

# Heterogeneous Asset Returns and Monetary Policy Redistribution\*

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## Abstract

The paper analyzes how wealth inequality influences the transmission of monetary policy to consumption in the short run. My mechanism operates via the differential impact of a monetary policy shock for equity & housing with its consequent implications for heterogeneous MPCs across the wealth distribution. I develop a flexible model free sufficient statistics framework that incorporates the ex-post returns heterogeneity post unexpected monetary policy to robustly estimate aggregate consumption from survey data. First, I report its elasticity in general equilibrium to be 1.34. It is 15% lower in the absence of returns heterogeneity and nearly 74% lower in the absence of MPC heterogeneity. Greater the gap between returns across assets, larger is the aggregate consumption response. Second, I further quantify the interaction between idiosyncratic borrowing constraints characterized by housing tenure and demographics with heterogeneity in asset returns. Outright homeowners who are significantly less leveraged than mortgage holders have an elasticity of 2.39 in comparison with only 0.96 for the latter. Similarly, middle aged people have an elasticity of 1.38 relative to 1.22 for the young. Finally, I document how borrowing constraints interact with returns heterogeneity to predict significant asymmetries in the monetary response. Aggregate consumption elasticity is now estimated to be only 1.02 under contractionary policy. Outright homeowners and mortgage holders now have elasticities of 1.44 and 0.77 respectively. The trend is less clear for age with the young and middle now having elasticities of -1.45 and -0.77. Household portfolio heterogeneity affects overall monetary transmission more than previously estimated, even for the short run.

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# 1 Introduction

One of the recent areas of interest for central banks has been evaluating the role of wealth inequality in influencing the transmission of monetary policy to aggregate consumption in the short run. A change in the central bank rate sets off endogenous wealth transfers across the wealth distribution. Redistributing equivalent resources from one group to another has a net non zero response on aggregate consumption since *MPCs* are heterogeneous throughout the population. This challenges the conventional view that redistribution is a channel and not a side effect of monetary policy transmission. The overall consumption response can be decomposed into five separate channels arising from changes in the real interest, nominal prices and idiosyncratic earnings. It can be quantified with only seven sufficient statistics, all of which can be estimated from survey data. [Auclert \(2019\)](#) finds that redistribution accounts for nearly one third of the overall aggregate consumption response. Relative to existing work, he correctly quantifies household balance sheets by adjusting for asset maturities, shifting the debate from the traditional discourse centering around asset prices. For his results, a change in the policy rate produces a symmetric & homogeneous response across returns and prices for all assets in the economy, particularly housing and equity.

However, I document empirically that a one time unexpected monetary policy shock produces very different changes in prices & returns for housing and equity as compared to liquid assets. Relative to equity, housing tends to respond slower with a much smaller persistent impact owing to relative illiquidity characterized by substantial transaction costs. Since holdings of these two principal assets vary widely across the wealth distribution, the combined effect is different unrealized capital gains/losses by wealth decile from both the nominal price (inflation or Fisher) and real interest rate channels. The decomposition of this overall effect into contributions from housing & equity are also heterogeneous across the distribution.<sup>1</sup> Redistributive wealth transfers now depends on post shock returns heterogeneity in conjunction with existing household portfolio holdings. Formally, the exposures across groups from the real interest rate and Fisher channels need to be calculated more precisely to definitely answer who gains and who loses from changes in monetary policy. Consequently, the question is whether there is a quantitatively significant impact on general equilibrium aggregate consumption in the short run.

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<sup>1</sup> See [Kuhn and Rios-Rull \(2020\)](#) for an updated discussion and related literature. They discuss how SCF data can be used to study the joint distribution of earnings, income, and wealth distributions in the United States. They also decompose the contributions with respect to income sources and asset classes for income and wealth concentration.

I develop a perfect foresight model based off [Auclert \(2019\)](#) to investigate the conditional impact of the one time monetary policy surprise on housing & equity relative to liquid assets on household consumption using sufficient statistics. There are three primary contributions. First, my sufficient statistics are conditioned on exogenous monetary policy. I can isolate the relative impact of housing or equity one at a time to obtain separate estimates across asset classes. Second, the setup can be extended to estimate these new redistribution measures from persistent changes in the real interest rate. Third, it can now handle on asymmetric shocks. I use the liquid asset as the benchmark for ease of comparison with the original results. Further, I show the setup is robust to the presence of durable goods, elastic labor supply and extends to incomplete markets, though the latter two are harder to estimate empirically. The importance of the differential asset returns channel is reflected in both the aggregate general equilibrium consumption response and the direct effects from a change in the policy rate. Both are unit free elasticity measures that can be compared across models. I perform limited policy counterfactuals without potential model misspecification errors that plague structural models. Since there is considerable debate over the ideal econometric method for calculating the conditional impact of a one time monetary policy surprise on asset premia & prices, my results are flexible in accommodating alternate estimates obtained using the methodology of choice.

I estimate the sufficient statistics that summarize the household exposures to real interest and Fisher channels from survey data with extensive information on consumption & household balance sheets. Based on these exposures, I estimate the household level *MPC* from an unexpected lumpsum fiscal transfer. My primary findings are as follows. First, if the Fed lowers rates by 75bp aggregate consumption would rise by 1% . The elasticity is 15% higher on decreasing the fed funds rate with separate returns for housing & equity & cash. The share of redistribution effects is two-thirds. (overall 43%) relative to [Auclert \(2019\)](#). My elasticity is three-fourths larger than the corresponding representative agent model. For a same 75bp raise in rates, aggregate consumption would decline by only 0.76% demonstrating strong asymmetric effects. Second, since the estimate of the *IES* is important for transmission in a RANK, I find that increasing it by 63% correctly accounts for aggregate transmission to consumption. Since the conditional impact on returns and prices for equity are far stronger, the amplification in the household exposures are higher for the former. Instantaneous consumption response is now 30% higher than the benchmark. In response to a contractionary shock, since housing wealth is affected the least, the decline is nearly 19% less (in comparison to 15% for equity).

Since households are forward looking, they can correctly anticipate the conditional impact of the transitory monetary surprise over the entire time path of prices and returns for all assets. The impact on wealth can be summarized by the unrealized capital gains/losses from the real interest rate and Fisher channel. The latter boosts asset prices with agents holding majority of wealth in equity gaining relative to agents with higher portfolio shares in housing. The former increases the relative excess returns on the asset while possibly lowering debt payments. Despite the changes being unrealized, households feel wealthier as they expect to convert the gains into liquid assets sometime into the future. Consequently, they consume more out of a dollar today leading to higher *MPCs* out of current income. *MPCs* out of income are now heterogeneous across the wealth distribution for each redistribution channel. They are also adjusted to accurately incorporate differential returns across the three assets. My estimates (15 % higher) are typically larger than the estimates of *MPC* out of realized wealth gains for housing in the literature since they are underestimated in the absence of returns heterogeneity.<sup>2</sup> The results indicate aggregate consumption is substantially higher from the incorporation of returns heterogeneity. Redistribution produces negligible consumption effects without heterogeneity in *MPCs* out of income. A representative agent counterpart with multiple asset returns is therefore ineffective in estimating aggregate consumption.

Monetary policy affects households differently leading to heterogeneous consumption responses. It depends critically on interaction of borrowing constraints and wealth at the household level. Households facing higher collateral constraints would find it difficult to realize these wealth changes and smooth consumption. Unpacking the aggregate change across different demographic groups and household portfolios, I find that homeowners who have little housing debt and considerable liquid income, stocks and corporate bonds and little housing debt have an elasticity of 2.4 which is 79% larger than the aggregate. In contrast, homeowners with high debt and low liquid assets have an elasticity of only 0.96 which is 28% lower since the former are much less constrained and can take on additional debt if required. They are better positioned to consume more today when rates go down. Similarly, for an increase in interest rates homeowners with little housing debt and considerable liquid income would reduce their consumption 41% higher than aggregate while the response is much smaller for the latter. Similarly, the older have elasticities higher than average while the young have much lower elasticities than the average with the latter group saddled with

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<sup>2</sup> [Paiella and Pistaferri \(2017\)](#) report values in the range of 3-7.5% from home-equity channel, consistent with [Mian and Sufi \(2014\)](#). [Di Maggio et al. \(2020\)](#) reports *MPC* out of unrealized equity gains is in the range of 23% for bottom 50% and only 3% for the top 30%. *MPC* out of dividends is nearly 10 times higher than out of capital gains as estimated by [Hartzmark and Solomon \(2019\)](#). For more details and other comparisons see appendix D.

considerable debt. The middle aged who are nearly 55% of the sample and have less housing debt have a 21% higher (31% lower) response than the aggregate for a 1% decrease (increase) in the federal rate. Expansionary monetary policy tends to benefit agents who have more liabilities (primarily with longer maturities eg mortgages) than assets (with shorter maturity eg stocks and bonds) since the former have higher  $MPCs$  than the latter. A strong negative correlation is expected. Similarly,  $MPCs$  would decline as the household net nominal position ( $NNP$ ) increases. The correlation is weaker since a majority hold housing both as asset and debt despite having positive  $NNPs$ . These households have inherently higher  $MPCs$ .

From a policy perspective, I explore the model predictions for an expansionary policy at the start of the pandemic & a contractionary policy before the GFC. The results are robust across years for expansionary policy. Restricting asset maturities to quarterly sharpens the importance of returns heterogeneity with a 24% increase in 2019 (share of redistribution is 67%). This support the aggressive quantitative easing policies of the Fed at the onset/during the pandemic. If all mortgages were adjustable rate, then it would lead to a rise of 30% (share at 58%) & 53% (share at 79%) for baseline (quarterly) asset maturities. I make a case for reducing refinancing costs for much of the population in times of need to support a faster consumption recovery. The model cannot produce sizeable additional declines in consumption around the GFC. Instead, an expansionary policy predicts an even larger consumption response since overall wealth gains from housing outperformed equity. In summary, my paper allows interaction of three key channels - returns heterogeneity, asset maturity and household portfolio heterogeneity. Wealth inequality influences monetary policy transmission towards aggregate consumption in the short run more than previously estimated.

I recognize some limitations of my current results. They are majorly dependent on having detailed information on household balance sheets. In this regard, I posit that my findings are conservative on the downside though further detailed investigation would be required in the future to back the claims. One solution is to use PSID data instead of CE. Second, sufficient statistics offers numerous advantages but model free environments can take us only so far. For joint interaction of fiscal & monetary policy in carefully controlled environments, one needs to rely on structural models. I hope my results motivate a canonical HANK model with two illiquid assets having separate returns. Despite the challenges, it proves to be an interesting extension for the future.<sup>3</sup>

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<sup>3</sup> Adding both returns and price heterogeneity would be even more difficult. I find that barring one or two cases, the interest rate channel is responsible for the majority of the variation. A suitable setup is [Kaplan et al. \(2018\)](#). Moreover, larger the returns gap, higher is the aggregate  $MPC$  as found by [Kaplan and Violante \(2020\)](#).

**Related Literature** - The paper contributes primarily to four main strands in the literature. First, there is an extensive empirical literature which has documented that marginal propensities to consume out of a transitory unexpected fiscal transfer are large and heterogeneous in the population (see [Jappelli and Pistaferri \(2010\)](#) for a survey, [Johnson et al. \(2006\)](#) for a relevant empirical application). My key finding is that aggregate *MPC* out of income is biased considerably on the downside in the absence of returns heterogeneity through the unrealized wealth changes channel, highlighting the importance of household balance sheets and redistribution in determining the aggregate consumption response.<sup>4</sup> I stress on the importance of these changing estimates in determining the aggregate consumption response by comparing the same with self-reported *MPCs* from the SHIW 2010 (for a detailed analysis of the suitability of the data in relation with empirical determinants of *MPC* see [Jappelli and Pistaferri \(2014\)](#)).<sup>5</sup>

There is considerable debate and extensive work in determining impact of a transitory unexpected monetary policy shock on the real interest rate, overall price level and asset prices & premia. There have been primarily two approaches - using a structural VAR or local projections. [Gertler and Karadi \(2015\)](#) builds a structural VAR with external instruments to estimate the impact on credit costs, extending the methods of [Mertens and Ravn \(2013\)](#) obviating the need of restrictive identification assumptions. The method has the advantage of generating arbitrarily long impulse responses inline with the theoretical exercise conducted by [Auclert \(2019\)](#). A similar exercise has been conducted by [Luetticke \(2021\)](#) using local projections for an impulse horizon of 16 quarters. The primary difficulty is the inability to forecast beyond some finite time period which is fairly small (32 to be precise for [Luetticke \(2021\)](#)) notwithstanding its robustness to model misspecification.<sup>6</sup> I use the former to obtain the empirical analogues of the model by using estimates of the present discounted values of the requisite variables which form the mainstay of the paper and prove to be both reliable

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<sup>4</sup> Recently, several papers in the literature have documented a positive relationship between *MPCs* and return heterogeneity in the response of household consumption, employment and income during the Covid-19 pandemic as examined by [Baker et al. \(2020\)](#); [Chetty et al. \(2020\)](#).

<sup>5</sup> I retain the assumption of having a single *MPC* that is identical across asset classes. For more details see section 4. The literature has found dependence of *MPCs* on household balance sheet positions, particularly housing ([Mian et al. \(2013\)](#); [Mian and Sufi \(2014\)](#)); [Cloyne et al. \(2020\)](#)) for *MPC* out of realized wealth changes. See footnote 2

<sup>6</sup> Recent work by [Plagborg-Møller and Wolf \(2021\)](#) show that for small time horizons less than equal to lag length of corresponding SVAR, local projections deliver nearly identical results and is clearly superior. Common issues with both is the persistence of impulse responses even at very large horizons. This and related empirical puzzles have been somewhat attenuated by the development of bayesian local projection techniques in [Miranda-Agrippino and Ricco \(2021\)](#).

and robust for the problem at hand.<sup>7</sup>

Thirdly, a major advantage of sufficient statistics is reducing the reliance on structural models which are susceptible to potential misspecification errors. At the same time, they preserve application of simple policy counterfactuals in a largely model-free environment. Auclert and Rognlie (2020) uses it estimates the impact of income inequality moments on aggregate demand, Auclert et al. (2018) uses for intertemporal *MPCs* to obtain empirically consistent *IRFs*. Berger et al. (2018) develops them for the impact of house prices on consumption movements, estimating them from PSID data. Besides obtaining more precise estimates at the aggregate level, I have estimates by asset class which are of interest to papers focusing exclusively on for example importance of housing in HANK (Hedlund et al. (2017)) instead of relying on a one-size fits all approach. One can of course directly estimate the overall consumption response from rich micro data that has adequate information on both consumption & household wealth as explored by Holm et al. (2021) using high quality Norwegian data. Such an exercise is quite difficult for the US and is clearly sub optimal to my reduced form approach owing to large noise in the estimates as for example in Coibion et al. (2017).<sup>8</sup>

Fourthly and most importantly, I discuss alternate approaches used in the literature instead of returns heterogeneity that tend to quantitatively target aggregate consumption. For example, structural models dealing with heterogeneity use reduced form idiosyncratic discount factors viz. Gornemann et al. (2021) who explore the question of how monetary policy should systematically respond to labor income and wealth. In contrast, I rely directly on uncovering changes in the consumption response through estimates of the impact of monetary policy on household portfolios observed directly in the data. They are also sufficient for performing simple policy making experiments that broaden the aggregate influence of heterogeneity in household wealth holdings. Kekre and Lenel (2021) calculates covariances between heterogeneous marginal propensities to take risk and redistribution exposures. They report a muted increase in consumption & a large increase in investment relative to RANK

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<sup>7</sup> Recently, Paul (2020) has improved on the techniques further and delivered robust estimates using a time-varying parameter VAR. The drawback with this approach is the very high persistence in the impulse response functions (*IRFs*) due to which I obtain quite different present discounted values of the interested variables. Gertler and Karadi (2015) is very robust to arbitrary impulse response horizon which are not persistent. The results for comparison are included in appendix A.2.

<sup>8</sup> Several papers have stressed on the importance of heterogeneous asset returns for substantial general equilibrium effects stemming from consumption changes. Ampudia et al. (2018) studies the heterogeneous *MPCs* from asset return data for European countries while Leombroni and Rogers (2021) find that portfolio rebalancing & life-cycle effects where young raise their consumption more than the old have a net positive impact on general equilibrium labor supply and output through consumption.



since their sufficient statistics correlate with marginal propensities to take risks which matter more for investment rather than for *MPCs*. My contribution here is twofold. Firstly, their sufficient statistics cannot handle the impact of monetary policy unlike mine and secondly, the quantitative response to consumption is far larger from the differential asset returns channel and nearly double relative to its representative agent counterpart.<sup>9</sup> [Kaplan and Violante \(2020\)](#) compares a large class of structural models & find that the 2-asset HANK model is satisfactory in depicting a realistic distribution of heterogeneous *MPCs*. The key finding is that larger the gap between asset returns, greater is the *MPC* which is consistent with my empirical results.

**Layout** - The rest of the paper is structured as follows. Section 2 lays down the procedures used to infer the impact of monetary policy shocks on requisite variables and subsequent motivating evidence. The model and theoretical results are contained in Section 3. Section 4 details the measurement of the sufficient statistics from survey data while section 5 discusses the key findings. A final section 6 concludes. Robustness checks, proofs for model extensions and additional results are contained respectively in appendices A - F.

## 2 Empirical Methodology

I want to characterize the instantaneous impact of a one time unexpected monetary policy surprise on household balance sheets, particularly the differential impact on housing and equity. This allows me to condition the sufficient statistics on monetary policy. The impact on the wealth distribution from the real interest rate cut would transmit through the excess premia on these two asset classes.<sup>10</sup> Additionally, the price of the assets change which is the second transmission channel operating through inflation. The third transmission channel is based on the real time impact on idiosyncratic earnings and is difficult to obtain from data. The former two are therefore the main reasons to obtain a more precise estimate of the

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<sup>9</sup> [Monacelli and Colarieti \(2022\)](#) lay out a heteroskedastic NK model matching the cross - section estimates in the income process estimated by [Guvenen et al. \(2021\)](#). The final consumption response in terms of sufficient statistics can be larger/smaller depending on the magnitude of cyclicity of income ( $\gamma$ ). My results are robust to market incompleteness as well as to RANK models which are homoskedastic. I perform sensitivity checks in this regard in section 5.2 and appendix C and find that my key results are largely the same to changing  $\gamma$ .

<sup>10</sup> I focus on excess returns and not real returns. Theoretically, I would normalize with the change in the real interest rate which is the change in the real return for the liquid asset. In reality, the return on the liquid asset varies nominally from the transitory monetary policy surprise. It is persistent because of which we need a measure of excess returns for the two assets before normalization of the PDVs.



instantaneous impact of monetary policy on the household wealth distribution. I later show in section 4 that these changes are essential for more accurate measures of the *MPC* at the household level. I adopt the SVAR approach based on the specification & methods of [Gertler and Karadi \(2015\)](#). Since majority of my theoretical results depend on a perfect foresight model as articulated in section 3, the closest empirical counterparts are present discounted values using one of the benchmark discount factors in [Auclert \(2015\)](#) with ideally as long a horizon as feasible. I also have to pay close attention to make sure the *IRFs* are stable and consistent at sufficiently long horizons, a feature difficult to achieve using local projections technique. A local projection exercise is conducted by [Luetticke \(2021\)](#) for precisely the same variables at quarterly frequency. I compare the results in section 5 with the local projection method for 16 quarters in appendix A.3 and show that they are qualitatively similar.

## 2.1 A structural VAR with external instruments approach

I need data on excess premia & nominal asset prices for housing & equity. The changes in the real interest rate and the aggregate price level denote the impacts for the benchmark liquid asset. Besides these 6 variables, I also include the industrial production as the broad gauge of overall economic activity. The frequency is monthly. The model is essentially a structural VAR of 7 variables estimated using an external instrument set that serves to identify monetary surprises. For the results in the main text, I set the lag length to be 7 for stable *IRFs* at arbitrarily long horizons. Checks for selection of lag & horizon length are included in appendix A.1. The definitions & data sources of the variables follow [Luetticke \(2021\)](#) with the exception of housing premium which is measured as the monthly excess return on housing using the combined house price index data from Robert Shiller’s website.<sup>11</sup> For more details about how to estimate the model, see section II of [Gertler and Karadi \(2015\)](#). I only use the estimation procedure for their baseline specification.

The set of external instruments consists of the surprises in the current & three month ahead monthly fed funds futures and in the six month, nine month & one year ahead futures on three month Eurodollar deposits. The sample period for the exercise is 1979:7 to 2012:6. Since I am not dealing with the issue of forward guidance in this paper, the current surprise in

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<sup>11</sup>The excess returns on housing at the quarterly frequency is calculated in [Luetticke \(2021\)](#) using the techniques of [Gomme et al. \(2011\)](#). I have found that the corresponding data sources are unavailable at the monthly frequency. Other estimates which include the change in rents are possible at monthly level. The drawback is the CPI for rent is unavailable for the entirety of the sample period. Substituting it with CPI for all items is unreliable. See appendix A.3 for variable definitions.

Table 1: Present discounted value estimates from VAR based in section 2.1 using  $\beta = 0.95$

| <b>Present Discounted<br/>Value at <math>t = 0</math></b> | Nominal<br>House<br>Price | Housing<br>Premium | Nominal<br>Stock<br>Price | Equity<br>Premium | Nominal<br>House<br>Price | Nominal<br>Equity<br>Price |
|---|---------------------------|--------------------|---------------------------|-------------------|---------------------------|----------------------------|
| Empirical   | 0.84                      | 1.28               | 2.43                      | 2.51              | 0.41                      | 1.18                       |
| Normalized (Y/N)  | <b>N (in% )</b>           | Y                  | <b>N (in% )</b>           | Y                 | Y                         | Y                          |

Note - Specification used is detailed in 2.1. Results with  $\beta = 0.95$  and one standard deviation positive monetary policy surprise for 1000 months ahead. Required for conditional impact of monetary policy. Most estimates normalized with respect to the liquid asset to make them comparable to the benchmark. See section 3.2 for more details and also section 4 for their use in measuring the sufficient statistics.

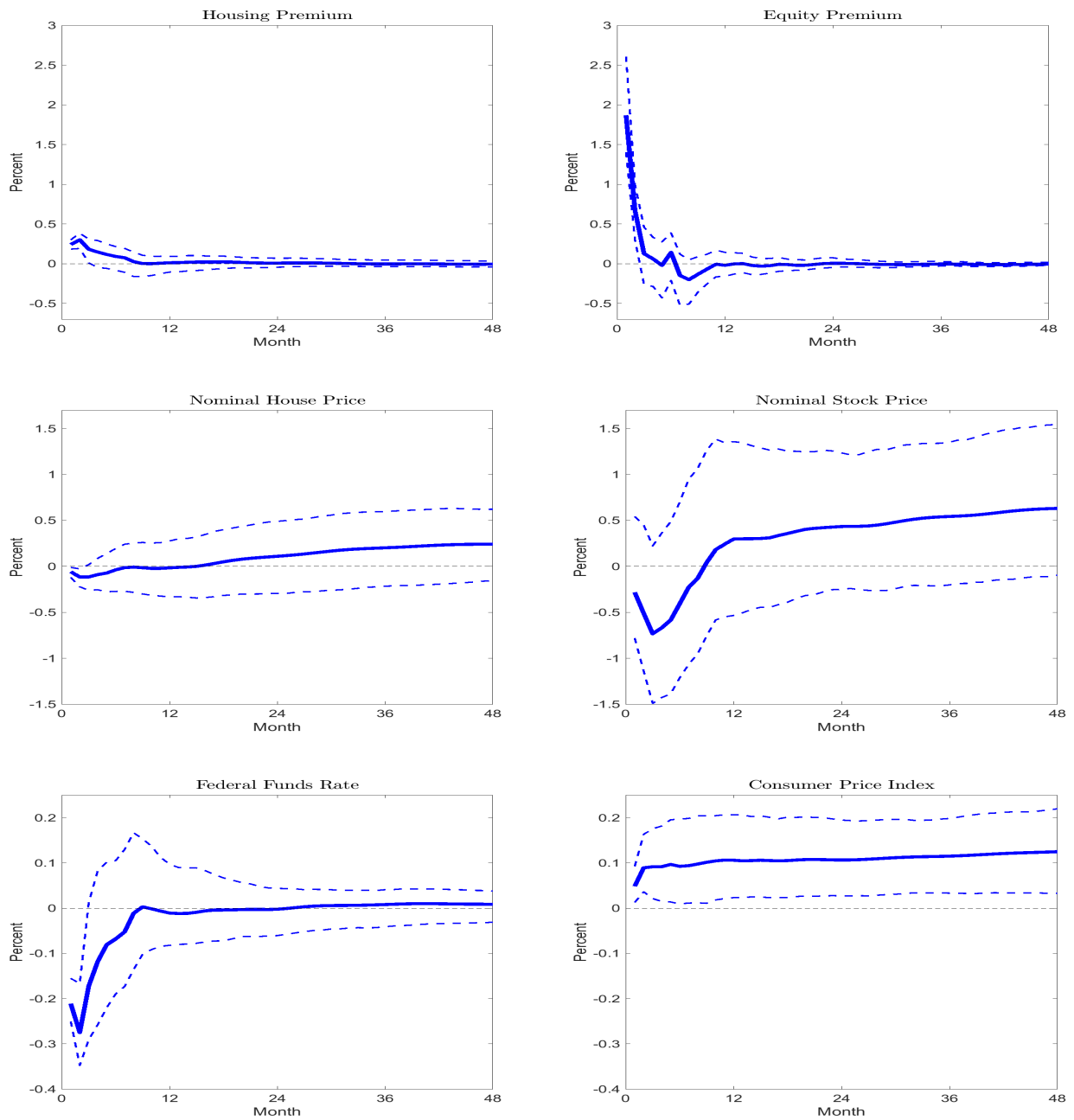
the fed funds futures serves as the policy variable. Another major advantage of this method lies in the fact that I do not need to include the real interest rate separately. As shown by Gertler and Karadi (2015) section C, there is negligible difference between the movement in nominal and real rates following a monetary policy surprise in HFI analysis. Their Figure 4 shows very little impact of inflation on two, five and ten year government bond rates.<sup>12</sup> The *IRFs* are generated for one-standard deviation decline in the monetary policy surprise for the expansionary shock. Figure 1 shows the *IRFs* for 4 years ahead. I show the complete *IRFs* for the entire horizon of 1000 months in Figure 6. Results are intuitive with *IRFs* for stock prices & excess returns responding faster and by a larger magnitude relative to housing, as expected. The PDV estimates, appropriately normalized, are presented in Table 1.

## 2.2 Unrealized Wealth Changes from Monetary Policy Shocks

Using the estimates in Table 1, I calculate the unrealized wealth changes from the SCF data to demonstrate that household wealth changes, as a percentage of gross wealth, are substantially different across gross wealth quantiles. I need to summarize the changes from the two channels - the real interest rate and the Fisher. Taking the SCF data for the interested year, I first calculate the gross (net) wealth and divide the sample into associated

<sup>12</sup>I have confirmed the negligible difference by adding the real interest rate to the existing specification. The addition of the extra variable reduces the necessary lag length to get stable estimates. I prioritize the stability of the IRF over the very slight change in the PDV estimates when the real interest rate is used explicitly.

Figure 1: *IRFs* for an expansionary one time monetary policy for the requisite variables



Note - Derived for a one standard deviation decrease in the monetary policy surprise considered in [Gertler and Karadi \(2015\)](#) for VAR specification in section 2.1 which has seven variables and seven lags. *IRFs* generated for 1000 months ahead. 95 percent confidence bands computed using bootstrapping methods identical to [Gertler and Karadi \(2015\)](#).

Figure 2: Estimated unrealized wealth gains as a percentage of gross wealth



Note - For a one unit decline in the real interest rate. The left panel summarizes the exposures to the real interest rate channel while the right summarizes the exposures to the Fisher channel.

Derived using portfolio wealth shares in the SCF data along with the PDV estimates in 1 for three separate returns. The mean of the change in wealth across quantiles is plotted on the y-axis.

The benchmark results in Auclert (2019) would lead to a mean growth of 1 uniformly across quantiles for both the real interest rate and Fisher channel.

quantiles. Using the present discounted value estimates and the gross (net) wealth shares for housing, stocks and liquid assets, I can calculate the unrealized wealth change for each wealth decile for both excess premia and nominal price changes. Here, I present the results for 2001 (the year for which  $MPC$  will be estimated from the consumer expenditure survey). I follow it up with the results by wealth component, specifically housing and stocks. To demonstrate that the trend continues with latest available data, I present Figure 8 using SCF 2019.

Figure 2 shows that the mean wealth growth is not homogeneous across quantiles for both the real interest rate and Fisher channels. This is true for the year for which  $MPC$  will be estimated (suggesting more precise estimates are possible) and it is not a one-off event as evidenced by the latest data available. The total gains hides substantial heterogeneity as in Figure 3 for both housing and equity holdings. The former plays a prominent role for the Fisher channel, for particularly the agents at the bottom of the wealth distribution. Similarly, for those towards the top, especially for the top 10%, almost all the gains are

Figure 3: Component wise unrealized wealth gains as a percentage of gross wealth



Note - Exact same exercise as in [Figure 2](#) subdivided for housing and stocks. See corresponding notes for more details. Additionally, the benchmark results would lead to the same mean growth for both housing and stocks.

from equity for both the channels. The findings are along expected lines, exacerbated by the existing household portfolio heterogeneity along the wealth distribution. For comparison, I present additional evidence to support my main exercise in section 3.2 in appendix A.4 for reported unrealized & realized wealth changes, both as percentage of net and gross wealth, as well as a comparison with having a common illiquid return for both housing and equity.

### 3 Model

The theoretical framework is identical to [Auclert \(2019\)](#) with the exception of the inclusion of ex-post return heterogeneity across asset classes. Specifically, I consider separate returns & prices for housing, equity and the liquid asset. The liquid asset serves as the benchmark to the original results. For more details, see section I and related mathematical appendices A.2 - A.8 of [Auclert \(2019\)](#).

### 3.1 Household Balance Sheets and wealth effects

The consumer has separable preferences over nondurable consumption  $\{c_t\}$  and hours of work  $\{n_t\}$ . For simplicity, there is no uncertainty with the exception of a one time unexpected monetary policy shock that results in the equivalent change of the real interest rate by one unit. It is a perfect-foresight setup with the consumer rationally forecasting the entire time path of nominal wages  $\{W_t\}$ , overall price level  $\{P_t\}$  as well as the individual prices & returns for each of the three separate assets. The household has a lifetime real earnings stream given by  $\{y_t\}$ . The consumer solves the following discrete time utility maximization problem. The time horizon may be finite or infinite and need not to be specified.

$$\begin{aligned} \max \quad & \sum_t \beta^t \{u(c_t) - (n_t)\} \text{ subject to} \\ P_t C_t = & P_t y_t + W_t n_t + ({}_{t-1}B_t) + \sum_{s \geq 1} ({}_tQ_{t+s}) ({}_{t-1}B_{t+s} - {}_tB_{t+s}) \\ & + P_t ({}_{t-1}b_t) + \sum_{s \geq 1} ({}_tq_{t+s}) P_{t+s} ({}_{t-1}b_{t+s} - {}_tb_{t+s}) \end{aligned} \quad (1)$$

The flow budget constraint (1) depicts the consumer household portfolio of assets in period  $t$  consisting of a portfolio of zero coupon bonds inherited from period  $t - 1$  as well as the ones carried over to the next period.  ${}_tQ_{t+s}$  is the price at time  $t$  of nominal zero-coupon bond payable at time  $t + s$ . Analogously,  ${}_tq_{t+s}$  denotes the price of a real zero-coupon bond with  ${}_tB_{t+s}$  &  ${}_tb_{t+s}$  denoting the respective quantities purchased. There is no arbitrage which is ensured by the Fisher equation for the nominal term structure, holding separately and across asset classes, broadly of the following form.

$${}_tQ_{t+s} = ({}_tq_{t+s}) \frac{P_t}{P_{t+s}}, \quad \forall t, s$$

The flow budget constraints consolidate into an intertemporal budget constraint by either use of terminal condition or transversality condition depending on whether the setup is under finite or infinite horizon.

$$\sum_{t \geq 0} q_t c_t = \underbrace{\sum_{t \geq 0} q_t (y_t + w_t n_t)}_{w^H} + \underbrace{\sum_{t \geq 0} q_t \left( ({}_{-1}b_t) + \left( \frac{{}_{-1}B_t}{P_t} \right) \right)}_{w^F} \equiv w \quad (2)$$

Keeping the notation consistent, (2) depicts the present value of consumption equals the

present value of wealth denoted by  $w$  which is the sum of present value of all future income  $w^H$  and the total present value of all financial wealth  $w^F$ . Ex-ante before the shock, the distinct portfolio shares of balance sheet components for the three separate asset with associated prices can be represented equivalently by the composite portfolio using arbitrage.<sup>13</sup> Since it matters post shock, I expand explicitly as housing  $h_t$ , equity  $s_t$  & liquid assets  $\ell_t$  for real (analogously nominal) terms at time  $t - 1$ .

$$(-_1b_t) \equiv (-_1\ell_t) + (-_1h_t) + (-_1s_t)$$

$$\left(\frac{-_1B_t}{P_t}\right) \equiv \left(\frac{-_1L_t}{P_t}\right) + \left(\frac{-_1H_t}{P_t}\right) + \left(\frac{-_1S_t}{P_t}\right)$$

These general consolidated nominal & real claims due in each period allows pursuit of the problem using sufficient statistics. Each component denotes the net stocks of assets viz. bank deposits, directly and indirectly held real estate and corporate equities over corresponding liabilities like credit card debt, mortgages (FRM or ARM), etc.

### 3.2 Main Theoretical Exercise

Keeping the notation consistent, I denote real wage at time  $t$  as  $w_t \equiv W_t/P_t$ . For the benchmark, the initial real term structure is  $q_t \equiv {}_0q_t$ , the initial nominal term structure is  $Q_t \equiv {}_0Q_t$  and I use the normalization  $q_0 = Q_0 = 1$ . Keeping balance sheet components fixed at  $\{-_1B_t\}_{t \geq 0}$  and  $\{-_1b_t\}_{t \geq 0}$ , the one time unexpected unit decline in real interest rate causes the following changes relevant for the consumer's problem.

1. All nominal prices rise in proportion across asset classes - housing  $H$ , equities  $S$  and liquid assets  $L$ .

$$\frac{dP_{x,t}}{P_x} = \frac{dP_x}{P_x} \quad \text{with} \quad \frac{dP_H}{P_H} \neq \frac{dP_S}{P_S} \neq \frac{dP_\ell}{P_\ell} \quad \forall t \geq 0, x = \ell, S, H$$

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<sup>13</sup>To support the explicit addition of housing services inside the utility function, composition of balance sheets need to matter ex-ante by the incorporation of modeling instruments that support multiple assets viz. portfolio adjustment costs. This complicates the derivation of sufficient statistics at both the household & aggregate level. A compromise is to consider how the relative price of durables changes with that of nondurables. I show in appendix B.2, this only modifies the measurement of the redistribution from the real interest rate channel. The other two redistribution channels are unaffected despite ex-post returns heterogeneity.



Figure 4: The time paths of interest rates, prices and unearned income for the perfect foresight model across asset classes.



Note - The conditional changes on asset excess premia and nominal prices are normalized with respect to the liquid asset which serves as the benchmark. The exact values are obtained from [Table 1](#) which summarize the instantaneous per unit exposures to the real interest rate and inflation change.

2. All present-value real discount rates rise in proportion for each asset class.

$$\frac{dq_{x,t}}{q_x} = -\frac{dR_x}{R_x} \quad \text{with} \quad \frac{dR_H}{R_H} \neq \frac{dR_S}{R_S} \neq \frac{dR_\ell}{R_\ell} \quad \forall t \geq 0, x = \ell, S, H$$

3. More specifically, the above two points imply that the prices and returns of each wealth component differ in their magnitudes ex-post the shock. Normalizing the changes with respect to the liquid asset, I have the following relations.

$$\frac{dR_H}{R_H} = \theta_1 \frac{dR}{R}, \quad \frac{dR_S}{R_S} = \theta_2 \frac{dR}{R}, \quad \frac{dP_H}{P_H} = \theta_3 \frac{dP}{P}, \quad \frac{dP_S}{P_S} = \theta_4 \frac{dP}{P}$$

where  $\frac{dR_\ell}{R_\ell} = \frac{dR}{R} \quad \& \quad \frac{dP_\ell}{P_\ell} = \frac{dP}{P}$

4. The Fisher equation holds for the new sequence of prices both across time & asset class and the agent's unearned income & real wage at  $t = 0$  rise by  $dy$  &  $dw$  respectively.

In addition to the above, at the time of the shock, I quantify the relation between the prices of real zero-coupon bonds for housing with respect to the benchmark  $q_{H,0} = \Theta_1 q_{L,0}$  &  $q_{S,0} = \Theta_2 q_{L,0}$ . Along with  $\{\theta_i\}_{i=1(1)4}$ , it gives the conditional impact of monetary policy on prices

& returns of housing & equity relative to the benchmark liquid asset assumed by [Auclert \(2019\)](#). This particular variation is captured in a stylized version in the three panels of [Figure 4](#) where the estimates are the present discounted values reported in [Table 1](#). There is substantial heterogeneity across asset classes. These estimates are the theoretical analogue for the precise instantaneous response.

### 3.3 Defining Household Exposures

The net of consumption wealth change depends on the household exposure to the price change, summarized by its *NNP* and to the real interest rate change, summarized by its *URE*. I present the definitions of these two measures along with their economic implications in the presence of ex-post price & returns heterogeneity. I start by stating the net of consumption wealth change  $d\Omega$  at the household level for the transitory shock as

$$d\Omega = dy + ndw - NNP \frac{dP}{P} + URE \frac{dR}{R} \quad (3)$$

The first term in equation (3) is the earnings change following the transitory shock. The second term is the product of the change in the individual balance sheets from the aggregate change in the overall price level  $dP$ . This is the *NNP* of the household affected by the Fisher channel and is given by

$$NNP \equiv \sum_{t \geq 0} Q_t \left\{ \left( \frac{-1L_t}{P_0} \right) + \theta_3 \left( \frac{-1H_t}{P_0} \right) + \theta_4 \left( \frac{-1S_t}{P_0} \right) \right\} \quad (4)$$

In general, since debtors have higher *MPCs* than creditors, we can expect *MPCs* to decline as *NNP* rises. The conditional effect on nominal prices ex-post across asset classes leads to a larger heterogeneous household exposure to inflation. The third and final term is the household's *URE* which is the effect on the individual household from the aggregate change in the real interest rate  $dR$  at time  $t$ .

$$\begin{aligned} URE_t \equiv & \left\{ y_t + w_t n_t + (-1\ell_t) + \left( \frac{-1L_t}{P_t} \right) \right. \\ & \left. + \Theta_1 \theta_1 \left[ (-1h_t) + \left( \frac{-1H_t}{P_t} \right) \right] + \Theta_2 \theta_2 \left[ (-1s_t) + \left( \frac{-1S_t}{P_t} \right) \right] - c_t \right\} \end{aligned} \quad (5)$$

The *URE* at any time  $t$  is viewed as the difference between all maturing assets (including income) and liabilities (including planned consumption). Following Auclert (2019), it remains the appropriate measure of exposure for the real interest rate channel. Households with negative net *URE* are net debtors with higher *MPCs*. they would benefit from expansionary monetary policy which raises price of future consumption relative to current consumption is equivalent to the decline in the price of the former to the latter. Similar to *NNP*, it marks the importance of considering separate asset classes for a more precise exposure of households to real interest rates. The altered definitions in (4) & (5) are theoretical counterparts to section 2.2. At any point of time, the flexibility of the expressions in (4) & (5) allows a clear comparison with the original results by substituting  $\{\theta_i\}_{i=1(1)4} = \{\Theta_j\}_{j=1,2} = 1$ .

Detailed mathematical derivations are included in appendix B.1. As in Auclert (2019), the updated theorem makes no assumption about the functional form of the utility (except that it is separable) or about the time horizon. It can be readily applied to general functional forms. Moreover, (4) & (5) are valid under persistent shocks. These results are stated in appendix B.1. The setup is also flexible to the additions of durable goods, a derivation for which is contained in appendix B.2. The current environment also encompasses market incompleteness where individual income is subject to idiosyncratic shocks as in appendix B.3.<sup>14</sup>

### 3.4 Evaluating Importance of Return Heterogeneity

The altered definitions of the household exposures preserves the structure of existing work allowing similar economy-wide aggregation as the benchmark for a large class of heterogeneous agent modeling setups. I restate the economy-wide consumption response to the first order idiosyncratic response from individual income  $dY_i$  along with aggregate variables  $dY$ ,  $dP$  and  $dR$  in (6).  $\gamma_i$  is the elasticity of individual income to aggregate income &  $\sigma_i$  is the individual *IES*. In section 4, I describe how to empirically measure & quantify these

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<sup>14</sup>Empirically, it would be very challenging to estimate the *MPC* accurately as a function of the these two specific balance sheet exposures at the individual level using survey data for the case of incomplete markets.

relations between exposures & corresponding  $MPC$ s.

$$\begin{aligned}
dC = & \underbrace{\mathbb{E}_I \left[ \frac{Y_i}{Y} \widehat{MPC}_i \right] dY}_{\text{Aggregate income channel}} + \underbrace{\gamma \text{cov}_I \left( \widehat{MPC}_i, Y_i \right) \frac{dY}{Y}}_{\text{Earnings heterogeneity channel}} - \underbrace{\text{cov}_I \left( \widehat{MPC}_i, NNP_i \right) \frac{dP}{P}}_{\text{Fisher channel}} \\
& + \left( \underbrace{\text{cov}_I \left( \widehat{MPC}_i, URE_i \right)}_{\text{Interest rate exposure channel}} - \underbrace{\mathbb{E}_I \left[ \sigma_i \left( 1 - \widehat{MPC}_i \right) c_i \right]}_{\text{Substitution channel}} \right) \frac{dR}{R} \quad (6)
\end{aligned}$$

where  $\widehat{MPC} = \frac{MPC}{1 + wMPN} \geq MPC$  &  $\gamma_i \approx \gamma \equiv \frac{\partial \left( \frac{Y_i}{Y} - 1 \right)}{\left( \frac{Y_i}{Y} - 1 \right)} \frac{Y}{\partial Y}$

The above result shows that a set of seven sufficient statistics, all of which can be estimated from survey data having information on household balance sheets and consumption expenditures, completely characterizes the aggregate consumption response to the unexpected transitory shock. One way to evaluate is by comparing the economy-wide consumption response in both partial and general equilibrium. This forms the basis of results in section 5.2. The Representative agent counterpart has a single  $MPC$  which leads to all the covariance terms being 0 and three separate returns. It serves to isolate the importance of heterogeneity of  $MPC$ s for HANK models. Additionally, there is only one common  $IES$   $\sigma$ .

$$dC = \widehat{MPC} dY - \sigma \left( 1 - \widehat{MPC} \right) C \frac{dR}{R} \quad \text{or} \quad \frac{dC}{C} = -\sigma \frac{dR}{R} \quad (7)$$

The class of sufficient statistics can also be estimated separately for housing and equity (which is important in its own regard as mentioned in section 1) by adding respective ex-post return & price heterogeneity relative to the benchmark. In summary, I therefore compare the results for 5 different models for the same one percent decline in the real interest rate and an accompanying one percent increase in inflation and aggregate income. This is denoted in the first panel of Figure 4 for the benchmark which is the liquid asset.

Second, one might be interested in quantifying the direct effects of monetary policy which is the interest rate elasticity of aggregate demand to the real interest rate.<sup>15</sup> Greater the proportion of unconstrained agents in the economy, larger is the response. The central bank's

<sup>15</sup>The first generation of HANK models pioneered by Kaplan et al. (2018) report that direct effects typically never exceed one-third of the total impact. Extensive work has since been conducted to analyze the quantitative contributions of the interest rate channel primarily in structural models. Notwithstanding its limitations as detailed in section 4 of Auclert (2015), I approach the problem instead from the sufficient statistics approach which incorporate the conditional impact of monetary policy. The advantage is having an environment free of misspecification errors while being backed up by extensive micro-data.

influence on aggregate demand is larger at this stage relative to second order price and income changes over which it has less control. It is given by the instantaneous consumption response to only the change in the real interest rate in partial equilibrium.

$$\frac{\partial C}{C} \frac{1}{\partial r} = \left( \underbrace{\text{Cov}_I \left( MPC_i, \frac{URE_i}{\mathbb{E}_I[c_i]} \right)}_{\varepsilon_R < 0} - \underbrace{\sigma \mathbb{E}_I \left[ (1 - MPC_i), \frac{c_i}{\mathbb{E}_I[c_i]} \right]}_{S > 0} \right)$$

$$\sigma^* \equiv \frac{-\varepsilon_R}{S} = \frac{-\text{Cov}_I \left( MPC_i, \frac{URE_i}{\mathbb{E}_I[c_i]} \right)}{\mathbb{E}_I \left[ (1 - MPC_i) \frac{c_i}{\mathbb{E}_I[c_i]} \right]}, \quad \because \sigma S \neq -\varepsilon_R \quad (8)$$

Focusing on the relevant term in (6), (8) shows the ratio of the *URE* & the corresponding substitution channel in a RANK. It is typically positive since the covariance between *URE* & *MPC* is negative (see section 3.3). Measuring  $\sigma^*$  does not depend on the value of *IES*, reported estimates for which can vary widely. One can simply redefine the *IES* parameter as the sum of  $\sigma^*$  &  $\sigma$  without amending the existing calibrated value of the latter. The model now gets more realistic partial consumption dynamics through its sole channel of transmission. The measure benefits applications where a RANK is preferred over the complexities of structural incomplete market models. The relevant results are in section 5.1 using analogous across model comparison as described in section 5.2.

## 4 Measuring the sufficient statistics from survey data

Assuming a common *IES*  $\sigma$  & elasticity of relative income to aggregate income  $\gamma$ , the estimable moments are the counterparts of (6). For convenience, I summarize their definitions by referring to Figure 5 from Auclert (2019) corresponding to (9). I map the theoretical definitions given by equations (4) & (5) to household survey data and the estimates from Table 1 using the consumer expenditure survey (CE) data from 1999-2002.

$$\frac{dC}{C} = (\mathcal{M} + \gamma \varepsilon_Y) \frac{dY}{Y} - \varepsilon_P \frac{dP}{P} + (\varepsilon_R - \sigma \mathcal{S}) \frac{dR}{R} \quad (9)$$

For (10) - (11),  $C_i$  is all expenditure on consumption including rent & interest payments (non-durables) with robustness checks for durable expenditure, fraction =  $1 - \epsilon$ . Assets  $A_i$  includes deposits & bonds while liabilities  $L_i$  is composed of primarily adjustable rate

mortgages & credit cards.  $T_i$  is taxes net of transfers.  $Y_i$  is gross income from all sources - labor, dividend, and interest income, as well as realized capital gains.

$$NNP_i = (1 + NSP) \times S_i + LiqA_i - (1 + NHP) \times HL_i - NHL_i \quad (10)$$

$$\begin{aligned} URE_i = & Y_i - T_i - C_i + (1 + SPC) \times (1 + NEP) \times S_i + LiqA_i \\ & - (1 + HPC) \times (1 + NHP) \times HL_i - NHL_i \end{aligned} \quad (11)$$

I maintain the assumption of excluding reported unrealized capital gains from income. Equations (10) & (11) aim to incorporate ex-post returns & price heterogeneity from the Fisher and real interest rate channels. Accordingly, directly held net nominal positions of equity is weighed by the normalized stock price change ( $NSP$ ). For housing, it is the normalized house price change ( $NHP$ ). Analogously, the interest rate exposure is adjusted to include the normalized changes in equity premium & housing premium ( $NEP$  &  $NHP$ ) with the corresponding changes in the nominal prices of these assets ( $SPC$  &  $HPC$ ). The values are listed in Table 1 and expressed in appropriate units. The rest of the sufficient statistics are identically estimated. If one wishes, they can use their preferred estimates obtained using the method of their choice for Table 1 to measure (11) & (10).

The main estimating equation is of the form (12). I follow the exact same method as Auclert (2019) to estimate the  $MPC$  from a windfall fiscal transfer based on stratification of the population depending on the measure of household exposure. I present here the specification for the real interest rate channel.  $c_{i,m,t}$  is household  $i$ 's consumption expenditures in month  $m$  and at date  $t$ ,  $\alpha_m$  is month fixed effects while  $X_{i,t}$  are controls.  $R_{t+1}$  is the dollar amount of the rebate at  $t + 1$  &  $QURE_{i,j}$  is a dummy indicating that household  $i$ 's  $URE$  in group  $j = 1 \dots J$ . In each  $URE$  bin, the average normalized  $URE$ ,  $NURE_j$  is the average over households in group  $j$  of  $\frac{URE_j}{\bar{c}}$  where  $\bar{c}$  is average consumption expenditure in the sample. The household panel is resampled around 100 times with replacement by a Monte-Carlo procedure to minimize sampling uncertainty before calculating the sufficient statistic. In line with the logic in section 3.3 for the  $URE$  channel, the ex-post returns heterogeneity amplifies the exposures leading to higher  $MPC$  estimates for the lower quantiles. Both of these amplify the covariance which is the corresponding sufficient statistic. Analogous

equations and intuition exist for the inflation & earnings heterogeneity channels.

$$C_{i,m,t+1} - C_{i,m,t} = \alpha_m + \beta X_{i,t} + \sum_{j=1}^J MPC_j R_{i,t+1} QURE_{i,j} + u_{i,t+1}$$

$$\hat{\varepsilon}_r = \frac{1}{J} \sum_{j=1}^J MPC_j NURE_j - \left( \frac{1}{J} \sum_{j=1}^J MPC_j \right) \left( \frac{1}{J} \sum_{j=1}^J NURE_j \right) \quad \& \quad \hat{S} = 1 - \left( \frac{1}{J} \sum_{j=1}^J MPC_j \right) \quad (12)$$

Following the discussion in section 3.3, to get the impact of changing estimates of  $MPC$ , I use a second survey data which has self-reported  $MPC$ s. The Survey of Household Income and Wealth (SHIW) 2010 is one of the very few publicly available sources that serves the purpose. I carry out the identical exercise as with the CE. I concede that the household portfolio heterogeneity and subsequent quantitative implications of monetary policy in section 2.2 are very different for US and Italian data. The exercise nevertheless gives implications from holding the heterogeneous  $MPC$ s at the household level invariant to adjusted balance sheet exposures.

I maintain the same assumptions as the benchmark case for dealing with durables and asset maturities. Alternate fiscal policy where the external sector (viz. the Government) withholds lumpsum transfer from the household sector rather than an instantaneous rebate gives the second set of sufficient statistics, labelled as the no rebate numbers. Issues of concern with the survey data centers around the limited information on household asset holdings. This is true for both the CE and SHIW data, both of which chronically under represent the rich. These pose more acute problems for my exercise since I require extensive household wealth information to quantify the role played by wealth inequality in measuring redistributive effects. To get an estimate of the scale of the problem and for further details, I refer the interested reader to section III. B, particularly Tables 2 and 3 as well as appendix C.6 of [Auclert \(2019\)](#).

## 5 Results

Notwithstanding the limitations of the survey data, I intend to demonstrate using sufficient statistics that the conditional impact of transitory monetary policy is very different in the absence of returns heterogeneity. The overall magnitude of transmission to aggregate con-



Figure 5: Seven cross-sectional moments that determine consumption in (9)

|                      | Definition   | Name                              | Channel                |
|----------------------|--|-----------------------------------|------------------------|
| $\mathcal{E}_R$      | $\text{cov}_I\left(MPC_i, \frac{URE_i}{\mathbb{E}_I[c_i]}\right)$    | Redistribution elasticity for $R$ | Interest-rate exposure |
| $\mathcal{E}_R^{NR}$ | $\mathbb{E}_I\left[MPC_i \frac{URE_i}{\mathbb{E}_I[c_i]}\right]$     | —, no rebate                      | —                      |
| $\hat{S}$            | $\mathbb{E}_I\left[(1 - MPC_i) \frac{c_i}{\mathbb{E}_I[c_i]}\right]$ | Hicksian scaling factor           | Substitution           |
| $\mathcal{E}_P$      | $\text{cov}_I\left(MPC_i, \frac{NNP_i}{\mathbb{E}_I[c_i]}\right)$    | Redistribution elasticity for $P$ | Fisher                 |
| $\mathcal{E}_P^{NR}$ | $\mathbb{E}_I\left[MPC_i \frac{NNP_i}{\mathbb{E}_I[c_i]}\right]$     | —, no rebate                      | —                      |
| $\mathcal{E}_Y$      | $\text{cov}_I\left(MPC_i, \frac{Y_i}{\mathbb{E}_I[c_i]}\right)$      | Redistribution elasticity for $Y$ | Earnings heterogeneity |
| $\mathcal{M}$        | $\mathbb{E}_I\left[MPC_i \frac{Y_i}{\mathbb{E}_I[c_i]}\right]$       | Income-weighted $MPC$             | Aggregate income       |

Note - Essentially there are five sufficient statistics for the three channels along with the traditional income and substitution channels. To minimize the measurement errors with the sufficient statistics for interest rate and inflation, there are two corresponding numbers given in rows 2 and 5 respectively.

sumption depends extensively on the redistributive channels, especially those arising from the real interest rate & nominal price changes.<sup>16</sup> Instead of relying on a structural model that could be prone to misspecification errors, the relatively restriction free theoretical framework of section 3 can be mapped to the empirics in section 4. Further, one can analyze the results by isolating the role of housing and equity taking into cognizance that returns heterogeneity interacts with portfolio heterogeneity, both within and across asset classes. The approach can also be used to conduct simple policy counterfactuals. As HANK models progress in their complexity they should remain consistent with the aggregate moments, derived specifically for the dimension of the wealth distribution that they seek to incorporate and explain. Of course, there could be alternate channels that I do not consider that have similar impacts (I briefly compare the results in section 1). I choose the one that is both intuitive as well as easily verified with publicly available micro-data using appropriate techniques.

The section is broadly divided into 5 parts. First, as articulated in section 3.4, I present the enhancements in direct effects (section 5.1) and then the quantitative significance for

<sup>16</sup>As mentioned in section 4, the unrealized capital gains reported in the survey data are excluded as the existing redistribution channels summarize the household exposures for the same. Instead, I focus on the best way to incorporate the conditional impact. One of the feasible channels of interest is returns heterogeneity that I focus exclusively on. To get an idea of how reported unrealized capital gains/losses affect wealth changes across wealth quantiles, see appendix A.4.

Table 2:  $\sigma^*$  across models for benchmark case with  $\sigma = 0.5$  for expansionary policy

| Measure    | Survey | Auclert | Housing + Stock | Housing | Stocks |
|------------|--------|---------|-----------------|---------|--------|
| $\sigma^*$ | CE     | 0.36    | 0.58            | 0.54    | 0.53   |
|            |        | —       | 62.68           | 49.83   | 47.56  |
| % Change   | SHIW   | 0.18    | 0.13            | 0.11    | 0.20   |
|            |        | —       | -31.25          | -41.07  | 10.00  |

Note - Expansionary shock refers to the transitory unexpected one percent decline in the real interest rate. Column 1 are benchmark numbers using baseline calibration. Percentage change is with respect to the benchmark. Columns 2-4 add the additional conditional differential impact in asset excess premium/premia & price(s) on top of the benchmark.

aggregate consumption (section 5.2). I explain how intuitively the results are expected to be different from the additional dimension of heterogeneity. I stress on the importance of estimating *MPCs* out of unrealized wealth changes. I measure the asymmetric consumption response from a contractionary shock in 5.3. Next, I discuss how other dimensions of heterogeneity like housing tenure and demographics interact with heterogeneity in asset returns. I conclude the section by a brief discussion of model predictions in 5.5. Analogous to Auclert (2019), I present the updated sufficient statistics in appendix C.1 along with associated figures depicting covariance between the measures of redistribution and estimated *MPCs* qualitatively.

## 5.1 The interest rate elasticity of aggregate demand

To scrutinize the claim that the updated sufficient statistics are "better" on incorporating the conditional returns heterogeneity channel, I suggested the use of two aggregate measures of interest to policy makers in 3.4 to evaluate the importance of conditional returns heterogeneity. The first is the magnitude of the elasticity to aggregate demand to the real interest rate. It is given by the sum of  $\sigma$  and  $\sigma^*$ . Greater the value of  $\sigma^*$ , bigger is the underestimation of the direct effects from ignoring market incompleteness towards aggregate consumption. I can compare three separate cases with the original model which featured unconditional homogeneous impact across asset classes. I can add both the returns to housing & equity or perform counterfactuals by adding one at time. Table 2 accordingly presents both the magnitude and the relative percentage change from the original for two cases - one

where  $MPCs$  are changing as in the CE data and the other where  $MPCs$  are fixed as in the SHIW data. The fact that both returns give the highest impact (63% higher than the baseline value) shows the importance of considering the impact of unrealized wealth changes more seriously for overall redistribution. Despite the fact that excess premia on housing is considerably smaller as compared to that on equity from [Table 1](#), not including unrealized wealth changes from housing prevents a large fraction of the population from having higher estimated  $MPCs$  from the sudden windfall transfer. The results support the claim that under the current setup, the real interest rate channel is stronger for overall redistribution than previously estimated. This not only underscores the importance of taking household portfolio heterogeneity seriously but also the need to combine it with the additional heterogeneity in asset returns.<sup>17</sup> As mentioned earlier, if one does not care about the finer nuances of different policies targeting different asset classes, structural models should at least get their responses to the aggregate accurate. My measures that allows for more precise estimates should prove useful in this regard. Consistent with the results so far, if we do not allow  $MPCs$  to change we are essentially limiting the usefulness of redistribution (in this context from the real interest rate channel) towards overall monetary transmission as can be evidenced by the fourth row. Of course, the total consumption response would involve the indirect effects to which I turn to next. Robustness checks with asset maturities are included in [appendix C](#).

## 5.2 Comparing the consumption response across models

I first present the results for expansionary policy. I can rank the instantaneous response to aggregate consumption, both in partial & general equilibrium, across models using sufficient statistics only.<sup>18</sup> Taking equation (9) and substituting the unit changes in aggregate income (positive), inflation (positive) for the unit percent decline in the real interest rate from first panel of [Figure 4](#), I can calculate the total percent change in general equilibrium.<sup>19</sup> Sub-

<sup>17</sup>One may well point out rightly the limitations in the survey data used make such inferences harder to accept. One of the objectives of this paper is to develop a new setup with associated empirical counterparts to avail the relevant data source of choice and test these important implications. I plan to carry out further robustness checks using the PSID data in the future.

<sup>18</sup>Since this is a transitory shock there is only a one period response. As mentioned in [appendix B.1](#), the theorems can handle persistent changes in the real interest rate from the transitory one time unexpected monetary policy surprise. One can derive the  $IRFs$  in this context using the technique in [A.3](#) and assuming that household portfolios cannot adjust over the entire horizon of 16 quarters in [appendix C](#).

<sup>19</sup>I point out the purpose of using the liquid asset as the benchmark since it allows me a clear evaluation of the importance of returns heterogeneity relative to [Auclert \(2019\)](#). I can shut down the two additional sources from housing and stocks to go back to the original results owing to the flexibility of the updated

Table 3: Percent change in aggregate consumption for expansionary shock with  $\sigma = 0.5$  &  $\gamma = -0.5$  in CE data for benchmark case

| Model with estimated <i>MPCs</i> | Consumption Response |      | In corresponding RANK |      |
|----------------------------------|----------------------|------|-----------------------|------|
|                                  | PE                   | GE   | PE                    | GE   |
| Auclert + House + Stock          | 0.90                 | 1.34 | 0.33                  | 0.77 |
| Auclert + House                  | 0.84                 | 1.28 | 0.32                  | 0.77 |
| Auclert + Stock                  | 1.06                 | 1.52 | 0.33                  | 0.79 |
| Auclert                          | 0.71                 | 1.17 | 0.32                  | 0.78 |

Note - Expansionary shock refers to the transitory unexpected one percent decrease in the real interest rate accompanied by an increase in the overall price level & aggregate income by one percent. Row 4 represent the benchmark numbers using baseline calibration and additionally setting the value of  $\gamma$ . Rows 1-3 add(s) the additional conditional differential impact in asset excess premium/premia & price(s) on top of the benchmark. Numbers represent the elasticity of aggregate consumption. Columns 2 and 3 refer to partial equilibrium and general equilibrium elasticities. RANK is counterpart of model in each row with constant *MPC*.

tracting the aggregate income change corresponding to (6), I can get the partial equilibrium response in percent. The corresponding response in a RANK is given by equation (7). I elaborate on how to interpret the results for sections 5.2 & 5.3. For either data source, I present in a table form. For example, in Table 3 the first row corresponds to the model developed in section 3 with return heterogeneity for housing & stocks. The second and third rows look examines only one source at a time. The last row presents the original results with the homogeneous conditional impact of the shock. For each model, I compare the response to its representative agent counterpart in the third and fourth columns. Other similar tables should be analyzed analogously. The parameter choices are  $\sigma = 0.5$  &  $\gamma = -0.5$ . The choice of  $\sigma$  is identical to the original model. Sensitivity checks for the choice of  $\gamma$  are included in appendix C.

Owing to the fact that stock excess returns & price changes outperform housing, the results are amplified for the former in Table 3. Only having the higher conditional impact of stocks leads to the biggest increase in consumption, both in partial and general equilibrium, from the one percent decline in real interest rate. It is almost 30 & 50% respectively in comparison to the original results. If we look at the share of redistribution from the three channels of real interest rate, Fisher and unearned income in general equilibrium then the share rises to

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definitions of household exposures conditional on the shock.

Table 4: Percent change in aggregate consumption for expansionary shock with  $\sigma = 0.5$  &  $\gamma = -0.5$  in SHIW data for benchmark case

| Model with fixed <i>MPCs</i> | Consumption Response |      | In corresponding RANK |      |
|------------------------------|----------------------|------|-----------------------|------|
|                              | PE                   | GE   | PE                    | GE   |
| Auclert + House + Stock      | 0.44                 | 0.93 | 0.28                  | 0.77 |
| Auclert + House              | 0.43                 | 0.92 | 0.28                  | 0.77 |
| Auclert + Stock              | 0.48                 | 1.03 | 0.28                  | 0.83 |
| Auclert                      | 0.51                 | 0.97 | 0.28                  | 0.74 |

Notes - For more details see notes in [Table 3](#). Here identical exercise for SHIW data.

48% (an increase of 15%). The real interest rate accounts for 3% while the Fisher accounts for 12%. Including both leads to an increase in aggregate consumption by 27 & 15% respectively. The corresponding share of redistribution is now 43% with the two channels being 9% & 2 % respectively. More precise estimates increase the significance of the redistribution channel towards the overall transmission, especially for the real interest rate and Fisher channels with the former being comparatively much larger. It works primarily through the associated heterogeneity in *MPCs* being higher. The overall response in partial equilibrium is higher since the net income effect opposes the impact. Adding an additional return or even two returns to a RANK does not materially help in quantifying the overall transmission. [Figure 11](#) panel (b) shows that there is hump shape response on using self-reported *MPCs*. This leads to lower *MPCs* on both sides of the distribution of *URE* resulting in smaller changes in the final consumption. As [Table 4](#) shows, the overall response would decline across models. This is in line with the explanation before that changing the distribution is artificially placing agents higher up who would be expected to have lower reported *MPCs*.<sup>20</sup>

Returning to the discussion about the importance of the no-rebate numbers which indicate the scale of the mismeasurement problem, I present the results for the 4 models using both datasets that feature heterogeneous *MPCs* in [Table 23](#). These estimates are empirically more reliable. The associated responses show that, across models, including returns heterogeneity conditional on the shock substantially boosts redistribution towards aggregate consumption.

<sup>20</sup>As conceded before, the data and household portfolio heterogeneity is not directly comparable for the same shock. It nevertheless serves as a check on the impact of changing *MPCs*. Even at the most conservative end, consumption response would be far lesser from just unrealized wealth effects.

Table 5:  $\sigma^*$  across models for benchmark case with  $\sigma = 0.5$  for contractionary policy

| Measure    | Survey | Auclert | Housing + Stock | Housing | Stocks |
|------------|--------|---------|-----------------|---------|--------|
| $\sigma^*$ | CE     | 0.36    | 0.39            | 0.26    | 0.16   |
|            |        | —       | 9.48            | -27.01  | -55.12 |
| % Change   | SHIW   | 0.18    | 0.25            | 0.27    | 0.16   |
|            |        | —       | 40.0            | 50.0    | 10.0   |

Note - Contractionary shock refers to the transitory unexpected one percent increase in the real interest rate. See notes in [Table 2](#) for more details.

This holds regardless of whether *MPCs* are held fixed or changes conditional on the shock. The general equilibrium increase is 48% in CE and 73% in SHIW. This true even if we just add the relative heterogeneity in housing returns, which empirically produces lesser unrealized wealth changes conditioned on the shock, as compared to equity. The corresponding increases in this case are 53% and 48% respectively. The only exception is having the impact only for equities in the CE data. In this case, aggregate consumption reduces substantially for both partial and general equilibrium. When one is relying on the conservative lower end of the redistribution estimates, there are no counter intuitive results where the aggregate consumption elasticity becomes negative. This is true for all cases, for both partial and general equilibrium, in an improvement over the original results.

### 5.3 Response to a contractionary shock

Including the conditional impact of the shock on sufficient statistics allows me to mechanically generate results for the contractionary monetary policy. Empirically, the estimates in [Table 1](#) reverse their signs. The contractionary one time monetary policy surprise produces symmetric changes in the prices and excess premia for housing & equity. I present results analogously for sections [5.1](#) and [5.2](#) for a transitory one percent increase in real interest rate. It highlights how heterogeneity in *MPCs* produces asymmetric responses in HANK models.<sup>21</sup> It also demonstrates the flexibility of the theoretical setup. Though all the signs are positive in [Table 6](#) - [Table 24](#), the elasticities (where applicable) correspond to an increase, and not decrease, in the real interest rate. The benchmark results are identical since the original results are unconditioned on the shock. The fact that the other estimates are substantially

<sup>21</sup>I refer to this growing literature briefly in section [1](#) in connection with my sufficient statistics approach.

Table 6: Percent change in aggregate consumption for contractionary shock with  $\sigma = 0.5$  &  $\gamma = -0.5$  in CE data for benchmark case

| Model with estimated <i>MPCs</i> | Consumption Response |      | In corresponding RANK |      |
|----------------------------------|----------------------|------|-----------------------|------|
|                                  | PE                   | GE   | PE                    | GE   |
| Auclert + House + Stock          | 0.53                 | 1.02 | 0.31                  | 0.80 |
| Auclert + House                  | 0.46                 | 0.95 | 0.31                  | 0.80 |
| Auclert + Stock                  | 0.54                 | 1.00 | 0.31                  | 0.77 |
| Auclert                          | 0.71                 | 1.17 | 0.32                  | 0.78 |

Note - Contractionary shock refers to the transitory unexpected one percent increase in the real interest rate accompanied by a decrease in overall price level & aggregate income by one percent. See notes in [Table 3](#) for more details.

different from their counterparts in sections [5.1](#) and [5.2](#) highlight the scale of asymmetry by asset class. I present additional results in appendix [5.2](#). In [Table 5](#), the direct effects are least for stocks since the decline in wealth are highest. The final consumption response is lowest from this channel because associated *MPCs* will be lesser. This is true for also housing though the declines are lesser. Having both leads to a larger decline in consumption. However, just focusing on the real interest rate channel in isolation is misleading. The final consumption response is declining by far less as documented in [Table 6](#). In this case, the Fisher channel leads to a far lesser decline by working in the opposite direction. For all the three separate cases, the reduction in wealth causes the redistribution measure to increase in the bottom part of the distribution while at the same time decreasing for the upper half. Since, the covariance is negative this leads to smaller estimated *MPCs* for the case of a wealth decline. The product of the two is now smaller than the reduction from solely the wealth change. The final aggregate outcome depends on the existing household portfolio heterogeneity. Not only is the response asymmetric, but redistribution facilitates a subdued response to final consumption. Since the estimated unrealized wealth changes are negative, equity is preferred over housing since the declines would be the highest and subsequent associated *MPCs* change the least producing the strongest asymmetric response. Consequently, the asymmetric response is strongest. From [Table 7](#), corresponding declines in consumption are the least for both partial and general equilibrium, being 35 and 18% higher than similar decline in the benchmark model. Having both housing & equity leads to a smaller decline of upto 25 and 12% higher in partial and general equilibrium respectively.



Table 7: Percent change in aggregate consumption for contractionary shock with  $\sigma = 0.5$  &  $\gamma = -0.5$  in SHIW data for benchmark case

| Model with fixed <i>MPCs</i> | Consumption Response |      | In corresponding RANK |      |
|------------------------------|----------------------|------|-----------------------|------|
|                              | PE                   | GE   | PE                    | GE   |
| Auclert + House + Stock      | 0.53                 | 1.16 | 0.28                  | 0.91 |
| Auclert + House              | 0.53                 | 1.16 | 0.28                  | 0.91 |
| Auclert + Stock              | 0.46                 | 1.01 | 0.28                  | 0.83 |
| Auclert                      | 0.51                 | 0.97 | 0.28                  | 0.74 |

Note - Contractionary shock refers to the transitory unexpected one percent increase in the real interest rate accompanied by a decrease in overall price level & aggregate income by one percent. See notes in [Table 4](#) for more details.

Again, what is important is the fact that we have to re-estimate the associated *MPCs*. The evidence from [Table 7](#) shows that the declines would be much larger if we just consider the wealth changes. Intuitively, one of the the channels is just the reverse. Now, agents are left with lesser wealth as measured by the appropriate redistribution measure, leading to higher *MPCs*. The final response to consumption depends to the product of the smaller decrease in *MPC* with the associated wealth decline. For the sake of completeness, I include the results accounting for sampling error in [Table 24](#). Holding the *MPCs* fixed displays counter-intuitive magnitudes for the aggregate consumption elasticities. The fact that there is no clear negative correlation in the SHIW for the redistribution & associated *MPC*, unlike in the CE, seems to be responsible. For the final model using the CE data, the consumption decline is 81% and 52% lower as compared to baseline estimates. Only in the case of housing does the asymmetric response work in the reverse direction with consumption declining more. A plausible explanation would be agents have least declines in wealth among all cases considered. This leads to higher *MPCs* since typically *URE* is negative for agents with majority of wealth in housing.

## 5.4 Interaction with other dimensions of heterogeneity

The sizeable increase in aggregate consumption is driven by the fact that households at some point of time in the future will convert their wealth changes to liquid assets. However, if they

Table 8: Percent change in aggregate consumption relative to benchmark with  $\sigma = 0.5$  &  $\gamma = -0.5$  for CE data by housing tenure

| <b>Housing<br/>Tenure</b> | <b>Outright<br/>Homeowner</b> | <b>Mortgage<br/>Holder</b> | <b>Renter</b> | <b>All</b> |
|---------------------------|-------------------------------|----------------------------|---------------|------------|
| Sample Size (in %)        | 26.27                         | 40.65                      | 33.08         | –          |
| Expansionary Shock        | 18.49                         | 3.73                       | 0.93          | 15.68      |
| Contractionary Shock      | -26.83                        | -14.14                     | -8.43         | -12.67     |

Note - Numbers represent the percentage change in aggregate consumption elasticity in general equilibrium for the model in section 3 from estimates of the benchmark model for housing tenure sample given by columns 2-4 without ex-post returns heterogeneity. For details regarding the shock please see associated table notes in Table 3 & Table 6.

were to face significant budgetary constraints that would prevent such future realizations, we would expect them to report only a muted increase in consumption. One of the common constraints would be the analyzing the role of housing tenure. Outright homeowners are significantly less leveraged than mortgage holders while renters possibly have significant non-housing debt. Another constraint would be the role of demographics. Young tend to take on more debt, chiefly housing while the old and middle aged have little debt. This section explores interaction of more precise measures of wealth changes from ex-post returns heterogeneity with these two other dimensions of household heterogeneity. More households are unconstrained, greater would be their tendency to increase consumption today from unrealized wealth gains and larger will be the subsequent aggregate response. Of course, there are other relevant dimensions that interact with balance sheet effects which are harder to study empirically using this setup.

I follow Cloyne et al. (2020) in defining three groups of households based on housing tenure, namely outright homeowners, mortgagors who I refer as mortgage holders and renters. Heterogeneity in demographics is consistent with the definitions in Wong (2019). I compare the relative change in the instantaneous responses in general equilibrium for the same group of households with returns heterogeneity to the benchmark numbers in Auclert (2019). Additional results for implied *IRFs* for demographics & housing tenure are presented in appendix E.

As in Table 8, mortgage owners do not really experience a higher consumption response

Table 9: Percent change in aggregate consumption relative to benchmark with  $\sigma = 0.5$  &  $\gamma = -0.5$  for CE data by demographic group

| Demographics         | Young<br>(25-34 yrs) | Middle<br>(35-64 yrs) | Old<br>(64-75 yrs) | All    |
|----------------------|----------------------|-----------------------|--------------------|--------|
| Sample Size (in %)   | 33.64                | 54.67                 | 11.69              | —      |
| Expansionary Shock   | 10.99                | 20.81                 | 49.31              | 15.68  |
| Contractionary Shock | -7.39                | -30.59                | -70.34             | -12.67 |

Note - Numbers represent the percentage change in aggregate consumption elasticity in general equilibrium for the model in section 3 from estimates of the benchmark model for demographics sample given by columns 2-4 without ex-post returns heterogeneity. For details regarding the shock please see associated table notes in Table 3 & Table 6.

due to enhanced wealth changes from returns heterogeneity. On the contrary, ability to realize the wealth gains leads to far bigger responses relative to the aggregate for outright homeowners since they have less debt by choice and are considerably more unconstrained than mortgage holders. Renters may not have the resources to take on much debt to begin with and the absolute elasticities are small for both the models despite a large percentage increase. Table 9 show the responses by age.<sup>22</sup> Consistent with the intuition so far, since old people would face least constraints, have minimal debt and more finite lifespans; they would realize their gains quicker resulting in the largest difference from the baseline. Young are expected to be the most constrained among the three groups limiting the impact of unrealized wealth gains from a positive shock.

## 5.5 Policy Experiments

To quantify the interaction of wealth inequality with/without ex-post returns heterogeneity, I calibrate the household balance sheets for different years and assume that consumption expenditures remain similar as 2001 CE. I analyze both expansionary and contractionary monetary policy. I use SCF data for 2007 and 2019 to target the GFC and the pandemic respectively. Of particular interest is a contractionary policy around 2007 to approximate

<sup>22</sup>The results can be roughly compared to Table 4 in Wong (2019) though the methods used are very different. Here based only on balance sheet effects, old and middle have much higher consumption response than the young in terms of aggregate elasticities.

the tightening of the interest rate that preceded the collapse of the housing bubble. Similarly, faced by the pandemic, the Fed undertook massive quantitative easing that is akin to an exogenous expansionary surprise in my setup. For mortgage design, I look at a widespread prevalence of adjustable rate mortgages (ARMs). In the US, most fixed rate mortgages carry an option for low cost refinancing (either cash-out or no cash-out). These can be approximated by assuming a greater share of mortgages being ARMs. The results vary significantly if I shorten asset maturity.

Since the key channel is the the changing  $MPC$ , I restrict attention to the CE data and focus on the elasticity of aggregate consumption in general equilibrium. For 2019 a one percent decline in the real interest rate would have lead to a 16% increase in aggregate consumption with a share of redistribution of 51%. At quarterly maturity, these are 24% & 67% . If all mortgages are ARMs, corresponding estimates are 30% & 58% with benchmark maturity and 53% & 79% for quarterly maturity. The evidence supports the aggressive monetary expansion by the Fed at the start of the pandemic in supporting the consumption recovery. More ARMs would hasten realization of wealth gains in the near future increasing  $MPC$  out of income today for especially constrained households. The same policy (though counter-intuitive) predicts even stronger responses for 2007. The magnitude depends on the race between housing vs equity markets where households with relatively higher housing wealth received a larger share of the wealth gains despite earning lower per unit returns. Accounting for redistribution implies higher  $MPCs$  for the former. A reduction in the wealth gini in the short run therefore leads to an even higher consumption response.<sup>23</sup>

The model counterfactual improvements in the aggregate consumption response for contractionary policy, in line with section 5.3. In 2007, a contractionary shock would have lead to an improvement in aggregate consumption by 9%. Having only returns for housing would improve by 14%. Having ARMs and/or restricting to quarterly maturity does not improve upon the results. Full results are reported in Table 27 - Table 28, appendix F. These experiments are of course limited. The reduced form model free environment has limited appeal vs alternately estimating complex structural models with micro-data. Recently, there has been significant progress in bayesian estimation of HANK models. However, I have demonstrated the importance of treating ex-post return heterogeneity seriously when the primary purpose

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<sup>23</sup>2004 - 2007 is roughly the time period where the gains to housing outperformed equity and led to decline in wealth inequality from a medium to long run perspective. The trend reversed post the GFC where equity recovered faster than housing, consistent with the evidence in Figure 1. Moreover the share of housing wealth has declined dramatically relative to equity holdings for the bulk of the wealth distribution. This trend is reflected in 2019. For more details, see Kuhn and Rios-Rull (2020). The model predicts a lower consumption response if wealth inequality is higher in the short run since redistribution is weaker.

is analyzing aggregate moments of consumption from aggregate monetary policy surprises.

## 6 Conclusion

Not accounting for the differential impact of monetary policy on housing and equity causes a significant underestimation of aggregate consumption through redistribution. The literature has relied on alternate sources of heterogeneity viz. discount factors, marginal propensity to take risks. However, the former is not observed in data directly while the latter under estimates *MPCs* from unrealized wealth changes, producing similar consumption response as a RANK. My contribution is twofold. First, I rely on a transmission mechanism that operates via asset excess premia and prices easily observed in publicly available data. Second, greater the gap between returns across assets, larger is aggregate consumption. I develop a perfect foresight model where sufficient statistics can handle the impact of policy experiments. Aggregate consumption is 15% higher in general equilibrium with a share of redistribution of 43%. Additionally, the response is nearly 74% higher relative to a RANK model enriched with separate returns to housing and equity. Theoretical results can flexibly accommodate alternate empirical estimates, appropriately derived. The intuition remains same behind changed quantitative results.

Limited data for household asset holdings, especially for equity in CE, is a challenge. Future work could start with the PSID data which has better information. The drawback is inferior data for consumption expenditures relative to the CE. Second, I have restricted myself to a reduced form model free environment. The model predicts that expansionary policy at the start of the pandemic would have contributed to a 30% higher increase in aggregate consumption if all mortgages are ARMs with a share of redistribution of 51%. The response is even higher for 2007 when housing outperformed equity. Wealth inequality influences aggregate consumption more than previously expected in the short run. Backed by irrefutable evidence in the data, differential asset returns proves more important than other sources of heterogeneity. For a full range of policy experiments, one can possibly develop a HANK model with atleast two separate illiquid assets (housing & equity) which I leave for future work.

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# APPENDIX

## A Robustness to Monetary Policy Shock

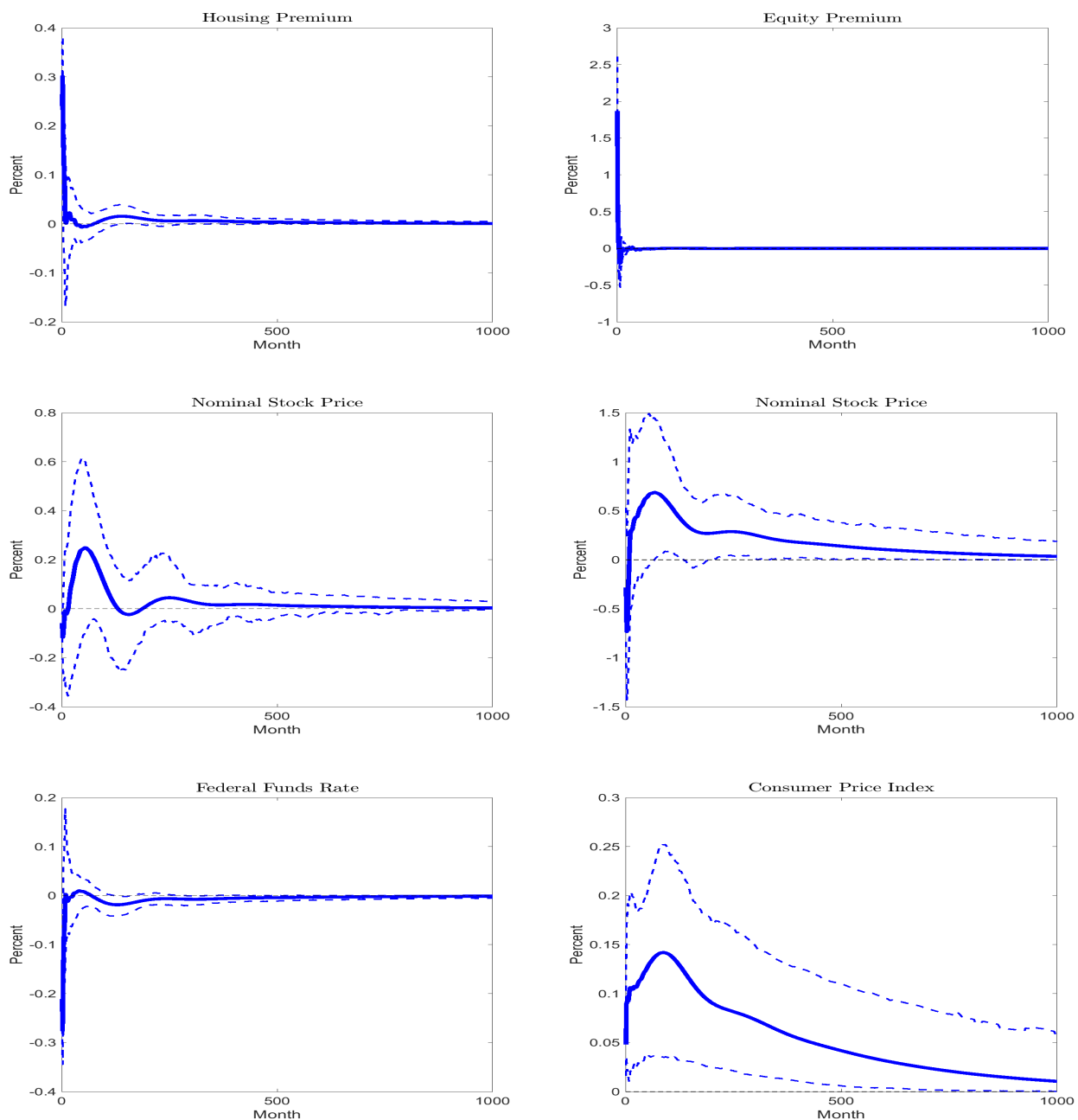
### A.1 Alternate Specifications of SVAR used

The baseline specification in section 2.1 uses 7 variables and 7 lags. The *IRFs* for the full horizon of 1000 months ahead is shown in Figure 6. The choice of the horizon ensures that the *IRFs* are still consistent and the persistence is negligible. The mainstay of my quantitative findings depends on the actual numerical estimates of the present discounted values of the excess premia to housing and equity along with their nominal price changes in Table 1. These summarize the conditional impact of the one time shock to a monetary policy surprise for housing and equity.

Robustness to alternate values of the discount factor for the same model with the IRF horizon fixed at 1000 is presented in Table 10. In general, increasing  $\beta$  leads to higher housing premia and lower equity premia indicating that the changes are more persistent for housing and slower to respond to the shock. This is consistent with the explanation of housing being slower to respond due to its higher degree of illiquidity. Though the values for the nominal prices seem substantially higher, normalized versions are similar. The third row with  $\beta = 0.975$  is of significance. Auclert (2019) has two kinds of agents with heterogeneity in discount factor for his structural model. Calibrating to the more impatient agent could tilt the balance of overall gains in favor of housing and will have very different policy implications. On the aggregate, the results will be quantitatively stronger since agents with housing tend to have negative *URE* and moderate *NNP*, both of which contribute to higher household *MPC* from the real interest rate and Fisher channels respectively.

Next, I check the sensitivity to choice of lag length in the SVAR specification used in Table 11. Again, consistent with my explanation for housing being in general slower to respond than equity, I report higher values of housing premia as the lag length reduces. Beyond 9 lags for the 7 variables, the *IRFs* are no longer consistently estimated and tend to diverge as the horizon increases. There is also higher persistence. The overall trend is not very different. The price changes are affected more leading to possibly higher estimates from the Fisher channel. I do not present any results for horizon length. Firstly, even though increasing

Figure 6: *IRFs* for complete horizon of 1000 months ahead for requisite variables for expansionary shock



Note - Derived for a one standard deviation decrease in the monetary policy surprise considered in [Gertler and Karadi \(2015\)](#) for VAR specification in section 2.1 which has seven variables and seven lags. The graph for the log of industrial production has not been shown. The first 48 months corresponding to 16 quarters is shown in [Figure 1](#). 95 percent confidence bands computed using bootstrapping methods identical to [Gertler and Karadi \(2015\)](#).

Table 10: Sensitivity of PDV estimates to choice of  $\beta$ .

| <b>Present Discounted<br/>Value at <math>t = 0</math></b> | Nominal<br>House<br>Price | Housing<br>Premium | Nominal<br>Stock<br>Price | Equity<br>Premium | Nominal<br>House<br>Price | Nominal<br>Equity<br>Price |
|---|---------------------------|--------------------|---------------------------|-------------------|---------------------------|----------------------------|
| $\beta = 0.935$   | 0.26                      | 1.25               | 0.48                      | 2.63              | 0.17                      | 0.33                       |
| $\beta = 0.965$   | 2.06                      | 1.23               | 6.58                      | 2.35              | 0.67                      | 2.13                       |
| $\beta = 0.975$   | 3.64                      | 1.33               | 12.39                     | 2.16              | 0.81                      | 2.76                       |
| $\beta = 0.99$  | 0.80                      | 1.74               | 38.63                     | 1.37              | 0.80                      | 3.44                       |

Note - For VAR specification, see section 2.1 -  $\beta = 0.975$  is the second discount factor used by the structural model in Auclert (2015) besides the benchmark of  $\beta = 0.95$  used in the main text. The lag length is fixed at 7. *IRFs* are generated for 1000 months ahead.

the number of periods 5 or 10 times hardly makes any difference to the PDVs since the *IRFs* are already converging. Second, for some specifications, this would lead to inconsistent estimation of the *IRFs* at very large horizons.

I analyze alternate specifications of the SVAR in along with different lag lengths. Here I present a subset of my results in Table 12. I observe that not having all the four variables together leads to higher responses for the stock price and equity premia. However, the changes are less accurate since all the requisite variables are not in the same SVAR. Moreover, there is influence of other variables which are not directly related viz. the excess bond premium. For specification 1, I have a SVAR of 6 variables. The first 4 are the log of consumer price index, log of industrial production, the federal funds rate and the excess bond premium (identical to used in Gertler and Karadi (2015)). The last two are either the asset excess premia or their nominal price changes. For specification 2, I have the SVAR of 5 variables with the four common variables and the last variable can be any of the 4 of interest. For both the cases, I ensure there is little persistence for 1000 months ahead. The *IRFs* are also consistent and do not diverge after a finite horizon. One can envision a specification which involve estimating the 4 requisite variables with the rest of the variables in the specification of Gertler and Karadi (2015). My arguments against this are three fold. First, their motivation was studying credit costs while mine is looking at the conditional

Table 11: PDV estimates using alternate lag lengths for 1000 months ahead

| Lag Length<br>used | Nominal      | Housing | Nominal      | Equity  | Nominal     | Nominal     |
|--------------------|--------------|---------|--------------|---------|-------------|-------------|
|                    | House        | Premium | Stock        | Premium | House       | Equity      |
|                    | Price (in% ) |         | Price (in% ) |         | Price Norm. | Price Norm. |
| 8                  | 0.74         | 1.28    | 3.79         | 2.34    | 0.33        | 1.71        |
| 6                  | 0.75         | 1.29    | 4.37         | 2.36    | 0.30        | 1.78        |
| 4                  | 1.84         | 1.57    | 3.81         | 4.12    | 0.70        | 1.45        |
| 1                  | 1.65         | 1.77    | 2.32         | 1.41    | 1.77        | 2.48        |

Note - To be compared with results in [Table 1](#). Specification used is detailed in [2.1](#). Results with  $\beta = 0.95$  and one standard deviation positive monetary policy surprise. Beyond a lag length of 9, the *IRFs* are not consistent and do not converge at the given horizon of 1000 for the given specification.

impact on asset excess premia & prices, not on their borrowing costs since households do not adjust their portfolios. Secondly, adding extra variables which are not directly expected to be related is counter-intuitive. Thirdly, increasing the number of variables needs shortening of the lag length for consistent *IRFs*. Otherwise, I need to reduce the horizon length drastically which gives PDVs incompatible with the model. Either compromise is not desirable. The effect is more pronounced for housing since the response is slower and more persistent. For all the above robustness checks, the data sources and duration are the same as defined in the main text.

## A.2 SVAR with exogenous variables and updated data

A recent alternative developed by [Paul \(2020\)](#) to the external instruments SVAR of [Gertler and Karadi \(2015\)](#) is integrating the data for monetary policy surprises directly into the vector autoregressive model as an exogenous variable (VARX). He shows analytically that his approach consistently identifies the true relative impulse responses. This holds even when the surprises contain measurement error that is orthogonal to all other variables. The major advantage is the extension of this constant parameter VARX for estimating a time-varying parameters using standard methods. I restrict my attention for ease of comparison with the constant parameter VARX. I use the same 7 variables used for the specification in [section 2.1](#) for monthly frequency. The data is updated till 2017 month 9. Notwithstanding the limitations with the approach as listed in [footnote 7](#), I show the corresponding estimates in

Table 12: PDV estimates using alternate specifications &amp; lag lengths

| Specification and<br>lag length | Nominal<br>House<br>Price (in% ) | Housing<br>Premium | Nominal<br>Stock<br>Price (in% ) | Equity<br>Premium | Nominal<br>House<br>Price Norm. | Nominal<br>Equity<br>Price Norm. |
|---------------------------------|----------------------------------|--------------------|----------------------------------|-------------------|---------------------------------|----------------------------------|
| Alt Spec 1<br>with 6 lags       | 1.24                             | 1.26               | 19.23                            | 4.45              | 0.48                            | 7.44                             |
| Alt Spec 1<br>with 11 lags      | 1.25                             | 0.76               | 17.77                            | 3.63              | 0.59                            | 8.36                             |
| Alt Spec 2<br>with 5 lags       | 3.55                             | 1.14               | 16.44                            | 5.09              | 2.60                            | 7.06                             |
| Alt Spec 2<br>with 10 lags      | 6.05                             | 1.17               | 23.55                            | 3.70              | 3.45                            | 10.96                            |

Note - For 1000 months ahead using techniques of [Gertler and Karadi \(2015\)](#) - to be compared with results in [Table 1](#). The base line specification is explained in [2.1](#). The data is the same. Results with  $\beta = 0.95$  and one standard deviation positive monetary policy surprise. Beyond certain lags, *IRFs* no longer consistent as before.

Alt Spec 1 refers to 2 VARs are estimated with the original specification of [Gertler and Karadi \(2015\)](#). For one, commercial spread is replaced with equity premium and mortgage spread is replaced with housing premium. For the second, replace the two by stock price & house price respectively.

Alt Spec 2 refers to a VAR with federal funds rate, consumer price index, industrial production, excess bond premium and a fifth variable. The fifth variable is housing premium, equity premium, nominal house price and nominal stock price.

Table 13: Present discounted value estimates from VAR based in section A.2 using  $\beta = 0.95$

| <b>Present Discounted<br/>Value at <math>t = 0</math></b> | Nominal<br>House<br>Price | Housing<br>Premium | Nominal<br>Stock<br>Price | Equity<br>Premium | Nominal<br>House<br>Price | Nominal<br>Equity<br>Price |
|---|---------------------------|--------------------|---------------------------|-------------------|---------------------------|----------------------------|
| Empirical   | 0.17                      | 1.07               | 0.77                      | 1.77              | 3.52                      | 3.71                       |
| Normalized (Y/N)  | <b>N (in% )</b>           | Y                  | <b>N (in% )</b>           | Y                 | Y                         | Y                          |

Note - Monthly data for monetary policy surprises updated till 2017-9. For more details see associated notes in Table 1.

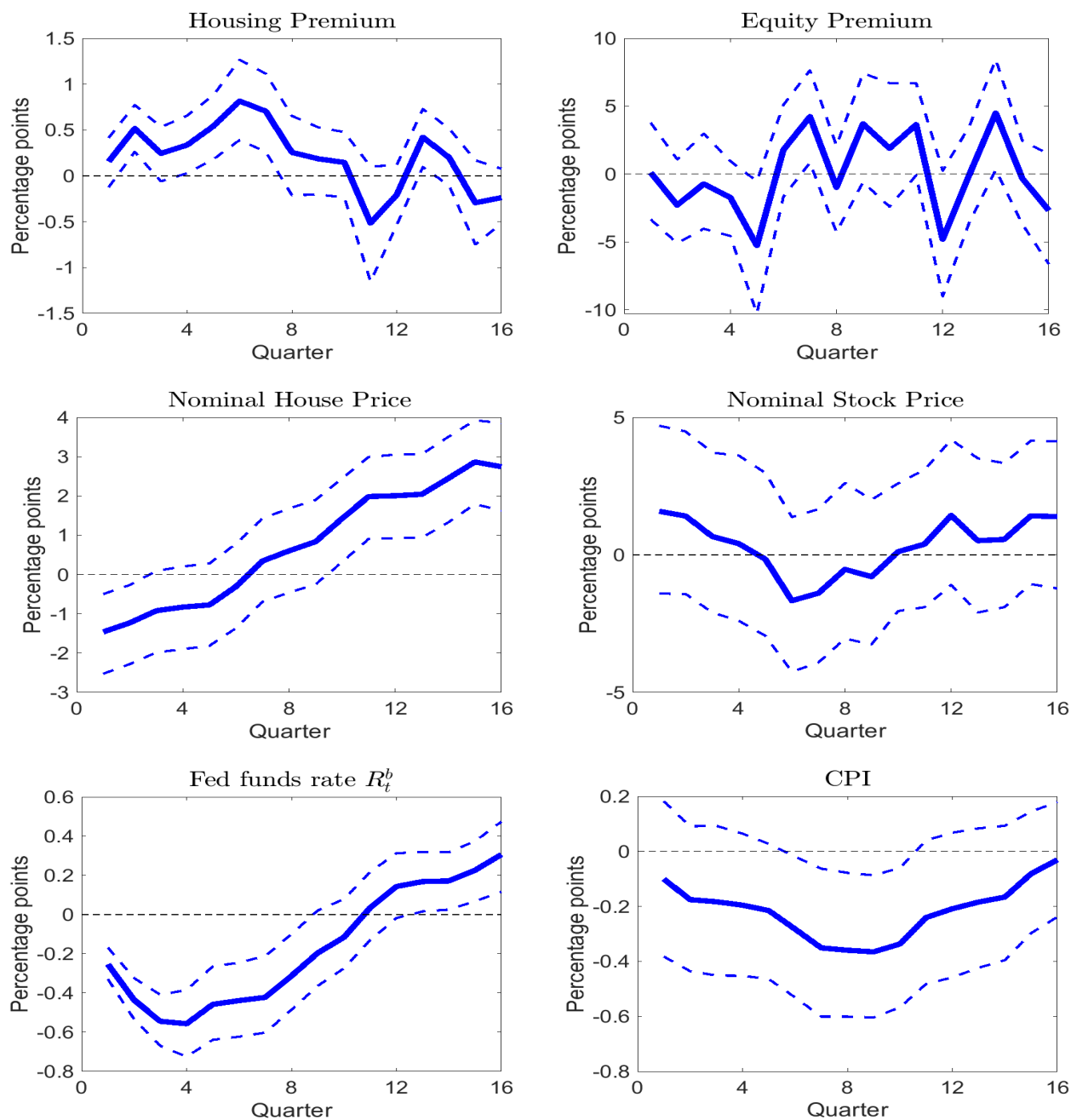
Table 1 for the same horizon of 1000 months ahead in Table 13. Aggregate consumption in general equilibrium is 21% higher for a one-time unexpected positive monetary policy surprise of comparable magnitude, of which redistributive effects account for 13%. Among the three redistribution channels, the real interest rate channel accounts for 8% while the Fisher channel accounts for 6%. Asymmetric effects are stronger with a negative surprise producing a 26% smaller decline in aggregate consumption in general equilibrium.

### A.3 Local Projections

I compare the main quantitative results with the local projection technique that does not rely on an explicit SVAR specified for the underlying data generating process. As mentioned in section 1, the biggest drawback is the very short time horizon of less than 100 months ahead for the generated *IRFs*. Since Luetticke (2021) studies similar trends economically for the interested variables, as a comparison I repeat my exercise using his technique and data which I mention briefly here. For more details, see section IV A of his paper. With the exception of the housing premium which is not available at monthly frequency, I follow his definitions and sources at monthly frequency for the main text.

At the aggregate level, to estimate the impact of the monetary policy shock on returns by asset class, Luetticke (2021) requires aggregate quarterly data for stock & house prices, federal funds rate, asset premia along with data on monetary policy shocks. Stock prices is measured by S&P 500. House prices come from the Case-Shiller S&P U.S. National Home Price Index (CSUSHPINSA) divided by the all-items CPI (CPIAUCSL). For the rest, he uses

Figure 7: *IRFs* for equivalent 16 quarters from [Luetticke \(2021\)](#) using local projection method



Note - For a one standard deviation positive monetary policy surprise for the [Romer and Romer \(2004\)](#) shock series. Results to be compared with [Figure 1](#). Data range is 1983Q1 to 2007Q4. Bootstrapped 90% confidence bands are shown in the dashed lines (block bootstrap).



national accounts data provided by the Federal Reserve Bank of St. Louis. The housing premium is measured as the excess realized return on housing. This is composed of the rent-price-ratio,  $R_{h,t}$ , in  $t$  plus the quarterly growth rate of house prices in  $t + 1$ ,  $\frac{H_{t+1}}{H_t}$ , over the nominal rate,  $R_t^B$ , (converted to a quarterly rate):

$$LP_t = \frac{R_{h,t}}{H_t} + \frac{H_{t+1}}{H_t} - (1 + R_t^B)^{\frac{1}{4}}$$

Rents are imputed on the basis of the CPI for rents on primary residences paid by all urban consumers (CUSR0000SEHA) fixing the rent-price-ratio in 1983Q1 to 4%. The equity premium is the growth rate of Wilshire 5000 Total Market Full Cap Index (WILL5000INDFC) minus the federal funds rate. Finally, the convenience yield, a measure of liquidity in financial markets, is equal to the Moody's Seasoned Aaa Corporate Bond Yield (AAA) minus 10-Year Treasury Constant Maturity Rate (GS10). He uses monetary shocks identified by [Wieland and Yang \(2020\)](#) that improve on the original shock series by [Romer and Romer \(2004\)](#) for 1983Q1 to 2007Q4. The impulse responses of the endogenous variables  $\Upsilon$  at time  $t + j$  to monetary shocks,  $\varepsilon_t^R$ , at time  $t$  are estimated using horizon-specific single regressions by local projections, in which the endogenous variable shifted ahead is regressed on the current normalized monetary shock  $\bar{\varepsilon}_t^R$  (with standard deviation 1), a constant, time trend, and controls  $\mathbf{X}_{t-1}$ . These controls are specified as the lagged normalized monetary shock  $R_{t-1}^B$  and the log of GDP  $Y_{t-1}$ , consumption  $C_{t-1}$ , investment  $I_{t-1}$ , and of lagged monetary shocks  $\varepsilon_{t-1}^R, \varepsilon_{t-2}^R$ :

$$\Upsilon_{t+j} = \beta_{j,0} + \beta_{j,1}t + \beta_{j,2}\bar{\varepsilon}_t^R + \beta_{j,3}\mathbf{X}_{t-1} + \nu_{t+j}, \quad j = 0 \dots 15$$

The *IRFs* for the baseline 16 quarters is presented in [Figure 7](#) for the expansionary shock. The major drawback is the high persistence which impacts the present discounted values substantially since the estimates for 17 quarters and beyond do not have negligible magnitude. Secondly, the inflation seems to decrease for the majority of the time period while the housing premium is larger than the equity premium at  $t = 0$ . The corresponding PDVs are presented in the first row of [Table 14](#). The results are counter-intuitive for especially the equity premium. Also, housing tends to respond faster than equity. As an additional sensitivity check, I use alternate measures of monetary policy surprises. A major issue is data availability for the shock and therefore the estimates cannot be widely compared. The motivation for including them is to argue that the robustness checks for the SVAR will produce similar results as the ones in the main text. Using the estimates for local projections

Table 14: Robustness of PDV estimates from local projections

| <b>Present Discounted<br/>Value at <math>t = 0</math></b> | Nominal<br>House<br>Price (in% ) | Housing<br>Premium | Nominal<br>Stock<br>Price (in% ) | Equity<br>Premium | Nominal<br>House<br>Price Norm. | Nominal<br>Equity<br>Price Norm. |
|---|----------------------------------|--------------------|----------------------------------|-------------------|---------------------------------|----------------------------------|
| Luetticke 16<br>quarters for 1969-2007                    | 4.45                             | 1.14               | 3.58                             | -0.31             | 1.81                            | 1.46                             |
| Luetticke 32<br>quarters for 1969-2007                    | 13.62                            | 1.09               | 1.19                             | -2.17             | 7.11                            | 0.62                             |
| Gertler & Karadi 16<br>quarters for 1990-2012             | 1.67                             | 0.82               | 5.01                             | -1.07             | 7.26                            | 21.84                            |
| BRW Unified 16<br>quarters for 1994-2015                  | 5.60                             | 1.5249             | -33.60                           | 11.12             | 1.65                            | -9.88                            |

Note - To be compared with results in [Table 1](#). Using local projections technique of [Luetticke \(2021\)](#) with  $\beta = 0.95$  for alternate horizons & alternate shock sources. For a one standard deviation positive monetary policy surprise. The estimates for the first row correspond to the *IRFs* in [Figure 7](#). Monetary policy surprises for the first two rows correspond to [Romer and Romer \(2004\)](#). For the third row it is identical to the one used in this paper. For the fourth row, it uses the estimates in [Bu et al. \(2021\)](#).

could have vastly different quantitative implications and it seems that the SVAR is better suited than a local projection technique for the current question of interest.

However, if I ignore the robustness issues and use the baseline specification of [Luetticke \(2021\)](#) and repeat the exercise with the estimates in the first row of [Table 14](#), I find that the aggregate results are qualitatively similar. Only the results by asset class are substantially different in keeping with the intuition since the numerical estimates for housing are relatively better to equity, especially for the interest rate channel.

I only present the results for the CE data since this involves changing estimates of *MPCs* which is the quantitatively significant channel. I report that excess sensitivity over a RANK with calibrated *IES* of 0.5 from the real interest rate change reported in [Table 15](#) declines by roughly 17% as compared to [Table 2](#). The general equilibrium consumption response from

Table 15:  $\sigma^*$  across models for benchmark case with  $\sigma = 0.5$  in CE data

| Measure    | Shock          | Auclert | Housing + Stock | Housing | Stocks |
|------------|----------------|---------|-----------------|---------|--------|
| $\sigma^*$ | Expansionary   | 0.36    | 0.52            | 0.54    | 0.30   |
|            |                | —       | 45.55           | 49.83   | -16.08 |
| % Change   | Contractionary | 0.36    | 0.43            | 0.38    | 0.32   |
|            |                | —       | 18.60           | 4.92    | -11.66 |

Note - Using Local projections method of [Luetticke \(2021\)](#) for 16 quarters. First two rows to be compared with first two rows of [Table 2](#) while the last two rows are to be compared with first two rows of [Table 5](#).

Table 16: Aggregate consumption for expansionary shock in CE data

| Model with estimated <i>MPCs</i> | Consumption Response |      | In corresponding RANK |      |
|----------------------------------|----------------------|------|-----------------------|------|
|                                  | PE                   | GE   | PE                    | GE   |
| Auclert + House + Stock          | 0.82                 | 1.26 | 0.32                  | 0.77 |
| Auclert + House                  | 1.06                 | 1.51 | 0.32                  | 0.77 |
| Auclert + Stock                  | 0.87                 | 1.33 | 0.32                  | 0.78 |
| Auclert                          | 0.71                 | 1.17 | 0.32                  | 0.78 |

Note - Numbers are in percent with  $\sigma = 0.5$  &  $\gamma = -0.5$ . Using local projections of [Luetticke \(2021\)](#) for 16 quarters. To be compared with [Table 3](#). For details on expansionary shock, see notes in [Table 3](#).

the first row of [Table 16](#) is only around 8% higher vs being 15% higher in the main text from [Table 3](#).

The asymmetric response is now substantially reduced for the main model with both housing and equity return heterogeneity from the first row of [Table 17](#). Aggregate consumption would decrease by only around 2% less compared to 12% in general equilibrium in the main text in [Table 6](#). For partial equilibrium, the corresponding numbers are around 6% & 25% respectively. This is true across asset classes. Since housing is responding more relative to equity in this case, the declines in wealth are also more from the increase in the real interest rate. Since agents with majority of housing have higher *MPCs*, they lead to much higher overall consumption decline reducing the magnitude of the asymmetric effect.

Table 17: Aggregate consumption for contractionary shock in CE data

| Model with estimated <i>MPCs</i> | Consumption Response |      | In corresponding RANK |      |
|----------------------------------|----------------------|------|-----------------------|------|
|                                  | PE                   | GE   | PE                    | GE   |
| Auclert + House + Stock          | 0.67                 | 1.15 | 0.31                  | 0.78 |
| Auclert + House                  | 0.58                 | 1.06 | 0.31                  | 0.79 |
| Auclert + Stock                  | 0.64                 | 1.10 | 0.32                  | 0.78 |
| Auclert                          | 0.71                 | 1.17 | 0.32                  | 0.78 |

Note - Numbers are in percent with  $\sigma = 0.5$  &  $\gamma = -0.5$ . Using local projections of [Luetticke \(2021\)](#) for 16 quarters. To be compared with [Table 6](#). For details on contractionary shock, see notes in [Table 6](#).

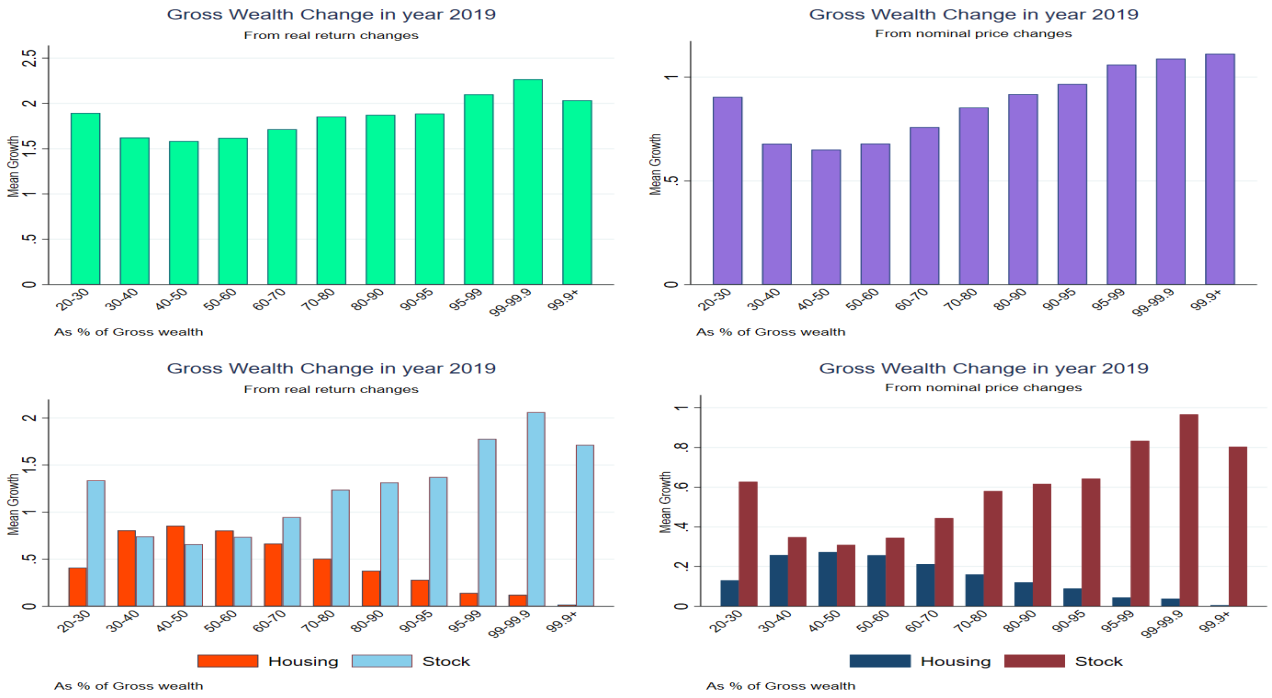
## A.4 Unrealized/Realized wealth changes from SCF data

In this section, I present additional motivating graphs to support my claim that the conditional impact of expansionary monetary policy produces very different impacts across the wealth distribution from the real interest rate and the Fisher channel. It is also not a one off effect in only the interested year of 2001. From [Figure 8](#), it is clear that even with the latest data, the motivation holds true. Intuitively, since households have different portfolio asset shares, the instantaneous changes reflect the heterogeneity of across class asset holdings.<sup>24</sup> For comparison, I depict the survey reported numbers for realized and unrealized capital gains/losses from the SCF data for the two years 2001 and 2019 in [Figure 9](#). I also break them down by housing and equity. These are however not the conditional instantaneous impacts for the transitory monetary policy surprise and therefore not directly comparable. The motivation behind including them is to show that even under the unconditional setup where ex-ante returns on housing and equity are equal to the liquid asset as in the benchmark results, there is substantial differences across the gross wealth quantiles. It is not uniformly 1 across quantiles.

Lastly, the literature on structural modeling has so far treated housing and equity as the same illiquid asset with both earning the same conditional return and experiencing the same

<sup>24</sup>In reality, the returns on debt is different from asset for both housing and equity. Getting similar conditional estimates to reflect within asset class portfolio heterogeneity separately at the aggregate level is hard.

Figure 8: Estimated Unrealized wealth changes from SCF 2019



Note - From the interest rate & Fisher channels. For more details, see notes in [Figure 2](#) and [Figure 3](#).

price change ex-post the monetary policy surprise. For a concrete example, I refer to the 2 - asset canonical HANK model of [Kaplan et al. \(2018\)](#) who consider only the real interest rate channel. Even then the estimated conditional impacts ex-post are very different for some quantiles, especially for those towards the top of the net wealth distribution as evidenced by [Figure 10](#). To get the quantitative impact on the aggregate *MPCs* more accurately, we need two separate illiquid assets. There remains significant theoretical and computational hurdles in developing such a model and proves to be exciting for future work.

## B Proofs of Results & Theoretical Model Extensions

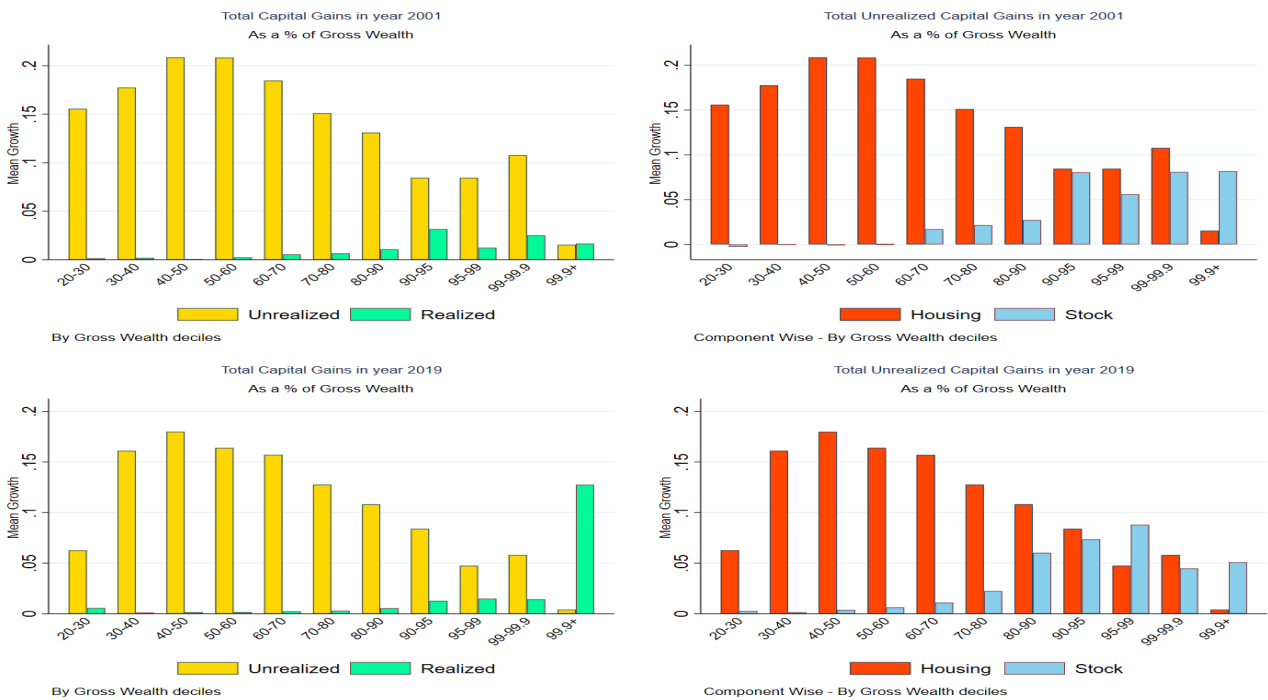
The experiment presented in section [3.2](#) is essentially listing the changes that occur in the standard representative-agent New Keynesian model following the one-period change in monetary policy. As mentioned in section [3.1](#), the general and flexible approach to representing complex household balance sheets in terms of consolidated nominal claims ( ${}_{-1}B_t$ ) & real claims ( ${}_{-1}b_t$ ) at the beginning of each period allows me to extend sufficient statistics to incorporate ex-post returns heterogeneity.

In section [B.1](#), I first present the mathematical expressions for arriving at equations [\(4\)](#) & [\(5\)](#) which lead to the main theoretical result for measuring aggregate consumption in [\(6\)](#). I restrict myself to only the principal points of departure in the context of my theoretical framework in section [3](#). Next, I show that the results hold with the addition of durable goods as a percentage of varying expenditure of household consumption in section [B.2](#). Finally, I show that these results can also be extended to encompass market incompleteness in section [B.3](#). For the complete step by step derivation, see [Auclert \(2019\)](#) appendices A.2 - A.8 for more details. I keep the notation as consistent as possible. Any explicit departures are explained.

### B.1 Deriving *NURE* and *NNP* for the perfect foresight model

As laid out in section [3.2](#), to incorporate the conditional impact of monetary policy on housing and equity through the differential asset returns. I treat the liquid asset as the benchmark and normalize the corresponding changes in the other two asset classes. Mathematically, the

Figure 9: Survey reported unrealized & realized wealth changes



Note - For the total wealth change and component wise from SCF 2001 & 2019 using the reported numbers in the data. The drawback is that these changes cannot account for the instantaneous monetary policy shock.

differences to the real interest rate and Fisher channels relevant for household measures of exposures can be captured by the values of  $\{\theta_i\}_{i=1}^4$  &  $\{\Theta_j\}_{j=1}^2$ . Setting all of them to be 1 gives back the original results which acts as the benchmark. As stated in the main text, there is no change in the conditional impact of the idiosyncratic earnings post the transitory monetary policy surprise across asset classes by assumption. They can be incorporated theoretically under this modified setup in a similar manner. Measuring the corresponding estimates are much harder. I therefore focus on only the household exposures summarizing the real interest rate channel which is defined as the *URE* and the one for the Fisher channel which is defined as the *NNP*.

The setup is described mathematically in section 3.1. Normalizing  $q_{\ell,1} = q_1 = 1$  and letting  $q_{\ell,0} = q_0$  vary for the liquid asset as

$$\frac{dq_{\ell,0}}{q_{\ell,0}} = \frac{dq_0}{q_0} = \frac{dR}{R} = \frac{dR_{\ell}}{R_{\ell}} \quad (\text{B.1})$$

Then at time  $t = 0$  when the one time shock is realized, only the values of  $y_0, w_0$  &  $q_0$  vary with the sequence in prices  $\{P_{\ell,t} = P_t\}$ . Equation (B.1) shows that a rise in the relative price of future goods from the positive monetary policy surprise relative to a current good is the same as a fall in the price of that current good relative to all future goods. The corresponding variations for housing and equity are normalized and given by the relations in section 3.2. The expenditure function is defined as

$$e(q_0, w_0, \mathcal{U}) = \min \left\{ \sum_t q_t (c_t - w_t n_t) \quad \text{s.t.} \quad \sum_t \beta_t \{u(c_t) - v(n_t)\} \geq \mathcal{U} \right\} \quad (\text{B.2})$$

The compensated demands for time 0 consumption and hours are  $c_0^h$  &  $n_0^h$ . The version of Shepherd's lemma relevant for the proof are

$$\begin{aligned} e_{q_0} &= c_0 - w_0 n_0 \\ e_{w_0} &= -q_0 n_0 \end{aligned}$$

Ex-ante, the composition of household balance sheets do not matter as reflected by (B.3). Ex-post the shock at  $t = 0$ , the conditional impacts on the prices and returns lead to the



following definition of unearned wealth from the variation as in (B.4)

$$\begin{aligned}\tilde{\omega} &\equiv \sum_{t \geq 0} q_t \left( y_t + (-1)b_t + \left( \frac{-1B_t}{P_t} \right) \right) \\ &= \sum_{t \geq 0} q_t \left( y_t + (-1)h_t + \left( \frac{-1H_t}{P_t} \right) + (-1)s_t + \left( \frac{-1S_t}{P_t} \right) + (-1)\ell_t + \left( \frac{-1L_t}{P_t} \right) \right)\end{aligned}\quad (\text{B.3})$$

$$\begin{aligned}d\tilde{\omega} &= \left( y_0 + (-1)\ell_0 + \left( \frac{-1L_0}{P_0} \right) \right) dq_{L,0} + \left( (-1)h_0 + \left( \frac{-1H_0}{P_0} \right) \right) dq_{H,0} + \left( (-1)s_0 + \left( \frac{-1S_0}{P_0} \right) \right) dq_{S,0} \\ &+ q_0 dy_0 - \sum_{t \geq 0} q_t \left( \frac{-1L_t}{P_t} \right) \frac{dP_{L,t}}{P_{L,t}} - \sum_{t \geq 0} q_t \left( \frac{-1H_t}{P_t} \right) \frac{dP_{H,t}}{P_{H,t}} - \sum_{t \geq 0} q_t \left( \frac{-1S_t}{P_t} \right) \frac{dP_{S,t}}{P_{S,t}}\end{aligned}\quad (\text{B.4})$$

Using the normalized relations defined previously and simplifying everything in terms of the change in the benchmark liquid asset.

$$\begin{aligned}d\tilde{\omega} &= \left( y_0 + (-1)\ell_0 + \left( \frac{-1L_0}{P_0} \right) \right) dq_{L,0} \\ &+ \left( (-1)h_0 + \left( \frac{-1H_0}{P_0} \right) \right) \Theta_1 \theta_1 q_{L,0} \frac{dq_{L,0}}{q_{L,0}} + \left( (-1)s_0 + \left( \frac{-1S_0}{P_0} \right) \right) \Theta_2 \theta_2 q_{L,0} \frac{dq_{L,0}}{q_{L,0}} \\ &+ q_0 dy_0 - \sum_{t \geq 0} q_t \left( \frac{-1L_t}{P_t} \right) \frac{dP_{L,t}}{P_{L,t}} \\ &- \sum_{t \geq 0} q_t \left( \frac{-1H_t}{P_t} \right) \theta_3 \frac{dP_{L,t}}{P_{L,t}} - \sum_{t \geq 0} q_t \left( \frac{-1S_t}{P_t} \right) \theta_4 \frac{dP_{L,t}}{P_{L,t}}\end{aligned}\quad (\text{B.5})$$

Using the Fisher Equation  $\frac{q_t}{P_t} = \frac{Q_t}{P_0}$  and the fact that  $\frac{dP_t}{P_t} = \frac{dP}{P}$  is a constant I rewrite  $d\tilde{\omega}$  from (B.5) in terms of the household exposures conditioned on the shock.

$$\begin{aligned}d\tilde{\omega} &= \left\{ y_0 + (-1)\ell_0 + \left( \frac{-1L_0}{P_0} \right) + \Theta_1 \theta_1 \left[ (-1)h_0 + \left( \frac{-1H_0}{P_0} \right) \right] + \Theta_2 \theta_2 \left[ (-1)s_0 + \left( \frac{-1S_0}{P_0} \right) \right] \right\} dq_0 \\ &+ q_0 dy_0 - \sum_{t \geq 0} q_t \left\{ \left( \frac{-1L_t}{P_t} \right) + \theta_3 \left( \frac{-1H_t}{P_t} \right) + \theta_4 \left( \frac{-1S_t}{P_t} \right) \right\} \frac{dP_t}{P_t}\end{aligned}\quad (\text{B.6})$$

The consumer's net nominal position  $NNP$  can be defined as the present value of the nominal assets. It summarizes the relevant measure of the household's balance sheet to the nominal

price changes from the Fisher channel. The consumer's unhedged interest rate exposure  $URE$  can be defined as the difference between all maturing assets and liabilities at a point of time. Analogously, it summarizes the relevant measure of household's balance sheet to the nominal price changes from the real interest rate channel. Conditioned on the transitory unexpected shock, they can be defined as

$$\begin{aligned} NNP &= \sum_{t \geq 0} q_t \left\{ \left( \frac{-1L_t}{P_t} \right) + \theta_3 \left( \frac{-1H_t}{P_t} \right) + \theta_4 \left( \frac{-1S_t}{P_t} \right) \right\} \\ &\equiv \sum_{t \geq 0} Q_t \left\{ \left( \frac{-1L_t}{P_0} \right) + \theta_3 \left( \frac{-1H_t}{P_0} \right) + \theta_4 \left( \frac{-1S_t}{P_0} \right) \right\} \end{aligned} \quad (\text{B.7})$$

$$\begin{aligned} URE_0 &\equiv \left\{ \omega_0 n_0 + y_0 + (-1\ell_0) + \left( \frac{-1L_0}{P_0} \right) \right. \\ &\quad \left. + \Theta_1 \theta_1 \left[ (-1h_0) + \left( \frac{-1H_0}{P_0} \right) \right] + \Theta_2 \theta_2 \left[ (-1s_0) + \left( \frac{-1S_0}{P_0} \right) \right] - c_0 \right\} \end{aligned} \quad (\text{B.8})$$

Equation (B.7) for  $NNP$  uses Fisher equation for equivalence with (4). Equation (B.8) is the  $URE$  at time  $t = 0$  for equation (5) which is defined for any time period. Equation (B.6) now can be rewritten as identical to (A.10) in Auclert (2019).

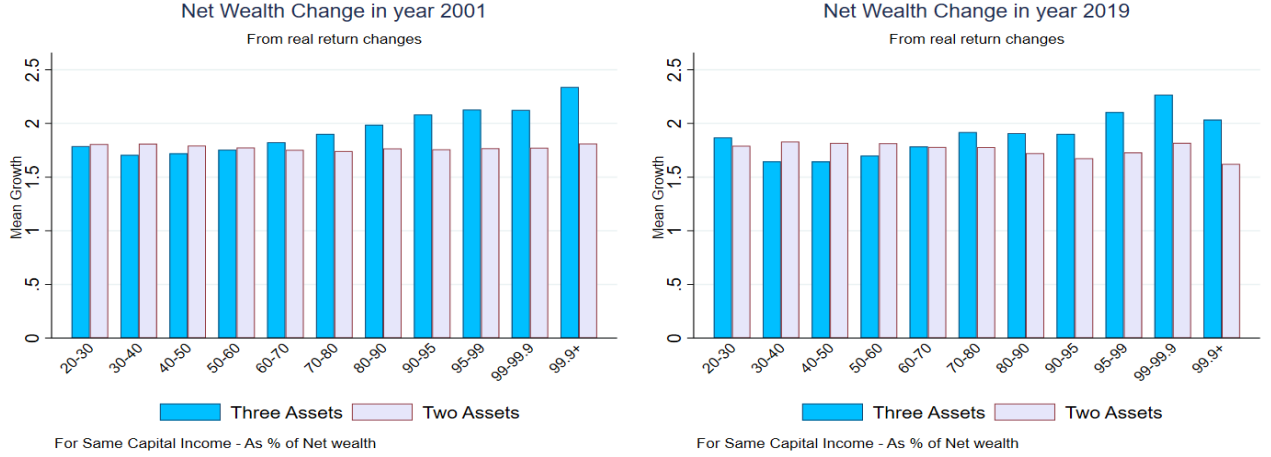
$$d\tilde{\omega} = (URE + c_0 - w_0 n_0) dq_0 + q_0 dy_0 - q_0 NNP \frac{dP}{P} \quad (\text{B.9})$$

The corresponding indirect utility function that attains the new  $\tilde{\omega}$  using equation (B.2) is also identical to (A.11)

$$V(q_0, w_0, \tilde{\omega}) = \max \left\{ \sum_t \beta_t \{u(c_t) - v(n_t)\} \quad \text{s.t.} \quad \sum_t q_t (c_t - w_t n_t) = \tilde{\omega} \right\} \quad (\text{B.10})$$

Using the definitions of Shepherd's Lemma with the resulting Marshallian demands, Slutsky's theorems can be applied. After following the steps for aggregation, the final result is given by (6) which also holds for persistent changes in the real interest rate with the constant changes being replaced with their time subscripts. Since the transitory monetary policy shock actually produces persistent changes in the real interest rate, the framework can be used to empirically estimate the per period consumption response from each period conditional impacts to the returns and prices instead of using the constant PDVs for the one time instantaneous response. See appendix A.3 for one example. I leave it to discretion in selecting the horizon of the consumption IRF cognizant of the assumption that households

Figure 10: Estimated Unrealized wealth changes from SCF data



Note - Three assets are the liquid asset, housing and equity. Two assets are liquid asset and a combined illiquid asset. The return on the latter is the same as the return from the representative portfolio of housing and equity held in equal amounts. The aim is to show that assuming housing and equity to be a single illiquid asset as in [Kaplan et al. \(2018\)](#) leads to underestimation of the gains from the real interest rate channel. See notes in [Figure 2](#) for more details.

cannot adjust their portfolios of asset holdings for any of the three assets. The setup is also flexible to alternate utility functions as well as aggregate uncertainty.

## B.2 Presence of Durable Goods

Keeping the setup identical to A.5, I look at the wealth changes arising from incorporating durable goods in the framework. The consumer durables expenditure does not affect the balance sheet at time  $t = 0$  since it is given. Since consumers do not adjust their balance sheets at for the instantaneous response to the shock, durable expenditures theoretically have no bearing on ex-post asset holdings. Empirically, they only alter how consumption will be measured at the household level. Ex-ante, balance sheets and durables expenditure can be correlated but that does not affect my exercise either theoretically or empirically since the starting point is taking the balance sheets at  $t = 0$  as given. Before the shock, the composition of balance sheets does not matter.

By expanding the household wealth into the three assets held, let  $\Omega$  be defined as

$$\Omega \equiv \sum_{t \geq 0} q_t \{Y_t + (-1)\ell_t + (-1)h_t + (-1)s_t - C_t - p_t I_t\} \quad (\text{B.11})$$

where  $p_t$  is the price of durables relative to nondurables. The exogenous variation in the benchmark liquid asset for  $dR$ ,  $dP$  &  $dY$  in (B.11) produces the change in net wealth as

$$\begin{aligned} d\Omega &= dY - IdP - \sum_{t \geq 0} dq_t \left\{ Y_t + (-1)\ell_t \frac{dR_\ell}{R_\ell} + (-1)h_t \frac{dR_H}{R_H} + (-1)s_t \frac{dR_S}{R_S} - C_t - p_t I_t \right\} \\ &= dY - IdP - \sum_{t \geq 0} q_t \{Y_t + (-1)\ell_t + (-1)h_t \theta_1 + (-1)s_t \theta_2 - C_t - p_t I_t\} \frac{dR}{R} \\ &= dY - pI_0 \frac{dp}{p} + \left( \underbrace{Y_0 + (-1)\ell_0 + (-1)h_0 \Theta_1 \theta_1 + (-1)s_0 \Theta_2 \theta_2 - C_0 - p_0 I_0}_{URE} \right) \frac{dR}{R} \quad (\text{B.12}) \end{aligned}$$

In (B.12),  $C_0$  is specifically consumption of nondurables while  $p_0 I_0$  is the consumption of durables. Total consumption is the sum of durables and non durables. (B.12) assumes that the relative price of durables to nondurables do not change post the transitory unexpected monetary shock. Since ex-post price of housing is different from the aggregate change in the CPI following section 3.2, accommodative monetary policy in my setup causes additional capital wealth loss from the increase in the relative price of durables. While the changes for the nondurables and housing services are not equivalent in terms of utility in general, these two effects could be consolidated into a single one, we can restrict ourselves to variations that feature a constant elasticity of the durable-good price to the nondurable real interest rate

$$\epsilon_{pR} \equiv -\frac{\partial p}{p} \frac{R}{\partial R}$$

which leads to the general definition of  $URE$  from (B.12)

$$d\Omega = dY + \left( \underbrace{Y_0 + (-1)\ell_0 + (-1)h_0 \Theta_1 \theta_1 + (-1)s_0 \Theta_2 \theta_2 - C_0 - p_0 I_0 (1 - \epsilon_{pR})}_{URE^\epsilon} \right) \frac{dR}{R} \quad (\text{B.13})$$

Empirically, as in section 4,  $URE$  is measured with consumption being total sum of durables and nondurables with the benchmark case of  $\epsilon_{pR} = 0$ . The rest of the derivation and results follow identically consistent with the definition of  $URE$  in (B.12) & (B.13).

### B.3 Incomplete Markets

The environment for the extension to incomplete markets is identical to section I.C of [Auclert \(2019\)](#). The consumer faces idiosyncratic income uncertainty and restrictions on the number of assets traded. The consumer faces an idiosyncratic process for real wages  $\{w_t\}$  and unearned income  $\{y_t\}$ . The choice variables are consumption  $c_t$  and labor supply  $n_t$  to maximize the expected utility function. As in the perfect foresight model, the horizon need not be specified.

$$\mathbb{E} \left[ \sum_t \beta^t \{u(c_t) - v(n_t)\} \right]$$

Market incompleteness is modeled in a general form. Ex-ante as in the complete markets setup, the composition of the balance sheets does not matter. Only the measures of household exposures unconditionally are pinned down exactly before the one time unexpected monetary policy surprise at  $t = 0$ . To consider the changes in consumption from the changes in the current unearned income  $dy$ , current real wage  $dw$  and the real interest rate  $dR$ .

I keep the assumption that this variation in asset prices adjusting to reflect the change in discounting alone given here by (B.14) for  $j = 1, \dots, N^x$  for any of the  $N^x$ ,  $\forall x = \{\ell, H, S\}$  assets that can be considered belonging to the class of assets for liquid, housing and equity.

$$dQ^x/Q^x = dS_j^x/S_j^x = -dR^x/R^x \quad \forall x = \{\ell, H, S\} \quad (\text{B.14})$$

$$dQ^\ell/Q^\ell = dQ/Q = dS_j/S_j = -dR/R = -dR^\ell/R^\ell = dS_j^\ell/S_j^\ell \quad (\text{B.15})$$

$$dS_j^H/S_j^H = -dR^H/R^H = -\theta_1 dR/R \quad \& \quad dS_j^S/S_j^S = -dR^S/R^S = -\theta_2 dR/R \quad (\text{B.16})$$

$$dP_H/P_H = \theta_3 dP_\ell/P_\ell \quad \& \quad dP_S/P_S = \theta_4 dP/P \quad \text{with} \quad dP_\ell/P_\ell = dP/P = d\Pi/\Pi \quad (\text{B.17})$$

$$Q_H = \Theta_3 Q_\ell = \Theta_3 Q \quad \& \quad Q_S = \Theta_4 Q_\ell = \Theta_3 Q \quad (\text{B.18})$$

Specifically (B.15) refers to the benchmark change for the liquid asset while (B.16) - (B.18) refers to the normalized relations for housing and equity analogous to section 3.2 conditioned on the transitory monetary policy surprise. Additionally, if  $MPC = \partial c / \partial y$  and both the marginal propensities to work and save are similarly defined as responses to current income transfers then the final aggregate consumption can be represented in terms of the sufficient statistics by (6). My interest in this context is to ensure that amended definitions of household exposures to real interest rate and the Fisher channels to account for the conditional

impact in the presence of market incompleteness remain consistent.

The aim is to show that equations (A.53) & (A.54) have to continue to hold analogous to equations (A.19) & (A.20) in the perfect foresight model (as proved in section B.1). There are two cases required to be proved separately. In the first case, the consumer is at the binding borrowing limit and spends all income or the consumer is hand-to-mouth. Here, the solution is on the boundary. In the second case, the consumer problem has an interior solution. Two sub cases are to be proved for the second case.

### Case I. Binding borrowing limit and hand-to-mouth consumers.

The problem is a static choice between  $c$  and  $n$ . For ease of comparison, I restate some of the definitions.  $Q$  is the nominal price,  $\delta$  is the nominal bonds holding while  $\lambda$  is the real bonds holding.  $\theta$  denotes portfolio shares,  $\mathbf{d}$  are real dividends while  $\mathbf{S}$  denote the real prices.  $Z$  is the measure of net wealth of the consumer. The consumption of the agent at the borrowing limit or being hand-to-mouth is given by

$$c = wn + Z \quad \text{where} \quad Z = z + (1 + Q\delta) \frac{\lambda}{\Pi} + \theta \cdot (\mathbf{d} + \mathbf{S}) + \frac{\bar{D}}{R} \quad (\text{B.19})$$

Using  $d\mathbf{S} = -\frac{S}{R}dR$ ,  $dQ = -\frac{Q}{R}dR$  and  $d(\frac{1}{\Pi}) = -\frac{1}{\Pi^2}d\Pi = -\frac{1}{\Pi} \frac{dP}{P}$  along with relations (B.15) - (B.18), if the agent is at the borrowing limit then splitting the household balance sheets by asset class.

$$\begin{aligned} Z &= z + (1 + Q_\ell S_\ell + Q_H \delta_H + Q_S \delta_S) \left( \frac{\lambda_\ell + \lambda_H + \lambda_S}{\Pi} \right) + \theta(\mathbf{d} + S_\ell + S_H + S_S) + \frac{\bar{D}}{R} \\ \implies dZ &= dz + \text{Price Effect} + \text{Real Interest Rate Effect} \end{aligned} \quad (\text{B.20})$$

The price effect in (B.20) for the Fisher channel is derived as

$$\begin{aligned} \text{Price Effect} &= - \left( 1 + Q_\ell \delta_\ell \frac{dP_\ell}{P_\ell} + Q_H \delta_H \frac{dP_H}{P_H} + Q_S \delta_S \frac{dP_S}{P_S} \right) \frac{\lambda}{\Pi} \\ &= - \frac{\lambda}{\Pi} \{ 1 + (\delta_\ell + \theta_3 \Theta_3 \delta_H + \theta_4 \Theta_4 \delta_S) \} \frac{dP}{P} \\ &= - \underbrace{\frac{\lambda}{\Pi} (1 + \delta_{m_1} Q)}_{\text{NNP}} \frac{dP}{P} \end{aligned} \quad (\text{B.21})$$

The real interest rate effect in (B.20) for the real interest rate channel is derived as

$$\begin{aligned}
\text{Price Effect} &= \frac{\left(\lambda_\ell \frac{dR_\ell}{R_\ell} + \lambda_H \frac{dR_H}{R_H} + \lambda_S \frac{dR_S}{R_S}\right)}{\Pi} Q \delta \\
&+ \frac{\lambda}{\Pi} \left( Q_\ell \delta_\ell \frac{dR_\ell}{R_\ell} + Q_H \delta_H \frac{dR_H}{R_H} + Q_S \delta_S \frac{dR_S}{R_S} \right) + \theta \cdot \mathbf{S} - \frac{\bar{D}}{R} \\
&= \left( Q \delta \frac{(\lambda_\ell + \lambda_H \theta_1 + \lambda_S \theta_2)}{\Pi} + \frac{\lambda}{\Pi} (\delta_\ell + \theta_1 \Theta_3 \delta_H + \theta_2 \Theta_4 \delta_S) \theta \cdot \mathbf{S} - \frac{\bar{D}}{R} \right) \left( -\frac{dR}{R} \right) \\
&= \underbrace{\left( \lambda_m \delta \frac{Q}{\Pi} + \delta_{m_2} \lambda \frac{Q}{\Pi} + \theta \cdot \mathbf{S} + \frac{\bar{D}}{R} \right)}_{-\text{URE}} \left( -\frac{dR}{R} \right) \tag{B.22}
\end{aligned}$$

Using (B.21) & (B.22), the variation in income given by (B.20) is given by

$$dZ = dz - \underbrace{\frac{\lambda}{\Pi} (1 + \delta_{m_1} Q)}_{\text{NNP}} \frac{dP}{P} + \underbrace{\left( \lambda_m \delta \frac{Q}{\Pi} + \delta_{m_2} \lambda \frac{Q}{\Pi} + \theta \cdot \mathbf{S} + \frac{\bar{D}}{R} \right)}_{-\text{URE}} \left( -\frac{dR}{R} \right) \tag{B.23}$$

If the agent is hand-to-mouth, then (B.23) still applies for (B.24) as the consumer is still making a static choice for consumption and labor supplied given the budget constraint in (B.19) and  $MPS = 0$ . The rest of the steps are identical.

$$dZ = dz \quad \& \quad NNP = URE = 0 \tag{B.24}$$

## Case II. a) Interior solution with $N = 0$ , all variables changing

The derivation till equation (A.65) is identical. The borrowing constraint is not binding and the value function is concave at the interior optimum. For this case, the updated notation to show that (6) still holds is given by the mapping

$$q \equiv Q, \quad z \equiv y + \frac{\lambda}{\Pi}, \quad a = \lambda', \quad b_1 = \delta_{m_1} \frac{\lambda}{\Pi}, \quad b_2 = \delta_{m_2} \frac{\lambda}{\Pi}$$

Using the benchmark relation for the liquid asset  $\frac{dP}{P} = \frac{d\Pi}{\Pi}$  and  $\frac{dQ}{Q} = -\frac{dR}{R}$  gives

$$dz = dy - \frac{\lambda}{\Pi} \frac{dP}{P}, \quad db_1 = -\delta_{m_1} \frac{\lambda}{\Pi} \frac{dP}{P}, \quad db_2 = -\delta_{m_2} \frac{\lambda}{\Pi} \frac{dP}{P} \quad \text{and} \quad \frac{dq}{q} = -\frac{dR}{R}$$

Then, the variation in the net wealth change from the two channels is given by

$$\begin{aligned}
dz + qdb_1 - (a - b_2)dq &= dy - \frac{\lambda}{\Pi} \frac{dP}{P} - q\delta_{m_1} \frac{\lambda}{\Pi} \frac{dP}{P} - \left( \lambda' - \delta_{m_2} \frac{\lambda}{\Pi} \right) dQ \\
&= dy - \underbrace{\frac{\lambda}{\Pi} (1 + \delta_{m_1} Q)}_{\text{NNP}} \frac{\lambda}{\Pi} \frac{dP}{P} + \underbrace{\left( \lambda' - \delta_{m_2} \frac{\lambda}{\Pi} \right) Q}_{\text{URE}} \frac{dR}{R} \quad (\text{B.25})
\end{aligned}$$

(B.25) is essentially of the form of (B.23) where the borrowing limit does not bind and can be directly used to derive the result form (A.63) & (A.65).

## Case II. b) For $N > 0$ , only interest rate changing and no bonds

For this case, there is no change in the wages and all the change in consumption come from the balance sheet changes. The result for the final consumption change of the form in (6) is proved by considering the following Lemma structured analogously to Lemma A.2.

**Lemma:** Let  $(\theta, Y, R, \Theta)$  be the solution to the following consumer choice problem under concave preferences over current consumption  $u(c)$  and initial balance sheet holdings  $W(\theta')$

$$\max_{c, \theta'} u(c) + W(\theta') \quad \text{s.t.} \quad c + (\theta' - \theta)\Theta\mathbf{S} = Y + \theta\mathbf{d} \quad \text{where} \quad \frac{dS}{dR} = -\frac{\mathbf{S}}{R},$$

$$(\theta' - \theta)\Theta\mathbf{S} = \sum_j s_j(\theta^j - \theta'^j)\theta_j, \quad \theta_j \in \{\theta_\ell = 1, \theta_H = \theta_1, \theta_S = \theta_2\}$$

$$\text{Then, to the first order, } dc = \text{MPC} \left( dY + \text{URE} \frac{dR}{R} \right) - \sigma(c)c(1 - \text{MPC}) \frac{dR}{R}$$

$$\text{where } \sigma(c) \equiv -\frac{u'(c)}{cu''(c)} \text{ is the local IES \& } \text{MPC} = \frac{\partial c}{\partial Y} \text{ and } \text{URE} = Y + \theta\mathbf{d} - c$$

The first order conditions characterizing the solution are given by

$$S^i u'(Y + \theta\mathbf{d} - (\theta' - \theta)\Theta\mathbf{S}) = W_{\theta^i}(\theta') \quad \forall i = 1, 2, \dots, N \quad (\text{B.26})$$



First considering the increase in income alone and differentiating along (B.26) gives

$$S^i u''(c) \left( 1 - \sum_j \underbrace{S^j \theta_j \frac{d\theta'^j}{dY}}_{\eta^j} \right) = \sum_j W_{\theta^i \theta^j}(\theta') \frac{d\theta'^j}{dY} \quad \forall i \implies \sum_j \left( \frac{1}{S^i S^j} W_{\theta^i \theta^j}(\theta') + u''(c) \right) \eta^j = u''(c) \quad (\text{B.27})$$

Defining matrix  $M$  with elements  $m_{ij}$ , the system can be represented in matrix form as

$$m_{ij} \equiv \frac{1}{S^i S^j} W_{\theta^i \theta^j}(\theta') + u''(c) \implies M\eta = u''(c)\mathbf{1} \implies \eta = u''(c)M^{-1}\mathbf{1}$$

$$\text{where } \sum \eta^j = \sum S^i \theta_j \frac{d\theta'^j}{dY} = \frac{d}{dY} \sum S^j (\theta^j - \theta'^j) \theta_j$$

which now leads to identical equations (A.68) and (A.69) as follows

$$MPC = \frac{dc}{dY} = 1 - \sum_j \eta^j = 1 - u''(c)m \quad (\text{B.28})$$

$$\text{where } m \text{ is defined as } m \equiv \mathbf{1}M^{-1}\mathbf{1} \quad (\text{B.29})$$

Considering a change in the real interest rate by  $dR$ . Differentiating along (B.26) by separately considering the three asset classes in the the household balance sheet.

$$\begin{aligned} \frac{dS^i}{dR} u'(c) + S^i u''(c) \left\{ - \sum_j S^j \frac{d\theta'^j}{dR} - \frac{dS^\ell}{dR} (\theta'^\ell - \theta^\ell) \right. \\ \left. - \frac{dS^H}{dR} (\theta'^H - \theta^H) - \frac{dS^S}{dR} (\theta'^S - \theta^S) \right\} = \sum_j W_{\theta^i \theta^j}(\theta') \frac{d\theta'^j}{dR} \quad \forall i \end{aligned} \quad (\text{B.30})$$

Using the subset of the relations assumed in equation (B.14) relevant for the real interest rate channel

$$\frac{dS^L}{dR} = -\frac{dR}{R}, \quad \frac{dS^H}{dR} = -\frac{dR_H}{R_H} = -\theta_1 \frac{dR}{R}, \quad \frac{dS^S}{dR} = -\frac{dR_S}{R_S} = -\theta_2 \frac{dR}{R} \quad (\text{B.31})$$

substituting the conditional impacts from (B.31) in (B.30) and rewriting as

$$\frac{dS^i}{dR} u'(c) + S^i u''(c) \left\{ - \sum_j S^j \frac{d\theta'^j}{dR} - \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j \right\} = \sum_j W_{\theta^i \theta^j}(\theta') \frac{d\theta'^j}{dR} \quad \forall i \quad (\text{B.32})$$

Defining  $\gamma^j \equiv S^j \frac{d\theta'^j}{dR}$  such that it solves

$$\sum m_{ij} \gamma^j = -\frac{1}{R} u'(c) + u''(c) \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j \quad \forall i$$

$$\begin{aligned} \text{In matrix form, } M\gamma &= \left( \frac{1}{R} u'(c) + u''(c) \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j \right) \mathbf{1} \\ \Rightarrow \gamma &= \left( \frac{1}{R} u'(c) + u''(c) \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j \right) M^{-1} \mathbf{1} \end{aligned} \quad (\text{B.33})$$

Differentiating with respect to  $R$  in the budget constraint defined as  $c + (\theta' - \theta)\Theta\mathbf{S} = Y + \theta\mathbf{d}$ ,

$$\frac{dc}{dR} = -\sum_j S^j \frac{d\theta'^j}{dR} + \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j = -\sum_j \gamma^j + \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j \quad (\text{B.34})$$

Substituting (B.33) and using  $m = M^{-1}\mathbf{1}$  from (B.29), (B.34) can be rewritten as

$$\frac{dc}{dR} = -\left( \frac{1}{R} u'(c) + u''(c) \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j \right) m + \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j \quad (\text{B.35})$$

Substituting  $u'(c) = -\sigma(c)u''(c)$  in (B.35) and rearranging terms,

$$\frac{dc}{dR} = -\sigma(c) \frac{c}{R} u''(c) m + \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j (1 - u''(c) m) \quad (\text{B.36})$$

Substituting the expression for  $MPC$  from (B.28), (B.36) can be written as

$$\frac{dc}{dR} = \sigma(c) \frac{c}{R} (1 - MPC) + \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j MPC \quad (\text{B.37})$$

The second term on the RHS of (B.37) can be simplified using the defined budget constraint  $c + (\theta' - \theta)\Theta\mathbf{S} = Y + \theta\mathbf{d}$  as follows

$$\begin{aligned} \sum_j \frac{S^j}{R} (\theta'^j - \theta^j) \theta_j MPC &= \frac{1}{R} \sum_j S^j (\theta'^j - \theta^j) \theta_j MPC = \frac{1}{R} [(\theta' - \theta)\Theta\mathbf{S}] MPC \\ &= \frac{1}{R} [Y - \theta\mathbf{d} - c] MPC = \frac{1}{R} URE \cdot MPC \end{aligned} \quad (\text{B.38})$$

where I have used the consistent definition of  $URE$  being the net wealth defined by con-

sidering all present and future assets & liabilities. Now, using (B.38), the real interest rate impact on consumption from (B.37) can be written as

$$\frac{dc}{dR} = \sigma(c) \frac{c}{R} (1 - MPC) + \frac{1}{R} URE \cdot MPC \quad (\text{B.39})$$

Now considering the entire change from the simultaneous income and real interest rate, using (B.28) along with (B.39), the lemma is proved

$$dc = MPC \left( dY + URE \frac{dR}{R} \right) - \sigma(c) c (1 - MPC) \frac{dR}{R} \quad (\text{B.40})$$

Using the result of the lemma from (B.40), the result for labor supply  $dn$  can be proved analogously. Given the restrictions of fixed balance sheets and only transitory shocks, following appendix A.7 using the lemma for both consumption and labor supply, the aggregation follows identically. This proves that (6) holds under general market incompleteness and completes all the required proofs for model extensions.

## C Sufficient Statistics - Additional Results

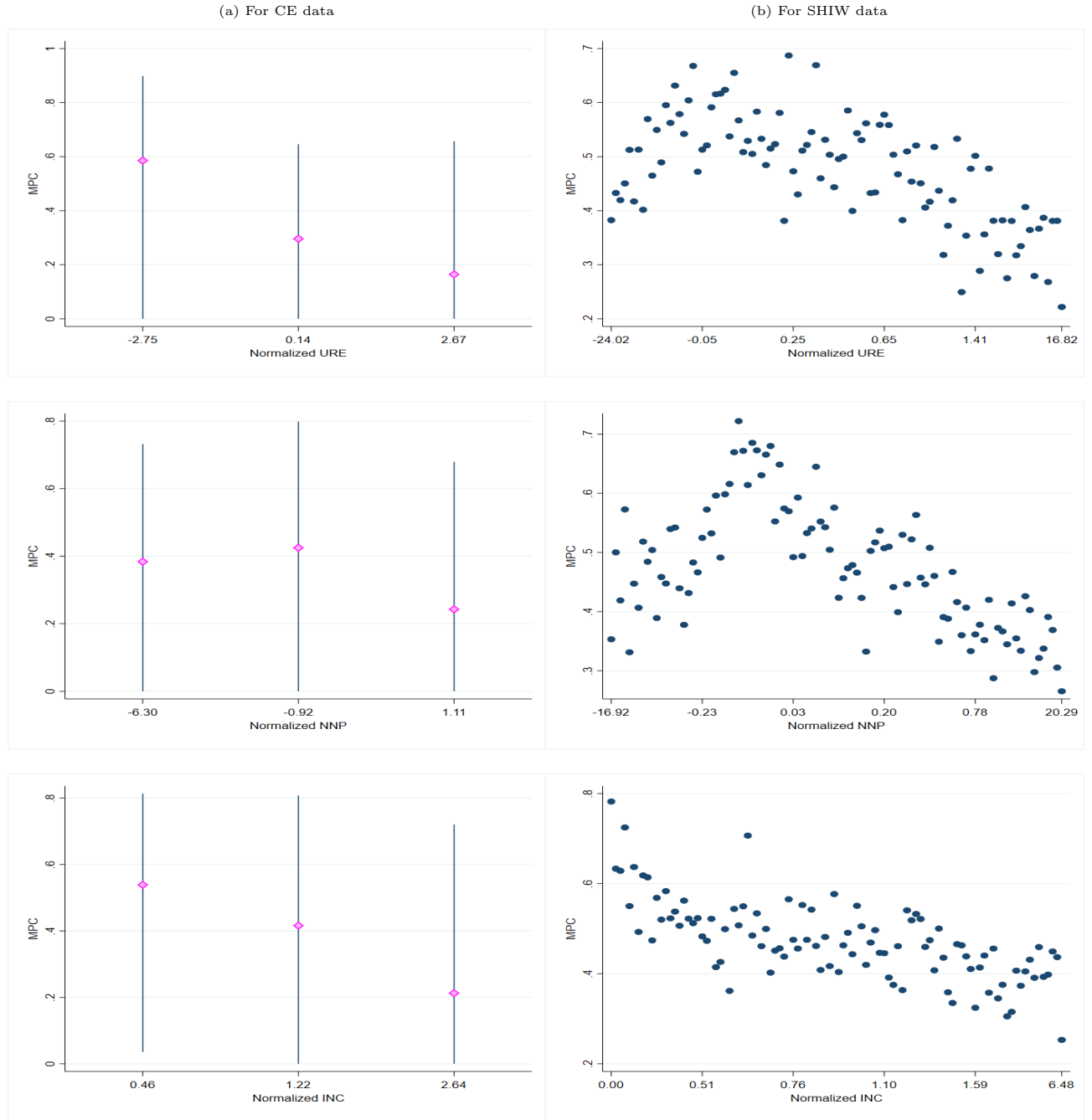
### C.1 Redistribution elasticities relative to benchmark

The differential impacts on prices & returns to housing and equity leads to the entire distribution of household exposure from both the real interest rate and Fisher channels to flatten. The capturing of longer tails not only makes them more accurate but also amplifies the exposures as revealed by panel (a) of Figure 11 for the CE data.<sup>25</sup> The distribution for earnings shifts slightly to the left. It is consistent since the survey reported numbers for unrealized capital gains are not included as they do not reveal any information about transitory monetary policy. Panel (b) compares the response in SHIW data assuming that agents face the exact same shock and are not directly comparable. However, both the panels visually indicate that there is a negative correlation between  $URE$ ,  $NIC$  & associated  $MPCs$  when conditioned on the shock. The relation is slightly less pronounced for  $NNP$ . The majority of US households own housing despite having mortgages and the net position on housing

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<sup>25</sup>Looking at Figure 11 seems it is possible to have similar graphs for only housing or equity wealth. However, following the same empirical method to estimate  $MPCs$  could involve substantial error on ignoring significant parts of household portfolio. Differences across the distribution in that case would be erroneously attributed to asset maturity. I comment on this issue in section 1.

Figure 11: Marginal Propensities to Consume and Redistribution Channels in survey data



Note - The normalization follows the definition of 12 for both the datasets. In SHIW, *MPCs* are self-reported. The number of bins to estimate *MPC* in CE as a function of household exposure is 3.

Table 18: Cross - sectional moments for the two surveys corresponding to [Figure 5](#)

| Survey:                        | CE       |               | SHIW     |               |
|--------------------------------|----------|---------------|----------|---------------|
|                                | Estimate | 95 percent CI | Estimate | 95 percent CI |
| $\widehat{\varepsilon}_R$      | -0.38    | [-0.94,0.17]  | -0.07    | [-0.15,0.01]  |
| $\widehat{\varepsilon}_R^{NR}$ | -0.38    | [-0.94,0.18]  | 0.08     | [0.00,0.16]   |
| $\widehat{\mathcal{S}}$        | 0.65     | [0.38,0.92]   | 0.56     | [0.52,0.59]   |
| $\widehat{\varepsilon}_P$      | -0.13    | [-0.90,0.63]  | -0.06    | [-0.13,0.02]  |
| $\widehat{\varepsilon}_P^{NR}$ | -0.85    | [-1.75,0.06]  | -0.10    | [-0.17,-0.03] |
| $\widehat{\varepsilon}_Y$      | -0.12    | [-0.34,0.10]  | -0.05    | [-0.06,-0.03] |
| $\widehat{\mathcal{M}}$        | 0.44     | [-0.06,0.94]  | 0.49     | [0.47,0.51]   |

Note - The final version of the model in [section 3](#) is used which includes separate conditional impact to both houses and equity. The robustness is ensured by re-sampling the panel 100 times with replacement to reduce errors.

is likely to be positive. They occupy the middle quantiles of wealth distribution and are expected to have higher *MPCs*. I maintain the benchmark assumptions regarding asset maturity and number of bins used to estimate the *MPCs* from CE data. The estimates along with their 95% confidence interval for the two surveys are presented in [Table 18](#). Compared to previous results, the point estimates are considerably larger for the two channels of interest. The earnings heterogeneity channel remains more or less same since it uses reported measures. The focus here is on the unrealized conditional changes on household balance sheets. The standard substitution and wealth effects present in a RANK do not show any appreciable improvement. On average, the confidence intervals admit more negative values for the *URE* & *NNP* channels. Even larger negative covariance between *MPCs* & interest rate channels is possible. This leads to bigger consumption responses conditioned on these unrealized changes arising from the differential effects to housing & equity. In general, expansionary monetary policy tends to benefit agents who have more liabilities (primarily with longer maturities eg mortgages - negative *URE*) than assets (with shorter maturity eg stocks and bonds - positive *URE* since the former have higher *MPCs* than the latter. On the contrary, once the *MPCs* are not allowed to change, the new estimates of redistribution elasticities are much smaller in absolute value. In this case, unrealized increases in wealth

Table 19: Variation of redistribution elasticity estimated with asset maturity assumption

|                           |      | Duration scenario |               |              |              |              |
|---------------------------|------|-------------------|---------------|--------------|--------------|--------------|
|                           |      | Quarterly         | Short         | Benchmark    | Long         | Annual       |
| $\widehat{\varepsilon}_R$ | CE   | -0.99             | -0.56         | -0.38        | -0.38        | -0.39        |
|                           |      | [-2.29,0.31]      | [-1.40,0.29]  | [-0.94,0.17] | [-0.81,0.04] | [-0.80,0.01] |
|                           | SHIW | -0.08             | -0.14         | -0.07        | -0.05        | -0.03        |
|                           |      | [-0.27,0.12]      | [-0.25,-0.03] | [-0.15,0.01] | [-0.11,0.01] | [-0.10,0.03] |

Note - exactly similar process as described in Table 18. See corresponding notes for more details. For description of maturities, see Auclert (2019) Table 2.

without corresponding increase in MPC, for majority of the distribution, mechanically reduces the negative covariance. Results in Table 19 highlight the relative importance of the asset maturity channel for  $\widehat{\varepsilon}_R$ . The updated results show no major changes in the overall trend on comparison with the original estimates. Consistent with the previous explanation, the estimates diminish in SHIW data. The role of asset returns enhances the impacts across horizons only when associated *MPCs* are changing. Even at quarterly horizon, commonly assumed in most structural models, not accounting for returns heterogeneity underestimates the targeted moment by almost 100 percent. Structural models would at least need to match the updated sufficient statistics to get an accurate aggregate impact. If the model is misspecified, then the errors would simply compound. This holds even if the model is not relevant for analyzing policy initiatives from the incorporation of return heterogeneity. Another striking result from Table 18 is the vastly improved performance with respect to the no-rebate numbers. These act as the lower bound for these point estimates. Accounting for the measurement error leads to even higher magnitudes while preserving the expected sign and prevents counter-intuitive positive covariances that sometimes appear in Auclert (2019). A requisite discussion in this context has been included in section 5.2. Additional results are included in section C.2.

## C.2 Additional results for comparing aggregate changes

To get an idea of the impact of asset maturity on aggregate consumption, one can directly see the impact on the redistribution elasticity from the real interest rate which is the only chang-

Table 20: Sensitivity of  $\sigma^*$  to Asset Maturity under expansionary policy in CE

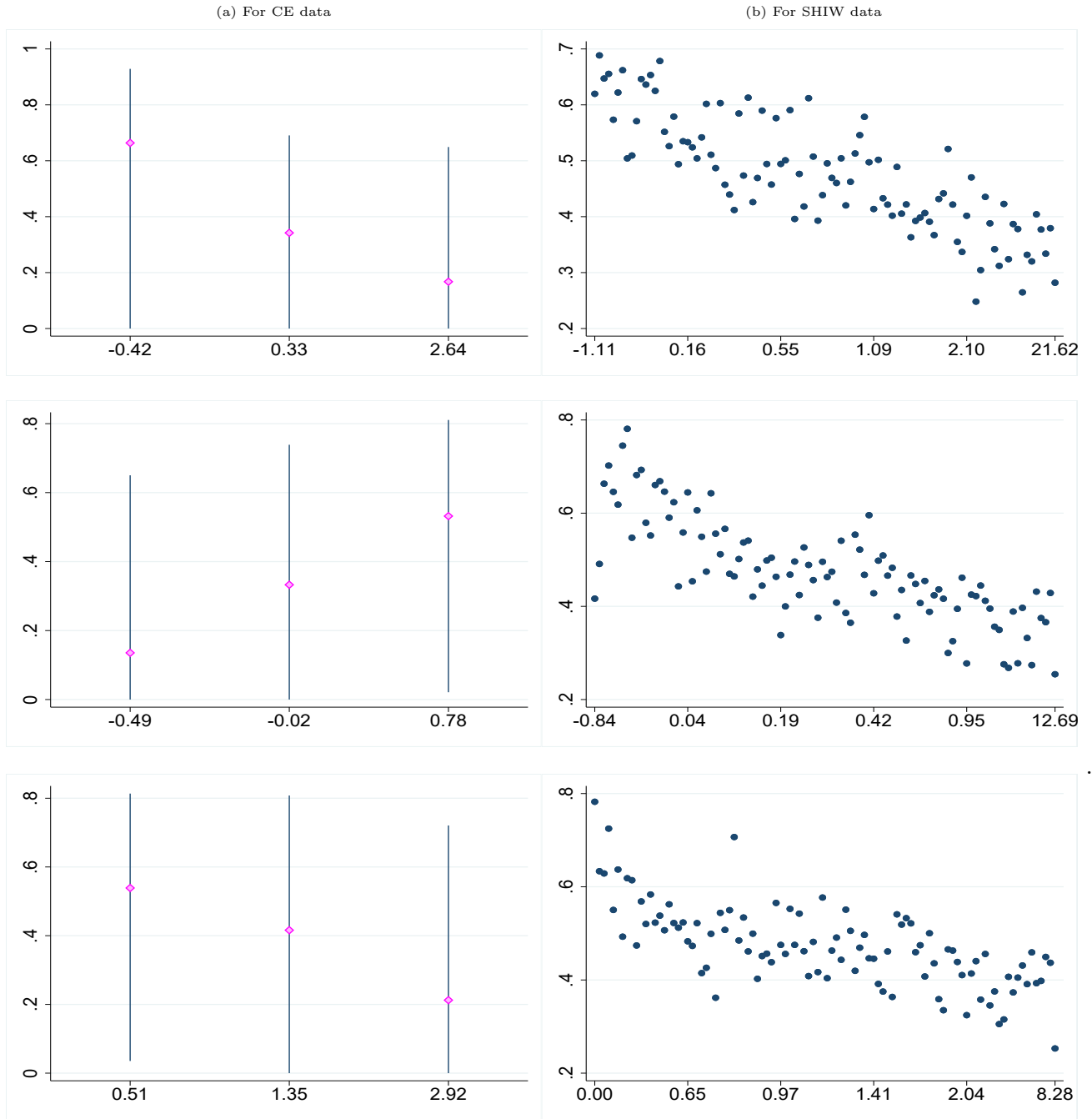
| Measure                | Maturity  | Auclert | Housing + Stock | Housing | Stocks |
|------------------------|-----------|---------|-----------------|---------|--------|
| $\sigma^*$<br>% Change | Quarterly | 0.86    | 1.52            | 1.28    | 1.50   |
|                        |           | —       | 77.23           | 48.59   | 74.55  |
|                        | Short     | 0.75    | 0.86            | 0.89    | 0.85   |
|                        |           | —       | 14.87           | 18.97   | 13.13  |
|                        | Long      | 0.34    | 0.58            | 0.42    | 0.58   |
|                        |           | —       | 70.07           | 20.84   | 67.49  |
|                        | Annual    | 0.36    | 0.60            | 0.45    | 0.59   |
|                        |           | —       | 66.96           | 24.15   | 64.43  |

Note - Results with  $\sigma = 0.5$ . To be compared with the first two rows of [Table 2](#). See associated table notes for more details.

ing sufficient statistic on altering the maturities. The first two rows of [Table 20](#) correspond to length of assets being shorter than the benchmark while the last two rows correspond to lengths being higher. Compared to the main text results in [Table 2](#), the impact increases by around 15% in the quarterly horizon. This is of interest to structural models which typically assume quarterly or shorter asset maturities. The direct effects rise as asset maturity shortens and is robust in general to changing the asset maturity. Surprisingly, the effects are almost equal at the short horizon. I also present the corresponding estimates keeping the *MPC* fixed in [Table 21](#) and find as before there is much lesser variation and in fact the effects decline when compared to the benchmark.

For the sake of completeness, I present the results analogous for the contractionary shock. From [Figure 12](#), the trend for the *URE* is similar while the trend for the *NNP* reverses since the entire distribution shifts leftward by a large magnitude from the wealth declines from the Fisher channel. The data for the SHIW now show clearer patterns of declining *MPC* with increased *URE* & *NNP* as intuitively expected. As stated before, since the two data sources are not strictly comparable, this would not qualify as an improvement. Comparing the redistribution elasticities for the negative shock in [Table 22](#) with the ones in [Figure 5](#), the asymmetric response is felt strongly for both the real interest rate and the Fisher channels. Owing to the new distribution of the *NNP* with its associated *MPC*, there is an increase in

Figure 12: *MPC* vs Redistribution Channels in survey data for contractionary shock



Note - Contractionary shock uses PDV estimates for one standard deviation rise in the monetary policy surprise. For more details, see associated notes in [Figure 11](#)



Table 21: Sensitivity of  $\sigma^*$  to Asset Maturity under expansionary policy in SHIW

| Measure                | Maturity  | Auclert | Housing + Stock | Housing | Stocks |
|------------------------|-----------|---------|-----------------|---------|--------|
| $\sigma^*$<br>% Change | Quarterly | 0.29    | 0.14            | 0.13    | 0.31   |
|                        |           | —       | -50.89          | -57.03  | 6.25   |
|                        | Short     | 0.36    | 0.09            | 0.23    | 0.36   |
|                        |           | —       | -75.45          | -36.16  | 0      |
|                        | Long      | 0.13    | 0.25            | 0.07    | 0.15   |
|                        |           | —       | 96.43           | -43.88  | 14.29  |
|                        | Annual    | 0.11    | 0.05            | 0.04    | 0.13   |
|                        |           | —       | -50.89          | -67.26  | 16.67  |

Note - Results with  $\sigma = 0.5$ . To be compared with the last two rows of [Table 2](#). See associated table notes for more details.

the consumption on raising the interest rate through the Fisher channel. The final impact on the aggregate consumption depends on the interaction of all the channels and is explained in section [5.3](#).

Since the asymmetric response to the interest rate channel is the strongest and intuitive, I look at its sensitivity to asset maturity. Shortening the time frame leads to far less reduction in aggregate consumption from direct effects across maturities. On comparing with [Table 19](#), the differences are most pronounced for the quarterly and short horizons. The asymmetric response to consumption increases in strength as the asset maturity shortens which is another feature of interest for structural models.

The value of  $\gamma$  is expected to be negative since idiosyncratic incomes are expected to be countercyclical. I take a wide range of permissible values and check the percentage change in the general equilibrium consumption from the main model which features separate returns to both housing and equity. I compare the baseline and the no-rebate numbers for both the shocks. The numbers in [Table 26](#) also indicate the magnitude of the asymmetric response with varying  $\gamma$ . In general as incomes become strongly counter-cyclical, the overall aggregate consumption response weakens since the net change from the income effects from the earnings heterogeneity channel start opposing the added substitution effects from equation (9). The degree of asymmetric response depends on the updated elasticities and gamma does not play

Table 22: Cross - sectional moments corresponding to [Figure 5](#) for a contractionary shock

| Survey:                        | CE       |               | SHIW     |               |
|--------------------------------|----------|---------------|----------|---------------|
|                                | Estimate | 95 percent CI | Estimate | 95 percent CI |
| $\widehat{\varepsilon}_R$      | -0.24    | [-0.55,0.07]  | -0.14    | [-0.18,-0.10] |
| $\widehat{\varepsilon}_R^{NR}$ | 0.09     | [-0.33,0.51]  | 0.54     | [0.49,0.58]   |
| $\widehat{\mathcal{S}}$        | 0.61     | [0.33,0.89]   | 0.55     | [0.53,0.58]   |
| $\widehat{\varepsilon}_P$      | 0.08     | [-0.03,0.20]  | -0.08    | [-0.10,-0.05] |
| $\widehat{\varepsilon}_P^{NR}$ | 0.11     | [-0.01,0.24]  | 0.24     | [0.22,0.26]   |
| $\widehat{\varepsilon}_Y$      | -0.13    | [-0.38,0.11]  | -0.06    | [-0.08,-0.04] |
| $\widehat{\mathcal{M}}$        | 0.49     | [-0.06,1.94]  | 0.60     | [0.60,0.65]   |

Note - Contractionary shock uses PDV estimates for one standard deviation rise in the monetary policy surprise. See associated notes in [Table 18](#) for more details.

Table 23: Comparison for expansionary shock with  $\sigma = 0.5$  &  $\gamma = -0.5$  for no-rebate numbers

| Model Consumption Response | Estimated <i>MPCs</i> |      | Fixed <i>MPCs</i> |      |
|----------------------------|-----------------------|------|-------------------|------|
|                            | PE                    | GE   | PE                | GE   |
| Auclert + House + Stock    | 1.62                  | 2.06 | 0.33              | 0.82 |
| Auclert + House            | 1.68                  | 2.12 | 0.21              | 0.70 |
| Auclert + Stock            | 0.61                  | 1.07 | 0.10              | 0.65 |
| Auclert                    | 0.93                  | 1.39 | 0.01              | 0.47 |

Notes - No rebate numbers refer to withholding the instantaneous transfers post the windfall transfer by other sector of the economy from the household sector. For more details see notes in [Table 3](#).

Table 24: Comparison for contractionary shock with  $\sigma = 0.5$  &  $\gamma = -0.5$  for no-rebate numbers

| Model Consumption Response | Estimated <i>MPCs</i> |      | Fixed <i>MPCs</i> |      |
|----------------------------|-----------------------|------|-------------------|------|
|                            | PE                    | GE   | PE                | GE   |
| Auclert + House + Stock    | 0.17                  | 0.66 | -0.48             | 0.16 |
| Auclert + House            | 1.00                  | 1.49 | 0.21              | 0.84 |
| Auclert + Stock            | 0.89                  | 1.35 | -0.17             | 0.38 |
| Auclert                    | 0.93                  | 1.39 | 0.01              | 0.47 |

Note - Contractionary shock refers to the transitory unexpected one percent increase in the real interest rate accompanied by a decrease in overall price level & aggregate income by one percent. See notes in [Table 23](#) for more details.

Table 25: Variation of  $\widehat{\varepsilon}_R$  with asset maturity assumption for a contractionary shock

|                           |      | Duration scenario      |                        |                        |                        |                        |
|---------------------------|------|------------------------|------------------------|------------------------|------------------------|------------------------|
|                           |      | Quarterly              | Short                  | Benchmark              | Long                   | Annual                 |
| $\widehat{\varepsilon}_R$ | CE   | -0.14<br>[-0.73,0.45]  | -0.07<br>[-0.6,0.46]   | -0.24<br>[-0.55,0.07]  | -0.17<br>[-0.41,0.07]  | -0.21<br>[-0.42,0.00]  |
|                           | SHIW | -0.27<br>[-0.35,-0.20] | -0.27<br>[-0.34,-0.19] | -0.14<br>[-0.18,-0.10] | -0.10<br>[-0.13,-0.07] | -0.08<br>[-0.11,-0.06] |

Note - Contractionary shock uses PDV estimates for one standard deviation rise in the monetary policy surprise. See associated notes in [Table 19](#) for more details.

Table 26: Sensitivity of general equilibrium consumption to value of  $\gamma$ 

| Value of $\gamma$ | Expansionary |           | Contractionary |           |
|-------------------|--------------|-----------|----------------|-----------|
|                   | Baseline     | No-rebate | Baseline       | No-rebate |
| -1.5              | -15.33       | -9.94     | 10.04          | 8.58      |
| -1.25             | -11.79       | -7.62     | 7.72           | 6.58      |
| -1.00             | -8.07        | -5.20     | 5.28           | 4.48      |
| -0.75             | -4.14        | -2.67     | 2.71           | 2.29      |
| -0.40             | 1.72         | 1.10      | -1.13          | -0.95     |
| -0.25             | 4.38         | 2.78      | -2.87          | -2.40     |
| -0.1              | 7.14         | 4.52      | -4.67          | -3.90     |
| -0.01             | 8.83         | 5.59      | -5.78          | -4.82     |

Note - Calculates the percentage changes relative to the general equilibrium consumption for the main model described in section 3 for the CE data with  $\gamma = -0.5$ . Numbers for negative shock show improved response if positive. The second and third columns use the results from the first row in Table 4 & Table 23 respectively. Similarly, the fourth & fifth columns correspond to Table 7 & Table 24 respectively. For more details, see associated notes.

any significant role since the earnings heterogeneity channel is almost similar to the original results.

## D Comparing *MPC* estimates with previous results

The consumption at the household level from the one time unexpected monetary policy surprise is essentially product of the household income times its *MPC* out of income. We can decompose this total effect into five separate channels as in (6). Each channel is again the product of the aggregate change times its associated *MPC*. The economy wide aggregate *MPC* out of income is the first two terms of the same equation. I compare these estimates with existing results for the *MPC* out of fiscal transfers.<sup>26</sup> The aggregate *MPC* out of income is 44% (vs 46% in the benchmark). Common estimates in the literature range from 15-25% .

<sup>26</sup>The estimation of MPCs requires a one time unexpected fiscal transfer. So these estimates are directly comparable. See section 4 for more details, specifically (12).

The higher numbers are primarily due to the enhanced effects of unrealized wealth changes from the separate redistribution channels on the household estimate of  $MPC$  out of income.

One of the assumptions regarding the theoretical exercise is that consumers cannot adjust their portfolios post the shock. Therefore, they cannot directly realize the wealth gains in exchange of transaction costs. The effect of balance sheets on the  $MPC$  out of income are a result of wealth changes from holdings of housing, equity and/or liquid assets. I also compare the aggregate  $MPC$  out of income with the estimates of  $MPC$  out of realized wealth changes for both housing and equity. I lay out previous numerical estimates in footnotes 2 and 5. Owing to large transaction costs,  $MPC$  out of home-equity based borrowings are much smaller than corresponding estimates out of realized wealth changes from equity. Estimating unrealized wealth changes from housing wealth is quite infeasible. Besides other estimates, [Hartzmark and Solomon \(2019\)](#) also estimate that the  $MPC$  out of dividends (equivalent to  $MPC$  out of realized wealth changes in equity) is 40-60% for top 50% of the wealth distribution.

I compare the model-implied elasticity of consumption to house price shocks as developed by [Berger et al. \(2018\)](#) given by

$$\eta = \frac{dC}{d(PH)} \times \frac{PH}{C} \equiv MPC \times \frac{(1 - \delta)PH}{C} \quad (D.1)$$

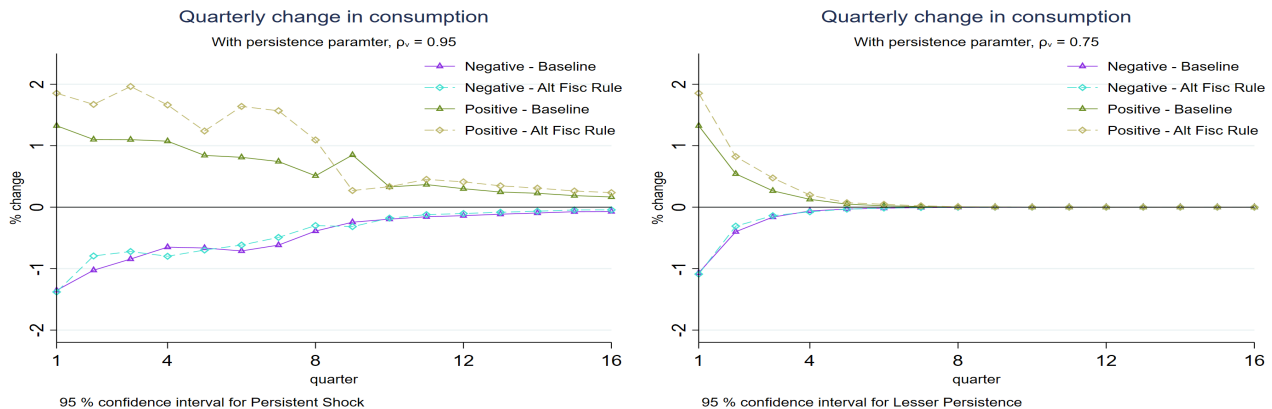
which is the sufficient statistic. For permanent house price changes of 4.59% and  $\delta = 2\%$ , they calculate the theoretical elasticity to be  $\in (0.23, 0.3)$ . For my model with an implied aggregate  $MPC$  out of income of 44%, using the permanent house price change of 4.59% leads to  $\eta = 0.45$ . If I use the estimated housing price change rather than the permanent shock in housing prices then estimate of  $\eta = 0.36$ , both being more or less similar.

Lastly, I also compare the estimates of  $MPC$  out of income with the  $MPC$  out of realized housing wealth changes in [Mian and Sufi \(2014\)](#). They find that the elasticity of consumption from housing net worth shock is 0.6 - 0.8 across counties when they have the housing net worth shock of

$$\text{HNW\_shock} = \left( \Delta \log p_{06-09}^{H,i} \times H_{2006}^i \right) / NW_{2006}^i \approx 10\% / NW_{2006}^i \quad (D.2)$$

Their average marginal  $MPC$  out of housing wealth is 5-7 cents. The most comparable estimates are for a negative shock and using a model with only housing returns heterogeneity and without any income change is roughly 0.59.

Figure 13: General equilibrium aggregate consumption response for different shocks



Note - Consumption change is corresponding to (9) for the model presented in section 3. Positive shock refers to the decline in the real interest rate by one percent for  $t = 1$ . Negative shock analogously refers to the increase in the real interest rate by one percent for  $t = 1$ . From  $t = 2$ , the one time change declines by  $\phi$  in absolute magnitude. Inflation and aggregate income both change by the same amount as the change in the real interest rate for all  $t \geq 1$ . Baseline refers to the benchmark model where fiscal transfers are instantaneously rebated. Alt Fisc Rule refers to the case where fiscal transfers are not instantaneously rebated.

## E Implied aggregate consumption *IRFs*

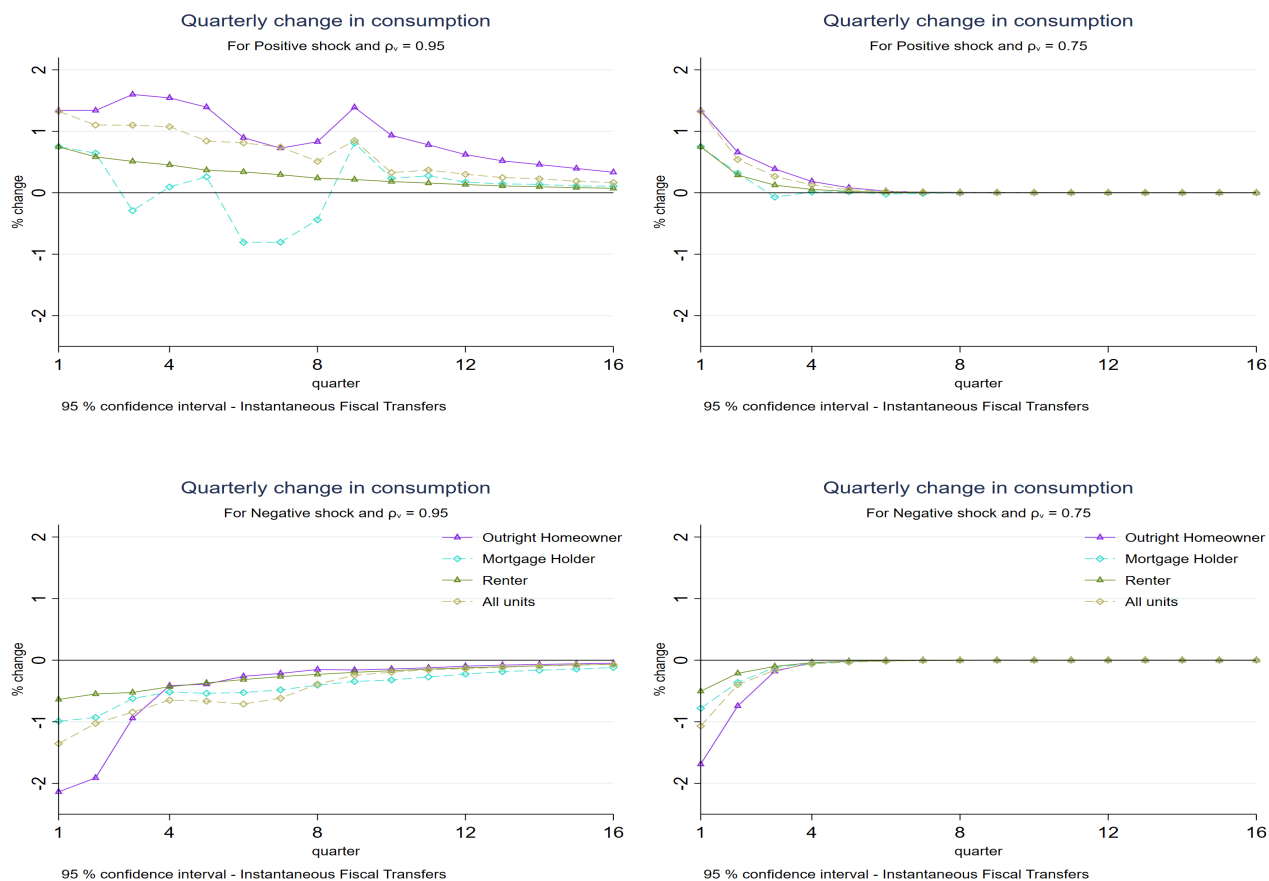
The flexibility of the sufficient statistics approach allows for measuring implied *IRFs* in line with the theoretical results in appendix B.1 beyond the instantaneous response in section 5.2 from the same transitory unexpected monetary policy surprise. The key assumption is that households cannot adjust their portfolios during the entire horizon of the response. A major motivation is the need to have *IRFs* for interested aggregate variables without relying on structural models that can study only a subset of the myriad redistribution channels. Empirically, this might be inconsistent with the evidence for households in especially top 10% of the wealth distribution. Since substantial proportion of the households have a major fraction of their wealth tied up in housing with high transaction costs, their portfolio rebalancing is much less frequent. I present the results here for 16 quarters ahead.

To estimate the results, firstly I need the PDV estimates for each of the 16 quarters ahead. One way to obtain them would be using the local projections approach detailed in appendix A.3. It is more robust than a SVAR for smaller time horizons. However, due to the nature of the exercise involved (section 3.2), the SVAR remains a superior method since consumers are theoretically forecasting infinitely ahead in the future for each quarter. Second, I need externally specified exogenous changes for the real interest rate, inflation and aggregate

income for 16 quarters ahead. I start with unit changes as used in section 3.4 for the instantaneous response. From the second quarter onwards, the one time change declines by a common persistence parameter  $\phi$  for all the three changes. As an extension to section 5.4, I also follow the same process to derive the implied *IRFs* for additional dimensions of heterogeneity. The purpose of this section is demonstrate the flexibility and usefulness of the sufficient statistics approach. Other possible specifications for exogenous changes in the aggregate real interest rate, inflation and income can be used. An interesting example in this context would be Taylor rules where the consumption deviations proxy for the output gap. In the interest of space and brevity, I do not include these additional results here. In summary, conditional on ex-post returns heterogeneity, sufficient statistics can be used in computing the aggregate general consumption for any quarter post the one time unexpected shock provided we maintain the assumption that consumers do not alter their balance sheets. I contrast the results for shocks of different persistence in Figure 13 using the general equilibrium aggregate consumption elasticity to the nominal interest rate. The increase in consumption declines slowly for the first year post the shock before dampening by the end of three years for a highly persistent shock in the left panel. The revaluation of consumer balance sheets is different for each individual quarter compared to the cumulative response for the instantaneous response. As can be seen from Figure 1, the increased valuation of stock and housing assets is higher immediately post the shock before declining gradually. Consumers, especially those who are unconstrained, would realize these gains at some point in the future leading to a rise in consumption today. The gains would be quantitatively large for the initial number of quarters. The logic is exactly the same as with the instantaneous response, the only exception being that the quantitative differences are different for each individual quarter.

The asymmetries are also sharper when comparing with the response for the negative shock. Consumption declines far less for the first two years from the shock. Since the revaluation affects both the debt and asset side of the balance sheets, consumers experience smaller declines in net wealth depending on both across and within class heterogeneity in their asset holdings leading to a far smaller decline in consumption. Both the results pertain to the baseline model where the government instantaneously refunds the transfers. The responses do not show the typical hump shape response oft observed empirically from VAR analysis where consumption responds with a lag and increases post a few quarters after the shock. Withholding fiscal transfers from households however does not solve the problem and produce a hump-shaped response in consumption despite being expected to constrain households and dampening the increase in consumption. The results also depend on the persistence of the shock. If the persistence is less, the wealth changes are smaller and taper

Figure 14: General equilibrium aggregate consumption *IRFs* by housing tenure



Note - For all the cases, fiscal transfers are instantaneously rebated. Housing tenure is as defined in section 5.4. For more details see associated notes in Figure 13.

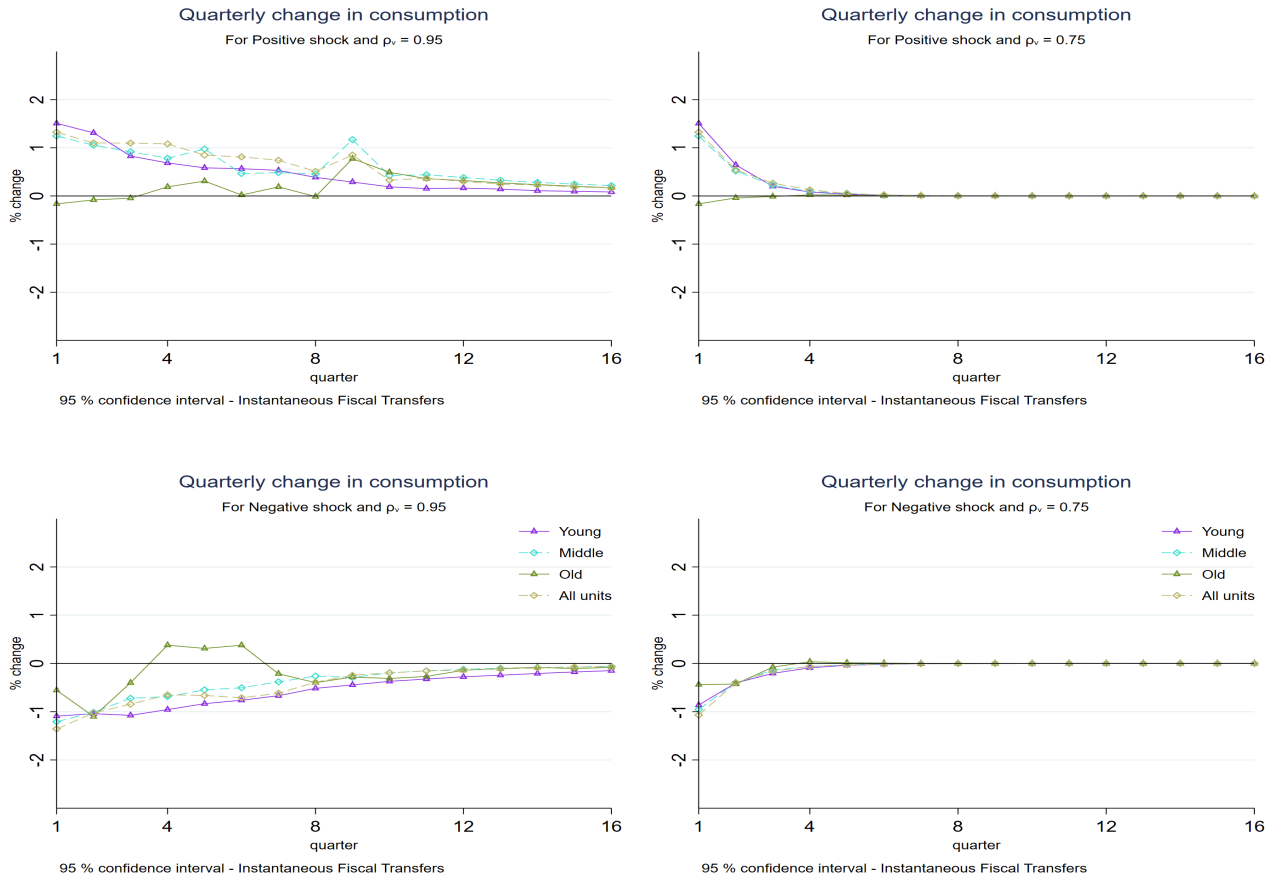


off sooner. Subsequently, consumption responses are dampened across shocks irrespective of the nature of fiscal policy in the model. There is also very little asymmetry for the negative shock of equal magnitudes.

Analogous to section 5.4, I present the results by housing tenure in Figure 14. I only use the baseline model where fiscal transfers are instantly rebated to households. Since outright homeowners are expected to be having higher positive liquid asset holdings, they are significantly less constrained. Similarly, mortgage holders are expected to be more constrained compared to the former. Accordingly, the consumption response for the same increase in returns & prices ex-post for the three classes of assets produces higher unrealized wealth gains for the former. Outright homeowners have a consistently higher response than the aggregate while for mortgage holders, the consumption response is similarly below aggregate. For a negative shock of exact same magnitude, the response is now strongly asymmetric with homeowners reducing their consumption higher since they see the largest decrease in their asset values. Being substantially closer to the borrowing limit prevents a similar consumption reduction for mortgage holders due to inherently higher *MPCs*. The intuition and results for section 5.4 applies here as well. Renters have much smaller changes and their consumption response is essentially uniform across quarters and depends only on the aggregate decrease in the real interest rate, increase in inflation and earnings quarter by quarter. Their response displays almost negligible asymmetry. Reducing the persistence of the shock understandably dampens the overall deviations from the steady state.

Analogous results by demographics are presented in Figure 15. The differences from the aggregate response are far less compared to the response by housing tenure. The response for old people is also highly asymmetric as observed for the negative shock in the bottom left panel. Young are expected to much more constrained than middle while old is expected to be the least constrained. The behavior of the old is kind of an outlier. In the left panel for the highly persistent shock, the response for the old is the least. Accordingly, the logic should have led to old people having the highest consumption elasticities. One possible reason could be bequests which means old do not increase consumption despite lesser savings. Reducing the persistence of the shock leads to nearly indistinguishable responses from the aggregate. The model is far less successful in exploiting the balance sheet differences based on age.

Figure 15: General equilibrium aggregate consumption *IRFs* by demographics



Note - For all the cases, fiscal transfers are instantaneously rebated. Demographics is as defined in section 5.4. For more details see associated notes in [Figure 13](#).

## F Results for Policy Experiments

I explore the interaction between wealth inequality and the presence of returns heterogeneity, conditional on the shock, using simple experiments. I restrict to comparing instantaneous responses only. The results for this section can be similarly presented in line with the methodology for section E. I target the household portfolios using SCF data for 2007 before the GFC and then again for 2019 before the pandemic. Specifically, I adjust the shares for housing, equity and liquid assets relative to the mean for both positive and negative asset positions. Since the results in sections 5.2 and 5.3 confirm that the household consumption change is primarily from the MPC channel, I restrict myself to the CE data. I focus only on the general equilibrium consumption response. Since the share of redistribution in partial equilibrium is always higher, quantitatively significant results in general equilibrium is always the lower bound for corresponding estimates in partial equilibrium. Higher the share of redistribution in overall aggregate consumption response, greater is the underestimation relative to the benchmark without returns heterogeneity. Of course, I assume that the consumption expenditures are similar across the time periods under consideration.

I report the results for the one time unexpected decline in the real interest rate by 1% in Table 27 for both the years. Columns 2 and 3 maintain the assumptions of the benchmark results in how to measure household debt. Unless a mortgage is explicitly specified as ARM, it is not treated as such. Columns 4 and 5 assumes that all mortgages are ARMs. In times of monetary easing, ARMs would lead to greater consumption responses since the pass through towards overall transmission is higher from the automatically declining mortgage rate. Intuitively, the reverse is expected to be true for negative monetary policy surprise. The responses for 2007 and 2019 are broadly similar and display a roughly 17% & 16% increase. The main result for a substantial increase in the aggregate consumption in the presence of the additional channel of returns heterogeneity stays robust for different time periods under consideration. Restricting to quarterly frequency increases them by 26% & 24% respectively. As mentioned in section 5.5, the exposures from the real interest rate channel are stronger which drives up the increase in consumption. Interestingly, having only separate returns for housing would lead to corresponding 24% & 22% against -3% & 4% for equity at quarterly maturity. Housing becomes more important for consumption since the bulk of the distribution who won housing wealth typically also hold mortgages. It leads to a negative *URE* which is associated with a higher *MPC*. The findings support the aggressive quantitative easing by the Fed at the start of the pandemic. Though, its primary aim was to prevent financial panic, the support for equity & housing markets rationalizes an even faster

Table 27: Predicted aggregate consumption responses under expansionary shock for  $\sigma = 0.5$  &  $\gamma = -0.5$

| In General Equilibrium  | All Mortgages |      |           |      | Only ARMs |      |           |      |
|-------------------------|---------------|------|-----------|------|-----------|------|-----------|------|
|                         | Benchmark     |      | Quarterly |      | Benchmark |      | Quarterly |      |
|                         | 2007          | 2019 | 2007      | 2019 | 2007      | 2019 | 2007      | 2019 |
| Auclert + House + Stock | 1.52          | 1.50 | 2.38      | 2.23 | 1.76      | 1.75 | 4.07      | 3.48 |
| Auclert + House         | 1.45          | 1.34 | 2.34      | 2.18 | 1.45      | 1.48 | 2.34      | 3.86 |
| Auclert + Stock         | 1.30          | 1.52 | 1.82      | 1.88 | 1.69      | 1.73 | 2.66      | 2.70 |
| Auclert                 | 1.30          | 1.29 | 1.88      | 1.80 | 1.41      | 1.34 | 2.26      | 2.27 |

Note - Columns 2 and 3 refer to baseline calculations for all types of mortgages. Columns 4 and 5 assumes all mortgages are only adjustable rate. The baseline model (Row 4) differs only by the addition of the required returns heterogeneity. Rows 1 - 3 refer to the updated model with separate returns for the three assets, either present together or one at a time. The wealth distribution is approximated using SCF 2007 and 2019 by using average asset positions (positive & negative) for the entire distribution relative to the information provided in CE 2001. See notes in [Table 3](#) for more details. The final general equilibrium estimate is comparable to column 3. The only sufficient statistic that varies with asset maturity assumption is  $\widehat{\varepsilon}_R$ . See Table 2 in [Auclert \(2019\)](#) for details regarding asset maturities.

recovery in consumption.

Similar results follow through for 2007 before the GFC. An expansionary policy during the housing bubble is of course not the policy recommendation. If households had relatively more housing wealth, they would experience bigger consumption gains in comparison with households who held more equity. The findings should be interpreted as the influence of a temporary decline in wealth gini on aggregate consumption with/without returns heterogeneity. What matters is not only the magnitude of overall gains but also who receives the larger share of these gains. The consumption responses are slightly higher in comparison to 2019 where the wealth gini increased. To check the robustness of this result, I focus on the importance of within class heterogeneity for housing on the aggregate consumption elasticity. Columns 5 - 8 report the analogous estimates if all mortgages are assumed to be ARMs. The benchmark maturity estimates for 2007 and 2019 increase to 25% & 30%\*-0.1cm. Restricting to quarterly frequency would lead to 80% & 53% corresponding increases. The numbers on isolating the returns to housing or equity are considerably lower. The numbers for an expansionary policy in 2007 show that ARMs allow stronger redistribution from housing relative to equity. Since the majority of the distribution who hold considerably more housing wealth have higher *MPCs*, the consumption response is progressively higher. The difference depends on the extent of the excess gains relative to equity despite overall lower returns on housing. The estimates are surprisingly powerful and motivate the need to consider the interaction of returns heterogeneity & wealth inequality for aggregate demand in the short run. As intuitively expected, fiscal and mortgage design policies should focus on reducing the costs associated with refinancing across the wealth distribution. Formally, this is akin to assuming all mortgages to be ARMs at short maturities. Priority would be expediting aid during times of need like at the onset of the pandemic for the more vulnerable sections who don't have enough liquid assets to avail the refinancing. The results show that the consumption recovery could be vastly improved.<sup>27</sup>

The same exercise is repeated for contractionary policy and the numbers are reported in [Table 28](#). Keeping with the intuition explained before in [section 5.3](#), consumption would have dropped 10% & 12% lesser for 2007 and 2019 with benchmark maturity. The corresponding numbers are 24% & 51% lesser for quarterly. Having only housing returns lead to 54% improvement in 2007 vs 41% for equity emphasizing the importance of housing before the GFC. Further assuming all mortgages are ARMs with quarterly maturity would have

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<sup>27</sup>The findings support both empirical and structural results in the literature on refinancing frictions. See [DeFusco and Mondragon \(2020\)](#) and [Chen et al. \(2020\)](#) for more details respectively.

Table 28: Predicted aggregate consumption responses under contractionary shock for  $\sigma = 0.5$  &  $\gamma = -0.5$

| In General Equilibrium  | All Mortgages |      |           |      | Only ARMs |      |           |      |
|-------------------------|---------------|------|-----------|------|-----------|------|-----------|------|
|                         | Benchmark     |      | Quarterly |      | Benchmark |      | Quarterly |      |
|                         | 2007          | 2019 | 2007      | 2019 | 2007      | 2019 | 2007      | 2019 |
| Auclert + House + Stock | 1.18          | 1.13 | 1.43      | 0.88 | 0.86      | 0.87 | 0.79      | 1.18 |
| Auclert + House         | 1.12          | 1.16 | 0.86      | 0.93 | 0.95      | 0.89 | 1.09      | 1.04 |
| Auclert + Stock         | 1.13          | 0.98 | 1.11      | 0.95 | 0.85      | 0.85 | 1.06      | 1.06 |
| Auclert                 | 1.30          | 1.29 | 1.88      | 1.80 | 1.41      | 1.34 | 2.26      | 2.27 |

Note - Numbers are negative elasticities of aggregate consumption. See notes in [Table 6](#) & [Table 27](#) for more details.

improved aggregate consumption by 65% & 48\*-0.1cm. As mentioned in section 5.5, the results for the asymmetric response are counter-intuitive when viewed in terms of a contractionary policy in 2007. Either way, the predicted results demonstrate that structural models need to take returns heterogeneity more seriously for calibrating the aggregate consumption response correctly.