual option is not standard in U.S. mortgage contracts, as we discuss further below. As a result, lock-in reduces household moving when Δr is low. In contrast, when Δr is high, households can capture the interest rate benefit from remortgaging without needing to move since they have the contractual option to refinance. We thus predict an asymmetric relationship between moving and Δr. As long as the benefit of remortgaging is smaller than the cost, an increase in Δr alleviates mortgage

[1] This calculation assumes a remaining term of 30 years, an initial loan balance of 270,000 USD, a discount factor of 0.96, and a mortgage rate change from 4.5% (matching the median monthly mortgage payment of around 1,400 USD) to 5.5%. This example does not take into account the option value of reducing payments again once interest rates decrease, lowering the expected present value of payments, which we address in subsequent simulation analysis.

[2] For discussions of this concern in the media, see, for instance, *Wall Street Journal*, September 22, 2022, *Financial Times*, January 12, 2023.

Figure 1. Average 30-year fixed-rate mortgage rates. This figure shows average monthly 30-year fixed-rate mortgage rates from the Federal Reserve Bank of St. Louis, which come from Freddie Mac's Primary Mortgage Market Survey (PMMS). The PMMS captures mortgage rates for "first-lien, conventional, conforming, purchase mortgages with a borrower who has a loan-to-value of 80% and excellent credit." (Color figure can be viewed at wileyonlinelibrary.com)

lock-in. Once the benefit of remortgaging exceeds the cost, the relationship between Δr and moving rates flattens, as moving only depends on fundamental moving shocks and costs. Thus, our framework predicts a kink in the relationship between moving rates and Δr, at a point where Δr is positive. Finally, we predict that low Δr attenuates household responsiveness to a given moving shock, such as an expected increase in income that can be obtained by moving. In other words, households are less likely to pursue higher paid employment opportunities due to the financial cost imposed by mortgage lock-in.

To test these predictions, we employ a novel consumer credit panel data set, the Gies Consumer and Small Business Credit Panel (GCCP), which allows us to measure locked-in mortgage rates and moving for millions of borrowers from 2010 to 2024. We measure households' mortgage rate deltas as the difference between the mortgage rate that the household locked in at the time of mortgage origination and the current mortgage rate. Our main empirical challenge is that a simple ordinary least squares (OLS) regression of moving rates on household-specific mortgage rate deltas may be biased if omitted factors correlate with both interest rates and moving. For instance, financially sophisticated households have been found to obtain lower rates (Keys, Pope, and Pope (2016), Agarwal, Rosen, and Yao (2016), Andersen et al. (2022), Agarwal et al. (2023b)) and may receive more favorable terms from lenders (Agarwal et al. (2017), Fuster et al. (2021), Agarwal et al. (2023a)). If these households are also more likely to move, this would lead to a downward bias in OLS estimates. To overcome this challenge, we use an instrumental variable (IV) research design and instrument household-specific mortgage rate deltas with the aggregate mortgage rate delta, defined as the difference between average prime mortgage rates in the month of mortgage origination and current average prime mortgage rates. We thus isolate the variation in mortgage rate deltas coming solely from the timing of mortgage origination, and control for zip code fixed effects, county×year fixed effects, mortgage and borrower controls, and a zip code house price index.

Our paper has three main findings. First, our two-stage least squares estimate implies that a 1 p.p. reduction in mortgage rate deltas leads to a 0.69 p.p. reduction in moving rates, or 9% of the sample mean. Restricting the sample to the period post-2022, this effect rises to 1.20 p.p., or 16% of the 2010 to 2024 sample mean.[3] Second, we show that the effect of mortgage deltas on moving is indeed asymmetric, consistent with our theoretical prediction that, once Δr is higher than the cost of remortgaging, only moving fundamentals matter, and moving propensities become unrelated to Δr. We provide graphical evidence consistent with this prediction, showing that the relationship between Δr and moving flattens at a level of Δr of around 1.8 p.p., corresponding to around 3,000 USD at a median loan balance of 165,290 USD, broadly consistent with recent estimates (Andersen et al. (2020), Fisher et al. (2024)) and survey measures (Keys, Pope, and Pope (2016)) of refinancing costs. This asymmetry also implies that the effect of mortgage rate deltas on moving changes over time, as the mass of borrowers in the steep and flat portions of this relationship changes. This can explain why the elasticity of moving with respect to mortgage deltas is higher in 2022 to 2024 after the wave of refinancing in 2020 to 2021 and the sharp increase in rates in 2022 shifted the vast majority of borrowers to the steep portion of the relationship between mortgage deltas and moving.

Third, consistent with our theoretical prediction, we find that low Δr attenuates household responsiveness to moving shocks such as shocks to nearby employment opportunities that require moving. We measure the availability of higher wage employment opportunities using wage growth in counties within a 50- to 150-mile ring, which we instrument using a shift-share instrument. We find that the slope of the relationship between wage growth in nearby counties and moving rates is positive for borrowers with above-median aggregate Δr but essentially flat for those with below-median aggregate Δr, meaning that mortgage lock-in dampens moving in response to higher wages. For borrowers with high aggregate mortgage delta, a one standard deviation increase in wage growth of counties within 50 to 150 miles increases out-of-county moving by 0.20 p.p., which is significant at 1%. On the other hand, out-of-county moving does not respond to nearby wage growth for borrowers with low aggregate mortgage deltas. This suggests that mortgage lock-in modulates the geographical allocation of labor and can lead to a mismatch between workers

[3] This estimate is consistent with Liebersohn and Rothstein (2024), who use our instrument and find that mortgage lock-in reduces moving by 16% between 2022 and 2023.

and jobs, as some households forego higher paid employment opportunities due to the financial cost imposed by mortgage lock-in.

To provide direct evidence of an impact on the allocation of workers across jobs, we also study the effect of mortgage lock-in on self-employment, which has been found to relate to domestic (Manuel (2024)) as well as international migration (e.g., Fairlie and Lofstrom (2015), Kerr and Kerr (2020), Azoulay et al. (2022)). We measure flows in and out of self-employment using two snapshots of the link between consumer credit records and business credit records in the GCCP, from 2020 and 2023. We find that a 1 p.p. decline in 2019 Δr reduces entry into small business ownership between 2020 and 2023 by 0.26 p.p. (or 5% of the sample mean) and exits by 0.30 p.p. (or 15%).

The two key identifying assumptions behind our IV research design are that (i) aggregate mortgage deltas are associated with household-specific mortgage deltas and (ii) aggregate mortgage deltas only affect moving rates through their effect on household-specific mortgage deltas. The latter would be violated if, conditional on controls, the timing of mortgage origination is related to moving rates through channels other than its effect on the aggregate mortgage delta. For instance, one potential concern is that financially sophisticated households are more likely to time their mortgage origination and may move at different rates from unsophisticated households. While the exclusion restriction is untestable, we conduct a range of robustness checks that support a causal interpretation of our findings.

We directly address the issue of market timing by exploiting increasingly narrow sources of variation in aggregate mortgage deltas. We show that our results are qualitatively identical and quantitatively larger when we include origination year, origination half-year, or origination quarter-year fixed effects. In the most stringent of these specifications—with origination quarter-year fixed effects—variation in aggregate mortgage deltas comes from monthly variation in aggregate mortgage rates within the same quarter of mortgage origination. This specification compares individuals who had a mortgage originated in, for instance, January with those with a mortgage originated in February or March of that same year, alleviating concerns that our results might be driven by market timing or business cycle effects. We also show that our instrument does not correlate with individual and loan characteristics. In particular, we show that the instrument does not correlate with mortgage term, years since origination, credit score at origination, age, occupation, past refinancing behavior, and more, making it unlikely that our results are driven by differences in loan or individual characteristics.

We provide further indirect evidence in support of a causal interpretation of our results by conducting an event study of moving rates around the 2022 rate increase. We show that moving rates are roughly flat from 2017 to 2021, but decline sharply once interest rates increase. Under the strong assumption that the only change in 2022 that impacted moving rates was the rise in interest rates, we use the 2022 rate increase as an alternative instrument and estimate an elasticity of moving with respect to mortgage deltas of 0.52, comparable to our baseline estimate of 0.69. We also conduct a placebo check in a sample of consumers without a mortgage and show that a counterfactual measure of mortgage lock-in, constructed using data on individuals' last move, does not affect moving in this sample. Finally, our results are also quantitatively similar when we measure the present value of future mortgage payments in dollars rather than focusing on mortgage rate differentials.

We further show that mortgage lock-in has knock-on effects on the housing market. Using individual property listing data aggregated to the county level, we show that a reduction in Δr at the county level, instrumented by aggregate Δr, reduces time on the market while raising list and sale prices. The effects are consistent with lock-in reducing the local supply of houses for sale. As a result, individual moving decisions under mortgage lock-in may impose an externality on aggregate housing market liquidity, reducing housing market matches for other households, including first-time buyers.

To quantify the dollar value of lock-in as of 2024, we estimate the minimum compensation that households would require to give up their locked-in mortgage rate, which we call the expected lock-in value.[4] We simulate future interest rate paths using a calibrated interest rate process and allow households to refinance optimally when interest rates decrease. We then compare the expected present value of future mortgage payments under an average locked-in rate of 4.34%, loan balance of 271,493 USD, and remaining loan term of 21 years, reflecting average values as of March 2024, to that of a similar loan initialized at prevailing mortgage rate levels of 7%. The expected lock-in value for the average household is around 51,000 USD, and thus of the order of more than half the average annual income of these borrowers in 2024. We find substantial geographic variation in lock-in values across states and counties, which line up with recent outcomes such as large reductions in house listings between 2022 and 2024 at the county level. This geographical variation may have longer term impacts given causal place effects on long-run household outcomes including education and income (e.g., Ludwig et al. (2013), Chetty et al. (2014), Chyn and Katz (2021)).

We provide quantitative estimates of mortgage lock-in effects and highlight unintended consequences of monetary tightening in the presence of long-term fixed-rate mortgages. The degree of mortgage lock-in suggests a large and unprecedented shock to overall household mobility, housing and labor markets, and other household outcomes, with distributional consequences given the heterogeneity in lock-in across households and locations.

A. Related Literature

Prior work by Quigley (1987) and Ferreira, Gyourko, and Tracy (2010) shows that mortgage lock-in reduces household mobility using Panel Study of Income Dynamics and American Housing Survey data, respectively. Our contribution to the existing literature on mortgage lock-in is fourfold. First, we propose a

[4] The measure does not account for household risk aversion, that is, the certainty equivalent would likely be higher.

novel identification strategy to estimate the causal effect of mortgage lock-in on household mobility. Using rich microdata, we exploit variation in the month of loan origination within time windows as narrow as one quarter, showing that this yields variation in locked-in mortgage rates that is plausibly exogenous and balanced across a wide range of observable loan and household characteristics. Second, we are the first to highlight an asymmetric relationship between Δr and moving, arising from the option to refinance when Δr is high but no option to move without remortgaging (e.g., to port[5]) when Δr is low. As a result, we show that mortgage lock-in reflects a contractual financial friction that skews households' real economic decisions. We do so by developing a theory of mortgage lock-in that yields testable predictions beyond those existing, primarily econometric models of mortgage lock-in and validating the predictions using nonparametric methods to provide direct evidence of the asymmetric relationship between moving and Δr. Third, we demonstrate that mortgage lock-in affects the allocation of workers across jobs and locations by showing that it dampens flows in and out of self-employment and reduces moving in response to wage growth in nearby regions that are too far to commute. Finally, we estimate the causal effect of mortgage lock-in in 2022 to 2024, highlighting the unintended real economic effects of interest rate tightening on mobility, housing, and labor markets, with an unprecedented magnitude and incidence in recent decades.

Two recent working papers follow our analysis and confirm our findings, using our IV and showing that our results are robust to the use of a hazard rate model (Liebersohn and Rothstein (2024)) and proprietary Government Sponsored Enterprise data with information on coupon rates (Batzer et al. (2024)). Amromin and Eberly (2023) study the response of house prices to interest rates and other shocks in a model similar to Garriga, Gete, and Tsouderou (2021) and use our empirical estimate to argue that mortgage lock-in can account for the fact that house prices remained stable during the 2022 to 2023 tightening cycle.

Our paper contributes to a broader literature on how housing markets affect household mobility (Ferreira, Gyourko, and Tracy (2010), Ferreira, Gyourko, and Tracy (2012)). While earlier studies found mixed evidence of negative home equity lock-in on labor mobility (e.g., Chan (2001), Schulhofer-Wohl (2012), Coulson and Grieco (2013)), more recent work using microdata shows that negative home equity reduces mobility, labor supply, wages, and job search intensity (Brown and Matsa (2020), Bernstein (2021), Gopalan et al. (2021), Bernstein and Struyven (2022)).[6] Negative effects on mobility have also been documented due to property tax lock-in, caused by caps on property tax growth for incumbent owners (Wasi and White (2005), Ferreira (2010), İmrohoroğlu, Matoba, and Tüzel (2018)). Other sources of lock-in are

[5] Portable mortgages exist, for instance, in the United Kingdom and Canada, meaning borrowers can take their mortgage with them and collateralize them against the new house to which they move.

[6] In addition, Karahan and Rhee (2019) quantify the effect using a structural approach.

down-payment constraints (Stein (1995), Genesove and Mayer (1997), Andersen et al. (2022)) and behavioral effects such as loss aversion and reference dependence (Genesove and Mayer (2001), Engelhardt (2003), Anenberg (2011), Badarinza et al. (2024), Andersen et al. (2022)).

Our findings highlight a seeming trade-off between insurance provision and allocative efficiency.[7] Fixed-rate mortgages provide insurance against interest rate increases, but can cause prolonged periods of lock-in and misallocation when rates rise. In addition, we find that lock-in may also reduce housing market liquidity. Understanding these novel channels of monetary tightening helps inform mortgage market design (Piskorski and Tchistyi (2010), Campbell (2012), Eberly and Krishnamurthy (2014), Campbell, Clara, and Cocco (2021), Guren, Krishnamurthy, and McQuade (2021), Liu (2022)). This paper raises the importance of alternative housing market policies such as mortgage assumability and portability, which provide a way to alleviate the distortionary effects of mortgage lock-in. These contractual features are common in many other countries but are not widely available in the United States (Quigley (1987), Lea (2010), Berg, Nielsen, and Vickery (2018), Madeira (2021)).[8]

Our work further relates to monetary policy transmission via the mortgage market (Scharfstein and Sunderam (2016), Beraja et al. (2019), DeFusco and Mondragon (2020), Di Maggio, Kermani, and Palmer (2020), Fuster et al. (2021), Agarwal et al. (2023b)) and the role of past mortgage rates (Berger et al. (2021), Eichenbaum, Rebelo, and Wong (2022)).[9] In contrast to these papers, we focus on the effects of monetary tightening as opposed to easing and directly study mobility, labor, and housing market outcomes. More broadly, our paper also relates to studies of the effect of monetary policy on productivity and the allocation of labor across occupations, firms, and sectors (e.g., Jordà, Singh, and Taylor (2020), Jasova et al. (2021), Guerrieri et al. (2021), Bergman, Matsa, and Weber (2022), Blanchard, Domash, and Summers (2022), Singh, Suda, and Zervou (2022), Ma and Zimmermann (2023)). We complement these works by focusing on how interest rate rises affect mobility and the geographical allocation of labor.

Our finding that mortgage lock-in affects flows in and out of small business ownership is related to work on housing collateral and entry into entrepreneurship (Black, Meza, and Jeffreys (1996), Adelino, Schoar, and

[7] These distortionary effects have been documented in studies on rent control, which can provide insurance against rent price increases but reduce allocative efficiency of housing (Glaeser and Luttmer (2003), Autor, Palmer, and Pathak (2014), Diamond, McQuade, and Qian (2019), Favilukis, Mabille, and Van Nieuwerburgh (2023)).

[8] Mortgages backed by government guarantee programs, the U.S. Federal Housing Administration (FHA) and Department for Veterans Affairs (VA), are typically assumable. However, borrowers can only assume the existing loan, meaning they may require a second lien or sufficient cash to pay for the house if the previous borrower has repaid parts of the loan principal and/or the house has appreciated in value.

[9] Berger et al. (2021) show that rate incentives matter for all prepayment decisions, including moving.

Severino (2015), Corradin and Popov (2015), Schmalz, Sraer, and Thesmar (2017), Bracke, Hilber, and Silva (2018), Jensen, Leth-Petersen, and Nanda (2022), Kerr, Kerr, and Nanda (2022)) and on the link between personal credit and entrepreneurship (Robb and Robinson (2014), Fonseca and Wang (2023)). We contribute to this literature by uncovering a new link between mortgage credit and self-employment arising from the effect of rising mortgage rates on mobility.

Finally, our paper suggests large mobility effects on the majority of U.S. mortgage borrowers, which could have long-run implications. Ludwig et al. (2013), Chetty et al. (2014), Chetty, Hendren, and Katz (2016), Chetty and Hendren (2018), Bergman et al. (2024), and Finkelstein, Gentzkow, and Williams (2021) highlight the causal importance of place effects and geographic mobility for long-run outcomes in education, crime, health, and income (Chyn and Katz (2021)), while Deryugina, Kawano, and Levitt (2018) and Nakamura, Sigurdsson, and Steinsson (2022) study the long-run effects of mobility shocks.

The remainder of the paper is structured as follows. Section I outlines the conceptual framework using a simple model of household moving and refinancing. Section II introduces the data and empirical strategy. Section III presents the main results and Section IV provides additional results and robustness checks. Section V concludes.

I. Theoretical Framework

This section outlines a model of household moving and remortgaging decisions and derives predictions for how Δr and shocks to future income (interpreted as moving shocks) affect household moving, which we subsequently take to the data.

A. A Simple Model of Household Moving and Remortgaging

Household Problem. Households live for two periods and are endowed with a house and mortgage loan of size L. The initial mortgage interest rate r_1 is fixed for both periods but households have the option of prepaying after period 1 and remortgaging, to obtain interest rate r_2 in period 2. Households maximize their lifetime utility, which is linear in consumption. For notational simplicity, there is no discounting. At the end of period 1, households face stochastic interest rate and moving shocks and, upon realization of these shocks, make decision $\mathbb{D} \in \{S, R, M\}$, which affects outcomes in period 2. Households choose between three actions: staying put ($\mathbb{D} = S$), refinancing ($\mathbb{D} = R$), or moving ($\mathbb{D} = M$). Note that we use the term "remortgaging" when referring to prepaying the existing loan and taking out a new loan at current mortgage rates more broadly, and "refinancing" more specifically when referring to prepaying the existing loan and taking out a new loan, but remaining in place in the existing home. A simplifying assumption is that households move into a similarly sized house, such that L stays the same, and there is no loan repayment in period 2.[10]

Moving requires households to pay a fixed moving cost κ^m and a cost κ^r to remortgage, prepay the existing loan, and take out a new loan at rate r_2. Refinancing requires households only to pay κ^r.

Households earn income Y_t, pay mortgage payment M_t, and consume C_t in each period $t \in \{1, 2\}$. The mortgage payment in period 1 is $r_1 \cdot L$. The mortgage payment in period 2 is:

$$M_2 = \begin{cases} r_1 \cdot L, & \text{if } \mathbb{D} = S \\ r_2 \cdot L, & \text{if } \mathbb{D} \in \{R, M\}, \end{cases} \tag{1}$$

that is, households are protected from interest rate changes in the second period, but they need to remortgage to obtain the mortgage rate r_2. Mortgage rates in period 2 are stochastic and follow a random walk:

$$r_2 = r_1 - \epsilon, \text{ where } \epsilon \sim \text{i.i.d. } \mathcal{N}(0, \sigma_\epsilon). \tag{2}$$

By defining r_2 this way, we can simply write $r_1 - r_2 \equiv \Delta r = \epsilon$.

In period 2, households also face a moving opportunity in the form of a potential shock to income η that they can realize if they move, and the realization of the shock is known before decision $\mathbb{D}$ needs to be made.[11] Y denotes the initial income level. Households obtain $Y_1 = Y$ in period 1. Income in period 2 is given by

$$Y_2 = \begin{cases} Y, & \text{if } \mathbb{D} \in \{S, R\} \\ Y \cdot (1 + \eta), & \text{if } \mathbb{D} = M, \text{ where } \eta \sim \text{i.i.d. } \mathcal{N}(0, \sigma_\eta). \end{cases} \tag{3}$$

Households solve the following optimization problem:

$$\max_{\mathbb{D}} U = C_1 + C_2 \text{ s.t. budget constraint } \Lambda, \tag{4}$$

where

$$\Lambda = \begin{cases} C_1 + C_2 = 2Y - 2r_1 L, & \text{if } \mathbb{D} = S \\ C_1 + C_2 = 2Y - (r_1 + r_2)L - \kappa^r, & \text{if } \mathbb{D} = R \\ C_1 + C_2 = (2 + \eta)Y - (r_1 + r_2)L - \kappa^r - \kappa^m, & \text{if } \mathbb{D} = M. \end{cases} \tag{5}$$

Household Decision Rules. Comparing total consumption (i.e., the sum of period 1 and period 2 consumption) when refinancing ($\mathbb{D} = R$) and subtracting

[10] Given the short time frame of two periods, there is no option value of waiting for the refinancing and moving decisions, but one can generalize the meaning of refinancing and moving benefits to incorporate a notion of option value, for example, using the framework by Agarwal, Driscoll, and Laibson (2013). Since this framework expresses households' optimal refinancing decisions as an interest rate gap rule, it would likely result in scaling of household optimality conditions, but would preserve model predictions qualitatively.

[11] This income shock is motivated by existing structural work on mobility (Kennan and Walker (2011)).

total consumption when staying put ($\mathbb{D} = S$) gives

$$(r_1 - r_2)L - \kappa^r \equiv \Delta r L - \kappa^r, \tag{6}$$

that is, the net benefit of refinancing can be represented as the mortgage rate delta (Δr) scaled by the loan balance, less the fixed cost of refinancing.

Similarly, comparing the budget constraint when moving ($\mathbb{D} = M$) and subtracting the budget constraint when staying put ($\mathbb{D} = S$) gives

$$\eta Y + \Delta r L - \kappa^r - \kappa^m, \tag{7}$$

that is, the net benefit of moving and remortgaging is the sum of the moving benefit and benefit from remortgaging, less the cost of remortgaging and moving.

We can define the following useful conditions: When

$$\Delta r L - \kappa^r \geq 0, \tag{8}$$

the household is a *potential refinancer*, as the benefit of remortgaging is greater or equal to the cost of remortgaging; in other words, the option of refinancing is in the money. In a world without moving concerns, households would find it optimal to refinance.

When

$$\eta Y - \kappa^m \geq 0, \tag{9}$$

the household is a *potential mover*, that is, in a world where the household does not have a mortgage, the household would move since the income benefit from moving is greater or equal to the cost of moving.

Solving the household's optimization problem yields the following optimal household decision rules:

$\mathbb{D}^* = S$, iff:

$$\Delta r L - \kappa^r < 0 \wedge \eta Y + \Delta r L - \kappa^m - \kappa^r < 0, \tag{10}$$

$\mathbb{D}^* = R$, iff:

$$\Delta r L - \kappa^r \geq 0 \wedge \eta Y - \kappa^m < 0, \tag{11}$$

$\mathbb{D}^* = M$, iff:

$$\eta Y - \kappa^m \geq 0 \wedge \eta Y + \Delta r L - \kappa^m - \kappa^r \geq 0. \tag{12}$$

Household Groups. To build intuition for households' decision rules, we can divide households into five different (mutually exclusive, collectively exhaustive) groups, by splitting them by their potential mover and potential refinancer status.

Group 1 (Stayers):

$$\Delta r L - \kappa^r < 0 \quad \wedge \quad \eta Y - \kappa^m < 0. \tag{13}$$

These households are neither potential movers nor potential refinancers, and clearly find it optimal to just stay put ($\mathbb{D}^* = S$).

Group 2 (Refinancers):

$$\Delta rL - \kappa^r \geq 0 \quad \wedge \quad \eta Y - \kappa^m < 0. \tag{14}$$

These households are potential refinancers, but not potential movers, meaning their net benefit of moving without remortgaging is negative. This implies that $\eta Y + \Delta rL - \kappa^m - \kappa^r < \Delta rL - \kappa^r$, such that households are better off exercising the refinancing option, without moving (thus, $\mathbb{D}^* = R$).

Group 3 (Movers):

$$\Delta rL - \kappa^r \geq 0 \quad \wedge \quad \eta Y - \kappa^m \geq 0. \tag{15}$$

These households are potential movers and potential refinancers, and clearly find it optimal to move and remortgage ($\mathbb{D}^* = M$).

What about households who are potential movers, but not potential refinancers? Ideally, these households would like to keep their current mortgage when moving or assume an existing mortgage, as they want to move, but not remortgage. In the absence of such mortgage policies, their behavior depends on whether the net moving benefit or net refinancing cost dominates, that is, whether $\eta Y + \Delta rL - \kappa^m - \kappa^r \gtreqless 0$. We can split this group of households into the following two subgroups.

Group 4a (Marginal Movers):

$$\Delta rL - \kappa^r < 0 \quad \wedge \quad \eta Y - \kappa^m \geq 0 \quad \wedge \quad \eta Y + \Delta rL - \kappa^m - \kappa^r \geq 0. \tag{16}$$

These households move marginally ($\mathbb{D}^* = M$), as the net benefit of moving and remortgaging is positive (last condition above), even though households pay a net penalty to remortgage, meaning the net income benefit from moving is large enough to prevent mortgage lock-in.

Group 4b (Marginal Stayers):

$$\Delta rL - \kappa^r < 0 \quad \wedge \quad \eta Y - \kappa^m \geq 0 \quad \wedge \quad \eta Y + \Delta rL - \kappa^m - \kappa^r < 0. \tag{17}$$

These households do not move ($\mathbb{D}^* = S$), as the net benefit of moving and remortgaging is negative. They are households in *mortgage lock-in*, in the sense that the financial cost of remortgaging prevents them from moving despite the net benefit of moving without remortgaging being positive.

The decision rules of these household groups lead to the optimal decision rules to stay, refinance, or move, in equations (10) to (12).

Share of Stayers, Refinancers, and Movers. Using our framework, we can obtain closed-form expressions for the share of households who stay, refinance, or move, which we use to derive comparative statics. To do so, we introduce a household i subscript, which we were able to omit thus far. Recall that households i are heterogeneous in moving shocks η_i, and interest rate shocks ϵ_i, and let the respective cumulative distribution functions be $F(\eta_i)$ and $G(\epsilon_i)$, with densities $f(\eta_i)$ and $g(\epsilon_i)$. Assume that both interest rate and moving shocks are i.i.d. normally distributed with mean 0 and standard deviation σ_ϵ and σ_η, respectively, and that there is a unit mass of households. Denote λ^j with $j \in \{S, R, M\}$ the share of stayers, refinancers, and movers, respectively, such that $\sum_{j\in\{S,R,M\}} \lambda^j = 1$.

Using condition 9, we can define a cutoff value η^* above which a household would be considered a potential mover:

$$\eta^* = \frac{\kappa^m}{Y}. \tag{18}$$

Similarly, using condition 8, we can define a cutoff value ϵ^* above which a household would be considered a potential refinancer:

$$\epsilon^* = \frac{\kappa^r}{L}. \tag{19}$$

Finally, using condition 7, we can define a household-specific cutoff value η_i^{**} (for a given value of ϵ_i) above which the joint moving and remortgaging net benefit is weakly positive:

$$\eta_i^{**} = \frac{\kappa^m + \kappa^r - \epsilon_i L}{Y}. \tag{20}$$

As a result, we obtain the fraction of stayers ($\mathbb{D}^* = S$) following equation (10) as:

$$\lambda^S = \iint_{\{(\eta_i,\epsilon_i):\ \eta_i<\eta_i^{**}\ \cap\ \epsilon_i<\epsilon^*\}} f(\eta_i)g(\epsilon_i)d\eta_i d\epsilon_i, \tag{21}$$

and the fraction of households who are refinancers ($\mathbb{D}^* = R$) as:

$$\lambda^R = \iint_{\{(\eta_i,\epsilon_i):\ \eta_i<\eta^*\ \cap\ \epsilon_i\geq\epsilon^*\}} f(\eta_i)g(\epsilon_i)d\eta_i d\epsilon_i. \tag{22}$$

To determine the fraction of movers ($\mathbb{D}^* = M$), we need to consider which of the two conditions in equation (12) is binding, that is, whether η_* or η_i^{**} is greater:

$$\lambda^M = \iint_{\{(\eta_i,\epsilon_i):\ \eta_i\geq\max\{\eta^*,\eta_i^{**}\}\}} f(\eta_i)g(\epsilon_i)d\eta_i d\epsilon_i. \tag{23}$$

B. Model Predictions and Simulation

We use these expressions to derive predictions regarding the comparative statics of moving. First, we are interested in how the probability of moving varies with respect to changes in the mortgage rate delta, $\Delta r_i = \epsilon_i$.

PROPOSITION 1: *The probability of moving is strictly increasing in Δr_i, up to a cutoff value of $\Delta r^* = \frac{\kappa^r}{L}$. Above the cutoff value Δr^*, moving is flat in Δr_i.*

The proof is provided in the Internet Appendix (Section II.1).[12] The intuition behind this result is reflected in the conditions that differentiate household groups: As Δr increases, more marginal stayers (Group 4b) will become marginal movers (Group 4a). However, once Δr is large enough (such that $\Delta rL - \kappa^r \geq 0$), what determines household choice is solely based on moving fundamentals: If $\eta Y - \kappa^m < 0$, households refinance (Group 2); if $\eta Y - \kappa^m \geq 0$, households move and remortgage (Group 3). Stayers (Group 1) may become refinancers (Group 2) as Δr increases, but not movers while their moving fundamentals are unchanged.

This yields the following predictions:

PREDICTION 1: *Asymmetric Relationship between Moving and Δr_i. The relationship between moving and Δr_i is asymmetric: Moving is increasing in Δr_i as an increase in Δr_i relaxes the moving and remortgaging constraint for some households. The relationship is flat once $\Delta r_i \geq \frac{\kappa^r}{L}$.*

In other words, as soon as $\Delta r_i \geq \frac{\kappa^r}{L}$, households have the outside option of refinancing to capture the financial benefit of lower interest rates, without the need to move. That means that the probability of moving is increasing in $\Delta r_i L$ only up to that point. Beyond that, moving only depends on moving fundamentals.

PREDICTION 2: *Asymmetry at $\Delta r_i > 0$. With a strictly positive cost of refinancing $\kappa^r > 0$, the increasing relationship between Δr_i and moving flattens out at $\Delta r_i > 0$.*

This means that mortgage lock-in can occur without changes in interest rates, but due to a positive fixed cost of remortgaging alone.

Next, we are interested in how moving varies with respect to the moving shock η_i when the degree of lock-in as measured by $\Delta r_i = \epsilon_i$ differs.

PROPOSITION 2: *(i) The probability of moving given a moving shock η_i, $\lambda^M(\eta_i)$, is increasing in η_i. (ii) The derivative of that moving probability with respect to the moving shock, $\frac{d\lambda^M(\eta_i)}{d\eta_i}$, is increasing and then decreasing in the interest rate shock ϵ_i if the probability density function $g(\epsilon_i)$ is unimodal.*

The intuition behind this is that, for a given level of η_i, there is a distribution of lock-in characterized by $g(\epsilon_i)$, which is alleviated as η_i increases. For low enough levels of ϵ_i, where lock-in binds, $g(\epsilon_i)$ is increasing. As a result, $\frac{d\lambda^M(\eta_i)}{d\eta_i}$ is larger for less locked-in households in that region (with the proof and further detail provided in Internet Appendix Section II.1). This yields the following prediction:

PREDICTION 3: *Moving Rate* w.r.t η_i and Δr_i. *The sensitivity of moving with respect to the moving shock η_i is greater when households are less locked in (i.e., when Δr_i is high).*

[12] The Internet Appendix is available in the online version of this article on *The Journal of Finance* website.

Model Simulation. In the empirical analysis, we map these model predictions to their empirical analogs by exploiting variation in Δr_i, and proposing an empirical proxy for moving shocks η_i. To illustrate the model predictions, we can also simulate moving rates based on the model. To more closely match dimensions of household heterogeneity in the data, we further assume heterogeneity in refinancing (k^r) and moving cost (k^m) (which can be thought of as introducing noise, but without changing the predictions of the model), and calibrate the income level and income shock (Y, σ_η), initial interest rate level and shock (r_1, σ_ϵ) to match stylized facts, with further detail provided in Internet Appendix Section II.2.

Figure IA.7 in the Internet Appendix illustrates Predictions 1 and 2, that moving is increasing in Δr_i up to $\Delta r_i = \frac{\kappa^r}{L}$, from which point on it is flat. Figure IA.8 illustrates Prediction 3, that less locked-in households (higher Δr_i) are more responsive to a given underlying moving shock η than more locked-in households (lower Δr_i).[13]

II. Data and Empirical Strategy

A. Data

Our main data set is the GCCP, a novel panel data set with credit record data on consumers and small businesses from Experian, one of the three major national credit reporting agencies in the United States. The GCCP consists of a 1% random sample of individuals with a credit report, which is linked to alternative credit records from Experian's alternative credit bureau, Clarity Services, and business credit records for individuals who own a business.[14]

We use snapshots of mainstream consumer credit records as of the end of the first quarter of each year between 2010 and 2024 and, given our focus on the effect of interest rates on mortgage rate lock-in, we restrict attention to consumers with positive mortgage balances. These records include detailed credit attributes and tradelines of each individual, including debt levels for all major forms of formal debt such as mortgages, student loans, and credit cards. The data include individuals' credit scores and payment history, as well as bankruptcies and other public records. The GCCP also has information on mortgage interest rates from Experian's Estimated Interest Rate Calculations enhancement, which provides interest rate estimates based on balance, term, and payment information.

To measure entry and exit from small business ownership, we use the link between mainstream records and business credit records (Fonseca and Wang

[13] Figure IA.9 provides a simplified simulation with a greater range of positive wage shocks, which illustrates that the moving gap between high and low Δr_i households widens as η_i increases, but once the wage shock η_i is sufficiently large, the wage shock dominates, such that the moving gap narrows again.

[14] See Fonseca (2023) and Correia, Han, and Wang (2023) for a discussion of the link between mainstream and alternative credit records in the GCCP and Fonseca and Wang (2023) on the link between consumer and business credit records. See also Gibbs et al. (2023) for a guide to credit reporting data and a survey of the literature.

(2023)). While Experian does not archive the link between these two types of records, we have access to two snapshots of this link, from 2020 and 2023. This allows us to identify consumers who were newly linked to a business between 2020 and 2023, which we define as entry into small business ownership, and those who were linked to a business in 2020 but not in 2023, which we flag as an exit from small business ownership.

Our data set also includes basic demographics such as zip code of residency, age, gender, marital status, broad occupation codes, and education. We define moving at time t as having a different zip code of residency at time $t+1$ from at time t.[15] In Internet Appendix Figure IA.2, we compare average moving rates in our sample to those in the U.S. Census Bureau's Current Population Survey (CPS).[16] While patterns are broadly similar across all types of moves, within-county moving rates in our sample are substantially lower than in the CPS (Panel B). Because we define moving as moving across zip codes, our variable misses within-zip code moves and, consequently, a subset of within-county moves. However, out-of-county, within-state moving rates (Panel C) and out-of-state moving rates (Panel D) are similar across both data sources.

We also use demographic variables to construct proxies for financial sophistication. We categorize borrowers as college educated if they have at least some college education and this education information is flagged by Experian as "high confidence." We also categorize borrowers as being in white collar occupations if they are in management, technical, professional, or clerical occupations.

The GCCP does not contain employment information or home values. We supplement these data with county-level employment and wages from the Quarterly Census of Employment and Wages from 2007 until 2022, the most recent year for which data are available for the full year, and a house price index at the zip code level from the Federal Housing Finance Agency. We obtain average 30-year fixed mortgage rates, which come from Freddie Mac's Primary Mortgage Market Survey (PMMS), from the Federal Reserve Bank of St. Louis. The PMMS captures mortgage rates for "first-lien, conventional, conforming, purchase mortgages with a borrower who has a loan-to-value of 80% and excellent credit," thus representing average rates for prime borrowers.

We report summary statistics for the final sample in Table I. The average mortgage loan balance is 221,510 USD, the average loan term is 27 years, and the average mortgage rate is 4.75%. The average Δr is 0.53%, with the distribution shown in Panel A of Internet Appendix Figure IA.3. In Panel B, we compare average and median mortgage rates with the average 30-year fixed rate from the PMMS by origination year. To make interest rates in our sample more comparable to rates reported in the PMMS, we restrict attention in this figure to borrowers with a Vantage Score of at least 740 and single liens with

[15] Note that, since we define moving as a forward-looking variable, our main dependent variable is not defined for the last year of available data, 2024.

[16] For a comparison of moving rates in the GCCP with migration data from the Internal Revenue Service, see Howard and Shao (2022).

Table I
Summary Statistics

This table shows descriptive statistics for our 2010–2024 sample. Credit outcomes and demographics are from the Gies Consumer and Small Business Credit Panel. Average 30-year fixed mortgage rates are from the Federal Reserve Bank of St. Louis.

	Mean	Med.	St. Dev.
Moving rate (p.p.)	7.52	0.00	26.36
Out-of-county moving rate (p.p.)	4.40	0.00	20.50
Refinancing rate (p.p.)	5.44	0.00	22.68
Δr (p.p.)	0.53	0.40	2.23
Aggregate Δr	0.41	0.51	1.58
Mortgage rate (p.p.)	4.75	4.37	2.00
Average 30-year fixed mortgage rate (p.p.)	4.23	3.99	0.93
Mortgage balance ($1,000)	221.51	165.29	233.13
Mortgage payment ($1,000)	1.76	1.39	2.87
Remaining mortgage term (years)	21.21	24.00	7.88
Time since origination (years)	5.31	4.00	4.38
Credit score	754.70	781.00	81.34
Female (p.p.)	47.99	0.00	49.96
Age (years)	50.13	50.00	13.35
White collar occupation (p.p.)	44.14	0.00	49.66
Observations	7,707,003		

a 30-year term and a balance below the conforming loan limit. We find that average interest rates at origination in this sample align fairly closely with the PMMS average, with an average difference of 7 basis points.

We also construct a sample of individuals who do not have a mortgage for use in placebo checks. We select individuals who do not have a mortgage between 2010 and 2024, including owners who have already paid off a mortgage and renters. We construct a counterfactual aggregate Δr for these borrowers who do not have a mortgage (and hence do not have an origination date) as the difference between the aggregate interest rate at the time of their last observed move and the current aggregate interest rate. We show summary statistics for this sample in Internet Appendix Table IA.I. As we would expect given that this sample includes renters, the average moving rate in this sample is 14.81%, substantially higher than the 7.52% in our baseline sample (Table I). Also, since the counterfactual Δr is set to zero with every move and borrowers in this sample move more, the counterfactual Δr varies less than the true Δr in our baseline sample.

B. Empirical Strategy

B.1. Baseline

Define household i's mortgage rate delta at time t, Δr_{it}, as the difference between the mortgage rate that the household locked in at the time of origination

$o(i)$, $r_{io(i)}$, and the current prime mortgage rate, r_t:

$$\Delta r_{it} = r_{io(i)} - r_t. \tag{24}$$

Consider a model that relates household moving rates to mortgage rate deltas:

$$\mathrm{I}[\text{Moved}]_{it\rightarrow t+1} = \alpha + \beta X_{it} + \gamma \Delta r_{it} + \varepsilon_{it}, \tag{25}$$

where i is a household, t is the year of observation, X_{it} is a vector of controls, and γ is the causal effect of mortgage rate lock-in on moving rates.

The key challenge that our empirical strategy seeks to overcome is that OLS estimates of equation (25) will be biased if moving rates are correlated with unobserved determinants of mortgage rate deltas. One concern is that household choices and characteristics might be related to both their propensity to move and their mortgage rate. For instance, more financially sophisticated households may shop around and obtain lower rates, but also move more.[17]

We estimate the effect of mortgage rate lock-in on moving rates by instrumenting household-specific mortgage rate deltas with the aggregate mortgage rate delta determined by current mortgage rates and mortgage rates in the month of mortgage origination:

$$\text{Aggregate } \Delta r_{it} = r_{o(i)} - r_t, \tag{26}$$

where $r_{o(i)}$ is the average 30-year fixed prime mortgage rate in the month of individual i's loan origination and r_t is the average 30-year fixed prime mortgage rate at time t.[18] We thus isolate the variation in mortgage rate lock-in coming solely from the timing of mortgage origination.

The first stage of this IV research design takes the form:

$$\Delta r_{it} = \delta_{z(i)} + \kappa_{c(i)t} + \alpha_1 \text{Aggregate } \Delta r_{it} + \alpha_2 X_{it} + \varepsilon_{it}, \tag{27}$$

where $\delta_{z(i)}$ are zip code fixed effects, $\kappa_{c(i)t}$ are county×year fixed effects, and X_{it} includes the log mortgage balance, mortgage payment, remaining mortgage term, credit score, age, age squared, gender, and a zip code house price index. We double cluster standard errors at the county and origination-month-year throughout.

The reduced-form equation relating moving rates and our IV takes the form:

$$\mathbb{I}[\text{Moved}]_{it\rightarrow t+1} = \delta_{z(i)} + \kappa_{c(i)t} + \gamma_1 \text{Aggregate } \Delta r_{it} + \gamma_2 X_{it} + \varepsilon_{it}. \tag{28}$$

We estimate the following second-stage equation using two-stage least squares:

$$\mathrm{I}[\text{Moved}]_{it\rightarrow t+1} = \delta_{z(i)} + \kappa_{c(i)t} + \beta_1 \widehat{\Delta r_{it}} + \beta_2 X_{it} + \varepsilon_{it}, \tag{29}$$

[17] Alternatively, households could choose to purchase points to reduce their mortgage rate when they anticipate that they are unlikely to move (Stanton and Wallace (1998)).

[18] For individuals with more than one mortgage loan, we compute a weighted average 30-year fixed rate across all originations, weighting by loan balance. We show robustness to restricting the sample to borrowers with one mortgage in Section IV.A.

where $\widehat{\Delta r_{it}}$ represents predicted mortgage rate deltas from estimating the first-stage equation (27) and β_1 is our main coefficient of interest.

Our two key identifying assumptions are that (i) aggregate mortgage deltas are associated with household-specific mortgage deltas and (ii) aggregate mortgage deltas only affect moving rates through their effect on household-specific mortgage deltas. The first assumption is empirically testable. Our first-stage F-statistic exceeds 1,000, indicating a strong instrument.

The second assumption would be violated if, conditional on controls, the timing of mortgage origination is related to moving rates through channels other than its effect on the aggregate mortgage delta. For instance, one concern is that financially sophisticated households might be more likely to time their mortgage origination and may have different moving propensities from unsophisticated households. While the exclusion restriction is untestable, we conduct a range of robustness checks that support a causal interpretation of our findings.

We directly address the issue of origination timing in Section IV.A by exploiting increasingly narrow sources of variation in aggregate mortgage deltas. We show that our results are qualitatively identical and quantitatively larger when we restrict the sample to individuals with only one mortgage, for whom we have a single origination date, and include origination year, origination half-year, or origination quarter-year fixed effects. In the most stringent of these specifications—with origination quarter-year fixed effects—variation in aggregate mortgage deltas comes from monthly variation in aggregate mortgage rates within the same quarter of the house purchase. This specification compares individuals who had a mortgage originated in, for instance, January, with those with a mortgage originated in February or March of that same year. Conditional on observables, it seems plausible that households cannot perfectly time their mortgage originations or predict the current level of mortgage rates within the span of a quarter. Moreover, by comparing households that originated within the same quarter, this specification also controls for differences in the time since the last loan origination, which may affect the propensity to move.

We support this assumption with the results of balancing regressions, shown in Figure 2. This test shows that, once we include origination quarter-year fixed effects, our IV does not correlate with individual or loan characteristics. In particular, we show that the instrument does not correlate with the log mortgage balance, fraction of the loan paid off, years since origination, remaining mortgage term, original mortgage term, credit score at origination, age, gender, education, and occupation. There is also no correlation with whether the borrower refinanced at $t-1$ or with their total number of refinancing events up to $t-1$, which is reassuring given evidence that financially sophisticated households use refinancing differentially and obtain lower rates (e.g., Keys, Pope, and Pope (2016), Agarwal, Rosen, and Yao (2016), Andersen et al. (2020), Agarwal et al. (2023b), Berger et al. (2023), Fisher et al. (2024)). These results underscore that our findings are unlikely to be driven by differences in loan or individual characteristics.

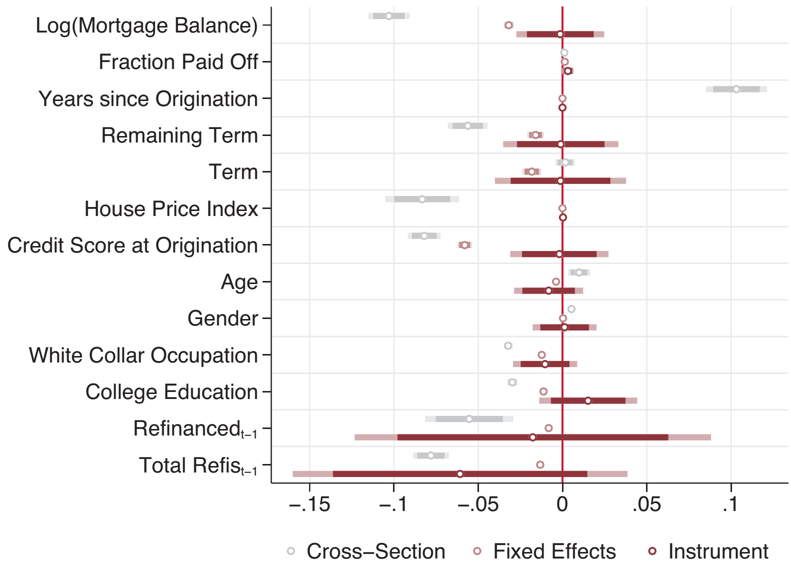

Figure 2. Balancing regressions. This figure shows coefficients of balancing regressions for a range of covariates, denoted in the y-axis. Cross-Section refers to OLS regressions of covariates on Δr without the inclusion of fixed effects. Fixed-Effects refers to OLS regressions of covariates on Δr with the inclusion of zip code, county-year, and origination quarter-year fixed effects. Instrument refers to OLS regressions of covariates on aggregate Δr with the inclusion of zip code, county-year, and origination quarter-year fixed effects. *Log(Mortgage Balance)* is the log of the current mortgage balance. *Fraction Paid Off* is the ratio between the current mortgage balance and the highest balance. *Years since Origination* is the time in years since the loan was originated. *Remaining Term* is the number of years until maturity. *Term* is the loan term in years. *House Price Index* is a zip code–level house price index. *Credit Score at Origination* is the borrower's credit score at the time the loan was originated. For borrowers with multiple originations, we take the credit score associated with the first origination. *Age* is the borrower's age in years. *Gender* is a binary variable equal to one if the borrower is female. *White Collar Occupation* is a binary variable equal to one if the borrower is occupied in managerial, technical, professional, or clerical work. *College Education* is a binary variable equal to one if the borrower as at least some college education. $Refinanced_{t-1}$ is a binary variable equal to one if the borrower refinanced between $t-2$ and $t-1$. $Total\ Refis_{t-1}$ is the number of times that the borrower refinanced up to $t-1$. All variables are standardized to have a mean of zero and a standard deviation of one. Dark bars and light bars denote 95% and 99% confidence intervals, respectively. Regressions do not include controls and standard errors are double clustered at the county and origination-month-year level. (Color figure can be viewed at wileyonlinelibrary.com)

Moreover, we provide indirect evidence in support of a causal interpretation of our results in Section IV.B by conducting an event study using the 2022 tightening cycle. We show that moving rates decline sharply after rates start rising. We also use the 2022 rate increase as another instrument to obtain an alternative estimate of the elasticity of moving with respect to mortgage deltas. Note that the exclusion restriction in this analysis requires that the post-2022 effect on moving come solely from the post-2022 effect on mortgage deltas. This assumption is stronger than the identifying assumptions behind our baseline IV analysis but, because it relies on a sharp change in mortgage rates and not the timing of origination, it is less susceptible to the concern that the timing of mortgage origination correlates with moving. We use this alternative approach to obtain a separate estimate of the elasticity of moving with respect to mortgage deltas and find that it is comparable to our baseline result.

Finally, we also conduct a placebo check in Section IV.C in a sample of renters and outright owners and show that moving is not related to counterfactual mortgage deltas, constructed using information on individuals' last observed move.

B.2. Interaction with Employment Opportunities

Our theoretical framework predicts that mortgage rate lock-in also modulates households' responsiveness to shocks to the monetary benefit of moving, such as shocks to employment opportunities. To generate shocks to employment opportunities that require moving, we instrument wage growth in nearby counties using a shift-share IV that interacts past industry-level wage shares with aggregate industry-level wage growth.

Let $w_{\ell t}$ denote wage growth in area ℓ in year t. We can write:

$$w_{\ell t} = \sum_k z_{\ell k} g_{\ell k t},$$

$$g_{\ell k t} = g_{kt} + \tilde{g}_{\ell k t},$$

where $z_{\ell k}$ is the wage share of industry k in area ℓ, and $g_{\ell k t}$ is the wage growth of industry k in area ℓ in year t. The latter has two components: g_{kt}, the national wage growth of industry k, and $\tilde{g}_{\ell k t}$, the idiosyncratic component of wage growth for industry k in area ℓ in year t.

We instrument $w_{\ell t}$ using a Bartik (1991) instrument:

$$b_{\ell t} = \sum_k z_{\ell k} g_{kt}.$$

The instrument exploits the fact that past local industry wage shares are predetermined and that industry-level wage growth at the national level is plausibly exogenous to local-area wage growth. We construct past local industry wage shares $z_{\ell k}$ using data from 2007, three years prior to the start of our sample.

For a household residing in county c, we define a local area ℓ as all counties within a 50- to 150-mile ring of county c. We describe the construction of county rings in Internet Appendix Section III. We impose that counties in county ring ℓ be at least 50 miles from the county of residence c to capture wage growth in labor markets that are farther than most Americans are willing to commute.[19] We show robustness to varying both the inner and outer bounds of county rings

[19] For instance, Rapino and Fields (2013) define workers who travel 50 miles or more to work one-way as "long-distance commuters" and as "mega commuters" if it takes them 90 minutes or more to travel this distance.

in Section IV.D and illustrate the different ring sizes we consider as robustness in Internet Appendix Figure IA.10.

We estimate the following second-stage regression using two-stage least squares:

$$\text{I[Moved out of County]}_{it\to t+1} = \delta_{l(i)} + \kappa_t + \gamma\widehat{w}_{l(i)t} + \beta X_{it} + \varepsilon_{it}, \quad (30)$$

where $\widehat{w}_{l(i)t}$ represents fitted values from the first-stage regression. In order to test whether the responsiveness of moving to local wage growth varies with the degree of mortgage rate lock-in, we estimate equation (30) separately for borrowers with aggregate mortgage deltas above or below the sample median.

B.3. Effect on Flows in and out of Self-Employment

While the exercise described in Section II.B.2 tests one of our key model predictions, it is also indirect given that we do not observe individuals' employment opportunities or outcomes. To supplement this test and provide direct evidence that mortgage lock-in affects the allocation of workers across jobs, we turn to an employment outcome that we can measure in our credit panel: self-employment. As we describe in Section II.A, we measure self-employment using whether the individual has a business credit record. We have access to two snapshots of this link, from 2020 and 2023. We thus flag individuals as having entered self-employment between 2020 and 2023 if they are linked to a business record in 2023 but not in 2020. Conversely, we define exits from self-employment as individuals who are linked to a business record in 2020 but not in 2023.

Since we only have access to a snapshot of entry and exit between 2020 and 2023, we run a cross-sectional version of our baseline regression equation (29) measuring mortgage deltas in 2019, the year preceding our first self-employment snapshot:

$$Y_{i2020\to 2023} = \delta_{z(i)} + \kappa_1\widehat{\Delta r}_{i2019} + \kappa_2 X_{i2019} + \varepsilon_{i2019}, \quad (31)$$

where $Y_{i2020\to 2023}$ is either entry into or exit from self-employment between 2020 and 2023 and $\widehat{\Delta r}_{i2019}$ represents fitted values from the first-stage regression of 2019 Δr on 2019 Aggregate Δr. The vector of controls X_{i2019} includes log mortgage balance, mortgage payment, remaining mortgage term, credit score, age, age squared, and gender. Unlike our baseline specification, we do not include a zip code house price index, which is absorbed by zip code fixed effects $\delta_{z(i)}$ in this cross-sectional specification.

III. Main Results

We begin by estimating the effect of mortgage rate lock-in on moving rates. We then explore how moving responds to shocks to employment opportunities and how that relationship changes with the degree of mortgage lock-in.

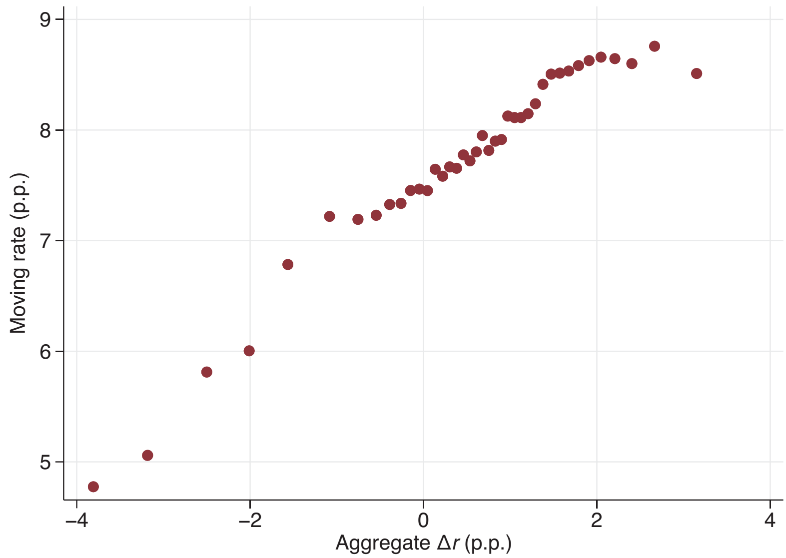

Figure 3. Moving rates and aggregate mortgage rate deltas. This figure shows a binned scatter plot of the relationship between individual-level moving rates and aggregate mortgage rate deltas. Variables are residualized from controls. Controls include mortgage balance, mortgage payment, remaining term, credit score, age, age squared, gender, a zip code house price index, and county×year fixed effects. (Color figure can be viewed at wileyonlinelibrary.com)

A. *Mortgage Lock-In and Moving Rates*

One of the key predictions of our framework is that mortgage rate deltas affect moving rates up to a point and, from that point onward, there is no relationship between the two variables (Prediction 1). Our framework also predicts that the kink point happens in the strictly positive region of Δr (Prediction 2).

In Figure 3, we provide graphical evidence consistent with these predictions through a binned scatter plot of the relationship between moving rates and aggregate mortgage rate deltas, with both variables residualized from controls. As our framework predicts, there is a kink in the relationship between aggregate mortgage rate deltas and moving rates in the strictly positive region of aggregate deltas. The kink point is at a level of around 1.8 p.p., broadly consistent with recent estimates (Andersen et al. (2020), Fisher et al. (2024)) and survey measures of refinancing costs (Keys, Pope, and Pope (2016)), amounting to around 3,000 USD at a median loan balance of 165,290 USD. Using the Cattaneo et al. (2024) parametric specification test, we reject the null of a linear relationship between mortgage rate deltas and moving rates at a 0.01 level. We also use the Cattaneo et al. (2024) least squares semilinear method as an alternative to residualizing variables from controls and find a very similar binned scatter plot that also displays a kink at around 1.8 p.p. (Internet Appendix Figure IA.4).

Table II reports estimates of the effect of mortgage rate deltas on moving rates for the full sample period in columns 2 to 4 and for the 2022 to 2024

Table II
The Effect of Mortgage Rate Deltas on Moving Rates

Columns 1 and 5 report OLS estimates of equation (29). Columns 2 and 6 report estimates of the first-stage equation (27). Columns 3 and 7 report estimates of the reduced form equation (28). Columns 4 and 8 report two-stage least squares estimates of equation (29). In columns 1 to 4, we use our full sample from 2010 to 2024. In columns 5 to 8, we restrict attention to the period from 2022 onward. Controls include mortgage balance, mortgage payment, remaining term, credit score, age, age squared, gender, and a zip code house price index. Standard errors, reported in parentheses, are double clustered at the county and origination-month-year level. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Sample Period:	2010–2024				2022–2024			
Dependent variable:	*I[Moved]* OLS (1)	Δr FS (2)	*I[Moved]* RF (3)	*I[Moved]* IV (4)	*I[Moved]* OLS (5)	Δr FS (6)	*I[Moved]* RF (7)	*I[Moved]* IV (8)
Δr	0.23***			0.69***	0.36***			1.20***
	(0.02)			(0.07)	(0.07)			(0.25)
Aggregate Δr		0.57***	0.39***			0.66***	0.79***	
		(0.01)	(0.04)			(0.02)	(0.18)	
Zip code FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County×Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-stat		3,169.63				1,755.95		
Observations	7,707,003	7,707,003	7,707,003	7,707,003	1,118,201	1,118,201	1,118,201	1,118,201

period in columns 5 to 8. We report OLS estimates in columns 1 and 5, which show a positive correlation between household-specific mortgage rate deltas and moving rates. In columns 2 and 6, we report the first-stage estimate of equation (27). We find that a 1 p.p. increase in the aggregate mortgage rate delta is associated with a 0.57 p.p. increase in the household-specific mortgage rate delta in the full sample (column 2).[20] The first-stage F-statistic is above 1,000, implying that the aggregate mortgage rate delta is a strong instrument. Columns 3 and 7 report the reduced-form estimate and columns 4 and 8 report the two-stage least squares estimate of equation (29). We estimate that a 1 p.p. increase in mortgage rate deltas leads to a 0.69 p.p. increase in moving rates in the full sample (column 4), or 9% of the sample mean. This estimate is substantially higher at 1.20 p.p. in 2022 to 2024 (column 8), or 16% of the 2010 to 2024 sample mean.

The IV estimates of columns 4 and 8 are higher than the respective OLS estimates of columns 1 and 5, suggesting that the latter are downward biased. OLS estimates might be downward biased if, for example, financially sophisticated borrowers lock in lower mortgage rates (leading to lower mortgage rate deltas) and are more likely to move than unsophisticated borrowers. We show evidence in favor of this explanation in Internet Appendix Table IA.II by constructing two measures of financial sophistication based on whether borrowers have a white collar occupation or a college education. According to either of these measures, financially sophisticated borrowers lock in lower rates (columns 1 and 2) and move more (columns 3 and 4).

Finally, in Internet Appendix Table IA.III, we report estimates of the effect on moving rates before and after the kink point in the relationship between aggregate mortgage rate deltas and moving rates. We do so by estimating equation (29) separately for borrowers with aggregate $\Delta r \leq 2$ and aggregate $\Delta r > 2$, respectively. A 1 p.p. increase in mortgage rate deltas leads to a 1.07 p.p. increase in moving rates for borrowers with aggregate $\Delta r \leq 2$, who are in the upward-sloping portion of the relationship between aggregate deltas and moving rates (column 3). By contrast, mortgage rate deltas have a small negative effect on moving rates for borrowers with aggregate Δr beyond the kink point (column 6), which may reflect a selection effect as borrowers who do not refinance when it would be advantageous to do so may also be less likely to move.[21] This nonlinearity can explain why the effect of lock-in is so much stronger in 2022 to 2024 than in the full sample (Table II, column 8 vs. 4): More than 99% of borrowers in 2022 to 2024 have an aggregate Δr lower than 2. In fact, we

[20] Note that the first-stage coefficient is below 1, meaning that individual mortgage rates rise by less than 1 p.p. when the market rate, measured as the average mortgage rate for prime borrowers, rises by 1 p.p. This is consistent with evidence that the gap between median rates on offer and the rates that borrowers pay is negatively correlated with the level of interest rates (Bhutta, Fuster, and Hizmo (2020)), potentially because borrowers search and negotiate more or are more likely to use points when rates are high.

[21] To ensure that this potentially selected sample is not driving the results on employment opportunities described in Section III.B, we show that results are robust to excluding borrowers beyond the kink point in Internet Appendix Table IA.IV.

Figure 4. Moving rates and wage growth by degree of mortgage rate lock-in. This figure shows a binned scatter plot of the relationship between out-of-county moving rates and wage growth in counties within a 50- to 150-mile ring. Variables are residualized from controls. Controls include mortgage balance, mortgage payment, remaining term, credit score, age, age squared, gender, a zip code house price index, and county and year fixed effects. High and low aggregate Δr refer to borrowers who are above or below the sample median aggregate Δr, respectively. (Color figure can be viewed at wileyonlinelibrary.com)

cannot reject that the 2022 to 2024 coefficient (Table II, column 8) is equal to the 2010 to 2024 coefficient for borrowers with aggregate Δr lower than 2 (Internet Appendix Table IA.III, column 3)

B. Interaction of Lock-In with Employment Opportunities

Next, we test the third prediction of our model: that mortgage rate deltas attenuate the sensitivity of moving rates to a moving shock. We explore how mortgage lock-in affects labor reallocation by studying the response of moving rates to employment opportunities and how this response varies with the degree of mortgage rate lock-in. We start by illustrating our main findings with a binned scatter plot of the relationship between out-of-county moving rates and predicted wage growth counties within a 50- to 150-mile ring in Figure 4. Consistent with our theoretical prediction, we find that the slope of this relationship is higher for borrowers with above-median aggregate Δr than for those with below-median aggregate Δr. This implies that borrowers who have locked in lower mortgage rates (and thus have lower mortgage rate deltas) move at lower rates in response to higher wages in surrounding counties.

Table III reports estimates of equation (30) separately for borrowers with below-median (columns 1 to 3) and above-median aggregate mortgage rate delta (columns 4 to 6). Columns 1 and 3 report OLS estimates and show no

Table III

The Effect of Wage Growth on Moving Rates by Degree of Lock-In

Columns 1 and 4 report OLS estimates of the relationship between out-of-county moving rates and wage growth in counties within a 50- to 150-mile ring. Columns 2 and 5 report first-stage estimates of the Bartik wage growth IV. Columns 3 and 6 report two-stage least squares estimates of equation (30). High and low aggregate Δr refer to borrowers who are above or below the sample median aggregate Δr, respectively. Controls include mortgage balance, mortgage payment, remaining term, credit score, age, age squared, gender, and a zip code house price index. Standard errors, reported in parentheses, are double clustered at the county and origination-month-year level. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Dependent Variable:	*I[Moved out of County]*					
Aggregate Δr Group:		Low			High	
	OLS	FS	IV	OLS	FS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Wage growth	−0.09***		−0.02	−0.01		0.20***
	(0.03)		(0.09)	(0.02)		(0.06)
Wage growth IV		1.82***			1.77***	
		(0.12)			(0.09)	
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-stat		241.33			390.83	
P-value of (3) = (6)						0.04
Observations	3,342,173	3,342,173	3,342,173	3,813,962	3,813,962	3,813,962

significant correlation between wage growth and moving for borrowers with high or low aggregate Δr. Columns 2 and 4 report first-stage estimates, with F-statistics of nearly 400 for both groups of borrowers. Columns 3 and 6 report estimates of equation (30). For borrowers with low aggregate mortgage delta, a one standard deviation increase in nearby wage growth has a small and statistically insignificant effect on moving (column 3). On the other hand, out-of-county moving increases by 0.20 p.p. for borrowers with high mortgage delta, and that estimate is significant at 1%. We show that these results are robust to using different samples and alternative definitions of county rings in Section IV.D.

These results imply that mortgage rate lock-in modulates borrowers' response to employment opportunities, with borrowers who have locked in lower rates being less likely to move in response to rising wages. While we do not observe individual employment outcomes, these results are suggestive of mortgage lock-in impacting the allocation of workers across locations and jobs, with some households foregoing higher paid employment opportunities due to the financial cost imposed by lock-in.

To quantify the magnitude of potentially foregone wages by not moving, we employ the National Industry-Specific Occupational Employment and Wage Estimates by the U.S. Bureau of Labor Statistics. These provide estimates of moments of the wage distribution across detailed industry occupation groups at the Core-Based Statistical Area (CBSA) level, which we further describe in Internet Appendix Section IV. We find that the interquartile wage range within CBSA for the average occupation is around 24,000 USD, while it is 36,000 USD across CBSAs. As a result, for the average occupation, a job move outside of the CBSA can raise the interquartile wage gap by another third in addition to moving jobs within the CBSA. The across-CBSA wage gradient differs across occupations. For instance, the across-CBSA interquartile range of wages is 99,830 USD for General and Operations Managers and only 9,650 USD for Medical Assistants.

These data suggest that across-CBSA moves can lead to quantitatively impactful wage increases. This implies that not moving across areas in response to employment opportunities—a consequence of lock-in that we document in this section—leads to potentially large losses that differ across occupations.

C. Mortgage Lock-In and Small Business Ownership

To provide direct evidence that mortgage lock-in affects the allocation of workers across jobs, we turn to the effect on flows in and out of self-employment, which we measure using snapshots of the link between consumer and small business credit records in 2020 and 2023.

The effect of lock-in on entry into small business ownership is ex ante ambiguous. We might expect mortgage lock-in to reduce entry because lock-in reduces mobility, which is correlated with starting a business. Manuel (2024) finds that individuals who recently moved within the United States are 43% more likely to start a business, echoing prior work on international migration and entrepreneurship (e.g., Fairlie and Lofstrom (2015), Kerr and Kerr (2020), Azoulay et al. (2022)). We find similar results on the correlation between moving and self-employment in the GCCP. In Internet Appendix Table IA.V, we show estimates of OLS regressions of small business entry (columns 1 to 2) and exit (columns 3 to 4) between 2020 and 2023 on both recent (columns 1 and 3) and future moving (columns 2 and 4). Individuals who moved between 2020 and 2023 are 2.5 p.p. or 44% more likely to become self-employed between 2020 and 2023 (column 1).

While it is likely that this correlation is driven partly by selection—as the types of individuals who move are more likely to start businesses—it may also reflect a causal relationship between moving and entrepreneurship. For instance, moving might expose individuals to new markets and opportunities to start a business. Moreover, the main goal of many small businesses is to provide an income to the business owner (Schoar (2010)). Thus, when individuals are forced to quit a salaried job because of a non–work-related move or a move related to a spouse's work, they might be more likely to start a business as they search for new income sources. To the extent that there is a causal relationship between moving and entrepreneurship, we should expect lock-in to reduce business entry.

Mortgage lock-in could also affect small business entry through its impact on the outside option of earning wage income. As we argue in Section III.B,

Table IV

The Effect of Mortgage Rate Deltas on Business Entry and Exit

All columns report two-stage least squares estimates of equation (31). Columns 1 and 2 report results for our baseline sample of mortgage borrowers. Columns 3 and 4 report results for a sample of renters and outright owners. We construct a counterfactual Δr for each individual in the sample of renters and outright owners using the average prime rate in the year of their last observed move. Controls include mortgage balance, mortgage payment, remaining term, credit score, age, age squared, and gender in columns 1 and 2. In columns 3 and 4, we do not control for mortgage balance, mortgage payment, and remaining term since individuals do not have a mortgage. Standard errors, reported in parentheses, are double clustered at the county and origination-month-year level in columns 1 and 2 and at the county and year-of-last-move level in columns 3 and 4. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Sample:	Baseline		Placebo Check: No Mortgage	
Dependent Variable:	*Bus.* $Entry_{2020\rightarrow 2023}$ (1)	*Bus.* $Exit_{2020\rightarrow 2023}$ (2)	*Bus.* $Entry_{2020\rightarrow 2023}$ (3)	*Bus.* $Exit_{2020\rightarrow 2023}$ (4)
Δr_{2019}	0.26***	0.30***	−0.17	−0.07
	(0.06)	(0.07)	(0.16)	(0.07)
Sample mean (p.p.)	5.72	2.02	1.84	0.48
% Change	4.63	14.87	−9.42	−15.34
Zip code FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	584,551	584,551	42,186	42,186

lock-in increases the reservation wage for jobs that require moving. Thus, self-employment might become more attractive relative to salaried employment to the extent that it does not require moving. On the other hand, lock-in might lead to less entrepreneurial activity by reducing job transitions, given that knowledge spillovers from different employers and peers can spur employee entrepreneurship (see Agarwal and Shah (2014) for a survey of this literature).

In terms of exits from self-employment, the channels described above would imply that mortgage lock-in should reduce exits and prolong self-employment spells. In Internet Appendix Table IA.V, we show that individuals are substantially more likely to exit self-employment before moving (column 4). This correlational evidence suggests that mortgage lock-in could dampen flows out of self-employment by reducing mobility. Similarly, lock-in could prolong self-employment by making it costlier to move to locations with better or more wage employment opportunities.

In Table IV, we report two-stage least squares estimates of equation (31). Consistent with the mobility and the knowledge spillover channels, we find that lock-in reduces entry into self-employment. As we expected, lock-in also prolongs self-employment spells by reducing exits. A 1 p.p. decline in 2019 Δr reduces entry into small business ownership between 2020 and 2023 by 0.26 p.p. or 5% of the sample mean (column 1) and exits by 0.30 p.p. or 15% (column 2). We are cautious in interpreting this evidence since it is purely cross-sectional and from a period that overlaps with a global pandemic. However, we provide further support for a causal interpretation of these results by using our sample of renters and outright owners to conduct a placebo check, which we report in columns 3 and 4 of Table IV. Coefficient estimates for this sample have the opposite sign and are statistically insignificant.

Note that we cannot determine whether this reallocation reflects misallocation since we do not have data on the productivity of these small businesses or of the business owners as salaried workers. Further work will be needed to determine the consequences of this reallocation for productivity, but these findings provide direct evidence from the 2022–2023 tightening cycle that mortgage lock-in affects the allocation of workers across self-employment and salaried jobs.

IV. Additional Results and Robustness

A. Robustness to Market Timing

In this section, we address the concern that the timing of mortgage origination might affect moving rates through channels other than its effect on aggregate mortgage rate deltas. We do so by restricting the sample to borrowers with a single mortgage, for whom we have a single origination date, and using increasingly narrow sources of variation in origination timing by including origination year, origination half-year, or origination quarter-year fixed effects in equation (29). In the most stringent of these specifications, with origination quarter-year fixed effects, we compare individuals who had their mortgage originated in the same quarter of the same year, exploiting only monthly variation in average 30-year fixed mortgage rates within a quarter.

Conditional on observables, households plausibly cannot perfectly time their mortgage origination or predict the current level of mortgage rates within the span of a quarter. Consistent with this assumption, Figure 2 shows that, once we include origination quarter-year fixed effects, our IV does not correlate with individual or loan characteristics. In particular, the instrument does not correlate with mortgage terms, years since origination, credit score at origination, age, education, occupation, past refinancing behavior, and more. The fact that we obtain balance on years since origination after including origination quarter-year fixed effects illustrates how comparing households that originated within the same quarter also controls for differences in the time since the last loan origination, which may affect the propensity to move.

Internet Appendix Table IA.VI reports the results of this exercise, with column 1 reporting our baseline estimate. In column 2, we show that we obtain a similar coefficient when restricting the sample to borrowers with a single mortgage. Across columns 3 to 5, we see that coefficients become slightly larger as we control for origination timing and remain significant at 1% or 5%, suggesting that our baseline estimate is a conservative estimate of the effect of mortgage lock-in. One interpretation of the fact that coefficients become larger is that, to the extent that omitted variables influence both origination timing and moving rates, they introduce a downward bias in our estimates. This would be the case if, for instance, financially sophisticated households are more likely to time the market to lock in lower rates (leading to lower aggregate mortgage rate deltas) and are more likely to move than unsophisticated households. As we discuss in Section III, we provide evidence in favor of this explanation in Internet Appendix Table IA.II using occupation and education as proxies for financial sophistication.

By comparing borrowers who had a loan originated in the same quarter-year, these results also help alleviate concerns that changes in house prices during the ownership period can also affect moving through their impact on home equity. However, because house price appreciation varies geographically, this specification does not fully control for differential changes in house prices. We further address this in Internet Appendix Table IA.VII by using the date of origination to construct a variable $\Delta HPI_{it} = \frac{(HPI_{it} - HPI_{io(i)})}{HPI_{io(i)}}$, where HPI_{it} is the value of the house price index in the zip code in which borrower i resides at time t and $o(i)$ is the origination year of borrower i. We obtain very similar results when controlling for the change in the house price index, especially in columns 3 to 5, which include origination fixed effects.

B. Event Study

In order to further support a causal interpretation of our findings, we study the response of moving rates to the 2022 interest rate hike. We estimate the following event-study specification:

$$\mathrm{I[Moved]}_{it\to t+1} = \delta_z + \sum_{\tau=2017}^{2023} \gamma_\tau \mathbb{I}[t=\tau] + \beta X_{it} + \epsilon_{it}, \tag{32}$$

where δ_z are zip code fixed effects and the vector of controls X_{it} includes mortgage balance, mortgage payment, remaining term, credit score, age, age squared, gender, and a zip code house price index. Our coefficients of interest are γ_τ, which show the evolution of moving rates across years.

We report coefficient estimates and 95% confidence intervals of equation (32) in Internet Appendix Figure IA.5, with 2020 as the omitted category. We can see that moving rates in our sample were roughly flat prior to the 2022 to 2023 tightening cycle, but sharply decline once interest rates start rising.

We then use the 2022 interest rate increase as another instrument for mortgage rate deltas to obtain an alternative estimate of the elasticity of moving with respect to mortgage deltas. As we show in column 3 of Internet Appendix Table IA.VIII, using as our instrument a variable that equals one for years greater or equal to 2022, we obtain an elasticity of 0.52 that is significant at 1%. The exclusion restriction in this analysis requires that the post-2022 effect on moving come solely from the post-2022 effect on mortgage deltas. To be clear, this assumption is stronger than the identifying assumptions behind our baseline IV analysis but, because this empirical strategy relies on a sharp change in mortgage rates and not the timing of origination, it is less susceptible to the specific concern that the timing of mortgage origination correlates with moving. The alternative estimate of 0.52 is comparable to our baseline elasticity of 0.69.

C. Placebo Check: Renters and Outright Owners

Next, we conduct a placebo check with individuals who do not have a mortgage and show that there is no effect of mortgage lock-in on moving rates in this sample. To do so, we use the sample of renters and outright owners described in Section II.A. We then regress the moving rates of outright owners and renters on the counterfactual Δr, constructed using information on individuals' last observed move. As in our baseline specification, we control for credit score, age, age squared, gender, and a zip code house price index. Unlike our baseline, we do not control for mortgage terms since these borrowers do not have mortgages. We show the results of this exercise in Internet Appendix Table IA.IX. In column 1, we reproduce our baseline estimate (column 4 of Table II). In column 2, we standardize both the moving rate and Δr to have a mean of zero and a standard deviation of one. This allows us to restate the magnitude of our baseline result as follows: a one standard deviation increase in Δr increases moving by 0.059 standard deviations.

Column 3 shows the analogous result of column 1 for the sample of owners and renters. As expected, there is no statistically significant relationship between counterfactual Δr and moving for borrowers who do not have a mortgage. The coefficient in column 3 may seem large, but recall that average moving rates are much larger for this sample (Internet Appendix Table IA.I). In column 4, we standardize both the moving rate and counterfactual Δr to have a mean of zero and a standard deviation of one and show that, when accounting for the mean and standard deviation of these variables, the coefficient is less than a third of our baseline effect, in addition to being statistically insignificant (column 2 vs. column 4). The absence of a mortgage lock-in effect on individuals without a mortgage further supports a causal interpretation of our findings.

D. Wage Growth Analysis Robustness

Next, we show that the results of the wage growth analysis of Section III.B are robust to restricting attention to different samples and to alternative definitions of county neighbor rings. Columns 1 and 2 of Internet Appendix Table IA.IV report our baseline results. In columns 3 and 4, we show that results are quantitatively similar when we restrict attention to borrowers with a single mortgage. In columns 5 and 6, we show that these results are robust to excluding borrowers who are past the kink point of the relationship between mortgage rate deltas and moving rates. Specifically, we exclude from the high aggregate Δr group those borrowers with aggregate $\Delta r > 2\%$. If anything, we find that the difference between borrowers who are more versus less locked in is even starker in this setting. Finally, columns 7 to 12 show robustness to alternative definitions of county neighbor rings. We illustrate these different ring sizes in Internet Appendix Figure IA.10.

E. Robustness to Present Value of Mortgage Payments

In this section, we show that our results are robust to focusing on changes in the present value of mortgage payments (ΔPVM) rather than on interest rate differentials. This measure, which we describe in detail in Internet Appendix Section V, captures how changes in interest rates affect the present value of all mortgage payments and more closely maps to the dollar effect of varying mortgage rates.

In Internet Appendix Table IA.X, we report two-stage least squares estimates of equation (29) with ΔPVM as the explanatory variable and find results that are consistent with our baseline findings, even in terms of magnitudes. In our baseline specification, we find that a 1,000 USD increase in ΔPVM leads to a 0.02 p.p. increase in moving (column 1). This implies that a one standard deviation (63,177 USD) increase in ΔPVM increases moving by 1.26 p.p. (63.177×0.02). Similarly, our baseline estimate suggests that a one standard deviation (2.23 p.p.) increase in Δr leads to a 1.54 p.p. increase in moving.

F. Heterogeneity Analysis

To assess if our findings are driven by particular subgroups of households and to gain better intuition for the baseline result, we reestimate the baseline IV specification of equation (29) separately by quartiles of the 2010 to 2024 average county-level unemployment rate, borrower age, credit score, and loan balance, as well as by broad occupation groups. We show results in Internet Appendix Figure IA.6. The results do not vary significantly by unemployment rate in the household's home county (Panel A). In addition, results are much more pronounced for households in the lowest age quartile (Panel B), which in our sample corresponds to borrowers up to the age of 40. This is consistent with the overall life cycle pattern that people aged 15 to 39 have the highest migration rates, which gradually decline over the life cycle.[22] Results are also stronger for households with an above-median credit score, and households with larger loan balances (Panels C and D), consistent with these households having smaller "stakes" in terms of the loan balance locked in at any given rate, being less responsive to interest rate incentives, or not being able to remortgage optimally.[23] Finally, our estimates are larger for borrowers in white

[22] See, for example, analysis by Brookings Institute: https://www.brookings.edu/wp-content/uploads/2023/02/Figure-4.png.

[23] According to a 2020 report by Freddie Mac, on average about 72% of households maintain the same maturity of their existing loan at refinance in recent years. As a result, most households can

collar occupations (Panel E), consistent with high-skilled workers being more responsive to lock-in.

Next, we assess how estimates vary for different types of moves. In Internet Appendix Table IA.XI, we report estimates of equation (29) for any move (our baseline estimate), and subsequently break down total moves into within-county, out-of-county but within-state, and out-of-state in Panel A and into less than 10 miles, between 10 and 100 miles, and more than 100 miles in Panel B. We find that different types of moves contribute similarly to the effect of mortgage rate deltas on total moves. In particular, lock-in significantly reduces out-of-state moves by 7.85% of the sample mean (Panel A, column 4) and long-distance moves by 9.24% (Panel B, column 4). This is in sharp contrast to related work on negative equity lock-in, which finds that negative equity does not reduce interstate migration (Coulson and Grieco (2013), Foote (2016)). Given that most interstate and long-distance moves are work related (Jia et al. (2023)), the finding of large and significant effects on out-of-state moving reinforces the conclusion that mortgage rate lock-in impacts labor reallocation.

Finally, in Internet Appendix Table IA.XII, we show the effect of lock-in separately on moves to counties with different characteristics. We use county-level variables from Chetty and Hendren (2018) that speak to the desirability of neighborhoods. Across all panels, column 1 shows our baseline estimate, and columns 2 to 4 show the effect on moves to counties with a lower, equal, or higher level of the characteristic.[24]

In Panel A, we can see that being more locked in (lower Δr) reduces moves to all types of counties, but the effect is relatively stronger for moves to counties with lower average third-grade math scores. We show this relative effect, namely the coefficient as a percentage of the sample mean, in the last row of each panel. We find that a 1 p.p. decline in Δr reduces moves to counties with lower math scores by 11.96% of the sample mean (column 2), while moves to counties with higher math scores decline by only 6.79% (column 4). We see a similar pattern in Panel B when sorting destination counties by whether the share of children in the county that graduate high school is lower, the same, or higher than in the origin county. A 1 p.p. decline in Δr reduces moves to counties with lower high school graduation share by 10.25% (column 2), while moves to counties with higher graduation share decline by 8.11% (column 4).

As a separate measure of the desirability of neighborhoods, we show similar results in Panel C using the share of county residents above the poverty line. Much like in Panels A and B, the effect of mortgage lock-in is stronger for moves to less desirable neighborhoods. A 1 p.p. decline in Δr reduces moves to counties with a smaller share of residents above the poverty line by 11.72%

alleviate payment constraints arising from a higher mortgage rate by lowering monthly payments via maturity extension, for instance, by refinancing into another 30-year term, and so these should not prevent households from remortgaging.

[24] These county characteristics are not available for all counties in our sample, which explains why the number of observations in columns 2 to 4 is lower than that of column 1 and also why the coefficients in columns 2 to 4 do not add up to that of column 1.

(column 2), while moves to counties with a larger share of residents above the poverty line decline by only 6.75% (column 4).

This pattern is strikingly different from what we observe using measures of job opportunities. In Panel D, we show results for a similar exercise using the number of jobs within five miles in 2014. In line with the results from Section III.B, mortgage lock-in affects moves to areas with high job opportunities the most. Specifically, we find that a 1 p.p. decline in Δr reduces moves to counties with more jobs within five miles by 12.53% (column 4), while moves to counties with fewer jobs decline by only 6.30% (column 2). Taken together, these results suggest that homeowners who are locked in are more likely to forego job-related moves than moves to more desirable neighborhoods. This suggests that welfare effects from neighborhood desirability are potentially less significant than those stemming from labor reallocation, or lack thereof.

G. Housing Market Outcomes

In this section, we ask whether mortgage lock-in affects households' listing behavior in the housing market, resulting in lower turnover and hence lower liquidity in the market as households move less. We study the relationship between Δr and measures of housing market activity using individual listing data from the CoreLogic Multiple Listing Services, aggregated to the county level. The data cleaning process is described in Internet Appendix Section VI. We estimate the effect of average Δr on the average list price, sales price, and days on the market, all aggregated to the county level and with dependent variables measured in logs. Similarly to our individual-level specification, we use two-stage least squares and instrument county-level average Δr using the average aggregate Δr and include county and year fixed effects and a range of county-level controls, with results shown in Table IA.XIII in the Internet Appendix. We study two sample periods, 2010 to 2019 and 2022 to 2023, and exclude the years 2020 and 2021 due to the strong effects of the pandemic on housing markets (see, e.g., Gupta et al. (2022), Gamber, Graham, and Yadav (2023)).

A 1 p.p. decrease in Δr increases the list price (columns 1 and 4) and realized sales price (columns 2 and 5) by 11% and 11% to 13%, respectively, and reduces the average number of days on the market (columns 3 and 6) by 18% to 33%. The effects are consistent with mortgage lock-in reducing the local supply of listings, raising list and sales prices, and reducing time on the market, with the latter effect being more pronounced over the 2022 to 2023 period.

These findings are consistent with recent evidence on the importance of list prices for measuring responses to monetary policy shocks to long-term rates (Anenberg and Laufer (2017), Swanson (2021), Gorea, Kryvtsov, and Kudlyak (2022)). Gorea, Kryvtsov, and Kudlyak (2022) show that list prices respond asymmetrically: They rise in response to easing shocks but do not decrease in response to tightening shocks. This is consistent with mortgage lock-in leading to asymmetric responses in the housing market, at least in the short term.

The household-specific decision not to move may further pose an externality on the aggregate housing market and other buyers such as first-time buyers and households looking to relocate by reducing liquidity. This could further reduce mobility as households may factor in the lack of liquidity when deciding whether to buy or sell.[25] The effects on *aggregate* house prices are somewhat ambiguous in equilibrium: While locked-in households are less likely to sell their existing house and so will put fewer houses up for sale locally, they are also not looking to buy houses elsewhere, likely reducing demand for houses in other locations. The net effect of lock-in on house prices is highly policy-relevant, as it would determine to what extent lock-in can generate inflationary effects on the housing market. While outside of the scope of our paper, we think these issues motivate future empirical and theoretical work on the topic.

H. Expected Lock-In Values

How locked in are households and does the degree of lock-in vary across households and locations? To answer this question, we compute the expected dollar value of lock-in by comparing the expected present value of future mortgage payments under the locked-in rate to that of a similar loan initialized at prevailing mortgage rate levels of 7%. Importantly, this requires simulating uncertain future mortgage rate paths and allowing households to refinance optimally should rates decrease. This expected lock-in value can be thought of as the minimum compensation that households would require to give up the mortgage rate that they have currently locked in.[26]

We briefly describe our approach below, with more detail provided in Internet Appendix Section VII. We obtain average mortgage rates, loan balances outstanding, and remaining mortgage term as of March 2024 from the GCCP. We use these data to compute expected lock-in values for the average U.S. mortgage borrower, as well as for the average borrower at the state and county level. Households face a stochastic interest rate process calibrated as in Campbell and Cocco (2015) and optimally refinance according to the interest rate gap rule derived by Agarwal, Driscoll, and Laibson (2013), at which point they pay a fixed cost of refinancing.[27]

The average U.S. household has locked in a rate of 4.34% as of March 2024, with an average loan balance of 271,493 USD, and a remaining term

[25] For instance, Anenberg and Bayer (2020) show that most households face a joint sales-and-buying problem when deciding whether to move, such that a lack of inventory in the market where they would want to buy may also affect their decision to put their own house on the market, causing a coordination problem.

[26] The measure does not account for household risk aversion, that is, the certainty equivalent would likely be higher.

[27] Our simulation approach likely provides a conservative estimate as households are assumed to refinance optimally and promptly, which would lower the difference in mortgage payments if rates decrease in the future. Agarwal et al. (2023b) further show that higher income households with larger loan balances were more active refinancers during the refinancing wave of 2020 to 2021, likely magnifying actual expected lock-in values and differences in lock-in values across households.

of approximately 21 years. The expected difference in discounted mortgage payments and refinancing costs starting with a market rate of 7%, compared to the locked-in rate of 4.34%, is around 51,000 USD. In Internet Appendix Figure IA.13, we show that this value varies across states, with an average expected lock-in value of around 104,000 USD in California, but only 31,000 USD in Ohio. Variation in expected lock-in values is affected by average loan values and hence house prices in a given location. To get a sense of how large this value is relative to local incomes, we scale these values by the average income of mortgage borrowers in the state. States such as California, Utah, Washington, and Colorado have some of the highest average values as a share of income, with lock-in values between 70% to 80% of annual income for these borrowers.

We further show that there is significant within-state variation in lock-in values across counties (Internet Appendix Figure IA.14). The results point to a rural-urban divide even when scaled by average county-level incomes, with households in urban areas being more locked in than nonurban areas. We also show in Internet Appendix Figure IA.15 that higher expected lock-in values are closely related to larger declines in the number of houses listed for sale between 2022 and 2024 at the county level (Panel A). They are only somewhat correlated with more days spent working from home (Panel B), suggesting that working from home may only be a partial remedy for the reduction in mobility caused by lock-in—although lock-in itself may also increase the demand for working from home going forward.

The heterogeneity we document in expected lock-in values is important in light of existing works by Ludwig et al. (2013), Chetty et al. (2014), Chetty, Hendren, and Katz (2016), Chetty and Hendren (2018), Bergman et al. (2024), and Finkelstein, Gentzkow, and Williams (2021) who emphasize the causal importance of place effects and geographic mobility for long-run outcomes in education, crime, health, and income (Chyn and Katz (2021)). Our estimates point to current substantial frictions to geographic mobility valued at up to 80% of average annual income for most mortgage borrowers in the United States. While interest rates may decrease in the future, our estimates are expectations computed over a range of simulated future interest paths and reflect that a baseline calibration for interest rates implies a relatively small probability that interest rates will decrease to levels below average locked-in rates. Given that the expected value of lock-in varies substantially across locations, lock-in may have heterogeneous effects on socioeconomic mobility and long-run outcomes over the foreseeable future.

V. Conclusion

This paper provides causal evidence of the effect of mortgage lock-in on moving and labor reallocation. We document three main findings. First, household moving rates decline as mortgage rate deltas decrease, or as households incur a greater financial cost when remortgaging. We estimate that a 1 p.p. decline in Δr reduces moving rates by 0.69 p.p. (9%) overall and by 1.20 p.p. (16%) in 2022 to 2024. Based on these estimates, we can conduct a simple back-of-the-envelope exercise for the effect of the 2022 to 2023 rise in interest rates on mobility, which led to approximately a 3 p.p. reduction in Δr for the average borrower. Our range of estimates suggests that the recent tightening cycle reduces mobility by between $3 \times 9\% = 27\%$ and $3 \times 16\% = 48\%$ for mortgage borrowers. Naturally, this extrapolation comes with many caveats, including that it will not reflect general equilibrium effects and movers without a mortgage.

Second, we show that this effect is asymmetric: Once Δr is high enough so that the benefit of refinancing exceeds the cost, moving probabilities become unrelated to Δr. This nonlinearity explains why the effect is higher in the 2022 to 2024 period when the vast majority of borrowers are in the range in which moving is sensitive to Δr. Third, we find that low Δr attenuates household responsiveness to moving shocks in the form of higher wage employment opportunities. Using a shift-share instrument for wage growth in counties within a 50- to 150-mile ring, we show that the responsiveness of out-of-county moving rates to wage growth is dampened for households who are more locked in (below-median aggregate Δr). We also show that mortgage lock-in dampens flows in and out of self-employment, providing direct evidence of an impact on the allocation of workers across jobs.

These findings highlight unintended consequences of monetary tightening in the presence of long-term fixed-rate mortgages. The predominant mortgage contract in the United States, the 30-year fixed-rate mortgage, provides households with insurance against interest rate increases but can cause prolonged periods of mortgage lock-in when mortgage rates rise. This further highlights the unique mortgage composition of the United States, with average interest rate fixation length in most other countries not exceeding 10 years (Badarinza, Campbell, and Ramadorai (2016), Liu (2022)). Mortgage lock-in contributes to a list of challenges with fixed-rate mortgages (Campbell (2023)), including weak monetary transmission (Di Maggio et al. (2017)), refinancing inequality (e.g., Andersen et al. (2020), Zhang (2022), Agarwal et al. (2023b), Berger et al. (2023), Fisher et al. (2024)), and financial stability risks (e.g., Jiang et al. (2024)), emphasizing the role of alternative mortgage contract designs (Campbell (2012), Eberly and Krishnamurthy (2014), Piskorski and Seru (2018)).

Our findings also underscore the importance of mortgage market policies that alleviate lock-in. Policymakers face a substantial ex post challenge: A large stock of mortgages is already outstanding at low rates and held by investors in mortgage-backed securities, with no contractual option for households to keep the low rate if they decide to move. Similar to mortgage policies following the Great Recession such as the Home Affordable Modification Program and the Home Affordable Refinance Program, any renegotiation process would be mediated by intermediaries such as mortgage servicers, and policies would thus need to take into account competitive frictions and intermediary-specific incentives (Agarwal et al. (2017, 2023a)).

In addition, lock-in raises the importance of alternative mortgage contract designs ex ante. In most countries other than the United States, mortgage contracts have some degree of assumability (allowing buyers to assume an existing mortgage on the same property), or portability (allowing borrowers to transfer their mortgage to a new property), such that households can move without having to prepay their current loan (Lea (2010)).[28] In the United States, "due-on-sale" clauses typically mandate that the mortgage loan balance is due and payable upon sale of the property (Quigley (1987)).[29] At the same time, introducing these alternative contractual features could raise equilibrium mortgage rates ex-ante, posing trade-offs. However, even with improvements in assumability and portability, our findings suggest that costs associated with assuming and porting could still generate mortgage lock-in effects.

Finally, the magnitude and incidence of lock-in are unprecedented and may impede geographic mobility and households' ability to pursue economic opportunities (Ludwig et al. (2013), Chetty et al. (2014, 2018)) going forward. The reduction in labor reallocation and housing market liquidity caused by lock-in may further affect labor productivity and inflationary pressures in the medium term, which is relevant for monetary, housing, and labor market policies.

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[28] In Denmark, mortgage borrowers can also buy back their loan at the current market value (Berg, Nielsen, and Vickery (2018)), in conjunction with loans being assumable.

[29] For assumability to alleviate widespread distortionary effects, these policies would likely need to be available to a broad range of households. Mortgages insured by the FHA, VA, and USDA are assumable, but only a subset of households is eligible for FHA-insured loans (see the *FHA Handbook* 4000.1). Moreover, loan amortization and house price appreciation can lead to substantial gaps between the house price and the remaining loan balance that can be assumed. Buyers would thus need to pay for the remainder in cash or take out a second lien at current rates.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix.
Replication Code.