Household Heterogeneity and the Transmission of Monetary Policy

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Abstract

To what extent does heterogeneity matter for the amplification (or dampening) of monetary policy shocks? Moreover, does a benchmark Heterogeneous Agent New Keynesian (HANK) model fit the heterogeneous response of monetary policy shocks observed in the data? The benchmark HANK model from Kaplan et al. (2018) implies that wealthier households benefit from a greater increase in their income than poorer households from an expansionary monetary policy shock. However, this prediction is at odds with the empirical evidence. Using data on U.S. households from the Consumer Expenditure Survey I find that households across the wealth distribution have comparable income responses to an expansionary monetary policy shock, while consumption increases the most for low wealth households. This finding points towards amplification of monetary policy shocks due to the distribution of agents within the economy. Motivated by these discrepancies I innovate on the profit distribution scheme, from a bonus-based scheme (profits are distributed in proportion to labour productivity) to a dividend-based scheme (profits are distributed in proportion to illiquid asset holdings). This innovation brings the distributional response from a monetary policy shock closer to the empirical evidence, however, a mixed scheme is required to ensure the response of aggregate investment is reasonable as it is highly dependent on the income of the wealthy hand-to-mouth households.

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1 Introduction

Following the aftermath of the financial crisis monetary policy tools used by central banks have come under increased scrutiny for their potential impact on inequality. The added attention from policymakers, academia and the public coupled with the increase in the availability of household-level data and improvements in computational techniques have lead to a boom in research in heterogeneous agent models. However, the evidence is mixed on how households, heterogeneous across income and wealth portfolios, are affected by interest rate changes.[1] Moreover, the efficacy of monetary policy to influence aggregate variables such as output, consumption and investment may also depend on the distribution of income and wealth in the economy. This paper seeks to add clarity to this debate by refining a benchmark heterogeneous agent New Keynesian (HANK) model and disciplining through additional empirical findings the effect of monetary policy on heterogeneous households.

The effect of monetary policy on income and wealth inequality is *a priori* ambiguous. An expansionary monetary policy shock, i.e. an exogenous, unexpected fall in the interest rate, can help boost employment and wages which would typically benefit poorer households the most. Additionally, a monetary policy stimulus generally leads to house price increases and a surge in financial markets, benefiting the richer in society. The standard theoretical model used within central banks, a representative agent New Keynesian (RANK) model, is unable to address this ambiguous response.

Moreover, the transmission of monetary policy is different in the representative agent New Keynesian model compared to the HANK model. In the RANK model direct effects of monetary policy are dominant, such that lowering the real interest rate boosts consumption as households spend rather than save, this means monetary policy works almost entirely through the substitution effect. Yet, in the HANK model the indirect effect of monetary policy is dominant, such that the consumption response from lowering the real interest rate is primarily through increased labour demand and higher wages afforded to the household, the income effect. This difference arises as HANK models feature agents who have limited liquid assets and therefore act hand-to-mouth by reacting strongly to income changes and being unable to alter their saving decisions thus reacting more to indirect than direct effects. As well as differences in the transmission mechanism, if the distribution of income and wealth of households affects the strength of monetary policy it is crucial to take this into account.

[1] Coibion et al. (2017), Mumtaz and Theophilopoulou (2017), Samarina and Nguyen (2019) find that an expansionary monetary policy shock reduces income inequality whereas Cloyne et al. (2018) and Inui et al. (2017) find the opposite. For a comprehensive summary of the empirical findings see Colciago et al. (2019).

Motivated by these issues I use a benchmark HANK model of Kaplan et al. (2018) to analyse the response of consumption and income over the wealth distribution of households to an expansionary monetary policy shock. The HANK model from Kaplan et al. (2018) provides an ideal starting point for my analysis as it closely matches the distribution of asset holdings for U.S. households. In the model, income increases markedly for the wealthiest households, driven by the return on their illiquid assets,[2] whereas this increase is more moderate for the poorer households, as countercyclical profits distributed to them weigh down on their income response. In contrast to their income response, the consumption response is muted for the wealthiest households, who choose to save rather than consume, compared to less wealthy, more likely to be hand-to-mouth, households who notably increase their consumption.

Following this theoretical result I use micro data on U.S. households from the Consumer Expenditure Survey by the Bureau of Labor Statistics to test the predictions of the model. The main empirical strategy uses monetary policy shocks cleaned of information effects by Jarocinski and Karadi (2018) in a Bayesian Proxy structural vector autoregression (BP-SVAR).[3] This paper focuses on household heterogeneity across wealth levels, moreover, additional analysis corroborates the findings when households are separated by income. I find that consumption rises by more for poorer households compared to wealthier households from an expansionary monetary policy shock, which is in line with the aforementioned theoretical predictions. Whereas the response of income is comparable across the wealth distribution, which is at odds with the theoretical predictions of the HANK model. Further decomposing income changes across the wealth distribution I find that the labour income of the low wealth households are more sensitive to monetary policy shocks.

Using tax rebate data from The Economic Growth and Tax Relief Reconciliation Act of 2001, following Johnson et al. (2006), I highlight that low wealth households have higher marginal propensities to consume and therefore act more hand-to-mouth than higher wealth households. These finding suggest that monetary policy has distributional effects, such that an expansionary monetary policy shock decreases income and consumption inequality. This is in accordance to findings by Coibion et al. (2017), who focuses on income and consumption inequality. Furthermore, these findings point towards an amplification of monetary policy shocks as an increase in income to households who are hand-to-mouth increases aggregate consumption

[2]The return on the illiquid assets is equal to the return on capital. Capital gains, the benefit from a change in the price of capital, is countercyclical in the HANK model due to countercyclical markups causing profits to be countercyclical. Therefore, from an expansionary monetary policy shock the return on illiquid assets rise whilst the price of capital falls.

[3]In the literature this is also known as a Bayesian SVAR-IV. Additional robustness checks use BP-Local Projection and Local Projections.

by more than an economy populated by high wealth-low marginal propensity to consume households.

Comparing my empirical evidence with the HANK model I find a qualitatively similar response of consumption to monetary policy shocks over the wealth distribution of households. However, the income response is at odds with my empirical exercise. One reason for this difference is that in this model, as well as other heterogeneous agent New Keynesian models, the majority share of profits are distributed proportionally by labour productivity (defined as Case 1 within this paper). I innovate on this scheme and assign profits in proportion to illiquid asset holdings, which is akin to equity shares, such that this scheme is comparable to dividend payouts (defined as Case 2). As in the representative agent New Keynesian model, the markups of monopolistically competitive firms are countercyclical, which induces countercyclical profits. When profits are distributed as bonuses (in proportion to labour productivity) the income of the highest net worth responds markedly, however, if profits are distributed as dividends the countercyclical profits dampens the income response of these households. Dampening the income of the highest net worth agents causes investment to become counterfactually countercyclical as investment is wholly undertaken by the wealthiest households within the model. This is at odds with the data as investment has been found to be procyclical, see Christiano et al. (2005). A mixed profit distribution scheme that also alters the share of profits automatically invested in the firm is required to achieve the correct aggregate and household response to a monetary policy shock (defined as Case 3).

Moreover, Case 3 increases the relevance of the direct effect of monetary policy from 19% of the total effect (Case 1) to 25%, which is still notably below the RANK model, as the income of wealthier households becomes more important. The transmission channel of monetary policy is also effected by changing the profit distribution scheme. For example, the rise in wages from an expansionary monetary policy shock increases labour income but higher wages also translate into higher costs for the firm, which cause profits to fall. When profits are distributed as bonuses the increase in labour income outstrips the negative effect of countercyclical profits for the wealthiest in the economy, leading to an increase in consumption from the wage increase. However, when profits are distributed as dividends the increase in wages, dampens the income of the highest net worth households, the firm owners, as the fall in profits is greater than the increase in labour income and therefore the increase in wages negatively impact their consumption.

The paper is organised as follows: Section 2 reviews the literature. Section 3 derives the HANK model used with Section 4 providing the baseline results. Section 5 outlines the empirical methodology and data used. Section 6 highlights the identification strategy and Section 7 shows the empirical results. Section 8 innovates on the profit distribution scheme and outlines the transmission of monetary policy. Section 9 concludes and the Appendix includes additional empirical exercises, model derivations and further model results.

2 Literature Review

This paper is motivated by the current empirical and theoretical literature on how heterogeneity across households affect the impact of monetary policy on economic aggregates as well as the heterogeneous impact of monetary policy shocks. A short literature review follows.[4].

Findings from empirical studies are mixed on the affect of monetary policy on income and wealth inequality. My work is closely related to Coibion et al. (2017), as we both analyse the household response from monetary policy shocks for the U.S. using the Consumer Expenditure Survey. The focus in Coibion et al. (2017) is on the response of income and consumption inequality to a contractionary monetary policy shock. They find that households at the upper end of the income distribution benefit from contractionary monetary policy shocks, a finding corroborated in this paper for the upper end of the wealth distribution. Moreover, using characteristics defined by Doepke and Schneider (2006) to divide households into low net-worth and high net-worth households, Coibion et al. (2017) find similar income response across the wealth distribution where high net-worth households increased their consumption relative to low net-worth households from a contractionary monetary policy shock. Additional studies for the UK by Mumtaz and Theophilopoulou (2017) and euro area Samarina and Nguyen (2019) also find that contractionary monetary policy increases income inequality. However, this evidence is not conclusive as Cloyne et al. (2018) show for the UK and USA that mortgagors (households that own a mortgage) benefit from an increase in income over other agents within the economy from an expansionary monetary policy shock, which would increase income inequality.[5]

From Bewley (1976), Huggett (1993) and Aiyagari (1994) heterogeneous agent models have evolved with added complexity to the household and firm dimension, in part due to advances in computational techniques. This has brought with it the ability to analyse the monetary policy transmission for households that are heterogeneous. In representative agent models the monetary policy transmission is typically defined by three channels i) an income effect ii) a wealth effect and iii) a substitution effect. In a heterogeneous agent framework these effects can interact with different dimensions of the household to create distributional channels of monetary policy.

[4]For an extensive survey on the latest empirical and theoretical work see Colciago et al. (2019)

[5]Mortgagors in Cloyne et al. (2018) can be thought of as wealthy hand-to-mouth households of Kaplan et al. (2014) as they tend to have little liquidity, despite owning sizable illiquid assets.

These channels can be decomposed into their direct and indirect effect, or partial equilibrium and general equilibrium channels respectively. The direct channel of monetary policy is the effect a change in the interest rate has on the households' incentive to save holding prices and income fixed. This channel is the most important in RANK models as households act Ricardian such that they can save and borrow freely, meaning that monetary policy works almost entirely through intertemporal substitution. The indirect channel impacts households through general equilibrium effects such as wage and price changes, greatly impacting the hand-to-mouth households found in Kaplan et al. (2018) and subsequently causing the indirect channel to dominate within this setup. The presence of incomplete markets ensures that households with low levels of liquid wealth rely solely on wage changes to influence their consumption response.

Auclert (2019) measures the distributive effect of monetary policy using a cross section of the Consumer Expenditure Survey and calculating the correlation of households' marginal propensity to consume to the agents net nominal position, income and unhedged interest rate exposure. Motivated by a theoretical model he finds that these are the three channels that are important to explain the winners and losers from monetary policy shocks. I construct my wealth measure based on the unhedged interest rate exposure (URE) found in Auclert (2019). The URE, measures the value of all maturing assets and liabilities at a point in time. I take the URE measure and remove the maturity transformation, thus providing a measure of end of period wealth from the Consumer Expenditure Survey. This allows for analysis of monetary policy shocks along the wealth distribution. There exists a growing literature on the distributional effects of monetary policy, analysing the impact of conventional and unconventional monetary policy along different household dimensions. With prominent examples including McKay and Reis (2016), McKay et al. (2016), Ravn and Sterk (2016), Farhi and Werning (2017), Guerrieri and Lorenzoni (2017), Debortoli and Galí (2017), Wong (2019), Cui and Sterk (2019).

The theoretical HANK model used is based on the baseline from Kaplan et al. (2018). This model introduces financial market incompleteness to a two-asset New Keynesian model. The model of Kaplan et al. (2018), like the standard New Keynesian model with price rigidities suffers from countercyclical markups that can cause profits to become countercyclical.[6] In a heterogeneous agent model the distribution of monopoly profits play a crucial role in the income and consumption by household net worth. The importance of which has been highlighted by Werning (2015) in determining the amplification or dampening of monetary policy shocks relative to a representative agent model. Broer et al. (2018) contrast a heterogeneous agent

[6]Christiano et al. (2005) and Nekarda and Ramey (2013) show that profits are procyclical following a monetary policy shock.

model of price rigidities versus one of wage rigidities when labour is the only input of production. The inclusion of wage rigidities means that the model has a more plausible response in output and hours worked from a monetary policy shock. However, as Kaplan et al. (2018) also has capital as a inupt of production the inclusion of wage rigidities in the same form as Broer et al. (2018) may not generate procyclical markups.

3 Model

This section outlines the HANK model used in this paper that will be empirically tested in Section 5. The baseline model is taken from Kaplan et al. (2018) as it provides a realistic benchmark of household heterogeneity, which includes two types of assets (liquid and illiquid) and uninsurable earning shocks, allowing the authors to closely match the distribution of wealth and marginal propensity to consume of agents seen in the data. Using this model as my baseline I analyse the response of consumption and income to a monetary policy shock for agents along the wealth and income distribution. Moreover, I innovate on the model by altering the profit distribution scheme, from a bonus based system to a more realistic scheme where profits are distributed as dividends to shareholders. This change, motivated by differences from the model impulse response functions and empirical results for income changes, brings the micro results closer to my empirical exercise, however, produces unrealistic macro results.

The main innovation in the HANK model of Kaplan et al. (2018) compared to a standard RANK model is the heterogeneity added on the household side, whilst keeping the rest of the model standard. Households are able to self-insure from uninsurable idiosyncratic income risk through the use of a liquid asset, which resembles short-term bonds or money in checking accounts, and an illiquid asset, which has properties similar to housing or retirement accounts that cannot be used for instant consumption without incurring a transaction cost of liquidation. On the firm side, price changes require a payment of an adjustment cost á la Rotemberg (1982), thus inducing the typical price stickiness in New Keynesian models that is required for non-neutrality of interest rate changes from the monetary authority. The response from the only shock analysed within this setup, a monetary policy shock, is modeled as an innovation within the Taylor rule followed by the central bank. This a one-time zero-probability shock that induces a deterministic and temporary transition away from the steady-state of the model. For ease of comparison the notation used is borrowed from Kaplan et al. (2018). The explanation of the supply side, intermediate and final good firms, are a continuous time counterpart to that found in Galí (2015) and are explained in detail in Appendix A.1. The calibration follows

Kaplan et al. (2018) and can be found in Appendix A.2.

3.1 Households

The economy is populated with a continuum of households that receive idiosyncratic labour productivity shocks z_t and hold liquid assets b_t and illiquid assets a_t. Labour productivity evolves following an exogenous Markov process that is described in detail in Section 3.6. To generate a realistic number of households with zero illiquid wealth, which is seen in the data, households die with an exogenous Poisson intensity ζ. New households are then born into the economy with zero illiquid wealth and receive a random draw from the labour productivity ergodic distribution. Perfect annuity markets are assumed such that the wealth of the deceased is distributed lump-sum to other individuals in proportion to their asset holdings. This distribution to surviving households is already in the return on assets. Time is continuous in this model and at each instant in time t the state of the economy is defined by the joint distribution of $\mu_t(da, db, dz)$.

Each household seeks to maximise utility $u(c_t, l_t)$, through consuming a non-negative amount of consumption goods c_t and supplying labour l_t, which provides a disutility flow but in return for working the household gains a wage w_t. Labour $l_t \in [0, 1]$ is modelled as a fraction of the time endowment within the economy and is normalised to 1. Preferences are separable and utility function is of the standard Constant Relative Risk Aversion (CRRA) form, with intertemporal elasticity of substitution denoted as γ and the inverse of the Frisch elasticity ν. Disutility of labour is scaled by φ.

$$u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \varphi \frac{l_t^{1+\nu}}{1+\nu} \tag{1}$$

Due to the law of large numbers and the lack of aggregate shocks within the model there is no economy-wide uncertainty. Instead, households face uncertainty due to the idiosyncratic labour productivity shocks and thus they maximise utility condition on the expected realisation of this shock. Conditional on surviving, the households also discounts the future at rate $\rho \geq 0$:

$$E_0 \int_0^\infty e^{-(\rho+\zeta)t} u(c_t, l_t) dt \tag{2}$$

Households can save using liquid and illiquid assets as well as borrow up to an exogenous borrowing limit $\underline{b}$. There is an exogenous wedge $\kappa > 0$ such that the borrowing rate is strictly above the lending rate r_t^b, which is the real interest rate. Therefore, the interest rate at which a household can borrow is given by $r_t^{b-} = r_t^b + \kappa$.

Illiquid assets are denoted by a and require a transaction cost $\chi(d_t, a_t)$, for depositing d_t or withdrawing (when $d_t < 0$) from, which depends on the amount deposited or withdrawn and the households illiquid asset holdings. Specifically, the transaction cost has a linear component that generates an inaction region as the gain from depositing or withdrawing the first dollar is smaller than the marginal cost of transacting $\chi_0 > 0$. χ_1 is added to ensure that the marginal cost of transacting depends on the share of illiquid assets being transacted rather than the size of the transaction. To ensure that deposit rates are finite a convex component is added ($\chi_1 > 0, \chi_2 > 1$) and therefore $|d_t| < \infty$. The parameters within the transaction cost function, χ_0, χ_1, χ_2, form part of the parameters used to calibrate the steady state of the model to match the distribution of liquid and illiquid wealth in the economy. The transaction cost function is given by:

$$\chi(d, a) = \chi_0 |d| + \chi_1 \left| \frac{d}{a} \right|^{\chi_2} a \tag{3}$$

Due to this transaction cost the illiquid asset return is strictly above the liquid asset return in equilibrium $r_t^a > r_t^b$ with short positions ($a_t < 0$) not allowed. The illiquid asset is part capital and part equity share, which at the individual level is indeterminate. Since the household can switch between capital and equity without a transaction cost the no-arbitrage condition means that the return on illiquid assets must equate the return on capital and the return on equity.[7] The share of profits that are distributed to the household's liquid account is given by π_t^b, which is described in greater detail in Section 3.2.

As in Kaplan et al. (2018) the household's positions evolve according to:

$$\dot{b}_t = (1 - \tau_t) w_t z_t l_t + r_t^b(b_t) b_t + \pi_t^b + T_t - d_t - \chi(d_t, a_t) - c_t \tag{4}$$

$$\dot{a}_t = r_t^a a_t + d_t \tag{5}$$

$$b_t \geq -\underline{b}, a_t \geq 0 \tag{6}$$

Households maximise equation (2) subject to equations (3) to (6). The households takes as given the paths of the real wage $\{w_t\}_{t \geq 0}$, which is the marginal product of labour, the real return to liquid assets $\{r_t^b\}_{t \geq 0}$, which is given by the Fisher equation and the Taylor rule, the return on illiquid assets $\{r_t^a\}_{t \geq 0}$ and taxes and transfers $\{\tau_t, T_t\}$.

The time-varying Hamilton-Jacobi-Bellman equation that summarises the household's problem is given and solved in Appendix A alongside the Kolmogorov Forward Equation that shows how the distribution of households move over time.

[7]This will be discussed in depth in Section 3.2

3.2 Composition of Illiquid Wealth and Profit Distribution

As stated earlier the illiquid asset is comprised of two components, capital k_t and equity shares s_t in intermediate firms. This can be expressed as $a_t = k_t + q_t s_t$, where q_t denotes the share price. Equity shares provide the holder a claim on the discounted future stream of the monopoly profits net of price adjustment costs produced by the intermediate firms. Therefore the dynamics of $\dot{a}_t$ is given by

$$\dot{k}_t + q_t \dot{s}_t = \left(r_t^k - \delta\right) k_t + \Pi_t s_t + d_t \tag{7}$$

Within the illiquid account it is assumed that the household can freely shift between capital and equity share holdings and therefore at the individual level the exact proportion of capital holdings are indeterminate. This assumption implies that the return on equity must equal the return on capital

$$\frac{\Pi_t + \dot{q}_t}{q_t} = r_t^k - \delta \equiv r_t^a. \tag{8}$$

A more realistic assumption would induce a transaction cost to switch between capital and equity, however, this addition would unnecessarily complicate the model with an additional state variable. Although the individual's illiquid asset portfolio is indeterminate due to the no-arbitrage condition the aggregate composition is determined. The benefit of equity is the claim on monopoly profits, however, as is typical in models or monopolistic competition with price rigidities these profits can be countercyclical as marginal cost, m_t, is procyclical since the price of inputs increase by more than the price that the intermediates goods are sold at, making price markups countercyclical. This feature is also present in the baseline representative agent New Keynesian model. Since prices are sticky but nominal marginal costs are not, expansionary monetary policy induces an increase in the real marginal cost (as the price of the factors of production rise) but this occurrence shrinks markups, causing in realistic calibrations countercyclical profits. In a heterogeneous agent model to whom profits are distributed is crucial in determining the strength of any policy changes as marginal propensity to consume can differ vastly over the distribution of income and wealth. Moreover, since this model features two assets further assumptions are required to determine whether profits are distributed back into the household's liquid or illiquid account. In the baseline HANK model of Kaplan et al. (2018) they assume that a fraction of profits $\omega \in [0, 1]$ are invested directly into the illiquid account. This fraction is set such that the effect of countercyclical profits do not weigh down directly onto the level of investment in the economy. The parameterisation that achieves this is where the share of profits distributed back into the illiquid account is equal to the capital share of output $\omega = \alpha$.

Aggregating total illiquid income flows (7) to the economy-wide level where aggregate equity share $S_t = 1$ and aggregate capital at time t is denoted by K_t. The benefit of holding capital is the return it provides subtracting the depreciation δ that it incurs, whereas the benefit of holding equity shares is in the stream of profits. This is outlined below

$$(r_t^k - \delta)K_t + \omega\Pi_t = \alpha m_t Y_t + \omega(1 - m_t)Y_t \tag{9}$$

$$\text{With } \ \omega = \alpha : \ \Rightarrow \ \alpha m_t Y_t + \omega(1 - m_t)Y_t \ = \ \alpha Y_t$$

3.2.1 Case 1: Profit distribution as bonuses

The remaining share of profits $1 - \omega$ that are not reinvested in the illiquid account are deposited lump-sum into the household's liquid account. Following Kaplan et al. (2018) these profits are distributed proportionally to household productivity

$$\pi_{it}^b = \frac{z_{it}}{\bar{z}}(1 - \omega)\Pi_t, \tag{10}$$

where $\bar{z}$ is average productivity. This distribution scheme is best aligned with bonuses, the profit-sharing component of worker compensation due to output produced within the firm. This is the baseline profit distribution scheme used in this paper and is known as Case 1. Following the empirical exercise I will experiment with distributing profits based on illiquid asset holdings, seen in Section 8.

3.3 Monetary Authority

The monetary authority sets the nominal interest rate following a Taylor rule that reacts to movements in inflation only,

$$i_t = \bar{r}^b + \phi\pi_t + \epsilon_t. \tag{11}$$

The nominal interest rate i_t forms the nominal part of the real return on liquid bonds, given by the Fisher equation $r_t^b = i_t - \pi_t$. The central bank dislikes movements in inflation from the steady-state and ϕ is set such that the central bank reacts accordingly. The innovation ϵ_t will form the basis of the future analysis as a fall in ϵ_t represents an expansionary monetary policy shock. In the steady state no shocks to the Taylor rule are present and as such $\epsilon = 0$. Further extensions can be made to allow the central bank to react to the output gap or suffer from the zero-lower-bound.

3.4 Government

The government is purposely kept simple as the focus is on monetary policy instead of fiscal policy. The government serves as the sole issuer of liquid assets in the economy, which are real bonds of infinitesimal maturity B_t^g. Government expenditure G_t is exogenous and held fixed, taxes exist on labour income and are also fixed at τ_t. Therefore to balance its intertemporal budget constraint the government adjusts transfers T_t. This budget constraint is given by:

$$\dot{B}_t^g + G_t + T_t = \tau_t \int w_t z_t l_t(a, b, z) d\mu_t + r_t^b B_t^g \tag{12}$$

3.5 Equilibrium

An equilibrium in this economy is characterised by the decisions of individual households and firms $\{a_t, b_t, c_t, d_t, l_t, n_t, k_t\}_{t \geq 0}$, input prices $\{w_t, r_t^k\}_{t \geq 0}$, return on assets, $\{r_t^b, r_t^a\}_{t \geq 0}$, share price $\{q_t\}_{t \geq 0}$, price inflation $\{\pi_t\}_{t \geq 0}$, taxes, transfers, government expenditure and the amount of real bonds in the economy $\{\tau_t, T_t, G_t, B_t\}_{t \geq 0}$ as well as the evolution of the distribution of households $\{\mu_t\}_{t \geq 0}$.

The liquid asset market clears as the total bonds in the economy are set in zero net supply. The total household holdings of liquid assets are denoted $B_t^h = \int b d\mu_t$, with the government forming the other side of the market B_t^g.

$$B_t^h + B_t^g = 0 \tag{13}$$

Illiquid asset market clears as total illiquid assets in the economy $A_t = \int a d\mu_t$ are shared between aggregate capital $_t$ and equity shares $q_t S_t$ where the total number of shares are normalised to 1, $S_t = 1$.

$$K_t + q_t = A_t \tag{14}$$

The labour market clears when the aggregate output from workers in firms N_t is equal to sum of labour production by household. As flexible wages are assumed in this economy they adjust such that no unemployment exists.

$$N_t = \int z l_t(a, b, z) d\mu_t \tag{15}$$

The goods market closes the model as total output in the economy Y_t must equate to the aggregate consumption C_t, investment I_t, government spending G_t, total price adjustment costs Θ_t and borrowing costs $\kappa \int \max\{-b, 0\} d\mu_t$.

$$Y_t = C_t + I_t + G_t + \Theta_t + \chi_t + \kappa \int \max\{-b, 0\} d\mu_t \tag{16}$$

3.6 Labour productivity dynamics

Households' labour earnings are dependent on their labour supply, the wage rate and productivity of the household. The log-earnings process below in Equation (17) highlights that productivity is the sum of two independent processes. Each one of these $z_{1,it}$ and $z_{2,it}$ are defined by a jump-drift process outlined in Equation (18). These jumps arrive at Poisson rate λ_j, where since this is a continuous time model the arrival rate of these shocks have been estimated. This choice has been motivated by the use of high-order moments of annual earnings changes, such as the kurtosis, Kaplan et al. (2018) to infer the arrival rate and size of shocks. Two independent processes is selected, one that has small but frequent shocks and the other with large but infrequent shocks. The processes with small but frequent shocks can be thought of as advancements within the agents career, whereas large but infrequent shocks more closely match career or life changes.

$$\log z_{it} = z_{1,it} + z_{2,it} \tag{17}$$

Condition on a jump the new log-productivity state $z'_{j,it}$ is drawn from a normal distribution $z'_{j,it} \sim N(0, \sigma_j^2)$. $J_{j,it}$ captures jumps in the process. These processes are analogous to a discrete-time AR(1) process with a stochastic arrival of each innovation, given by λ_j

$$dz_{j,it} = -\beta_j z_{j,it} dt + dJ_{j,it} \tag{18}$$

4 Model Results

This section provides the results for the baseline HANK model of Kaplan et al. (2018), grouping households by their wealth holdings and decomposing their income change from an expansionary monetary policy shock.

4.1 Case 1: Profit distributed as bonuses

Case 1, following the baseline HANK model of Kaplan et al. (2018), distributes the portion of profits that flow back into the households' liquid account by relative labour productivity. As seen in Table 1 these profit flows form a larger share of net income for the households with the lowest net worth, compared to those in the highest quartile of net worth. In the data, using the Survey of Consumer Finances, profit flows typically form a smaller share of income as net wealth of the household decreases. The household in the bottom quartile of the net worth distribution is a borrower and therefore has to pay borrowing costs, this can be seen as the return on the liquid asset dampens the income of the poorest households. Other than the top quartile labour income forms the dominant share of income flows for these households. The return on the illiquid asset, which by the no-arbitrage condition is equal to the return on capital, includes as well the profits that are distributed directly into the illiquid account of the households ($\omega = 0.33$). The return on the illiquid asset, which due to adjustment costs between asset types is always above the liquid asset return forms the largest share of income flows for the top net worth households. The differences between quartiles in Table 1 helps to motivate splitting the distribution into low wealth households (bottom 75% of net worth) and high wealth households (top 25% of net worth). The empirical counterpart to Table 1 can be found in Appendix B.

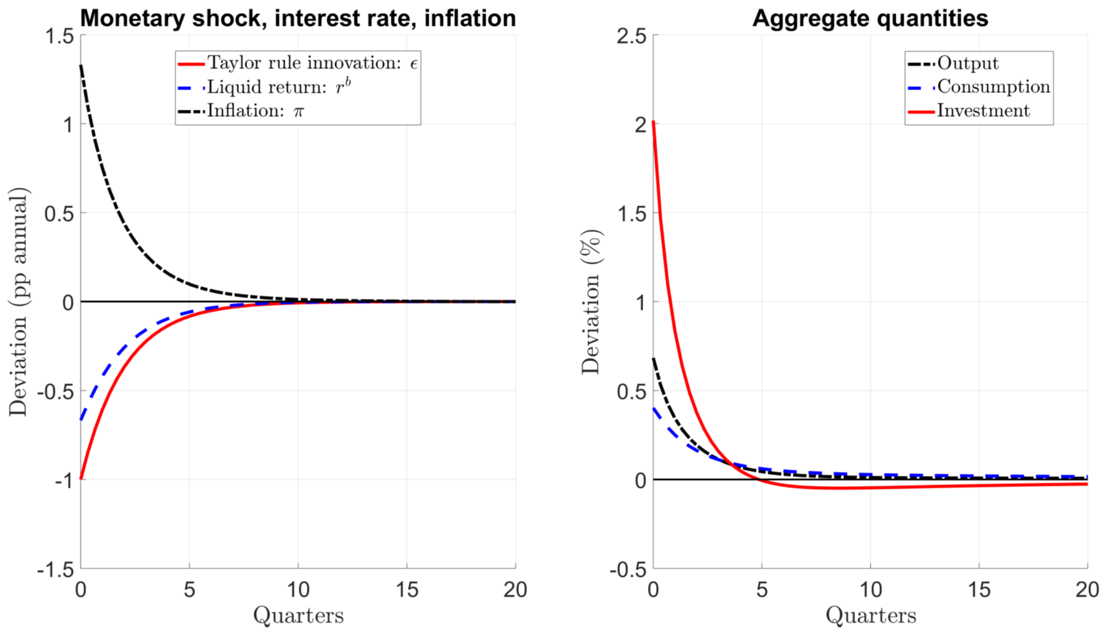
Table 1: Case 1: Net income sources by net worth

	0-25%	25-50%	50-75%	75-100%
Labour Income	77%	79%	77%	33%
Transfer Income	15%	12%	10%	4%
Profit flows	8%	8%	8%	4%
Liquid Asset	-1%	0%	2%	2%
Illiquid Asset	0%	0%	3%	58%

Steady state decomposition of net income by household net worth quartiles.

Figure 1 outlines the aggregate response to the economy of a 0.25 percentage, or 1 percentage annually, fall in the Taylor rule innovation on the aggregate variables within the economy. This figure replicates that found in Kaplan et al. (2018) and is empirically plausible, such that investment is the most volatile part of output with consumption being one of the least.

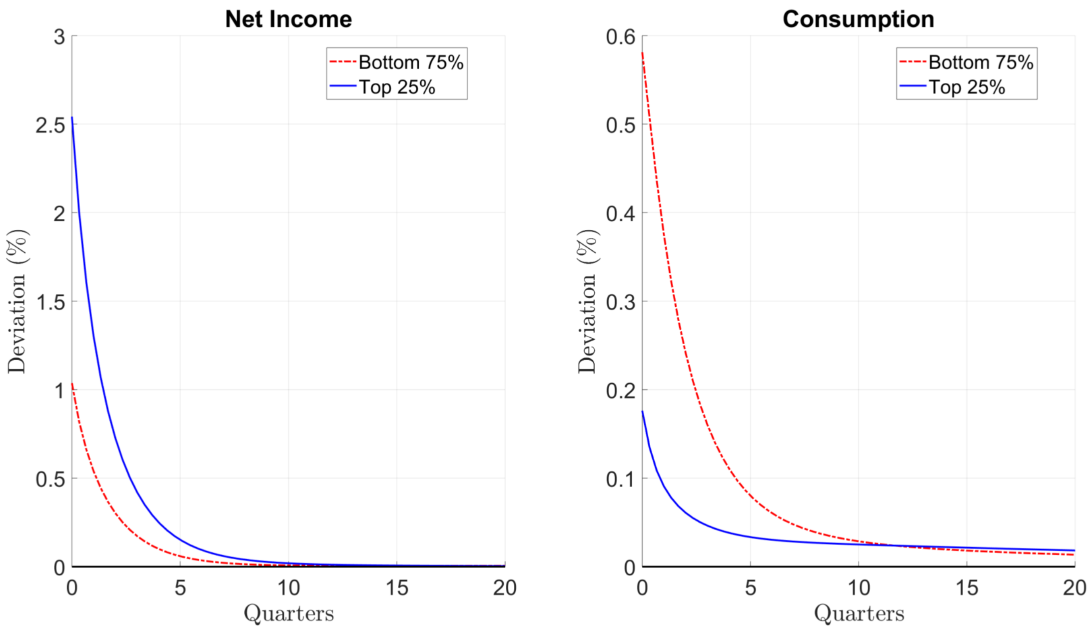
Figure 1: Case 1: Aggregate response to an expansionary MP shock



Note: Response of aggregate variables to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

Figure 2 shows the response of an expansionary monetary policy shock by household net worth. Net income is defined as the total of net labour income, $(1-\tau_t)w_t z_t l_t$, transfers from the government T_t, income from profits, π_t^b, the return on liquid asset holdings, $r^b(b)b_t$, and the return on illiquid asset holdings, $r_t^a a_t$. Income increases by more for the households in the top 25% of the net worth distribution compared to those in the bottom 75%. Although income increases the most for the wealthiest households in the economy their consumption response is muted in comparison to the poorest households, who have a higher marginal propensity to consume.

Figure 2: Case 1: Consumption and income response by net worth



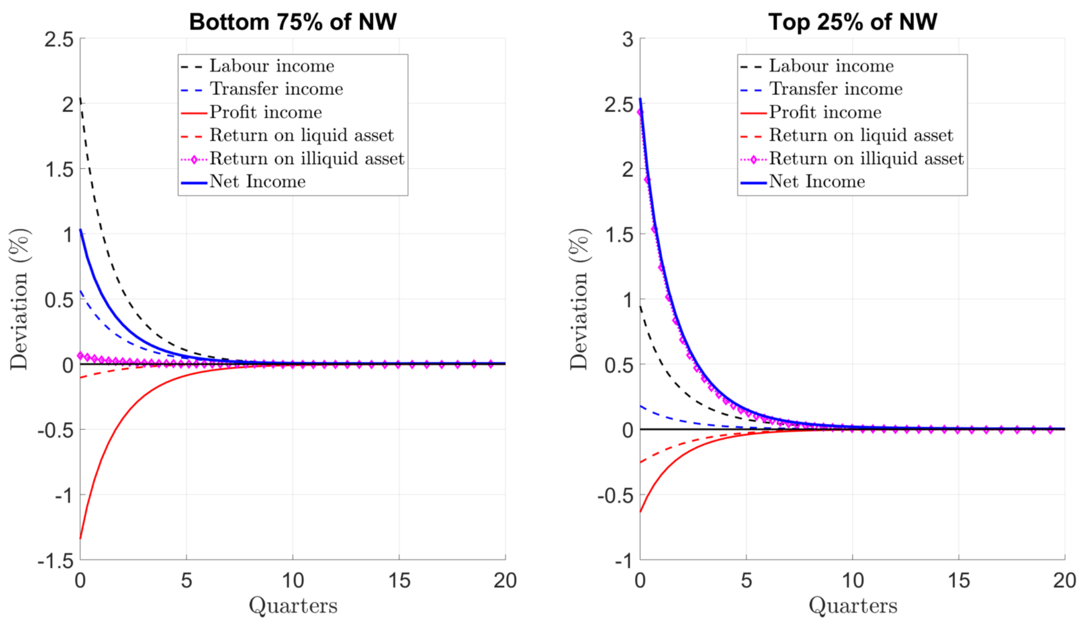
Note: Response of consumption and income by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

Analysing Figure 3 provides the detailed breakdown of the sources of income to households by their net worth. The black dashed line is net labour income, $(1 - \tau_t)w_t z_t l_t$, the dashed blue line is government transfers T_t, the red line is the income from profits, π_t^b, the return from liquid assets, $r^b(b)b_t$, is represented by the red dashed line and finally the pink dashed line with diamonds is the return from illiquid asset holdings, $r_t^a a_t$, which is equal to the marginal product of capital minus its depreciation rate. From this Figure it is clear that the large income increase that the highest net worth households benefit from is due to the increase in the return on illiquid assets, which they hold the majority of. The increase in labour income, which all households benefit from,[8] is offset by countercyclical markups that lead to countercyclical profit income during a period when output is increasing. This balancing of income is present for all households across the net wealth distribution, however, the poorest households hold an immaterial measure of illiquid assets and thus do not benefit from the increase in the illiquid return to the extent of the richest households. Futhermore, due to the adjustment cost between liquid and illiquid assets it is costly for households to transfer their liquid assets to benefit from the increased returns of the illiquid asset. Moreover, there is a desire of households within the economy to insure against idiosyncratic productivity

[8]The wage rises in the economy following an expansionary monetary policy shock and labour supply for the bottom 75% and top 25% of households by net worth increase comparably, as seen in Appendix G.

shocks through holding liquid wealth, ensuring that they are unlikely to hit their budget constraint. The counteracting force of the profit income and labour income in Figure 3 is unsurprising as the rise in wages, above prices, is a major source of the countercyclical markups.

Figure 3: Case 1: Income response decomposed by net worth



Note: Decomposing income response by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ. The decomposition represented is scaled by the share of net income, so that the lines (excluding net income) will sum to net income. The black dashed line is net labour income, $(1-\tau_t)w_t z_t l_t$, the dashed blue line is government transfers T_t, the red line is the income from profits, π_t^b, the return from liquid assets, $r^b(b)b_t$, is represented by the red dashed line and finally the pink dashed line with diamonds is the return from illiquid asset holdings, $r_t^a a_t$.

5 Empirical Methodology

Following from the theoretical exercise above it is important to verify if the aggregate and household response to an expansionary monetary policy shock are in line with the empirical evidence. Below I outline the empirical strategy used in this paper.

5.1 Econometric tools

The baseline empirical exercise is conducted using a Bayesian Proxy Structural VAR (BP-SVAR) following closely the approach outlined in Miranda-Agrippino and Ricco (2018a), Miranda-Agrippino and Ricco (2018b) and Caldara and Herbst (2019) and combines the seminal work for the Bayesian VAR of Sims (1980) and Litterman et al. (1979),Doan et al. (1984) with the incorporation of instrumental variables into VARs by Stock and Watson (2012) and Mertens and Ravn (2013).[9] Given the limited length of the data available, quarterly data from 1996 to 2017, overparamerisation is likely in a standard Structural Vector Autoregression making the estimation of the VAR diffifcult with standard (frequentist) techniques even if a small set of variables are used. This is known as the *curse of dimensionality* and can be efficiently dealt with by incorporating prior information about the model coefficients.

Equation 19 outlines the structural vector autoregression (SVAR), which cannot be estimated directly and therefore an identification scheme is required. The vector of observables is y_t, which is a [K x 1] vector, B_i is a [K x K] matrix of coefficients with $i = 1 \ldots p$ denoting the autoregressive order, the unobserved zero-mean structural shocks are u_t, which is a [K x 1] vector with $E[u_t u_s'] = D$ if $t = s$ and 0 otherwise.

$$B_0 y_t = B_1 y_{1,t-1} + \cdots + B_{p,t-p} + u_t \tag{19}$$

The reduced form counterpart to equation 19 is equation 20, which can be obtained by pre-multiplying both sides of equation 19 by B_0^-1. The reduced form VAR represents the data generated from the SVAR model. The reduced form error term, also known as innovations, is ε_t is also a [K x 1] vector with the standard assumptions that $E[\varepsilon_t] = 0$, $E[\varepsilon_t \varepsilon_t'] = \Sigma_\varepsilon$ and $E[\varepsilon_t \varepsilon_s'] = 0$ for $s \neq t$.

$$y_t = \underbrace{B_0^{-1} B_1}_{A_1} y_{t-1} + \cdots + \underbrace{B_0^{-1} B_p}_{A_p} y_{t-p} + \underbrace{B_0^{-1} u_t}_{\varepsilon_t} \tag{20}$$

Assuming invertibility of the B matrix, such that $u_t = B_0 \varepsilon_t$ and that B_0 identifies the mapping between the structural shocks and the reduced form innovations. However, since Σ_ε is symmetric, it only has $(K + 1)/2$ independent parameters. This means that only $(K + 1)/2$ can be uniquely identified out of the K^2 parameters in B_0. As the coefficients are not uniquely identified we cannot observe the causal effect of a monetary policy shock on our dependent variables without further assumptions. One such identifying assumption is a short-run restriction, recursively ordering the model variables using lower triangular Cholesky decomposition of Σ_ε by defining a new matrix P such that $PP' = \Sigma_\varepsilon$. Since P is lower triangular it has $K(K-1)/2$ zero parameters and allows for exact identification of a monetary policy shock. However, recursive ordering does not always correspond well to perceptions of when a shock occurred, outlined further by Rudebusch (1998). One solution, used within this paper is to use an instrumental variables approach, instrumenting the change in the interest rate by an exogenous monetary policy surprise. The proposed

[9]Robustness checks are conducted using Bayesian local projections as in Miranda-Agrippino and Ricco (2018b). See Appendix F for a description of this technique and corresponding results.

instrument is the high frequency identified monetary policy surprise cleaned of any information effects derived by Jarocinski and Karadi (2018) and explained in further detail in Section 6. This external instrument is used in the first stage regression to explain the movements in the rate of the one-year Treasury bond.[10] The advantage of this approach is that the resulting explained component, the monetary policy shock, is not contaminated by other news since the initial external instrument is a noisy measure of the true shock. Furthermore, it is important to include variables that proxy for financial conditions when using high frequency instruments, as outlined by Caldara and Herbst (2019). In this regard the excess bond premium constructed by Gilchrist and Zakrajšek (2012), which "represents variation in the average price of bearing exposure to US corporate credit risk, above and beyond the compensation for expected defaults," provides a good measure of the financial state of the economy.

Given an instrument z_t it is possible to identify the shock of interest - monetary policy shock denoted as u_t^{mp} - if :

Instrumental Relevance

$$(i) \quad E[u_t^{mp} z_t'] = \phi \tag{21}$$

Instrumental Exogeneity

$$(ii) \quad E[u_t^{\cancel{mp}} z_t'] = 0 \tag{22}$$

Lead-lag Exogeneity

$$(iii) \quad E[u_{t+j}^{i} z_t'] = 0 \quad \forall j \neq 0 \text{ and } \forall i \tag{23}$$

condition (i), instrumental relevance and condition (ii), instrumental exogeneity hold. The addition of condition (iii) allows the shock to be estimated in a single regression without controls. u_t^{mp} represents a monetary policy shock and $u_t^{\cancel{mp}}$ denotes any other shock. An advantage of using the Bayesian setting here is that weak identification does not pose a problem, as long as the prior distribution is proper, inference is possible, as highlighted by Caldara and Herbst (2019) and originally found by Poirier (1998).

To address the *curse of dimensionality* induced through the limited sample size I use a Bayesian Proxy SVAR. Following the general framework outlined in Sims

[10]Further robustness using the shadow rate from Wu and Xia (2016) is also used and the results are available upon request.

and Zha (1998) the Structural VAR can be rewritten compactly as:

$$yB_0 = xB + u, \tag{24}$$

where y and e are vector of [TxK], with T representing the time dimension and x is the independent variables within dimension [TxN]. One can write this problem as a likelihood of form

$$p\left(y|B_0, B\right) \propto |B_0|^T \exp\left\{-\frac{1}{2}\operatorname{tr}\left[\left(yB_0 - xB\right)'\left(yB_0 - xB\right)\right]\right\}, \tag{25}$$

where $|B_0|$ is the determinant of B_0. Defining $\beta = vec(B)$ and $\beta_0 = vec(B_0)$ the SVAR coefficients can be factorised as

$$p\left(\beta_0, \beta\right) = p\left(\beta|\beta_0\right) p\left(\beta_0\right). \tag{26}$$

$p(\beta_0)$ represents the marginal distribution for β_0. An assumption typically made in the literature is that the prior of β conditional on β_0 is normal probability distribution function

$$\beta|\beta_0 \sim \mathcal{N}\left(\underline{\beta}_0, \lambda^{-1} I_n \otimes \underline{\Gamma}_{\beta_0}\right). \tag{27}$$

The posterior distribution of β is therefore given by

$$\beta|\beta_0, \mathbf{y} \sim \mathcal{N}\left(\bar{\beta}_0, I_n \otimes \bar{\Gamma}_{\beta_0}\right) \tag{28}$$

where the posterior moments are updated as in the standard VAR with Normal-Inverse Wishart priors of Rao Kadiyala and Karlsson (1993). The benefit on using a Normal-Inverse Wishart prior is that the posterior distribution can be easily obtained without additional simulations and facilitates the use of the Gibbs sampler.

Ultimately the object of interest is to understand the impact of a monetary policy shock on aggregate and household specific variables. This is done through the structural impulse response function

$$IRF_h = \Theta_h B_0^{-1} \quad h = 0, \ldots, H, \tag{29}$$

where $\Theta_h = \sum_{\tau=1}^{h} \Theta_{h-\tau} A_\tau$. Θ_h is the matrix of dynamic multipliers, how the variable of interest changes with respect to a structural shock and A_τ are the reduced form autoregressive coefficients from Equation 20. The impulse response function is given as the response of a variable i from shock j at the horizon h. The impulse responses reported from the empirical exercise are point-wise estimates providing the median impulse response and the appropriate quantiles of the IRF posterior distribution to display the confidence intervals at the 68% and 90% level.

5.2 Household level data and MPC calculation

The household data[11] used is from the Consumer Expenditure Survey (CEX), which is the most comprehensive source of consumption data for the United States currently available. Furthermore, as shown in Auclert (2019) the CEX is able to match household liabilities from the Survey of Consumer Finances (SCF) closely.[12] The CEX data is collected by the Census Bureau for the Bureau of Labor Statistics and is comprised of two surveys, the Interview Survey and the Diary Survey. The Interview Survey details the major and recurring items purchased by households, whereas the Diary Survey focuses on minor but frequently purchased items. The research conducted focuses on the Interview Survey. The Interview Survey "provides information up to 95% of the typical household's consumption expenditures" Coibion et al. (2017). The CEX is a monthly rotating panel, such that households are interviewed for four consecutive quarters (detailing their monthly consumption and expenses), with an additional preliminary interview, before they are dropped from the sample. The survey is conducted and weighted such that it is representative of the U.S. population and about 1500-2000 households are surveyed in a given month, up to 6000 each quarter. The households report their consumption for the three months prior to the interview month, which does not need to coincide with calendar quarters. Since households tend to report smoothed consumption values within-interview (such that consumption is smoothed over the reported three months), one may be concerned that aggregating at the calendar quarterly frequency may introduce a serial correlation structure which would be problematic for VAR analysis. As shown in the Appendix of Coibion et al. (2017), this worry has no impact on their results. For the empirical exercise the data will be aggregated to the quarterly frequency and will range from 1996-Q1 to 2017-Q4, which is the span of the publicly available data. Furthermore, as explained further the data series that I will use to construct measures of household wealth are only available from 1994 in the CEX.

Consumption at the household level is the sum of non-durable expenses and services. Non-durable expenses include food and beverages, clothing, gasoline, personal care, magazines, newspapers and tobacco. Services included in this measure of consumption are household utilities, recreational services, financial services, telecommunication services and transportation services.

Net Income in the CEX is expressed as income gained over the past year. The income measure used follows Coibion et al. (2017), where it is the sum of labour income, financial income, business income and transfers (defined as other income)

[11] Description of the aggregate data can be found in D.1.

[12] The Survey of Consumer Finances by the Federal Reserve Board is a triennial cross-sectional survey of U.S. families' wealth and income. The SCF is typically regarded as the most accurate and exhaustive measure of U.S. families' balance sheets.

minus state and federal taxes. Labour income is the salary or wage earned over the last 12 months. Financial income is defined as the sum of income received from interest, dividends, royalties, estates or trusts, net rental income and income from pensions. Business income is the amount of income received from self-employment. Transfers is the total amount received from Social Security benefits, public assistance or welfare and unemployment benefits.

Following Coibion et al. (2017) tax is computed using the NBER TAXSIM calculator[13] as this helps to improve the missing tax data in the earlier sample of the CEX. To remove large anomalies in the data that could bias results I winsorise the variables used at the bottom and top 1%.

5.2.1 Wealth calculation

The main measure used to separate households within this paper is wealth. Wealth here is calculated in an end-of-period fashion, such that income and consumption over the year is also taken into account. This is the natural measurement of wealth since assets and liabilities are only available in the last interview undertaken by the households in the Consumer Expenditure Survey. Equation (30) outlines how this wealth measure is calculated, where Y_i is gross income, T_i is taxes, C_i is consumption, A_i is assets and L_i is liabilities. Net income (gross income minus taxes) as well as consumption are explained in the previous subsection. Assets are calculated as the total value of savings and checking accounts of the household as well as total bonds and securities held by the household.[14] Liabilities are calculated as the total mortgage principal and home equity loan outstanding, principal outlays on vehicles and credit card debt. Due to the lack of house values on the asset side of the household balance sheet the asset measure provides the largest data limitation to the measure of wealth from the CEX. This shortcoming is highlighted by Auclert (2019), who compares asset values in the CEX with the Survey of Consumer Finances[15]. To ensure the lack of housing data does not impact the empirical results, a robustness exercise is conducting taking housing values by age and income groups and assigning them to the equivalent household in the CEX data, results of this can be found in Appendix D.5. The wealth measure used in this paper is given by

$$Wealth_i = Y_i - T_i - C_i + A_i - L_i \tag{30}$$

[13] See Feenberg and Coutts (1993) for further explanation of the NBER TAXSIM.

[14] House values, which is a large part of household's assets, are not available in the CEX. Therefore in Appendix D.5 further robustness is undertaken using house values by income and age groups from the Survey of Consumer Finances. The underlying results are qualitatively unchanged with the inclusion of housing.

[15] The Survey of Consumer Finances, conducted tri-annually provides an in-depth measure of household wealth and liabilities but the survey occurs too infrequently to be easily used in time-series analysis.

As well as analysing households by their position along the wealth distribution I also consider their position along the income distribution. Moreover, motivated by Auclert (2019), who highlights three channels that affect spending following a monetary policy shock, I focus on the measure of unhedged interest rate exposure (URE) as an additional robustness exercise. The URE is the differences between all maturing assets and liabilities, which also includes income minus consumption. This provides a measure of the value of currently available income and liquid assets. A_i^m is assets maturing this period and L_i^m is liabilities maturing this period. The asset and liability measures use the same variables as the wealth calculation but now require additional assumptions to the expected maturity. A household with a low level of URE typically acts hand-to-mouth as they have a high marginal propensity to consume out of additional cash since they have a small amount of liquid assets (or assets close to maturity). This is explored further in Auclert (2019).

$$URE_i = Y_i - T_i - C_i + A_i^m - L_i^m \tag{31}$$

The other channels featured in Auclert (2019), an earnings heterogeneity channel and Fisher channel from unexpected inflation are related to my two aforementioned measures. The empirical results using the URE measurement and heterogeneous income channel can be found in Appendix D.4.

5.2.2 Marginal Propensity to Consume calculation

Highlighted by Auclert (2019) and going back to Tobin (1982), if households within the economy have similar marginal propensity to consume then heterogeneity across households would not matter for the aggregate response of the economy .[16] The marginal propensity to consume calculation for each wealth group follows the exercise of Johnson et al. (2006). Their work benefits from the randomly assigned timing of tax rebates during a ten-week period from late July to the end of September during 2001. Tax rebates, due to The Economic Growth and Tax Relief Reconciliation Act of 2001 that enacted substantial reductions in federal, personal and estate tax rates, were retroactively enforced for income earned from the start of 2001. These tax rebates represented an advance payment of this tax cut and were typically \$300 to \$600 in value. These were randomly assigned as the timing of the mailing of the rebates was due to the second-to-last digit of the Social Security number (SSN) of the tax filer that received it. This random assignment provides an ideal natural experiment to assess the marginal propensity to consume out of additional income to test whether poorer households are more hand-to-mouth, such that they consume a

[16] If the marginal propensity to consume across the wealth distribution was similar then it would be more appropriate to use a RANK model rather than a HANK model.

large majority of their additional income. Random assignment is crucial so that the timing of receiving the rebate is independent of any household characteristics. These rebates were preannounced as the Tax Act was passed in May 2001, which should dampen the consumption response if households follow the rational-expectations permanent income hypothesis.

Equation (32) outlines the estimation procedure conducted at the monthly level to measure the MPC of high and low wealth agents. The dependent variable is the change in monthly consumption, a seasonal dummy called *month* is used to absorb the seasonal variation in consumption expenditures. Additional control variables, X, including age and family composition to absorb any preference driven factors that could influence the growth rate of consumption across households. The rebate variable $R_{i,t+1}$ is the distributed lag of the value of the rebate that uses a dummy variable, $I(Rebate > 0)$, indicating whether the rebate was received in $t+1$ along with other regressors as an instrument in a two-stage least squares (2SLS) regression. This measures the longer-run effect of the rebate on consumption up to six months after the rebate has been received[17].

$$\Delta C_{i,t+1} = \sum_{m} \beta_{0s} \times month_{s,i} + \beta_1' X_{i,t} + \beta_2' R_{i,t+1} + u_{i,t+1} \tag{32}$$

I cut the wealth distribution of households into the top 25%, the high wealth, and the bottom 75%, low wealth. As motivated further in Appendix C, this selection provides a good measure of households with some positive wealth and should be seen as a lower bound from an alternative top 10% vs bottom 90% measure. As shown below in Table 2 the marginal propensity to consume of the highest wealth agents is the lowest with the cumulative MPC not statistically different from zero with a large standard error of 0.53.[18] A negative MPC means that the households use the rebate to induce further savings in order to purchase goods later, as outlined further by Misra and Surico (2014) who use quantile regressions to analyse the impact of the 2001 and 2008 tax rebate. Whereas the households at the bottom 75% of the wealth distribution consume on average a significant amount of 0.59 of this rebate over two quarters with a standard error of 0.26.

[17]Due to the rolling panel data nature of the CEX using two quarters after the rebate provides a longer-run measure of consumption whilst retaining a large fraction of households.

[18]Part of this large standard error could be explained by to the existence of wealthy hand-to-mouth households within my wealth measure, as outlined by Kaplan et al. (2014).

Table 2: Cumulative MPC for households by wealth in 2001

	Cumulative MPC for 2001
Bottom 75% Wealth	0.59
	(0.26)
Top 25% Wealth	-0.02
	(0.53)
Number of Observations	11,856

Cumulative MPC for households in the top 25% and bottom 75% of the wealth distribution. Exercise is conducted following Johnson et al. (2006).

This result is supported by Johnson et al. (2006), who find that older, higher income households with more liquidity all have lower MPC than younger, lower income households with less liquidity following the 2001 tax rebate. This result is also in line with additional findings by Misra and Surico (2014) who conduct a similar exercise for the tax rebates for 2001 and 2008 using quantile regressions in. Additional results analysing the marginal propensity to consume for households across the wealth distribution using tax rebate data from 2008 can be found in Appendix E.

6 Identification Strategy

The preferred monetary policy surprises used as an instrument for the Bayesian Proxy SVAR are provided by Jarocinski and Karadi (2018).[19] These surprises are cleaned of the superior information on the economic outlook that is released through the monetary policy announcement by the Federal Reserve's Federal Open Market Committee (FOMC). Using monetary policy surprises that are not cleaned of this informational effect "can lead to biased measurements of monetary non-neutrality," Jarocinski and Karadi (2018).

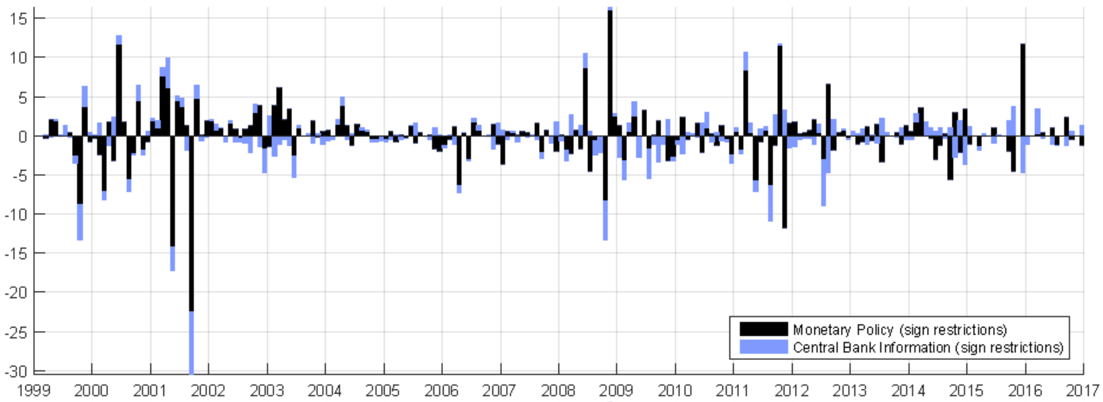
Initially high-frequency movements in interest rates and asset prices surrounding 240 FOMC announcement dates, from 1990 to 2017, are used from an updated version of Gürkaynak et al. (2005). The preferred measure of interest rate surprise in Jarocinski and Karadi (2018) is the 3-month fed fund futures, typically denoted as $FF4$. This duration of the futures contract coincides nicely with the date of the next FOMC meeting and therefore reflects the expected future monetary policy decision, moreover, the three month time-span is able to capture a broad measure

[19]Further robustness checks are conducted using monetary policy surprises from Miranda-Agrippino and Ricco (2018b) as these are also cleaned of additional information on the state of the economy which have been shown to create empirical puzzles. Moreover Bayesian local projection following Miranda-Agrippino and Ricco (2018b) is also used as a further robustness to the BP-SVAR.

of monetary policy - including both short-term fluctuations and near-term forward guidance. In order to clean for the additional information released during the FOMC meeting a measure of the state of the economy is required. The measure chosen is the change in the *S&P 500*, an index based on the 500 largest U.S. companies, 10 minutes before and 20 minutes after the FOMC announcement. The authors take these two surprises and construct a Bayesian Structural VAR with sign restrictions to disentangle a pure monetary policy shock from an informational shock. A monetary policy shock is identified by a negative co-movement between the interest rate surprise and the stock price surprise, whereas an information shock is found from a positive co-movement. This co-movement is informative as standard theoretical models are clear on how stock prices should react following a monetary policy shock.

The monetary policy and central bank information shocks derived from the sign restrictions in a Bayesian SVAR are displayed in Figure 4.

Figure 4: Monetary Policy surprises from Jarocinski and Karadi (2018)



Monetary policy surprises from Jarocinski and Karadi (2018). Surprises identified using sign restrictions in a Bayesian SVAR.

7 Empirical Results

This section outlines the response of heterogeneous response of a monetary policy shock dependent on the distribution of household wealth. The response of aggregate variables to an expansionary monetary policy shock can be seen in Appendix D.2.

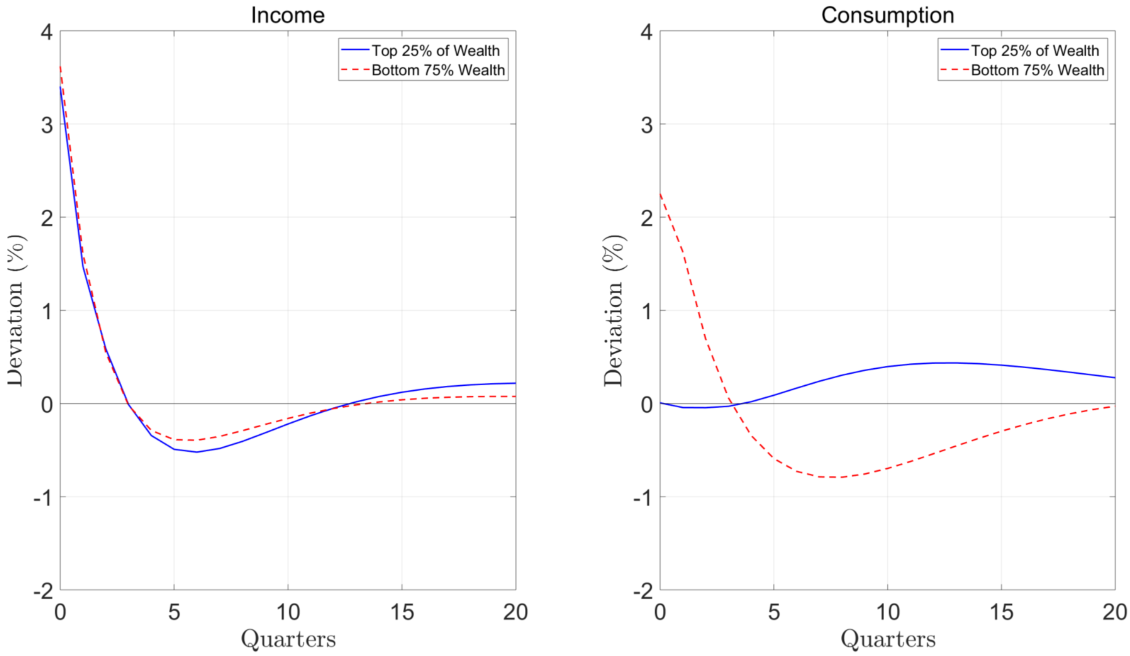
7.1 Monetary Policy shock by wealth groups

Figure 5 highlights the differences in the individual responses to an expansionary monetary policy shock when households are separated due to their wealth. The 1% fall in the one year Treasury bond rate causes the increase in income for both the high wealth (top 25% wealth) and low wealth (bottom 75% wealth) households. On impact the wealthier household's income is closely aligned to the lower wealth household, with very little discernible difference between the two responses. However, the wealthier households' consumption response following an expansionary monetary policy shock contrasts the low wealth households. The wealthier households do not adjust consumption, whereas households in the bottom three quartiles of the wealth distribution increase their consumption markedly. The consumption response for the bottom 75% of the wealth distribution is more sensitive to monetary policy shocks as it rises on impact, which persists for a year only to return back to the original value. The negative response of consumption for households in the bottom 75% of the wealth distribution is not statistically significant.[20] The households with more wealth, likely save their income increases and choose to smooth their consumption instead - as we see consumption rising after one year of the shock.

Comparing Figure 5, from the empirical exercise, with Figure 2, from the equivalent theoretical exercise, it is apparent that the income response of households along the wealth distribution in the theoretical model is at odds with the empirical findings. In the theoretical model the income response of the lowest net worth households was muted, dampened partly by the fall in profits that were being distributed by labour productivity. The response of consumption from an expansionary monetary policy shock found in the HANK model is qualitatively similar to that in the empirical exercise, such that the highest net worth households that typically have a low marginal propensity to consume do not increase their consumption to the same extent as the other households in the economy. The magnitude of the income response is in line with the model however the consumption response of the poorer household outstrips the equivalent response in the model. This could be due to over-reporting consumption changes in the CEX or a limitation of the theoretical model.

[20] Error bands are not shown in Figure 5 to highlight the differences in median response.

Figure 5: Individual Response by Wealth groups

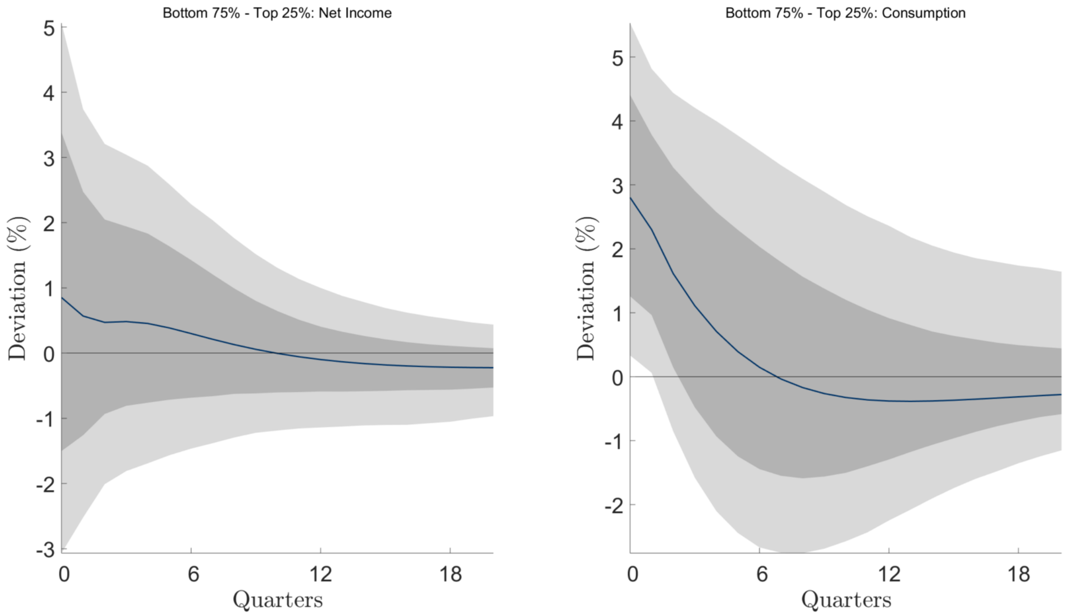


Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by wealth. Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Wealth groups are rotated following Anderson et al. (2016).

7.2 Difference in income and consumption

Motivated by the differences found in Figure 5, Figure 6 analyses these differences to see if they are statistically significant. The increase on impact of the difference in income responses for the low wealth group versus the high wealth group signifies the lack of discrepancies that were present above. The response of income is not significantly different throughout the 20 quarters observed between these two groups. The differences in consumption found previously are statistically different at the 10% level on impact.

Figure 6: Difference between wealth groups: Mostly in Consumption



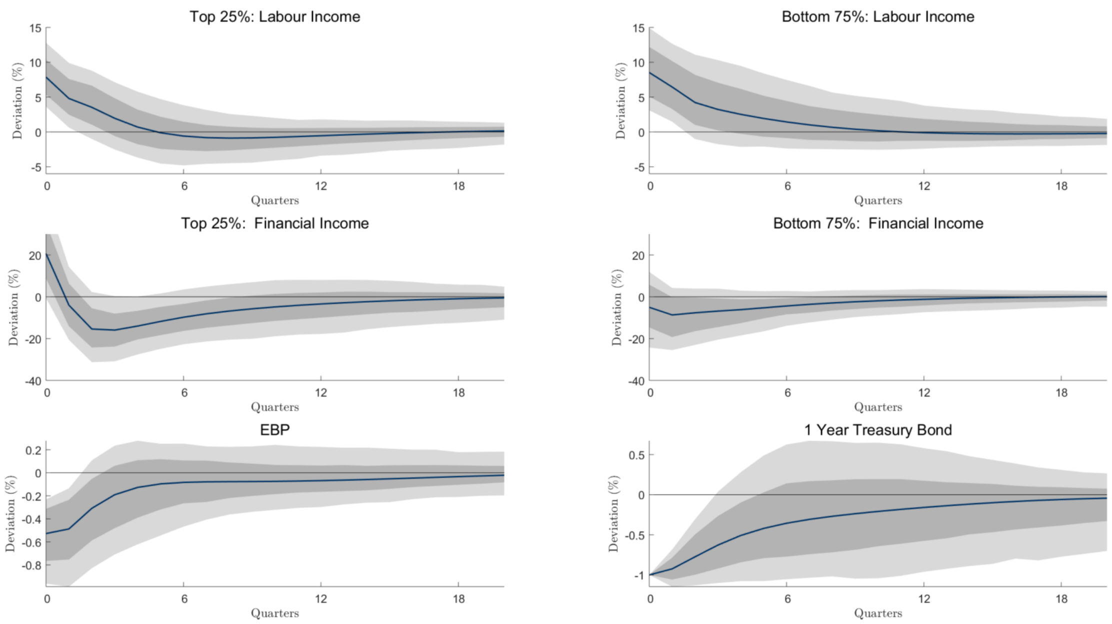
Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by wealth. Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws.

This result highlights the finding that there is an increase in disparity between consumption by high and low wealth groups from a contractionary monetary policy shock but less of a disparity is found for income, this finding is supported by work of Coibion et al. (2017). Using household characteristics that are associated with being close to high net worth by Doepke and Schneider (2006), namely "rich, old households" versus "young, middle-class households with fixed-rate mortgage debt," Coibion et al. (2017) analyse the response of consumption and income from a monetary policy shock. They too find that income differences between high and low wealth groups are limited whereas larger differences occur in consumption.

7.3 Decomposing the income response

Decomposing these income results further into changes in salary and changes in financial income it is apparent that the heterogeneous income sources found in the aggregate results of Figure 15 translate into the individual effects for households that are grouped by wealth. The top row of Figure 7 shows that the labour income of the households in the bottom 75% of households increase by more than the salary of the top 25 % of the wealth distribution. One explanation for this is the increased fragility of unemployment status for the low wage jobs that are held by the workers with the lowest wealth. Once a shock occurs that boosts the economy, such as an expansionary monetary policy shock, the low paid workers increase their hours of employment by more than the higher paid and likely high wealth workers. The second row of Figure 7 highlights the financial income response from a monetary policy shock. This response is extremely volatile but shows a fall in income from the higher interest rate for the high wealth household, whereas financial income change is statistically insignificant for the low wealth households. The high wealth households are more likely to be savers, whose interest on savings and checking accounts would fall due to the rise in the interest rate. Whereas, the low wealth households are more likely to be borrowers such that as the interest rate falls the interest payment on their loans decrease and therefore financial income should rise or remain muted. Not shown here is the income from business ownership and transfers such as food stamps and unemployment benefits that make up the remaining income response.

Figure 7: Further decomposing the income response



Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by wealth. Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws.

The main conclusion from the empirical exercise is that there exists a heterogeneous response of income and consumption from a monetary policy shock, where the low wealth households' consumption and income rise by more than the wealthier households. The difference in consumption response cannot be fully explained by the income response and therefore it is likely that these households differ in their wealth holdings and their marginal propensity to consume. The differing response from a monetary policy shock between high and low wealth households points to an amplification in the effect of monetary policy shocks on aggregate variables due to the distribution of households within the economy. This amplification arises since a larger number of low wealth households within the economy, where their income and consumption increases by more than the wealthier households, would lead to a greater fall in aggregate consumption and output. Yet the same monetary policy action can have different and potentially offsetting effects on the distribution of households dependent on the dimension of heterogeneity analysed. To concretely understand if the distribution of households within the economy amplifies or dampens the response of monetary policy shocks a HANK model is required. However, in the baseline HANK model used in this paper the difference in income response between the households in the bottom 75% of the wealth distribution compared to the top 25% is at odds with the data.[21] Part of this difference can be explained by countercyclical profits dampening the income response of the lowest net worth households in the economy. This finding motivates innovating on the profit distribution scheme of the HANK model and is outlined in detail below.

8 Extending the Model: Changing the Profit Distribution Scheme

In this section I deviate away from the profit distribution scheme outlined in Kaplan et al. (2018), which distributes the majority of profits lump-sum to households dependent on their productivity share in the economy to one that distributes the profit based on their illiquid wealth share.

8.1 Case 2: Profits as Dividends

An alternative scheme, which is more realistic, has the remaining profit share deposited lump-sum into the household's liquid account proportionally to households' holdings of illiquid assets.[22] This closely resembles dividends, the share of profits

[21] Moreover in Appendix H the response of the Gini coefficient in the HANK model for income is at odds with the empirical finding of Coibion et al. (2017) for the U.S. economy. Comparing movements in Gini coefficients further strengthens my results and crucially does not depend on wealth data.

[22] This case is similar to the "wealth-based" rule outlined in Debortoli and Galí (2017) where profit is distributed to shareholders in proportion to their holdings of shares in an equity fund. A key difference is the HANK model used, as the HANK model of Kaplan et al. (2018) includes adjustment costs between the liquid and illiquid asset.

paid out to shareholders.[23] As equity shares are indeterminate at the individual level I take the share of illiquid asset holdings within the economy as the measure to use when proportionally distributed the remaining profits.

$$\pi_{it}^{b} = \frac{a_{it}}{\bar{a}}(1-\omega)\Pi_t \tag{33}$$

Case 2, completes the same exercise as seen in Section 3 for Case 1, except now profit is distributed as dividends, such that households with a larger proportion of illiquid assets will receive a greater share of profit flows. This change in profit distribution scheme is apparent in Table 3 since the highest net worth households now receive the largest share of profit as dividends. This means that the net income in steady state of the bottom three quartiles of the net wealth distribution now receive a larger share of their income as labour income compared to Case 1.

Table 3: Case 2: Net income sources by net worth

	0-25%	25-50%	50-75%	75-100%
Labour Income	86%	87%	85%	30%
Transfer Income	15%	12%	9%	3%
Profit	0%	0%	1%	11%
Liquid Asset	-1%	0%	2%	1%
Illiquid Asset	0%	0%	3%	53%

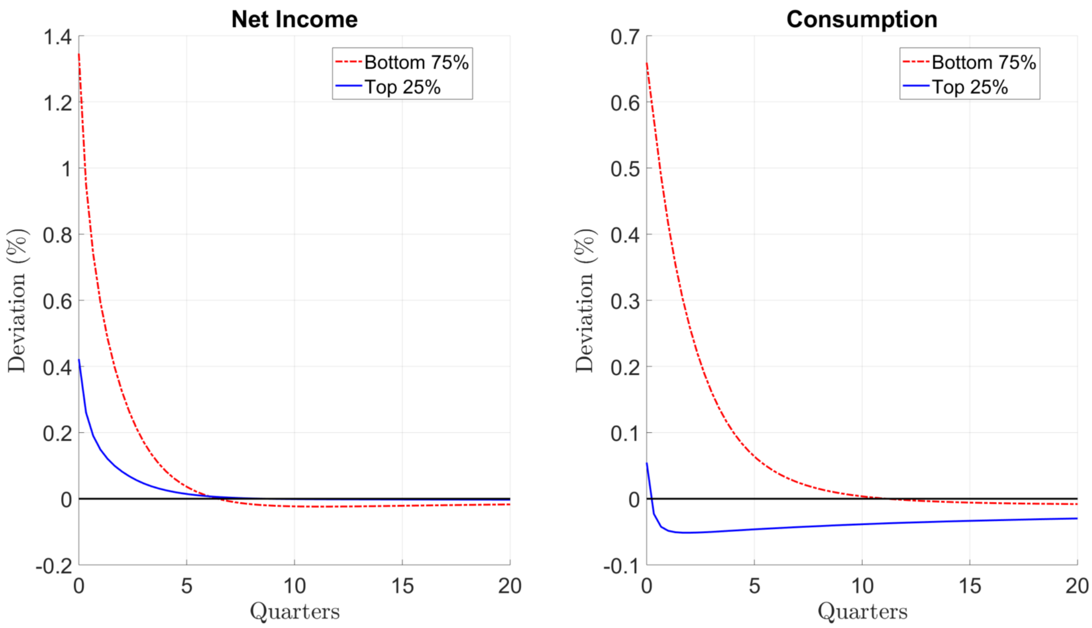
Steady state decomposition of net income by household net worth quartiles.

Under Case 2 the highest net worth households receive income from profits into their liquid and illiquid accounts, dampening their income and causing a fall in consumption from an expansionary monetary policy shock. As seen in the right-hand-side panel of Figure 8 the income of the wealthiest households now increase the least. Moreover, as outlined in Figure 9 due to the countercyclical profits income flows into the liquid account are negative, causing the highest net worth households to reduce their consumption very slightly. This is partly because the top quartile of net worth households also include wealthy hand-to-mouth households, who do not have a buffer of liquid assets and therefore their consumption follows closely the change in their income. Furthermore, the return on illiquid assets, which is supporting the income of the wealthy households enters into their illiquid account and requires an adjustment cost to for it to be transferred to their liquid account where they can use it to purchase consumption goods. Moreover, the wealthy households that are unconstrained choose to save rather than consume, as the return on the

[23] In Kaplan et al. (2018) dividends refer to altering ω, the share of profits distributed into the illiquid account, whereas in this paper dividends are seen as profits distributed into the liquid account of households dependent on their illiquid asset holdings.

illiquid asset increases. The lack of consumption response and more subdued income response for the wealthiest households is qualitatively in-line with the previous empirical exercise.[24] The difference in income (bottom 75% of the wealth distribution - top 25%) increased due to an expansionary monetary policy shock in the empirical exercise. The same movement is replicated here, although the income of the wealthiest households does not follow as closely the other households.

Figure 8: Case 2: Consumption and income response by net worth

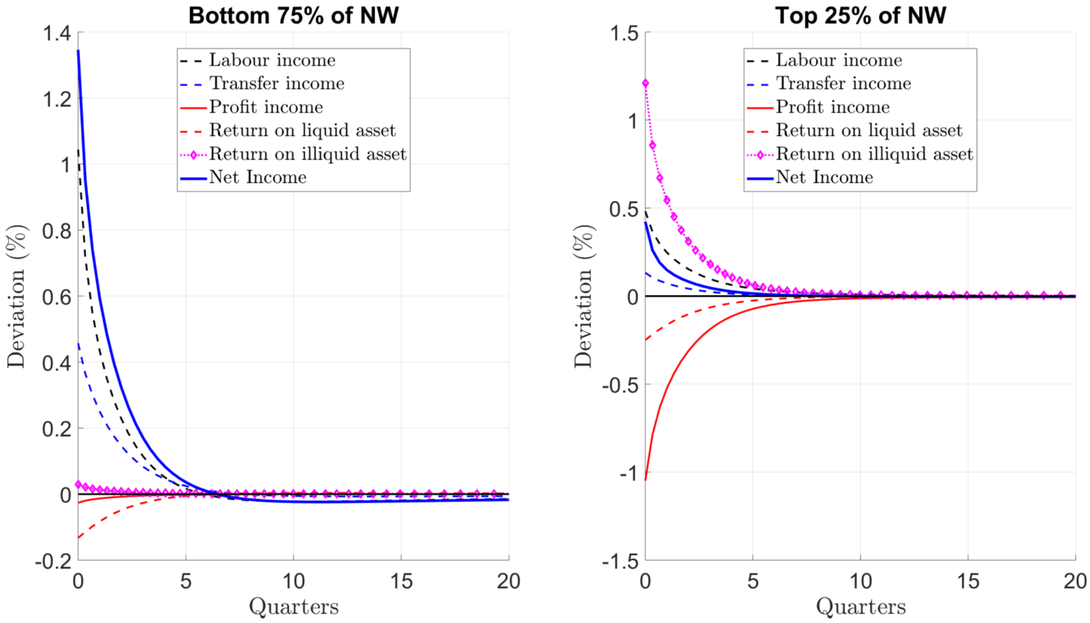


Note: Response of consumption and income by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

Decomposing the income changes by net worth it is clear to see that the negative effect of profits is primarily attributed to the income of the highest net worth households. Figure 9 shows that for the bottom 75% of the wealth distribution labour income continues to dominate their source of income, as seen in Case 1, but now this increase in labour income is not dampened by the profit distribution scheme allowing the income of the lowest net worth households to increase by the most. The income decomposition for the wealthy households in 9 sheds light on the fall in consumption seen for these households. The illiquid return is deposited back into the illiquid account and the households face a cost to transfer it over to the liquid account where it can be used for consumption. Additionally, the return on labour income, the liquid asset and profits flow into the liquid account, which due to the countercyclical profits causes a fall in the liquid account.

[24]The income response represents an extreme due to the profit distribution scheme chosen.

Figure 9: Case 2: Income response decomposed by net worth

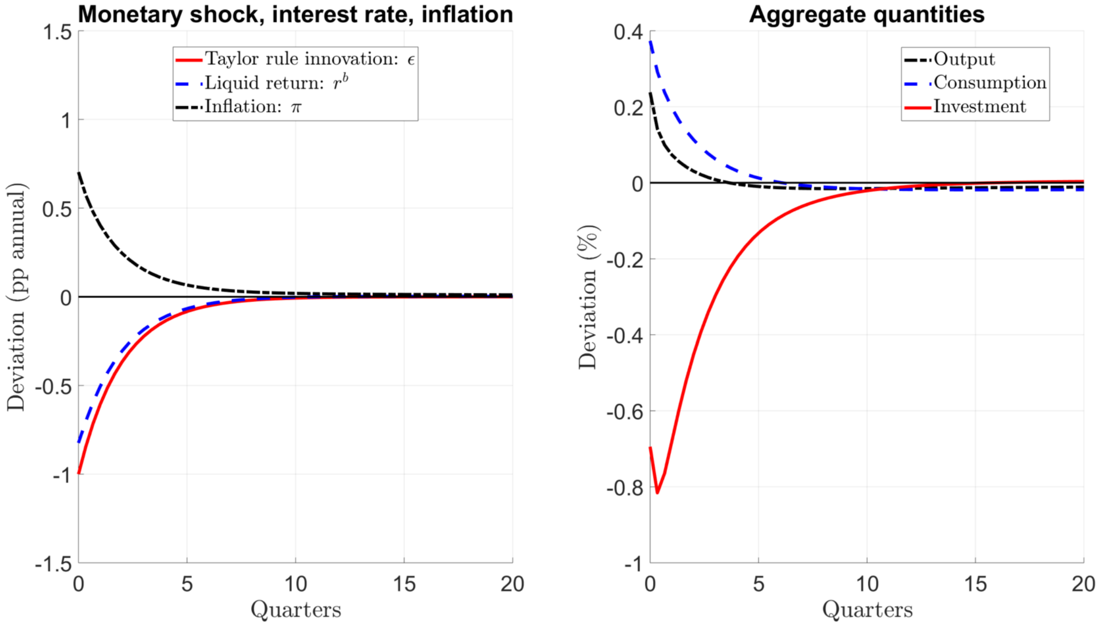


Note: Decomposing income response by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ. The decomposition represented is scaled by the share of net income, so that the lines (excluding net income) will sum to net income. The black dashed line is net labour income, $(1-\tau_t)w_t z_t l_t$, the dashed blue line is government transfers T_t, the red line is the income from profits, π_t^b, the return from liquid assets, $r^b(b)b_t$, is represented by the red dashed line and finally the pink dashed line with diamonds is the return from illiquid asset holdings, $r_t^a a_t$.

Figure 10 highlights the consequences of fixing the distributional impact of the monetary policy shock. Since investment in this model is determined by the change in illiquid assets and the illiquid assets are held by the highest net wealth households we see a fall in investment following an expansionary monetary policy shock. This aggregate result is counterfactual[25] and stems from the countercyclical profits that is placed solely on the illiquid and liquid account of the highest net worth households, the same households that would be typically conducting investment following an expansionary monetary policy shock. Moreover, since the return on assets r^a increases as the return on capital rises it is more profitable to invest following an expansionary monetary policy shock. Yet, since liquid income falls for the highest net worth agents they must sell illiquid assets to try and sustain consumption, thus causing investment to fall.

[25] Appendix D.2 shows that investment is procyclical, such that it increases following an expansionary monetary policy shock. This is a standard result in the literature.

Figure 10: Case 2: Aggregate response to an expansionary MP shock



Note: Response of aggregate variables to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

The share of profits that go directly into the illiquid account ω that would typically play an important role in the cyclicality of investment in Case 1, when profits are distributed proportionally to labour productivity, have little effect in Case 2. This is because lowering the share of profits that go directly into the illiquid account, by changing $\omega = 0.1$ for example, would only serve to change the account (liquid or illiquid) that the highest net worth households receive this negative profit income into.

8.2 Case 3: 50% bonus and 50% dividend profit distribution with $\omega = 0.1$

The final scheme to be analysed takes a proportion of Case 1 and Case 2 as well as lowering the share of profits that go directly into the illiquid account (lowering ω). The value ν^π determines the size of the share of each Case to be used, with the value endogenously set to 50%. The value of ω, the amount of profits automatically distributed to the illiquid account, is set sufficiently low that a large majority of profits are distributed into the liquid account.

$$\pi_{it}^b = \nu^\pi \cdot \frac{z_{it}}{\bar{z}}(1-\omega)\Pi_t + (1-\nu^\pi) \cdot \frac{a_{it}}{\bar{a}}(1-\omega)\Pi_t, \tag{34}$$

An agnostic approach is taken when deciding the value of the shares from the previous two cases as well as the value of ω. The combined profit distribution scheme is analysed in isolation from altering ω in Appendix G, as well as the affect of altering ω for the baseline Case 1.

Case 3 encompasses an equal part of the bonus distribution scheme of Case 1 and combines it with an equal share of the dividend distribution scheme of Case 2. Importantly, this case also deviates from the baseline share of profits that are distributed directly into the illiquid account ω. Lowering this share so that $\omega = 0.1$, means that a larger share of profits are now distributed into the liquid account than if $\omega = 0.33$. Table 4 retains the appealing properties of Table 3 where the profit shares were highest for the higher net worth households.

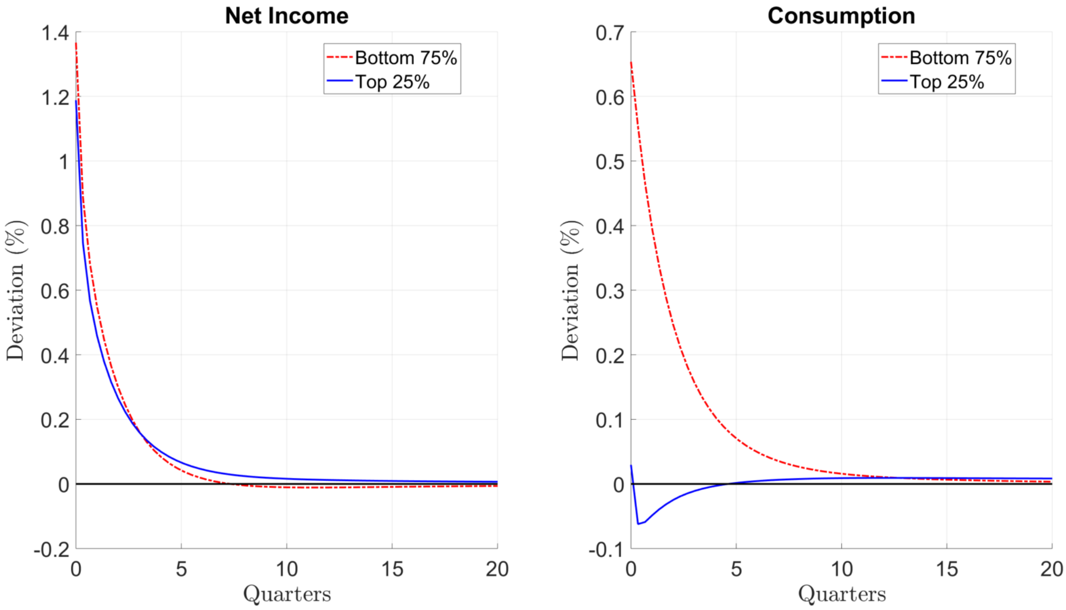
Table 4: Case 3: Net income sources by net worth

	0-25%	25-50%	50-75%	75-100%
Labour Income	79%	82%	81%	34%
Transfer Income	15%	12%	10%	4%
Profit	6%	6%	6%	11%
Liquid Asset	-1%	0%	2%	2%
Illiquid Asset	0%	0%	2%	49%

Steady state decomposition of net income by household net worth quartiles.

Figure 11 outlines the response of consumption and income by net worth to the same expansionary monetary policy shock experienced in Case 1 and Case 2. However, the income response in the right panel of Figure 11 mimics the insignificant difference found in the income response of the top 25% wealth household versus the bottom 75% seen in the empirical exercise. The consumption response by net worth is also in-line with the micro evidence as the highest net worth household have a muted response in consumption as wealthy hand-to-mouth households need to transfer assets from their illiquid account to consume whereas wealthy households with a sizable liquid account wish to obtain the higher earnings from the illiquid assets and therefore save.

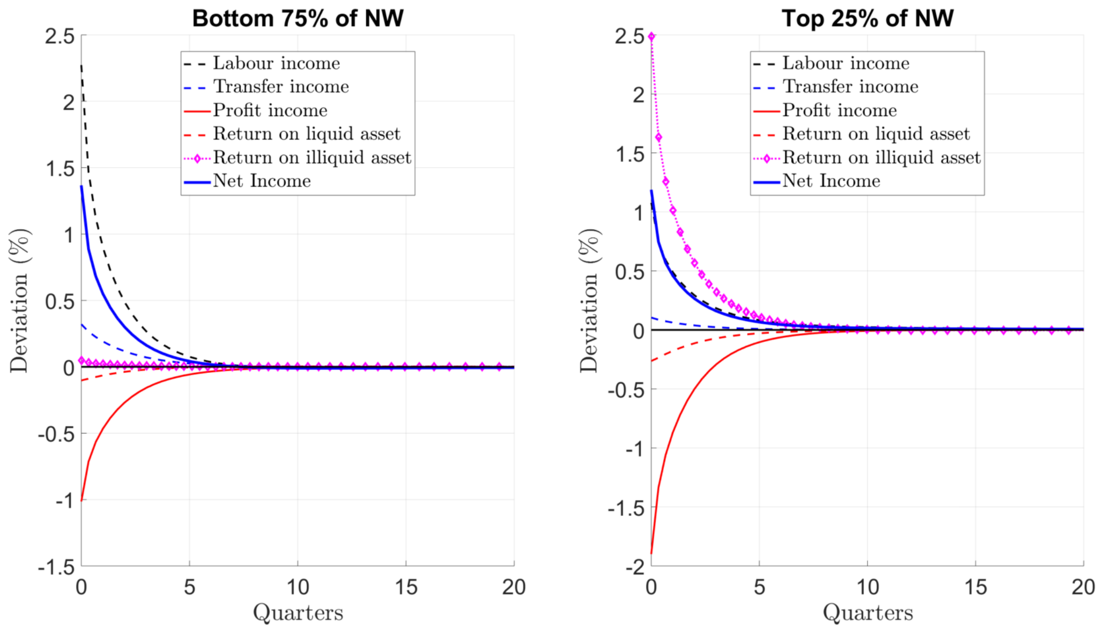
Figure 11: Case 3: Consumption and income response by net worth



Note: Response of consumption and income by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

Figure 12 shows the result of selecting a mixed profit distribution scheme and lowering the share of profits distributed to the illiquid account. The negative income due to the countercyclical profits now appear on the liquid account of all of the households within the economy, spreading out the effect to the lower wealth households in compared to Case 2. The increase in income from the return on illiquid assets is balanced out by the negative profits that the high net worth households receive, such that on aggregate their income response is muted. For the remaining households, as with Case 1 and Case 2 labour income remains the dominant source of their income flows. However, unlike Case 1, labour income is now double the negative profit income that these households receive, helping to support their income response.

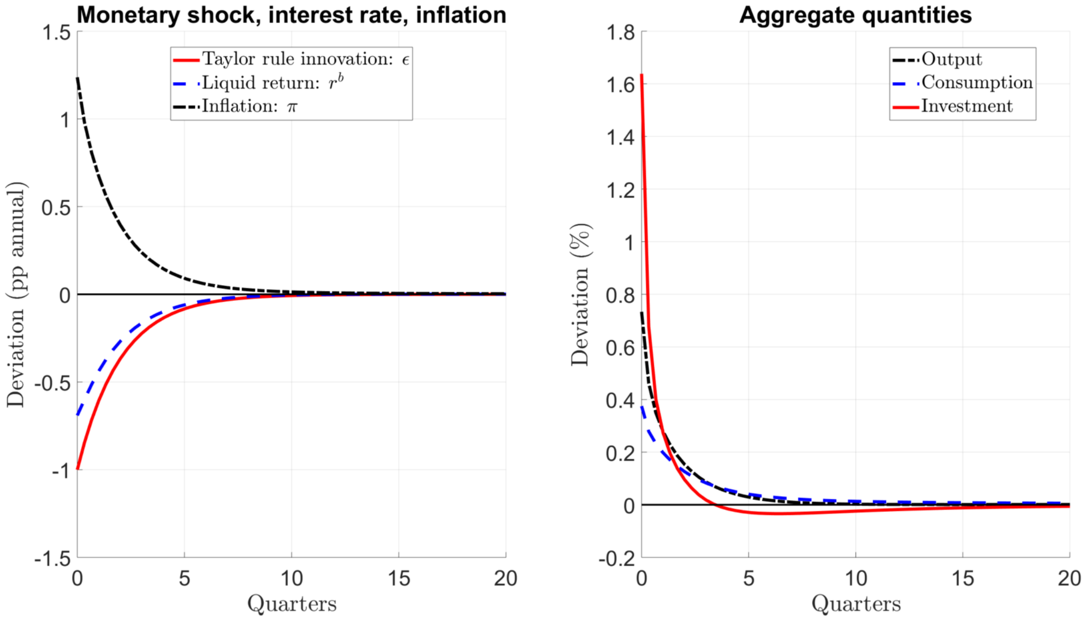
Figure 12: Case 3: Income response decomposed by net worth



Note: Decomposing income response by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ. The decomposition represented is scaled by the share of net income, so that the lines (excluding net income) will sum to net income. The black dashed line is net labour income, $(1-\tau_t)w_t z_t l_t$, the dashed blue line is government transfers T_t, the red line is the income from profits, π_t^b, the return from liquid assets, $r^b(b)b_t$, is represented by the red dashed line and finally the pink dashed line with diamonds is the return from illiquid asset holdings, $r_t^a a_t$.

Since the negative income flows due to the countercyclical markups causing profits to fall in response to an expansionary monetary policy is distributed amongst households, and importantly to households that do not hold illiquid assets, the investment response is upheld. Investment increases on impact with output and consumption also rising, restoring the expected aggregate response to an expansionary monetary policy shock.

Figure 13: Case 3: Aggregate response to an expansionary MP shock



Note: Response of aggregate variables to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

Case 3 served as an example of a fix to the counterfactual aggregate results that Case 2 suffered from, whilst still being supported by the empirical exercise conducted earlier in this paper. However, research by Christiano et al. (2005) and Nekarda and Ramey (2013) show that profits are not countercyclical following a monetary policy shock and therefore although the profit distribution scheme of Case 2 is more realistic than Case 1, the dampening affect of countercyclical profits on the income of the net worth is not observed in reality. This calls for further research into a suitable mechanism to ensure procyclical profits whilst retaining the distributional and aggregate results.

8.3 The transmission of monetary policy

Aggregate consumption C_t can be written explicitly as a function of the sequence of equilibrium prices, taxes, and transfers. $\Gamma_t = \{r_t^b, r_t^a, w_t, \tau_t, T_t\}$.

$$C_t\left(\{\Gamma_t\}_{t\geq 0}\right) = \int c_t\left(a, b, z; \{\Gamma_t\}_{t\geq 0}\right) d\mu_t \tag{35}$$

$c_t(\cdot)$ is the household consumption policy function. $\mu_t(\cdot)$ is the joint distribution of liquid and illiquid assets and idiosyncratic income. This allows through totally differentiating to decompose the total effect of monetary policy on aggregate consumption into its direct and indirect effects:

$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt}_{\text{direct effect}} + \underbrace{\int_0^\infty \left(\frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial \tau_t} d\tau_t + \frac{\partial C_0}{\partial T_t} dT_t \right) dt}_{\text{indirect effects}} \tag{36}$$

Equation 36 decomposes the total change in consumption by the partial differentiation of each price change. The first term, the direct effect, reflects the impact on aggregate consumption caused by the change in the real return on liquid assets, holding wages, the return on illiquid assets, taxes and transfers constant. The direct effect is the dominant channel in the RANK model as households react to interest rate changes through intertemporal substitution.

The indirect effects, the general equilibrium effects, are dominant in HANK models. Following an expansionary monetary policy shock Ricardian agents, non-hand-to-mouth, increase their consumption as would be typical in a RANK models. This increase in consumption leads to greater demand for production of goods, which in turn causes wages to rise and hence the consumption of low wealth, hand-to-mouth- households increase as well. The increase in the return on illiquid assets following an monetary policy shock causes agents to rebalance their asset portfolios. This expansionary monetary policy shock, which boosts wages, causes an increase in labour income tax revenue received by the government. As in the baseline model government expenditure G_t by is assumed to be fixed, transfers T_t must adjust to balance the government's budget constraint. As tax revenue has increased following an expansionary monetary policy shock the transfers that households receive also rise, leading to an increase in consumption.

Table 5 outlines the elasticity of output, investment and consumption across the three different cases studied, Case 1, Case 2 and Case 3 as well as additional intermediate cases.

Table 5: Decomposition of the effect of monetary shock on aggregate consumption

	Case 1	Case 2	Case 2 w/ $\omega = 0.1$	50% Case 1 & 50% Case 2	Case 3
Change in $r^b(pp)$	-0.27	-0.33	-0.32	-0.31	-0.29
Elasticity of Y	-3.96	-0.73	-1.13	-1.70	-3.31
Elasticity of I	-9.43	6.10	4.49	1.98	-4.11
Elasticity of C	-2.93	-1.86	-1.76	-2.21	-2.27
Partial eq. elasticity of C	-0.55	-0.49	-0.52	-0.50	-0.55
Component of percent change in C due to					
Direct effect: r^b	0.19	0.26	0.29	0.23	0.24
Indirect effect: w	0.51	0.49	0.45	0.50	0.47
Indirect effect: T	0.32	0.29	0.25	0.30	0.23
Indirect effect: r^a and q	-0.02	-0.04	0.03	-0.03	0.06

Note: Average responses over the first year to consumption following an expansionary monetary policy shock. Case 1 is the baseline specification from Kaplan et al. (2018). Case 2 implements a profit distribution scheme based on illiquid asset holdings. Case 2 with $\omega = 0.1$, reduces the share of profits that go directly into the illiquid account. 50% Case 1 & 50% Case 2 is an equal mix of Case 1 and Case 2. Case 3 uses 50% of Case 1 & 50% of Case 2 as well as $\omega = 0.1$.

Table 5 highlights the different elasticity of investment from the profit distribution schemes analysed. Only Case 1 and Case 3 display procyclical investment following an expansionary monetary policy shock. Moreover, the elasticity of output and elasticity of consumption are similar for Case 1 and Case 3. The lower part of Table 5 reports the contribution of each component to the change in consumption over the first year following the shock. Changing the profit distribution scheme from a bonus based scheme to a dividend scheme has caused the direct effect to become more relevant. However, the overall indirect effect is still dominant. The figures that decompose the change in aggregate consumption into its direct and indirect effects can be seen in Appendix G.3.

9 Conclusion

In this paper I used a benchmark HANK model of Kaplan et al. (2018) to analyse the consumption and income response of an expansionary monetary policy shock over the wealth distribution. In the model studied, the income response by household wealth was at odds with the empirical findings. The income increase for the wealthier households in the model outstripped the poorer households from an expansionary monetary policy shock, whereas in the data their response was dampened. However, the consumption response across the wealth distribution is in line with my empirical findings, such that low wealth households, likely to be hand-to-mouth, respond the most. This consumption response points towards an amplification of monetary policy shocks due to the distribution of households within the economy. That is to say, an economy populated with a greater number of low wealth households would lead to a larger increase in output from an expansionary monetary policy shock compared to an economy populated with wealthier households. An implicit assumption here is that the response of individual households within the economy is independent of the wealth distribution. This motivates further theoretical or cross-country research to identify the influence of the wealth distribution on the efficacy of monetary policy shocks.

I innovated on the profit distribution scheme, distributing profits in proportion to illiquid asset holdings, which brought household response from a monetary policy shock in line with the data, but caused the investment response to become counterfactual. To restore plausible aggregate results whilst maintaining a household response consistent with my empirical evidence a mixed profit distribution scheme is required. Combining a profit distribution scheme based on labour productivity and illiquid asset holdings whilst lowering the share of profits that automatically are reinvested in the firm aligns the model response to an expansionary monetary policy shock with the response found in the data. The mixed distribution scheme balances dampening the income of the high net worth agent through countercyclical profits from countercyclical markups that are present in the standard New Keynesian model, spreading the negative income effect of these profits across the wealth distribution and ensuring that investment is procyclical by reducing the direct flow of countercyclical profits into investment.[26]

This paper highlights the importance of analysing the heterogeneous effects from a monetary policy shock in order to understand the aggregate response. Due to the different monetary policy transmission mechanisms in RANK and HANK models it is crucial to discipline the heterogeneous and aggregate response of the model by the empirical findings to determine the preferred model. A key policy takeaway is that the strength of the direct effect of monetary policy is determined by the response across the whole distribution of households, which in part, is sensitive to assumptions made such as the profit distribution scheme analysed in this paper.

[26] As in the HANK model of Kaplan et al. (2018), where monetary policy was amplified compared to an equivalent RANK model, under the mixed profit scheme amplification is also expected. This is because in the RANK model the profit distribution scheme is irrelevant.

A Further Derivations

This section includes further derivations and additional explanation of the model.

Equation 37 outlines the Hamilton-Jacobi-Bellman equation, which represents the optimisation problem for an individual household separated by their illiquid assets a, illiquid assets b and labour productivity z. Households discount time at rate ρ and die with probability ζ. Due to perfect annuity markets the return on liquid assets is $r_t^b + \zeta$ and return on illiquid assets $r_t^a + \zeta$. There is a borrowing limit of $\bar{b}$. Households receive productivity shocks following a Markov Process and receive a share of profits $\pi_t(z)$. The productivity shocks drift towards zero at rate β.

$$
\begin{aligned}
(\rho+\zeta)V_t(a,b,z) = \max_{c,l,d} & \, u(c,l) + V_{b,t}(a,b,z)[(1-\rho_t)w_t zl + (r_t^b(b)+\zeta)b + T_t \\
& - d - \chi(d,a) + \pi_t(z) - c] \\
& + V_{a,t}(a,b,z)((r_t^a+\zeta)a+d) + V_{y,t}(a,b,z)(-\beta z) \\
& + \lambda\int_{-\infty}^{\infty}(V_t(a,b,x)-V_t(a,b,z))\phi(x)dx + \dot{V}_t(a,b,y) \\
\text{s.t.} & \\
b \geq -\underline{b}; a \geq 0; & \, 0 \leq l \leq 1; r_t^b(b) = r_t^b + I\{b \leq 0\}\kappa
\end{aligned}
\tag{37}
$$

The boundary conditions, such that the liquid asset cannot be below an exogenous lower bound and the illiquid asset cannot fall below zero is given by:

$$V_b(a,\bar{b},z) \geq u_c(c,l) \tag{38}$$

$$V_a(0,b,z) \geq u_c(c,l) \tag{39}$$

Assuming standard CRRA utility form $u(c,l) = \frac{c^{1-\gamma}}{1-\gamma} - \varphi\frac{l^{1+\nu}}{1+\nu}$. The first order conditions of the household's problem can be written as:

$$u_c = V_b \tag{40}$$

$$V_b\left(1+\chi_d(d,a)\right) = V_a \tag{41}$$

$$l = \left(\frac{V_b(1-\tau)wy}{\varphi}\right)^{1/\nu} \tag{42}$$

Equation 43 outlines the Kolmogorov Forward Equation that shows how the distribution of households move over time. Let $g_t(a,b,z)$ correspond the density function of households, dependent on their asset holdings and productivity. For starting assets and income, defined as (a_0, b_0) and $g*(z)$ respectively, a Dirac delta function δ is required to map the households with a point mass at zero assets.

$$\begin{aligned}\partial_t g_t(a,b,z) = &-\partial_a(s_t^a(a,b,z)g_t(a,b,z)) \\ &-\partial_b(s_t^b(a,b,z)g_t(a,b,z)) - \partial_y(-\beta y g_t(a,b,z)) \\ &-\lambda g_t(a,b,z) + \lambda\phi(z)\int_{-\infty}^{\infty} g_t(a,b,x)dx - \zeta g_t(a,b,z) + \zeta\delta(a-a_0)\delta(b-b_0)g_t^*(y)\end{aligned} \tag{43}$$

A.1 Firms

A.1.1 Final Good producers

The supply side of this model follows a standard setup and is therefore kept brief. The economy consists of a competitive representative final good firm that bundles intermediate inputs $j \in [0,1]$ into the aggregate economic output Y_t. This bundling takes the form:

$$Y_t = \left(\int_0^1 y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{44}$$

where the elasticity of substitution across goods is given by ε. The demand for intermediate good j is given in the Dixit-Stiglitz fashion from cost minimization:

$$y_{j,t}(p_{j,t}) = \left(\frac{p_{j,t}}{P_t}\right)^{-\varepsilon} Y_t, \quad \text{where} \quad P_t = \left(\int_0^1 p_{j,t}^{-1\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}} \tag{45}$$

A.1.2 Intermediate Good Producers

The intermediate inputs used in Section A.1.1 are produced by the intermediate good producers. Each intermediate good j is produced by a monopolistically competitive producer using the production function in Equation (46) using capital $k_{j,t}$ and labour $n_{j,t}$, with intensities α and $1-\alpha$ respectively:

$$y_{j,t} = k_{j,t}^{\alpha} n_{j,t}^{1-\alpha} \tag{46}$$

Intermediate good producers aim to maximise their output in Equation (46) whilst minimising their cost of production. In this case, the price at which the firm hires labour is the wage rate w_t and the price for renting capital in a competitive capital market is given by r_t^k. The marginal cost, denoted m_t, is derived from the first order condition of the intermediate producers problem. Since the intermediate good producers follow a Cobb-Douglas production function the form of the marginal cost is typical :

$$m_t = \left(\frac{r_t^k}{\alpha}\right)^{\alpha}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha} \tag{47}$$

Each intermediate producer, differentiated by production good j, has a monopoly in its production and therefore chooses the price to maximise profits. Changing prices induce an adjustment cost as in Rotemberg (1982), which is the cause of the nominal rigidity within this model. This quadratic adjustment cost is given by $\Theta_t\left(\frac{\dot{p}_t}{p_t}\right) = \frac{\theta}{2}\left(\frac{\dot{p}_t}{p_t}\right)^2 Y_t$ and is expressed as a fraction of aggregate output Y_t.[27] For convenience, and as this problem is common across intermediate good producers j, j is dropped from the price setting problem given in Equation (48) and (49). As briefly explained above and will shortly be explained in greater detail below, the correct interest rate to discount the flow of future profits at is r^a. Therefore, by choosing the price $\{p_t\}_{t\geq 0}$ to sell their intermediate good at the firm wishes to maximise

$$\int_0^{\infty} e^{-\int_0^t r_s^a ds}\left\{\tilde{\Pi}_t(p_t) - \Theta_t\left(\frac{\dot{p}_t}{p_t}\right)\right\}dt \tag{48}$$

taking into account the flow profits before price adjustment costs are added.

$$\tilde{\Pi}_t(p_t) = \left(\frac{p_t}{P_t} - m_t\right)\left(\frac{p_t}{P_t}\right)^{-\varepsilon} Y_t \tag{49}$$

The maximisation problem can be written in its recursive form with $J(p,t)$ representing the real value of the firm. Equation (50) features the aggregate price inflation rate $\pi_t = \dot{P}_t/P_t$:

$$r^a(t)J(p,t) = \max_{\pi}\left(\frac{p}{P(t)} - m(t)\right)\left(\frac{p}{P(t)}\right)^{-\varepsilon} Y(t) - \frac{\theta}{2}\pi^2 Y(t) + J_p(p,t)p\pi + J_t(p,t) \tag{50}$$

Using the envelope condition and that the equilibrium will be symmetric as all firms face the same problem and hence $p = P$, the solution to this maximisation problem is the continuous time New Keynesian Phillips curve

$$\left(r_t^a - \frac{\dot{Y}_t}{Y_t}\right)\pi_t = \frac{\varepsilon}{\theta}(m_t - m^*) + \dot{\pi}_t, \quad m^* = \frac{\varepsilon - 1}{\varepsilon} \tag{51}$$

where $1/m^*$ is the markup when prices are flexible. In this model intermediate firms raise their price when their markup is above that of the flexible price case.

[27] An alternative formulation is to use Calvo (1983) price rigidities, whereby a firm can only change prices under a certain probability, but once selected can do so costlessly has be shown to be comparable under the correct parameterisation of the model.

A.2 Calibration

The calibration strategy follows Kaplan et al. (2018) and therefore only the key elements are outlined below.

Table 6 below outlines the parameters used in the theoretical model. The parameters follow closely Kaplan et al. (2018), with the major difference of the profit ristribution scheme shares ν^{π} .

On the household side of the model the intertemporal elasticity of substitution and the Frisch elasticity of labour supply are both set to 1, a standard value found in the literature. As the intertemporal elasticity of substitution is set to 1 this means that we have log preferences over consumption as the utility function is CRRA. The disutility of labour is set such that on average the household hours worked is equal to 1/2 (with 1 representing a full day). The production side of the economy follows standard calibration values as seen in Galí (2015). The elasticity of substitution for final goods is $\varepsilon = 10$, which means that the steady-state markup $1/(\varepsilon - 1) = 11\%$. The government policy is calibrated such that labour income tax is set $\tau = 0.3$ and the lump-sum transfer is 6% of steady state output. Government expenditures is then the residual of the government budget constraint in the steady-state 12. During the transition process following a monetary policy shock labour income tax and government expenditure is held fixed whilst transfers T are allowed to fluctuate. Monetary policy follows the Taylor rule that reacts to deviations from steady state inflation with the Taylor rule coefficient $\phi = 1.25$. The parameters of the adjustment cost function and the household discount rate ρ are calibrated using the model to match the steady state distribution of the mean of the illiquid and liquid wealth distribution and the fraction of poor and wealthy hand-to-mouth households from Kaplan et al. (2014). The parameters of the profit distribution form a crucial basis for the experiments conducted within this paper. The fraction of profit distributed to the illiquid account ω controls the amount of profit that flow directly back into investment. Following Kaplan et al. (2018) the baseline value of $\omega = \alpha = 0.33$, which neutralises the direct effect of countercyclical markups on investment. However, when this share is reduced less profits flow directly into the illiquid account and therefore investment is not dampened as much and increases, causing a rise in consumption and output. The baseline profit distribution scheme (Case 1), where profits are distributed related to labour productivity is when $\nu^{\pi} = 0$. Case 2, where the profits that are distributed to the liquid account in proportion to illiquid asset holdings sets $\nu^{\pi} = 1$. For case 3, half of the profits that flow into the liquid account are distributed in proportion to productivity, such as bonuses, and the other half are distributed in proportion to illiquid asset holdings, therefore $\nu^{\pi} = 0.5$. Case 2 and Case 3 are introduced in greater depth in Section 8.

Table 6: List of Parameter Values

	Description	Value	Target/Source
Preferences			
ζ	Death rate	1/180	Average lifespan 45 years
$1/\gamma$	Intertemporal elasticity of subst.	1	
$1/\nu$	Frisch elasticity of labour supply	1	
φ	Disutility of labour	2.2	Avg. hours worked equal to 1/2
ρ	Discount rate (p.a.)	5.1%	Internally calibrated
Production			
ε	Demand elasticity	10	Profit share of 10 percent
θ	Price adjustment cost	100	Slope of Phillips curve $\varepsilon/\theta = 1$
α	Capital share	0.33	
$\bar{\delta}$	Steady-state depreciation rate (p.a.)	7%	
Government			
τ	Proportional labour tax	0.3	
T	Lump-sum transfer (rel GDP.)	0.06	40% hh with net govt. transfer
Monetary Policy			
ϕ	Taylor rule coefficient	1.25	
$\bar{r}^b$	Steady-state real liquid return (p.a.)	2%	
Unsecured borrowing			
r^{borr}	Borrowing rate (p.a.)	8%	
$\underline{b}$	Borrowing limit	$\$16,500$	
Adjustment cost function			
ξ_0	Linear Component	0.0438	
ξ_1	Convex component	0.956	
ξ_2	Convex component	1.402	
$\underline{a}$	Min a in denominator	$\$1,000$	
Profit distribution			
ω	Profit to illiquid acc.	[0,1]	Kaplan et al. (2018)
ν^{π}	Profits to liq acc. as bonus or dividend	[0,1]	Experimented (Case 1,2,3)

B Income decomposition from the Survey of Consumer Finances

To understand the breakdown of income into their respective sources the highest quality data available for households in the United States is from the Survey of Consumer Finances (SCF) maintained by the Federal Reserve Board. The income decomposition using the SCF includes capital gains, which is not included in the CEX. Table 7 below outlines the income sources for households grouped by their net worth levels. Labour income is income from wage and salary. Business income is defined as income from business, sole proprietorship, and farm ownership. Interest and dividend income is interest earned on savings and bonds as well as other sources of interest income and dividend income. Capital gains is the capital gains or losses from asset holdings. The variable social security includes social security and pension income. Finally, welfare is defined as income from unemployment benefits, alimony/child support, TANF/food stamps/SSI, and other income of this nature. From Table 7 it can be seen that the households in the bottom three quartiles of net worth receive a large majority of their income as labour income. The poorest in the economy, the households at the bottom of the net worth distribution, receive part of their income through welfare benefits. Whereas the richest in the economy have multiple income sources, such as income from business ownership, interest and dividiend income as well as capital gains (income from the changing value of their asset holdings).

Table 7: Income decomposition from the Survey of Consumer Finances by net worth

	0-25%	25-50%	50-75%	75-100%
Labour Income	76%	80%	70%	53%
Business Income	3%	4%	7%	19%
Interest and Dividend Income	0%	0%	0%	5%
Capital Gains	0%	0%	3%	8%
Social Security	12%	13%	19%	13%
Welfare	9%	3%	4%	2%

Income decomposition from the Survey of Consumer Finances using data for 2016. Variable names follow closely the summary variables that are taken from the summary extracted public data.

To compare Table 7 with the corresponding table of the baseline HANK model, found in Section 4 Table 1 some assumptions must be made. Firstly labour income is defined as wages and transfer income is welfare income. Profit income tries to follow the definition in HANK, whereby $1-\omega$ of business income flows back to the household, plus the dividends.[28]. The remaining half of the interest and dividend variable is attributed to liquid asset holdings. The illiquid asset return is the sum of capital gains, the remaining ω of business profits and social security benefits (as the social security accounts like a 401K account are somewhat illiquid). From these assumptions Table 8 is created. Comparing this table to Table 1 we see that labour income is still the most important part of income for the poorest households. However, the share of income from profits is now lower for the bottom three quartiles of the net wealth distribution than the top quartile. The income from liquid assets are small in the data and theoretical model. The part of illiquid income that the

[28]An alternative assumption here for profit would be that the dividends flow black to the illiquid account. This would only serve to increase the illiquid asset income of the highest net worth household whilst lowering the profit income of these households.

model is unable to capital, social security payments, as it does not feature in the model appears in the bottom row of Table 8.

Table 8: Income decomposition from the SCF put into the HANK catagories

	0-25%	25-50%	50-75%	75-100%
Labour Income	76%	80%	70%	53%
Transfer Income	9%	3%	4%	2%
Profit	3%	3%	5%	17%
Liquid Asset	0%	0%	0%	3%
Illiquid Asset	13%	14%	21%	27%

Income decomposition from the Survey of Consumer Finances using data for 2016. Data is taken from the summary extracted public data. Variable transformations from the raw catagories are as follows: Labour Income = wage. Transfer Income = welfare income. Profit = $(1-\omega)$ business + 0.5 (interest and dividends). Liquid asset = 0.5(interest and dividends). Illiquid asset = Capital gains + ω business + social security.

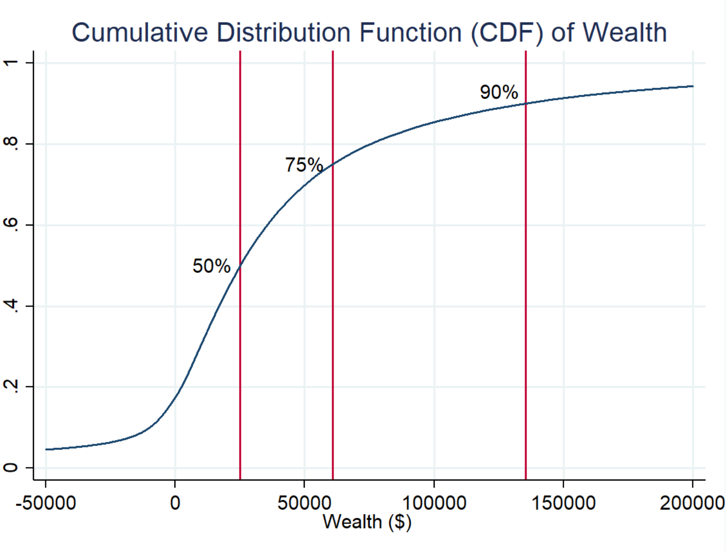
C Additional CEX info

The main empirical analysis focuses on partitioning households by end of period wealth, as further outlined above in Section 5.2.1. The wealth calculation used is replicated below. Due to the nature of the Consumer Expenditure Survey it is more natural to calculate end of period wealth as I have done below:

$$Wealth_i = Y_i - T_i - C_i + A_i - L_i$$

The distribution of wealth, in 2018 Q1 dollars, is provided below in Figure 14. The red vertical lines in this figure highlight the 50%, 75% and 90% wealth values at each of this percentiles.

Figure 14: Distribution of Wealth



Note: Real wealth in Q1 2018 dollars

The dollar amount that corresponds to the percentiles at each of the red lines shown in Figure 14 above are provided below in Table 9. The lower end of the distribution matches up well to the Survey of Consumer Finances, however, since the CEX is unable to capture the wealth of high net worth households the top percentiles of the wealth distribution are misspecified. This point is explained in Auclert (2019), who compares the assets and liabilities of the CEX with the SCF and finds that the liabilities of households from the CEX match with those of the SCF however assets in the CEX are underrepresented.

Table 9: Dollar amount of wealth at each percentile

	50%	75%	90%
Wealth values	$25,100	$60,800	$135,200

Note: Real wealth in Q1 2018 dollars

Table 10 provides descriptive statistics between the two groups focused on in this paper, the bottom 75% of the wealth distribution and the top 25%. Higher wealth households are older, have a larger share of home owners and mortgage holders and are less likely to be renters. This is in line with the definition of high wealth households in Doepke and Schneider (2006). These descriptive statistics of the household characteristics provides confidence in the measure of Wealth.

Table 10: Descriptive statistics by Wealth

	Average Age	Share of Home Owners	Share of Mortgagors	Share of Renters
Bottom 75%	48.6	24%	36%	38%
Top 25%	50.5	29%	50%	19%

Note: Share of housing tenure need not sum to 100% as two categories are ignored: i) Occupied without payment of cash rent and ii) student housing.

D Additional Empirical Results

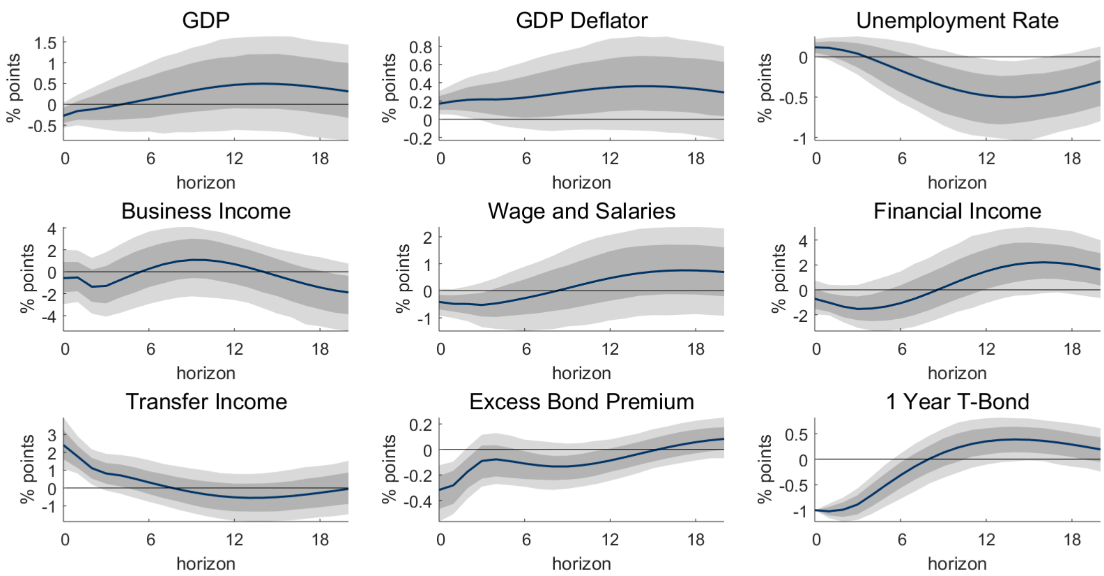
D.1 Aggregate data

The data for the United States economy comes from the Federal Reserve Economic Data (FRED) maintained by the Federal Reserve Bank of St.Louis. Analysis is conducted at the quarterly frequency and the data range from 1984-Q2 to 2017-Q4. The starting date is after the Volcker Disinflation, which is identified as ending in 1984-Q1 in Bernanke and Mihov (1998). Standard macroeconomic indicators such as real GDP, the GDP deflator and the unemployment rate are assessed in the empirical analysis with the addition of corporate profits after tax and income from inventory valuation adjustments which represents the income from business ownership. Compensation of employees wages and salary accruals used for the wage and salary variable, personal income receipts on assets is used for financial income and personal current transfer receipts is taken for transfer income. For consumption I use the real personal consumption expenditures and for aggregate investment I use real gross private domestic investment, both of these series are from FRED.

D.2 Aggregate Results

Analysing the aggregate response, although not the main purpose of this paper, provides a sanity check to ensure the shock is correctly specified and the aggregate impulse response functions behave in the manner expected. As discussed previously the aggregate Bayesian Proxy SVAR sample period is from 1984-Q2 to 2017-Q4, after the Volcker disinflationary period. From Figure 15 we see that an expansionary monetary policy shock causes real Gross Domestic Product to rise as well as the GDP Deflator, providing confidence in the empirical strategy. The increase on impact of the GDP Deflator shows that there is no price puzzle in this BP-SVAR, which may stem from the identification strategy of Jarocinski and Karadi (2018) cleaning the monetary policy of any information effects. The median response in the SVAR is given by the blue line with the darkest grey line signifying 68% confidence bands and the lighter grey bands for 90% confidence. Unemployment and the expected bond premium fall as expected and as shown throughout the literature. The response of real wages is not significantly different from zero, whereas financial income falls, business income increases and income from transfers significantly increases and reverts back to its original level. This shows that if households have heterogeneous sources of income from a monetary policy shock this may lead to distributional changes in the consumption, income and wealth of the households.

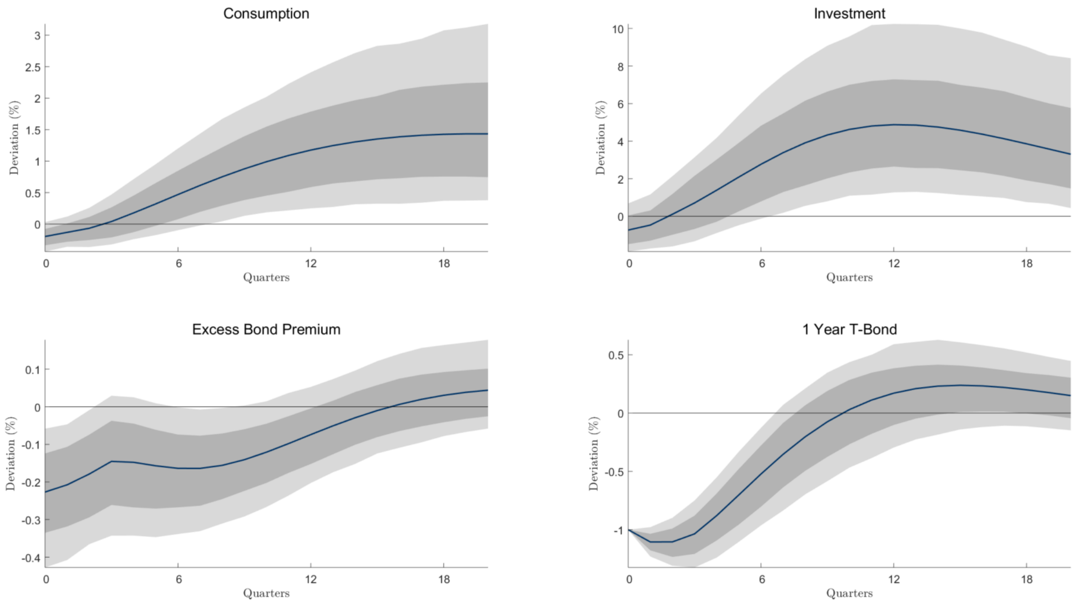
Figure 15: Aggregate response of the economy to an expansionary monetary policy shock



Note: Aggregate response to a 1% decrease in the 1 year Treasury bond . Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1984-2017. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws.

Figure 16 outlines the response of consumption and investment from an expansionary monetary policy shock. The increase in investment seen in Figure 16 is used to test the aggregate response from different profit distribution schemes seen in the main text of the paper.

Figure 16: More Aggregate responses to an expansionary monetary policy shock

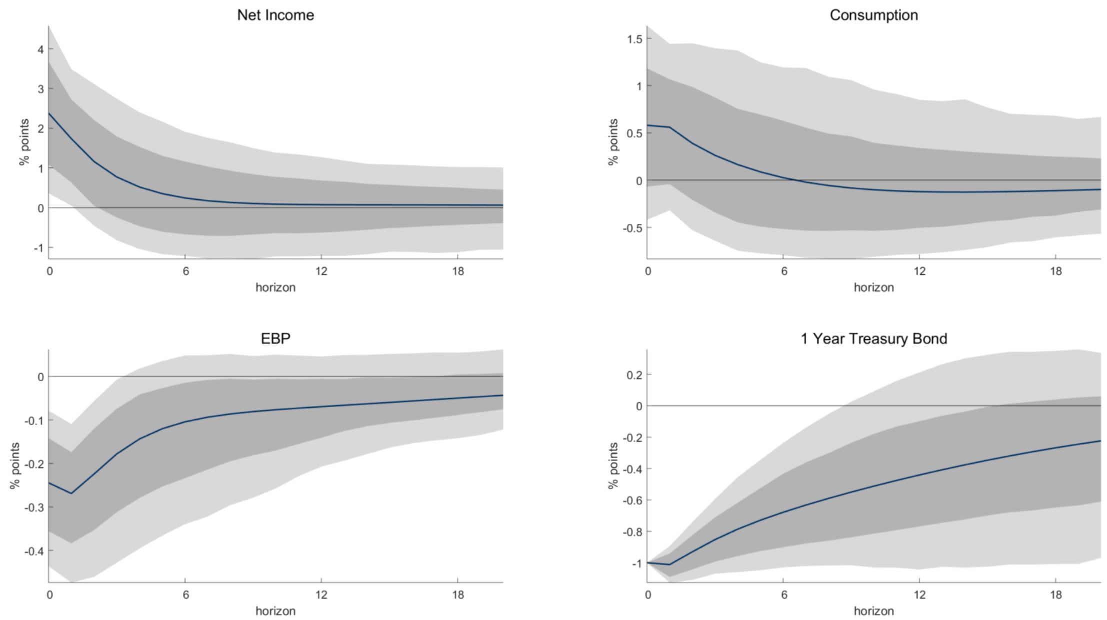


Note: Aggregate response to a 1% decrease in the 1 year Treasury bond . Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1984-2017. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws. GDP and GDP Deflator as added as controls but not displayed.

D.3 Average CEX results

Figure 17 highlight the average response of income and consumption from the Consumer Expenditure Survey to a monetary policy expansion. As is expected consumption and income both increase. The increase in consumption is now statistically significant but the increase in income is. Figure 17 provides a further sanity check to ensure that data from the CEX respond in accordance to theory and that the monetary policy shock used and empirical specification are correct.

Figure 17: Mean responses from the CEX



D.4 Response by URE and Income groups

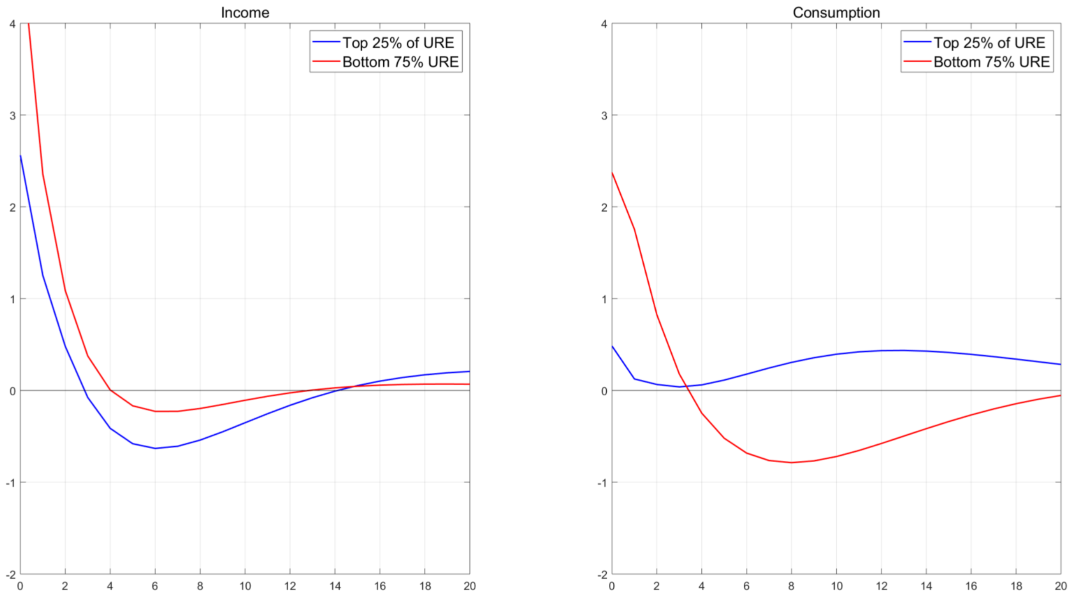
This subsection replicates the empirical exercise seen in Section 7 for households distributed by their unhedged interest rate exposure and income levels.

The unhedged interest rate expose, from Auclert (2019), provides a measure of the balance sheet available to the household within this period. The URE is the difference between all maturing assets and liabilities at a point in time, provides a measure of balance sheet exposure to real interest rate changes. The calculation is replicated below in Equation **??**.

$$URE_i = Y_i - T_i - C_i + A_i^m - L_i^m \tag{52}$$

Similarly to household wealth I take the unhedged interest rate exposure and split it into the top 25% of households and the bottom 75%. The households at the top 25% of the URE measure typically have a large sum of liquid assets and do not react hand-to-mouth. Whereas, households with a lower value of URE may own sizeable assets but these assets are illiquid and therefore these households react more hand-to-mouth when they receive a shock. Figure 18 highlights the response of income and consumption for each of these groups to an expansionary monetary policy shock. The income of both types of agent, low and high URE, increase however their consumption response is markedly different. The households in the top 25% of the URE measure have a dampened response in consumption compared to those households in the bottom 75% of URE.

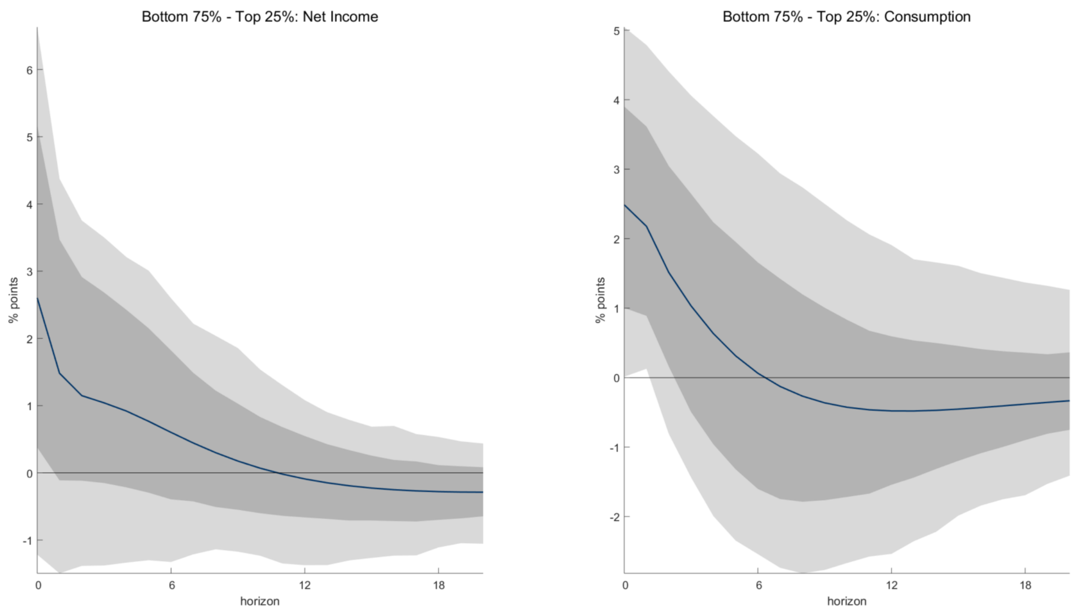
Figure 18: Individual Response by URE groups



Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by URE. Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. URE groups are rotated following Anderson et al. (2016).

The difference between these households is highlighted in Figure 19. Although the median impulse response function is sizeable and positive between these two groups it is only statistically significant at the 68% level on impact. The response of consumption follows a similar path but is statistically significant at the 10% level on impact.

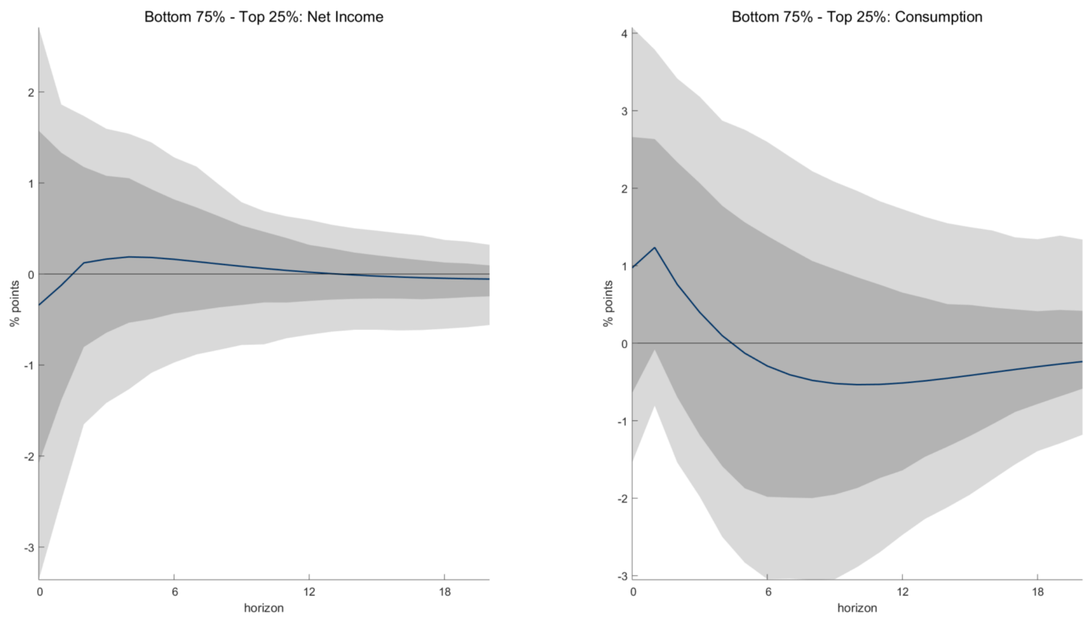
Figure 19: Differences in Income and Consumption response by URE groups



Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by URE. Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws.

The following Figure 20 show the response of households when they are split by their income. The difference response in income and consumption between the groups is not statistically significant.

Figure 20: Differences in Income and Consumption response by Income groups



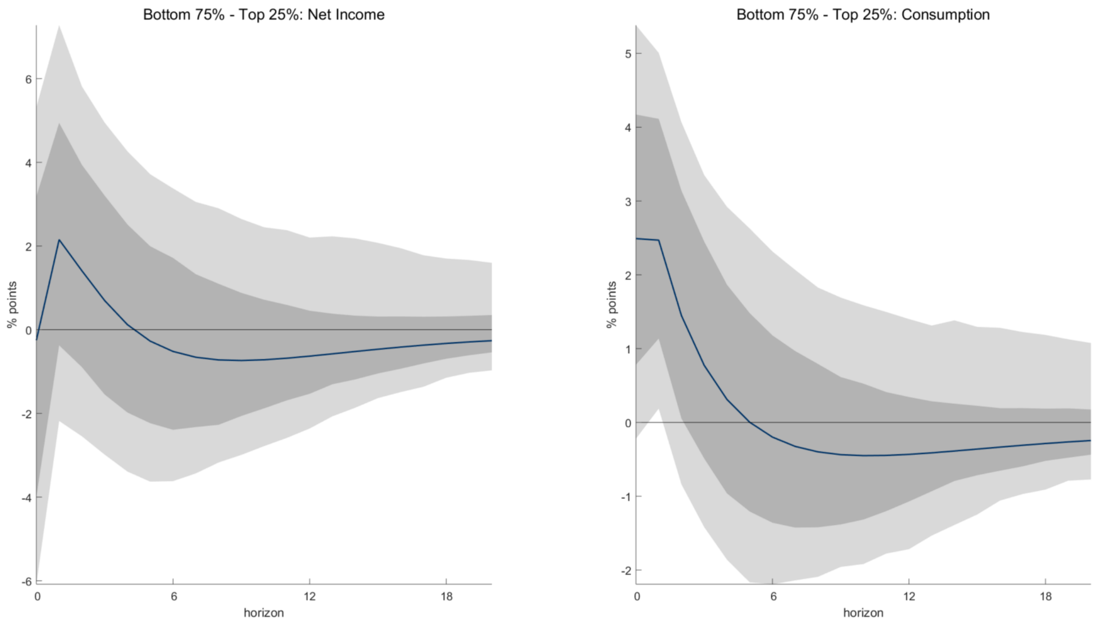
Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by Income. Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws.

D.5 Wealth calculation and Results with Housing

The initial calculation of household wealth using the Consumer Expenditure Survey lacks house values as an asset on the household's balance sheet. Housing is an important part of many households portfolio and should be taken into account for the household's wealth level. Different years of the SCF are used and households are split into 5 age groups and 10 income groups. From this split the average house price value for age-income pair is calculated and then attributed to households that own a home within the original Consumer of Expenditure Survey wealth caluclation.

As seen in Figure 21 the underlying conclusions drawn from the baseline empirical exercise hold true. Such that the difference in income response between high and low wealth households is muted from an expansionary monetary policy shock. In contrast to this I still find a difference in consumption responses at the 68% level.

Figure 21: Differences in Income and Consumption response by Wealth groups including house values



Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by Wealth with additional house value data from the Survey of Consumer Finances. Using a Bayesian Proxy SVAR instrumented by the monetary policy surprise from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws.

E Further MPC Calculation

This analysis of the 2008 U.S. tax rebate follows Parker et al. (2013), which is a follow-up paper to their analysis of the 2001 tax rebate Johnson et al. (2006) that is explained earlier in Section 5.2.2. The 2008 tax rebate is from the Economic Stimulus Act of 2008, which consisted primarily of a 100 billion dollar program that sent tax rebates, called economic stimulus payments (ESPs), to approximately 130 million US tax filers. The methodology used for analyse the 2008 tax rebate follows Johnson et al. (2006) such that we can compare the marginal propensity to consume across the to studies. The 2008 study also makes use of the randomised distribution of the tax rebate due to the recipients social security number. There are important differences between the 2001 and 2008 tax rebates. The dollar amount received in 2008 was greater than the rebate of 2001. In 2008 single individuals received between \$300 to \$600, couples received \$600 to \$1,200 and an additional \$300 per child who qualified for the child tax credit. In comparison the tax rebate in 2001 ranged from \$300 to \$600. Furthermore, the U.S. was in the midst of a recession caused by the financial crisis in 2008.

The equation below represents the regression run to analyse the impact of the tax rebate on consumption. As in the analysis in Section 5.2.2 the variable $R_i, t+1$ uses a distributed lag such that the longer duration of the tax rebate can be taken into account. Following Parker et al. (2013) standard errors are corrected to allow for heteroskedasticity and within-household serial correlation.

$$C_{i,t+1} - C_{i,t} = \sum_s \beta_{0s} \times \text{month}_{s,i} + \boldsymbol{\beta}_1' \mathbf{X}_{i,t} + \beta_2 R_{i,t+1} + u_{i,t+1} \tag{53}$$

Table 11 outlines the result of the 2001 and 2008 tax rebate with standard errors in parenthesis. In 2001 the households with the lowest levels of wealth consumed a large part of their tax rebate over the 6 months analysed, however, this is not the case for 2008. For 2008 the highest wealth households have a larger marginal propensity to consume out of the tax rebate compared to the less wealthy households. Due to the size of the standard errors we cannot discern a statistical difference between the high and low wealth household's MPC for 2008. This result is corroborated with that of Parker et al. (2013), where households with the highest levels of liquid wealth reacted the strongest to the 2008 tax rebate. The finding for 2008 in the table below as well as Parker et al. (2013) is at odds with the original findings for the 2001 tax rebate, where the poorer households had a higher MPC. The difference between 2001 and 2008 may be due to differences in credit constraints across households between the 2001 and 2008 recessions and differences in expectations about the length and severity of the recessions. Parker et al. (2013) also state that "Another key characteristic of the recent recession was the large decline in housing wealth and the reduced ability to borrow against home equity." Therefore with the lack of liquidity available to the higher wealth households due to the financial crisis it may rationalise the increased marginal propensity to consume of these households.

Table 11: Cumulative MPC calculation for 2001 and 2008

	Cumulative MPC for 2001	Cumulative MPC for 2008
Bottom 75% of Wealth	0.59	0.41
	(0.26)	(0.30)
Top 25% of Wealth	-0.02	0.51
	(0.53)	(0.36)
Number of observations	11,856	9,921

F Bayesian Local Projection

F.1 Description of Bayesian Local Projection

Following Miranda-Agrippino and Ricco (2018b) I complete the empirical exercise found in the main body of the paper, Section 7, for my wealth measure using Bayesian local projection and local projection techniques.

Impulse response functions estimated using a VAR may be susceptible to model misspecification. This could occur when using a small size VAR that fails to control for any dynamic interactions that are relevant for the propagation of the shock. Moreover, the lag order may be underestimated and non-linearity are not taken into account that could potentially be important. One way to mitigate against these worries is to use a direct method such as local projections from Jordà (2005), which supposedly are more robust to misspecification. However, due to the small sample used local projections methods deliver highly imprecise estimates and noisy impulse responses. This bias-variance trade-off is addressed by Miranda-Agrippino and Ricco (2018b) through using a Bayesian Location Projection that optimally spans the model space between a VAR and LP. Bayesian Local Projection works by "specifying a (Normal-Inverse Whishart) prior for the local projection coefficients at each horizon, centred around the iterated coefficients of a similarly specified VAR estimated over a pre-sample"Miranda-Agrippino and Ricco (2018b). The posterior mean of BLP responses takes the form

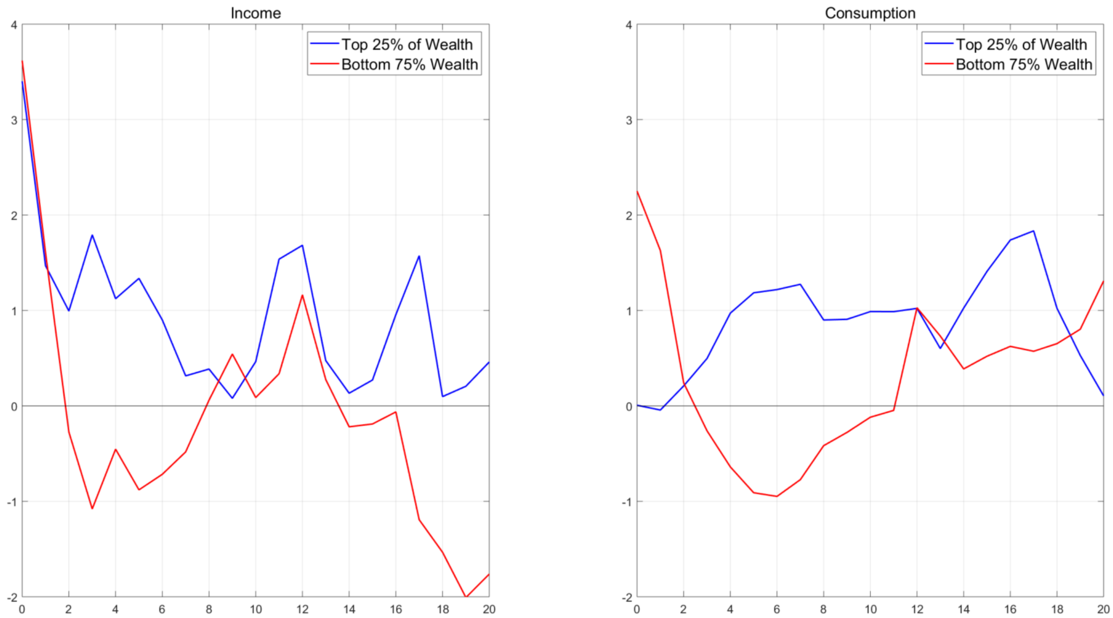
$$B_{\mathrm{BLP}}^{(h)} \propto \left(X'X + \left(\Omega_0^{(h)} \left(\lambda^{(h)} \right) \right)^{-1} \right)^{-1} \left(\left(X'X \right) B_{\mathrm{LP}}^{(h)} + \left(\Omega_0^{(h)} \left(\lambda^{(h)} \right) \right)^{-1} B_{\mathrm{VAR}}^{h} \right), \quad (54)$$

where $X \equiv (x_{h+2}, \ldots, x_T)'$ with $x_t \equiv \left(1, y'_{t-h}, \ldots, y'_{t-(h+1)} \right)'$. This technique regulates the local projection impulse response function by imposing structure using priors centered around the iterated VAR. Another recent approach to discipline the local projection approach is through smoothed LP of Barnichon and Brownlees (2019).

F.2 Results

These results below, which are more robust to misspecification, outline the same conclusion found in Section 4 where a Bayesian Proxy SVAR was used. Although the BVAR approach produces impulse responses that are eratic the underlying message can still be gleaned from Figure 22. Such that the income of the wealthiest households and those in the bottom three quartiles of the wealth distribution respond similarly following an expansionary monetary policy shock. The consumption response is different, with the highest net worth households not reacting on impact and slowly increasing their consumption, whereas the poorest households immediately consume a large part of their increase in income and over the space of a year reduce their consumption back to their steady state level.

Figure 22: Bayesian Local Projection: Individual Response by Wealth groups



Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by wealth. Using a Bayesian Local Projection with the monetary policy shock from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Wealth groups are rotated following Anderson et al. (2016).

Figure 23 highlights the differences found in Figure 22. As in the main text the blue line is the median of the posterior distribution with the error bands at 68% and 90%. The difference between income responses in these two wealth groups is negligible and not statistically significant. Whereas, on impact the difference in consumption between the households in the top 25% of wealth compared to the households in the bottom 75% is statistically significant at the 10% level. Thus, finding support for differences in consumption responses across the distribution of wealth following a monetary policy shock.

Figure 23: Bayesian Local Projections: Difference between wealth groups

Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by wealth. Using a Bayesian Local Projection with the monetary policy shock from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Shaded areas are 68% and 90% posterior coverage bands obtained with 10,000 draws.

For further robustness and transparency the response of the three models used in this paper are displayed below in Figure 24. The error bands now only represent 90% confidence with the darker band for the BLP, lighter band for BVAR and no error bands shown for LP. The three different specifications co-move, although the response from a standard local projection is very volatile.

Figure 24: BLP, LP, BVAR: Difference between wealth groups

Note: Response to a 1% decrease in the 1 year Treasury bond by households grouped by wealth. Using a Bayesian VAR (dashed teal), BLP (solid dark blue) and LP (orange) specification with the monetary policy shock from Jarocinski and Karadi (2018). Quarterly data from 1996-2017. Excess bond premium and GDP Deflator are added as controls. Shaded areas are the90% posterior coverage bands obtained with 10,000 draws for the BVAR (light grey) and BLP (dark grey).

G Additional Model Results

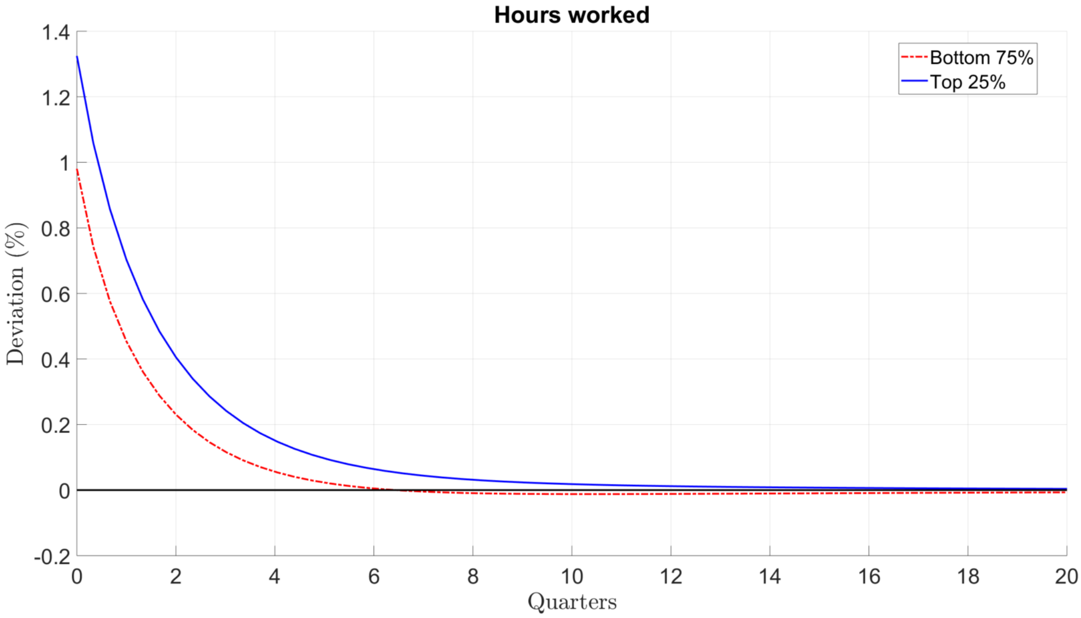
G.1 Change in hours worked by net worth

The labour market in the HANK model of Kaplan et al. (2018) features flexible wages and different hours worked (which is the same as labour supply due to flexible wages and no unemployment) across the wealth distribution. The wage increases from an expansionary monetary policy as firms demand more labour to boost production. This increase in wage incentives households along the wealth distribution to supply more labour with the result that aggregate hours worked in the economy increases. Figure 25 highlights the response of hours worked averaging over the bottom 75% of the net wealth distribution and the top 25%. As seen in this Figure, the response of hours worked is similar, with the wealthiest in the economy increasing their hours by more than the poorest.[29] Although not seen in the data, one reason for this occurrence in the model is the willingness to work to sustain income in their liquid

[29] In the steady state the households at the bottom 75% of the wealth distribution hours worked is 30% higher than the households in the top 25%.

account, so they do not hit their budget constraint, whilst they are investing in the illiquid asset that has an increase in return.

Figure 25: Case 1 (KMV): Hours worked from expansionary monetary policy shock



Note: Response of hours worked (labour supply) by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

G.2 Mix of 50% Case 1 and 50% Case 2

Case 1 (profits are distributed as bonuses), Case 2 (profits are distributed as dividends) are outlined in the main body of text in Section 4. Case 3 combines an equal share of Case 1 and Case 2 whilst lowering the amount of profits that automatically flow back into the illiquid account (ω). An obvious candidate to explore further is the mixing of Case 1 and Case 2 without altering the share of profits that are automatically put back into the firm (the illiquid account). This section highlights this result.

Table 12 outlines the income sources across the distribution of households by their net worth. The households in the bottom three quartiles of net worth receive the majority of their income from labour whereas the highest net worth households receive most of their income from the illiquid asset. The share of profits distributed into the liquid account of households is distributed equally as profits and as dividends. Compared to Case 1, we see a more realistic profit distribution as the highest net worth households receive a larger share, compared to the low wealth households, of their income from profits.

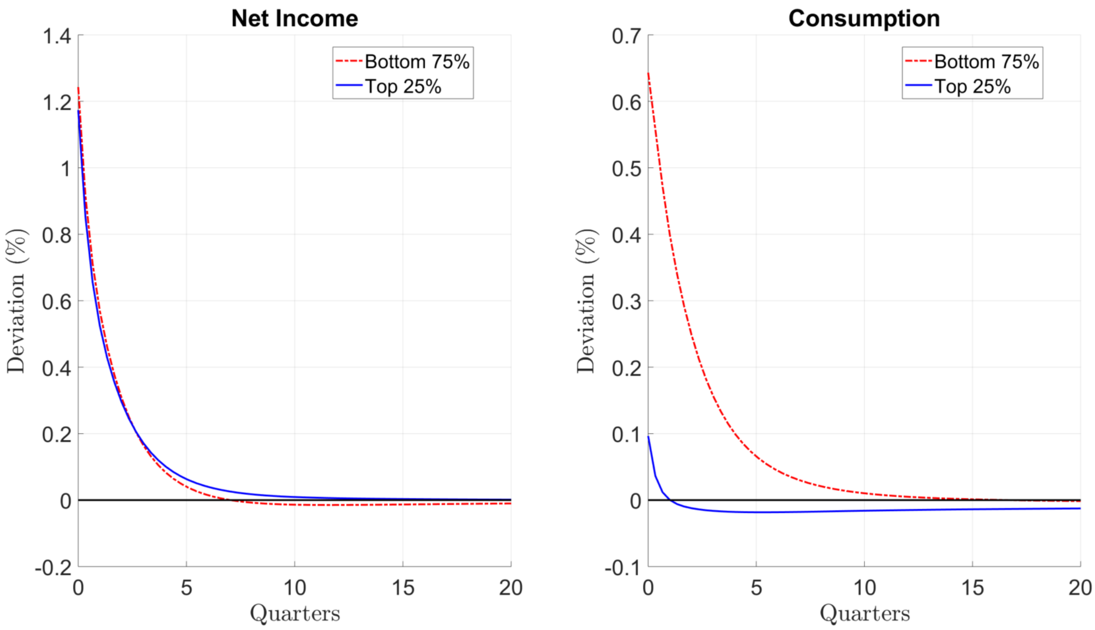
Table 12: Mixed Case 1 and Case 2: Net income sources by net worth

	0-25%	25-50%	50-75%	75-100%
Labour Income	81%	83%	81%	32%
Transfer Income	15%	12%	10%	4%
Profit	4%	4%	5%	7%
Liquid Asset	-1%	0%	2%	2%
Illiquid Asset	0%	0%	3%	56%

Steady state decomposition of net income by household net worth quartiles.

Figure shows the resulting consumption and income responses from an expansionary monetary policy shock. The income response (right-hand-side) of the bottom 75% and top 25% of the net wealth distribution is now very similar. However, their consumption response (left-hand-side panel) differs as these households are not hand-to-mouth and instead choose to save.

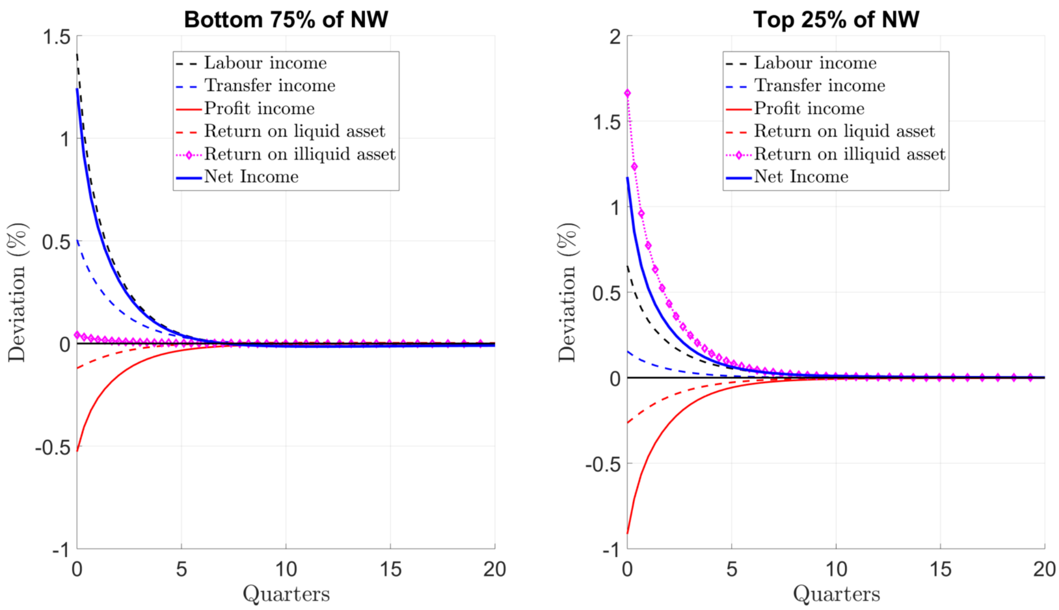
Figure 26: Mixed Case 1 and Case 2: Consumption and income response by net worth



Note: Response of consumption and income by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

The increase in income following an expansionary monetary policy shock comes from different sources dependent on the households net wealth, as outlined in Figure 27. Households in the bottom 75% of the net wealth distribution receive the majority of their income from the rise in wages following an expansionary monetary policy shock. As with Case 1 profits dampen their overall net income increase as they are now distributed, in part, due to labour productivity. The return on the liquid or illiquid asset does not directly play a significant role for their income source as they hold little of either. In contrast, the households in the top 25% of the net wealth distribution benefit from the increase in the return on the illiquid asset, pushing income up on its own by 1.5% for these households. However, since profits are distributed, in part, due to illiquid asset holdings their income is dampened due to this. Moreover, as these households hold liquid assets they also lose out when the interest rate falls. In the end, although the income sources across the distribution of net worth is different, their net income response is similar.

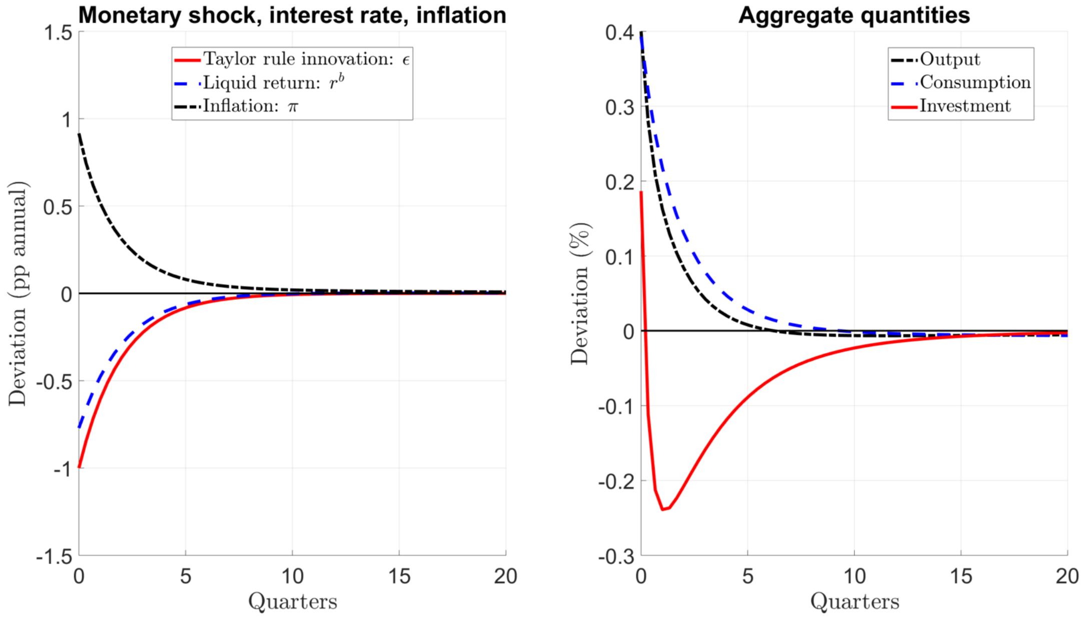
Figure 27: Mixed Case 1 and Case 2: Income response decomposed by net worth



Note: Decomposing income response by net worth to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ. The decomposition represented is scaled by the share of net income, so that the lines (excluding net income) will sum to net income. The black dashed line is net labour income, $(1-\tau_t)w_t z_t l_t$, the dashed blue line is government transfers T_t, the red line is the income from profits, π_t^b, the return from liquid assets, $r^b(b)b_t$, is represented by the red dashed line and finally the pink dashed line with diamonds is the return from illiquid asset holdings, $r_t^a a_t$.

Figure 28 outlines the aggregate response from an expansionary monetary policy shock when profits are distributed using an equal share of Case 1 and Case 2. As was the issue in Case 2 investment is now countercycical, which is in contrast to the empirical evidence. Although investment does increase on impact of the shock, it is below output and consumption, where in the data typically investment is the most volatile component. Although the highest net worth households' income increases the countercyclical profits that flow into their liquid account cause these households to transfer their assets from illiquid to liquid. Liquid assets are required to purchase consumable goods and provide a buffer to the borrowing constraint. This transfer causes investment to fall for the quarters following the monetary policy shock.

Figure 28: Mixed Case 1 and Case 2: Aggregate response to an expansionary MP shock



Note: Response of aggregate variables to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

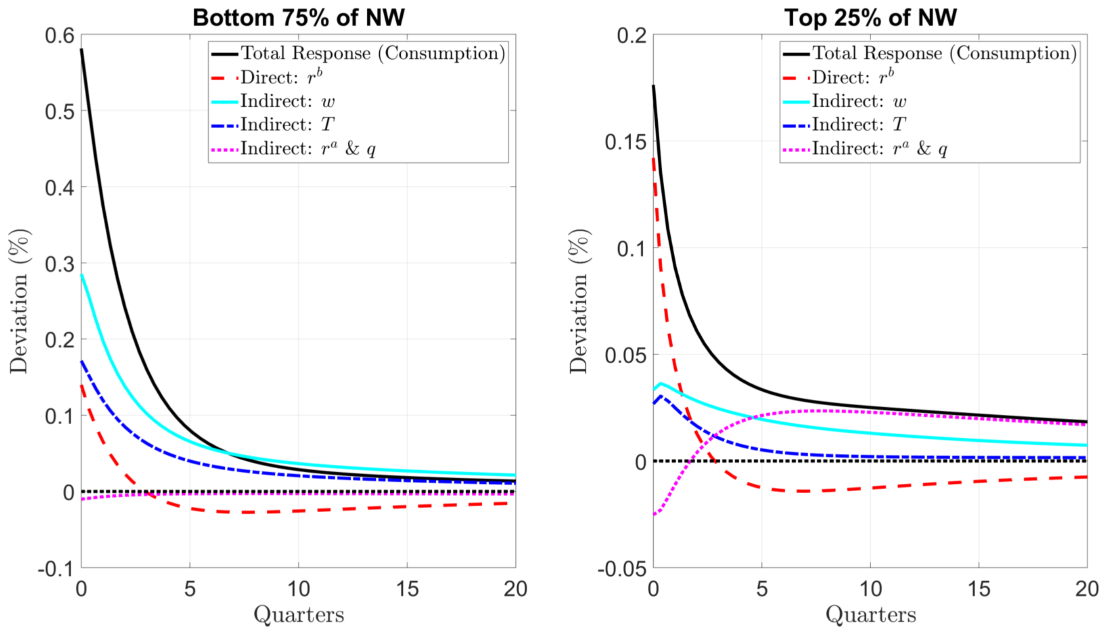
G.3 Consumption decomposed

As explained in Section 8.3 it is possible to decompose the change in aggregate consumption due to the direct and indirect effect of monetary policy, outlined for convenience below:

$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt}_{\text{direct effect}} + \underbrace{\int_0^\infty \left(\frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial \tau_t} d\tau_t + \frac{\partial C_0}{\partial T_t} dT_t \right) dt}_{\text{indirect effects}} \tag{55}$$

Figure 29 outlines the channels monetary policy impacts the bottom 75% of household net worth and top 25% of household net worth. Case 1, which is the baseline in Kaplan et al. (2018), shows that for the low wealth households transfers and wages, both indirect effects of monetary policy, play the majority role in their consumption response. Whereas the direct effect, the classical intertemporal substitution channel found in RANK models, is the largest contributor to households at the top of the net worth distribution. The wealthy households, who have enough assets to freely save, increase their consumption as the benefit of saving in the liquid account (the real interest rate on liquid bonds) falls. However, their consumption is dampened slightly as the return on illiquid assets increases in the model, which causes these households to save and benefit from the higher interest rate on illiquid assets.

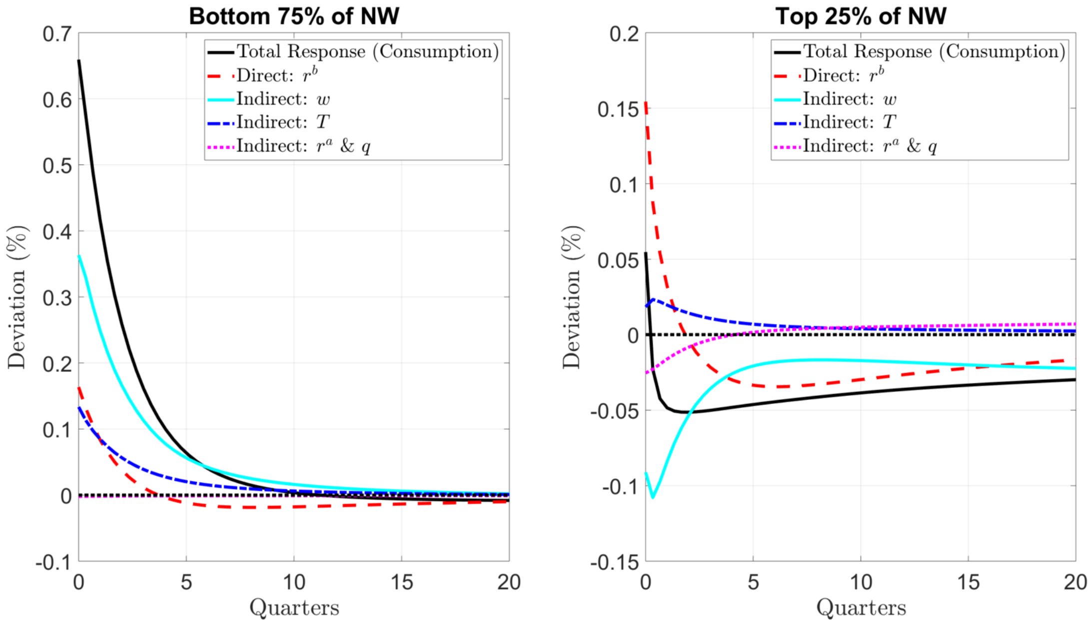
Figure 29: Case 1: Consumption Decomposed



Note: Response of consumption by net worth decomposed into the direct and indirect effect of a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

Contrasting the above Figure 29 with Figure 30 where profits are distributed dependent on illiquid asset holdings there are some obvious differences. For the low wealth households the picture is similar, their largest contributor is the increase in wages, which is an indirect effect of monetary policy. Moreover, for the wealthier households the fall in the return on liquid assets, the direct effect, still positively impacts their consumption response on impact. However, the increase in wages, which previously lead to an increase in consumption now negatively impacts the consumption response of the high net worth households. As seen in Section 4 Figure 9 labour income increases for the highest net worth households but wages have a negative effect on the consumption of the wealthier households. This is due to the increase in wages, the cost of labour in production, causing an increase in production costs and hence lowering the markup charges by the firm and reducing profits. Since in Case 2 profits are almost entirely distributed to households in the top 25% of net worth this rise in wages has a negative impact on their consumption.

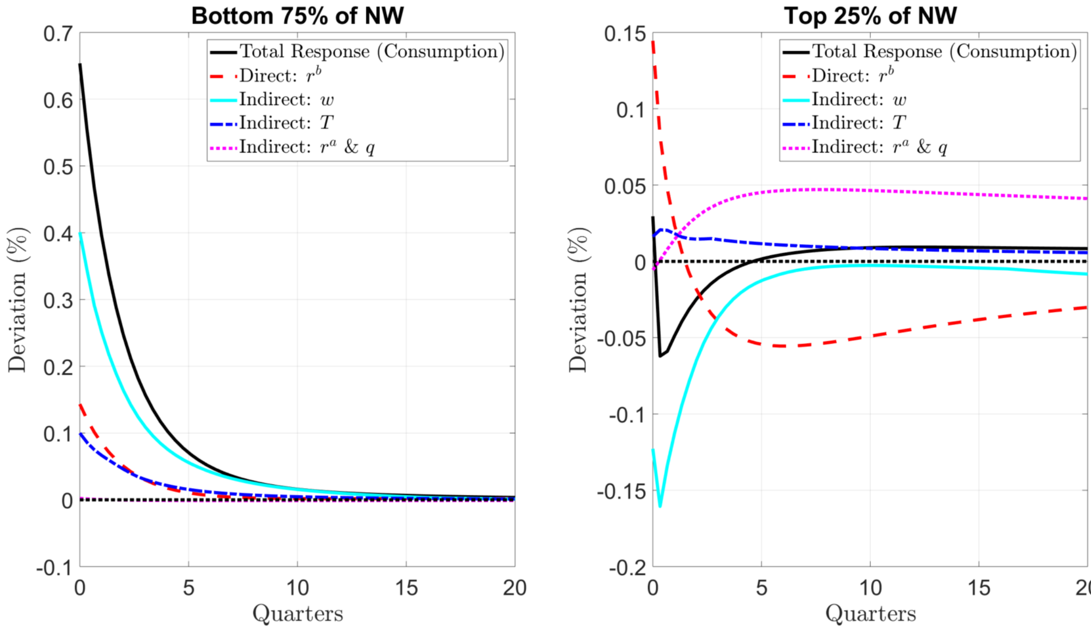
Figure 30: Case 2: Consumption Decomposed



Note: Response of consumption by net worth decomposed into the direct and indirect effect of a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

The consumption response of Case 3, where the share of profits distributed into the liquid account increases as well as mixing the bonus based profit distribution scheme of Case 1 and the dividend distribution scheme of Case 2, is highlighted in Figure 31. As in Figure 30 wages have a negative impact on the consumption response of the highest net worth households. Moreover, wages remain to be the most important component of the consumption response of lower wealth households. Unlike in the previous cases the combined response of the illiquid asset return and the stock price now put upward pressure on the consumption response of the highest net worth.

Figure 31: Case 3: Consumption Decomposed



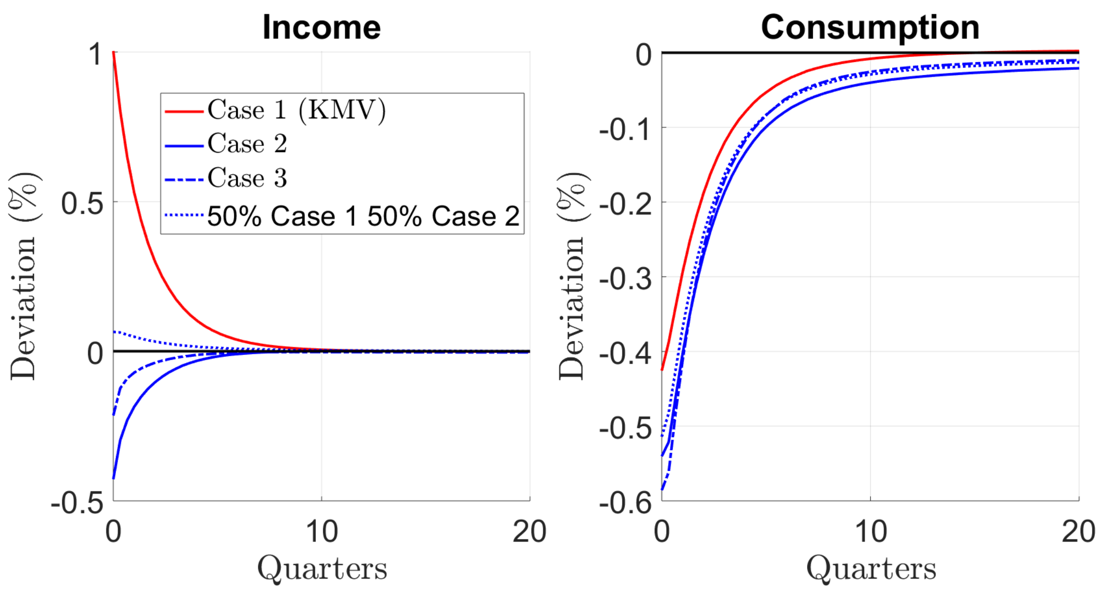
Note: Response of consumption by net worth decomposed into the direct and indirect effect of a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ.

H Response of Gini Coefficients

The response of the Gini coefficient for income and consumption within the model and the extensions conducted in the main text of the paper provide an ideal measure to test against empirical findings. The response of the Gini coefficient, a measure of statistical dispersion used to quantify inequality within an economy, to monetary policy shocks has been studied previously by Coibion et al. (2017) and Mumtaz and Theophilopoulou (2017). One strength of this approach is that it does not require the use of data on wealth, which my main empirical exercise relies upon. Coibion et al. (2017) finds that a contractionary monetary policy shock increases consumption inequality by more than income inequality. In the context of my paper, which solely focuses on expansionary monetary policy, this means that we would expect to see a fall in income and consumption inequality, with the Gini coefficient on consumption falling by more than income.

Figure 32 highlights the response from the model. In red, Case 1, which is the baseline from Kaplan et al. (2018) where profits are distributed to households depending on their labour productivity, features an increase in income inequality that is at odds with the current findings in the literature. However, the response of the Gini coefficient for consumption is in line, as it falls from an expansionary monetary policy shock. Innovating on the profit distribution scheme, as in Case 2 where profits are distributed due to illiquid asset holdings and Case 3, which features a mixture of Case 1 and Case 2 whilst increasing the amount of profits distributed feature the correct sign for the income and consumption Gini coefficients. Moreover, Case 3, where the aggregate and micro response to an expansionary monetary policy shock was in line with the empirical evidence also features the Gini coefficient on consumption falling my more than income, a finding supported by Coibion et al. (2017).

Figure 32: Response of Gini Coefficients



Note: Response of Gini coefficients for consumption and income by profit distribution scheme to a 0.25 (1% annual) fall in the innovation in the Taylor rule ϵ. Case 1 is the baseline profit distribution scheme of Kaplan et al. (2018), where profits are distributed in proportion to labour productivity. Case 2 profits are distributed in proportion to illiquid assets. Case 3 combines Case 1 and 2 whilst increasing the share of profits distributed.

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