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Distributional effects of monetary policy in Norway

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Abstract

We quantify the short-term effects of both non-systematic and systematic monetary policy on the income and wealth distribution in Norway, and measure the relative importance of the various channels. An expansionary monetary policy shock is found to disproportionally benefit the young as well as households with middle to lower income and wealth, and it reduces inequality in disposable income and wealth. The key channel for disposable income is the savings redistribution channel, whereby households with high debt-to-income ratios gain relatively more from a lower interest rate. Because of the high home ownership rate in Norway, most households gain from higher house prices, but the middle and lower part of the distribution gain relatively more as they are more indebted. We also find that systematic monetary policy, aimed at stabilizing cyclical fluctuations in output and inflation, also tends to stabilize income and wealth inequality.

JEL Classification: E2, E3, E5, G5

Keywords: Monetary policy, Inequality, Household heterogeneity, Income and wealth distribution

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1 Introduction

Recent years have witnessed an increased focus on the distributional effects of monetary policy, both in the research literature and among central bankers.[1] Rising income and wealth inequality in advanced economies[2], central banks' extensive use of unconventional policy tools in the aftermath of the Great Recession and the Covid-19 pandemic, and a prolonged period of low interest rates all make it important to understand how monetary policy affects subgroups of the population. The empirical evidence on the distributional effects of monetary policy is, however, mixed, and varies in both sign and size across studies and countries.[3] Apart from substantial challenges related to data and methodology[4], there is also reason to believe that the distributional effects of monetary policy differ across countries. The share of home owners in the population, the debt-to-income levels across the distribution, the share of floating and fixed-rate mortgages, the functioning of the labor market and the social safety net all contribute to notable differences in the distributional impact of monetary policy.

This paper aims to quantify the short-term effects of conventional non-systematic and systematic monetary policy on the distribution of income and wealth in Norway using a two-step procedure. First, we quantify the effect of monetary policy on aggregate variables such as unemployment, wage growth and asset prices using a large scale DSGE model estimated for the Norwegian economy. In the second step, we employ detailed micro data on income and wealth for all Norwegian households to understand how the aggregate changes are distributed across households. This evaluation requires detailed data on the composition of income and wealth at the household level.

When quantifying the distributional effects of monetary policy, it is important to take into account the composition of disposable income and wealth among different groups. In an economy where rich and poor households hold different types of assets, the effects of monetary policy on wealth inequality are determined by the effect on the relative prices between these assets. For instance, if a reduction in the interest rate results in a rise in stock prices that is larger than the change in house prices, households who hold a higher share of their wealth in stocks gain more than those who have more of their wealth in real estate. In the taxonomy laid out by Colciago et al. (2019), this channel is called *portfolio composition channel*. In addition, a higher rate of inflation, all else equal, lowers the value of debt and assets that are fixed in nominal terms (*unexpected inflation channel*), which by itself benefits households that are more indebted.

A lower nominal interest rate has a direct effect on income inequality by lowering interest income net of payments on debt (*savings redistribution channel*), thus disproportionately benefiting households with a high debt-to-income level. However, monetary policy also has an indirect effect on other income sources. First, firm profits and dividend payments typically increase when monetary policy is more accommodative, which benefits those who hold a lot of wealth in the stock market. Second, a lower interest rate typically increases economic activity, which leads to

[1] See e.g. Yellen (2016), Haldane (2018), Daly (2020), Orr (2020).

[2] See e.g. Piketty (2014) and OECD (2015)

[3] See e.g. Colciago et al. (2019) for an informative survey on the empirical literature measuring the distributional impact of monetary policy.

[4] Measuring inequality is challenging as household-level data often suffer from sample selection issues, top coding of data or from lacking coverage of important income or wealth components. Second, data on income and wealth inequality are typically only available at low frequencies, often yearly, and for a limited period and display little variation from year to year which makes identification difficult. And finally, quantifying which transmission channels are more important requires good quality data on a range of variables at the household level.

higher wages and lower unemployment. As long as the effects on different income sources are not all the same, and the composition of income varies across households, there is an *income composition channel* of monetary policy. Moreover, changes in wages and labor demand do not affect all households equally. A contribution of this paper is to develop a procedure for measuring the distributional impact of an aggregate shock to wages and unemployment, to capture the *earnings heterogeneity channel*. In particular, we take into account how movements between employment states and wage growth rates differ across groups based on age and educational attainment.

Our dataset consists of all tax returns filed in Norway between 1993 and 2015, with detailed observations on components such as wage income and pensions, interest income, dividends, stocks and real estate holdings. We also observe a rich set of household characteristics such as age, education and employment status. This allows us to understand how the impact of monetary policy varies across households, and quantify the relative importance of the different channels described above.

We find that a temporary and unexpected reduction in the nominal policy rate disproportionately benefits households with lower net wealth and disposable income. These poorer households also tend to be younger and to have lower levels of education. A lower interest rate pushes inflation up, leading to a lower real interest rate, which raises both stock and house prices. A large share of Norwegian households are home owners, and for those from the middle to lower end of the net wealth distribution, this gross housing wealth is backed by a large debt burden with floating rates. These households thus benefit more, relatively speaking, than richer ones from higher house prices, and higher inflation that pushes down the real debt burden. Similarly, households in the middle to lower end of the disposable income distribution have a higher debt to income ratio, and thus benefit relatively more from lower interest payments on debt.

The results also show that higher wages and lower unemployment resulting from a temporary and unexpected reduction in the nominal policy rate disproportionately benefit lower income households, reducing inequality in labor income. However, this effect is small in the short run compared to the direct effect on net interest income. The savings redistribution channel, also called the cash-flow channel, is not only the most important transmission channel in the short run but is also the channel which contributes the most to the differential effects across the distribution. Overall, we find that an expansionary monetary policy shock with a peak reduction in the interest rate of one percentage point reduces inequality measures such as the Gini coefficient for disposable income by 0.003 (from 26.1) and the Gini coefficient for net wealth by 0.325 (from 69.3) after one year, which is a quite modest change.

Although it is useful to understand how a monetary policy shock affects the distribution of income and wealth, central banks do not throw random shocks at the economy, but rather react to shocks hitting the economy in order to stabilize cyclical fluctuations in inflation and output. When we come to the systematic monetary policy, the key question is whether central banks aiming to stabilize the macro economy amplify or dampen the distributional effects of the aggregate shocks hitting the economy. In other words, how would the distribution have evolved in the counterfactual scenario with no monetary policy response?

To study this question, we use our macro model to generate the changes in aggregate variables with and without a monetary policy response for two different types of shocks. First, we find that a negative demand shock by itself lowers the income of the poorest and the richest households

the most. The former is due to the fact that real interest payments increase as lower inflation increases the real interest rate. Moreover, the negative demand shock disproportionately lowers labor income for the low-income households. The latter is due to the fact that the negative demand shock lowers dividend payments. As for wealth, the fall in house prices leads to an increase in inequality by primarily affecting households in the lower and middle part of the wealth distribution. By reacting through setting a lower interest rate, the policymaker counteracts the fall in disposable income and wealth for all groups, but particularly for households in the middle and lower parts of the income and wealth distribution.

Second, a negative supply shock itself leads to a higher inflation, which reduces the real interest rate. This leads directly to lower inequality in disposable income by lowering real interest payments on debt, and indirectly to lower wealth inequality primarily via increasing house prices. On the other hand, unemployment rises more for poorer households, but the total effect on labor income is still positive for most groups as real wages increase. Taken together, our simulations indicate that the negative supply shock leads to lower levels of income and wealth inequality when the systematic monetary policy response is absent. Depending on the policymaker's preferences for inflation versus output stabilization, the policy rate might be either increased or reduced. Based on the reaction function used in the simulations, the monetary policy response is to increase the key policy rate, which then dampens the effect on both income and wealth inequality. Overall, we find that systematic monetary policy tends to dampen the cyclical fluctuations in inequality.

Some caveats to our analysis are in order. We focus on the cyclical effects of monetary policy in the short run, taking into account the adjustments made within the first year. Hence, our goal is not to understand whether, and how, monetary policy may have contributed to the rise in inequality seen over the last decades. We also assume that all households face the same price changes within an asset class, such as stocks, and we do not consider portfolio reallocations resulting from aggregate shocks. Our limited horizon approach and the assumption of fixed portfolio allocation limit the scope of our analysis to fully capture the effects of monetary policy on inequality as that requires evaluating the effects over a longer horizon. Moreover, we have focused on two particular scenarios of aggregate shocks labeled "demand" and "supply", which are meant to capture typical business cycle shocks hitting the Norwegian economy. However, each cycle is different and the aggregate responses to other mixes of shocks could vary greatly from our scenarios. Furthermore, as the distribution of portfolio weights, income sources and debt-to-income levels in the population differ greatly between countries, empirical evidence on the distributional effects of monetary policy from one country may not be relevant for others.

The rest of the paper is organized as follows. In section 1.1 we relate our findings to the literature. Section 2 describes the data, section 3 presents the methodology used to quantify the short-term effects of monetary policy, and section 4 provides the empirical results. Finally, section 5 concludes.

1.1 Related literature

Our study is related to a growing literature on the theoretical and empirical interplay between monetary policy and inequality. First of all, recent advances in modelling have uncovered the various channels through which interest rate affects income and wealth distributions across households, and how those distributions may affect the transmission of aggregate shocks, see e.g. Auclert (2019), Kaplan et al. (2018), Gornemann et al. (2016), and Luetticke (2021). In this

paper, we focus only on the effects of monetary policy on the distributions, ignoring the possible second round effects this may have on the aggregate development. This is clearly a simplification, but given our focus on the short run effects, this is less of a concern.

Our paper indicates that two channels are particularly important for understanding the distributional effects of monetary policy for Norwegian households, at least in the short run; the savings redistribution channel for income and the portfolio composition channel for wealth. As Norwegian households are highly indebted, and more than 90 percent of the debt have floating rates, changes in the interest rate have large direct impact on disposable income. Lower income households typically have higher debt-to-income ratios and thus benefit relatively more from a monetary policy easing. However, to understand the development for the very top of the income distribution (top 1%), it is also important to account for the evolution of dividends. As the home ownership rate in Norway is high, housing is the most important asset for most of the wealth distribution, but its share in total wealth is declining with wealth. Thus, the key to explain the effects of monetary policy on wealth inequality is the change in house prices relative to equity prices. This is in line with the findings by Adam and Tzamourani (2016), who argue that the rise in equity prices following expansionary unconventional monetary policy benefits the top 5% of the net wealth distribution while house price growth reduces inequality. The finding that the savings redistribution channel is an important transmission channel is in line with the findings by Cloyne et al. (2020). They use household level data for the US and UK, and show that the aggregate response of consumption to interest rate changes is driven by households with a mortgage.

Doepke and Schneider (2006) quantify the wealth redistribution from moderate inflationary episodes for different groups of households in the Unites States, and find that richer and older households lose while younger and middle-class households gain. Within the time horizon we consider, the "unexpected inflation" channel is found to have very small re-distributional effects for wealth. Looking across the net wealth distribution, all net wealth percentiles are net nominal debtors in Norway (deposits-debt<0). More importantly, our macro scenario predicts that inflation responds very gradually to a monetary policy shock so that the inflation response is very small within the horizon we explore.

Although an expansionary monetary policy leads to higher wages and lower unemployment in aggregate, the effect on labor earnings varies across the income distribution - known as the *earning heterogeneity channel*. Labor incomes of low and middle income households, who are generally younger and less educated households as well, are typically found to be more cyclical and thus are affected more by monetary policy (Heathcote et al. (2010), Coibion et al. (2017), Bunn et al. (2018), and Furceri et al. (2018)). Our paper includes an analysis of business cycle sensitivity of labor income for different groups of households. Using individual data on labor income and labor market transitions from 1993 to 2014, we construct a measure of the business cycle sensitivity of labor income for each individual based on their age, education and current labor market status. We explicitly measure the sensitivity of transitions between employment and non-employment, and the sensitivity of income growth. We find that younger and less educated individuals have more cyclical employment and wage growth. Unlike Coibion et al. (2017) who find that contractionary monetary policy raises labor income at top deciles and reduces labor income at bottom deciles, we find that labor income increases for all deciles in response to an expansionary shock. However, we find that the earning heterogeneity channel is quantitatively quite small in the first year as unemployment and real wages respond gradually to the interest

rate.

To assess the distributional effects of monetary policy, it is important to consider all channels jointly since different channels have both different signs and sizes. More recently, there has been an increase in empirical studies quantifying the total effect of monetary policy shocks on inequality. Broadly speaking, there are two empirical approaches taken in the literature. The first approach uses time series econometric tools and estimates the effect of monetary policy shocks on various measures of income and wealth inequality. This approach is taken by e.g. Mumtaz and Theophilopoulou (2017), Coibion et al. (2017); Guerello (2018); and Furceri et al. (2018) Samarina and Nguyenc (2019).[5] There seems to be a consistent finding that contractionary monetary policy tends to increase labor income inequality, but the effects on total income inequality and wealth inequality seem to vary. Coibion et al. (2017) find that contractionary monetary policy increases total income inequality in the United States, and that monetary policy shocks account for a non-trivial share of the cyclical fluctuations in inequality. Guerello (2018) and Samarina and Nguyenc (2019) analyze the distributional effects for the Euro zone countries, and also find that contractionary monetary policy raises inequality. Samarina and Nguyenc (2019) argue that the "macro channel" via wages and employment and the "financial" channel via asset prices and returns have opposing effects on inequality, but they find that the "macro channel" dominates. Using a panel of 32 advanced and emerging countries, Furceri et al. (2018) also find that an unexpected increase in the policy rate increases income inequality. Unlike most empirical contributions, they also study the effect of the systematic component of monetary policy and find that an increase in policy rates driven by an increase in growth and inflation is associated with lower inequality. It is worth noting that the effect of the systematic component cannot be interpreted as a causal effect, but merely the effect of improved economic conditions on inequality. Our simulation methodology allows us to compare the outcome with and without a systematic monetary policy response, and interpret the results as causal effects. Finally, another closely related paper is Andersen et al. (2021) that studies the effects of monetary policy on income, wealth and consumption inequality using administrative household-level data covering the whole population in Denmark from 1987 to 2014. They use the fixed exchange rate regime in Denmark as a source of exogenous variation in monetary policy. They find that the gains from loose monetary policy in terms of disposable income, wealth and consumption are monotonically increasing in the income level and those gains are mostly related to non-labor channels of monetary policy. The methodology followed in their paper is different from ours as we rely on macro scenarios from a DSGE model estimated on data for Norway while they empirically exploit the currency peg in Denmark.

The second approach, which is also the approach pursued in this paper, studies the distributional effects of monetary policy by decomposing the effects of aggregate shocks at the micro level using survey data for income and wealth. The main advantage of this approach is that it is straight forward to quantify the relative importance of different channels through which monetary policy has distributional effects, and to consider those effects between many different groups in the population. As inequality measures typically change little from year to year and the sample period is fairly short, it is challenging to make good inference using standard econometric techniques. The simulation strategy overcomes this problem, but comes at the cost of lacking confidence bands. This two-stage simulation method is used by Bunn et al. (2018) and Casiraghi

[5]See e.g. Colciago et al. (2019) for an informative survey on the empirical literature measuring the distributional impact of monetary policy.

et al. (2018).

Bunn et al. (2018) estimate the distributional impacts of UK monetary policy between 2008 and 2014, using survey data on income and wealth. The sample period considered includes both the large cuts in interest rates and the quantitative easing program launched by the Bank of England. They find that monetary policy has disproportionately benefited the income of the young by lowering unemployment and has dampened the fall in wages that would have taken place without the easing of policy. On the other hand, they find that older households have benefited the most in terms of wealth as the accommodative monetary policy dampened the fall in real asset prices. Casiraghi et al. (2018) focus on the distributional effects of non-standard monetary policy using micro data for Italian households, and find that monetary policy measures have a negligible overall effect on inequality in Italy.

We add to the existing literature by quantifying the distributional impact of a monetary policy shock for Norwegian households, but also by providing new insights on the role of systematic monetary policy in stabilizing inequality over the business cycle. Moreover, we make use of more detailed micro data with better coverage. First, our data cover the universe of Norwegian citizens, most data are third party reported, and there is no top-coding of the data. This gives us a good measure of income and wealth for the whole distribution.[6] Second, we have detailed data on assets and income sources which allow us to decompose the aggregate effects at a fine level. Finally, combining this with detailed data on labor market transitions, we can construct a good measure of the business cycle sensitivity of labor income for each household to fully capture the *earnings heterogeneity channel*.

2 Data

To quantify the effect of monetary policy on households' income and wealth inequality, we use observations on all Norwegians' income and wealth. As the components of income and wealth react differently to monetary policy, our analysis requires detailed household level data on all sources of income, debt and wealth. Moreover, we want to allow for heterogeneous effects on job loss risk and wage growth across households. We therefore need information on demographics such as age and education as well as employment history, which is important in predicting both individual job loss risk and wage growth. We obtain this information for the universe of Norwegians aged 16 and above from administrative data between 1993 and 2015, made available by Statistics Norway. Using a unique household identifier, we can link household members.[7] In 2014, which is the reference year for our analysis, the sample consists of about 2,1 million households. Importantly for our purpose, this data has no top coding of income nor wealth, and the only attrition is due to migration and death.[8]

[6] As many of the richest hold a larger proportion of assets in non listed firms, which are measured according to accounting principles, there is a tendency to undervalue the market values of wealth of the richest. As the "true" share of net wealth invested in stocks most likely is higher for this group, we will predict a too low impact of stock prices on net wealth for this group. For dividend income, this is less of a concern as an undervaluation of the stock value will lead us to overestimate the dividend ratio (dividend/stock value) which in the end will give us the correct impact on dividend payments and the correct placement in the distribution.

[7] We focus on a financial unit, and limit our definition of households to families that contain no more than two generations. We exclude student households from the analysis, defined as either the family head or his/hers spouse/cohabitant receiving a student scholarship.

[8] Most information is third-party reported. Although asset values are third-party reported, the tax value of self-owned businesses and other non-listed stocks and bonds are based on accounting principles, and are often undervalued. Because the richest individuals hold more unregistered assets than other people, our data is likely to

Our data set comes from several sources. Detailed information on income, debt and wealth is from the Tax Registry. This data set includes annually reported labor income, private pension income, all government transfers, capital income and taxes. Moreover, it provides information on debt and all real and financial assets including deposits, stocks and bonds, houses, holiday homes, cars and boats.[9] Although the data is very detailed for most asset classes, we miss information on pension wealth. The Tax Registry contains no information on state pension rights or private pension wealth, except for voluntary individual pension accounts which we include. The distribution of public pension rights is only affected by the cyclical changes considered in this paper if these changes have long lasting effects on employment. Since we consider relatively small and short-lived shocks, we expect this effect to be minor. The value of future private pension claims could be affected for some types of pension agreements. Again, as we focus on smaller short lived shocks, this effect should be small for most households.[10]

Information on birth year, the number of children and their age, and the household identifier are from the National Registry.[11] All household aggregates are adjusted using the EU household equivalent scale.[12] Education is measured as the highest obtained education level and is obtained from the National Education Database (NUDB). The education level is a six digit number specifying both the type of profession and the degree. In our analysis, we only consider 4 levels: "no High School diploma", "High School graduate", "University, lower" and "University, higher".[13] We define a household's age and level of education as those of its head.

To measure the indirect effects of monetary policy on transitions between employment and non-employment, we use data from the employment register. This data set provides information on all job relations and all registered unemployment spells, including start and end dates. By combining information on labor income and labor market status, we define all individuals as either employed or non-employed. An individual is defined as employed in any given year if she is not registered as unemployed during the year *and* is registered with a job relation *or* has labor income above half the median income that year.[14] Individuals above 70 years old receiving pension income are assumed to be non-employed if they do not have a job relation that year. The rest are defined as non-employed.

3 Methodology

We study the distributional impact of monetary policy using a bottom up approach. In the following sections, we explain which effects we particularly seek to capture, how we estimate the macroeconomic effects of monetary policy, and how these aggregate macroeconomic movements are distributed across the population of households in Norway in terms of income and wealth

understate wealth inequality.

[9] We adjust all tax values to reflect the market value of assets.

[10] Although the impact on future pension claims most likely is rather modest it could still affect the relative change in net wealth as pensions as a share of net wealth varies across households. We leave for future research to explore this effect.

[11] Statistics Norway has modified the household identifier to include more cohabiting couples.

[12] The household head has a weight of one, additional adults 0.7 and each child 0.5. The equivalence scale is well suited for adjusting income across household of different size, and we apply the same scale for wealth.

[13] The category "University lower" includes those individuals who graduated from a college or university with a degree lasting up to four years. Similarly, the category "University higher" includes individuals with a degree lasting more than four years in total, including master's degrees and doctoral degrees.

[14] We use this definition because some individuals have a job that is not in the official registry, for instance because they are self-employed.

inequality.

3.1 From macro shocks to household inequality

Aggregate changes in the macro economy do not affect all households in the same way. The first, and the most obvious, reason is that households vary in the type of assets they own and in their sources of income. Consider the effect of a reduction in the nominal policy rate by the central bank in such a way that the real interest rate also falls.[15] On the income side, the direct result of this policy change is to increase the income (net of interest rate payments) of households with net debt while reducing the income of households with net savings. In the taxonomy laid out by Colciago et al. (2019), this is the *savings redistribution channel* of monetary policy. However, a lower policy rate also tends to stimulate production and labor demand, thus driving up wages, while potentially increasing dividend payments from equity holdings. As long as these effects are not all the same, and the composition of income varies across households, there is an *income composition channel* of monetary policy. In addition, it has been documented (see e.g. Delaney and Devereux (2019) and the references therein) that younger workers and those with less education face more labor market volatility. As explained below, we estimate how the cyclicality of labor market attachment and wages vary with education and age, allowing us to capture the *earnings heterogeneity channel* of monetary policy.

On the wealth side, a lower interest rate typically drives up inflation, thus all else equal, reducing the real value of non-indexed assets such as bank deposits (the *unexpected inflation channel*). At the same time, certain assets such as real estate and stocks might appreciate due to increased demand. Households who disproportionately hold assets that appreciate the most benefit more relative to other households (the *portfolio composition channel*). Households might also choose to rebalance their portfolios in response to movements in relative asset prices. This channel would only affect our results if monetary policy affected portfolio composition in different ways for poor and rich households within our horizon of roughly one year, and we do not attempt to identify it in our data.

We estimate the household-level changes in income and wealth due to monetary policy in two steps. First, we estimate how monetary policy affects certain key macroeconomic variables. Second, we map these aggregate movements to changes for individual households and study the distributional effects. Using the principles outlined above, households are affected differentially based on their holdings of assets, their income sources, and their demographic characteristics.

3.2 Aggregate shocks

In the analysis below, we consider changes in six aggregate variables: the nominal interest rate, inflation, real house prices, real stock prices, real wages, and the non-employment rate. We are not only interested in the response of these variables to a monetary policy shock but also how systematic monetary policy affects these variables over the business cycle. To quantify the responses, we use Norges Bank's core macro model NEMO, a large scale DSGE model estimated for the Norwegian economy.[16] We use the evolution of real price of capital in the model to pin

[15] Throughout the paper, we will focus on changes in real income and real wealth, ignoring the potential differential effect for liquidity constraint households and others.

[16] See Kravik and Mimir (2019) for a detailed description of the model and the estimation procedure.

down changes in stock prices.[17] The non-employment rate are not directly in the model, but we assume that it is linked to the output gap via the Okun's law and estimate the parameter.[18]

Figure 1 shows the impulse responses of our key macro variables to an expansionary monetary policy shock.[19] The shock is scaled to yield a peak decline of 1 percentage points in the nominal policy rate. A lower interest rate raises prices and real wages, and leads to higher output and employment. The peak response in output and house prices occur after one year, whereas inflation and wages increases more gradually and peak after two years. For the reasons described below, we focus on changes in annual income and wealth within the first year. The variables affecting components of income are averaged over the first four quarters after impact, while wealth effects are measured in the fourth quarter.

To quantify the effect on inequality of the systematic monetary policy over the business cycle, we consider shocks typically hitting the Norwegian economy, which are identified by our estimated DSGE model, NEMO. Based on those typical business cycle shocks identified within NEMO, we generate two scenarios which we label "demand shock" and "supply shock", where both scenarios consist of a group of shocks. Since NEMO features 26 structural shocks hitting many different sectors in Norway and affecting different intratemporal and intertemporal margins of adjustment, it is difficult to find a pure "text-book" demand or supply shock. To overcome this issue, we simply group all demand or all supply shocks that are used to create "demand" and "supply" scenarios, respectively. Depending on the scenario, we either use many one-standard-deviation shocks or a large shock in the magnitude of many standard deviations. In particular, in the case of the demand scenario, we use a large positive shock to savings, which reduces the aggregate domestic demand as well as one-standard-deviation negative shocks to global demand, trading partners' output and their import demand. In order to mitigate the impact of a reduction in the policy rate on the real exchange rate and hence on the imported and the aggregate inflation, we also use a one-standard-deviation negative shock to external risk premium. In the case of the supply scenario, we use one-standard deviation negative shocks to temporary productivity, marginal efficiency of investment, price and wage markups, and oil prices. In both scenarios, we compute the developments in relevant macro variables with and without an active monetary policy. For our purposes, active monetary policy is a policy rule that replicates the optimal monetary policy under discretion in the model. Due to the Taylor principle that governs the determinacy of equilibrium in standard New Keynesian models, it is not straightforward to implement a policy rule that involves not responding to shocks. We follow the approach taken by Bunn et al. (2018) and implement the scenarios without monetary policy by applying a sequence of unanticipated monetary policy shocks.[20]

Table 1 shows the response of the variables of interest to a negative demand and a negative supply shock, respectively, with and without a monetary policy response.[21] The negative demand

[17] VAR evidence (see e.g. Bjørnland (2009)) suggest that the stock price increase is somewhat stronger compared to what we have, but also that there is great uncertainty about the effect. To have a reasonable trade off between not adjusting too much outside the model and having a more realistic response of stock prices, we scale up the responses from NEMO by 2.5.

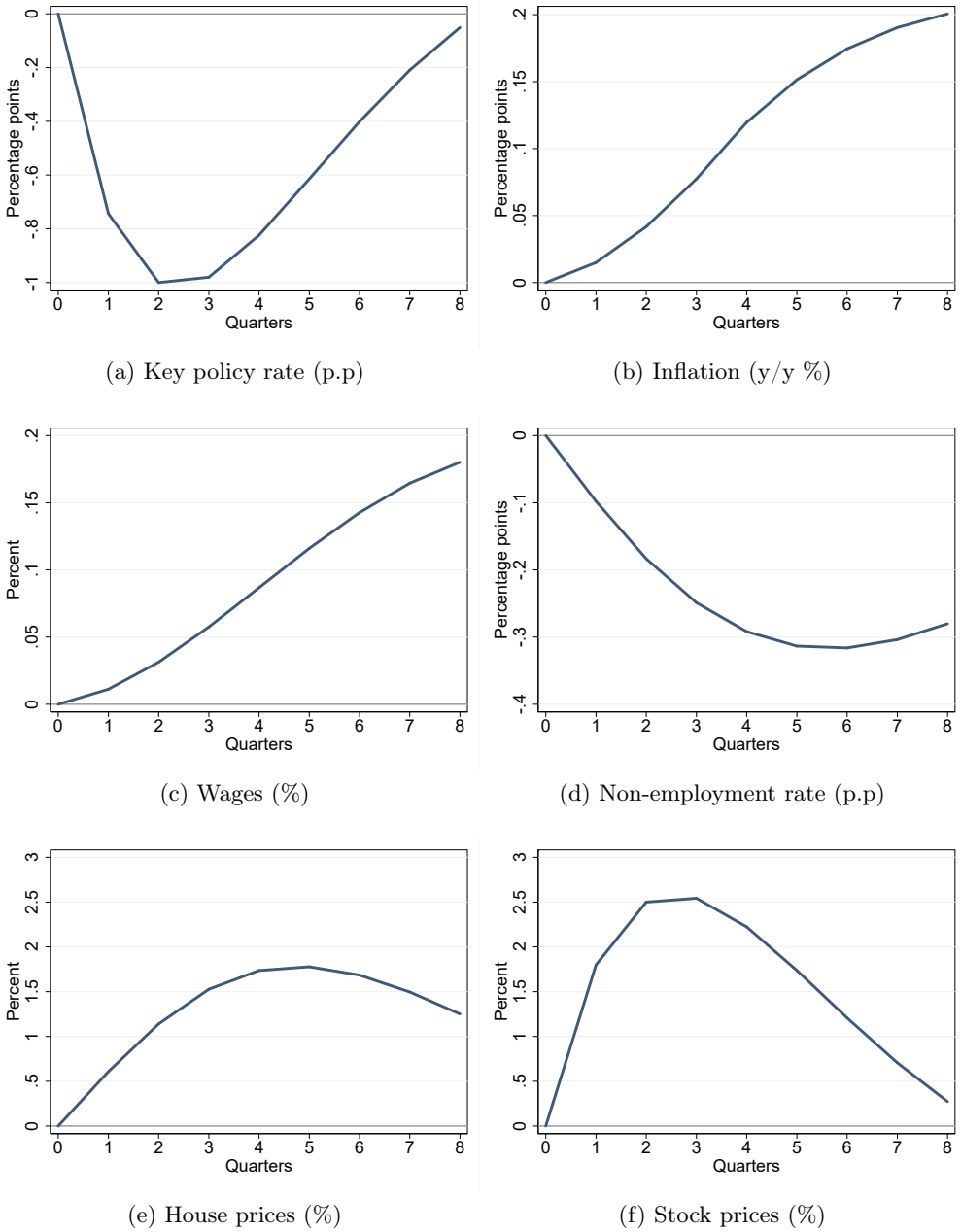
[18] The Okun's law parameter used for non-employment is -0.9, which is based on an estimation of annual (1994-2014) aggregate non-employment, measured from micro data, on Norges Bank's output gap.

[19] As the model is solved by linearization around steady-state, positive and negative shocks have symmetric effects.

[20] The method implies that agents expect the policy rate to change according to the monetary policy rule, but are surprised each time it does not.

[21] The evolution of aggregate variables in the demand and supply shock scenarios are shown in appendix B.

Figure 1: Aggregate responses to a monetary policy shock. Deviation from steady state



(a) Key policy rate (p.p)

(b) Inflation (y/y %)

(c) Wages (%)

(d) Non-employment rate (p.p)

(e) House prices (%)

(f) Stock prices (%)

Notes: House prices, stock prices and wages are real variables. The non-employment rate is not directly from the model, but is obtained using an OKUN's law parameter of -0.9.

shock leads to lower economic activity and a reduction in prices and real wages. However, if the central bank reacts by lowering the policy rate, it will dampen the fall in output and real wages but inflation and house prices increase somewhat. Following a negative supply shock, real economic activity falls, but prices and wages increase. The central bank reacts by increasing the policy rate to bring inflation down. The increased policy rate also dampens the increase in real wages and house prices, but depresses economic activity further.

Table 1: Development in key variables over the first year with an without a monetary policy response

	Policy rate	Real rate	Non-empl. rate	Wages	Inflation, Q4	Stock prices, avg.	Stock prices, Q4	House prices, Q4
"**Monetary policy shock**"								
	−0.89 pp.	−1.01 pp.	−0.21 %	0.05 %	0.12 pp.	2.27 %	2.22 %	1.74 %
"**Demand shock**"								
Without	0 pp.	0.10 pp.	0.80 %	−0.16 %	−0.10 pp.	−2.60 %	−0.65 %	−4.11 %
With	−0.49 pp.	−0.50 pp.	0.62 %	−0.12 %	0.01 pp.	−0.43 %	1.88 %	−2.56 %
"**Supply shock**"								
Without	0 pp.	−0.36 pp.	0.16 %	0.13 %	0.36 pp.	1.33 %	1.21 %	1.01 %
With	0.19 pp.	−0.12 pp.	0.23 %	0.11 %	0.31 pp	0.53 %	0.36 %	0.40 %

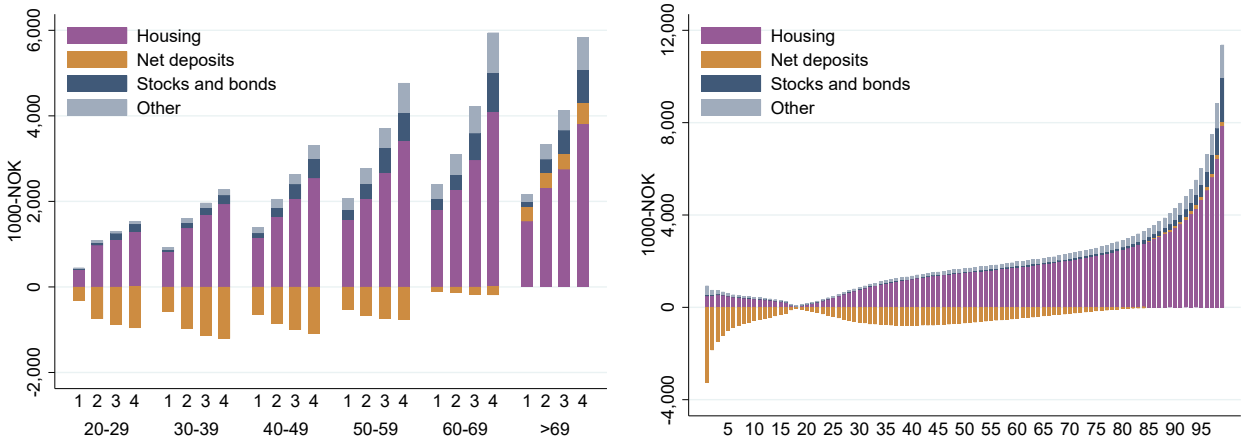
Notes: Average deviation from steady state first four quarters, except where denoted "Q4" which are deviation after four quarters. House prices, stock prices and wages are real variables. For a more detailed description of the shocks, see text.

3.3 Household wealth

We divide a household's net wealth into five components: net deposits, equity, housing, other financial assets, and other real assets. All variables are measured in real terms, and we assume that all households experience the same price changes. The value of equity is assumed to move according to aggregate stock prices.[22] The value of households' holdings of housing wealth follows the real house price. Net deposits are measured as bank deposits net of debt. In real terms, these fall with the rate of inflation, so any change in nominal interest payments are treated as a change in income, not in wealth.[23] Other financial assets are assumed to be mostly fixed in nominal terms within our one year horizon, while other real assets are fixed in real terms. Because other real and financial assets are small components of total wealth and are relatively equally distributed throughout the wealth distribution, these assumptions do not matter much for our results.

Figure 2 (a) displays the distribution of average net wealth across groups based on the age and education level of the household head. Figure 2 (b) similarly shows the distribution of household wealth components across percentiles of net wealth. While most equity is held at the top of the distribution, housing wealth is more equally distributed. For younger and less wealthy households, this housing is heavily mortgaged, while older and wealthier households hold little debt. In addition, the households with lowest *net* wealth are not those with lowest *gross* wealth. 18 percent of the households have negative net wealth. Although some households indeed have negative net wealth, there is reason to suspect that this also comes from too low valuation of non-listed stocks, holiday homes and other properties such as farms and forests.

Figure 2: Distribution of net wealth



(a) Wealth by age and education

(b) Wealth by percentile net wealth

Notes: The level of education is 1 "Not finished high school" 2 "High school diploma" 3 "University, lower" 4 "University, higher". "Other" includes "other financial assets" and "other real assets". The top percentile of wealth holds on average 31 mill NOK, but is excluded for better visualization. Households' net wealth are adjusted using the EU household equivalent scale.

[22] Mutual funds include also funds which are invested abroad but sold by domestic firms. Due to lack of information on the assets included in the mutual funds, we treat them as domestic stock. For most households owning mutual funds, this is a very small fraction of net wealth and should not impact our results.

[23] The implicit assumption is that households consume any additional interest income, while they make additional payments on debt by reducing consumption. It is conceptually possible to, for instance, assume that parts of additional payments are made out of new debt. The most important thing is that we avoid double counting interest on net deposits as both income and wealth.

3.4 Household income

Our measure of disposable income is after-tax household income net of interest payments on debt. We divide this income into six components: labor income and labor-related transfers, pensions, other government transfers, net interest income, dividends, and other capital income including imputed income from owner-occupied residences. Since the changes to capital income are the most straightforward, we treat them first.

3.4.1 Capital income

We assume that dividend payments from equity holdings vary proportionally with the evolution of the value of equity holdings, which are pinned down by the change in stock prices from the macro model.[24] The implicit assumption is that firms pay out a constant fraction of their value each year as dividends, but the fraction can vary between firms.[25] To account for the varying dividend payout ratios across equity holdings, we estimate household-level dividend payout ratios. Let the equity position (value) of household i at the end of year t be given by $A_{i,t}$, and let $D_{i,t}$ denote the dividends paid out to household i throughout year t. We estimate the dividend rate for household i by

$$\hat{r_{A,i,t}} = \frac{D_{i,t}}{\omega A_{i,t-1} + (1-\omega)A_{i,t}}, \tag{1}$$

where ω is the fraction of overall dividend payments that are paid out in the first half of the year, which we get from aggregate statistics. To avoid outliers, we censor the estimated rate at 15%, which corresponds to the 99 percentile. [26] The after-shock dividend income is then computed as the households specific dividend rate multiplied with the new value of equity.

In order to derive the new net interest income, we take the stock of debt and deposits at the end of 2014 as our starting point and compute group specific interest rates. We first estimate household-level implied interest rates separately on gross bank deposits and on debt using the same strategy as for the dividend rate and setting $\omega = 0.5$. We then compute the average deposit and debt rates within groups, excluding the top and bottom 5 percent. The groups are based on age (six levels), education (four levels) and the deposit/debt decile within the age-education group. We assume full pass-through of the policy rate to interest rates paid on both of these components, except that interest rates are not allowed to go below zero.[27]

To have a fair comparison between renters and self-owners, we need to account for the income the household could have received had they rented out their house to a tenant. Statistics Norway estimates the value of owner-occupied housing services in the National Accounts as the rental price for all owner-occupied residences, less expenses for maintenance and insurance, based on a representative sample of renter-occupied housing units. We follow Eika et al. (2020) and distribute the aggregate value across households according to each household's share of the total

[24] See figure 1A in appendix A which show strong co-movement between dividend payments and stock prices.

[25] Although we do observe dividend income in the data, we do not make use of this directly as households might buy and sell stocks in the course of a year. Thus, reported dividend payments do not accurately capture the end-of-year value of stocks and hence not the distribution of dividends that would result from the observed distribution of equity holdings.

[26] Households with a positive stock holding i period t, but with no stocks last period ($A_{i,t-1} = 0$), are assigned a group specific dividend rate based on: age (six levels), education (four levels) and the stock value decile within the age-education group.

[27] The deposits rates are increasing in the level of deposits, but varies little between age and education groups. The interest rate on debt is increasing in age, and decreasing in debt level and education. The implied debt rates range from 1.6% to 9.3%, whereas the deposit rates varies between 0.5% and 3.5%

value of primary residences. In response to shocks, we assume that the value of owner-occupied housing services is constant in real terms. This is motivated both by institutional constraints and empirical findings for the rental rate. By law, tenant contract should last for at least three years and the annual increase in rent cannot exceed the increase in the consumer price index. This is also supported by the data, where changes in the rental price is very similar to changes in the consumer price index and less similar to the evolution of house prices.[28]

Other capital income, which includes taxable rental income, is assumed to be constant in real terms in response to the macroeconomic shocks we consider.

3.4.2 Labor income and government transfers

We define labor income as income derived from work and government transfers that are directly tied to a person's labor market participation.[29] We consider two effects of monetary policy on labor income. First, a lower interest rate might prevent employed people from becoming unemployed or exit the labor force, and it might induce more non-employed people to enter employment. Since labor income is generally higher for those who are employed, this *employment effect* increases aggregate labor income. Second, a lower interest rate boosts wages for those who are employed, and potentially also for those who are not, generating an *income growth effect*. For instance, a person's labor market income might fall in a recession because she lost her job, or because wages fall for those who are employed. From the macro model, we obtain the changes in aggregate wages and the aggregate unemployment rate. The challenge is to distribute these aggregate changes across households, as there is potentially large heterogeneity in how households are exposed to aggregate shocks. Figures 3 and 4 show that the cyclicality of labor income varies widely across groups of households. Younger individuals and those with lower levels of education not only have higher *average* rates of unemployment and labor income growth, but they also experience more volatility over time. Compared to those who are older and more highly educated, their labor income is more pro-cyclical and should be more affected by shocks.

In order to account for the heterogeneity in exposure to aggregate shocks, we estimate how changes in labor income at the macro level influence households based on their demographic characteristics. We conduct the analysis at the individual level before aggregating into households. Every person over the age of 20 is assigned to a demographic group based on membership in six age groups and four groups based on the highest level of education achieved in the year considered.[30]

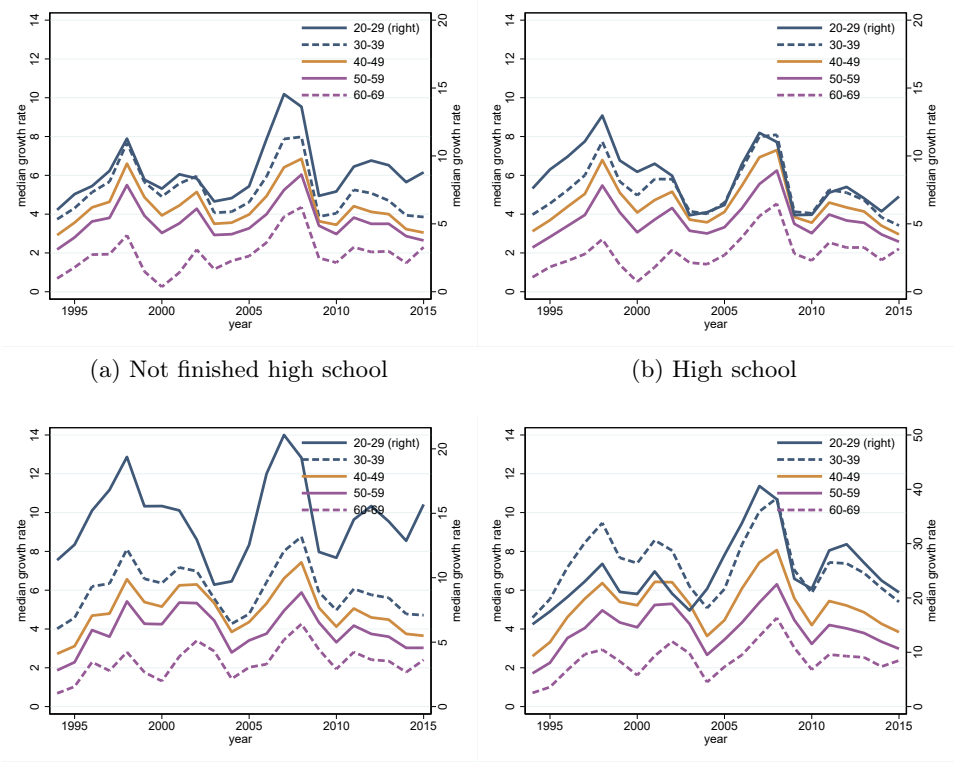
We assume that labor market status (employed or non-employed) follows a Markov chain with transition probabilities that vary across demographic groups and time. Between two years, a person can then be characterised by her demographic group (e.g. $30-39$ years old with a high school degree) and which labor market transition she makes (e.g. employed to non-employed). Since there are $6 \times 5 = 30$ demographic groups and four possible labor transitions, we have a total of $30 \times 4 = 120$ groups. As shown in appendix A, we can then disaggregate exactly both the yearly aggregate growth rate of labor income relative to mean, and the change in the fraction of people

[28] See appendix A for more information.

[29] The most important ones of these transfers are unemployment benefits and payments for sick leave and parental leave.

[30] The age groups are: $20-29$, $30-39$, $40-49$, $50-59$, $60-69$, and ≥ 70. The education groups are: less than high school, high school, university with bachelor's degree or less, university degree above bachelor's degree (typically, master's degree og PhD).

Figure 3: Median growth in labor income for employed people, by age and level of education.



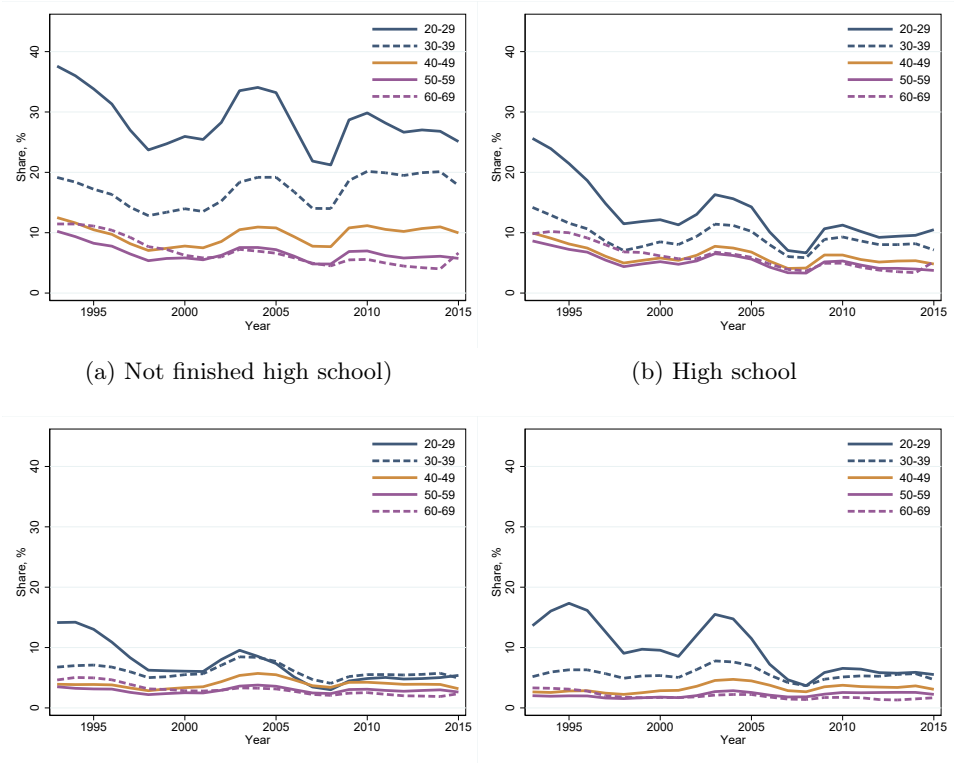
(a) Not finished high school

(b) High school

(c) University, lower

(d) University, higher)

Figure 4: Share unemployed within year, by age and level of education.



(a) Not finished high school)

(b) High school

(c) University, lower

(d) University, higher)

who are employed, into group-level contributions. We compute these group-level contributions using individual level data for the years 1993 to 2015. This allows us to see for instance how

Table 2: Predicted increase in non-employment rate (p.p.) by age and level of education when the aggregate non-employment rate increases by one percentage point.

Education/Age	20-29	30-39	40-49	50-59	60-69
< High School	4.34	3.61	1.94	0.95	0.16
High School	3.31	1.75	0.82	0.60	0.21
University, lower	1.33	0.74	0.40	0.35	0.11
University, higher	0.73	0.41	0.23	0.18	0.08

Table 3: Predicted increase in labor income growth rate (p.p.) by age and level of education when the aggregate labor income growth rate increases by one percentage point.

Education/Age	20-29	30-39	40-49	50-59	60-69
< High School	2.30	3.18	2.24	1.27	0.36
High School	1.55	1.34	0.63	0.42	0.44
University, lower	1.17	0.84	0.54	0.44	0.41
University, higher	0.43	0.56	0.45	0.55	0.44

Notes: Increase in labor income for individuals that are employed in both year t-1 and year t.

much people in their 30s without a high school degree who lost their jobs contributed to the aggregate fall in income from 2008 to 2009.

We assume that the group-level contributions to the aggregate changes follow their historical pattern. The appendix demonstrates that a natural way to aggregate the yearly contributions of the groups is to weigh each year by its contribution to the overall variance, so that years with larger deviations from trend are more important. This allows us to predict how much the labor market transition rates and income growth rates move for each demographic group following given movements in the aggregate employment rate and labor income growth rate. The predicted increase in non-employment for each age-education group following a one percentage point increase in the aggregate non-employment rate is given in table 2. We see that these predicted rates generally fall with both age and human capital level. A similar pattern is found for the predicted increase in labor income growth for individuals who stay employed, shown in table 3.

In order to implement this procedure at the micro level, we first use estimates of the Markov chain for labor market status to predict the probability that a person will be either employed or non-employed next year, both with and without macroeconomic shocks. These probabilities are based on the person's demographic characteristics and current labor market status. Then we randomly draw people into employment and non-employment. The no-shock scenario serves as the benchmark relative to which we measure the effect of shocks.[31]

Finally, the remaining government transfers are treated as follows. By law, payments from public pension plans in Norway are adjusted by the average growth rate of labor income subtracted

[31]The change in labor income following a change in status are, as described above, based on historical averages and are shown in appendix A.

0.075 percentage points. Government transfers that are neither pensions nor tied to labor market status are generally adjusted rarely and not cyclically. For that reason, we keep their nominal value fixed in our analysis.

3.4.3 Taxes

The tax system contributes to lower inequality by redistributing from rich to poor. While we do not consider any endogenous responses of fiscal policy to changes in monetary policy, adjusting for taxes gets us closer to measures of disposable income that matter for welfare. Our data set contains information on total taxes paid (excluding local property taxes) and the wealth tax. Based on the 2014 tax code, we compute after-tax measures of each income component.[32]

Generally – excluding some smaller tax free components – income above a standard deduction is taxed at a flat rate of 27%. Interest payments on debt are subtracted from this measure of total income before it is taxed, which all else equal increases post-tax net interest income.[33] In addition, labor income and transfers, including pensions, are taxed in brackets on top of the fixed rate.[34] We use households' municipality of residence to calculate the local property tax, which is used to compute after-tax income from owner-occupied residences. Wealth subtracted a standard deduction is taxed at a flat rate of 1%. In this measure of total wealth, housing wealth is only valued at 25% of its estimated market value. The wealth tax is split on deposits, housing and other financial and real assets according to the each components share of total taxable wealth. In the analysis, we deduct the wealth tax from wealth and not from income, which we do with the other taxes. We do this to avoid that households with temporary low income and very large wealth – and thus high wealth tax – constitutes a large fraction of the lower part of the income distribution.

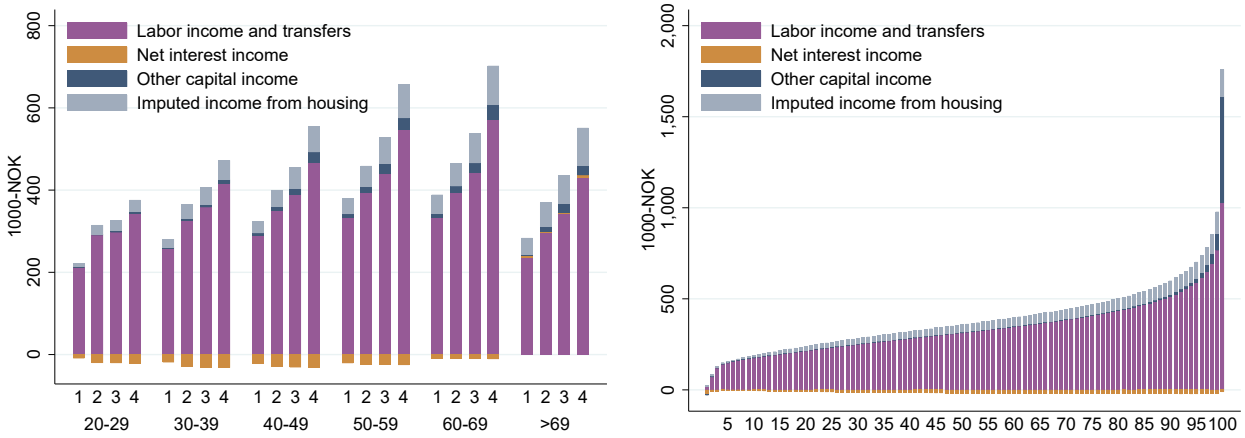
Figure 5 shows the distribution of disposable after-tax income by age and education, and by percentiles of disposable income, respectively. Since we are not able to separately calculate taxes on labor income, pensions and other government transfers, we combine all categories of non-capital income, which make up the bulk of disposable income for almost all households. Older, more educated and richer households get more of their income from dividends and interest, but labor income and transfers are the biggest components even for the top one percent. On the other hand, interest payments on debt are more important for middle aged households and those in the middle of the income distribution.

[32] Due to lack of information, we do not account for special tax deductions such as e.g. deductions due to travelling or gifts to non-profit organizations. Gains from selling financial instruments are also taxable and losses are deductable, but due to limited information we do not account for these taxes/deductions.

[33] By itself, this interest deduction makes the savings redistribution channel more important relative to the indirect channels.

[34] These rates are 9% and 12%.

Figure 5: Distribution of disposable income



(a) Income by age and education

(b) Income by percentile net wealth

Notes: The level of education is 1 "Not finished high school" 2 "High school diploma" 3 "University, lower" 4 "University, higher". Households' disposable income are adjusted using the EU household equivalent scale.

4 Results

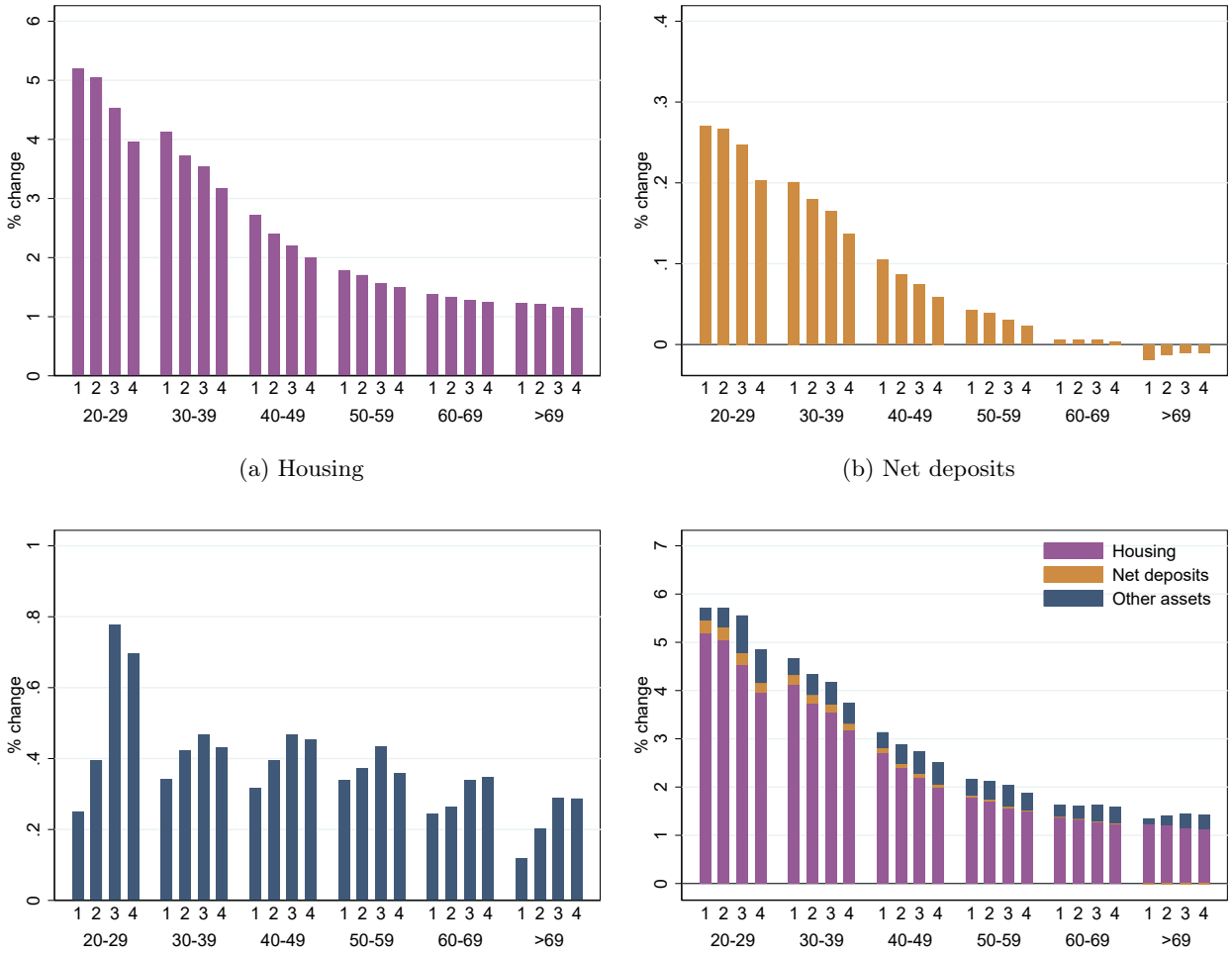
In section 3, we showed the aggregate responses of our key macro variables and described how we map them into individual households' income and wealth. In this section, we put it all together and quantify how different households are affected by the macro scenarios considered. First, we describe how a monetary policy shock affects the distribution of income and wealth. This is a useful starting point to show the distributional effects of changes in the interest rate. Many empirical analyses in the literature stop there. We are, however, also interested in how systematic monetary policy, with a goal to stabilize cyclical fluctuations in inflation and output, affects different households. Thus, we seek to understand how typical business cycle shocks affect the distributions of income and wealth, and how the systematic monetary policy response amplifies or dampens those distributional changes. We focus on two scenarios, which we label the "demand shock" and the "supply shock".

4.1 Expansionary monetary policy shock

As described in section 3.2, we consider an expansionary monetary policy shock and evaluate the distributional effects after one year. First, we evaluate how the average net wealth and disposable income across different demographic groups are affected. Figure 6 (a)-(d) shows the percent change in average housing wealth, net deposits and other assets relative to net wealth, by age and education groups. Increased house prices disproportionately benefit the young and the less educated as they hold a larger share of their wealth in housing. Increased inflation benefits net debtors, while net creditors lose, and again the young gain the most relative to their initial net wealth. However, the inflation effect is very small compared to the other effects. The effect on "other real and financial assets" is mainly due to the rise in stock prices, which increases the value of equity. Most groups gain modestly, but higher educated households gain more because they have more of their wealth in the stock market. Perhaps surprisingly, the youngest age group benefits most in relative terms. While their equity holdings are smallest as a proportion of *gross* wealth, due to a large debt burden, it is largest as a proportion of *net* wealth. As summarized in

figure 6 (d) the average distributional effects of a monetary policy shock on households net wealth mainly transmit via house prices, with younger and less educated households gaining the most.

Figure 6: Effect on average net wealth from a monetary policy shock, by education and age groups



(a) Housing

(b) Net deposits

(c) Other real and financial assets

(d) Net wealth

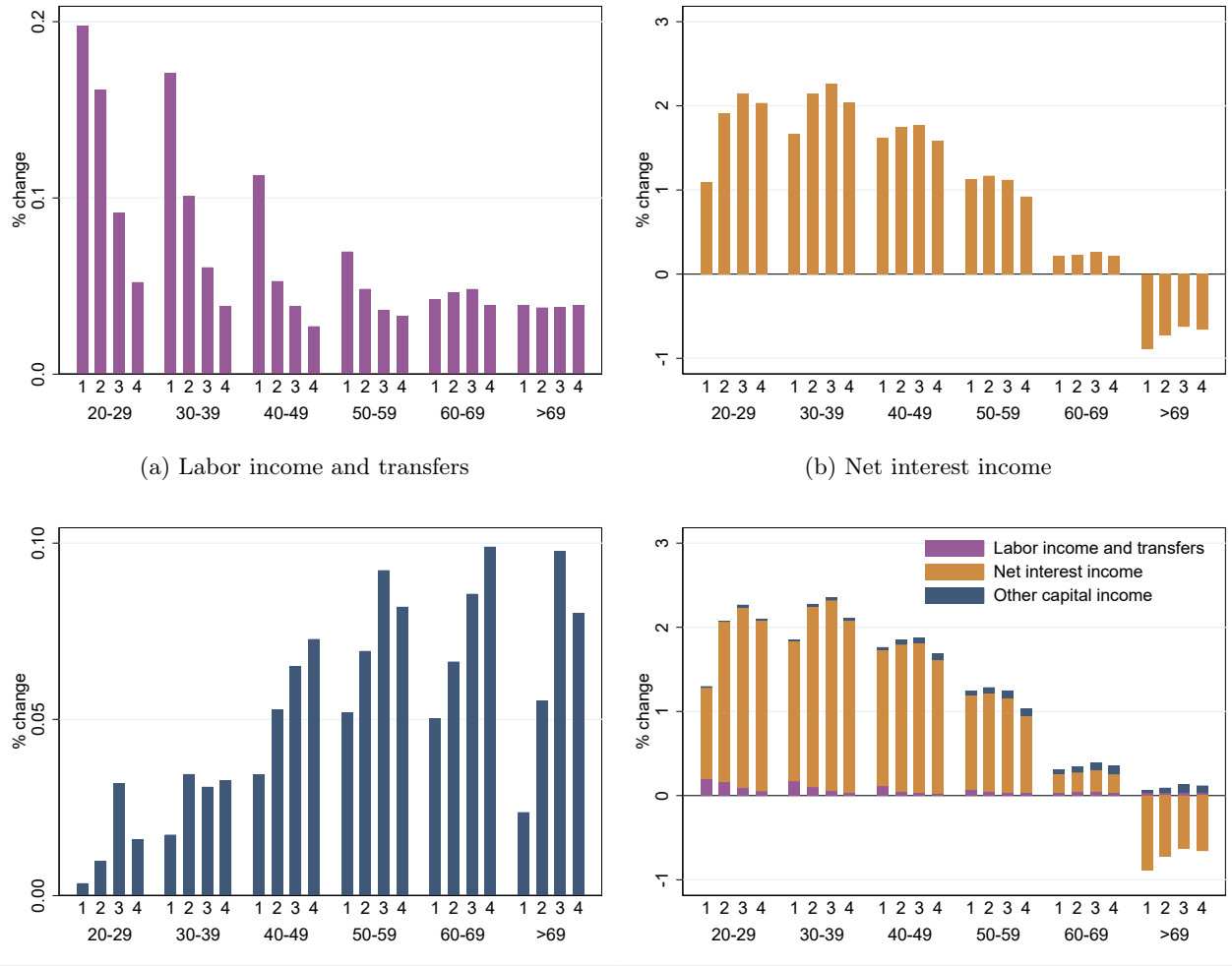
Notes: The figures show the responses of group-averages of net wealth to the monetary policy shock described in section 3.2 for each asset relative to total net wealth. Any changes in wealth tax are allocated proportionally to the asset. The level of education is 1 "Less than High School" 2 "High School diploma" 3 "University, lower" 4 "University, higher"

The effects on disposable income, averaged within age and education groups, are shown in figure 7 (a)-(d). A more expansionary monetary policy increases labor income through higher wages and lower non-employment. On average, all groups gain from this, including retired households whose public pensions are linked to the aggregate wage growth. As the young and less educated have more cyclical labor market attachment and wages, they benefit the most from the expansionary policy in terms of labor income, but the effect relative to disposable income is small for all groups. It is worth mentioning that our approach underestimates the effect via labor income as it takes more time before wages and employment are affected, and because effects via wages and particularly employment may have long-lasting effects on labor income.[35] Therefore, the relative effects on the permanent income across groups are probably similar to the ones shown, but the magnitude is most likely substantially larger. The effect on other capital income, such as

[35]The long lasting effects omitted here also includes effects on future pension rights.

dividend payments, is higher for older and more educated household, but are negligible for all groups. The dominant channel is the direct effect of monetary policy on households' net interest income, often referred to as the *savings redistribution channel* or *cash-flow channel*. On average, all groups except the oldest, hold more debt than deposits and hence they gain from the reduction in interest rate payments. Younger households with at least a High School degree gain the most, with the reduction in after-tax interest rate expenses amounting to more than two percent of annual disposable income. On average, younger households own a heavily mortgaged house and have high interest expenses relative to their income. Retirees are typically net creditors and lose when less interest is paid on their savings. Figure 7 (d) shows that when looking at all channels jointly, an expansionary policy benefits the income of households below 50 years old the most and the effects are quite similar across education groups.

Figure 7: Effect on average disposable income from a monetary policy shock, by education and age groups



(a) Labor income and transfers

(b) Net interest income

(c) Other capital income

(d) Total income

Notes: The figures show the responses of group-averages of disposable income to the monetary policy shock described in section 3.2 for each income source (after tax) relative to total income after tax. The level of education is 1 "Less than High School" 2 "High School diploma" 3 "University, lower" 4 "University, higher"

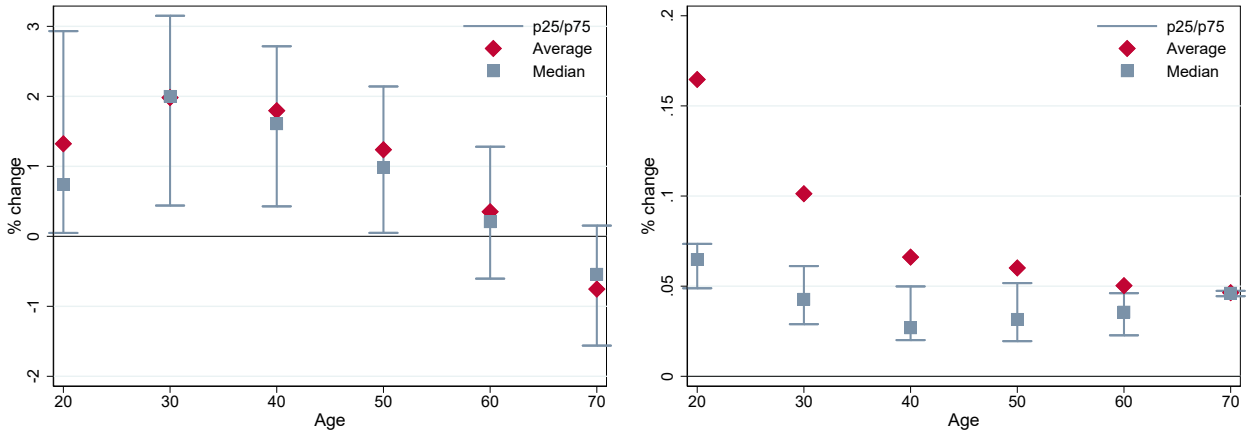
Broadly speaking, the "key" to gaining from an interest cut, and then to "lose" from a hike, is having a high loan-to-value ratio and a high debt-to-income ratio. In other words, highly indebted homeowners benefit (or lose) more than others. As Norway has a high share of homeowners – about

3 out of 4 households are homeowners – and most of them have a mortgage, the vast majority of the households gain from an interest rate cut. Perhaps surprisingly, the age group 20-29 are the group gaining most in terms of net wealth and among the highest for disposable income even though the share of homeowners are lowest for the young. The effect on the average portfolio and average disposable income for different groups may mask some important heterogeneity within the groups. Since a substantial fraction of households have negative wealth, where the percentage change is not comparable to the ones with positive wealth, and the share of households with negative net wealth are particularly high among the young, it is challenging to display the heterogeneous effects for wealth. However, we come back to this below where we look at the change in inequality measures.

For disposable income, there are so few with negative values that we can simply ignore them and analyse the heterogeneity in percentage change across households. Indeed, there are large differences in the effect on disposable within groups, see figure 8. The differences in the change in disposable income are largest for the youngest age group reflecting that the home ownership rates are lowest among the young. As the main effect of expansionary monetary policy in the short run is to reduce interest expenses, that mainly benefits households with large debt. It should also be noted that the group 20-29 is a very heterogenous group, and if we excluded households below 25 years the group would have been very similar to the households age 30-39. The differences between age groups, measured as the distance between the 25th and the 75th percentile, fall with age.

For labor income, it is the youngest who benefit the most for all the four measures considered. The average effect is particulary high for the young as the increase in employment rates is largest for this groups, which has a substantial impact on labor income for the ones that get employed. Over time, the effect via labor income probably increases whereas the effect on interest payments falls as rates go back to their steady-state levels.

Figure 8: Differential effects on income after a monetary policy shock within age groups



(a) Disposable income

(b) Labor income (after-tax)

Notes: The figure show the average, median and the 25th and 75th percentile of the percentage change in disposable income and labor income within age groups. The monetary policy shock is shown in figure 1, and have a peak response after 2 quarters of -1 percentage point and average decline of 90 basis points the first year.

To further explore the distributional effects of a monetary policy shock, we compute changes in

overall inequality using six different measures: the Gini coefficient[36], the Gini coefficient excluding the top one percent, the share of net wealth held by the top 10 percent, and the 90th percentile relative to the median (p90/p50), the median relative to the 10th percent (p50/p10), and the mean relative to the median. The two latter measures are only computed for disposable income as they are not well defined for net wealth due to negative values. Since around 20 percent of households hold negative net wealth in our data set, we follow Chen et al. (1982) in adjusting the Gini coefficient so that it retains its usual meaning in the face of negative values. Within the time horizon we consider (1 year) the distributional effects may not necessarily be the same as the more long term effects as it often take some time before inequality measures are fully affected by a shock. Moreover, part of the differences in income and wealth are simply due to life cycle effects. Older households may simply be wealthier because they have worked for many years and accumulated wealth, whereas younger households may have a large expected wealth but current wealth is low. There are methods for adjusting the Gini coefficient for e.g. age effects. However, they typically cannot handle negative values in a sufficient way. As about 20 percent of the households have negative wealth, and the share is strongly declining with age, it is important to include negative values. We have therefore focused on including negative values rather than adjusting for age effects. Another option would be to focus on permanent income or life-time wealth. Measuring permanent income or life-time wealth, and capturing all the changes are beyond the scope of this paper and are probably best investigated within a rich heterogenous agent model. Therefore, the results presented below should be interpreted with caution.

Table 4 summarizes the change in different measures of inequality, for both income and wealth, after an expansionary monetary policy shock with a peak response of 1 percentage point. We find that an expansionary monetary policy shock reduces all measures of wealth inequality.[37] The key reason for the reduction in inequality is that most of the lower part of the distribution have a higher loan-to-value ratio, which make net wealth more sensitive to house price movements.

An expansionary monetary policy shock is also found to reduce Gini for disposable income. It is the very low part of the income distribution, and the middle of the distribution, which gain relatively more from expansionary monetary policy as they have a higher debt-to-income ratio compared to other groups. Although the rich (measured by the top ten percent) gain more from higher equity prices, they lose relative to middle of the distribution as they have a lower debt-to-income ratio, which makes them benefit less from an interest cut. [38] The median relative to the 10th percentile (p50/p10) increases moderately as households at the 10th percentile have little debt and thus do not gain from lower interest expenses which the median does.

[36]The Gini coefficient takes values between 0 for full equality (all households receive the same income) to 1 for full inequality (one household receives all income).

[37]Figure B3 shows the wealth effects by percentile of initial wealth.

[38]As shown in figure B3, most of the gains from higher dividend payments are found among the top one percent of households, but this channel is relatively minor.

Table 4: Change in measures of inequality after a monetary policy shock

	Disposable income		Net wealth	
	2014	Shock	2014	Shock
Gini	26.1	−0.003	69.3	−0.325
Gini perc. 1-99	24.1	−0.003	65.1	−0.379
Share top 10%	21.3	−0.024	48.5	−0.186
p90/p50	1.7	−0.003	4.3	−0.051
p50/p10	1.8	0.012	-	-
Mean/p50	1.1	−0.002	-	-

Notes: The 2014 column show measures of inequality for Norway in 2014*, based on our data. Changes are measured in percentage points, and the Gini coefficient is adjusted to account for negative values following Chen et al. (1982). The monetary policy shock is shown in figure 1, and have a peak response after 2 quarters of -1 percentage point and average decline of 90 basis points the first year.*

4.2 Systematic monetary policy

The key goal for monetary policy is to stabilize the aggregate economy over the business cycle according to the mandate. In Norway, the mandate is to stabilize inflation but also to contribute to high and stable output and employment, and to counteracting financial imbalances. As shown above, changes in the interest rate have distributional effects. However, the key distributional concern should be whether the systematic monetary policy response amplifies or dampens the distributional effects of the shocks they try to stabilize. If the systematic monetary policy amplifies the distributional impact of the shocks hitting the economy, there is perhaps need for counteracting fiscal policies and certainly greater attention concerning the distributional effects from central banks. On the other hand, if monetary policy also stabilizes the distributional effects of the shocks through stabilizing the macro economy, there is less need for distributional concerns for the central bank. In this section, we quantify the distributional effects of two groups of shocks, labeled "demand shock" and "supply shock", and isolate the role of monetary policy. The scenarios are two stylized examples of shocks and does not reflect any historical events, but represent typical business cycle shocks hitting the Norwegian economy. However, each cycle is different and the aggregate responses to other shock combinations could vary greatly from our scenarios. However, this is a useful starting point to examine the effects of systematic monetary policy.

The aggregate changes in the two scenarios are discussed in section 3.2, and table 1 summarizes the changes in the aggregate variables used in the analysis. A negative demand shock by itself reduces asset prices, wages and inflation, and increases unemployment and the real rate. The left column of figure 9 shows the impact of the shock on income and wealth for different age and education groups, and per percentiles. The income of all age and education groups considered are negatively affected by the shock (figure 9(a)). Young and low educated households are mainly affected through lower labor market income, whereas older households are mostly affected by lower dividend payments. The bottom and the top of the distribution are most affected, where the bottom loses due to lower labor market income and the top loses due to lower capital income.

The reduction in interest rates dampens the fall in output, and thus reduces non-employment and the fall in capital income from stocks. Moreover, as shown above, the direct effect of the reduction in interest payments are substantial. Almost all households gain from the monetary policy response, except the oldest age group which lose as they hold most of their liquid assets in deposits and thus lose even more from the lower interest rate.

As house prices and stock prices fall due to the negative demand shock, wealth is reduced for all groups, but more so for younger households and those in the lower part of the wealth distribution. With the monetary policy response, the fall in wealth is reduced for all groups and for the middle of the distribution, it is almost mitigated entirely.

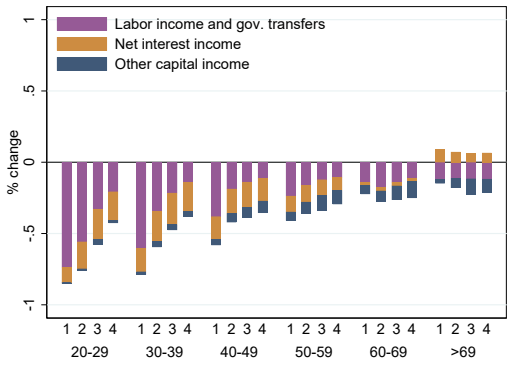
The effects with and without monetary policy of a negative supply shock are shown in figure 10. The negative supply shock lead to higher inflation, wages, house prices and non-employment, and lower real interest rate and stock prices. The reduction in the real interest rate due to higher inflation lowers real interest rate payments, which benefit the young and lower income households. As the increase in non-employment is very modest, the positive effects from higher real wages dominate and labor income increases for all groups. The effect is however small compared to the effect on interest payments. The increase in the policy rate almost neutralizes the effect on the real interest rate, and interest expenses remain almost unchanged with the monetary policy response.[39] Monetary policy also dampens wage growth and lead to higher non-employment and even lower stock prices. This effect is larger than the effect of the initial shock for the lowest income decile, and leads to lower total income. The very top percentile loses even more with active monetary policy, as stock prices fall even more. For the other income deciles, the active monetary policy almost neutralizes the effect of the shock on income.

As house prices increase, the supply shock leads to higher net wealth for all groups, except for the top one percent which loses due to lower stock prices. The contractionary monetary policy reduces house prices and dampens the effect on net wealth. The top one percentile loses even more with the contractionary monetary policy.

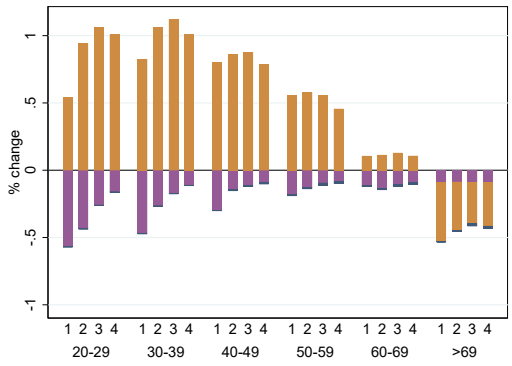
[39] In our approach we do not distinguish between the changes in the real rate brought by changes in the nominal rate or changes in inflation. However, for households that are liquidity constrained this will matter and will affect the consumption inequality measure at least in the short term. We leave it for future research.

Figure 9: Changes in household income and wealth from demand shock

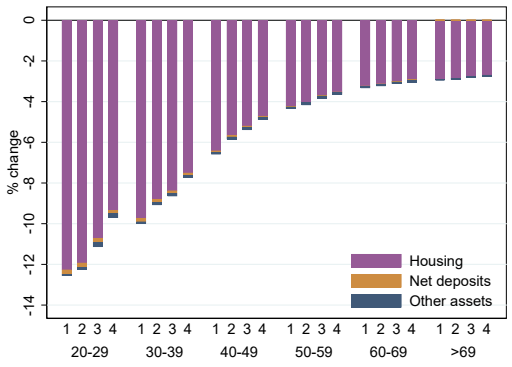
No monetary policy | Monetary policy



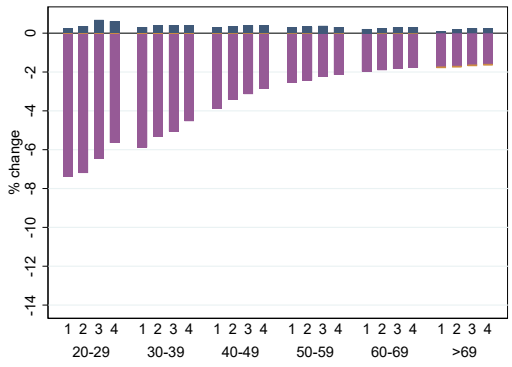
(a) Disposable income



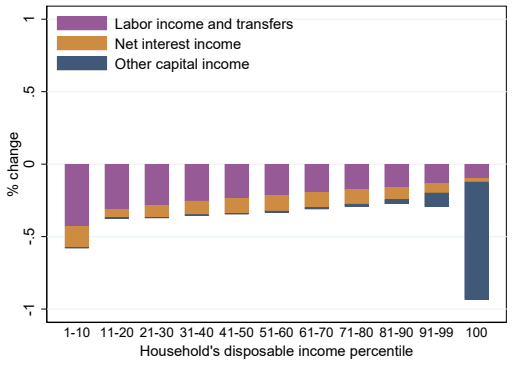
(b) Disposable income



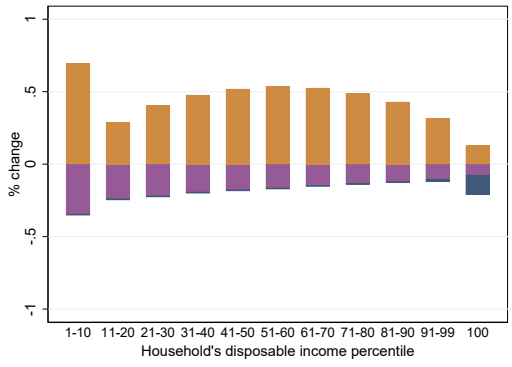
(c) Net wealth



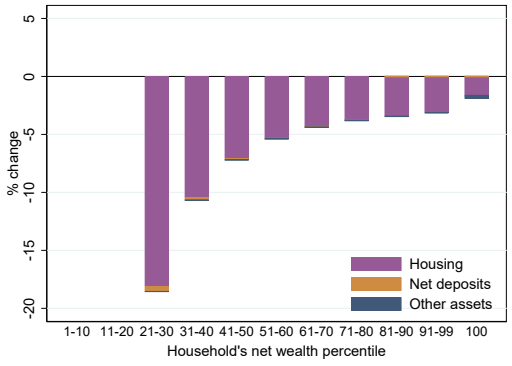
(d) Net wealth



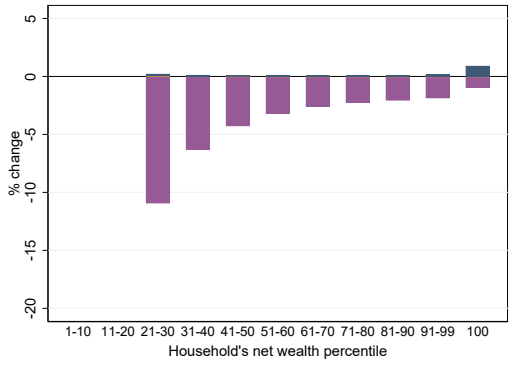
(e) Disposable income



(f) Disposable income



(g) Net wealth

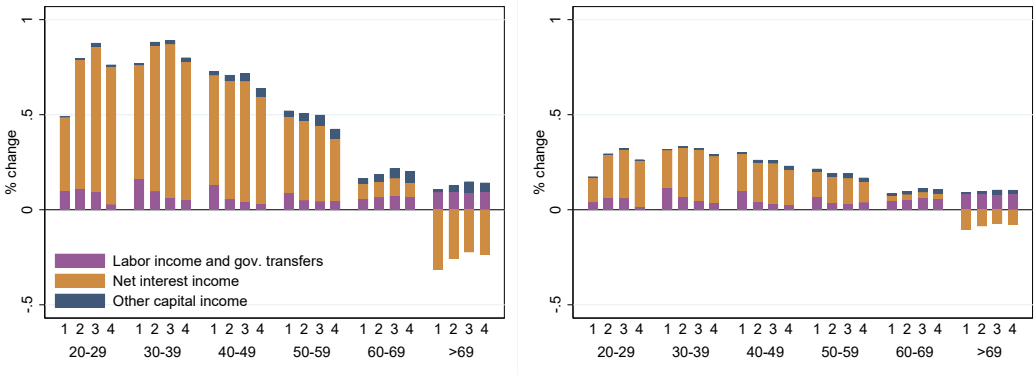


(h) Net wealth

Notes: The figures show the average response within groups to the demand shock described in section 3.2. The Level of education is 1 "Less than High School" 2 "High School diploma" 3 "University, lower" 4 "University, higher"

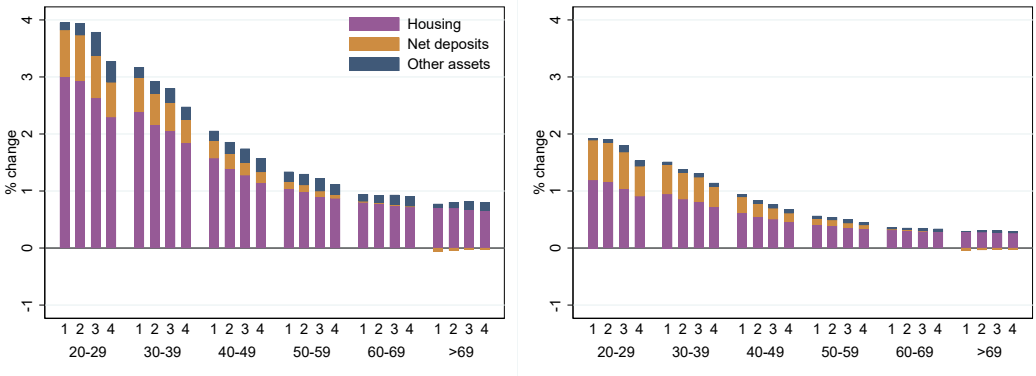
Figure 10: Changes in household income and wealth from supply shock

No monetary policy | Monetary policy



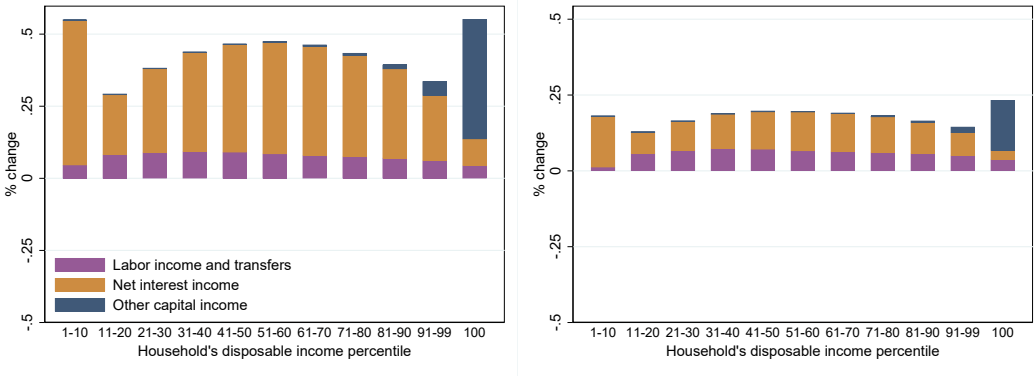
(a) Disposable income

(b) Disposable income



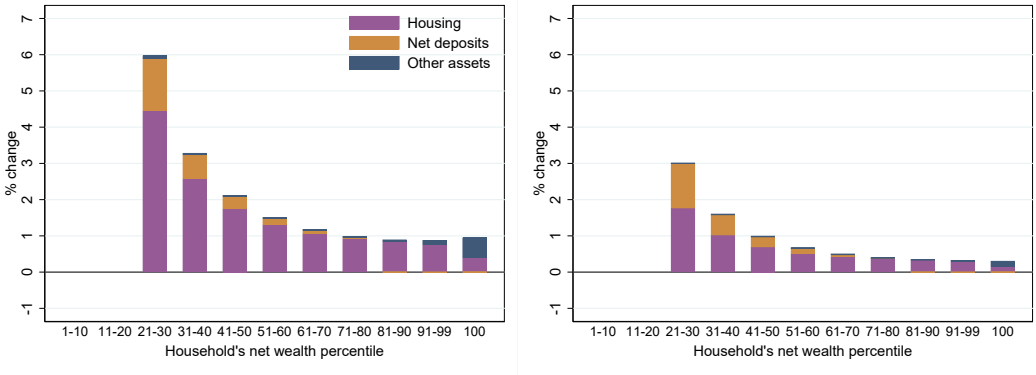
(c) Net wealth

(d) Net wealth



(e) Disposable income

(f) Disposable income



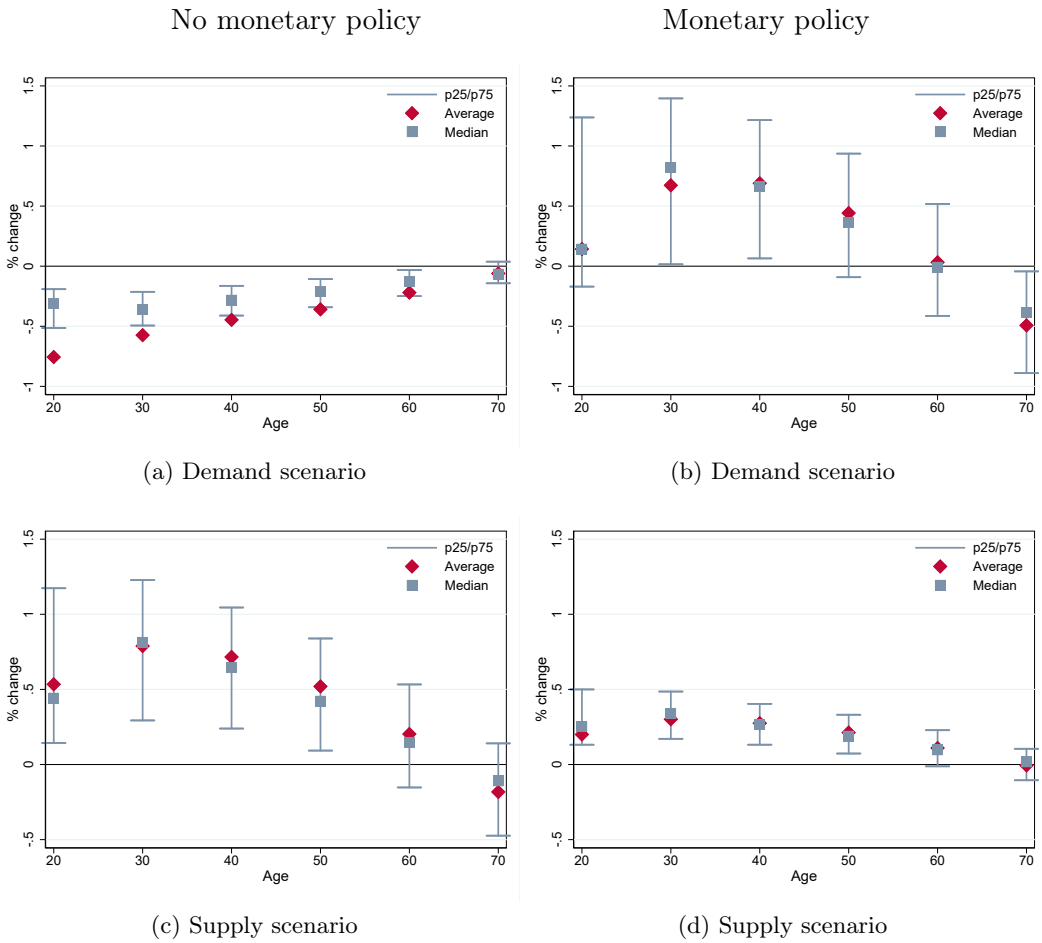
(g) Net wealth

(h) Net wealth

Notes: The figures show the response of group within groups to the supply shock described in section 3.2. The Level of education is 1 "Less than High School" 2 "High School diploma" 3 "University, lower" 4 "University, higher"

Similar to the case of the monetary policy shock, there are substantial heterogeneity in how households are affected by the demand and supply shocks, see figure 11. For the demand scenario, the differences within age groups are smallest when monetary policy does not react, but for the supply scenario it is the opposite. Although households are differentially affected by changes in aggregate wages and employment, the difference is rather small for most households as their employment status are unaffected. What is generating large differences are changes in the real rate, because there is substantial heterogeneity in the debt-to-income ratio. In the demand scenario, real rates increase marginally when monetary policy does not respond, but fall by 50 basis points when monetary policy reacts. Similarly, for the supply shock, real rates fall by 36 basis points when monetary policy does not respond as inflation increases, but by increasing the key policy rate, the central bank reduces the fall in real rates to 12 basis points. Therefore, depending on the shock, monetary policy may lead to more or less heterogeneity in how households are affected.

Figure 11: Differential effects on disposable income in the demand and supply scenario, within age groups



(a) Demand scenario

(b) Demand scenario

(c) Supply scenario

(d) Supply scenario

Notes: The figure show the average, median and the 25th and 75th percentile of the percentage change in disposable income and labor income within age groups. The aggregate effects in the two scenarios, with and without monetary policy are summarized in table 1.

To evaluate the distributional effects of monetary policy, it is important to take into account where in the distribution the "winners" and "losers" are. To answer that, we focus on the same five measures as above. Overall, we find that the distributional effects would have been larger if monetary policy had not responded. That is, we find that systematic monetary policy dampens

Table 5: Change in measures of inequality with and without a monetary policy response

		Income		Wealth	
		No mon. policy	Mon. policy	No mon. policy	Mon. policy
Demand shock	Gini	0.015	0.008	0.891	0.567
	Gini perc. 1-99	0.036	0.020	0.934	0.545
	Share top 10%	−0.013	−0.021	0.672	0.495
	p90/p50	0.001	−0.001	0.13	0.076
	p50/p10	0.002	0.008	-	-
	Mean/p50	−0.000	−0.001	-	-
Supply shock	Gini	−0.001	0.000	−0.250	−0.136
	Gini perc. 1-99	−0.006	−0.000	−0.288	−0.153
	Share top 10%	−0.006	−0.002	−0.149	−0.086
	p90/p50	−0.002	−0.001	−0.038	−0.021
	p50/p10	0.005	0.002	-	-
	Mean/p50	−0.001	−0.000	-	-

Note: Changes are measured in percentage points. The Gini coefficient is adjusted to account for negative values following Chen et al. (1982).

the effects on inequality from both the supply and demand shocks, see table 5.[40] If monetary policy does not react, the supply shock leads to reduced inequality in both income and wealth. With monetary policy, the reduction in inequality is significantly dampened. For the demand shock, most measures of wealth inequality increase when monetary policy is kept constant, but increase less when monetary policy responds. The share of top ten is reduced with the demand shock, as stock prices fall, and are further reduced with an active monetary policy as other groups gain relatively more due to house prices falling less.

Therefore, even though monetary policy has distributional effects, these results indicate that the distributional effects over the business cycle would be larger without a systematic monetary policy. If the economic responses to positive and negative shocks are about the same, and the share of positive and negative effects are about the same, this indicates that monetary policy stabilizes inequality around a more long term value, which are potentially determined by fiscal policy and other trends. That being said, this analysis focuses on typical business cycle movements, and are not suited to analyse the effects of declining neutral real rates which may have also affected inequality.

[40] Under the assumption of no portfolio reallocation, we have analyzed the effects in year two. The results are similar to the first years, and we find that monetary policy overall dampens the effects of the supply and demand shock on inequality. The results are available upon request.

5 Conclusion

This paper contributes to the ongoing debate on the distributional effects of monetary policy by exploring the relative importance of different transmission channels and by studying the role of systematic monetary policy. In the short run, the direct response via interest rate expenses and income is the main effect on households disposable income as almost all households have floating rates. As the middle and lower parts of the distribution have a higher debt-to-income ratio, expansionary monetary policy is found to reduce income inequality. Expansionary monetary policy boosts asset prices where the very rich benefit from the increase in stock prices and most other households benefit from higher house prices. As the homeownership rates in Norway are high, and for many households this is funded with large mortgages, it is the lower part of the distribution which gets the largest increase in net wealth which leads to lower wealth inequality in the short run.

The role of monetary policy is not throw shocks at the economy, but rather to stabilize the aggregate economy over the business cycle according to its mandate. Analyzing two stylized scenarios, which represent a "demand" and a "supply" shock, we find that systematic monetary policy dampens the effect of macro shocks on inequality. Therefore, although monetary policy do have distributional effects, the effect on inequality would have been larger if monetary policy had not reacted to stabilize the macro economy. This indicates that the need to address the distributional effects of monetary policy is less of a concern. However, there are large differences across households in how they are affected, and it is important for central banks to constantly monitor the distributional effects of their actions not only to be aware of the distributional effects but also because the distributional effects may in turn affect the transmission of monetary policy. Moreover, this paper only explores the short-run effects an focus on two stylized scnearios, hence more research is needed to explore this further.

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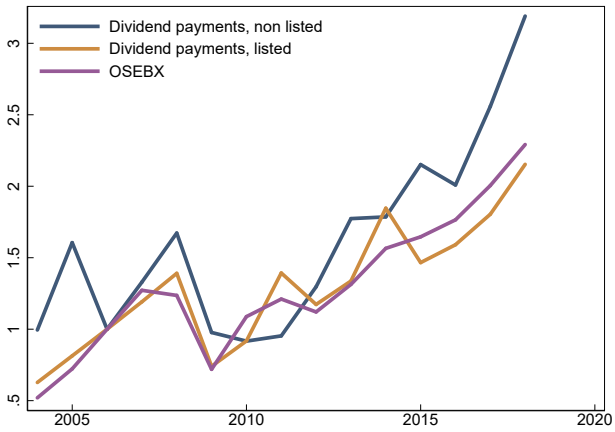
A Detailed explanation of method

A.1 Asset prices and dividend payments

Aggregate dividend payments have historically followed the evolution of stock prices, see figure A1, and we assume that dividend payments change with stock prices in the counterfactual scenarios.

Figure A1: Co-movement between stock prices and dividend payments

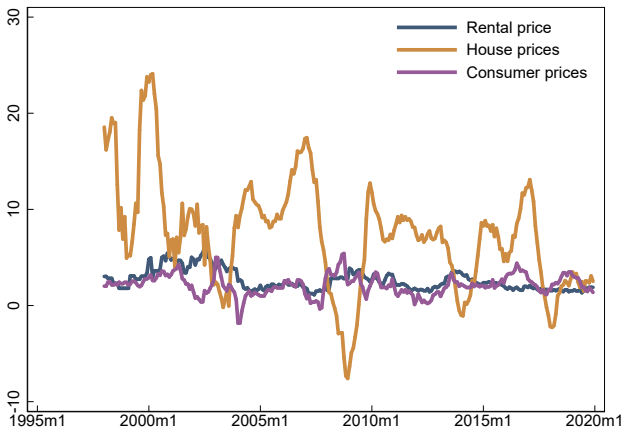


Notes: The OSEBX are taken from Oslo Stock Exchange, and dividend payments to households are from Statistics Norway.

A.2 Rental income

Rental income is an important income source for some households. We only observe taxable rental income, which may understate the income for some households and place them in the wrong income percentile.[41] We assume that rental prices increase with inflation, so that rental income in real terms is unaffected. Rental prices are very sticky, as the annual price increase for existing contracts is restricted by law to be at most equal to the increase in the consumer price index. Figure A2 show the 12-month growth in rental prices, house prices and the consumer price index, and confirms that historically rental prices seem to be closer linked to consumer prices than to house prices.

Figure A2: Cyclical movements in rental prices, house prices and the consumer price index



Notes: Rental prices and consumer prices are from Statistics Norway, and house prices are taken from Eiendom Norge.

[41] Generally, rental income is taxable if you rent out a residence you do not live in. If you rent out part of your own residence, it is taxable if you rent out less than 50 percent of the value of the residence. Income from short term rental, defined by less than 30 days, are taxable if they exceed 10000 NOK. However, one can subtract all costs associated with the residence such as maintenance, insurance, property tax, municipal taxes.

A.3 Decomposition of shocks at the group level

A.3.1 A general decomposition scheme

Suppose the time-varying variable y_t is made up of contributions from N groups, with group n contributing $x_{n,t}$, so that $y_t = \sum_n x_{n,t}$. For instance, $x_{n,t}$ can be the size of a group relative to the overall number of people; the contribution of the group to the level of a variable; or the contributon of the group to the overall growth rate of a variable. Whatever the source, we want to decompose the time-variation in y_t (relative to its mean) into contributions made by each group.

We can decompose the time-variation in y_t into the n components using the regression

$$x_{n,t} = \beta_{n,0} + \beta_{n,y} y_t + \varepsilon_t.$$

Estimating this by OLS, the coefficient $\hat{\beta}_{n,y}$ can be interpreted as the contribution of group n to the variation in y over time. It is given by the expression

$$\hat{\beta}_{n,y} = \frac{\mathrm{Cov}(x_n, y)}{\mathrm{Var}(y)} = \frac{\sum_i \mathrm{Cov}(x_n, x_i)}{\sum_{i,j} \mathrm{Cov}(x_i, x_j)}. \tag{2}$$

It is obvious that $\sum_n \hat{\beta}_{n,y} = 1$.

The variance of y consists of the variances of each of the components, plus the covariances between them. The OLS decomposition method allocates half of the covariance between groups n and m to group n, and the other half to group m. Other ways of allocating these covariances are possible, but in fact the method above has an intuitive interpretation. To see this, note that

$$\begin{aligned}\hat{\beta}_{n,y} &= \frac{\sum_i \sum_t (x_{n,t} - \bar{x}_n)(x_{i,t} - \bar{x}_i)}{\sum_{i,j} \sum_t (x_{i,t} - \bar{x}_i)(x_{j,t} - \bar{x}_j)} = \sum_t \frac{\sum_i (x_{n,t} - \bar{x}_n)(x_{i,t} - \bar{x}_i)}{\sum_{t'} \sum_{i,j} (x_{i,t'} - \bar{x}_i)(x_{j,t'} - \bar{x}_j)} \\ &= \sum_t \underbrace{\frac{\sum_{i,j} (x_{i,t} - \bar{x}_i)(x_{j,t} - \bar{x}_j)}{\sum_{t'} \sum_{i,j} (x_{i,t'} - \bar{x}_i)(x_{j,t'} - \bar{x}_j)}}_{w_t} \underbrace{\frac{\sum_i (x_{n,t} - \bar{x}_n)(x_{i,t} - \bar{x}_i)}{\sum_{i,j} (x_{i,t} - \bar{x}_i)(x_{j,t} - \bar{x}_j)}}_{s_{n,t}},\end{aligned}$$

where $\bar{x}_i$ is the time-average of variable $x_{n,t}$. Here w_t is the fraction of the overall variance of y accounted for by year t, which is the weight put on the contribution of group n in year t. Furthermore, it is straightforward to show that

$$s_{n,t} = \frac{x_{n,t} - \bar{x}_n}{\sum_i (x_{i,t} - \bar{x}_i)}, \tag{3}$$

so that the contribution of group n in year t equals simply the contribution of this group to the overall distance of y_t from its mean. Obviously, we have $\sum_n s_{n,t} = 1$ for each t.

Hence using the OLS coefficients as weights is equivalent to the following procedure. First, in a single year t we do a simple decomposition of the contributions each group makes to the distance of y_t from its mean, $y_t - \bar{y} = \sum_n (x_{n,t} - \bar{x}_n)$. Second, to create a time-average of the contributions, we weight each year by that year's contribution to the overall variance of y_t. Other weights of these year-contributions are of course possible, but the weights w_t are the only ones that give us back the OLS coefficients.

To simplify notation, we will let $s_n = \hat{\beta}_{n,y}$ denote the contribution of group n to the variation in an arbitrary variable y. Using these shares, we can predict x_n based on some observed level of the aggregate y. It is simply given by $\hat{x}_n = s_n y$. Hence this method can be used to predict

group-level variables in cases when we only have access to the aggregate impact, the assumption being that new shocks are distributed across the groups according to the historical pattern.

Note that there is nothing restricting the shares s_n to be positive. A negative value will typically appear if the covariance between x_n and other x_i is negative and large enough to make up for the direct contribution of group n to the variance of y. Under the alternative formulation of the procedure, this happens when x_n is below its mean in some years when y is above its mean, and that these are years when y is particularly far away from its mean. For instance, a particular demographic group could make a negative contribution to the overall unemployment rate if the unemployment rate in that group declined during the Great Recession, a period when the overall unemployment rate was large and positive.

A.3.2 Decomposing growth rates

We want to decompose the time-variation in the growth rate of a variable y_t into contributions by an arbitrary set of groups. Let an individual i have $y_{i,t}$, and let the set of people present at time t be Π_t. Furthermore, let $\{\Omega_n\}_{n=1}^N$ be a partition of the set Π_{t-1} into N subgroups of people present at $t-1$, based on some characteristics. These characteristics can be demographics such as age and education at either t or $t-1$, or it can be based on some joint behavior across periods.

We have $y_t = \sum_{i\in\Pi_t} y_{i,t}$, and the growth rate

$$\begin{aligned}\frac{y_t - y_{t-1}}{y_{t-1}} &= \frac{1}{y_{t-1}}\left\{\sum_{i\in\Pi_t} y_{i,t} - \sum_{i\in\Pi_{t-1}} y_{i,t-1}\right\} \\ &= \sum_n \sum_{i\in\Omega_n} \frac{y_{i,t-1}}{y_{t-1}}\left(\frac{y_{i,t}-y_{i,t-1}}{y_{i,t-1}}\right) + \frac{1}{y_{t-1}}\sum_{i\notin\Pi_{t-1}} y_{i,t} - \frac{1}{y_{t-1}}\sum_{i\notin\Pi_t} y_{i,t-1},\end{aligned}$$

where the last two terms are the contributions from newcomers and leavers, respectively. For the rest of this section, assume that we only consider the set of people present in both periods, so that $\Pi_{t-1} = \Pi_t$ and the last two terms in the equation above are both zero.

We can now decompose the variance of the growth rate into the shares s_n, using the OLS method outlined above. Once we have these shares, we can predict the growth rate of group n based on some arbitrary level of the aggregate growth rate and the observed contribution of group n to the *level* of y at time $t-1$:

$$\widehat{\left(\frac{y_{i,t}-y_{i,t-1}}{y_{i,t-1}}\right)} = \overline{\left(\frac{y_{i,t}-y_{i,t-1}}{y_{i,t-1}}\right)} + s_n\left(\frac{y_{i,t-1}}{y_{t-1}}\right)^{-1}\left\{\left(\frac{y_t-y_{t-1}}{y_{t-1}}\right) - \overline{\left(\frac{y_t-y_{t-1}}{y_{t-1}}\right)}\right\}. \quad (4)$$

Given a contribution s_n to overall growth, the predicted growth rate of group n is higher the smaller the contribution this group makes to the overall level of the variable.

A.3.3 Decomposing employment changes

We divide people into two groups based on their labor market status, employed (E) and non-employed (N). The latter category comprises those who are either registered as unemployed or considered outside the labor market. Between years, people move between these groups and in that way generate the aggregate movements in the unemployment rate and the fraction of people who are in the labor force. For instance, the unemployment rate (the fraction of people in the

labor force who are unemployed) can increase because more people go from being employed to being unemployed or outside the labor force, or because more of the unemployed stay in that category for a longer time. In this section we explain how we decompose the aggregate changes in employment status and income growth.

Let $a \in \{E, N\}$ denote a person's labor market status, $p_t(a)$ the probability that a person has status a at time t, and $p_t(a|b)$ the probability that someone has status a at t given that she had status b at $t-1$. We can further condition on the membership of demographic group n at a fixed reference time, which will be t in the following. Then we can write the probability of being in status a at $t+1$ as

$$p_{t+1}(a) = \sum_{b \in \{E,N\}} p_{t+1}(a|b) p_t(b) = \sum_n \sum_{b \in \{E,U,O\}} p_{t+1}(a|b,n) p_t(b|n) p(n). \tag{5}$$

Similarly, we have

$$p_{t+1}(a) - p_t(a) = \sum_n \sum_{b \in \{E,N\}} \left[p_{t+1}(a|b,n) p_t(b|n) - p_t(a|b,n) p_{t-1}(b|n) \right] p(n), \tag{6}$$

where we only consider the subset of people who are observed at $t-1$, t and $t+1$. Furthermore, membership of group n is fixed at time t, so the probability of membership in group n, $p(n)$, does not change across periods.

Now let s_{nab} denote the contribution of people in group n and initial state b to the change in the fraction of people who are in state a. As before, these are found by regressing each of the right hand side terms in equation (6) on the left hand side. Using observables at time t, we can then predict each new transition rate $p_{t+1}(a|b)$ based on the aggregate change $p_{t+1}(a) - p_t(a)$, as follows:

$$\widehat{p_{t+1}(a|b,n)} = \frac{p_t(a|b,n) p_{t-1}(b|n) + \frac{s_{nab}}{p(n)} (p_{t+1}(a) - p_t(a))}{p_t(b|n)}. \tag{7}$$

We use this method to predict $\widehat{p_{t+1}(N|E,n)}$ and $\widehat{p_{t+1}(N|N,n)}$ for each group n following an aggregate shock to the non-employment rate, $p_{t+1}(N) - p_t(N)$. Then $\widehat{p_{t+1}(E|E,n)} = 1 - \widehat{p_{t+1}(N|E,n)}$ and $\widehat{p_{t+1}(E|N,n)} = 1 - \widehat{p_{t+1}(N|N,n)}$. Hence, following an aggregate shock, we can predict each of the transition rates between states for each demographic group. Furthermore, we use the method described in Section A.3.2 to predict the growth rates of income for people transitioning between any pair of states at the group level. For instance, we get the average income growth rate of $25-35$ year old people with lower university education who go from being unemployed to gaining employment. As a simplification, we assume that the proportional changes in income are the same for everyone with the same combination of demographic group and labor market state transition.

A.3.4 The income growth rate

We are now ready to decompose the change in the aggregate growth rate of work-related income Y stemming from an aggregate shock. First, we divide the population into $N \times 4$ groups: within each of the N demographic groups, people can move between employment and non-employment. Let $g_Y(a|b,n)$ be the growth rate of those people in demographic group n who move from status b before the shock happens to a after the shock, while $\overline{g_Y(a|b,n)}$ is the corresponding growth

Table A1: The fall in income (percent), relative to staying employed, when transitioning from employment to non-employment per group

Education/Age	20-29	30-39	40-49	50-59	60-69
< High School	-20.3	-18.9	-19.6	-26.2	-55.7
High School	-18.1	-18.5	-19.6	-27.0	-59.9
University, lower	-21.5	-25.3	-27.1	-32.3	-65.9
University, higher	-25.8	-28.7	-36.9	-44.3	-60.1

Notes: Historical averages based on data from 1993 to 2014.

rate in the same period if the shock were not to happen. Similarly, $p(a|b,n)$ and $\overline{p(a|b,n)}$ are the corresponding transition rates with and without the shock, respectively. Then the change in the aggregate growth rate because of the shock can be decomposed as

$$
\begin{aligned}
& g_Y - \overline{g_Y} \\
=& \sum_{n=1}^{N} \sum_{a,b \in \{E,N\}} \left\{ p(a|b,n)p(b|n)w_Y g_Y(a|b,n)p(n) - \overline{p(a|b,n)}p(b|n)w_Y \overline{g_Y(a|b,n)}p(n) \right\} \\
=& \sum_{n=1}^{N} \sum_{a,b \in \{E,N\}} \left\{ \underbrace{[p(a|b,n) - \overline{p(a|b,n)}]\overline{g_Y(a|b,n)}}_{\text{unemployment effect}} + \underbrace{p(a|b,n)[g_Y(a|b,n) - \overline{g_Y(a|b,n)}]}_{\text{income growth effect}} \right\} p(b|n)w_Y p(n),
\end{aligned}
$$

where w_Y is the average income for people transitioning from b to a within group n divided by the average income in the population.

This equation shows how changes to the unemployment rate and income growth rate for different groups separately impact the aggregate income growth rate. Consider an aggregate shock that decreases the growth rate of wages and increases the fraction of people not working. One the one hand, this will lead to more of the currently non-employed staying non-employed, while more currently employed become non-employed. These people get a lower labor income growth rate than they otherwise would. On the other hand, the shock also lowers the labor income growth rate of, for instance, those who stay on as employed even after the shock. The former effect is the "unemployment effect" in the equation above, while the latter constitutes the "income growth effect".

The change in income when individuals change employment status ("unemployment effect") is based on historical averages and computed separately for each group. Table A1 and A2 show the historical average income growth when changing employment status, per age and education group.

The group specific change in growth rates ("income effect"), conditional on a one percentage point increase in aggregate wages, are shown in the main text for individuals who stay employed. The change in growth rates after a shock for the other transitions are available upon request.

Table A2: The increase in income (percent), relative to staying non-employed, when transitioning from non-employment to employment per group

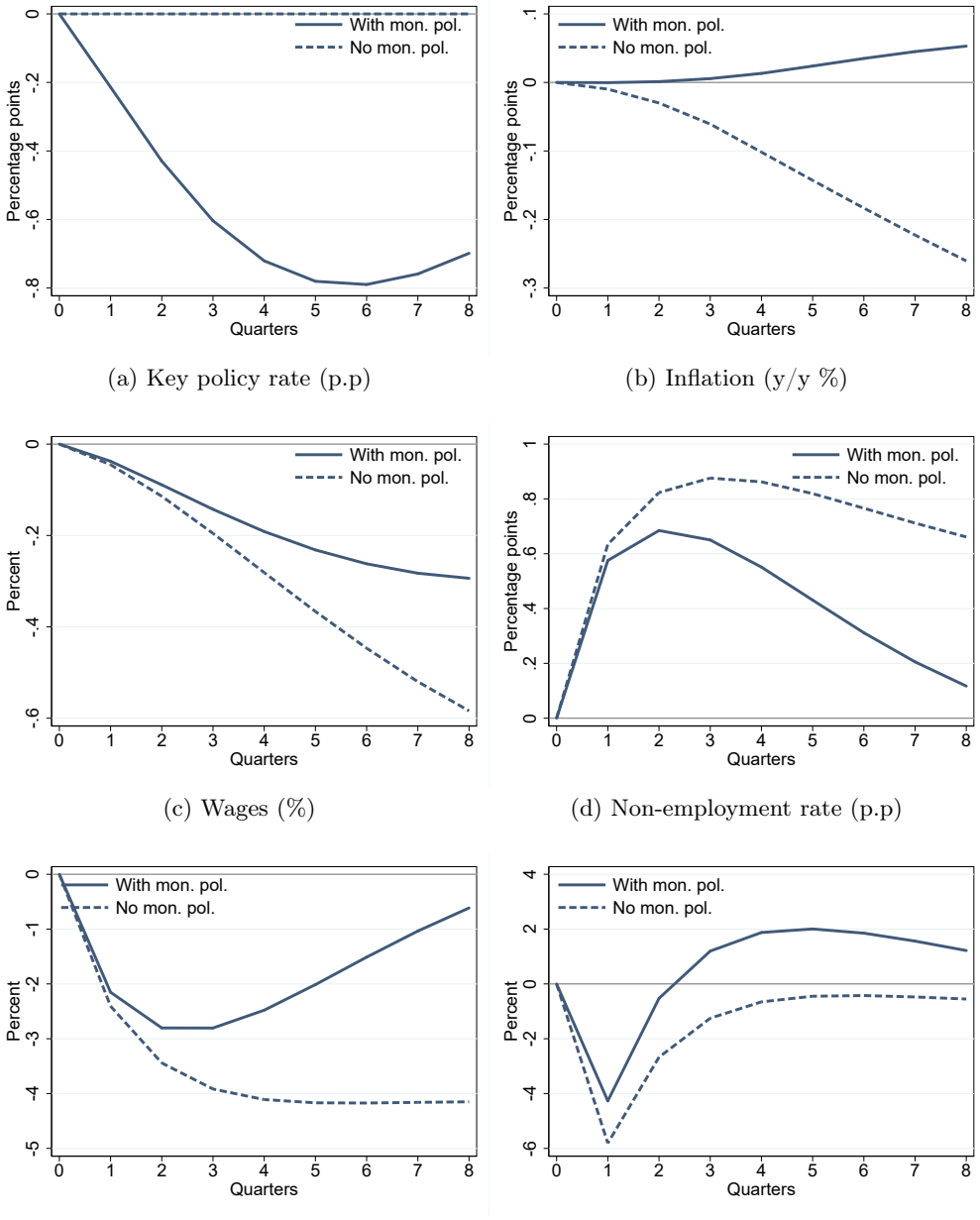
Education/Age	20-29	30-39	40-49	50-59	60-69
< High School	31.0	27.2	27.3	29.3	29.9
High School	24.5	22.9	24.5	29.5	36.1
University, lower	34.0	32.3	37.7	39.2	44.7
University, higher	39.9	41.5	70.3	81.3	77.9

Notes: Historical averages based on data from 1993 to 2014.

B Additional results

B.1 Aggregate scenarios

Figure B1: Aggregate responses to the "demand shock", with and without monetary policy response. Deviation from steady state



(a) Key policy rate (p.p)

(b) Inflation (y/y %)

(c) Wages (%)

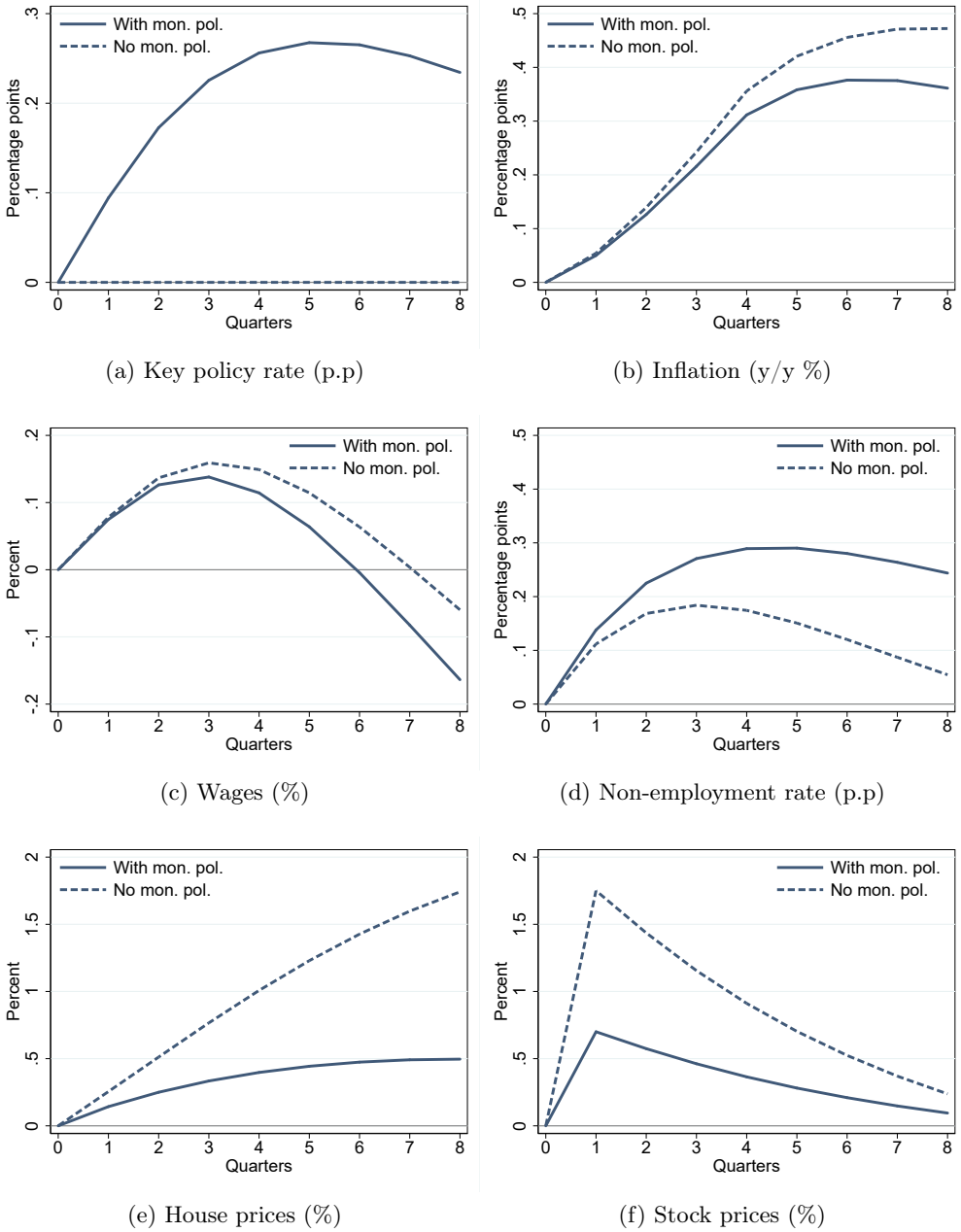
(d) Non-employment rate (p.p)

(e) House prices (%)

(f) Stock prices (%)

Notes: House prices, stock prices and wages are real variables. The non-employment rate is not directly from the model, but is obtained using an OKUN's law parameter of -0.9.

Figure B2: Aggregate responses to the "supply shock", with and without monetary policy response. Deviation from steady state



(a) Key policy rate (p.p)

(b) Inflation (y/y %)

(c) Wages (%)

(d) Non-employment rate (p.p)

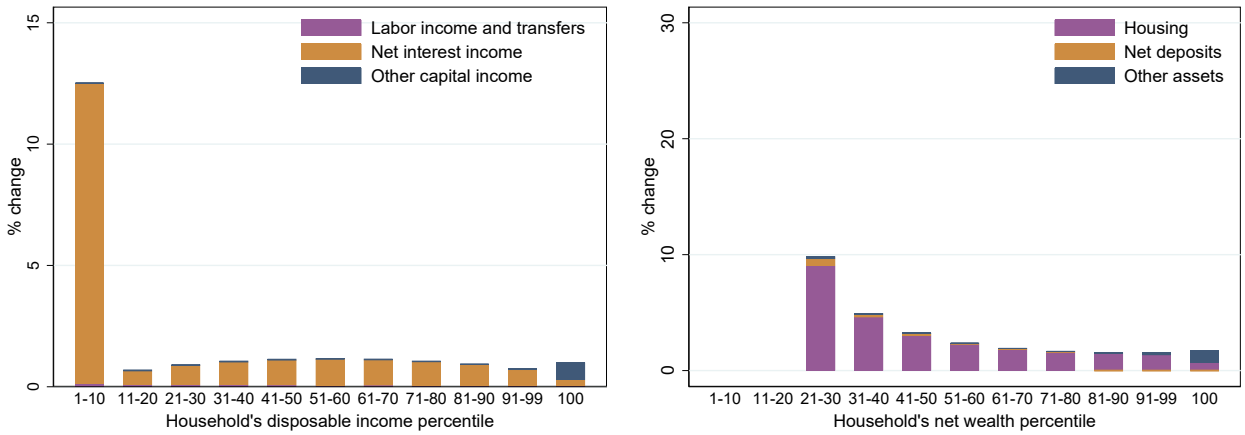
(e) House prices (%)

(f) Stock prices (%)

Notes: House prices, stock prices and wages are real variables. The non-employment rate is not directly from the model, but is obtained using an OKUN's law parameter of -0.9.

B.2 Effect of a monetary policy shock by percentiles

Figure B3: Effect on household income and wealth from a monetary policy shock, by percentiles



(a) Total income, after tax

(b) Net wealth

Notes: The two lowest deciles for wealth are excluded, as the percentage change is misleading because they have negative net wealth. The monetary policy shock is described in section 3.2