Inflation Heterogeneity and Household Financial Decisions: Evidence from the Mortgage Market

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Abstract

Low-income households have experienced higher inflation since the 2000s. This inflation heterogeneity leads to differences in real returns. A parsimonious model predicts that lower-income households will borrow from the national mortgage market and invest in "local" housing markets for hedging purposes. Empirically, I find consistent evidence that households increase mortgage taking to buy houses when income-specific inflation rates rise. For identification, I use the Chinese Yuan to US Dollar exchange rate as an instrumental variable, as low-income households consume more tradable goods in their consumption baskets. I further exploit the July 2005 Chinese Yuan reform as a shock, and similar results hold. Last, I calibrate an overlapping generation model to explain the empirical findings quantitatively. The model also suggests that the current inflation heterogeneity leads to a lower interest rate by encouraging more savings from high-income households.

Keywords: Inflation Heterogeneity, Real Return Differences, Mortgage and Housing Markets, Chinese Yuan Exchange Rate, Interest Rate
JEL Classification: G51, D14, E31

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1. Introduction

Many financial assets deliver the same nominal payoff for all investors, for example, the S&P500 index and 1 Year US treasury. However, different investors potentially consume different consumption baskets and thus experience systematically different inflation processes.Given the same nominal return, the real returns can differ across investors because of inflation heterogeneity. Differences in real returns can lead to differences in asset holdings. This paper studies the effect of inflation heterogeneity on household financial decisions as well as the further impacts on asset prices.

A growing body of research shows a robust pattern that households across the income distribution systematically experience different inflation rates. Kaplan and Schulhofer-Wohl (2017) and Jaravel (2019) find that, between 2004 and 2015, the average inflation faced by the bottom income households is 0.66 percentage points higher than the top income households. In this paper, I find a consistent heterogeneity also exists in household inflation expectation using Michigan Surveys of Consumers. From the bottom to the top income quintile, the median inflation expectation monotonically decreases (Figure 1a). The size of inflation heterogeneity across income groups is not trivial. The 0.66pp inflation heterogeneity is 11 percent of the average nominal mortgage rate paid by a median-income household and 40 percent of the average 1 Year US Treasury Yield between 2005 and 2015.

Nevertheless, inflation heterogeneity does not affect all financial markets in the same way. Standardized assets traded in a national market are more likely to offer the same nominal returns to all investors, regardless of which inflation process that investors face. Thus, inflation heterogeneity leads to differences in real returns. Examples are bonds, stocks, and mortgages (Figure 2b). However, some other types of assets are more segmented and "local". In the housing market, low-income households tend to buy properties in similarly low-income neighborhoods (Table 1). Given the segmentation, nominal housing market returns reflect the differences in the income-specific inflation rates (Figure 3a and Figure 3b).

Motivated by the previous patterns, I set up a parsimonious two periods model to explore how inflation heterogeneity will affect household financial decisions. In the model, households will save more in nominal terms when the income-specific inflation rises to smooth the real consumption. Because household spends a relatively stable share of the nominal budget on housing services, as shown by Davis and Ortalo-Magné (2011); Fav-

ilukis and Van Nieuwerburgh (2021), the nominal spending on housing will increase. The "local" rent and house prices will rise with income-specific inflation because of the inelastic supply. Furthermore, as the real return from the national market is evaded by the income-specific inflation, the household will move her portfolio towards "local" housing assets, which can offer a higher nominal return and serve as a hedge toward the income-specific inflation.

The above model predictions can be mapped into household mortgage-taking decisions. When taking a mortgage, a household increases her holding in "local" housing markets and decreases her holding in the national fixed income markets. The central hypothesis in this paper is that when the income-specific inflation is high, the corresponding households will increase their mortgage takings. Focusing on the mortgage market also has the following advantages. First, taking a mortgage is one of the most major financial decisions that a typical US household makes, given that real estates (mortgages) are the largest assets (liabilities) for US households across all income quintiles (Figure IA.5). Second, rich data with detailed information on the mortgage market empowers carefully designed empirical investigations.

Consistent with the model predictions, using a census tract by year panel of mortgage taking based on HMDA data, I find a positive association between income-specific inflation and mortgage taking. The data suggest that the number of originated mortgages in a census tract increases when the inflation of the given income quintile increases. I use county-by-year fixed effects to absorb county-level time-varying macroeconomic variations and census tract fixed effects to control for census tract level time-invariant characteristics. 1-year local housing market return and 5-year local housing market return are controlled to capture the short term momentum and the long term reversal in local housing markets caused by either extrapolative beliefs (Armona et al. (2019) and Kuchler and Zafar (2019)) or improved home equity and relaxed collateral or liquidity constraints (Fuster and Zafar (2016)). The results are not driven by heterogeneous sensitivity to the interest rate term structure and national inflation rate across income groups.

With similar empirical specifications but using individual household-level data from American Community Survey, I also find home ownership increases when income-specific inflation rises, which suggests mortgage takings are associated with real home purchases by households in the corresponding income groups. Moreover, the increased mortgage takings are mostly driven by first-lien loans rather than home equity or second-lien loans. Consistent with the model prediction. All of the above results are robust in the subsam-

ple for the Financial Crisis, which suggests the housing boom and bust do not drive the documented patterns.

To address endogeneity concerns, I use the Chinese Yuan exchange rate to US Dollar as an instrumental variable for US inflation heterogeneity. This strategy is based on the literature that documents tradable goods take more significant shares in the baskets of low-income households, and trade shocks have greater impacts on the prices of low-end products (Fajgelbaum and Khandelwal (2016); Cravino and Levchenko (2017); Jaravel and Sager (2019)). As a result, exchange rate movements affect the price of consumption baskets of low-income households and high-income households in heterogeneous ways. Cravino and Levchenko (2017) shows currency devaluation in Mexico disproportionally increased the inflation rate for low-income households. China is the US's largest trading partner (as a single country) in 2017 and the largest country where the US imports. The value of total US imports from China is \$505 trillion dollars [i], which is 3.7% of the \$13,333 trillion dollars total personal spending in the US [ii]. Jaravel and Sager (2019) find the magnitude of the domestic price response is larger for product categories that cater to the lower-income households. One percentage point increase in import penetration leads to a 4.3% (0.9%) decline in consumer prices for a lower (higher) income product.

Consistent with the literature, I find the correlation between income-specific inflation is stronger for the lowest income quintiles, and the correlation declines for higher-income quintiles (6). Moreover, there is a positive correlation between Chinese Yuan appreciation and the US inflation gap between the bottom income households and the top income households (Figure 7a and Figure 7b). Table 5 shows the positive correlation is statistically significant, with the F-statistic equal to 45.86, and is robust after controlling for the fed funds rate, change of gas price, change of dollar index, seasonality fixed effects, and a linear long-run trend. Using the exchange rate movements of the Chinese Yuan relative to the US Dollar as the instrumental variable, Table 6 shows a one percentage point increase in the inflation gap between the bottom income households and the top income households leads to an increase in the number of mortgage taking in a bottom income census tract by 19.5 percent. The F-statistic indicates that the instrument is strong. The estimated 19.5 percent is economically significant but still smaller than the finding in Malmendier and Nagel (2016), where the authors show a 1 pp increase in learning-from-experience inflation leads to a 35 percent increase in household mortgage taking. As robustness checks,

[i] Data source: United States Census Bureau
[ii] Data source: US Bureau of Economic Analysis

I also show the above findings are not driven by an alternative income story (Section 6.4), where the bottom income households could be more likely to work in industries with higher China trade exposure (David et al. (2013) so that their incomes and employment opportunities could, in theory, benefit from the Chinese Yuan appreciation. Nor is the effect driven by an interest rate story, where the bottom income households could be more sensitive towards credit supply shocks, which the Chinese Yuan appreciation could cause through the saving glut channel (Bernanke (2005)).

To further reinforce the identification, I exploit a plausibly exogenous reform of the Chinese exchange rate system in 2005. From 1997 to 2005, the Chinese government maintained a peg of 8.27 RMB per USD. However, the Chinese government had been under intense pressure from the U.S. and Europe, who urged the RMB to appreciate and help rebalance their trade deficits with China (Frankel and Wei (2007)). Finally, on 21 July 2005, China lifted the peg and moved to a managed float exchange rate system against a basket of major currencies. RMB immediately appreciated by 2.1% against USD within one day, and further appreciated by nearly 20% against USD by July 2008 (Figure IA.6a). The exact timing of reform is unexpected by the market (Section 7.1). I find the unexpected Chinese Yuan reform is associated with a widened gap in both inflation expectation and realized inflation between the bottom income households and the top income households. A 1 percentage point RMB appreciation is associated with a 0.15 percentage point increase in the gap of inflation expectation between the bottom income households with the others. Moreover, there is no effect on income expectation and gas price expectation (Section 7.3). Consistent with previous findings, I document that mortgage takings by the bottom income households increased after the RMB reform in July 2005.

In the last section, construct a overlapping generation model and solve the general equilibrium to quantitatively explain the above findings and further study the effects of inflation heterogeneity on the national interest rate and household welfare. With a realistic parameter calibration, Table 11 shows the model can match the estimated household response in mortgage and housing market decisions to income specific inflation. The model also generates comparable home value to income ratios to the data. The counterfactual equilibrium analysis (Figure 11) suggests, a 1pp increase (decrease) in the bottom (top) income-specific inflation can make the equilibrium interest rate lower by 0.43 pp than a counterfactual scenario with no inflation heterogeneity. Inflation heterogeneity with higher income specific inflation for the bottom households creates a saving glut of the rich mechanism similar in Mian et al. (2020). I also find that the welfare loss is equiv-

alent to a 4.2% drop in real consumption for the bottom income households. Meanwhile, the equivalent consumption increase is 2.4% for the top income households. The smaller consumption gain experienced by the top income households than the loss by the bottom income households is the result of decreasing marginal utility.

The paper is organized as follows: Section 2 discusses the related literature, Section 3 presents the data, Section 4 shows motivating evidence and a conceptual frame with empirical predictions, Section 5 estimates the effect of inflation heterogeneity on mortgage taking and home ownership, Section 6 use an instrumental variable for identification, Section 7 exploits the July 2005 RMB reform as an event study, and Section 8 construct and calibrate a structural model for counter-factual analysis.

2. Related Literature

The research is motivated by a growing literature about heterogeneous inflation rates across households. Households can consume different baskets and potentially experience different inflation rates if price changes are disproportional across goods. The question is whether the differences are systemic. Powered by granular household consumption data, there is growing evidence that shows low-income households systemic experience higher inflation rates. Kaplan and Schulhofer-Wohl (2017) employ the Kilts-Nielsen Consumer Panel data and find average inflation cumulates to 33% for households with incomes below $20,000 but to 25% for households with incomes above $100,000 between 2004 and 2013. The inflation heterogeneity across income groups is further confirmed by Jaravel (2019). Using the same scanner data, the author finds that annual inflation for retail products was 0.661 percentage points higher for the bottom income quintile relative to the top income quintile. When including changes in product variety over time, this difference increases to 0.885 percentage points a year. The same pattern also holds in the CEX-CPI data covering greater parts of household consumption baskets during a longer period from 1955 to 2015. Consistent results are reported by Argente and Lee (2020) as well. The underlying economic forces causing inflation heterogeneity across income groups have not been fully examined. Jaravel (2019) proposes that firms cater more new products to high-income households and effectively lower prices for continuing products. Argente and Lee (2020) find that high-income households experienced lower inflation rates during the Great Recession because they were able to substitute for lower-quality goods. This

paper contributes to the literature by connecting the documented inflation heterogeneity to household financial decisions and further to the broader asset prices. Inflation directly enters the household inter-temporal Euler equation, and any persistent heterogeneity in inflation can cause persistent heterogeneity in household savings and investment choices. This paper tries to advance our understanding of the potential real effects of inflation heterogeneity on household decisions.

This research is also closely related to the question of whether households' inflation experiences and inflation expectations affect their financial choices? A vast literature on New Keynesian assumes a close link between inflation expectations and household consumption-savings decisions. Using 57 years of data on inflation expectations from the Michigan Survey of Consumers, Malmendier and Nagel (2016) find differences in household inflation experiences strongly predict differences in inflation expectations, and experience-induced inflation expectations explain household borrowing and lending behaviors, including the choice of mortgages. DAcunto et al. (2021) utilize microdata that uniquely matches individual expectations, detailed information about consumption bundles, and item-level prices. They document that consumers update their inflation expectations from their grocery shopping experiences, although partially driven by some behavioral biases. Vellekoop and Wiederholt (2019) directly link survey data on quantitative inflation expectations to administrative data on income and wealth, and they document that households with higher inflation expectations save less. A one percentage point increase in a household's inflation expectation over time is associated with a 250 euro reduction in the household's change in net worth per year on average. My paper contributes to the literature by showing that systematic inflation heterogeneity across income groups affects household financial decisions. I find households move their portfolio allocations from national assets toward "local" assets, such as housing, which can offer payoff flows indexed by household-specific inflation.

The last but not the least, this paper contributes to the comprehensive literature on the current low interest rate environment. Bernanke (2005) proposes the excessive foreign savings from emerging countries increases the demand for US treasury bonds and decreases the equilibrium interest rate. Summers (2014) emphasize the rising credit supply from the aging demographics, while Hubmer et al. (2021) and Mian et al. (2020) address the widening wealth inequality create saving gults from the richer. In addition, Gordon (2016) argue low interest rate is a natural result of slowing productivity growth. Different from all the above, this paper shows that inflation heterogeneity can affect household

portfolio allocations and indirectly the national interest rate. The current lower income specific inflation for the top income households encourages more savings from the richer and cause a lower national interest rate.

3. Data and Inflation Heterogeneity

This study uses American Community Survey for individual-level home ownership, mortgage status, income, and geographic and demographic characteristics. Home Mortgage Disclosure Act data (HMDA) and Zillow's Assessor and Real Estate Database (ZTRAX) are used to measure household mortgage takings, Nielsen Consumer Panel to measure income specific inflation, and Michigan Surveys of Consumers to measure households inflation expectations. Household income growth rates, local rent index, and home value index are estimated from the American Community Survey following the standard procedure to calculate Zillow Home Value Index. As the Nielsen Consumer Panel only starts from 2004, the sample period in this paper is between 2005 and 2019.

3.1 Heterogeneity in Realized Inflation Across Income Groups

Figure IA.1 replicates the main findings in Jaravel (2019) using Nielsen Consumer Panel data. Between 2004 and 2015, lower-income households on average experienced higher inflation rates. The difference is about 0.6 percentage points.

The Nielsen Consumer Panel records consumption starting from 2004 for a rotating panel of about 40,000 households, who are instructed to scan and input the price and quantity of any product they purchase that has a barcode, typically from retail stores. The Nielsen Consumer Panel data have detailed information on household characteristics such as income, age, education, size, occupation, marital status, and zip code. All products are classified into broad departments (dry grocery, general merchandise, health and beauty care, alcoholic beverages, deli, etc.), which are further subdivided into detailed product groups and very detailed product modules. Following the method used in Jaravel (2019), month-to-month Törnqvist inflation of a household or an income group of households can be calculated as follows:

$$1+\pi^i_{t,t+12}=\Pi^n_{k=1}\left(\frac{p^i_{k,t+12}}{p^i_{k,t}}\right)^{\frac{s^i_{k,t}+s^i_{k,t+12}}{2}}=\exp\left(\sum_{k=1}^{n}\frac{s^i_{k,t}+s^i_{k,t+12}}{2}\cdot\log\left(\frac{p^i_{k,t+12}}{p^i_{k,t}}\right)\right),$$

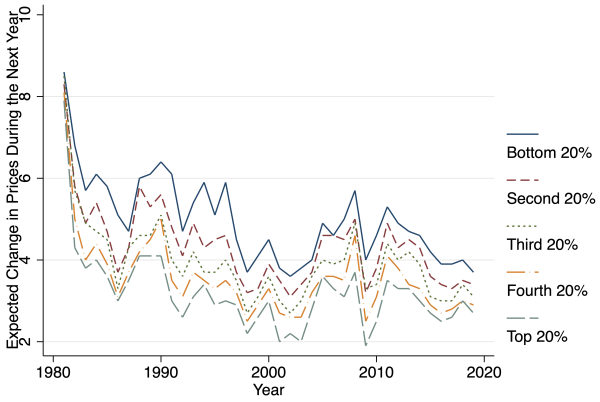
where i indexes households or income groups, k products, and t months; $s^i_{k,t}$ is the spending share of i on product k in month t; and $p^i_{k,t}$ is the average price paid by household i on product k in month t. $t+12$ is 12 months after month t, for example, July 2005 and July 2006. Note that the spending shares $s^i_{k,t}$ are updated each month to better approximate the changes in consumption baskets. In the Nielsen Consumer Panel data, a product k is defined by its barcode, which allows me to control the qualities of products.

3.2 Heterogeneity in Inflation Expectation Across Income Groups

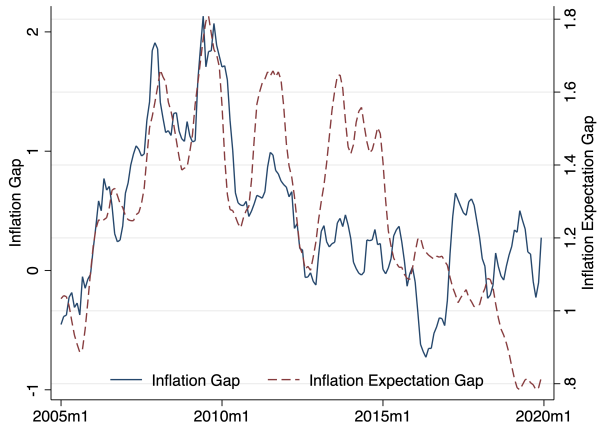
Do households have a consistent perception and expectation of inflation heterogeneity? This question is important as much research demonstrates the crucial role that inflation expectation plays in household financial decisions, for example, Malmendier and Nagel (2016); Vellekoop and Wiederholt (2019); DAcunto et al. (2021). Plotting the smoothed monthly average one year forward inflation expectation by household income groups, Figure 1a shows that the bottom quintile income households always expect inflation to be higher than what the top quintile income households expect. Also, inflation expectation seems to be monotonically decreasing as household income increases and follows the same pattern of inflation heterogeneity documented by Jaravel (2019) and Kaplan and Schulhofer-Wohl (2017). Moreover, the gaps in inflation and inflation expectation between the bottom and the top income households appear to comove together. Figure 1b shows the monthly inflation gap and inflation expectation gap between 2005 and 2019. The monthly inflation gap is calculated based on the methodology introduced in Section 3 using Nielsen Consumer Panel that starts from 2004. The correlation between the monthly inflation gap and the inflation expectation gap is 0.58. Taking them together, Figure 1a and Figure 1b suggest that household inflation expectation is at least on average consistent with the documented heterogeneity in realized inflation.

Figure 1: **Inflation Heterogeneity and Inflation Expectation Heterogeneity**

Figure (a) reports the smoothed monthly average one year forward inflation expectation by household income groups based on Michigan Surveys of Consumers. Figure (b) reports the comovements between the smoothed monthly inflation gap and the inflation expectation gap between the bottom and top income households. The inflation gap is calculated based on the Nielsen Consumer Panel data. The correlation between the inflation gap and the inflation expectation gap is 0.58.



(a) Inflation Expectation Heterogeneity



(b) Inflation Expectation Gap and Inflation Gap (Bottom Income - Top Income)

4. A Conceptual Framework

Many financial assets deliver the same nominal returns for all investors. Given systematic inflation heterogeneity, a homogeneous nominal return implies differences in real returns. How large is the inflation heterogeneity in the context of household financial decisions? The 0.66pp inflation heterogeneity is 11 percent of the average nominal mortgage rate paid by the median income households. Meanwhile, it is 40 percent of the average 1 Year US Treasury Yield between 2005 and 2015. The core question that this paper tries to answer is how household financial decisions will respond to inflation heterogeneity.

4.1 Two Types of Financial Assets

Nevertheless, inflation heterogeneity does not necessarily affect the real returns of all types of assets in the same way.

Assets traded in national markets are more likely to offer the same nominal returns to all investors, regardless of which inflation process that investors face. The existence of national arbitrageurs eliminates any significant differences in nominal returns. As a result, inflation heterogeneity can create differences in real returns. Examples are deposits, bonds, stocks, mortgages, and other publicly traded standardized financial instruments.

Nevertheless, some other types of assets are more segmented and "local". Transactions are more likely to happen within a specific group of investors who potentially experience similar inflation processes. Therefore, nominal returns can differ in response to the group-specific inflation heterogeneity. The most prominent example is the house markets.

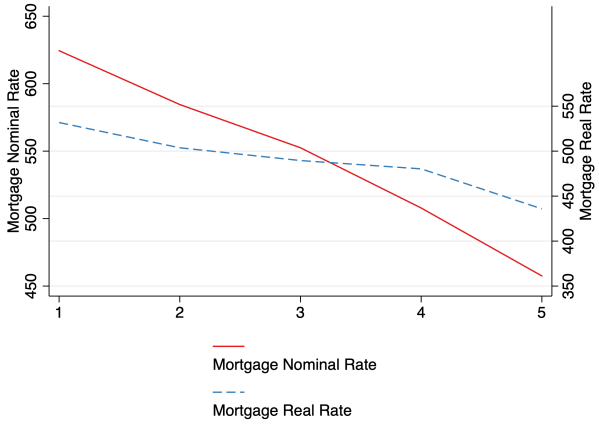
4.1.1 National Financial Markets

It is relatively straightforward to see that deposits, bonds, and stocks deliver the same nominal cash flow to all investors. What about the mortgage market? The mortgage market is arguably the most important financial market for a median US household. Hurst et al. (2016) show mortgage rates are national and do not vary spatially. Figure 2a and Figure 2b suggest that risk-adjusted mortgage rates do not vary across income groups neither.

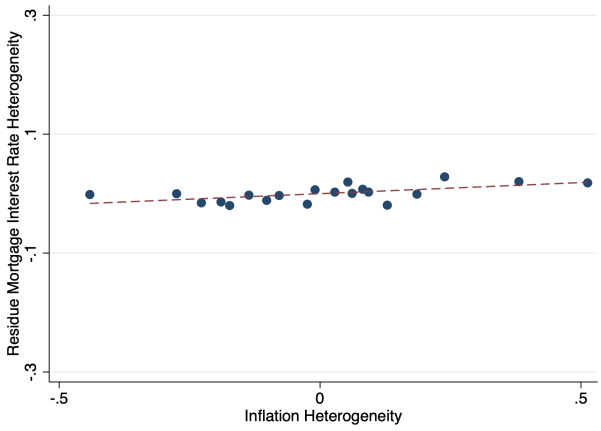
Using data from the Survey of Consumer Finance between 2004 and 2019, Figure 2a shows the average nominal interest rates of mortgages across income groups and the average real interest rates adjusted with inflation heterogeneity. On average, the bottom in-

Figure 2: **Inflation Heterogeneity and Mortgage Interest Rate Heterogeneity**

Figure (a) shows the average nominal interest rate of mortgages across income groups, using data from the Survey of Consumer Finance between 2004 and 2019, and the average real interest rate adjusted with inflation heterogeneity. Figure (b) reports the residue nominal mortgage interest rate across income groups, using GSE conforming loan performance data.



(a) Nominal and Real Mortgage Rate



(b) Risk Adjusted Nominal Mortgage Rate (Conforming Loans)

come households pay a higher nominal rate (625 basis points) than the top income households (470 basis points). The difference in nominal rates is 155 basis points, while the difference in real rates becomes much smaller and is only 95 basis points once inflation heterogeneity is considered.

However, Figure 2a does not consider the differences in default risk across income groups. Bottom-income households need to pay a higher nominal mortgage rate to compensate for their higher default risk. Figure 2b reports the residue nominal mortgage interest rate across income groups, using GSE conforming loan performance data. After controlling for predicted mortgage default risk, the difference in mortgage rate between the bottom income households and the top income households is only ten basis points, significantly smaller than the 66 basis points inflation heterogeneity. As a result, after adjusting for default risk and inflation heterogeneity, the bottom income households pay a lower real mortgage rate than the top income households.

4.1.2 "Local" Financial Markets

Table 1: **The Distribution of Buyers' Income Quintile and Locations' Income Quintile**

This table reports the percentage of mortgages in a census tract that belongs to income quintile j (columns) are taken by a buyer in income quintile i (rows), using mortgage level HMDA data between 2005 and 2017.

%	Property Census Tract Income Quintile				
Buyer Income Quintile	1	2	3	4	5
1	65.93	45.18	15.84	7.98	2.69
2	17.39	28.69	38.85	13.45	6.02
3	8.83	13.53	26.18	30.63	10.79
4	5.00	8.27	12.30	35.52	23.68
5	2.85	4.33	6.83	12.41	56.81
Total	100	100	100	100	100

Houses are classified as "local" assets because they are mostly traded within a certain group of investors. Figure IA.2 and Table 1 are constructed using mortgage level HMDA data between 2005 and 2017. They show that properties in low-income areas are more likely to be purchased by similarly low-income households. Meanwhile, properties in high-income areas are more likely to be purchased by high-income households. For a

given mortgage, HMDA allows identifying the income quintile that the buyer belongs to and the income quintile of the average household in the census tract where the property locates at. Figure IA.2 and Table 1 display the distribution of buyers' income quintiles for a typical census tract by census tracts' income quintiles. In the bottom income quintile census tract, 66% of properties are purchased by bottom income households. In the top income quintile census tract, 57% of properties are purchased by top income households. In general, houses are "local" assets as they are mostly traded within similar income groups.

4.1.3 Income Specific Rent Growth, Home Value Growth, and Inflation

As "local" assets are mostly traded within a certain income group, the nominal returns from the housing markets can potentially correlate with income-specific inflation rates. In contrast, national assets offer the same nominal rates for all households (Section 4.1.1).

Consistent with housing markets being "local", data suggest a positive correlation between income-specific home value growth (Figure 3a) and inflation, as well as between income specific rent growth and inflation (Figure 3b)[iii]. On average, income-specific rent growth rates and home value growth rates move one to one in response to income-specific inflation.

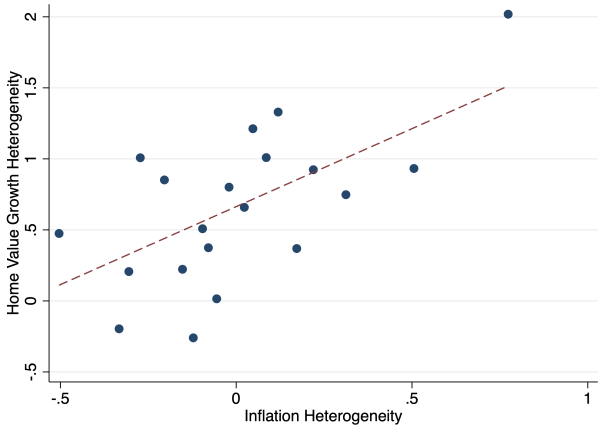
To calculate annual home value growth rates and rent growth rates across income quintiles, I construct an annual home value index and rent index for each income quintile with individual level ACS data by estimating the income quintile by year fixed effects from

$$Y_{i,j,k,t} = a_{j,t} + b_k + \epsilon_{i,j,j,t},$$

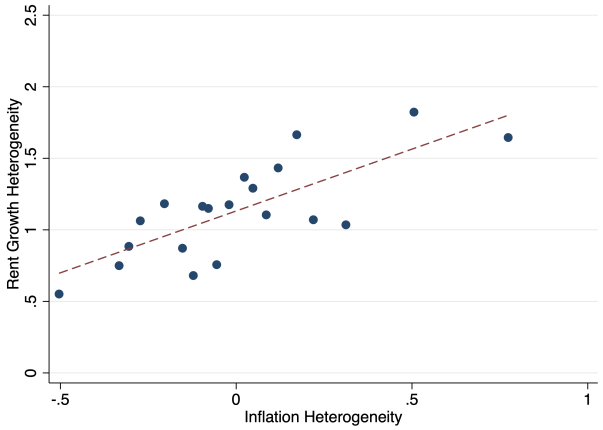
where Y is the reported home value or monthly rent by household i, belonging to income quintile j, living at county k, in year t. b_k is the county fixed effects, and $a_{j,t}$ is the income quintile by year fixed effects. To remove outliers, the sample is restricted between the 10th and 90th percentiles[iv]

Figure 3: **Income Specific Rent Growth, Home Value Growth, and Inflation**

Figure (a) shows the correlation between the income-specific annual home value growth, estimated from American Community Survey data, and income-specific inflation, estimated from Nielsen Consumer Panel data. Figure (b) shows the correlation between the income-specific annual rent growth, estimated from American Community Survey data.



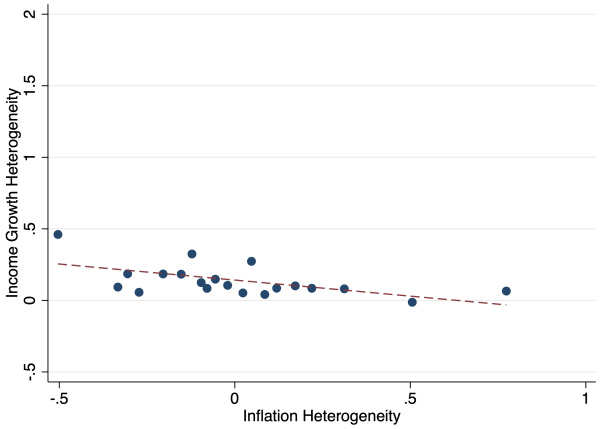
(a) Income Specific Home Value Growth and Inflation



(b) Income Specific Rent Growth and Inflation

Figure 4: **Income Specific Household Income Growth and Inflation**

This figure reports the correlation between the income quintile specific annual household income growth, estimated from American Community Survey data, and income specific inflation, estimated from Nielsen Consumer Panel data.



4.1.4 Income Specific Household Income Growth and Inflation

It is also important to understand the correlations between inflation heterogeneity and nominal household income growth heterogeneity. If the correlation is positive and close to one, inflation heterogeneity does not affect real income growth heterogeneity. If the correlation is small or close to zero, inflation heterogeneity also means heterogeneity in real income growth rates.

Using a similar approach with ACS data (Section 4.1.3), I estimate the annual nominal household income growth rates for each income quintile. Figure 4 suggests a small and negative correlation between income-specific household nominal income growth and inflation. Figure IA.4 plots the comovements between the annual inflation gap and nominal income growth gap across the bottom and top income quintiles from 1965 to 2015. The inflation gap is calculated by Jaravel (2019) based on the matched CPI-CEX data, and the income growth gap is calculated based on the Current Population Survey. The correlation between the inflation gap and nominal income growth is only 0.06, which means inflation

[iii] In addition, during the same sample period, Consumer Expenditure Surveys show the shelter cost increased more for the lower income households than the higher income households (Figure IA.3a). Based on American Housing Survey, Larsen and Molloy (2021) also find that, between 2001 and 2019, the lower income households experienced faster rent price growth.

[iv] The methodology shares similar spirit used by Zillow Rental Index.

heterogeneity is not offset by nominal income growth. Inflation heterogeneity contributes to the heterogeneity in real income growth. Regression analysis shows that the correlation between inflation gap and income growth gap is never statistically significant from zero, even with different lagging choices (Table IA.1).

4.2 An Illustrative Model

Motivated by the previous patterns, I explore the theoretical implications of inflation heterogeneity on household financial decisions in a simple general equilibrium framework.

4.2.1 Environment

Consider an overlapping-generation (OLG) economy with J groups of households living on isolated islands for two periods. The t-th generation of group j exogenously experience group-specific inflation $\pi_{j,t}$ between the first and second period.

Household j of generation t receives endowment $w_{j,t}$ in the first period, consumes non-storable good $c_{j,t}$ and housing service $h_{j,t}$, and save for the second period. In the second period, the household consume non-storable good $c'_{j,t}$ and housing service $h'_{j,t}$. The utility from a bundle of $\{c, h\}$ is

$$u(c,h) = \frac{\left(c^{\theta_j} \cdot h^{1-\theta_j}\right)^{1-\gamma}}{1-\gamma}$$

Households can save via a national bond market and corresponding local housing markets. The national bond market provides one-period nominal bonds with a risk-free rate $R_{f,t}$. Households can buy houses with the price of $P_{j,t}$ in the first period. In the second period, owning one unit of the house will deliver one unit of housing services, as well as a monetary resale payoff, $P_{j,t+1}$, which is the continuous value of the house. The local housing market has a fixed supply of H_j. In the background, there are competitive financial institutions who hold residential rental capital (as in İmrohoroğlu et al. (2018)).

To maximize expected utility, household j of generation t chooses savings $s_{j,t}$ in the national bond market and next period housing consumption $h'_{j,t}$ in the local housing market

$$\max_{s_{j,t}, h_{j,t}, h'_{j,t}} = u(c_{j,t}, h_{j,t}) + \beta \cdot u'(c'_{j,t}, h'_{j,t})$$

subject to the budget constraints

$$c_{j,t} + r_{j,t} \cdot h_{j,t} = w_{j,t} - s_{j,t} - h'_{j,t} \cdot P_{j,t},$$
$$e^{\pi_{j,t}} \cdot c'_{j,t} = s_{j,t} \cdot R_{f,t} + h'_{j,t} \cdot P_{j,t+1}$$

4.3 Equilibrium with an Exogenous Risk-free Rate

In this section, I consider the stationary equilibrium of a small open economy, with an exogenous risk-free rate $R_{f,t}$. The extended general equilibrium with endogenous risk free rate is explored in section 8.

In equilibrium, given the prices $\{r_{j,t}, P_{j,t}\}$, households in group j of generation t solve their problems by choosing quantities $\{c_{j,t}, h_{j,t}, c'_{j,t}, h'_{j,t}, s_{j,t}\}$.

Household intra-temporal consumption choices are

$$\frac{c_{j,t}}{\theta_j} = \frac{r_{j,t} \cdot h_{j,t}}{1 - \theta_j}$$

Household inter-temporal consumption choices are

$$\frac{\partial u}{\partial c_{j,t}} = \frac{\partial u'}{\partial c'_{j,t}} \cdot R_{f,t} \cdot e^{-\pi_{j,t}}$$
$$\frac{\partial u}{\partial c_{j,t}} \cdot P_{j,t} = \frac{\partial u'}{\partial c'_{j,t}} \cdot P_{j,t+1} \cdot e^{-\pi_{j,t}} + \frac{\partial u'}{\partial h'_{j,t}}$$

House price $P_{j,t}$ adjusts to clear the local housing market

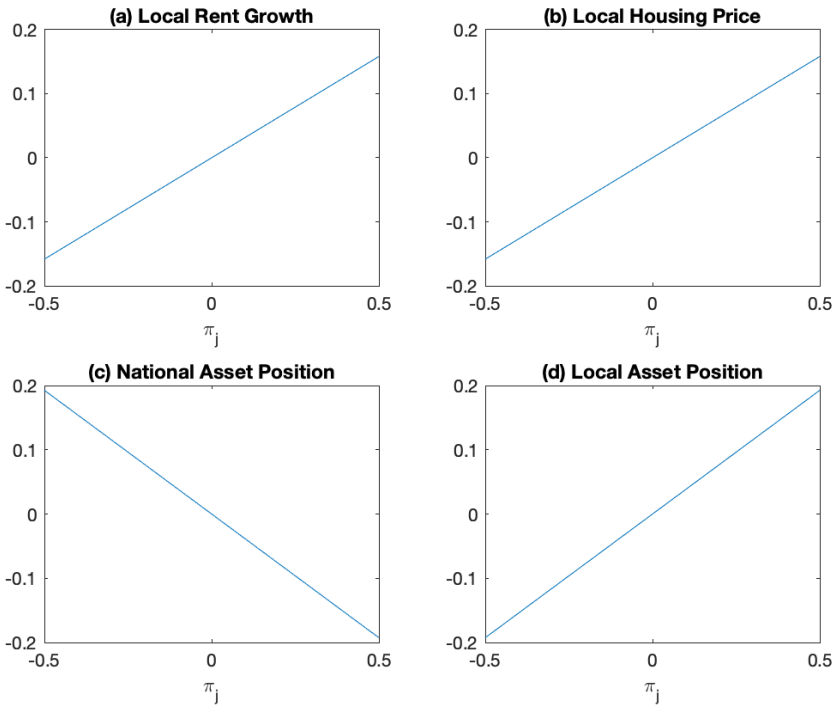
$$h_{j,t} + h'_{j,t-1} = H_j$$

The rental rate is determined by the competitive financial institutions such that it covers the interest payments,

$$r_{j,t} = P_{j,t} \cdot (R_{f,t} - 1)$$

Figure 5: **Heterogeneous Inflation and Household Portfolio Allocation**

This figure shows the effect of changing income specific inflation π_j on group-specific rent $r_{j,t}$, group-specific home value $P_{j,t}$, net position in the national bond market $s_{j,t}$, and net position in the "local" housing market $h'_{j,t} \cdot P_{j,t}$. The x-axes of all subplots are income-specific inflation, π_j, in percentage points between -0.5pp and 0.5pp. The y-axes are also in percentage points. As π_j rises, figures (a) and (b) show the group-specific rent growth rate and home value increase, which is qualitatively consistent with the empirical patterns in Section 4.1.3. Figure (c) shows household j's position in the national bond market decreases with income specific inflation π_j, meanwhile figure (d) shows household j's position in "local" housing assets increases with pi_j. In combination, household j moves her portfolio from national assets to "local" assets. In fact, her position in the national bond market is negative, which means she borrows from the national bond (mortgage) market to finance her positive position in the "local" housing market.



4.3.1 Comparative Statics

In the OLG framework, we can do comparative statics by changing income-specific inflation π_j to understand how inflation heterogeneity affect household portfolio allocation $s_{j,t}$ and $h'_{j,t} \cdot P_{j,t}$. I calibrate the OLG economy following Davis and Ortalo-Magné (2011):

- Coefficient of relative risk aversion: $\gamma = 5$
- Discount factor: $\beta = 0.96$
- Housing share in utility: $1 - \theta_j = 0.25$
- Rate of return on the safe asset $R_f - 1 = 0.04$

Figure 5 shows the effect of increasing income specific inflation π_j on group-specific rent $r_{j,t}$, group-specific home value $P_{j,t}$, net position in the national bond market $s_{j,t}$, and net position in the "local" housing market $h'_{j,t} \cdot P_{j,t}$. The x-axes of all subplots are income-specific inflation, π_j, in percentage points between -0.5pp and 0.5pp. The y-axes are also in percentage points. As π_j rises, figures (a) and (b) show the group-specific rent growth rate and home value increase, which is qualitatively consistent with the empirical patterns in Section 4.1.3. Figure (c) shows household j's position in the national bond market decreases with income specific inflation π_j, meanwhile figure (d) shows household j's position in "local" housing assets increases with pi_j. In combination, household j moves her portfolio from national assets to "local" assets. In fact, her position in the national bond market is negative, which means she borrows from the national bond (mortgage) market to finance her positive position in the "local" housing market.

Why do "local" rent growth and home value positively comove with income-specific inflation in non-storable goods? When π_j increases, the real value of the same nominal savings in the second period decreases. With the elasticity of intertemporal substitution $\frac{1}{\gamma} < 1$, household j will save more in nominal terms to smooth real consumption in the second period. Then the nominal spending on housing will increase because household j spends a relatively stable share of the nominal budget on housing services, in heterogeneous inflation, given the Cobb-Douglas utility or the elasticity between housing and non-storable consumption estimated in the literature (Favilukis and Van Nieuwerburgh (2021)). With higher nominal spending on housing services and inelastic supply, rent and house price rise with π_j, the income specific inflation for non-storable goods.

Furthermore, the household wants to increase nominal savings, but the real return from the national market decreases because of high inflation π_j. Household j will move her portfolio towards "local" housing assets, which can offer higher nominal return when π_j is high and serve as a hedge toward income-specific inflation.

5. Empirical Predictions and Evidence from the Mortgage and Housing Markets

5.1 Empirical Predictions

Housing and mortgage markets are the ideal places to test the model predictions. First, as shown in Figure IA.5, housings are the largest asset, and mortgages are the largest liabilities for US households across all income quintiles. Buying a house and taking a mortgage is the most important financial decision that a typical household makes. Second, the mortgage rates are national as shown in Section 4.1.1 and housing markets are "local" in Section 4.1.3.

The model predicts that when income-specific inflation increases, a household will borrow more from the national bond (mortgage) market to finance her investment in the "local" housing market. Here comes the main empirical hypothesis:

Hypothesis. *When the (income) group-specific inflation π_j is high, households in the (income) group j will increase mortgage taking and housing investment.*

5.2 Evidence from the Mortgage Market

The first analysis is run on a balanced census tract by year panel constructed from HMDA from 2005 and 2019. The panel starts in 2005 because the Nielsen Consumer Panel starts in 2004, and 2005 is the first year that the heterogeneous inflation π_j across income groups can be calculated.

The first regression is to test whether households in income quintile j increase mortgage taking in a year when the income specific inflation π_j becomes larger:

$$\ln(Number_{k,j,t} + 1) = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{k,j,t}$$

where $Num_{k,j,t}$ is the number of mortgages originated at census tract k in year t. The

Table 2: **Mortgage Taking and Inflation Heterogeneity**

$$\ln(Number_{k,j,t}+1) = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{k,j,t}$$

where $Num_{k,j,t}$ is the number of mortgages originated at census tract k in year t. The average borrower in census tract k belongs to income quintile j in year t. And $\pi_{j,t}$ is the income-specific inflation of the income quintile j in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the census tract fixed effects. $X_{k,t}$ are other control variables of census tract k, including the log of median income, Zillow home value at the census tract, one-year local housing market return, 5-year housing market return, 1-year local rent growth, and local rent index. I also control for interest rate term structure and national inflation rate and allow heterogeneous sensitivity to those variables across income groups. The sample period is from 2005 to 2019. Column 5 has fewer observations because rent data have limited coverage. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	ln(Num + 1)			
Heterogeneous Inflation	0.0709*	0.0840**	0.0615*	0.0933***
	(0.0380)	(0.0344)	(0.0309)	(0.0325)
1-Year Housing Ret		0.561***	0.413***	0.542***
		(0.0947)	(0.0740)	(0.111)
5-Year Housing Ret		-0.0106***	-0.00835***	-0.0117***
		(0.00217)	(0.00174)	(0.00294)
1-Year Rent Growth				0.0864***
				(0.0291)
Observations	660,015	592,313	592,313	348,801
R-squared	0.897	0.899	0.903	0.897
Control Variables	Yes	Yes	Yes	Yes
Inflation Exposure			Yes	Yes
Interest Rate Curve Exposure			Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

average borrower in census tract k belongs to income quintile j in year t. And $\pi_{j,t}$ is the income-specific inflation of the income quintile j in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the census tract fixed effects. $X_{k,t}$ are other control variables of census tract k, including the log of median income, Zillow home value at the census tract, 1-year local housing market return, 5-year housing market return, 1-year local rent growth, and local rent index.

By including year by county fixed effects, I compare census tracts k with other census tracts in the same county in the same year, which allows nonparametrically absorb county-level time-varying macroeconomic variations, for example, changes in local labor markets and local credit markets. Moreover, I also control for interest rate term structure and national inflation rate and allow heterogeneous sensitivity to those variables across income groups. I use census tract fixed effects to control census tract level time-invariant characteristics. 1-year local housing market return and 5-year local housing market return are used to capture the short term momentum and the long term reversal in local housing markets caused by either extrapolative beliefs (Armona et al. (2019), and Kuchler and Zafar (2019)) or improved home equity and relaxed collateral or liquidity constraints (Fuster and Zafar (2016)).

The results are shown in Table 2. Consistent with the model prediction in Section 5.1, in years when the heterogeneous inflation for a given income quintile is large, households in the corresponding income group increase mortgage takings compared to the other households in the same county in the same year. This positive association between income-specific inflation and mortgage taking is robust in specifications controlling for local housing market momentum and long-term reversal and local rent growth. In column 5 of Table 2, one percentage point increase in income-specific inflation is associated with a 9 percent increase in mortgage taking by households.

It is reasonable to suspect whether the above results are driven by the subprime mortgage crisis between 2007 and 2009, either through a household demand channel as shown by Mian and Sufi (2009, 2011), or a financial system supply channel as shown by Ramcharan et al. (2016). To address this question, I run the same specification using the subsample starting from 2010. The results are shown in Table IA.3 and are consistent with the full sample findings. The robustness suggests that inflation heterogeneity plays a systematic role in household mortgage-taking decisions beyond the well-studied crisis period.

5.3 Evidence from Home Ownership

Table 3: **Home Ownership and Inflation Heterogeneity**

$$\text{Home Ownership}_{i,j,k,t} = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{k,t}$$

where Home Ownership$_{i,j,k,t}$ is a dummy variable that equals to one if household i reports as a homeowner. $\pi_{j,t}$ is the income-specific inflation of the income quintile j that household i belongs to in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1-year PUMA home value appreciation, 1-year PUMA rent growth, and PUMA rent index. I also control interest rate term structure and national inflation rate and allow heterogeneous exposure to those variables across income groups. The sample period is from 2005 to 2019. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	Home Ownership			
Heterogeneous Inflation	0.0270***	0.0350***	0.0334***	0.0337***
	(0.00646)	(0.00633)	(0.00703)	(0.00706)
1-Year Housing Ret		-0.0100	-0.00962	-0.00951
		(0.00638)	(0.00635)	(0.00578)
1-Year Rent Growth				-0.00497
				(0.00884)
Observations	9,677,676	8,872,562	8,872,562	8,833,397
R-squared	0.224	0.221	0.221	0.221
Control Variables	Yes	Yes	Yes	Yes
Inflation Exposure			Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Section 4.1.3 shows housing markets are largely "local" in the sense that households in income quintile j typically buy properties that locate in neighborhoods in the same

or similar income quintile. However, it is still possible that buyers from very different income quintiles drive the increase in mortgage takings.

The second regression is run on household-level ACS data, where household home ownership status can be directly observed:

$$\text{Home Ownership}_{i,j,k,t} = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{i,j,k,t}$$

where $\text{Home Ownership}_{i,j,k,t}$ is a dummy variable that equals to one if household i reports as a homeowner. $\pi_{j,t}$ is the income-specific inflation of the income quintile j that household i belongs to in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1-year PUMA home value appreciation, 1-year PUMA rent growth, and PUMA rent index. I also control for interest rate term structure and national inflation rate and allow heterogeneous exposure to those variables across income groups.

Table 3 shows that home ownership is positively correlated with the income specific inflation π_j. A one percentage point increase in income-specific inflation is associated with a three percentage points increase in household home ownership in the corresponding income group. The same pattern holds using the subsample starting from 2010, both qualitatively and quantitatively, as shown in Table IA.4.

Together, the results from Table 2 and Table 3 suggest that households increase mortgage takings to finance home purchases when income specific inflation rises.

5.4 First Lien Mortgage or Home Equity Loan?

Besides home ownership, ACS asks households whether they have a first lien mortgage and whether they additionally have a home equity loan. Testing the response of mortgage taking on inflation heterogeneity by lien types can further disentangle omitted contaminating factors that drive the overall mortgage and housing market. The model in Section 4.2 predicts that household j will decrease savings in the national bond market to finance the investment in the "local" housing market as π_j rises. The prediction is consistent with taking a first lien mortgage to buy a house. However, the effect on a second lien loan or home equity loan is ambiguous. Because home equity loans not only can be used to buy real estate property as first lien loans but also can be used to finance non-storable good

Table 4: **Mortgage Lien Status and Inflation Heterogeneity**

$$\text{Mortgage Lien}_{i,j,k,t} = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{i,j,k,t}$$

where Mortgage Lien$_{i,j,k,t}$ is a dummy variable that equals to one if household i reports having a first lien or home equity mortgage. $\pi_{j,t}$ is the income-specific inflation of the income quintile j that household i belongs to in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1-year PUMA home value appreciation, 1-year PUMA rent growth, and PUMA rent index. I also control interest rate term structure and national inflation rate and allow heterogeneous exposure to those variables across income groups. The sample period is from 2005 to 2019. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	First	First	Second (Home Equity)	Second (Home Equity)
Heterogeneous Inflation	0.0394***	0.0394***	-0.0234***	-0.0235***
	(0.0100)	(0.0100)	(0.00660)	(0.00659)
1-Year Housing Ret	-0.00676	-0.00627	-0.00316*	-0.00392**
	(0.00489)	(0.00456)	(0.00177)	(0.00167)
1-Year Rent Growth		-0.00538		0.00625
		(0.00543)		(0.00400)
Observations	8,872,562	8,833,397	8,872,562	8,833,397
R-squared	0.191	0.191	0.069	0.069
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

consumption, which means saving less. While as the model suggests, household j will increase nominal savings in total when income-specific inflation is high.

Consistent with the model, Table 4 shows that income-specific inflation π_j is positively correlated with first-lien mortgage taking but negatively correlated with the second lien mortgage taking. A one percentage point increase in income-specific inflation is associated with a four percentage points increase in having a first lien mortgage, but a two percentage points decrease in further having a second lien mortgage. The same pattern holds using the subsample starting from 2010, as shown in Table IA.5.

6. Chinese Yuan Exchange Rate as An Instrumental Variable

Obviously, we should be careful to interpret the above results for endogeneity concerns. The key challenge in constructing the instrument is identifying a source of exogenous variation in inflation across income quintiles. I supplement the OLS results by using exchange rate movements to instrument the income-specific inflation processes [v]. My strategy relies on the literature that 1) documents tradable goods are more significant shares in the baskets of low-income households and 2) trade shocks have a greater impact on the prices of goods consumed by the low-income households (Fajgelbaum and Khandelwal (2016); Cravino and Levchenko (2017); Jaravel and Sager (2019)). As a result, exchange rate movements affect the price indexes of consumption baskets of low-income and high-income households in heterogeneous ways. The most relevant work is by Cravino and Levchenko (2017), who show the domestic currency devaluation in Mexico disproportionally increased the inflation rate for low-income households.

6.1 The Relevance Condition

The specific instrument I use is the exchange rate of the Chinese Yuan against the US Dollar, which has the following unique features. First of all, China is the US's largest trading partner (as a single country) in 2017 and the largest country where the US imports from. The total US value of imports from China is $505 trillion dollars [vi], which is 3.7% of the

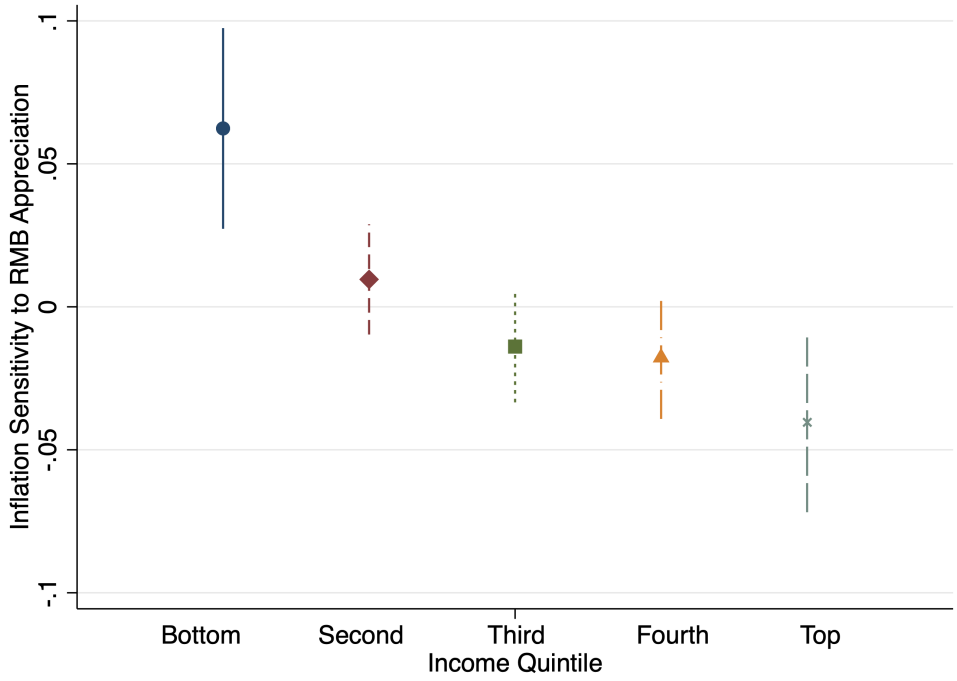
[v] An example in the literature using exchange rate movements as instrumental variables is Bastos et al. (2018)

[vi] Data source: United States Census Bureau

$13,333 trillion dollars total US personal spending [vii]. Second, Jaravel and Sager (2019) find the US domestic prices response stronger to the China trade shock in product categories that cater to lower-income households. One percentage point increase in China's import penetration leads to a 4.3% (0.9%) decline in prices for a product targeting lower (higher) income households.

Figure 6: **Regression Coefficients of Income Specific Inflation on Chinese Yuan Appreciation by Income Quintiles**

This figure plot the coefficients of regressing income-specific inflation on Chinese Yuan Appreciation by income quintiles. The income-specific inflation of the bottom income quintile shows the strongest and most positive correlation with Chinese Yuan Appreciation relative to the US Dollar. And the correlation declines monotonically for higher-income quintiles.



Motivated by the above facts, we may expect the exchange rate movements of the Chinese Yuan against the US Dollar will disproportionally affect the income-specific inflation of low-income US households. Consistent with this idea, I find the income-specific inflation of the bottom income quintile shows the strongest and most positive correlation

[vii] Data source: US Bureau of Economic Analysis

with Chinese Yuan Appreciation. Furthermore, the correlation declines monotonically for higher-income quintiles. Figure 6 shows this pattern by plotting the coefficients of regressing income-specific inflation on Chinese Yuan Appreciation by income quintiles.

With a similar spirit, Figure 7a reports the monthly 12-month Chinese Yuan (RMB) appreciation relative to the US Dollar and the difference in the monthly 12-month inflation rates between the bottom income households and the top income households. The correlation between RMB appreciation and the inflation gap is 0.45. Figure 7b instead shows the difference in the 3-month smoothed monthly 1-year forward inflation expectation between the bottom income households and the top income households based on the Michigan Survey of Consumers from 2005 through 2019. The correlation between RMB appreciation and the 1-year forward inflation expectation gap is 0.53.

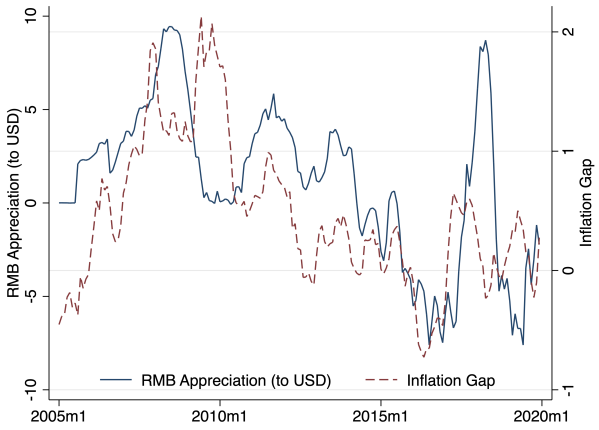
To formally test the relevance condition, I regress the time series of RMB appreciation on the Inflation Gap$_t = \pi_{1,t} - \pi_{5,t}$:

$$\text{Inflation Gap}_t = \beta \cdot \text{RMB Appreciation}_t + \gamma \cdot X_t + \epsilon_t,$$

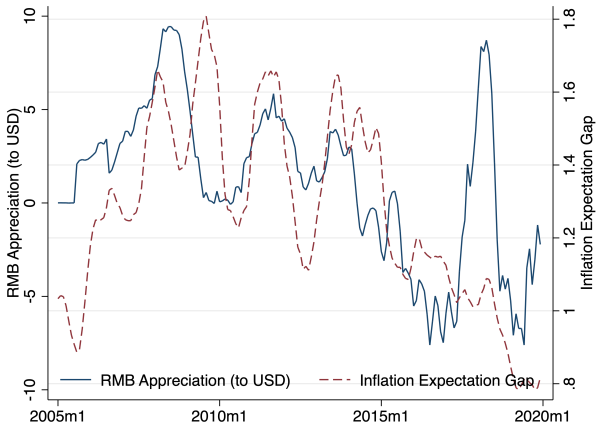
where RMB Appreciation$_t$ is the monthly percentage points of 12-month Chinese Yuan (RMB) appreciation relative to the US Dollar, $\pi_{1,t}$ is the monthly 12-month income specific inflation rates of the bottom income quintile and $\pi_{5,t}$ is that of the top income quintile. Column (1) in Table 5 confirms the positive correlation between RMB appreciation and the US inflation gap between the bottom income households and the top income households is statistically significant, with the F-statistic equals to 45.86. In column (2), I control for potentially critical co-moving variables such as aggregate inflation rate, fed funds rate, gas price change, and dollar index change. In column (3), I add month fixed effects to absorb seasonality, and in column (4), I add year as a control variable to capture the linear long-run trend. The positive correlation between RMB appreciation and the inflation gap remains statistically significant among all specifications.

Figure 7: **Correlation Between Inflation Gap and Chinese Yuan Exchange Rate Movement**

Figure (a) reports the monthly 12-month Chinese Yuan (RMB) appreciation relative to the US Dollar and the difference in monthly 12-month inflation rates between the bottom and top income households. The correlation between RMB appreciation and the inflation gap is 0.45. Figure (b) reports the monthly 12-month Chinese Yuan (RMB) appreciation relative to the US Dollar and the difference in the 3-month smoothed monthly 1-year forward inflation expectation between the bottom income households and the top income households based on the Michigan Survey of Consumers from 2005 through 2019. The correlation between RMB appreciation and the 1-year forward inflation expectation gap is 0.53.



(a) Inflation Gap



(b) Inflation Expectation Gap

Table 5: **Correlation Between RMB Appreciation and US Inflation Gap**

$$\text{Inflation Gap}_t = \beta \cdot \text{RMB Appreciation}_t + \gamma \cdot X_t + \epsilon_t,$$

where Inflation Gap$_t$ is the difference of the monthly 12-month inflation rates between the bottom income households and the top income households based on the Nielsen Consumer Panel from 2005 through 2019, RMB Appreciation$_t$ is the monthly percentage points of 12-month Chinese Yuan (RMB) appreciation relative to the US Dollar. Column (1) shows that the positive correlation between RMB appreciation and the US inflation gap between the bottom income households and the top income households is statistically significant, with the F-statistic equal 45.86. In column (2), I control for potentially important co-moving variables such as aggregate inflation rate, fed funds rate, gas price change, and the dollar index change. In column (3), I add month fixed effects to absorb seasonality, and in column (4), I add year as a control variable to capture the linear long-run trend. Newey-West standard errors are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
VARIABLES	Inflation Gap	Inflation Gap	Inflation Gap	Inflation Gap
RMB Appreciation	0.0734***	0.0731***	0.0734***	0.0731***
	(0.0173)	(0.0203)	(0.0178)	(0.0210)
Observations	180	180	180	180
Controls		Yes		Yes
Month Fixed Effects			Yes	Yes
Newey-West Standard Errors	Yes	Yes	Yes	Yes

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6.2 The Exclusive Condition

What about the exclusive restriction? The assumption of using RMB appreciation as the instrumental variable is that the RMB to USD exchange rate affects households mortgage taking through and only through the inflation heterogeneity channel. Although there is no way to test the exclusive condition perfectly, I try to address this question in several ways. First, I include county-by-year fixed effects in the following 2SLS using the instrumental variable to absorb other factors at the county level that comove with RMB appreciation. After controlling the county-by-year fixed effects, the identification is valid if RMB appreciation is orthogonal to other omitted variables other than the inflation heterogeneity across income groups. Second, there are still reasonable concerns about whether RMB appreciation can affect household incomes in a heterogeneous way and consequently change their mortgage-taking decisions. David et al. (2013) find the local industry structure of a US county determines its exposure to the rise of trade with China. In particular, a county will suffer a greater employment opportunity loss if its local industry overlaps with China's competitive advantages. If the bottom income households were more likely to work in manufacturing industries, their incomes could be affected to a greater extent. In Section 6.4, I will discuss this hypothesis in more detail. However, a short answer is that the empirical results do not support this alternative explanation. Third, it is also possible that RMB appreciation affects the US housing market through an interest rate channel. In the influential global saving glut speech, Bernanke (2005) proposes that excessive savings from developing countries, especially China, contribute to the low-interest-rate environment in the United States. The exchange rate movements of the Chinese Yuan may impact the US interest rate by changing China's foreign reserve and demand for savings. Moreover, the changed US interest rate may affect the supply of mortgages and impact the bottom income households and the top income households in a heterogeneous way. Fourth, exchange rate fluctuations can also be the results of US monetary policy shocks. Higher US domestic interest rate can make the US dollar appreciate relative to other foreign currencies. These alternative channels can be eliminated by directly controlling the interest rate term structure and allowing households to have different sensitivity towards the interest rate environment. The results are still robust and significant, both statistically and economically.

6.3 Evidence from The Instrumental Variable Approach

After validating the Chinese Yuan exchange rate against the dollar as an instrumental variable for US inflation heterogeneity, I run two-stages OLS regressions following the estimations from Section 5. The IV estimations are all consistent with the OLS estimations qualitatively and stronger quantitatively. The robust consistency suggests a causal effect of inflation heterogeneity on household mortgage-taking behaviors.

The first and second stage equations in the IV specification are

$$\ln(Num_{k,j,t}+1) = \beta \cdot \hat{\pi_{j,t}} + \gamma \cdot X_{k,t} + \psi_{k,t} + \eta_k + \epsilon_{k,t},$$
$$\pi_{j,t} = \tilde{\beta_k} \cdot \mathbf{Z_t} + \tilde{\alpha},$$

where k indexes census tract, t the year, $Num_{t,k}$ is the number of mortgages originated at census tract k in year t recorded by HMDA. $\pi_{j,t}$, the income specific inflation of group j in year t, is instrumented by Z_t = RMB Appreciation$_t$, which is the appreciation of the Chinese Yuan relative to the US dollar over the past 12 months. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the census tract fixed effects. $X_{k,t}$ are other control variables of census tract k, including the log of median income, Zillow home value at the census tract, 1-year local housing market return, 5-year housing market return, 1-year local rent growth, and local rent index. I also control for interest rate term structure and national inflation rate and allow heterogeneous sensitivity to those variables across income groups. Under the identification condition $\mathbb{E}[\tilde{\beta_k} \cdot Z_t \cdot \epsilon_{k,t} | X_{k,t}, \psi_{k,t}, \eta_k] = 0$ and relevance condition $\mathbb{E}[\tilde{\beta_k} \cdot Z_t \cdot \pi_{j,t} | X_{k,t}, \psi_{k,t}, \eta_k] \neq 0$, the coefficient β gives the effect, causally induced by RMB appreciation, of a one percentage point increase in the income-specific inflation on the percentage increase in the number of mortgages taken at the census tract level.

The results are shown in Table 6. In column (4), after controlling county by year fixed effects, census tract fixed effects, the log of median income, Zillow home value index, 1-year local housing return, 5-year local housing return, as well as sensitivities to the interest rate environment, I find that a one percentage point increase in income specific inflation leads to an increase in the number of mortgage taking in an average census tract by 17.5 percent. The F-statistic indicates that the instrument is strong. The IV estimations are stronger than the OLS estimations in Section 5.2, which suggests that omitted variables biases or reverse causality attenuates the estimated relationship between the inflation heterogeneity and mortgage taking.

Table 6: **Mortgage Taking and Inflation Heterogeneity: RMB Appreciation as IV**

The second stage equation and the first stage in the IV specifications are

$$\ln(Num_{k,j,t}+1) = \beta \cdot \hat{\pi_{j,t}} + \gamma \cdot X_{k,t} + \psi_{k,t} + \eta_k + \epsilon_{k,t},$$
$$\pi_{j,t} = \tilde{\beta_k} \cdot \mathbf{Z_t} + \tilde{\alpha},$$

where k indexes census tract, t the year, $Num_{t,k}$ is the number of mortgages originated at census tract k in year t recorded by HMDA. $\pi_{j,t}$, the income specific inflation of group j in year t, is instrumented by Z_t = RMB Appreciation$_t$, which is the appreciation of the Chinese Yuan relative to the US dollar over the past 12 months. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the census tract fixed effects. $X_{k,t}$ are other control variables of census tract k, including the log of median income, Zillow home value at the census tract, 1-year local housing market return, five-year housing market return, 1-year local rent growth, and local rent index. I also control for interest rate term structure and national inflation rate and allow heterogeneous sensitivity to those variables across income groups. The sample period is from 2005 to 2019. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)
	ln(Num + 1)				
$\widehat{Heterogeneous\ Inflation}$	0.115**	0.156***	0.150*	0.195***	0.175***
	(0.0486)	(0.0486)	(0.0814)	(0.0463)	(0.0468)
1-Year Housing Ret		0.603***	0.585***	0.438***	0.564***
		(0.0975)	(0.0978)	(0.0762)	(0.114)
5-Year Housing Ret		-0.0105***	-0.0105***	-0.00832***	-0.0115***
		(0.00214)	(0.00215)	(0.00173)	(0.00291)
1-Year Rent Growth					0.0887***
					(0.0291)
Observations	660,015	592,313	592,313	592,313	348,801
R-squared	0.9017	0.9018	0.9039	0.9039	0.9037
Inflation Exposure			Yes	Yes	Yes
Interest Rate Curve Exposure				Yes	Yes
County-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The IV results for home ownership are shown in Table IA.6. I find that a one percentage point increase in income-specific inflation leads to an increase in the home ownership by nine percentage points. Similar to the findings on mortgage taking, the IV estimations are stronger than the OLS estimations in Section 5.3.

The IV results for difference lien type loans are shown in Table IA.7. I find that a one percentage point increase in income-specific inflation leads to an increase in the first lien mortgage by 11 percentage points while leading to a decrease in the second lien or home equity loan by six percentage points. Again, the IV estimations are stronger than the OLS estimations in Section 5.4.

6.4 Income or Inflation? A Trade Exposure Channel

The exclusive condition for instruments could be violated if RMB appreciation affects not only the inflation heterogeneity but also the income heterogeneity between the bottom income households and the top income households. A potential alternative explanation to the above findings through income channel is based on trade exposures to the Chinese economic growth, as argued by David et al. (2013). If the bottom income households are more likely to work in industries with higher China trade exposure, such as manufacturing industries, RMB appreciation can potentially hurt the competitiveness of Chinese factories and benefit US firms as well as the bottom income households by improving their employment opportunities and incomes. The improved economic status can encourage home buying and mortgage taking, as documented empirically in the previous sections.

Although the above hypothesis sounds plausible, many will disagree. Notably, Alan Greenspan, the then chairman of the US Federal Reserve, said "U.S. workers would not benefit from reduced Chinese competitiveness" and "Goods that were suddenly to become too expensive to import from China would then be imported from Malaysia, Indonesia, Bangladesh or whoever is the next cheapest maker. South Carolina would definitely not be the next cheaper supplier of textiles, for example, and its manufacturers would not suddenly become busier." [viii]

One way to test the trade and income channel hypothesis is to check whether the effect of the income-specific inflation on mortgage taking is particularly stronger in counties with greater China trade exposure. I first download the exposures of US industries to the China trade shock and the county level employment compositions by industry from the

[viii] "Greenspan's Yuan Policy", the Wall Street Journal, May 23, 2005

authors' websites of David et al. (2013). Then, I construct county-level employment exposures to the China trade shock. Suppose RMB appreciation affects mortgage taking through the income channel. In that case, the effect should be stronger in counties with larger China trade exposures because their employment opportunities might be improved the most once the local industries regain competitiveness thanks to more expensive Chinese goods because of RMB appreciation. In the following test, I run the 2 stages IV regressions on the subsample with low China trade exposure counties and the subsample with high China trade exposure counties.

The results on mortgage taking with HMDA data are reported in Table 7. Columns (1) and (2) are run on the subsample of low China trade exposure counties, and Columns (3) and (4) are run on the subsample of high China trade exposure counties. If anything, the effect of the inflation heterogeneity seems to be slightly stronger in low China trade exposure counties, which is the opposite direction of the income hypothesis.

Table IA.8 and Table IA.9 show the results on home ownership and mortgage taking by loan types using ACS data. Consistent with the findings in Table 7, the effects of the income specific inflation seems to be slightly stronger in low China trade exposure counties.

Overall, the results do not support the hypothesis that RMB appreciation affects U.S. household mortgage takings through a trade exposure and income channel.

7. Chinese Yuan Exchange Rate Reform: An Event Study

To provide additional identification of the effects of inflation heterogeneity on household financial decisions, I exploit an exogenous reform of the Chinese Yuan (RMB) exchange rate system in 2005. I find both inflation expectation and realized non-food inflation rose more for the bottom income quintile households right after the reform and following RMB appreciation, which further shows Chinese Yuan exchange rate is relevant to US inflation heterogeneity. Moreover, bottom income households increased mortgage taking, and household income expectation was unchanged after the RMB reform, consistent with the exclusive condition.

Table 7: **Mortgage Taking and Inflation Heterogeneity: China Trade Exposure**

The second stage equation and the first stage in the IV specifications are

$$\ln(Num_{k,j,t}+1) = \beta \cdot \hat{\pi_{j,t}} + \gamma \cdot X_{k,t} + \psi_{k,t} + \eta_k + \epsilon_{k,t},$$
$$\pi_{j,t} = \tilde{\beta_k} \cdot \mathbf{Z_t} + \tilde{\alpha},$$

where k indexes census tract, t the year, $Num_{t,k}$ is the number of mortgages originated at census tract k in year t recorded by HMDA. $\pi_{j,t}$, the income specific inflation of group j in year t, is instrumented by Z_t = RMB Appreciation$_t$, which is the appreciation of the Chinese Yuan relative to the US dollar over the past 12 months. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the census tract fixed effects. $X_{k,t}$ are other control variables of census tract k, including the log of median income, Zillow home value at the census tract, 1-year local housing market return, 5-year housing market return, 1-year local rent growth, and local rent index. I also control for interest rate term structure and national inflation rate and allow heterogeneous sensitivity to those variables across income groups. The sample period is from 2005 to 2019. Columns (1) and (2) are run on the subsample of low China trade exposure counties, and Columns (3) and (4) are run on the subsample of high China trade exposure counties. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	Low Trade Exposure	Low Trade Exposure	High Trade Exposure	High Trade Exposure
$\widehat{Heterogeneous\ Inflation}$	0.213***	0.197***	0.180***	0.155***
	(0.0532)	(0.0549)	(0.0458)	(0.0480)
1-Year Housing Ret	0.353***	0.481***	0.511***	0.633***
	(0.0636)	(0.0904)	(0.112)	(0.165)
5-Year Housing Ret	-0.00823***	-0.0161***	-0.00797***	-0.00361
	(0.00190)	(0.00337)	(0.00266)	(0.00466)
1-Year Rent Growth		0.0861*		0.0906**
		(0.0503)		(0.0366)
Observations	285,559	153,443	302,507	193,720
R-squared	0.904	0.906	0.908	0.910
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure Yes	Yes	Yes	Yes	
County-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

7.1 Chinese Yuan Exchange Rate Reform on July 21 2005

From 1997 to 2005, the Chinese government maintained a peg of 8.27 RMB per USD. However, the Chinese government had been under intensive pressure from the U.S. and Europe, who urged the RMB to appreciate and help rebalance their trade deficits with China (Frankel and Wei (2007)). As a response, finally, on 21 July 2005, China lifted the peg and moved to a managed float exchange rate system against a basket of major currencies. RMB immediately appreciated by 2.1% against USD within one day, and further appreciated by nearly 20% against USD by July 2008 (Figure IA.6a).

Was the market surprised by the reform? Frankel and Wei (2007) show the spot and forward rates of USD/RMB around July 21 2005 (Figure IA.6b). Before the reform, the 12-month forward rate was lower than the spot rate, 1-month forward rate, and 3-month forward rate, which indicates that the market anticipated RMB would appreciate within a year but not within three months. The exact timing of the RMB exchange regime reform was unanticipated, and the reform on July 21 2005 was an absolute surprise to both spot and forward markets. Analysts at Citigroup wrote, "The Chinese authorities had always said that they would make an announcement when no one was expecting it. In this regard, they have chosen well."[ix]. Given the role of China as one of the largest US trading partners, the following RMB appreciation triggered many worries about high inflation in the US (Online Appendix: Section IA.1).

7.2 Chinese Yuan Reform and the US Inflation Expectation Heterogeneity

Based on the same argument as in Section 6, we expect the bottom income US households to have greater exposure to the 2005 RMB appreciation. Because tradable goods are bigger shares in the baskets of low-income households, and China trade shocks have a larger impact on the prices of products catering to low-income households

To empirically measure the impact of the RMB reform on US household inflation expectation, I use the disaggregated monthly household inflation expectation interviews from Michigan Surveys of Consumers from 2003 to 2007.

$$\text{Inflation Expectation}_{i,t} = \beta \cdot \text{Bottom}_{i,t} \cdot \text{RMB Appreciation}_t + \gamma \cdot X_{i,t} + \eta \cdot Z_{i,t} + \psi_{i,t} + \epsilon_{k,t},$$

[ix] "Washington, Wall Street React To Chinese Yuan Revaluation", Wall Street Journal, July 21 2005

where Inflation Expectation$_{i,t}$ is the inflation expectation of survey participant i at year-month t, the dummy variable Bottom$_{i,t}$ equals to one if the income of the survey participant is at the bottom quintile, and RMB Appreciation$_t$ is the 12-month RMB appreciation relative to USD. $X_{i,t}$ are the participant's demographic characteristics, including income, gender fixed effects, education fixed effects, age fixed effects, and birth year fixed effects to account for potential cohort effects (Malmendier and Nagel (2016)). Moreover, I also control $Z_{i,t}$, which are participants' expectations of future income, unemployment, interest rate, and aggregate economy to make sure other expectations do not drive the result. $\psi_{i,t}$ are the region by year by month fixed effects to absorb any aggregate and local economy variations.

The results are reported in Table 8. Column (1) shows the 1-year forward inflation expectation is higher among the bottom income households after the Chinese Yuan reform. Column (2) shows the same pattern also holds for the 5-year forward inflation expectation. One percentage point RMB appreciation is associated with a 0.15 percentage point increase in the gap of inflation expectation between the bottom income households with the others. Columns (3) and (4) indicate no effect on income and gas price expectations.

7.3 Chinese Yuan Reform and the US Realized Inflation Heterogeneity

The heterogeneity in inflation expectation responses to the Chinese Yuan reform does not mean or require households to directly learn the news and update their beliefs accordingly. Instead, the households can update their inflation expectation from their daily experience, such as grocery shopping, as shown by DAcunto et al. (2021). To test whether there are any changes in realized inflation heterogeneity, I use the granular Nielsen household consumption panel data to construct the household level realized inflation. I focus on non-food retail products, which are much more likely to be imported from China (Figure IA.7b). Non-food products in Nielsen Consumer Panel are covered by three departments, i.e., dry grocery, general merchandise, health and beauty care, including 47 product groups and 419 product modules.

Figure 8a plots the median month-to-month (for example, July 2004 to July 2005) inflation by income groups. There are two interesting observations. First, inflation rose for all households after the RMB reform on July 21 2005. Second, inflation rises more for the bottom income quintile households, which means the realized inflation gap between the bottom income households and the top income households became wider after the Chi-

Table 8: **Inflation Expectation Heterogeneity and the 2005 Chinese Yuan Reform**

The regression uses the disaggregated monthly household expectation interviews from Michigan Surveys of Consumers from 2003 to 2007.

$$\text{Inflation Expectation}_{i,t} = \beta \cdot \text{Bottom}_{i,t} \cdot \text{RMB Appreciation}_t + \gamma \cdot X_{i,t} + \eta \cdot Z_{i,t} + \psi_{i,t} + \epsilon_{k,t},$$

where $\text{Inflation Expectation}_{i,t}$ is the inflation expectation of survey participant i at year-month t, the dummy variable $\text{Bottom}_{i,t}$ equals to one if the income of the survey participant is at the bottom quintile, and $\text{RMB Appreciation}_t$ is the 12-month RMB appreciation relative to USD. $X_{i,t}$ are the participant's demographic characteristics, including income, gender fixed effects, education fixed effects, age fixed effects, and birth year fixed effects to account for potential cohort effects (Malmendier and Nagel (2016)). Moreover, I also control $Z_{i,t}$, which are participants' expectations of future income, unemployment, interest rate, and aggregate economy to make sure other expectations do not drive the result. $\psi_{i,t}$ are the region by year by month fixed effects to absorb any aggregate and local economy variations. Column (1) shows that the 1-year forward inflation expectation is higher among the bottom income households after the Chinese Yuan reform. Column (2) shows the same pattern for 5-year forward inflation expectation. Columns (3) and (4) indicate no effect on income and gas price expectations. Standard errors double clustered at the year-month level and birth year level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
VARIABLES	1 Year Inflation	5 Year Inflation	Income	Gas Price
Bottom · RMB Appreciation	0.162**	0.151***	-0.0520	2.716
	(0.0714)	(0.0538)	(0.655)	(2.574)
Observations	23,578	23,348	25,195	18,487
R-squared	0.135	0.081	0.099	0.130
Control Variables	Yes	Yes	Yes	Yes
Birth Year Fixed Effects	Yes	Yes	Yes	Yes
Income Quintile-Year Fixed Effects	Yes	Yes	Yes	Yes
Region-Year-Month Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

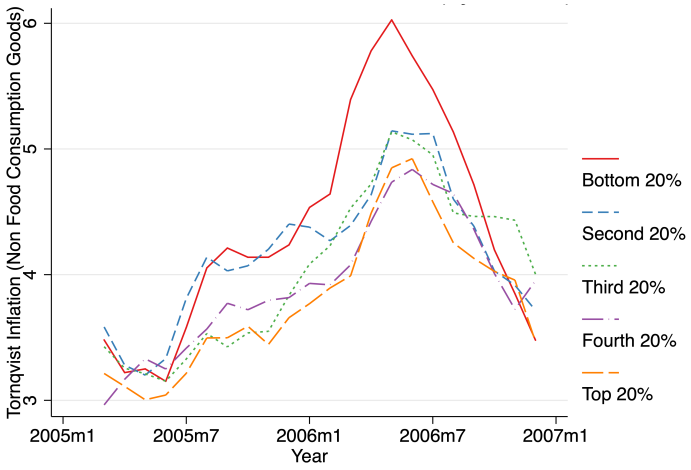
*** p<0.01, ** p<0.05, * p<0.1

Figure 8: **Chinese Yuan Exchange Rate Reform and US Realized Inflation Heterogeneity**

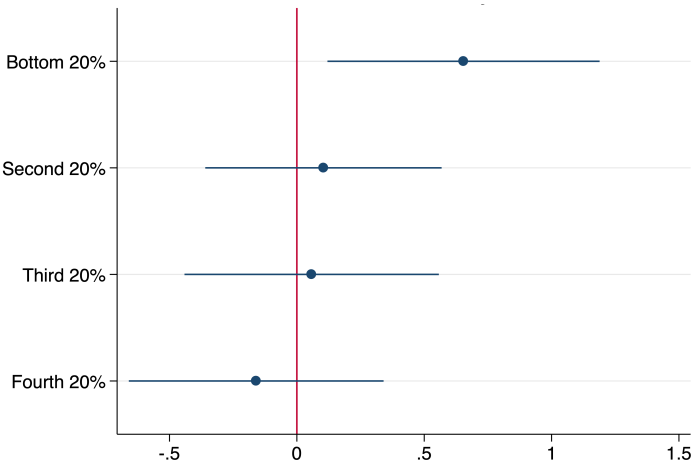
Figure 8a plots the median month-to-month (for example, July 2004 to July 2005) inflation by income groups. To test whether the widening inflation gap is statistically significant, I regress the realized month-to-month inflation $\pi^i_{t-12,t}$ for household i on the interaction of income quintile dummies $Qunitile_i$ and a post dummy variable $Post_t$ equal one within 12 months after the RMB reform in July 2005.

$$\pi^i_{t-12,t} = \alpha + \beta \cdot Post_t \cdot Qunitile_i + h_i + \psi_{i,t} + \eta_{i,t} + \epsilon_{i,t}.$$

To control for macro and local economy variations, I include $\psi_{i,t}$ MSA-year-month fixed effects. h_i are household fixed effects and $\eta_{i,t}$ are income quintile by year fixed effects. The results are shown in Figure 8b.



(a) Nielsen Non-Food Goods Inflation



(b) Nielsen Non-Food Goods Inflation by Income Qunitiles

nese Yuan Reform. To test whether the widening inflation gap is statistically significant, I regress the realized month-to-month inflation $\pi^i_{t-12,t}$ for household i on the interaction of income quintile dummies $Qunitile_i$ and a post dummy variable $Post_t$ equal one within 12 months after the RMB reform in July 2005.

$$\pi^i_{t-12,t} = \alpha + \beta \cdot Post_t \cdot Qunitile_i + h_i + \psi_{i,t} + \eta_{i,t} + \epsilon_{i,t}.$$

To control for macro and local economy variations, I include $\psi_{i,t}$ MSA-year-month fixed effects. As a result, I compare the realized inflation changes of other income groups with the top income quintile within the same metropolitan area. I also control for h_i household fixed effects and $\eta_{i,t}$ income quintile by year fixed effects. The results are shown in Figure 8b. Consistent with what I find in Table 8, bottom quintile income households not only have higher inflation expectations but also experience higher realized inflation for their non-food consumption baskets after the RMB reform on July 21 2005. The results are consistent Cravino and Levchenko (2017), where they find low-income Mexican households experienced higher inflation after Mexico's currency devaluation.

7.4 Chinese Yuan Reform and the US Household Mortgage Taking

Given the RMB reform happened as a surprise to the market and created heterogeneous impacts on both inflation expectation and realized inflation of US households across income groups, I can use a standard difference in differences approach to estimate the effects on mortgage-taking decisions. Bottom income households are regarded as the treated group, as data suggest the associated rise in income-specific inflation was strongest for them.

Instead of annual data from HMDA and ACS, I use high-frequency real estate transaction data from ZTRAX for two reasons. First, the 2008 financial crisis might contaminate the estimation for the 2005 RMB reform using the annual frequency data. Second, the future price in Figure IA.6b suggests that the market had been anticipating an RMB reform at the 12-month horizon. Estimations with annual frequency data might also be contaminated by the expectation effect. Within the ZTRAX data, I can overcome the above concerns with the following specification at the monthly frequency:

$$\ln(Number_{k,j,t} + 1) = \beta \cdot \text{Bottom}_k \cdot \text{Reform}_t + \gamma \cdot X_t + \psi_{k,t} + \eta_{k,t} + \xi_{k,t} + \epsilon_{k,j,t}$$

Figure 9: **Mortgage Taking around the Chinese Yuan Reform**

This figure shows the estimated coefficients from the following regression at the monthly level.

$$\ln(Number_{k,j,t}+1) = \beta \cdot \text{Bottom}_k \cdot \text{Reform}_t + \gamma \cdot X_t + \psi_{k,t} + \eta_{k,t} + \xi_{k,t} + \epsilon_{k,j,t}$$

where $Num_{k,j,t}$ is the number of mortgages originated at zip code k in year-month t. Bottom_k is a dummy variable and equals one if zip code k belongs to the bottom income quintile. Reform_k is also a dummy variable and equals to one if year-month t is after the RMB Reform in July 2005. $\psi_{k,t}$ are the county by year by month fixed effects, $\eta_{k,t}$ are the zip code by year fixed effects, $\xi_{k,t}$ are the zip code by month fixed effects. $X_{k,t}$ are other control variables, like last month's home value at the zip code and one year local home value appreciation. By including county-by-year-by-month fixed effects, I can tightly control for any county-level time-varying macroeconomic variations. With zip code by year fixed effects, I can control for the long-run variations at a zip code level associated with the housing market boom and bust between 2003 and 2007. The zip code-by-month fixed effects are further used to control for seasonality variations in the zip code level housing markets. The sample period is from 2003 to 2007. Standard errors clustered at the county level are reported in parentheses.

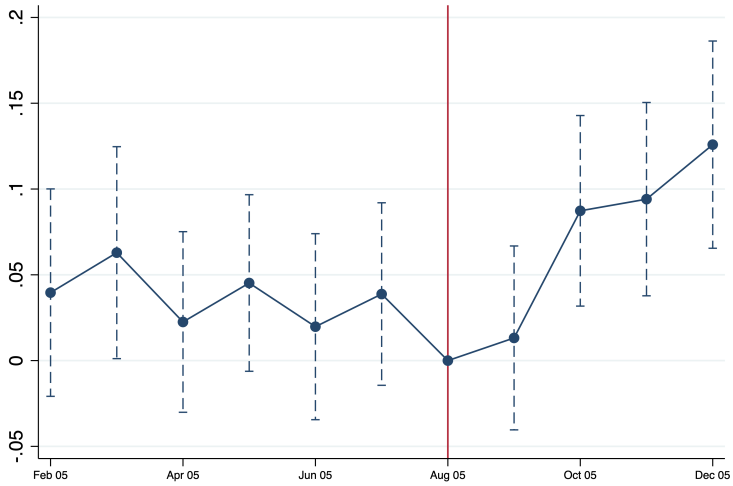


Table 9: **Mortgage Taking and the Chinese Yuan Reform**

$$\ln(Number_{k,j,t}+1) = \beta \cdot \text{Bottom}_k \cdot \text{Reform}_t + \gamma \cdot X_t + \psi_{k,t} + \eta_{k,t} + \xi_{k,t} + \epsilon_{k,j,t}$$

where $Num_{k,j,t}$ is the number of mortgages originated at zip code k in year-month t. Bottom_k is a dummy variable and equals one if zip code k belongs to the bottom income quintile. Reform_k is also a dummy variable and equals to one if year-month t is after the RMB Reform in July 2005. $\psi_{k,t}$ are the county by year by month fixed effects, $\eta_{k,t}$ are the zip code by year fixed effects, $\xi_{k,t}$ are the zip code by month fixed effects. $X_{k,t}$ are other control variables, like last month's home value at the zip code and one year local home value appreciation. By including county-by-year-by-month fixed effects, I can tightly control for any county-level time-varying macroeconomic variations. With zip code by year fixed effects, I can control for the long-run variations at a zip code level associated with the housing market boom and bust between 2003 and 2007. The zip code-by-month fixed effects are further used to control seasonality variations in the zip code level housing markets. In columns (2) and (4), I control for the share of private labeled securtization (PLS) mortgages among all mortgages and the share of mortgages with misreported owner occupancy and second lien among all PLS mortgages, at the zip code by month level. The sample period is from 2003 to 2007. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	log(Loan Number + 1)			
	(1)	(2)	(3)	(4)
	All	All	Exclude Katrina	Exclude Katrina
Bottom Qunitile · RMB Shock	0.0266*	0.0268*	0.0358**	0.0356**
	(0.0160)	(0.0160)	(0.0165)	(0.0165)
PLS Share		-0.220***		-0.212***
		(0.00875)		(0.00911)
Misreporting Share		0.112***		0.114***
		(0.00660)		(0.00722)
Observations	453,802	453,802	402,982	402,982
R-squared	0.941	0.942	0.939	0.940
Control Variables	Yes	Yes	Yes	Yes
ZipCode-Year Fixed Effects	Yes	Yes	Yes	Yes
ZipCode-Month Fixed Effects	Yes	Yes	Yes	Yes
Year-Month-County Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

where $Num_{k,j,t}$ is the number of mortgages originated at zip code k in year-month t. Bottom$_k$ is a dummy variable and equals one if zip code k belongs to the bottom income quintile. Reform$_k$ is also a dummy variable and equals to one if year-month t is after the RMB Reform in July 2005. $\psi_{k,t}$ are the county by year by month fixed effects, $\eta_{k,t}$ are the zip code by year fixed effects, $\xi_{k,t}$ are the zip code by month fixed effects. $X_{k,t}$ are other control variables, like last month's home value at the zip code, and 1-year local home value appreciation. By including county-by-year-by-month fixed effects, I can tightly control for any county-level time-varying macroeconomic variations. With zip code by year fixed effects, I can control for the long-run variations at a zip code level associated with the housing market boom and bust between 2003 and 2007. The zip code-by-month fixed effects are further used to control seasonality variations in the zip code level housing markets. The sample period is from 2003 to 2007, including two years before the RMB reform and two years after.

The results are shown in Table 9 and Figure 9. Consistent with all previous findings, after the RMB reform in July 2005, the bottom income households started to increase mortgage takings compared to the other households in the same county in the same year-month. Given the high-frequency nature of this empirical design, the increase in mortgage taking can be interpreted as causally driven by the RMB reform. As shown in Table 8, the effect is most likely channelled by the consequent inflation heterogeneity rather than income heterogeneity. As robustness checks, Table 9 shows the effect is not driven by Hurricane Katrina that damaged Mississippi, Louisiana, and Florida in August 2005. In columns (2) and (4), I control for the share of private labeled securtization (PLS) mortgages among all mortgages and the share of mortgages with misreported owner occupancy and second lien among all PLS mortgages, at the zip code by month level. The results remain robust, which suggests the estimation is not biased by the subprime bubble documented by Mian and Sufi (2009) and Griffin and Maturana (2016).

8. Effects on National Asset Prices and Household Welfare

As shown in previous sections, households response to inflation heterogeneity by adjusting portfolio positions in the national bond (mortgage) market and "local" housing markets. In this section, I further extend the small open economy equilibrium analysis in Section 4.2 to endogenous the national risk free rate and study the effects of inflation

heterogeneity on national asset prices and household welfare.

8.1 Environment

The new economic environments features more realistic frictions and labor income dynamics to deliver quantitatively more accountable estimations,comparing to the illustrative model in Section 4.2.

This OLG economy has J groups of households living on isolated islands for three equally long periods (young, middle age, and retirement). The t-th generation of group j exogenously experience group-specific annual inflation $\pi_{j,t}$ between the first, second period, and third period.

Household j of generation t consumes non-storable good $c_{j,t,n}$ and housing service $h_{j,t,n}$, and receives labor income $w_{j,t,n} = w_{j,t} \cdot \alpha_n \cdot \epsilon_{j,t,n}$, in the n-th period. α_n is the life stage labor efficiency to capture a deterministic life cycle income process. $e_{j,t,n}$ represents the idiosyncratic stochastic shock to labor income every period. The utility from a bundle of $\{c, h\}$ is

$$u(c,h) = \frac{\left(c^{\theta_j} \cdot h^{1-\theta_j}\right)^{1-\gamma}}{1-\gamma}$$

8.1.1 Financial Markets

At the end of the first and second periods, households can choose to save or borrow in the national bond market $s_{j,t,n}$, with an interest rate $R_{f,t}$. Uncollateralized borrowing is not allowed, and the maximum loan-to-value ratio is η.

At the end of the first period, households can buy houses with the price of $P_{j,t}$. In the second and third periods, owning one unit of the house will deliver one unit of housing services. Households can also refinance and consume the home equity at the third period, whereas are subject to a depreciation rate δ and a property tax rate τ. The local housing market has a fixed supply of H_j. In the background, there are competitive financial institutions who hold residential rental capital (as in İmrohoroğlu et al. (2018)).

8.1.2 Household's Problem

To maximize expected utility, household j of generation t chooses savings national bond market $s_{j,t,1}$ at the first period and $s_{j,t,2}$ at the second period. In addition, the household

choose rented home $h_{j,t,1}$ and also home purchase $h_{j,t,2} = h_{j,t,3}$ in the local housing market at the first period.

So, in the first period, the household solves

$$\max_{s_{j,t,1}, h_{j,t,1}, h_{j,t,2}} V_{j,t,1} = u(c_{j,t,1}, h_{j,t,1}) + \beta \cdot \mathbb{E}V_{j,t,2}$$

subject to the budget constraint

$$c_{j,t,1} + r_{j,t} \cdot h_{j,t,1} = w_{j,t,1} - s_{j,t,1} - h_{j,t,2} \cdot P_{j,t}$$

And, in the second period, the household solves

$$\max_{s_{j,t,2}} V_{j,t,2} = u(c_{j,t,2}, h_{j,t,2}) + \beta \cdot \mathbb{E}u(c_{j,t,3}, h_{j,t,3})$$

subject to the budget constraints

$$\begin{aligned} e^{\pi_{j,t}} \cdot c_{j,t,2} + s_{j,t,2} &= w_{j,t,2} + s_{j,t,1} \cdot R_{f,t} \\ e^{2 \cdot \pi_{j,t}} \cdot c_{j,t,3} &= w_{j,t,3} + s_{j,t,2} \cdot R_{f,t} + h_{j,t,3} \cdot P_{j,t+2} \cdot (1 - \delta - \tau) \end{aligned}$$

The household's problem can be solved backwards.

8.2 General Equilibrium

In equilibrium, given the prices $\{r_{j,t}, P_{j,t}, R_{f,t}\}$, households in group j of generation t solve their problems by choosing quantities $\{c_{j,t,1}, h_{j,t,1}, c_{j,t,2}, h_{j,t,2}, s_{j,t,1}, s_{j,t,2}\}$.

House price $P_{j,t}$ adjusts to clear the local housing market

$$h_{j,t,1} + h_{j,t-1,2} + h_{j,t-2,3} + = H_j$$

The rental rate is determined by the competitive financial institutions such that it covers the interest payments, depreciation, and taxes,

$$r_{j,t} = P_{j,t} \cdot (R_{f,t} + \delta + \tau - 1)$$

Table 10: Calibration of the Baseline Scenario

	High Income	Low Income
Number of groups J:	2	
Coefficient of relative risk aversion γ:	5	
Discount factor β:	0.96	
Housing share in utility θ_j:	0.3	0.4
Income Specific Inflation π_j:	-0.3pp	0.3pp
Endowment w_j:	80,000	40,000
Life-stage efficiency profile:	0.75, 1.31, 0.4	
Idiosyncratic income volatility σ:	0.16	
Housing depreciation rate δ:	0.02	
Property tax rate τ:	0.01	
Maximum loan-to-value η:	0.8	

In addition to equilibrium conditions in Section 4.2, the national risk free rate adjusts to clear the national bond market with the net supply of 0,

$$\sum^{J} s_{j,t,1} + s_{j,t,2} = 0$$

8.3 Calibration

For tractability, I assume $J = 2$ in the OLG model. There is a high income group and low income group in the economy. The high income group is calibrated to match the top 50% income US households, and the bottom income group is calibrated to match the bottom 50% income US households. Consistent with the consumer expenditure survey, I assume housing takes a bigger share in the utility of the low income groups. The time period selected to be 20 years. Following İmrohoroğlu et al. (2018), I assume 1) the subjective time discount factor, β, to be 0.96, 2) maximum loan-to-value (LTV), η, at 80 percent, 3) property tax rate, τ, at 1 percent, 4) housing depreciation rate, δ, at 2 percent, and 5) life stage working efficiency, α_n, to be 0.75 for the young period, 1.31, for the middle age, and 0.4 for the retirement age. The relative risk aversion, γ, is 5. Table 10 summarizes the parameters used in the baseline calibration.

8.4 Model Generated Moments

The model is able to generate comparable moments as what we estimated from the data. Although the model does not target to match those moments during the above calibration. First, in data, the average home value to income ratio from American Community Survey is 2.7 for the high income households and 6.8 for the low income households. The model delivers very similar numbers, which are 3.5 and 6.3 respectively. Second, the real interest rate during the sample period of 2004 and 2019 is 1 pp, measured as the 10 year US treasury yield. The equilibrium interest rate in the model is 0.96 pp. And the model suggests that a 1pp increase in the income specific inflation for the low income households can lead to a 0.43pp decrease in the national interest rate. Third, the instrumental variable estimations show that the low income household increases mortgage taking or home ownership by 9 percent to 20 percent in response to a 1pp increase in the low income specific inflation. Households in the model show a sensitivity of 12 percent, which is covered by the empirically estimated range.

Table 11: **Moments from the Data and the Model**

This table compare moments estimated from the data and moments generated by the model. First, in data, the average home value to income ratio from American Community Survey is 2.7 for the high income households and 6.8 for the low income households. The model delivers very similar numbers, which are 3.5 and 6.3 respectively. Second, the real interest rate during the sample period of 2004 and 2019 is 1 pp, measured as the 10 year US treasury yield. The equilibrium interest rate in the model is 0.96 pp. And the model suggests that a 1pp increase in the income specific inflation for the low income households can lead to a 0.43pp decrease in the national interest rate. Third, the instrumental variable estimations show that the low income household increases mortgage taking or home ownership by 9 percent to 20 percent in response to a 1pp increase in the low income specific inflation. Households in the model show a sensitivity of 12 percent, which is covered by the empirically estimated range.

	Home Value to Income Ratio		Real Interest Rate	
	High Income	Low Income	Level (pp)	Changes (pp) w.r.t 1pp Increase in π_j
Data	2.7	6.8	1.00	
Model	3.5	6.3	0.96	-0.47
	The Low Income Household's Response to a 1pp Increase in π_j			
	Number of Mortgages	Home Ownership	Mortgage Payment	Owned Home Size
Data	19.5	9.1	10.9	
Model				11.7

8.5 Equilibrium Risk-free Rate

Comparing to a counterfactual world with no inflation heterogeneity, intuitively, the equilibrium interest rate could be higher or lower for the following reasons. On the one hand, the bottom income households who experience higher inflation borrow more in the national bond market, which creates additional demand of credit that can lead to higher interest rate. On the other hand, the top income households who experience lower inflation save more in the national bond market, which creates additional supply of credit that can lead to lower interest rate. The equilibrium effect of inflation heterogeneity on interest rate depends on the relative magnitude of the two forces.

Figure 10 shows how the equilibrium household's portfolio allocation changes with the inflation heterogeneity. Consistent with the exogenous interest rate model in Section 4.2, given the income specific inflation for the bottom (top) income group being 0.3pp (-0.3pp), the bottom (top) income households invest less (more) in the national bond market but hold more (less) local housing assets, comparing to the counter-factual world without inflation heterogeneity.

Figure 11 (a) shows how the equilibrium interest rates move with the inflation heterogeneity. In the baseline scenario, given the income specific inflation for the bottom (top) income group being 0.3pp (-0.3pp), the equilibrium interest rate is 0.96pp. In the counterfactual scenario with no inflation heterogeneity, the equilibrium interest rate is 1.03pp. The realized inflation heterogeneity leads to a 6 basis-points decrease in the equilibrium interest rate. This pattern suggests that the increase in savings by the top income households in the national bond market dominates the de-investment by the bottom income households, simply because the top income households take a larger share in the economy. Inflation heterogeneity with higher income specific inflation for the bottom households creates a saving glut of the rich mechanism similar in Mian et al. (2020). Furthermore, figure 11 (b) shows that the house price in the bottom income housing market rises relative to the top income housing market when the income specific inflation is higher for the bottom income households, consistent with the pattern documented in Section 4.1.3.

8.6 Welfare Analysis

The last exercise is to estimate the welfare loss and gains caused by inflation heterogeneity across income groups. Figure 11 (c) and (d) show, under the current 0.3pp inflation hetero-

Figure 10: **Heterogeneous Inflation and Household Portfolios**

The figures (a) and (b) show the effect of income specific inflation π_j on the bottom household's positions in the national bond market and local housing markets. The figures (c) and (d) show the effect of income specific inflation π_j on the bottom household's positions in the national bond market and local housing markets. The x-axes of all subplots are income-specific inflation, π_j, in percentage points between -0.5pp and 0.5pp. The y-axes are also in percentage points. Consistent with the exogenous interest rate model in Section 4.2, given the income specific inflation for the bottom (top) income group being 0.3pp (-0.3pp), the bottom (top) income households invest less (more) in the national bond market but hold more (less) local housing assets, comparing to the counter-factual world without inflation heterogeneity.

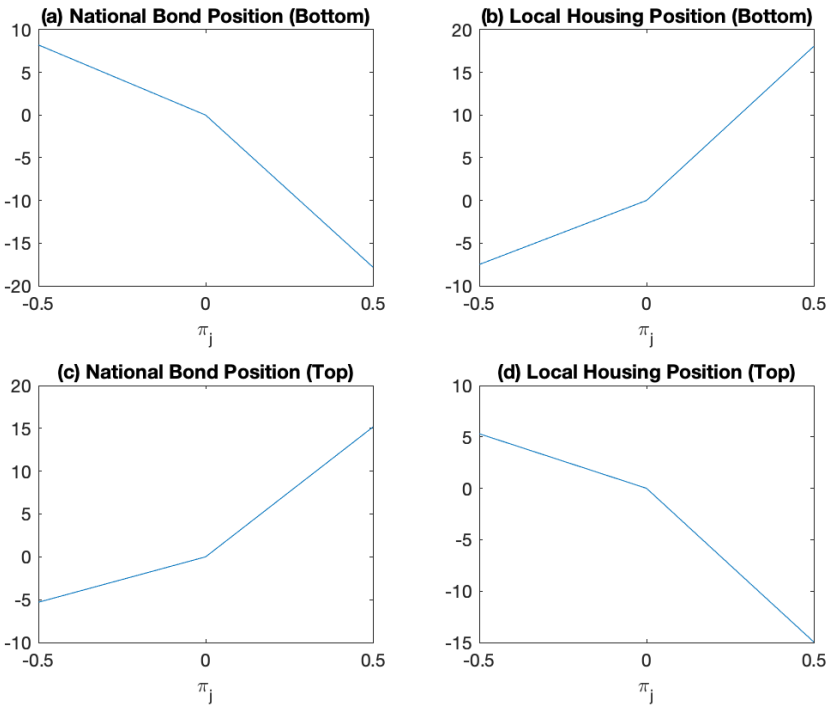
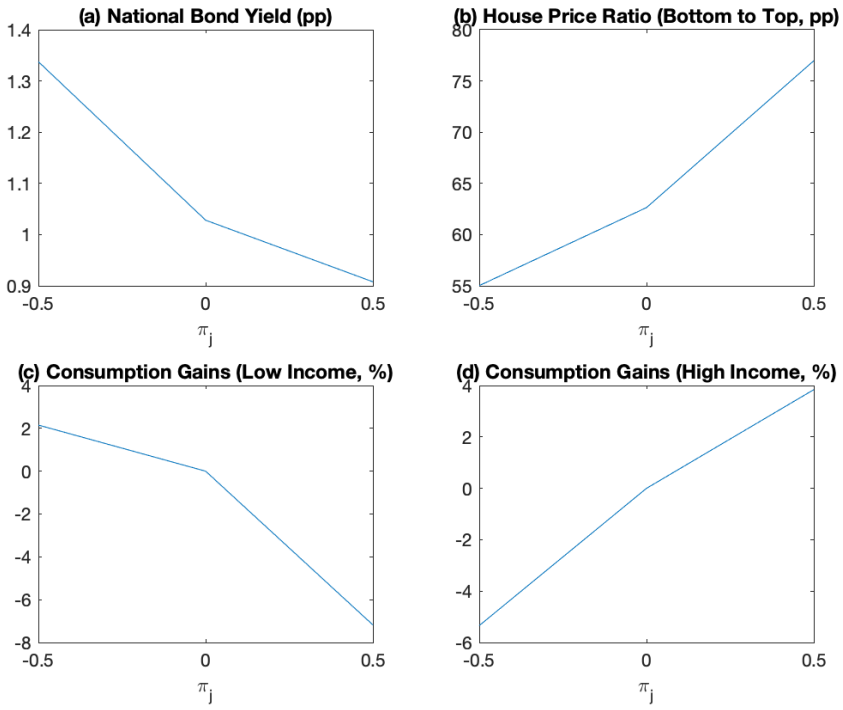


Figure 11: **Heterogeneous Inflation and Welfare Gains (Loss)**

This figure (a) how the equilibrium interest rates move with the inflation heterogeneity. In the baseline scenario, given the income specific inflation for the bottom (top) income group being 0.3pp (-0.3pp), the equilibrium interest rate is 0.96pp. In the counterfactual scenario with no inflation heterogeneity, the equilibrium interest rate is 1.03pp. The realized inflation heterogeneity leads to a 6 basis-points decrease in the equilibrium interest rate. Figure (b) shows that the house price in the bottom income housing market rises relative to the top income housing market when the income specific inflation is higher for the bottom income households, consistent with the pattern documented in Section 4.1.3. Figure (c) and (d) show the equivalent consumption gains (loss) for the top (bottom) income households because of income specific inflation π_j. The x-axes of all subplots are income-specific inflation, π_j, in percentage points between -0.5pp and 0.5pp. The y-axes are also in percentage points.



geneity, the welfare loss is equivalent to a 4.2% drop in real consumption for the bottom income households. Meanwhile, the equivalent consumption increase is 2.4% for the top income households. The smaller consumption gain experienced by the top income households than the loss by the bottom income households is the results of decreasing marginal utility caused by CRRA utility.

9. Conclusion

This paper investigates the effects of inflation heterogeneity on household portfolio allocation. The previous literature documented that the low-income households have experienced higher inflation since the 2000s. This inflation heterogeneity leads to differences in real returns. A parsimonious model predicts that lower-income households will borrow from the national mortgage market and invest in "local" housing markets for hedging purposes. Empirically, I find consistent evidence that households increase mortgage taking to buy houses when income-specific inflation rates rise. For identification, I use the Chinese Yuan to US Dollar exchange rate as an instrumental variable, as low-income households consume more tradable goods in their consumption baskets. I further exploit the July 2005 Chinese Yuan reform as a shock, and similar results hold. Last, I calibrate an overlapping generation model to explain the empirical findings quantitatively. The model also suggests that the current inflation heterogeneity leads to a lower interest rate by encouraging more savings from high-income households.

Inflation heterogeneity can generate comprehensive impacts on the financial markets because it affects the real returns, which play crucial roles in the inter-temporal consumption Euler equation. However, the systematic differences in the households inflation process have been mostly neglected in the finance literature. This paper tries to call more attention to the real effect of household inflation heterogeneity and its interaction with the financial system.

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Internet Appendix for "Inflation Heterogeneity and Household Financial Decisions Evidence from the Mortgage Market"

Zhao Zhang

Figure IA.1: **Inflation Heterogeneity Across Household Income Quintile**

This figure replicates the main finding from Jaravel (2019). The figure reports the average annual inflation rate across income groups using the Nielsen Consumer Panel data.

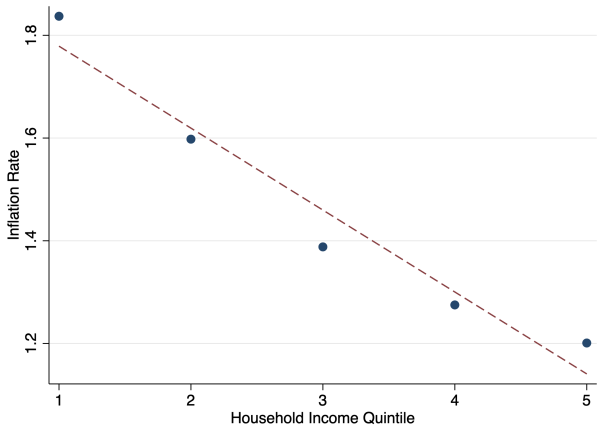


Figure IA.2: **The Distribution of Buyers' Income Quintile and Locations' Income Quintile**

This figure shows the percentage of mortgages taken by a household in income quintile i (left axis) to buy a property in a census tract that belongs to income quintile j (right axis), using mortgage level HMDA data between 2005 and 2017.

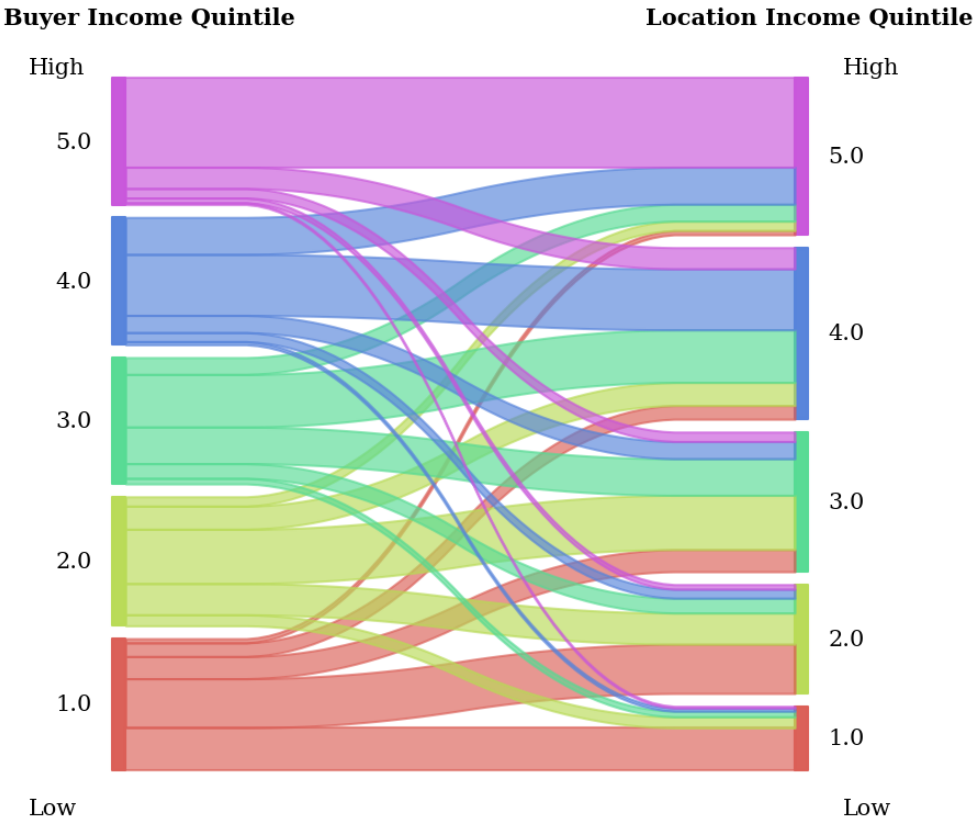
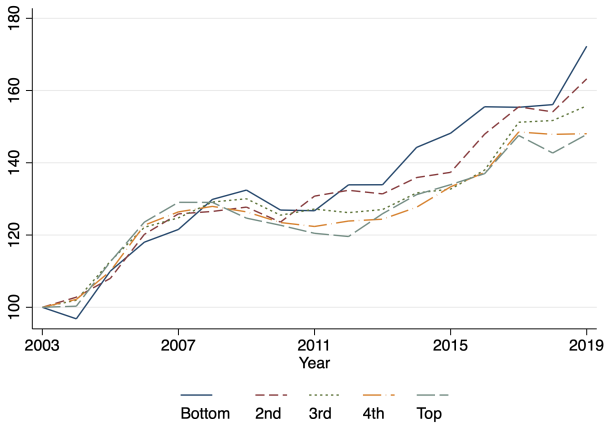
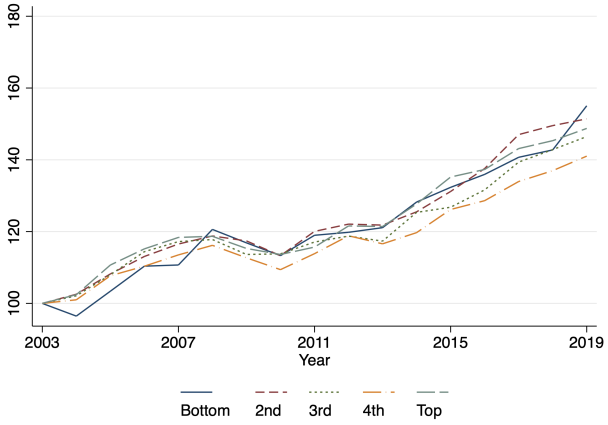


Figure IA.3: **Income Specific Shelter and Total Expenditure Growth**

Figure (a) shows the cumulative growth of shelter expenditure by income quintiles between 2003 and 2019, estimated from Consumer Expenditure Survey data. Figure (b) shows the growth of total expenditure by income quintiles between 2003 and 2019, estimated from Consumer Expenditure Survey data



(a) Income Specific Shelter Expenditure Growth



(b) Income Specific Total Expenditure Growth

Figure IA.4: **Inflation Heterogeneity and Income Growth Heterogeneity**

This figure reports the comovement between the inflation gap and income growth gap across the bottom income households and the top income households. The inflation gap is calculated based on the Nielsen Consumer Panel data. The income growth gap is calculated based on American Community Survey data. The correlation between the inflation gap and the income growth gap is 0.06.

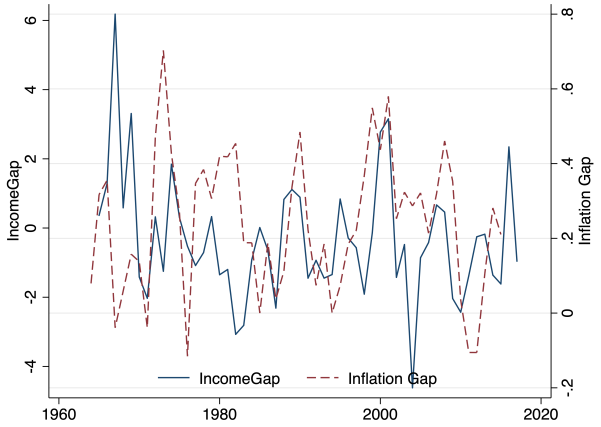


Table IA.1: **Correlation between Inflation Gap and Income Growth Gap**

This table reports the correlation between inflation gap and income growth gap between the bottom income households and the top income households. Newey-West Standard errors are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)
	Inflation Gap				
L2.Income Gap	-0.00816				
	(0.0156)				
L.Income Gap		0.0212			
		(0.0177)			
Income Gap			0.00726		
			(0.0151)		
F.Income Gap				0.00453	
				(0.0153)	
F2.Income Gap					0.00196
					(0.0148)
Observations	48	49	50	51	51
R-squared	0.006	0.029	0.005	0.002	0.000

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure IA.5: **Household Portfolio by Income Quintiles**

Figure IA.5 shows the percentages of each asset category in household balance sheets across income groups. Positive percentages represent net asset positions and negative percentages represent net liability positions. Percentages are calculated based on household net wealth. Data are from Survey of Consumer Finances.

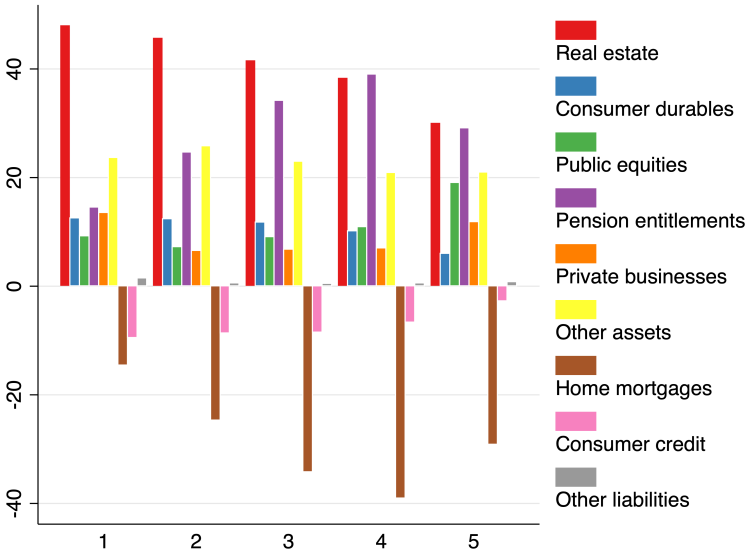


Table IA.2: **Autocorrelation of Inflation Gap**

Columns (1)-(3) report the autocorrelation of the monthly inflation gap between the bottom income households and the top income households. Column (4) reports the autocorrelation of the annual inflation gap between the bottom income households and the top income households between 1969 and 2015. Newey-West Standard errors are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
Inflation Gap	2005-2019	2005-2010	2011-2019	Annual 1969-2015
L.Inflation Gap	0.807***	0.776***	0.694***	0.480***
	(0.0412)	(0.0489)	(0.102)	(0.0960)
Observations	179	71	84	46
Newey-West Standard Errors	Yes	Yes	Yes	Yes

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table IA.3: **Mortgage Taking and Inflation Heterogeneity: After the Financial Crisis**

$$\ln(Number_{k,j,t}+1) = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{k,j,t}$$

where $Num_{k,j,t}$ is the number of mortgages originated at census tract k in year t. The average borrower in census tract k belongs to income quintile j in year t. And $\pi_{j,t}$ is the income-specific inflation of the income quintile j in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the census tract fixed effects. $X_{k,t}$ are other control variables of census tract k, including the log of median income, Zillow home value at the census tract, 1 year local housing market return, 5 year housing market return, 1 year local rent growth, and local rent index. I also control for interest rate term structure and national inflation rate, and allow heterogeneous sensitivity to those variables across income groups. The sample period is from 2010 to 2019. Column 5 has fewer observations because rent data have limited coverage. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	OLS	OLS	2SLS	2SLS
Heterogeneous Inflation	0.0543**	0.0477*	0.103***	0.113***
	(0.0231)	(0.0282)	(0.0320)	(0.0374)
1-Year Housing Ret	0.485***	0.561***	0.492***	0.573***
	(0.0704)	(0.0769)	(0.0699)	(0.0759)
5-Year Housing Ret	-0.00571***	-0.00751***	-0.00565***	-0.00739***
	(0.00175)	(0.00277)	(0.00174)	(0.00276)
1-Year Rent Growth		0.111***		0.112***
		(0.0306)		(0.0307)
Observations	413,315	255,640	413,315	255,640
R-squared	0.919	0.915	0.909	0.899
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table IA.4: **Home Ownership and Inflation Heterogeneity: After the Financial Crisis**

$$\text{Home Ownership}_{i,j,k,t} = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{k,t}$$

where Home Ownership$_{i,j,k,t}$ is a dummy variable that equals to one if household i reports as a home owner. $\pi_{j,t}$ is the income-specific inflation of the income quintile j that household i belongs to in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1 year PUMA home value appreciation, 1 year PUMA rent growth, and PUMA rent index. I also control for interest rate term structure and national inflation rate, and allow heterogeneous exposure to those variables across income groups. The sample period is from 2010 to 2019. Column 5 has fewer observations because rent data have limited coverage. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	Home Ownership			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
Heterogeneous Inflation	0.0314***	0.0317***	0.0636***	0.0639***
	(0.00646)	(0.00633)	(0.00703)	(0.00706)
1-Year Housing Ret	-0.0101	-0.00975	-0.0101	-0.00977
	(0.00834)	(0.00737)	(0.00830)	(0.00734)
1-Year Rent Growth		-0.00437		-0.00464
		(0.00956)		(0.00945)
Observations	6,535,834	6,502,583	6,535,834	6,502,583
R-squared	0.218	0.218	0.218	0.218
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table IA.5: **Mortgage Lien Status and Inflation Heterogeneity: After the Financial Crisis**

$$\text{Mortgage Lien}_{i,j,k,t} = \beta \cdot \pi_{j,t} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{k,t}$$

where Mortgage Lien$_{i,j,k,t}$ is a dummy variable that equals to one if household i reports having a first lien or home equity mortgage. $\pi_{j,t}$ is the income-specific inflation of the income quintile j that household i belongs to in year t. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1 year PUMA home value appreciation, 1 year PUMA rent growth, and PUMA rent index. I also control for interest rate term structure and national inflation rate, and allow heterogeneous exposure to those variables across income groups. The sample period is from 2010 to 2019. Column 5 has fewer observations because rent data have limited coverage. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
	First	Second (Home Equity)	First	Second (Home Equity)
Heterogeneous Inflation	0.0378***	-0.00711	0.0738***	-0.0151*
	(0.0105)	(0.00525)	(0.0172)	(0.00782)
1-Year Housing Ret	-0.00560	-0.00239	-0.00562	-0.00238
	(0.00591)	(0.00223)	(0.00588)	(0.00222)
1-Year Rent Growth	-0.00311	0.00122	-0.00340	0.00128
	(0.00547)	(0.00384)	(0.00542)	(0.00383)
Observations	6,502,583	6,502,583	6,535,834	6,502,583
R-squared	0.184	0.049	0.184	0.049
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table IA.6: **Home Ownership and Inflation Heterogeneity: RMB Appreciation as IV**

The second stage equation and the first stage in the IV specifications are

$$\text{Home Ownership}_{i,j,k,t} = \beta \cdot \hat{\pi_{j,t}} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{i,j,k,t}$$
$$\pi_{j,t} = \tilde{\beta_k} \cdot \mathbf{Z_t} + \tilde{\alpha},$$

where $\text{Home Ownership}_{i,j,k,t}$ is a dummy variable that equals to one if household i reports as a home owner. $\pi_{j,t}$, the income specific inflation of group j in year t, is instrumented by $Z_t = \text{RMB Appreciation}_t$, which is the appreciation of the Chinese Yuan relative to the US dollar over the past 12 months. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1 year PUMA home value appreciation, 1 year PUMA rent growth, and PUMA rent index. I also control for interest rate term structure and national inflation rate, and allow heterogeneous exposure to those variables across income groups. The sample period is from 2005 to 2019. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	Home Ownership			
$\widehat{Heterogeneous\ Inflation}$	0.0756***	0.0800***	0.0905***	0.0909***
	(0.0143)	(0.0142)	(0.0165)	(0.0165)
1-Year Housing Ret	-0.00914	-0.00914	-0.00931	-0.00926
		(0.00626)	(0.00626)	(0.00571)
g_Rent_FE				-0.00497
				(0.00867)
Observations	9,677,676	8,872,562	8,872,562	8,833,397
R-squared	0.224	0.221	0.221	0.221
Control Variables	Yes	Yes	Yes	Yes
Inflation Exposure			Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table IA.7: **Mortgage Lien Status and Inflation Heterogeneity: RMB Appreciation as IV**

The second stage equation and the first stage in the IV specifications are

$$\text{Mortgage Lien}_{i,j,k,t} = \beta \cdot \hat{\pi_{j,t}} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{i,j,k,t},$$
$$\pi_{j,t} = \tilde{\beta_k} \cdot \mathbf{Z_t} + \tilde{\alpha},$$

where Mortgage Lien$_{i,j,k,t}$ is a dummy variable that equals to one if household i reports having a first lien or home equity mortgage. $\pi_{j,t}$, the income specific inflation of group j in year t, is instrumented by Z_t = RMB Appreciation$_t$, which is the appreciation of the Chinese Yuan relative to the US dollar over the past 12 months. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1 year PUMA home value appreciation, 1 year PUMA rent growth, and PUMA rent index. I also control for interest rate term structure and national inflation rate, and allow heterogeneous exposure to those variables across income groups. The sample period is from 2005 to 2019. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	First	First	Second (Home Equity)	Second (Home Equity)
$\widehat{Heterogeneous\ Inflation}$	0.108***	0.109***	-0.0577***	-0.0578***
	(0.0204)	(0.0204)	(0.0141)	(0.0140)
1-Year Housing Ret	-0.00638	-0.00597	-0.00335*	-0.00407**
	(0.00479)	(0.00450)	(0.00179)	(0.00167)
1-Year Rent Growth		-0.00539		0.00626
		(0.00545)		(0.00392)
Observations	8,872,562	8,833,397	8,872,562	8,833,397
R-squared	0.191	0.191	0.069	0.069
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-by-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table IA.8: **Home Ownership and Inflation Heterogeneity: China Trade Exposure**

The second stage equation and the first stage in the IV specifications are

$$\text{Home Ownership}_{i,j,k,t} = \beta \cdot \hat{\pi_{j,t}} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{i,j,k,t}$$
$$\pi_{j,t} = \tilde{\beta_k} \cdot \mathbf{Z_t} + \tilde{\alpha},$$

where $\text{Home Ownership}_{i,j,k,t}$ is a dummy variable that equals to one if household i reports as a home owner. $\pi_{j,t}$, the income specific inflation of group j in year t, is instrumented by $Z_t = \text{RMB Appreciation}_t$, which is the appreciation of the Chinese Yuan relative to the US dollar over the past 12 months. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1 year PUMA home value appreciation, 1 year PUMA rent growth, and PUMA rent index. I also control for interest rate term structure and national inflation rate, and allow heterogeneous exposure to those variables across income groups. The sample period is from 2005 to 2019. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	Low Trade Exposure	Low Trade Exposure	High Trade Exposure	High Trade Exposure
$\widehat{Heterogeneous\ Inflation}$	0.0995***	0.0995***	0.0822***	0.0831***
	(0.0183)	(0.0184)	(0.0154)	(0.0155)
1-Year Housing Ret	-0.00836	-0.00958	-0.00954	-0.0101*
	(0.00708)	(0.00729)	(0.00657)	(0.00595)
1-Year Rent Growth	-0.00921			-0.00181
	(0.00851)			(0.0115)
Observations	4,438,346	4,451,946	4,384,161	4,358,596
R-squared	0.252	0.243	0.251	0.244
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure	Yes	Yes	Yes	Yes
County-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table IA.9: **Mortgage Lien Status and Inflation Heterogeneity: China Trade Exposure**

The second stage equation and the first stage in the IV specifications are

$$\text{Mortgage Lien}_{i,j,k,t} = \beta \cdot \hat{\pi_{j,t}} + \gamma \cdot X_t + \psi_{k,t} + \eta_k + \epsilon_{i,j,k,t},$$
$$\pi_{j,t} = \tilde{\beta_k} \cdot \mathbf{Z_t} + \tilde{\alpha},$$

where Mortgage Lien$_{i,j,k,t}$ is a dummy variable that equals to one if household i reports having a first lien or home equity mortgage. $\pi_{j,t}$, the income specific inflation of group j in year t, is instrumented by $Z_t =$ RMB Appreciation$_t$, which is the appreciation of the Chinese Yuan relative to the US dollar over the past 12 months. $\psi_{k,t}$ are the county by year fixed effects, and η_k are the public use micro area (PUMA) effects. $X_{k,t}$ are other control variables, including the log of household income, PUMA home value index, 1 year PUMA home value appreciation, 1 year PUMA rent growth, and PUMA rent index. I also control for interest rate term structure and national inflation rate, and allow heterogeneous exposure to those variables across income groups. The sample period is from 2005 to 2019. Standard errors clustered at the county level are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

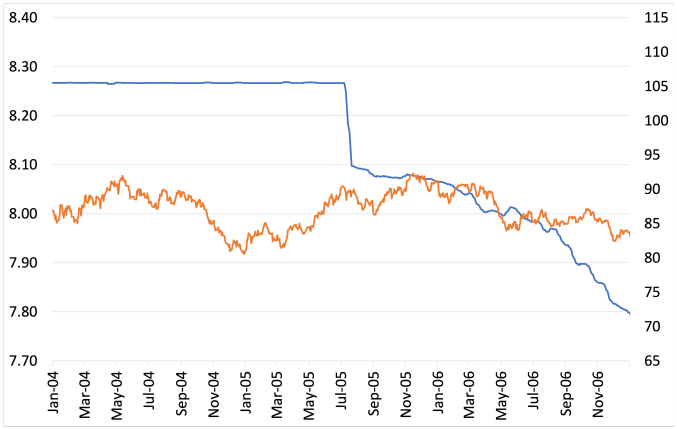
	(1)	(2)	(3)	(4)
	Low Trade Exposure	Low Trade Exposure	High Trade Exposure	High Trade Exposure
	First	Second (Home Equity)	First	Second (Home Equity)
$\widehat{Heterogeneous\ Inflation}$	0.116***	-0.0604***	0.102***	-0.0546***
	(0.0226)	(0.0147)	(0.0189)	(0.0136)
1-Year Housing Ret	-0.00397	-0.00157	-0.00684	-0.00475**
	(0.00534)	(0.00394)	(0.00433)	(0.00180)
1-Year Rent Growth	-0.0125	0.00359	-0.00167	0.00760
	(0.00791)	(0.00534)	(0.00736)	(0.00501)
Observations	4,438,346	4,438,346	4,358,596	4,358,596
R-squared	0.252	0.243	0.251	0.244
Inflation Exposure	Yes	Yes	Yes	Yes
Interest Rate Curve Exposure Yes	Yes	Yes	Yes	
County-Year Fixed Effects	Yes	Yes	Yes	Yes
Census Tract Fixed Effects	Yes	Yes	Yes	Yes
Clustered Standard Errors	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

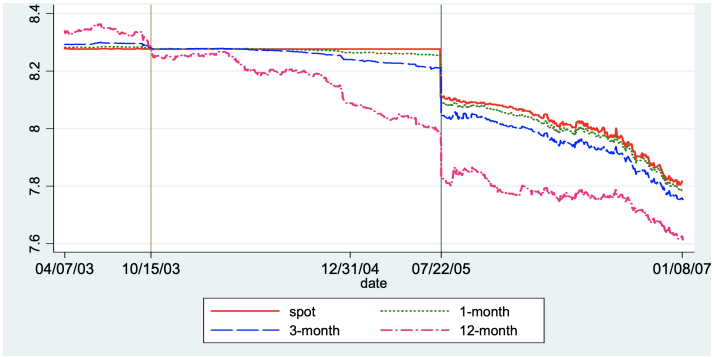
*** p<0.01, ** p<0.05, * p<0.1

Figure IA.6: **Chinese Yuan Exchange Rate Reform in July 21 2005**

The blue line in figure (a) shows the daily exchange rate between US Dollar and the Chinese Yuan (RMB) between 2004 and 2006. Before July 21 2005, RMB was pegged to USD with 8.27 RMB per USD. On 21 July 2005, China lifted the peg and moved to a managed float exchange rate system against a basket of major currencies. RMB immediately appreciated by 2.1% against USD within one day. The orange line in figure (a) reports the daily Dollar Index. Figure (b) is from Frankel and Wei (2007) and shows the spot and forward rates of USD/RMB around July 21 2005.



(a) RMB Reform on July 21 2005 (2004 to 2006)



(b) Spot and Forward Rates of USD/RMB

Source: Frankel and Wei (2007)

IA.1. Chinese Yuan Reform and the US Inflation

Right after the RMB reform on July 21 2005, consistent with the 12-month forward rate, many practitioners in Wall Street believed RMB would continue to appreciate. Jay Bryson, global economist for Wachovia Securities, "Will the yuan be 30 percent stronger vs. the dollar a year from now? I doubt that. Could it be 10 percent stronger? Yeah, that's reasonable."[x]

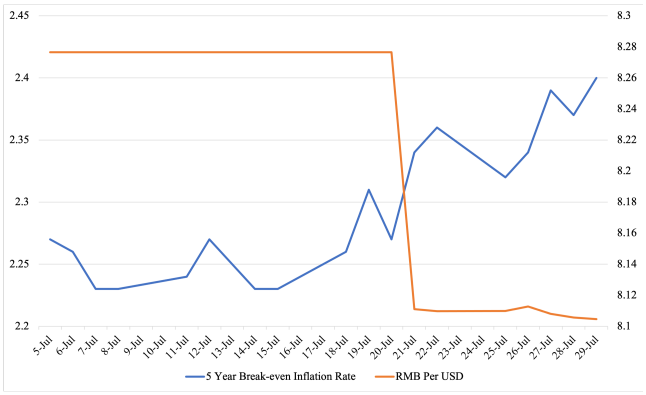
How would the 2005 Chinese Yuan reform and the following RMB appreciation expectation affect the inflation in the US? Allen Greenspan, the then Chairman of Fed, expressed his concern about potential domestic inflation risk because of RMB appreciation. Mr. Greenspan said "revaluation would amount to higher prices for consumers, as retailers passed the higher costs of Chines imports by raising prices" and "The effect will be a rise in domestic prices in the United States and, as a consequence of that, we will have other impacts."[xi] Mr. Greenspan's view on RMB appreciation and US inflation is consistent with the evidence from the 5 year break even inflation expectation (Figure IA.7a) and the price index of imported goods from China (Figure IA.7b). Figure IA.7a shows US inflation expectation rises by about 7 basis points within a three-day window, around the RMB reform on July 21 2005. Figure IA.7b shows the price indexes of imports from China start to increase after 2005 while are previously decreasing before 2005. The response of US inflation to RMB appreciation is in line with the findings by Amiti and Davis (2009); Auer (2015); Fair (2010); Chen et al. (2011); Bai and Stumpner (2019); Hottman and Monarch (2020).

[x] "China Revalues Yuan", CNN, July 21, 2005

[xi] "Greenspan's Yuan Policy", Wall Street Journal, May 23, 2005

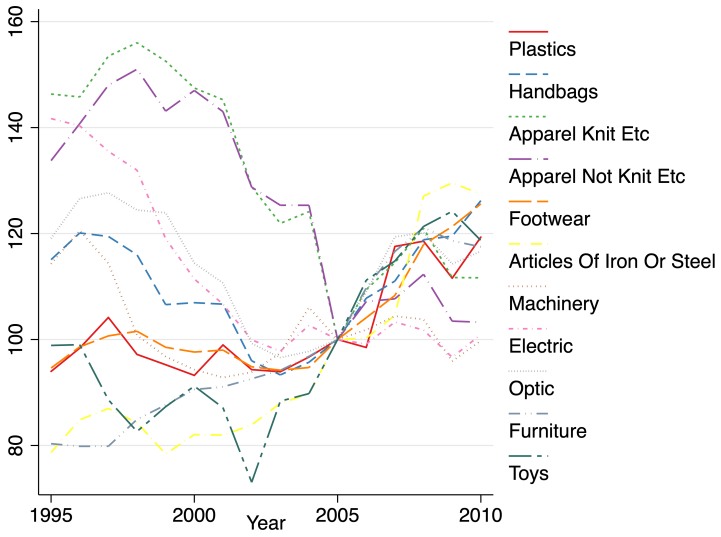
Figure IA.7: **Chinese Yuan Exchange Rate Reform and US Inflation**

Figure IA.7a shows the daily RMB exchange rate to USD and 5-year break even inflation expectation based on 5-year US treasury and the inflation indexed 5-year treasury in July 2005. Around the RMB reform on July 21 2005, US inflation expectation rises by about 7 basis points within a three-day window. Figure IA.7b shows the price indexes of the top 10 product categories of US imports from China, based on disaggregated data from U.S. Import and Export Merchandise Trade Statistics following the methodology in Amiti and Davis (2009). The disaggregated US import data use a ten-digit classification of the Harmonized System and covers 12,499 product codes for goods imported from China, with monthly records of total value and unit price of each product code. The top 10 categories constitute about 80 percent of US total imports from China.



(a) RMB Reform in July 21 2005 (2004 to 2006)

Source: Federal Reserve Bank of St. Louis



(b) Spot and Forward Rates of USD/RMB

Source: U.S. Import and Export Merchandise Trade Statistics and Amiti and Davis (2009)