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## **Monetary policy and inequality**

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# Monetary Policy and Inequality\*

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## Abstract

We analyze the *distributional effects* of monetary policy on income, wealth and consumption. For identification, we exploit administrative household-level data covering the entire population in Denmark over the period 1987-2014, including detailed information about income and wealth from tax returns, in conjunction with exogenous variation in the Danish monetary policy rate created by a long-standing currency peg. Our results consistently show that all income groups gain from a softer monetary policy, but that the gains are monotonically increasing in the ex-ante income level. Over a two-year horizon, a decrease in the policy rate of one percentage point raises disposable income by less than 0.5% at the bottom of the income distribution, by around 1.5% at the median income and by around 5% at the top. The effects on asset values through increases in house prices and stock prices are larger than the effects on disposable income by more than an order of magnitude and exhibit a similar monotonic income gradient. We show how all these distributional effects reflect systematic differences in the exposure to the direct and indirect channels of monetary policy. Consistent with the main results for disposable income and asset values, we also find that the effects on net wealth and consumption (car purchases) increase monotonically over the ex-ante income distribution. Our estimates imply that softer monetary policy increases income inequality by raising income shares at the top of the income distribution and reducing them at the bottom.

JEL codes: E2, E4, E5, G2, G1, G5

Keywords: Monetary policy, Inequality, Household heterogeneity

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# 1 Introduction

Recent theory highlights the role of heterogeneous households in monetary policy transmission. When households differ in terms of balance sheets and occupations, monetary policy shocks affect their income and wealth differentially. For instance, when the central bank reduces the policy rate, debtors may benefit from a drop in interest expenses, the unemployed from job creation, entrepreneurs from higher demand and homeowners from increasing property prices. The distribution of gains and losses is important for several reasons. First, it matters for the direct and indirect channels through which monetary policy operates (Kaplan, Moll and Violante, 2018) thereby affecting the aggregate effects of monetary policy (Auclert, 2019) as households have different marginal propensities to consume (Japelli and Pistaferri, 2014). Second, it defines how monetary policy affects inequality in society (Bernanke, 2015; Draghi, 2016).

Despite the importance of the distributional effects of monetary policy for theory and policy, the empirical evidence is scant. Existing papers have mainly used survey data where the tails of the income distribution are poorly represented (Ampudia et al., 2018) and have often focused on summary measures of inequality (Coibon et al., 2017; Mumtaz and Theophilopoulou, 2017). By contrast, our paper draws on rich, administrative micro-data to analyze how monetary policy affects income, wealth and a proxy for consumption of durables at different positions in the income distribution. Moreover, we shed light on the various channels of monetary policy by studying how changes in, for instance, interest expenses, housing prices, salaries and business income contribute to the overall effects at each income level. Finally, we lay out the implications for inequality by studying how monetary policy affects income shares throughout the entire income distribution.

Our main data source is individual-level tax records for the entire population in Denmark with detailed information about income and balance sheets for the period 1987-2014: more than 70 million individual-year observations. In the tax records, we observe all major components of households' disposable income (e.g. salaries, dividends and interest expenses) as well as the main balance sheet components (e.g. housing, stocks and debt). This information is generally reported by third parties such as employers and financial institutions and mismeasurement due to tax evasion is therefore limited (Alstadsæter et al, 2019). Matching observations on unique personal identifiers, we combine the tax records with a number of other administrative data sources: The auto register with information on car purchases, an important component of durable consumption, as well as the population register with information on demographics, place of residence and household structure.

This granular information allows us to estimate how monetary policy differentially affects the income, wealth and consumption dynamics of households at different income levels and over different time horizons. Specifically, we consider 21 income groups corresponding to different positions in the within-age income distribution (p0-5,...,p95-99, top1%). Our dependent variable is always the change in a household-level outcome, from the *ex ante* period to some future period, scaled by *ex ante* disposable income to allow for direct quantitative comparison across the different channels.

A key challenge is the potential endogeneity of monetary policy to local economic conditions. We address this challenge by exploiting the long-standing commitment of the Danish monetary authorities to exchange rate stability: For more than three decades the Danish Krone has been pegged to the German Mark (1987-1998) and the Euro (1999-2020) and the exchange rate has been virtually constant throughout this period. With cross-border capital mobility, central banks cannot use the policy rate to control demand for currency and at the same time use it to pursue other policy objectives (Mundell, 1963; Fleming, 1962), so Denmark typically imports its monetary policy stance from Frankfurt: When the European Central Bank changes its leading interest rate, the Danish Central bank generally changes its rate on the same day to restore the interest rate differential that is consistent with a fixed exchange rate. This introduces a source of exogenous variation in the Danish policy rate that we exploit for identification.<sup>1</sup>

Our main explanatory variable is the change in the Danish policy rate interacted with indicators of the household's position in the *ex ante* income distribution. We address the endogeneity concern by using the change in the German/Euro Area policy rate as an instrument for the change in the Danish policy rate while at the same time controlling for the German/Euro Area business cycle (output growth and inflation). This implies that the identifying variation comes from the German/Euro Area monetary policy shocks in the sense of Christiano et al. (1999). In robustness tests, we include time fixed effects that absorb all aggregate shocks (including the aggregate effect of monetary policy) and expand the set of macro controls in several dimensions (each control interacted with income group indicators).

Our first set of results concerns the effects of monetary policy on disposable income. We find that softer monetary policy increases disposable income at *all* income levels. However, the gains are highly heterogeneous and monotonically increasing in the income level: A decrease in the policy rate of one percentage point raises disposable income by less than 0.5% at the bottom of the income distribution, by around 1.5% at the median income level and by around

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<sup>1</sup>Jordà et al. (2020) use the same source of variation to estimate the effect of monetary policy on real GDP growth.

5% for the top-1% over a two-year horizon.<sup>2</sup> The estimated effects tend to grow over time (larger over a two-year than a one-year horizon), which is consistent with dynamic general-equilibrium spillovers through indirect channels.

We identify the key economic channels underlying this first main result by estimating the effect on each component of disposable income separately. Consistent with theory and the perception of policymakers (e.g. Draghi, 2016), we find that softer monetary policy has the largest effect on salary income at relatively low income levels, reflecting a sizeable increase in employment for this group. However, most other components of disposable income contribute to a positive income gradient. First, gains in the form of higher business income and stock market income (indirect channels) are highly concentrated at the top of the income distribution. Second, gains in the form of lower interest expenses (direct channel) are increasing in income, which mainly reflects that higher-income households have more debt relative to their disposable income.<sup>3</sup> Summing over all the channels, the gains from a lower monetary policy rate are increasing monotonically over the income distribution.<sup>4</sup>

Our second set of results concerns the effects of monetary policy on asset values through changes in property prices and stock prices (for given portfolios). We find that softer monetary policy creates capital gains for all income groups with a pronounced positive income gradient: A one percentage point decrease in the policy rate increases asset values by around 20% of disposable income at the bottom of the income distribution over a two-year horizon and by around 75% of disposable income at the top. Comparing to the previous set of results, this suggests that the effects of softer monetary policy through appreciation of assets are generally much larger, more than an order of magnitude at all income levels, than the effects through higher disposable income. The gradient largely reflects that households at higher income levels hold more assets relative to their disposable income and to a lesser extent that the asset returns created by monetary policy are higher: Expressed relative to total asset values, the estimated effects range from around 6% at the bottom to around 8% at the top.<sup>5</sup>

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<sup>2</sup>The positive income gradient in the effects of monetary policy on disposable income is consistent with earlier evidence that high-income households are more exposed to aggregate fluctuations in the economy (Parker and Vissing-Jorgensen, 2009).

<sup>3</sup>The positive correlation between household income and leverage also emerges in other countries, including the United States (Kuhn et al., 2015).

<sup>4</sup>Changes in government transfers and taxes tend to mitigate the income gradient suggesting that economies with less fiscal redistribution than Denmark may exhibit an even steeper income gradient in the effects of monetary policy.

<sup>5</sup>The finding that the asset returns created by monetary policy are similar across income groups can be explained by three observations: (i) the returns on property, the largest asset in all income groups, correlate only weakly with income; (ii) high-income households have a higher portfolio share of stocks and a smaller portfolio share of housing than low-income households, but the returns on these two asset classes are similar;

We conduct a range of tests to probe the robustness of these core results. We show that the income gradient survives when we include time fixed effects that absorb the (average) effect of *any* macro shock. It remains largely unchanged when we add *ex ante* macro forecasts to the set of controls to account for the (heterogeneous) effect of expectations, and it becomes only slightly flatter when we further control for *ex post* Danish exports to account for the (heterogeneous) effect of monetary policy in Frankfurt through external demand for Danish products. It barely changes when we control for serial correlation in the policy innovations or modify the instrument to account for the zero lower bound. Finally, it remains similar when we augment the baseline model with household fixed effects to control for time-invariant household-level characteristics.

As a first extension of the core analysis, we investigate the role of household debt in the transmission of monetary policy. Concretely, we estimate an augmented model where the effect of changes in the policy rate is allowed to vary with leverage at each income level. When we compare households with similar leverage, the estimated effect on disposable income and housing wealth is much more similar across income groups. Nevertheless, debt does not account for the entire income gradient in the effects of monetary policy. In terms of disposable income, the top-1% have much larger gains from softer monetary policy than any other income group at each level of leverage. Moreover, the effect on stock portfolio values tends to be larger for households with low or no debt and is generally much larger for the top-1% within groups with similar leverage.

Second, we study the distributional effects of monetary policy on consumption and wealth accumulation. The intertemporal budget constraint requires that the gains created by softer monetary, whether in the form of disposable income or asset values, must be either consumed or added to the household's wealth. However, by changing market interest rates, monetary policy also changes the trade-off between consumption and savings more broadly as captured by the intertemporal elasticity of substitution. Accounting for both of these channels of monetary policy as well as others (e.g. changes in asset holdings), we re-estimate the model using household-level changes in net wealth and new cars as outcomes. The results indicate that the net wealth and consumption gains of softer monetary policy are both highly unequally distributed. The effects on net wealth, ranging from 20-30% of disposable income below the median income to almost 80% of disposable income at the top, are strikingly similar to the estimated price effects on asset values, which is consistent with an important role for "saving by holding" (Fagereng et

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(iii) all groups have a similar share of their net wealth, around 25-30%, in assets (e.g. deposits) with no price effects.

al., 2019).<sup>6</sup>

Third, as exposure to the various channels of monetary policy varies systematically over the life cycle, we also examine the distributional effects of monetary policy in the age dimension. The analysis employs a modified version of the baseline model where the change in the policy rate is interacted with indicators of age rather than indicators of income. We find that effects on disposable income are hump-shaped in age, largest for the middle-aged and almost zero for the young and the elderly. This pattern reflects a host of differences, for instance that the middle-aged are more often self-employed and have more debt than other age groups and therefore benefit more from higher business income and lower interest expenses when the policy rate is lowered. By contrast, the effect on asset values is monotonically increasing in age, reflecting that average portfolios of stocks as well as housing assets are increasing in age. In sum, softer monetary policy creates the largest benefits for the middle-aged through income and for the elderly through asset prices while the young benefit very little through either channel.

Finally, to relate our findings to the broader literature on inequality (e.g. Piketty, 2014), we undertake a simulation exercise that summarizes the distributional implications of our estimates. The results suggest that softer monetary policy unambiguously increases income inequality by raising the income shares at the top of the income distribution and lowering them at the bottom. Specifically, accounting for direct as well as indirect channels, reducing the policy rate by one percentage point raises the share of aggregate disposable income for the top-1% by around 3% over a two-year horizon and lowers it by around 1.5% for the bottom income group.

A key contribution of the paper is to inform theory models about the various direct and indirect channels of monetary policy (Kaplan, Moll and Violante, 2018; Auclert, 2019; Slacalek, Tristani and Violante, 2020). Most notably, our results highlight that non-labor channels (e.g. net interest income, business income, asset values) contribute importantly to both the aggregate and distributional effects of monetary policy.

We also contribute to the emerging literature on monetary policy and inequality. This question has attracted significant attention from policy makers, with some arguing that softer monetary policy reduces inequality because it primarily helps the low-skilled find jobs (Draghi, 2016), and others emphasizing that the well-to-do also benefit through increasing asset prices so that the net effect on inequality is ambiguous (Bernanke, 2015). Contrary to our findings, some recent studies find that lower policy rates are associated with less inequality (Coibon et al., 2017; Mumtaz and Theophilopoulou, 2017; Ampudia et al., 2018). Our methodology differs

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<sup>6</sup>This analysis does not assume that stock market returns follow the national index, but account for the actual change in market value in household-level stock portfolios.

substantially from these papers in many respects. In particular, we estimate the effects of monetary policy on household-level outcomes rather than summary measures of inequality; we use administrative data covering the entire population rather than top-coded survey data, which is crucial given the key role of the upper tail for inequality; and we document that monetary policy has particularly stark distributional implications through its effect on asset prices.

Finally, we contribute to the broader literatures using micro-data to study the heterogeneous effect of monetary policy on firms (e.g. Kashyap and Stein, 2000; Jimenez et al 2012, 2014) and the effect of pass-through from policy rates to market interest rates on household consumption (Di Maggio et al., 2017; Flodén et al., 2019; Cloyne et al., 2019). Most similar in terms of the empirical approach is a concurrent paper that studies the heterogeneous effects of monetary policy by household *liquidity* using micro-data from Norway (Holm et al., 2020). As both the research question and the empirical strategy are different from ours, we consider the two analyses to be complementary.

The rest of the paper is structured in the following way. Section 2 lays out the institutional framework underlying monetary policy in Denmark. Section 3 describes the data sources, the sample and offers descriptive statistics. Section 4 develops the empirical model and discusses identification. Sections 5-7 present the results. Section 8 concludes.

## 2 Background

The monetary policy rule in Denmark is simpler than in many other countries such as the U.S., the U.K., the Euro Area and Japan (Taylor, 1993). For more than three decades, the Danish Krone has been pegged to the German Mark and the Euro and exchange rate stability is the overriding objective of monetary policy. In the words of Bodil Nyboe Andersen, then Governor of the Danish Central Bank: “[Our] aim is to ensure that the Krone’s rate against the Euro is stabilized close to the central rate within ERM II, and the exchange rate is the sole basis for our monetary policy deliberations”.<sup>7</sup>

This institutional fact is a key part of our identification strategy. Theory tells us that to keep the exchange rate fixed in an open economy, the central bank must use the policy rate to control the demand for local currency and therefore cannot at the same time use it to control other local economic conditions (Mundell, 1963; Fleming, 1962). Although there is some alignment between business cycles in Denmark and the Euro Area, the currency peg introduces a source

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<sup>7</sup>Speech at the annual meeting of the Danish Bankers Association on 4 December 2002, quoted in Abildgreen (2010).



of exogenous variation in Danish monetary policy that we will exploit in the empirical analysis. Given the importance of the institutional framework for our identification strategy, we describe the background in some detail in this section.

## 2.1 Currency pegs

Denmark participated in the first attempts to reduce exchange rate volatility in Europe after the collapse of the Bretton Woods system in 1973. This cooperation evolved into the Exchange Rate Mechanism (ERM) in 1979 with exchange rates between European currencies floating within relatively narrow bands. In this period, Denmark suffered from high inflation rates and repeatedly devalued the target value of the Danish Kroner within the ERM to restore its competitiveness and reduce external imbalances. Consequently, interest rates were high because investors required a premium to compensate them for the expected future depreciation of the Krone.

In a sharp and lasting policy reversal, the center-right government coming into office in 1982 almost immediately announced that it was firmly committed to a fixed exchange rate. The exchange rate target was first stated in terms of ECU, a weighted average of the currencies participating in ERM, and importantly, in 1987, restated in terms of German Mark. The economic rationale of the policy was to reduce inflation by shifting market expectations. If two countries permanently maintain a fixed exchange rate, their inflation rates should eventually converge. To the extent that markets perceived the commitment to a fixed exchange rate with Germany to be credible, expectations about German inflation should anchor expectations about Danish inflation.

When twelve members of the European Union adopted the Euro in 1999, Denmark remained outside the monetary union: a popular vote in Denmark had rejected the treaty introducing the Euro and a political compromise allowed Denmark to opt out while the other ERM countries proceeded toward a common currency. The monetary collaboration between Denmark and the Euro Area was formalized in ERM II: the peg was restated in terms of Euro with a target exchange rate that was an exact conversion of the existing target in German Mark.

## 2.2 Exchange rates and policy rates

Figure 1 illustrates the exchange rates of Danish Kroner relative to German Mark, Euro and US dollar. Between the collapse of Bretton Woods to the announcement of the fixed exchange rate regime (1973-1982), Kroner depreciated quickly against Mark, losing almost half of its value in

less than a decade. In the first years of the fixed exchange rate regime (1982-1987), Kroner was pegged to ECU and continued to depreciate slightly against Mark although at a much slower pace: as other ERM countries occasionally devalued their currencies against Mark, a fixed rate against ECU implied a depreciation against Mark.

By contrast, in the period where Kroner was pegged to Mark (1987-1998), the fluctuations around the target rate were generally small and well within the acceptable bands of 2.25%. The only notable exception was the temporary depreciation in August 1993 in the context of massive volatility in European currency markets with speculative attacks forcing a number of European countries to adjust or even give up their currency pegs.<sup>8</sup> In the past two decades (1999-2020), Kroner has been pegged to Euro and the exchange rate between the two currencies has been almost completely fixed. The highly volatile exchange rate of Kroner against US Dollar over the past 50 years serves as a useful comparison.

Figure 2 illustrates the leading monetary policy rates in Denmark, Germany and the Euro Area. The spread between Denmark and Germany increased significantly after the first oil crisis in 1973 and generally hovered around 10 percentage points in the late 1970s and early 1980s reflecting the pronounced difference in inflation rates and the expected depreciation of Kroner. After the adoption of the fixed exchange rate regime, and notably after the peg was stated in terms of the German Mark in 1987, the spread narrowed quickly. Since the early 1990s, the Danish policy rate has generally tracked the policy interest rate of the Bundesbank (until 1998) and the European Central Bank (from 1999) closely. The policy rate spread has been fairly constant and close to zero throughout the whole period.

The figures tell us that Danish monetary policy is conducted in accordance with standard theory for an economy with cross-border capital flows and a fixed exchange rate. In normal times, Denmark effectively imports its monetary policy stance from Frankfurt: when the European Central Bank changes its leading interest rate to pursue some policy objective for the Euro Area, the Danish Central Bank generally changes its rate by the same amount on the same day to restore the interest rate differential that is consistent with a fixed exchange rate. On rare occasions, however, the exchange rate objective requires that the policy rate is changed unilaterally. The Danish policy rate was temporarily raised far *above* the German/Euro Area

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<sup>8</sup>A major attack on Kroner occurred in February 1993 when a center-left government came into office on a policy agenda emphasizing job creation and growth. The new government quickly affirmed its commitment to the fixed exchange rate and the Danish central bank successfully defended the peg to Mark with interventions in currency markets and temporary increases in the policy rate. However, when the entire ERM came under attack and it was agreed to expand the fluctuation bands from 2.25% to 15%, Kroner depreciated temporarily against Mark. The U.K. famously left the ERM as a consequence of this currency attack.

rate when uncertainty in global currency markets caused capital to flow out of Kroner: during the speculative attacks in 1992-1993; when Mexico and Russia abandoned their currency pegs in 1994 and 1998; and when Lehman Brothers failed in 2008. More recently, the Danish policy rate has often been slightly *below* the Euro Area rate to prevent excessive capital flows into Kroner: during the European debt crisis in 2011 and when Switzerland suddenly abandoned its peg to the Euro in 2015.

In sum, by committing to exchange rate stability, Danish monetary authorities have voluntarily renounced on the ability to mitigate domestic shocks by adjusting the policy rate. Since 1987, keeping the exchange fixed has generally been achieved by mimicking the interest rate decisions made in Frankfurt; only in rare periods with turmoil in global markets, they have temporarily adjusted the interest rate spread.

### 3 Data

This section describes the micro-data on income, wealth and consumption used in the main analysis. We specify the sample, describe the data sources and provide summary statistics of the key variables. The micro-data come from different administrative registers and are matched with a unique personal identifier.

#### 3.1 Sources, variables and sample

The main source of micro-data is the Danish tax register, which contains annual information about taxable income and wealth at the individual level for the period 1987-2014. The information derives from tax returns and since tax filing is compulsory for all individuals with primary residence in Denmark, the dataset covers the entire adult population. The information is generally reliable as it is overwhelmingly reported by third parties like employers and financial institutions rather than by taxpayers themselves (Kleven et al., 2011).<sup>9</sup>

The tax register contains information about total taxable income as well as its various positive components (income) and negative components (deductions). The most important positive components are salary income, business income (from self-proprietorships), stock market income (dividends and realized capital gains), interest income (from deposits and bonds), government transfers (including public pensions) and private pension income (payouts from private pension accounts). The most important negative component is interest expenses. We define *disposable*

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<sup>9</sup>A recent paper reinforces this point by showing that tax evasion, the systematic misreporting of income on the tax return, is negligible, around 3%, in the aggregate (Alstadsæter et al., 2019).

*income* as the sum of the income components minus interest expenses and tax liabilities.<sup>10</sup>

The tax register also contains information about important categories of assets and liabilities.<sup>11</sup> Specifically, we observe the value of deposits, listed stocks and loans as reported by financial institutions as well as the value of real estate as assessed by the tax authorities for the purpose of property taxation. As the tax value of real estate often understates the market value, we use transaction prices retrieved from the real estate register to construct local market price indices, which allows us to approximate capital gains on real estate, including properties that do not change hands in a given period, at market value (see details in the Online Appendix).<sup>12</sup> The main wealth components for which no information is available on the tax return are loans from private persons and foreign banks (without a presence in Denmark); unlisted stocks; and savings in tax favored pension accounts.<sup>13</sup>

To study household-level consumption, we retrieve information about registration of cars from the auto register. We do not observe car values and therefore use the number of new cars registered in a given year as our key measure of consumption. This approach has several advantages relative to other consumption measures used in the literature: it has population-wide coverage and includes cars paid without external financing as opposed to measures based on auto loan balances obtained from financial institutions (e.g. Di Maggio et al, 2017) and it is not mechanically related to income and wealth as opposed to imputed measures of consumption (e.g. Holm et al., 2020).<sup>14</sup> However, our approach also has limitations: given that information on purchase prices is not available, we are not able to make quantitative comparisons between, say, income gains and consumption gains.

Finally, the population register provides information on age and place of residence and defines

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<sup>10</sup>There is a small residual income category "other income", which is the sum of a large number of rare and highly diverse income types that do not fit any of the other categories. While we include other income in overall disposable income, we do not study this income component separately.

<sup>11</sup>While this information previously served to levy a tax on net wealth, most of it remained on the tax return when the net wealth tax was abolished in 1997 (Jakobsen et al., 2020).

<sup>12</sup>Our qualitative results are robust to measuring capital gains on real estate as the change in tax values without any adjustments.

<sup>13</sup>Since the abolition of the net wealth tax in 1997, taxpayers are no longer required to complement the information reported by domestic banks with self-reported information on loans from other sources. Similarly, taxpayers are not required to provide estimated values of unlisted stocks. Tax favored pension accounts are similar to 401k in the United States: the accounts are personal and managed either by the individuals themselves or by private pension funds. Access to assets in pension accounts prior to pension age is possible, but triggers a significant penalty.

<sup>14</sup>A number of recent papers impute consumption from income and wealth data based on the accounting identity  $consumption = disposable\ income + net\ capital\ gains - change\ in\ net\ wealth$  (Browning and Leth-Petersen, 2003; Jensen and Johannesen, 2017; Eika et al., 2020). While we could, in principle, use imputed consumption as an outcome, we are concerned that systematic imputation errors may bias the results in the present context. For instance, a decrease in the policy rate causes the market value of fixed-rate mortgage loans to increase and the (unobserved) capital loss increases the imputed measure of consumption.

households, which is the unit of analysis throughout the paper. Two adults are considered to belong to the same household if they are married, registered partners or cohabiting partners. For variables such as income and wealth, we always take averages over adults belonging to the same household to ensure comparability across households with one and two adults. We define household age as the age of the oldest household member.

We limit the sample to households where the oldest adult member is at least 25 years old. Young households with low incomes are often students with high life-time incomes receiving considerable financial support from their parents (Andersen et al., 2020), so income rankings are not a good measure of economic resources for this group. We also exclude a small number of households with annual disposable income below a threshold of \$10,000 (in 2015 prices), since a recorded income below this level presumably reflects that true income is not measured well.<sup>15</sup>

## 3.2 Descriptive statistics

The main goal of the analysis is to estimate how the effects of monetary policy vary with the position in the income distribution. We capture positions in the income distribution by ranking households *within* age cohorts according to a three-year average of their total income and assigning them to income groups based on the rank. We prefer ranking within age cohorts as income, wealth and consumption change systematically over the life-cycle (Friedman, 1957; Ando and Modigliani, 1964).

To provide a basis for understanding the various channels through which monetary policy may differentially affect households at different income levels, we describe the composition of income and net wealth by income group in Table 1. For expositional simplicity, the table employs only 7 groups, each corresponding to 20% of the population except that the top group is further split into three subgroups (p80-90, p90-99 and top-1%) to highlight the pronounced heterogeneity at the top. Our regressions generally employ 21 groups, each corresponding to 5% of the population except that the top group is further split into two subgroups (p95-99 and top-1%).<sup>16</sup>

Panel A summarizes the relative importance of the various types of income and expenses by income group. Each item is scaled by disposable income so that the sum of the income components minus interest expenses equals 100% within each group (except for rounding). Net

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<sup>15</sup>To be precise, we use the threshold 60,000 kroner, which is lower than social benefits at the lowest rate. Measurement problems could arise due to work in the informal sector, unreported emigration or other similar reasons.

<sup>16</sup>In some regressions, we also study heterogeneous effects of monetary policy by age and thus group households by age rather than by income ranks.

government transfers are defined as transfers *from* the government in the form of pensions and benefits net of transfers *to* the government in the form of taxes. For the bottom income group (bottom-20%), salaries and government transfers are the main income components whereas business income, stock market income, interest income and private pension income are negligible. Moving up the income distribution, the importance of salary income increases until the 90th percentile and then decreases whereas the importance of business income, stock market income and, to a lesser extent, interest income increases throughout. In the top income group (top-1%), business income is almost as important as salary income and stock market income makes up a substantial part of disposable income. Reflecting the redistributive effects of government intervention, net government transfers decrease steeply as income increases. Interest expenses account for an increasing share of disposable income throughout the income distribution reflecting, as we shall show below, that household leverage tends to increase with income.

The differences in the composition of income is suggestive of how the quantitative effects of monetary policy may differ over the income distribution. For instance, if softer monetary policy increases salaries at the same rate for all income groups, it will create the largest relative increases in disposable income for the middle class; if it lowers interest expenses at the same rate for all income groups, the relative increase in disposable income will generally be larger at higher income levels; and if it increases dividend income at the same rate for all income groups, the top income group will enjoy the largest relative increase in disposable income. While these considerations are instructive, they also have clear limitations. First, the price effects need not be homogeneous across households: wage rates may increase more and interest rates may decrease less for some households than for others depending on the industries they work in and the type of loans they hold. Second, monetary policy may also have heterogeneous non-price effects: unemployed workers may find jobs and start earning salary income when the business cycle is improving and households may decide to take more loans or invest more in stocks when the market interest rate is falling. The magnitude of these effects could differ markedly across groups. Our regression results generally differ from the mechanical inference based on the Table 1 by accounting for heterogeneous price and non-price effects.

Panel B summarizes the value of the various types of assets and liabilities by income group.<sup>17</sup>

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<sup>17</sup>When comparing the balance sheet components to the corresponding income components, one should account for the fact that not all assets and liabilities are recorded (as discussed in 3.1). For instance, the ratio of stock market income to assets in the form of stocks is more than 20% in the top income group. This is likely to reflect the importance of unlisted stocks (i.e. closely held firms) for this particular group. Since unlisted stocks are not recorded on the tax return but the income derived from such stocks is recorded, the ratio of income to recorded assets is high.

Each item is scaled by disposable income so that summing across asset classes and subtracting debt gives the ratio of net wealth to disposable income (except for rounding).

Balance sheets are quite similar for the three lowest income groups (bottom-60%): net wealth amounts to around two times disposable income, real estate is by far the most important asset and financial assets are almost exclusively in the form of deposits.<sup>18</sup> Moving higher up in the income distribution, net wealth increases monotonically and reaches almost seven times disposable income in the top income group (top-1%). All three types of assets increase through the income distribution but not in the same proportions: housing roughly doubles (relative to disposable income) when moving from the bottom to the top income group, while deposits more than triples and the value of stocks increases more than twenty times. Debt also increases almost monotonically through the income distribution: it roughly doubles (relative to disposable income) when moving from the bottom to the top income group. This is tightly related to homeownership: households in higher income groups are more likely to own their home, which typically involves a significant degree of debt financing. The positive correlation between household income and leverage also emerges in other countries, including the United States (Kuhn et al., 2015).<sup>19</sup>

The composition of the balance sheet is suggestive of how monetary policy may affect households differentially through asset prices: if softer monetary policy increases house prices at the same rate across income groups, the gains will be only slightly increasing through the income distribution when measured relative to disposable income; however, if it increases stock prices at the same rate, the gains will be highly concentrated within the top income group. Again, these considerations are instructive, but do not account for heterogeneous price effects: if real estate prices are more responsive to monetary policy in some price segments than in others, it will contribute to the heterogeneity in gains and losses across households belonging to different income groups. Our regressions results account for this source of heterogeneity.

For completeness, Panel C describes six extensive margins: the fraction of individuals within each group that is net creditors, has no debt at all, holds any securities, owns any real estate, has any income (positive or negative) from self-employment, and buys a new car. All six statistics are monotonically related to income: as we move up through the income distribution, there are more net creditors, more stock market participants, more home owners, more self-employed and

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<sup>18</sup>Note that the category "deposits" also includes bonds.

<sup>19</sup>In 2013, the ratio of debt to income in the United States was around 80% for households in the bottom 20% of the income distribution and peaked at around 140% for households just below the top 10% (Kuhn et al., 2015 based on data from the U.S. Survey of Consumer Finances).

more households buying new cars, but less households with no debt at all.

## 4 Empirical design

The aim of the empirical analysis is to estimate how monetary policy differentially affects the income, wealth and consumption dynamics of households at different income levels. The endogeneity of monetary policy is a key challenge and we first describe how we address it with an instrumental variable strategy in section 4.1. Next, we develop a specification that uses the instrument to estimate heterogeneous effects of monetary policy over different time horizons in section 4.2.

### 4.1 Instrumenting monetary policy

Our measure of monetary policy is  $\Delta i_t$ , the change in the Danish policy rate from period  $t - 1$  to period  $t$ . Since monetary policy could potentially be endogenous to the business cycle, and thus to the income, wealth and consumption dynamics we are studying, we instrument  $\Delta i_t$  with the change in the German/Euro Area policy rate  $\Delta i_t^*$ . The peg to the German Mark / Euro, starting in 1987, ensures that the instrument is relevant: policy rate changes decided in Frankfurt are typically mimicked in Denmark.<sup>20</sup> However, to the extent that the Danish and the German/Euro Area business cycles are correlated, an endogeneity problem remains: if Frankfurt lowers the policy rate in years where German/Euro Area output is below potential, this may coincide with years where Danish output is also below potential. To address this concern, we further control for the macroeconomic environment in Germany/Euro Area. The residual variation in the instrument when conditioning on macro variables is effectively the German/Euro Area monetary policy shock in the sense of Christiano et al. (1999).<sup>21</sup>

Figure 3 illustrates the variation that identifies the effects of monetary policy in our baseline model. It plots the annual change in the German/Euro Area policy rate (red line) and in the Danish policy rate (green line) together with the German/Euro Area monetary policy shock (blue bars), in this case the residual from a regression of the change in the policy rate in period  $t$  on GDP growth and inflation in periods  $t - 1$  and  $t$ . The macro controls absorb a lot of the variation in the policy rate. For instance, the largest negative change in the German/Euro Area

<sup>20</sup>In a time-series regression with annual observations, regressing the change in the Danish policy rate in period  $t$  on the change in the German/Euro Area policy rate in period  $t$  while controlling for German/Euro Area GDP growth and inflation in periods  $t - 1$  and  $t$ , the same macro controls as in the household-level regression below, produces a coefficient on the change in the German/Euro Area policy rate of 1.36 [s.e.: 0.24; F-value: 32.1].

<sup>21</sup>In section 5.3, we show that our main results barely change if we instead instrument the change in the Danish policy rate with estimated German/Euro Area monetary policy *shocks*.



policy rate occurred in 2009 just after the financial crisis; however, after purging for the effect of GDP growth and inflation, the monetary policy shock is slightly positive.

In the regression analysis, we conduct a number of robustness tests where we broaden the set of macro controls and thus further restrict the identifying variation in the German/Euro Area policy rate. Specifically, we control for *ex ante* forecasts of GDP growth and inflation, as expectations about the future macroeconomic environment may well influence monetary policy decisions, and for the macroeconomic environment in Denmark. We also control for *ex post* Danish exports to address the concern that monetary policy choices in Frankfurt may affect household outcomes through its impact on Germany/Euro Area demand for Danish products and account for serial correlation in the monetary policy shocks.

The key advantage of the Danish institutional setting is that the currency peg introduces a highly transparent source of exogenous variation in monetary policy: Denmark adopts the monetary policy that is decided in Frankfurt with essentially no regard to the economic conditions in Denmark. A recent paper applies the same argument in a macro-setting, exploiting the currency pegs of 17 advanced economies over more than a century to estimate the effect of monetary policy on real GDP growth (Jordà et al., 2020). It also resembles the argument used by recent papers estimating the effect of monetary policy on the risk-taking of Spanish banks by exploiting that the monetary policy decisions made jointly by the members of the Euro Area are partly exogenous to the economic conditions in Spain (Jiménez et al., 2012, 2014).

## 4.2 Specification

In the first part of the analysis, we are interested in the heterogeneous effect of monetary policy on *income* dynamics. The explanatory variable of interest is the change in the policy rate from year  $t - 1$  to  $t$  interacted with income group indicators to allow for heterogeneity. The dependent variable is the change in disposable income (or an income component)  $Y$  from the *ex ante* level (before  $t$ ) to the level in either year  $t + 1$  or  $t + 2$ . The model thus captures the short-term and medium-term effects of monetary policy: the change in income taken over the year where the policy rate changes and the following one or two years. Our approach resembles the local projection method, which has become popular in empirical macroeconomics (Jordà, 2005). It yields reduced-form estimates of how today's changes in the policy rate (the impulse) shapes income in the future (the response). We thus obtain the following model:

$$\frac{Y_{j;t+n} - \bar{Y}_{j;<t}}{\bar{D}_{j;<t}} = \sum_{k=1}^K \mathbb{1}[j \in k] \left[ \alpha^k + \beta^k(-\Delta i_t) + \delta^k Z_t \right] + \varepsilon_{j,t} \quad (1)$$

where  $j$ ,  $t$  and  $k$  denote the household, the year and the income group and  $n = 1, 2$  indicates the time horizon. On the left-hand side,  $\bar{Y}$  expresses the *ex ante* levels of the outcome and  $\bar{D}$  the *ex ante* level of disposable income; both are averages taken over the three years before year  $t$  to reduce the effect of transitory shocks on these baseline income levels. On the right-hand side,  $\mathbb{1}[j \in k]$  indicates if household  $j$  belongs to income group  $k$  and  $Z$  denotes the vector of macro controls. We estimate the model using micro-data for the period 1987-2014 and report standard errors that are clustered at the level of households and year-municipality.<sup>22</sup>

The main coefficients of interest are in the vector  $\beta^k$ . Given that the change in the policy rate enters the model with a negative sign, these coefficients measure the effect of lowering the monetary policy rate by one percentage point, a *softening* of monetary policy, on the outcome for the average household in income group  $k$ . We note that the model allows for heterogeneous effects of the macro environment on household outcomes (i.e. separate coefficients on  $Z$  by income group). In robustness tests, we also include time fixed effects that absorb the (average) effect of *any* aggregate shock.<sup>23</sup> The model includes no household-level controls as our goal is not to compare otherwise similar households at different income levels, but to measure how systematic differences across income groups creates differential exposure to monetary policy. In robustness tests, however, we include household fixed effects. Since the model is in changes, this effectively allows for a household-specific linear trend in the level of the outcome variable.

Disposable income is our main income variable and, given the scaling, estimating the model with this outcome expresses the change in disposable income relative to its *ex ante* level. When we investigate the *channels* through which disposable income is affected by monetary policy, we apply the model separately to each of the positive and negative income components: salary income, business income, stock market income, interest income, private pension income, net government transfers and interest expenses. In these regressions, we retain the scaling with *ex ante* disposable income to obtain an (approximate) decomposition of the total effect on disposable income through the different channels.

In addition to the effects on disposable income, monetary policy may also create important gains and losses of wealth through its effect on asset prices. While monetary policy may, in

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<sup>22</sup>Clustering at the level of households crucially corrects standard errors for auto-correlation in the error term (Bertrand et al., 2004). The monetary policy stance varies by time and local economic conditions and, moreover, the variation in the main explanatory variable is at the level of income groups and time, suggesting that we should cluster at the level of year-municipality-income group (Moulton, 1986, 1990; Abadie et al., 2017). We generally present standard errors with clustering at the level of municipality-years, which is more general; however, we also show how standard errors change under alternative clustering schemes in Section 5.3.

<sup>23</sup>This specification only identifies the *gradient* in the effects of monetary policy, i.e. the average effect for a given income group relative to the average effect for a reference group.

principle, affect the prices of all types of assets and liabilities, our analysis focuses on two major asset classes: stocks and housing assets.<sup>24</sup> We use a slightly modified framework to estimate the price effects of monetary policy on these assets. Letting  $P$  and  $Q$  denote prices and quantities respectively, we define the capital gain on a given asset over time horizon  $n$  as  $P_{j,t+n}Q_{j,t-1} - P_{j,t-1}Q_{j,t-1}$  and use this as the outcome in the model (scaled by disposable income as usual). By holding quantities constant (i.e. fixing the portfolio), this concept of capital gains is unaffected by potentially endogenous portfolio adjustments, but may differ from actual capital gains and from actual changes in wealth in the presence of such adjustments.

For stocks, we observe the market value of each household's portfolio at the end of each year but have no information on the underlying securities. In practice, we therefore approximate capital gains and losses with the percentage change in the national stock market index multiplied by the *ex ante* value of the portfolio.<sup>25</sup> This approach yields capital gains estimates that are roughly correct in the aggregate (assuming that most Danish households invest in Danish stocks or foreign stocks with similar returns). The income gradient in the capital gains estimates captures systematic differences in portfolio sizes across income groups, but not systematic differences in portfolio risk (Calvet et al., 2007) and heterogeneous returns conditional on risk (Fagereng et al., 2020).

For housing assets, we know the location of each property and construct local price indices based on real estate transaction data. We compute the capital gain on each property as the *ex ante* market value of the property multiplied by the percentage change in the local housing price index (see details in the Online Appendix). The fact that we observe heterogeneous price developments across local areas is a major advantage compared to the analysis of stocks. The income gradient in the capital gains estimates captures both systematic differences in the value of housing assets across income groups as well as systematic cross-locality differences in the responsiveness of house prices to monetary policy.

Finally, we study the effects of monetary policy on wealth accumulation and consumption across the income distribution. Importantly, monetary policy may affect wealth and consumption through a range of channels. First, directly related to the analysis above, it creates gains

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<sup>24</sup>Due to specific institutional arrangements, mortgage loans with a fixed rate are also an important source of capital gains and losses: since borrowers have an option to repay mortgage loans at the market price of the underlying bonds, the market value of existing loans vary inversely with the market interest rate. The strength of this mechanism, however, depends strongly on the maturity of the loan, which we do not observe in our data; hence, we are unable to estimate the capital gains and losses on mortgage loans with any precision.

<sup>25</sup>Formally, the approximation is  $(P_{j,t-1}Q_{j,t-1})((\Pi_{t+n} - \Pi_{t-1})/\Pi_{t-1})$  where  $\Pi$  is the national stock price index. It is easy to see that the approximation assumes that the price of the individual portfolio ( $P_{j,t}$ ) exhibits the same growth rate as the price of the national portfolio ( $\Pi_t$ ).

and losses, which must pass through to either wealth or consumption due to the intertemporal budget constraint. These gains and losses are created through direct channels (e.g. household interest expenses go down when the policy rate is reduced because of pass-through to market interest rates) as well as more indirect channels (e.g. salary income goes up when the policy rate is reduced because of job creation and upward pressure on wage rates). Second, by changing market interest rates, monetary policy affects the trade-off between consumption and saving as captured by the intertemporal elasticity of substitution. Third, monetary policy may induce households to restructure their balance sheets, for instance to increase their leverage, with possible implications for wealth accumulation.

Concretely, we study the effect of monetary policy on wealth accumulation by using the change in net wealth (scaled by disposable income) as an outcome. Compared to the analysis of capital gains and losses, we no longer hold quantities constant (do not fix the portfolio); we make no assumptions about stock price returns (as we do observe the market values of stock portfolios); and we include all observable balance sheet components in the net wealth measure (including deposits and loans). We study the effect of monetary policy on consumption by using the change in the number of new cars registered by the household (compared to the *ex ante* period) as an outcome.

## 5 Main results

### 5.1 Disposable income

Figure 4 shows the estimated effects on disposable income of a one percentage point reduction in the policy rate at different positions in the income distribution and at different time horizons. Both the one-year effects (red line) and the two-year effects (blue line) are positive at all income levels. At the middle of the income distribution, the magnitude is slightly above 1% after one year and slightly below 1.5% after two years. The income gradient in the estimated effects is strikingly positive and becomes more pronounced over time. After two years, the effect is virtually zero for the lowest incomes and as high as 5% for the top-1%. This key result is robust to extending the set of macro controls and to different sets of fixed effects, as shown in Section 5.3.

Figure 5 investigates the channels underlying this striking income gradient by showing estimates for each component of disposable income.<sup>26</sup> In order to illustrate the income gradient

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<sup>26</sup>The analogous results over a one-year horizon are shown in Figure A1 in the Online Appendix.

as clearly as possible for all components, the panels have different scales on the y-axis, but we illustrate the results in an alternative way that facilitates quantitative comparisons in Figure 6 below.

As shown in Figure 5A, a decrease in the policy rate increases disposable income by lowering interest payments, which is consistent with pass-through to market interest rates.<sup>27</sup> There is a pronounced income gradient in these gains as households with higher incomes tend to experience a larger drop in interest expenses when the policy rate is reduced. The income gradient partly reflects that the ratio of debt to disposable income increases up through the income distribution (see Table 1) so that households with higher income benefit more from a given decrease in market interest rates. However, differences in the debt-income ratios cannot fully account for the estimated income gradient suggesting that the pass-through from policy rates to market interest rates is higher at the top of the income distribution. Presumably, pass-through is muted at lower income levels due to a lower propensity to use mortgage products with variable interest rates and more frequent failures to take advantage of opportunities to refinance mortgage loans with a fixed rate (Andersen et al., 2020).

As shown in Figure 5B, a decrease in the policy rate reduces disposable income by lowering interest income, which is again consistent with pass-through to market interest rates.<sup>28</sup> A clear income gradient emerges with households at higher income levels suffering more larger losses of interest income when the policy rate is reduced. Analogous to the case of interest expenses, the estimated income gradient partly owes itself to balance sheet differences: households at higher income levels tend to hold more interest bearing assets relative to their disposable income.<sup>29</sup>

In sum, Figures 5A-5B are concerned with the *direct channels* of monetary policy, i.e. the effect on income components that are mechanically linked to interest rates: interest payments on loans and interest income from deposits and bonds. The remaining panels of Figure 5 are concerned with the *indirect channels* of monetary policy, i.e. the effect on income components such as salary income, business income and stock income.

As shown in Figure 5C, softer monetary policy tends to increase disposable income by raising

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<sup>27</sup>For instance, the ratio of debt to disposable income is roughly 200% at the median income level, suggesting a pass-through rate of around one half given the estimated effect of around -1%.

<sup>28</sup>For instance, the ratio of deposits to disposable income is roughly 50% around the middle of the income distribution, suggesting a pass-through rate of around 80% given the estimated effect of around -0.4%.

<sup>29</sup>The reduction in households' interest income is smaller than the reduction in their interest expenses estimated above because only a small fraction of outstanding mortgage bonds, the majority of total lending, are held by households (see Table A1 in the Appendix). Most mortgage bonds are owned by banks, insurance companies, pension funds and foreign investors. We will capture the indirect effect on households of a reduction in the interest income of financial intermediaries when we analyze households' stock market income (Figure 5E) and stock portfolio values (Figure 8B).

salary income. The gain is largest for households at the 25th percentile of the income distribution, significantly smaller at the top and almost exactly zero at the bottom. The estimates may reflect quantity effects as well as price effects: salary income goes up because workers are employed more hours or because the hourly wage rate goes up. In Figure A2 in the Online Appendix, we show that a similar hump-shaped relation between the effects of monetary policy and the income level emerges when we use weeks of employment as the outcome, suggesting that quantity effects are at least partly driving the income gradient in salary income. This is consistent with the commonly held view that the gains created by monetary policy through the labor channel are concentrated among relatively low-income workers. However, the results also highlight that the most disadvantaged groups who have very low employment rates through the business cycle do not appear to reap any gains through the labor channel.

As shown in the next panels, reducing the policy rate generally increases disposable income by raising business income (Figure 5D) and stock market income (Figure 5E), but the effect is much stronger at the highest income levels. This pattern, at least partly, reflects that the propensity to be self-employed is increasing in income and that stock ownership is heavily concentrated at the very top of the income distribution (see Table 1). However, the strong non-linearity in the effects on business income also suggests that self-employed at different positions in the income distribution are differentially exposed to monetary policy shocks. Similarly, the steep gradient in the effect on stock market income may reflect that stockholders at different income levels systematically prefer stocks with different dividend policies and risk characteristics (Fagereng et al., 2020) and exhibit different propensities to realize latent capital gains over the business cycle (Hoopes et al., 2016).

As shown in Figure 5F, softer monetary policy tends to decrease net transfers from the government: by raising taxable income (e.g. salary income) and at the same time lowering deductible expenses (interest expenses), a lower policy rate indirectly reduces transfers from the government (such as unemployment benefits) and increases transfers to the government (such as tax payments). This mechanism is particularly strong in two parts of the income distribution: around the 25th percentile where most of the employment gains occur and within the top income group where the overall effect on non-salary income and interest expenses is largest. The results highlight that taxes and transfers moderate the effect of monetary policy on disposable income, notably at the top of the income distribution. In economies with less fiscal redistribution than in Denmark, we should therefore expect an even steeper income gradient in the effects of monetary policy.

Finally, as shown in Figure 5G, softer monetary policy tends to lower payouts from private pension plans. This is consistent with employees postponing retirement in response to improved labor market opportunities and retirees suspending annual pay-outs in response to income gains from other sources. The effect is uniformly negative at all income levels except at the very top of the income distribution where it is marginally positive (but statistically insignificant).

Figure 6 visualizes the same results in a way that facilitates a quantitative comparison of the various channels: at different positions in the income distribution, we show the overall effect of a one percentage point decrease in the policy rate on disposable income (horizontal lines) as well as the contribution to this effect from each of the components (colored bars).<sup>30</sup>

In the lower end of the income distribution (25th percentile) and around the middle (50th percentile), lower policy rates primarily expand disposable income by raising salary income (green bars) and, to a lesser extent, by lowering interest expenses (red bars). These positive effects are muted by lower net government transfers (orange bars) and, less importantly, by a reduction in interest income (light brown) and private pensions (dark brown). At the upper end of the income distribution (75th percentile), the picture is much the same except that interest expenses are a more important channel than salary income and that net government transfers do not mitigate these positive effects. Finally, at the very top of the income distribution (top-1%), the decrease in interest expenses is the most important channel and far larger than the analogous decrease in interest income (light-brown bars). The increase in salary income is dwarfed by the relatively large increases in business income (blue bars) and stock market income (black bars).

In sum, while softer monetary policy tends to increase disposable income more at higher income levels, as shown in Figure 4, this is the product of many channels working in different directions. A lower policy rate produces gains in the form of higher business incomes, higher stock market incomes and lower interest expenses, which are concentrated at the highest incomes, whereas gains in the form of higher salaries are larger near the bottom. Losses in the form of lower interest income are borne primarily by households at the top whereas losses in the form of lower government transfers and higher taxes are largest at the lower end of the distribution and at the very top.

## 5.2 Asset values

Figure 7 shows the estimated effect of a lower policy rate on asset values at different positions in the income distribution and at different time horizons. The estimates capture the "price

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<sup>30</sup>The contributions by individual components approximately sum to the total as illustrated in Figure A3 in the Online Appendix.

effects” of monetary policy, the effects on asset values working through changes in house prices and stock prices holding *ex ante* portfolios constant, but not the effect working through changes in the portfolios.

The estimated effects are positive at all income levels: softer monetary policy boosts asset prices and, thus, drives up asset values. There is a clear income gradient in the effects, which becomes more pronounced over time: a one percentage point decrease in the policy rate increases asset values by around 20% of disposable income at the bottom of the income distribution and by around 75% of disposable income at the top over the two-year horizon. While the gradient is qualitatively similar to the one we found for disposable income (Figure 4), the effects are generally larger by more than an order of magnitude. Measured relative to total asset values (see Table 1), the estimated effects range from around 6% at the bottom to around 8% at the top.

Figure 8 investigates the channels underlying these estimates by showing the contribution from housing assets and stocks to the overall two-year effect.<sup>31</sup> As shown in Figure 8A, softer monetary policy increases the value of housing assets at all income levels and the magnitude of the effect is monotonically increasing in income: the estimated gain is around 20% of disposable income at the bottom of the income distribution and by around 50% of disposable income at the top. The positive income gradient is largely explained by *ex ante* differences in the ratio of housing assets to disposable income (see Table 1). Combining the estimates in the figure with statistics on the value of housing assets suggests that a one percentage point reduction in the policy rate increases the value of housing assets by 6-9%, slightly more at the top than at the bottom.<sup>32</sup> Thus, the results suggest that the gradient in the estimated effects is mainly due to high-income households owning more real estate (relative to their disposable income) and to a lesser extent due to a differential sensitivity of real estate prices to interest rates.<sup>33</sup>

As shown in Figure 8B, softer monetary policy generally increases the value of household portfolios of stocks, but the gains are highly concentrated at the top of the income distribution: the estimated gain is around 15% of disposable income in the top income group and entirely negligible below the median income level. The striking income gradient in the estimates reflects

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<sup>31</sup>The analogous contributions to the one-year effect are shown in Figure A4 in the Online Appendix. The contributions by individual components approximately sum to the total as illustrated in Figure A5 in the Online Appendix.

<sup>32</sup>These estimates are very close to estimates of the effect of monetary policy rates on house prices of around 8-9% often cited in the literature (e.g. Taylor, 2007).

<sup>33</sup>As shown in Figure A6 in the Online Appendix, using the raw changes in the appraisal values of property rather than the imputed changes in market values gives similar results, although with a considerably steeper slope at the very top of the income distribution. These estimates capture both changes in the appraisal values as well as sales and purchases of property.



the concentration of stock ownership in the highest income groups (see Table 1). Combining the estimates with statistics on the value of stock portfolios suggests that a one percentage point reduction in the policy rate increases the value of stocks by around 6% for the top income group.<sup>34</sup>

In sum, the results suggest that a softer monetary policy creates gains in the form of higher asset values that are substantially larger than the gains in the form of higher disposable income. Moreover, both housing and stock portfolios contribute importantly to the heterogeneous effects on asset values. The gains created through increases in housing prices contribute most to the overall gains, but the gains created through increases in stock prices are most unequally distributed.

### 5.3 Robustness

We first test whether our main finding, a significant income gradient in the gains from a lower policy rate (through higher disposable income and asset values), is robust to including further controls. Our baseline model controls for *ex ante* GDP growth and inflation in Germany/Euro Area (interacted with income group indicators). We now sequentially add time fixed effects, more macro controls (also interacted with income group indicators) and household fixed effects. Figure A7 in the Online Appendix illustrates the two-year effects on disposable income (Panel A) and asset values (Panel B) estimated in the different models.

We start by introducing time fixed effects that absorb unobserved factors affecting all income groups in the same way (black line). This comes at the cost that only the income gradient in the estimates is identified. We choose the median income group (p45-p50) to be the omitted category and thus measure the effects of monetary policy for other income groups relative to the effects for that income group. The results suggest that lowering the policy rate by one percentage point raises disposable income by almost 4 percentage points more in the top income group than at the median and by almost 2 percentage points less in the bottom group than at the median. Similarly, the asset price effects (measured as a fraction of disposable income) are almost 50 percentage points larger in the top income group and almost 10 percentage points smaller in the bottom group than at the median.

Next, we sequentially add more controls to assess whether the income gradient emerging in the baseline model may be driven by omitted variables. Specifically, we add: (i) *ex ante* forecasts of Germany/Euro Area GDP growth and inflation (red line) to account for the fact

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<sup>34</sup>This is close to the widely cited estimate of the effect of monetary policy rates on stock prices of 6.8% (Rigobon and Sack, 2004).

that expected business cycle developments affect monetary policy choices; (ii) *ex ante* GDP growth and inflation in Denmark (green line) to account for a possibly differential importance of local economic conditions; (iii) *ex post* exports from Denmark (light brown line) to control for the effect of monetary policy decisions in Frankfurt through changes in demand for Danish products; (iv) policy rate changes in period  $t + 1$  (blue line) to account for any serial correlation in the monetary policy interventions. All the new controls are interacted with a full vector of income group indicators.

The results are qualitatively unchanged but adding more controls attenuates the income gradient modestly. For instance, in a saturated model that controls for *ex ante* GDP growth, inflation and macro forecasts in Germany/the Euro Area, *ex ante* GDP growth and inflation in Denmark and *ex post* exports from Denmark, decreasing the policy rate by one percentage point creates a differential gain of disposable income for the top income group of around 3 percentage points (compared to 4 percentage points in the more parsimonious baseline model) and a differential increase in asset values of around 35% of disposable income (compared to just below 50% in the baseline model).

Further, we re-estimate the baseline model with an alternative estimation procedure, an alternative measurement of the policy rate and an alternative sample period. Specifically, (i) we estimate the German/Euro Area monetary policy shock in a "stage zero" and use it to instrument for the change in the Danish policy rate (red line);<sup>35</sup> (ii) measure the policy rate with the shadow rate that accounts for the zero lower bound (green line);<sup>36</sup> and (iii) add observations for the period 2015-2017 in the asset value model (light brown line), which is possible because we impute the outcome from *ex ante* asset values observed on the tax return (available until 2014) and subsequent changes in real estate and stock prices (available until 2017). For each of these variations of the baseline model, Figure A8 in the Online Appendix illustrates the two-year effects on disposable income (Panel A) and asset values (Panel B). The results are qualitatively robust to all of these perturbations and quantitatively very similar to the baseline model. First, adding an extra stage to the estimation procedure makes the gradient somewhat steeper for disposable income and somewhat flatter for asset values. Second, using the shadow rate makes virtually no difference for any of the estimates. Third, extending the sample period makes the gradient slightly steeper for asset values.

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<sup>35</sup>The monetary policy shock is the residual from a regression of the change in the German/Euro Area policy rate in year  $t$  on GDP growth and inflation in years  $t - 1$  and  $t$ .

<sup>36</sup>The shadow rate is not bounded at zero and captures the effect of both conventional and unconventional monetary policy measures (Wu and Xia, 2016).

Moreover, we augment the baseline model with household fixed effects. Given that our outcomes are *changes* in income or asset values, household fixed effects effectively allow for a household-specific linear trend in the level of the outcome. As shown in Figure A9 in the Online Appendix, the results are qualitatively robust to this demanding extension of the model. The gradient in the income gains created by a decrease in the policy rate is substantially steeper, with estimated gains to the top-1% exceeding gains to the median income group by more than 5 percentage points (Panel A). By contrast, the gradient in the gains of asset values is moderately flatter than in the baseline model (Panel B).

Finally, we probe the sensitivity of the standard errors to assumptions about the correlation structure in the error term. Specifically, Figure A10 in the Online Appendix shows the two-year effects from the baseline model for disposable income (Panel A) and asset values (Panel B) with four different confidence intervals based on clustering at the level of: (i) households; (ii) households and year-municipality; (iii) households and year-municipality-income group; (iv) households and municipality-income group. While clustering at the level of households corrects standard errors for auto-correlation in the error term (Bertrand et al., 2004), we add a second dimension of clustering to reflect that the monetary policy stance varies by time and local economic conditions and that the variation in the main explanatory variable is at the level of income groups and time (Moulton, 1986, 1990; Abadie et al., 2017). Clustering at the level of households alone produces tiny standard errors. Adding a second dimension of clustering generally widens the confidence intervals considerably; however, the income gradient continues to be statistically significant in all cases.

## 6 Further results

### 6.1 Leverage

To investigate the role of household leverage in monetary policy transmission, we re-estimate the baseline model, allowing the effect of the policy rate to vary with household leverage. While the baseline model includes interactions between the policy rate variable and indicators of *ex ante* income, we now interact each of these terms with indicators of *ex ante* leverage.<sup>37</sup> Specifically, we define leverage as the ratio of debt to gross income and consider four groups defined with reference to the within-year sample distribution of this ratio: households with no debt, low debt (< 20th percentile), medium debt (20th - 80th percentile) and high debt (> 80th percentile).

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<sup>37</sup>The augmented model also includes a full set of three-way interactions between macro controls, income group indicators and leverage indicators.

We start by considering how leverage mediates the effect of monetary policy on interest expenses. Specifically, Figure 9A shows the estimated gain in the form of lower interest expenses associated with a decrease in the policy rate at different positions in the income distribution and for each leverage group separately. The results highlight that the magnitude of the direct effect of monetary policy is tightly linked to the size of the debt. Comparing within income groups, the gain is increasing monotonically in leverage. Comparing within leverage groups, the gain is roughly the same size across households with different income. The main exception is that gains are larger for the top income group than for households with comparable leverage in other income groups.<sup>38</sup>

As shown in Figure 9B, the striking monotonicity in leverage remains when we consider the effect of softer monetary policy on overall disposable income: at each position in the income distribution, the increase in disposable income following a decrease in the policy rate is larger for households with more leverage. Only in the top income group do households with no debt appear to gain more from a softer monetary policy than households with moderate leverage, suggesting that they have large gains through indirect channels. As before, comparing households with roughly the same leverage, the increase in disposable income is roughly similar across income levels, suggesting that differences in leverage account for a significant part of the income gradient in the effect of monetary policy on disposable income. The only exception to this pattern is the top-1% where gains are considerably larger than elsewhere in the income distribution at all levels of leverage, suggesting larger gains through indirect channels.

Next, we consider how leverage mediates the effect of monetary policy on wealth through asset prices. Figure 10 shows the "price effect" on the value of housing assets (Panel A) and stock portfolios (Panel B) for households with different income and leverage. The patterns for the two asset classes are strikingly different. On the one hand, leverage explains most of the income gradient in the effect on housing assets: when comparing households with the same

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<sup>38</sup>Pass-through may be stronger for high-income households to the extent that they more frequently have mortgage loans with a variable rate or have a higher propensity to refinance mortgage loans with a fixed rate. Unrecorded debt is a potential issue because tax returns, our main data source, only include information on debt from domestic financial institutions (including domestic branches or subsidiaries of foreign banks), as discussed in Section 3. Note that interest expenses do not suffer from the same measurement problem as households must self-report interest payments to foreign banks without a presence in Denmark on the tax return (and have an incentive to do so in order to obtain a tax deduction). Finally, it may be the case that households in the top income group have higher leverage than the other groups within each leverage group and that leverage itself responds more strongly to the interest rate in the top income group (e.g. paying back more debt in periods with falling interest rates). Relatedly, the gains estimated for households with no debt may reflect interest payments on unrecorded debt or the extensive margin of borrowing: some households with no *ex ante* leverage take on debt and thus start incurring interest expenses when the policy rate is raised (for instance, because they buy a house in response to falling house prices induced by the tighter monetary policy).

leverage, the gain is similar across income levels. This reflects that most real estate is partly financed with debt so that highly levered households have more housing assets and therefore benefit more from increases in housing prices. This mechanism applies to a lesser extent to the top income group where owning significant housing assets without debt is more prevalent.

On the other hand, leverage explains almost none of the income gradient in the effect on stock values: when comparing households with the same leverage, the income gradient remains highly pronounced. Moreover, when comparing households in the same income group, the effect is generally stronger for households with less debt. These patterns reflect that leverage and stock holdings tend to be negatively correlated.<sup>39</sup>

## 6.2 Wealth and consumption

We now turn to the effect of monetary policy on wealth accumulation and consumption. This relates directly to our main analysis because the gains created by a softening of monetary policy, whether in the form of disposable income or increased asset values, are necessarily either consumed or added to the wealth stock due to the intertemporal budget constraint. However, monetary policy also affects wealth accumulation and consumption through other channels. Most importantly, by changing market interest rates, it affects the overall fraction of income saved for future consumption as captured by the intertemporal elasticity of substitution. Moreover, it may induce households to restructure their balance sheets with possible implications for wealth accumulation, for instance by increasing leverage or changing the share of risky assets.

Figure 11A shows the estimated effect on net wealth at different positions in the income distribution over a two-year horizon. The results suggest that monetary policy has a strong effect on net wealth across the entire income distribution, but more so at higher income levels: the estimate is in the range of 20-30% of disposable income below the median income level and then rises monotonically to almost 80% of disposable income in the top income group. These estimates are strikingly similar to the estimated "price effects" on asset values (Figure 7). This is consistent with existing evidence that only a small fraction of the gains and losses created by asset price changes are channelled into consumption in the short term (Aladangady, 2017; Di Maggio et al., 2020). The results are also consistent with an important role for "saving by holding" (Fagereng et al., 2019) whereby capital gains on, for instance, homes are only to a limited extent transformed into consumption through a reduction in liquid assets or new

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<sup>39</sup>Whether we compare households in the full sample or within income groups, households with more leverage have smaller stock portfolios. This negative correlation is, for instance, consistent with a simple behavioral rule where households first use savings to pay off mortgage debt and then use them to invest in financial assets.

mortgage loans (Andersen and Leth-Petersen, 2019).

Measured relative to net wealth (see Table 1), the estimated effects are generally above 10%, which is somewhat larger than the estimated capital gains on housing and stocks measured relative to total assets (discussed above). The difference is due to two factors: First, the increase in net wealth is larger than the estimated capital gains (larger numerator). Second, a given capital gain causes a larger relative increase in net wealth than in asset values holding other things constant (smaller denominator).

Figure 11B shows the estimated two-year effect on the propensity to purchase a new car. Cars are arguably the most important durable consumption good and many empirical papers use changes in car consumption to approximate changes in total durable consumption (e.g. Di Maggio et al., 2017). The results indicate that the effects of softening monetary policy on car consumption are highly heterogeneous across income groups: a one percentage point reduction in the policy rate increases the annual purchases of new cars by around 0.001 cars at the median income level; four times more at the top of the income distribution and only negligibly at the bottom.<sup>40</sup> This suggests that the differential income gains and capital gains created by a softening of monetary policy are also associated with a differential increase in consumption for high-income households.

### 6.3 Age

While our analysis until now has focused on the heterogeneous effects of monetary policy across income groups, this section investigates the heterogeneity in an entirely different dimension: age. Exposure to the various channels of monetary policy varies across age groups due to life cycle patterns in labor market participation, borrowing and wealth accumulation, as summarized in Table A2 in the Online Appendix. Our model remains the same as the baseline except that the change in the policy rate is now interacted with indicators of age rather than with indicators of income.

Figure 12 illustrates the estimated effects on disposable income (Panel A) and asset values (Panel B) for different age groups over a two-year time horizon. There is a hump-shaped relation between the effects on disposable income and age: the effects are close to zero for the young (below age 35) and the old (above age 75) and roughly at the same positive level for the age groups in between. By contrast, the effect on asset values is almost monotonically increasing

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<sup>40</sup>As we do not observe car values, we are not able to estimate the effect of monetary policy on car consumption in fractions of disposable income. It is not obvious how the gradient would change as both disposable income and the average value of newly purchased cars would increase though the income distribution.

in age. These relationships reflect that exposure to the various direct and indirect channels of monetary policy change markedly over the life cycle (Table A2). Importantly, the middle-aged (age 35-65) have most debt relative to disposable income and therefore benefit most from lower interest expenses when the policy rate is lowered and the elderly (above age 65) have most assets and therefore benefit most from higher prices on stocks and houses.

In sum, the results suggest that the disposable income channel of softer monetary policy is stronger for middle-aged households whereas the asset price channel is stronger for old households. Younger households have the smallest gains through both channels.

## 7 Income inequality

The strong income gradient in the effects of monetary policy suggests that there may be important implications for inequality. In this section, we use our estimates of the heterogeneous effects of monetary policy to conduct a simple simulation exercise that quantifies the effect of a one percentage point decrease in the policy rate on one of the most commonly used distributional measures: income shares (e.g. Piketty, 2014).

We first determine the *actual* shares of aggregate disposable income for each of the 21 income groups. We then compute the gain in disposable income for each household over a two-year horizon in a *counterfactual* scenario where the policy rate is lowered by one percentage point. To establish the counterfactual, we assume that the effects of a decrease in the policy rate vary across income groups in the way we estimated in our baseline model (Figure 4), accounting for direct as well as indirect channels. We finally plot the percentage difference between the counterfactual shares and the actual shares of aggregate disposable income in Figure 13.

The results show that the effect of monetary policy on income shares is strongly monotonic: a lower policy rate increases the income share for high-income households and decreases it for low-income households. Specifically, lowering the policy rate by one percentage point increases the share of aggregate disposable income by around 3% for the top-1% and decreases it by around 1.5% for the bottom income group. Hence, our results suggest that monetary policy, through a range of direct and indirect channels, has an economically significant impact on the distribution of disposable income. While disposable income increases for *all* income groups when monetary policy is softened, the gains are larger for high-income than for low-income households so the distribution of disposable income becomes more unequal.

To put these estimates in perspective, we note that the income share of the top-1% in Denmark has increased by around 50% over our sample period, from around 7.5% in 1990

to around 11% in 2013 (World Inequality Database, 2020). Importantly, however, the income concepts are different: our estimates concern the distribution of disposable income whereas most of the literature, including the one cited here, concerns the distribution of market income before government transfers and taxes. As government transfers and taxes generally mute the income gradient in the effects of monetary policy on income, as shown in Figure 5, our simulation results most likely understates the effect of monetary policy on inequality in market income. Finally, the simulation does not account for the distribution of the gains created by the wealth channel, as shown in Figure 7.

## 8 Conclusion

In this paper, we have studied the *distributional effects* of monetary policy across income groups. Our results document a strong income gradient in the gains from expansionary monetary policy: while households at all income levels benefit from a lower policy rate in terms of disposable income, asset values, net wealth and durable consumption, households at higher income levels generally benefit more. The distributional effects reflect systematic differences across income groups in the exposure to the direct and indirect channels of monetary policy. The results suggest that monetary policy has a sizeable effect on inequality: lowering the policy rate by one percentage point increases the share of aggregate disposable income by around 3% for the top-1% and decreases it by around 1.5% at the bottom of the income distribution.



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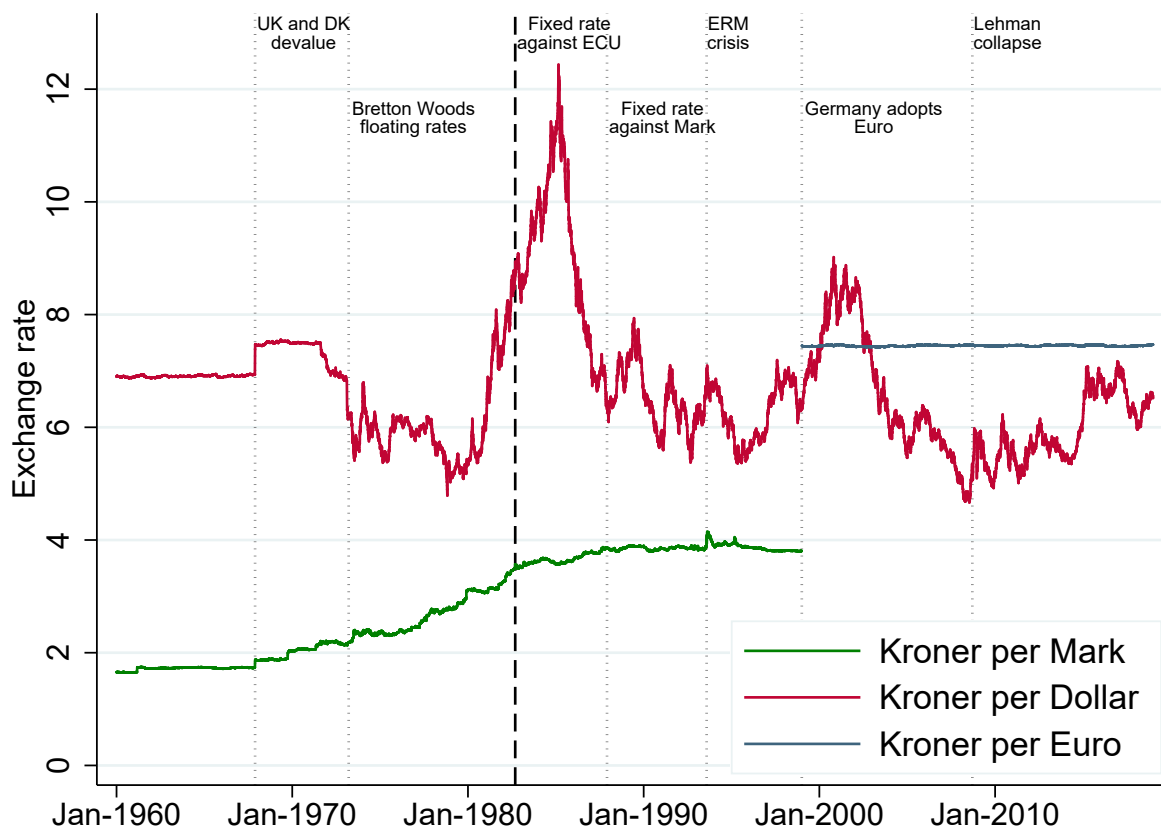
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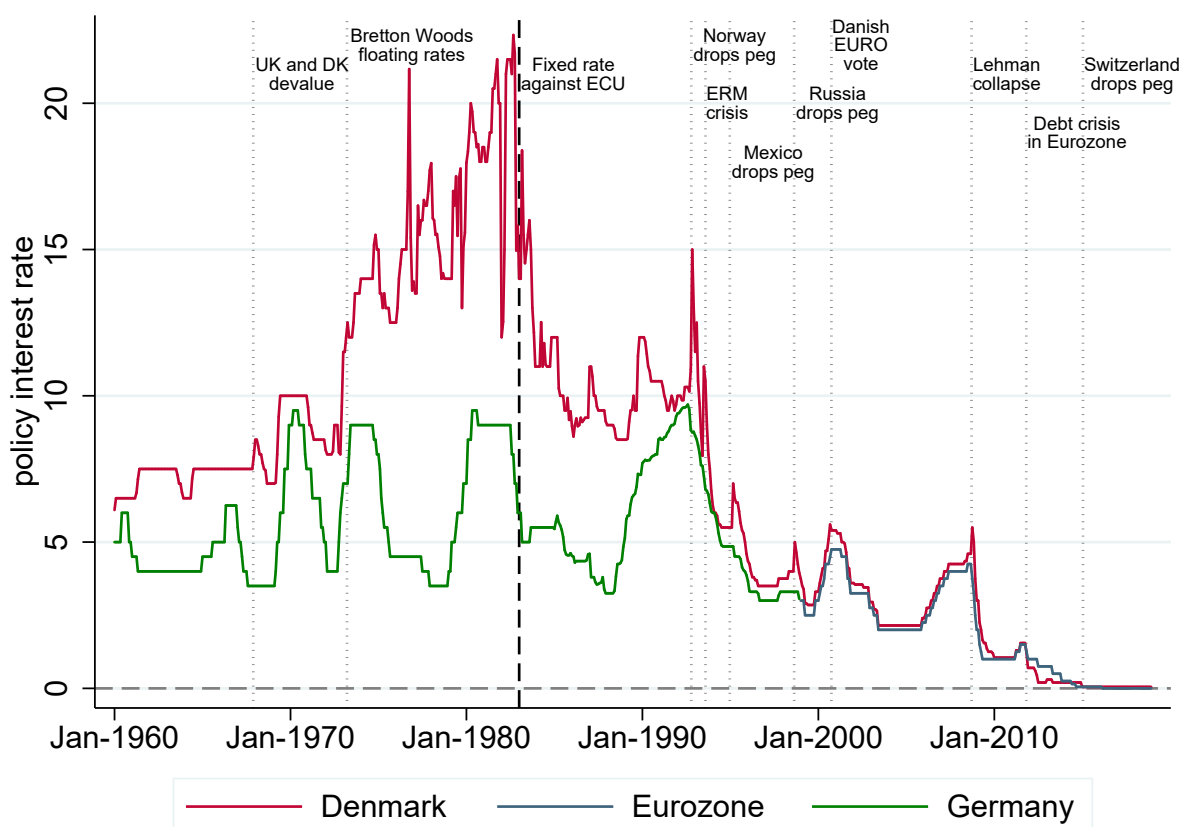
**Table 1: Descriptive statistics** The table shows describes the composition of disposable income (Panel A) and net wealth (Panel B) and describes some important behavioral margins (Panel C) by income groups. All income and wealth elements are expressed as a fraction of disposable income. To define the income groups, we rank households within each age-cohort. The seven income groups are: individuals up to the 20th percentile (*p0-20*); between the 20th and 40th percentile (*p20-40*); between the 40th and 60th percentile (*p40-60*); between the 60th and 80th percentile (*p60-80*); between the 80th and 90th percentile (*p80-90*); between the 90th and 99th percentile (*p90-p99*) and above the 99th percentile (*p99-100*). To construct Panels A and B, we have aggregated each income and wealth element within each income group over the entire sample period and divided with disposable income aggregate in the same way.

	p0-p20	p20-p40	p40-p60	p60-p80	p80-p90	p90-p99	p99-p100
<b>Panel A: income components (% of disposable income)</b>							
salary income	40%	96%	118%	128%	135%	130%	73%
business income	4%	5%	6%	8%	12%	27%	62%
stock market income	0%	0%	1%	1%	2%	6%	41%
interest income	1%	2%	2%	2%	3%	5%	10%
net government transfers	58%	5%	-18%	-35%	-51%	-67%	-80%
interest expenses	8%	13%	15%	16%	18%	21%	23%
private pension	4%	5%	6%	10%	15%	17%	11%
other income	1%	1%	1%	1%	2%	3%	7%
<b>Panel B: net wealth components (% of disposable income)</b>							
deposits	64%	67%	66%	82%	96%	129%	234%
stocks	8%	10%	11%	16%	23%	42%	180%
housing	283%	348%	366%	435%	506%	604%	578%
debt	145%	210%	235%	263%	294%	337%	321%
net wealth	210%	214%	208%	270%	331%	438%	671%
<b>Panel C: descriptive indicators</b>							
is net creditor	64%	71%	74%	77%	81%	84%	87%
has no debt	30%	25%	23%	20%	18%	16%	15%
holds stocks	19%	27%	31%	40%	48%	58%	70%
owns real estate	37%	54%	59%	68%	74%	82%	90%
is self-employed	8%	9%	10%	12%	16%	26%	49%
buys new car	1%	3%	3%	4%	5%	6%	7%

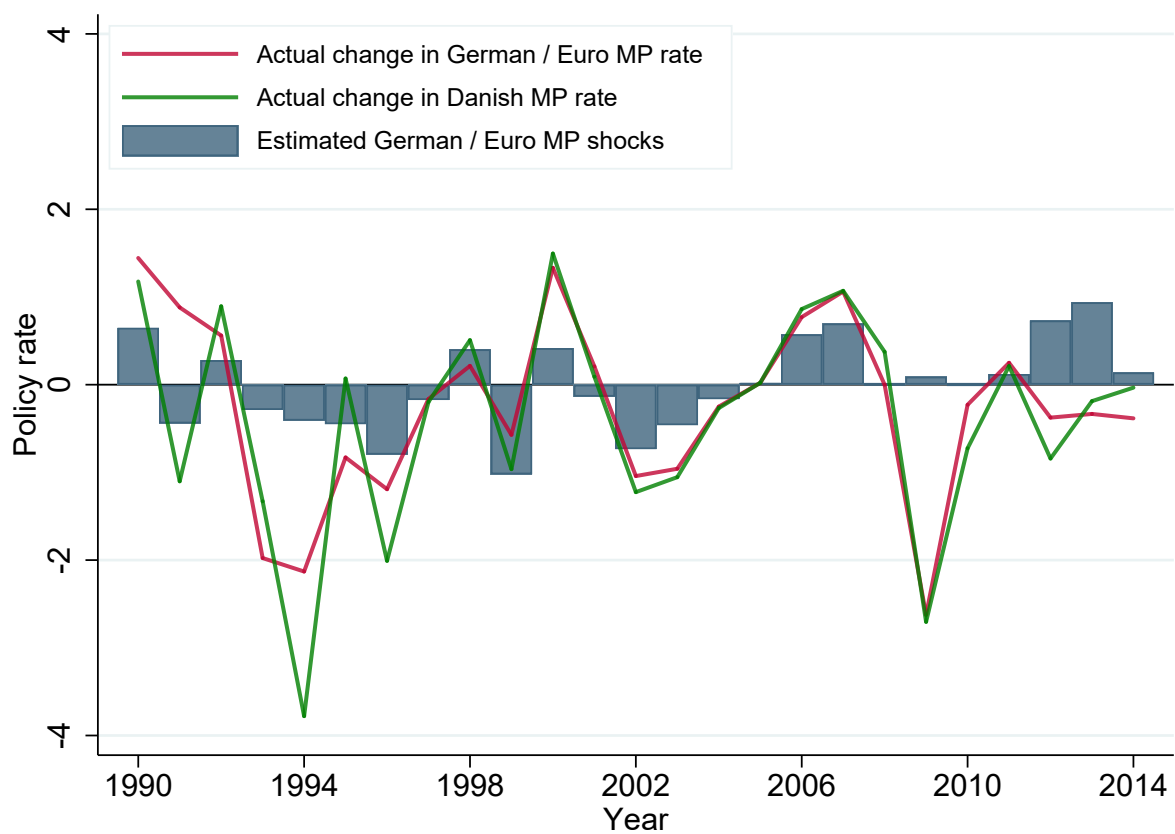
**Figure 2 – Exchange rates.** Notes: The figure shows the following daily exchange rates: Danish Kroner per German Mark (1/1-1960-31/12-1998); Danish Kroner per Euro (1/1-1999-31/12-2018) and Danish Kroner per US Dollar (1/1-1960-31/12-2018). The dashed lines indicate the following events: *UK and DK devalue* indicates 20 November 1967 where the UK devalued the Pound and Denmark swiftly followed; *End of Bretton Woods* indicates 19 March 1973 where the European currencies started to float against the dollar effectively ending the pegged exchange rate regime known as Bretton Woods; *Fixed rate against the ECU* indicates 10 September 1982 where a new Danish center-right government took office and announced its commitment to a fixed exchange rate; *Fixed rate against Mark* indicates 12 January 1987 where ERM governments decided a major realignment of the ERM exchange rates, the last one where Kroner was devalued against Mark; *ERM crisis* indicates 2 August 1993 where the ERM governments decided to broaden the fluctuation bands to 15% in response to almost 12 months of speculative attacks; *Germany adopts Euro* indicates 1 January 1999 where Germany adopted the Euro; *Lehman collapse* indicates 15 September 2008 where Lehmann Brothers Filed for bankruptcy.



**Figure 3 – Policy interest rates.** Notes: The figure shows leading policy interest rates for Denmark, Germany (January 1960 - December 1998) and the Euro Area (January 1999 - December 2018). The leading policy rate is: the lending rate until November 2013 and then the deposit certificate rate (Denmark); the Lombard rate until 1987 and then the repo rate (Germany); the major refinancing operations rate until November 2013 and then the deposit rate (Eurozone). The dashed lines indicate the following events: *UK and DK devalue* indicates 20 November 1967 where the UK devalues and Denmark swiftly follows; *End of Bretton Woods* indicates 19 March 1973 where the European currencies start to float against the dollar effectively ending the pegged exchange rate regime known as Bretton Woods; *Fixed rate against the ECU* indicates 10 September 1982 where a new center-right government takes office and announces its commitment to a fixed exchange rate; *Fixed rate against Mark* indicates 12 January 1987 where ERM governments decide a major realignment of the ERM exchange rates, the last one where Kroner is devalued against Mark; *Norway drops peg* indicates 10 December 1992 where Norway abandons the to the ECU; *ERM crisis* indicates 2 August 1993 where the ERM governments decide to broaden the fluctuation bands to 15% in response to almost 12 months of speculative attacks; *Mexico drops peg* indicates 20 December 1994 where Mexico abandons the peg to the US dollar; *Russia drops peg* indicates 17 August 1998 where Russia abandons the peg to the dollar; *Danish EURO vote* indicates 28 September 2000 where a Danish referendum rejects that Denmark join the Euro; *Lehman collapse* indicates 15 September 2008 where Lehmann Brothers files for bankruptcy; *Debt crisis in Eurozone* indicates 26 October 2011 where 50% of the Greek sovereign debt held by banks is written off; *Switzerland drops peg* indicates 15 January 2015 where Switzerland abandons the peg to the Euro.

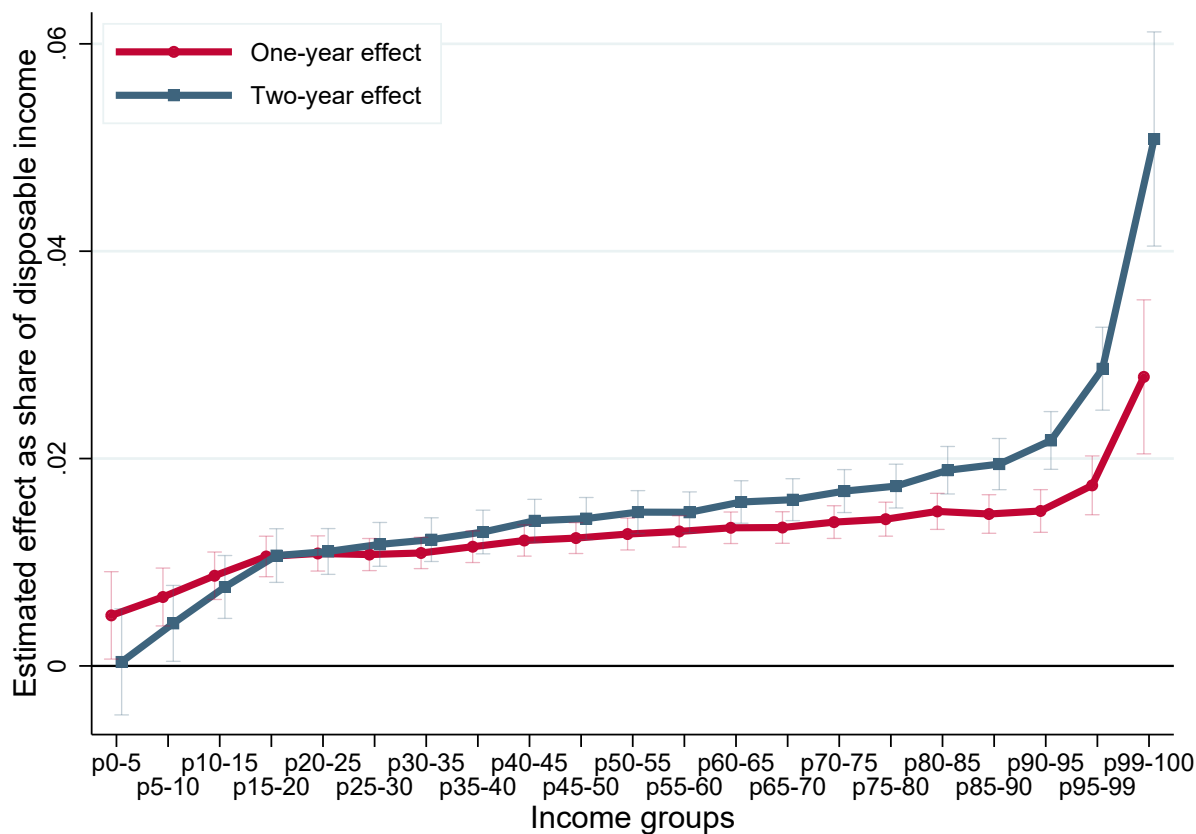


**Figure 3: Monetary policy rates** The figure shows the annual change in the policy rate in Germany / Euro Area (red line); the annual change in the policy rate in Denmark (green line); and the residual variation in the policy rate in Germany / Euro Area after regressing on current and lagged values of GDP growth and inflation (blue bars).

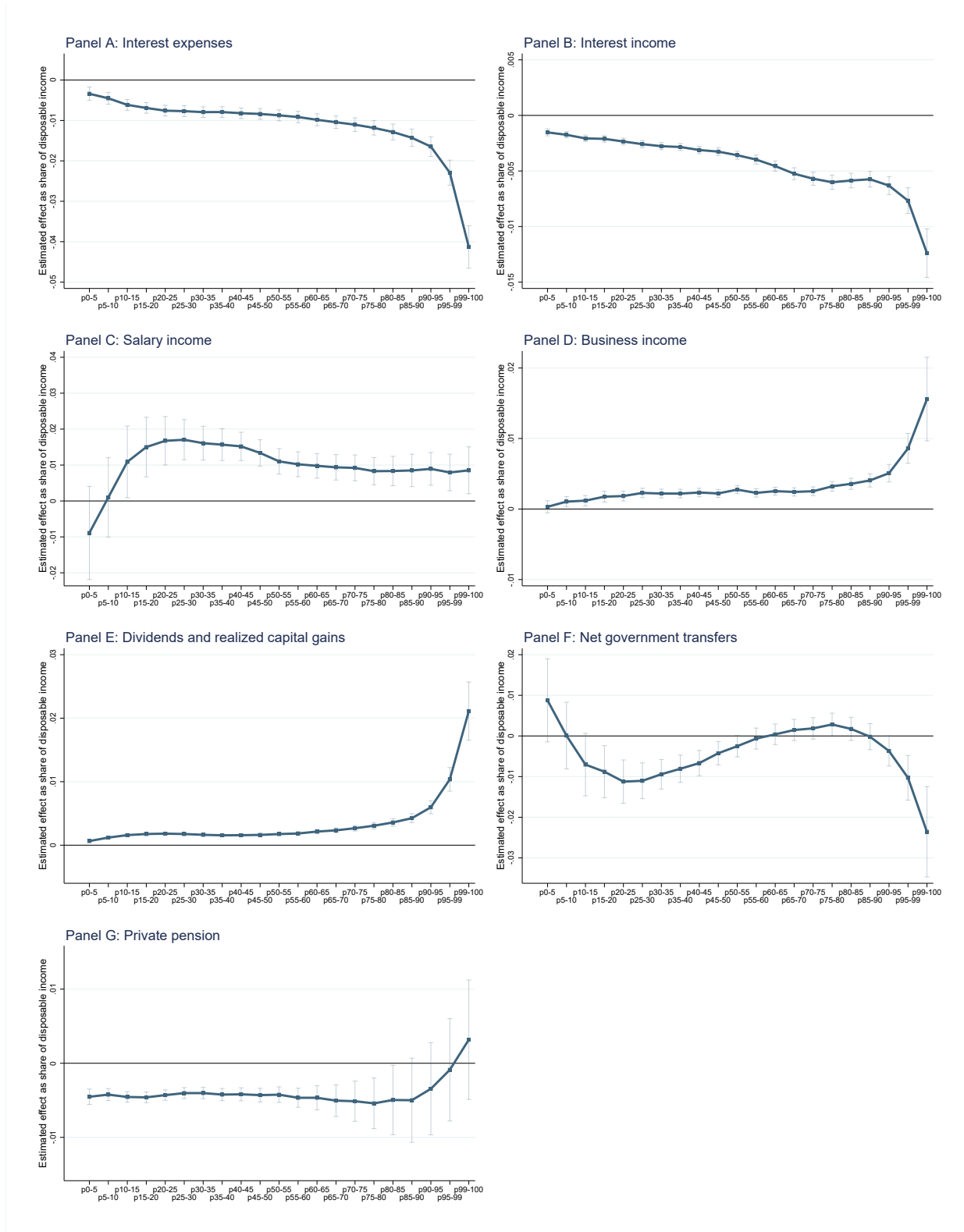




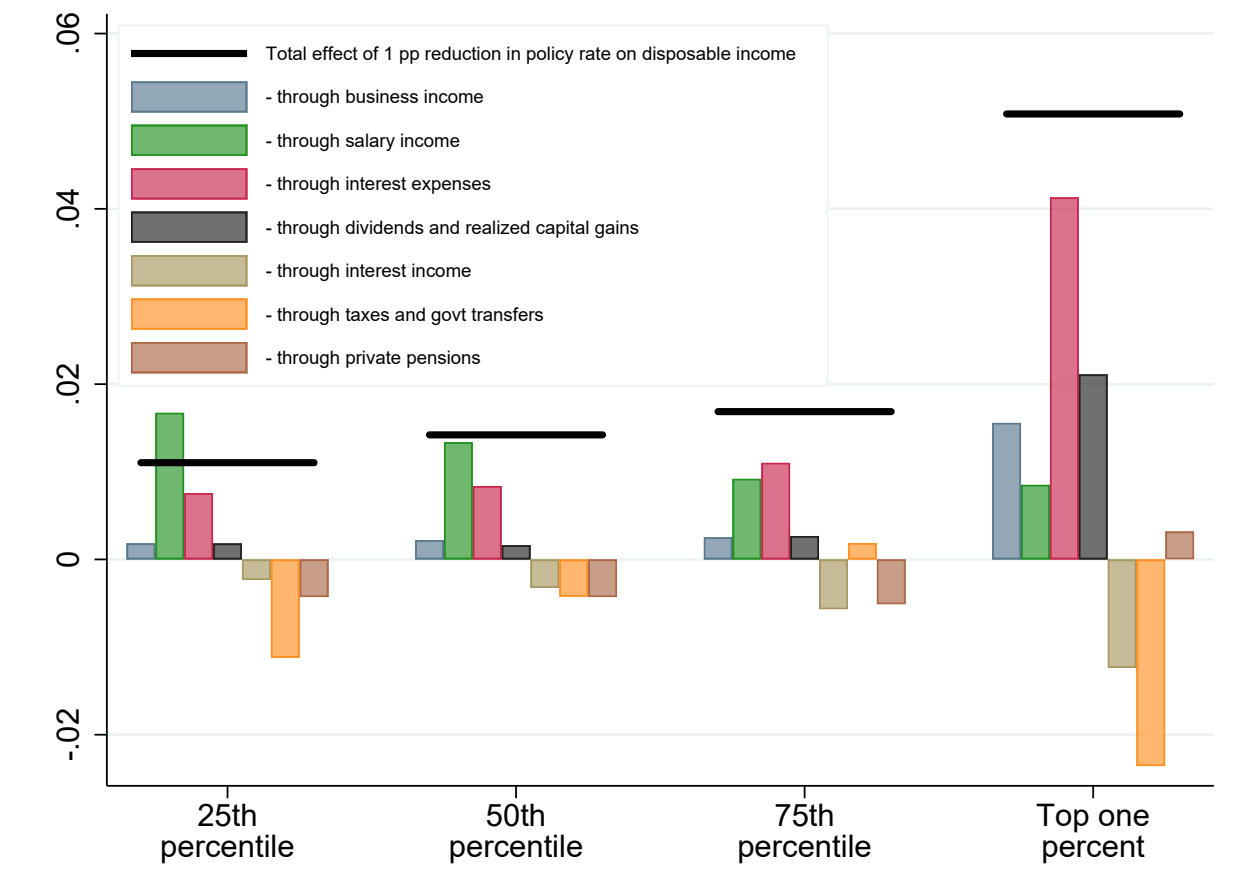
**Figure 4: Heterogeneous effects of monetary policy on disposable income.** The figure shows the estimated effects of a one percentage point decrease in the monetary policy rate on disposable income at different positions in the income distribution and over different time horizons: one year after the policy rate is changed (red squares) and two years after the policy rate is changed (blue squares).



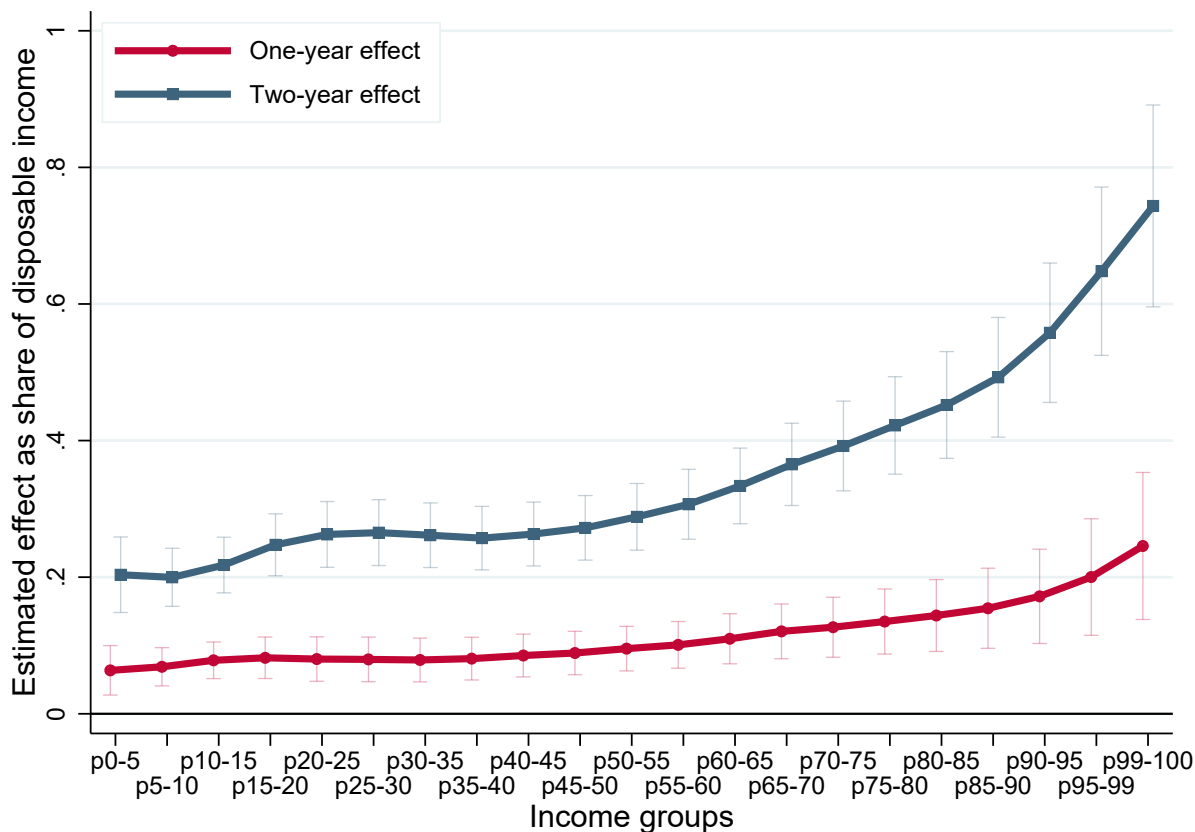
**Figure 5: Heterogeneous effects of monetary policy on income by component.** The figure shows the estimated two-year effect of a one percentage point decrease in the monetary policy rate on the components of disposable income at different positions in the income distribution. The estimates for shorter time horizons are reported in Figure A1 in the Online Appendix.



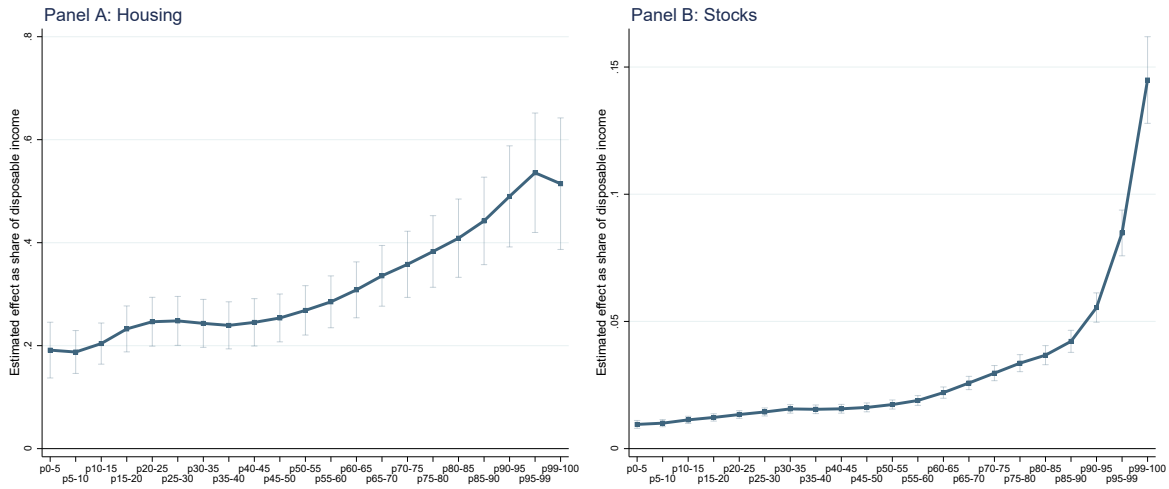
**Figure 6: Heterogeneous transmission of monetary policy to disposable income.** The figure shows the estimated two-year effect of a one percentage point decrease in the monetary policy rate on disposable income at four distinct positions in the income distribution (black horizontal lines) as well as the contributions to this overall effect from each of the components of disposable income (colored bars). The four income groups refer to households between the 20th and 25th percentiles ("25th percentile"); between the 45th and 50th percentiles ("50th percentile"); between the 70th and 75th percentiles ("75th percentile"); and above the 99th percentile ("top one percent").



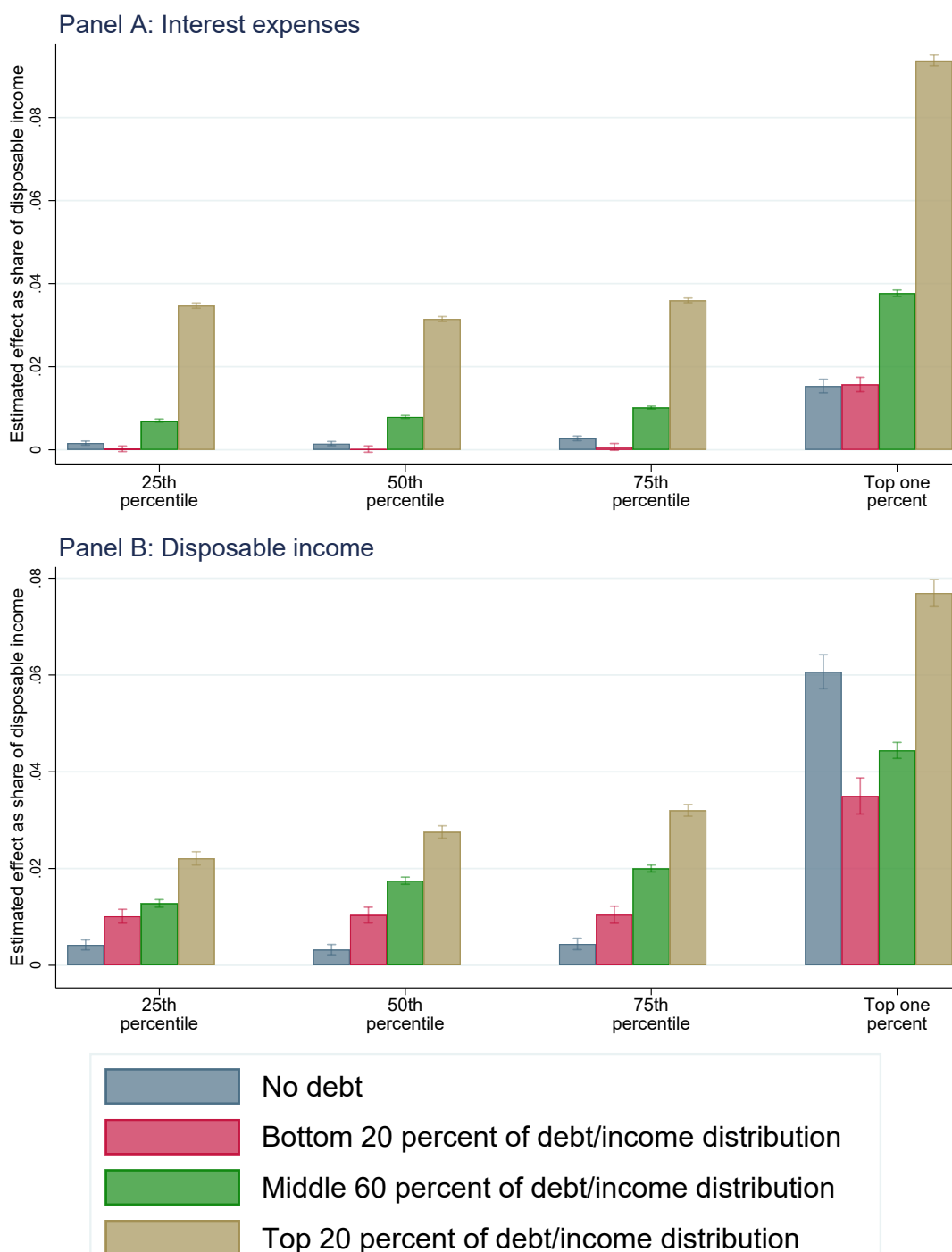
**Figure 7: Heterogeneous effects of monetary policy on asset values.** The figure shows the estimated "price effect" of a one percentage point decrease in the policy rate on the combined value of housing and stocks at different positions in the income distribution and over different time horizons: one year after the policy rate is changed (red squares) and two years after the policy rate is changed (blue squares).



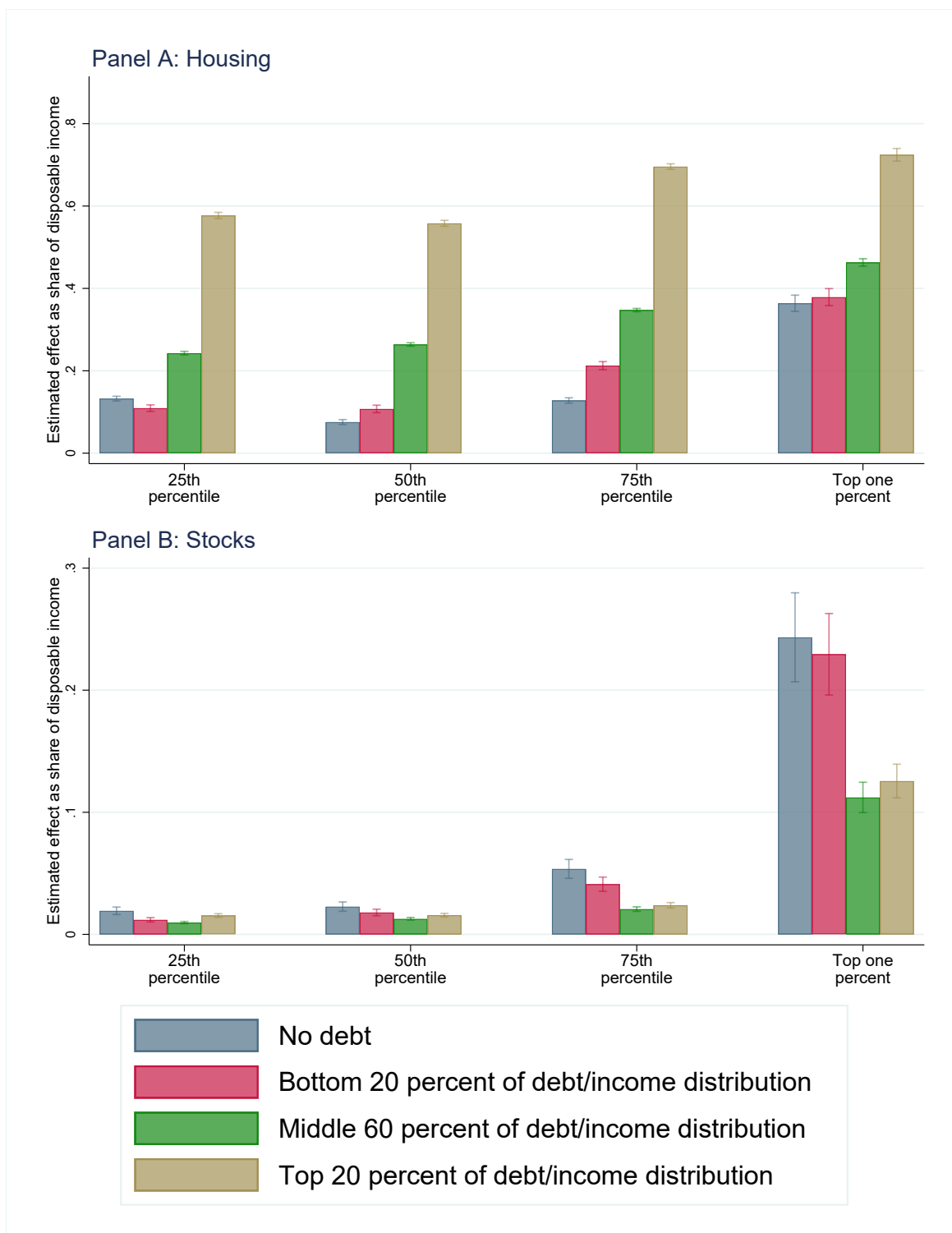
**Figure 8: Heterogeneous effects of monetary policy on asset values by type.** The figure shows the estimated two-year "price effect" of a one percentage point decrease in the monetary policy rate on the value of housing assets and stock portfolios at different positions in the income distribution. The estimates for shorter time horizons are reported in Figure A4 in the Online Appendix.



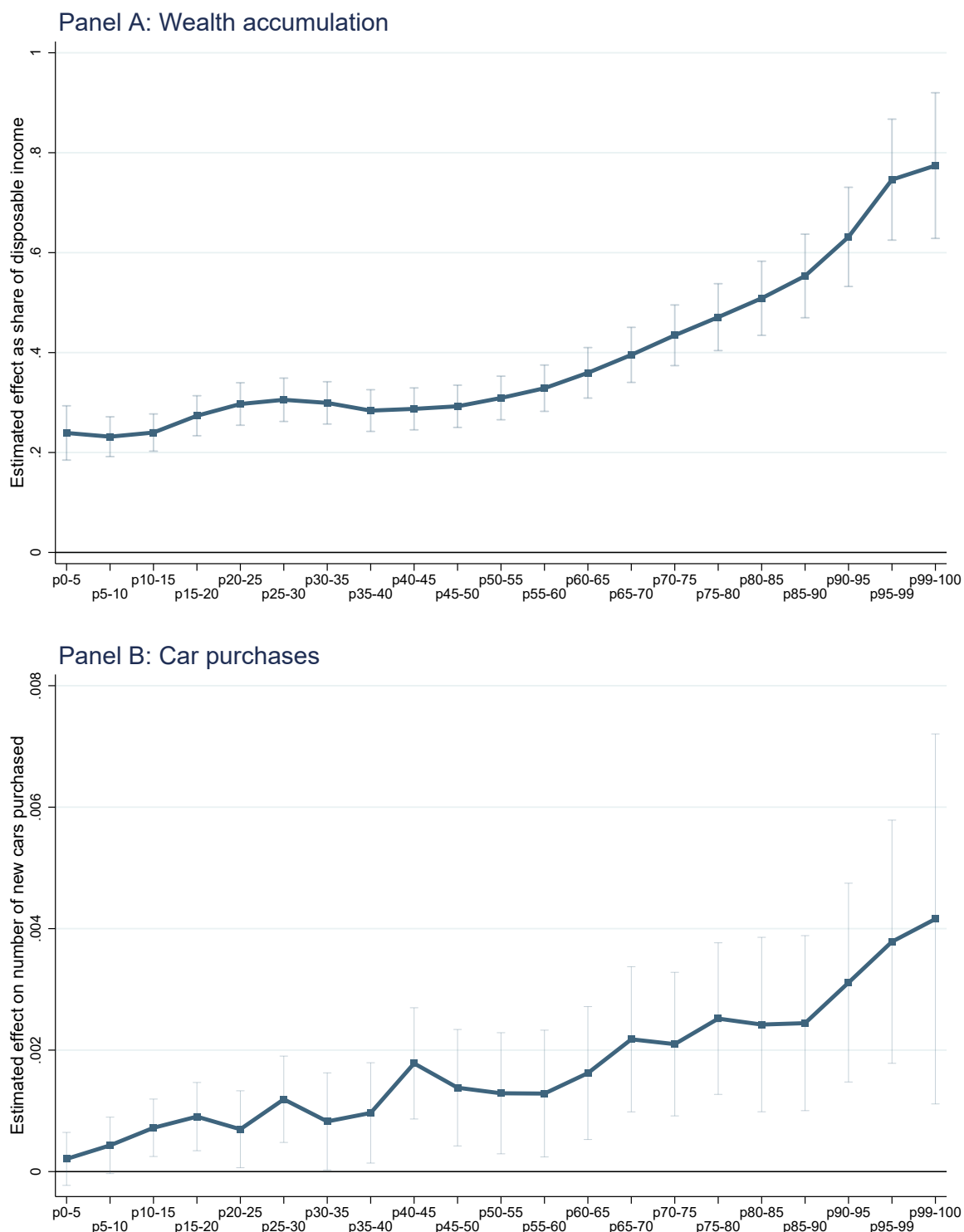
**Figure 9: Household leverage and the effect of monetary policy on income.** The figure shows the estimated two-year gain created by a one percentage point decrease in the monetary policy in the form of interest expenses (Panel A) and higher disposable income (Panel B) at different positions in the income distribution and for households with different ratios of debt to income. To derive the results, we split the sample into four groups based on their ratio of debt to income (DTI) and interact the explanatory variables in the baseline model with indicators of belonging to the four groups in the *ex ante* period. The four income groups refer to households between the 20th and 25th percentiles ("25th percentile"); between the 45th and 50th percentiles ("50th percentile"); between the 70th and 75th percentiles ("75th percentile"); and above the 99th percentile ("top one percent").



**Figure 10: Household leverage and the effect of monetary policy on asset values.** The figure shows the estimated two-year price-effect of a one percentage point decrease in the policy rate on the value of housing assets (Panel A) and stock portfolios (Panel B) at different positions in the income distribution and for households with different ratios of debt to income. To derive the results, we split the sample into four groups based on their ratio of debt to income (DTI) and interact the explanatory variables in the baseline model with indicators of belonging to the four groups in the *ex ante* period. The four income groups refer to households between the 20th and 25th percentiles ("25th percentile"); between the 45th and 50th percentiles ("50th percentile"); between the 70th and 75th percentiles ("75th percentile"); and above the 99th percentile ("top one percent").

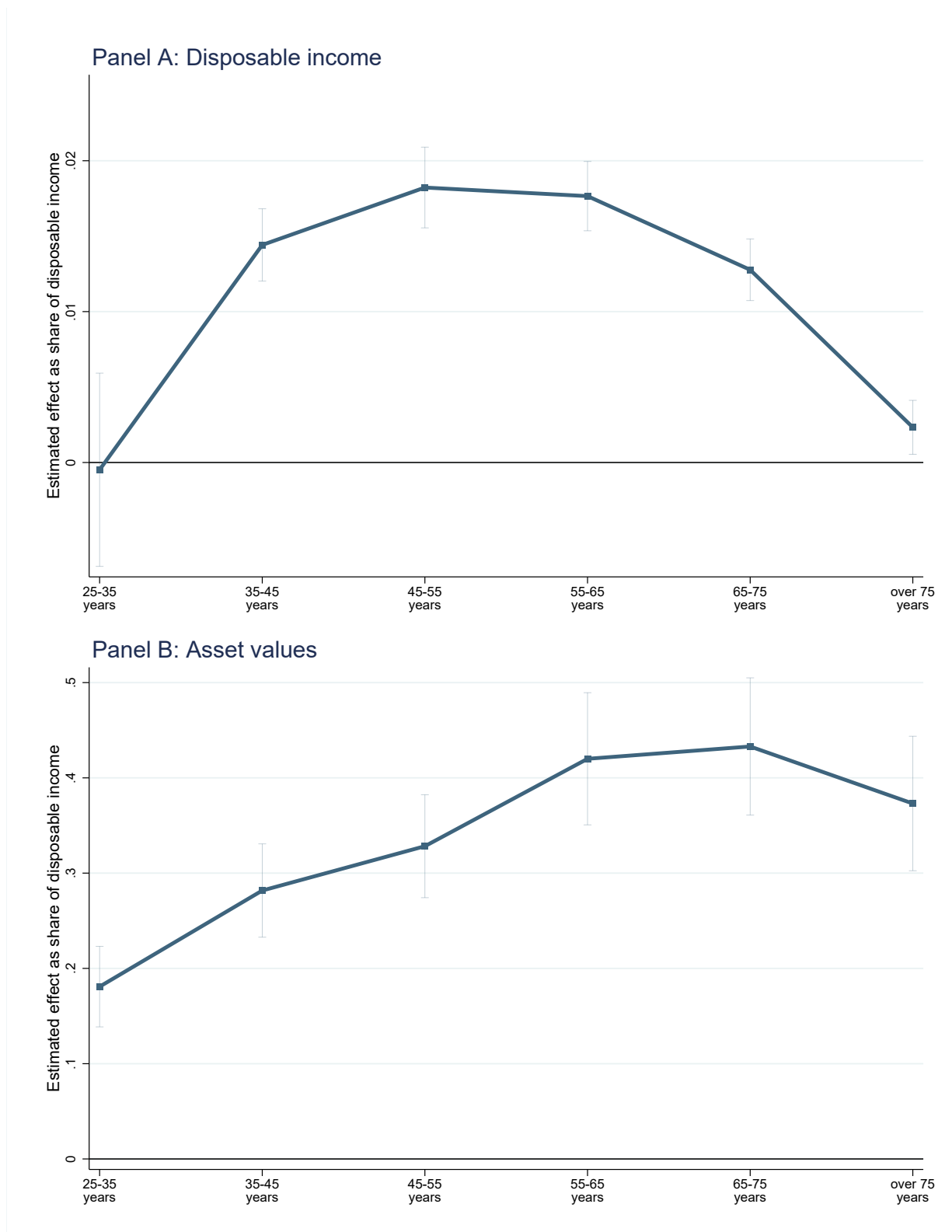


**Figure 11: Implications for wealth accumulation and consumption.** The figure shows the estimated two-year effect of a one percentage point decrease in the policy rate on the change in net wealth (Panel A) and the number of newly registered cars (Panel B) at different positions in the income distribution.

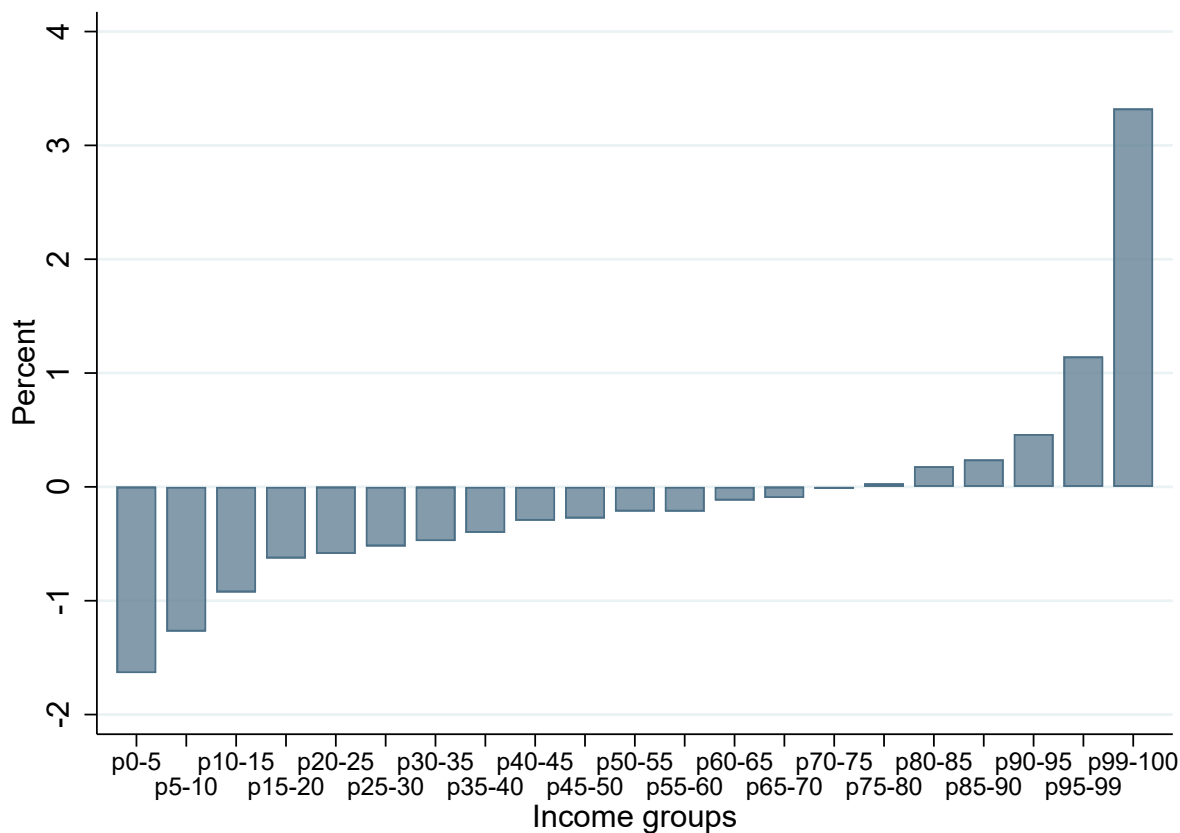




**Figure 12: The heterogeneous effect of monetary policy by age groups.** The figure shows the estimated two-year effects of a one percentage point decrease in the policy rate on disposable income (Panel A) and asset values (Panel B) for different age groups.



**Figure 13: Implications for income inequality.** The figure shows the simulated percentage change in each income group's share of total disposable income resulting from a one percentage point decrease in the policy rate. Applying the two-year coefficients from Figure 4, the simulation first computes the counterfactual income gain accruing to each household given its position in the income distribution if the policy rate were lowered by one percentage point and, next, computes the resulting counterfactual shares of total disposable belonging to each income group. The bars indicate the percentage difference between the actual and counterfactual income shares.



# APPENDIX

## Appendix: Property values

From the real estate transaction register ("EJSA"), we have information about each property transaction, including the transaction price, the tax value of the property and a unique property identifier. Combining with the property register ("BOL"), we also obtain information about property characteristics (e.g. type of property, number of square meters).

To construct the house price index, we consider private transactions of one-family houses that are traded no more than two times within the year. Following Finance Denmark (2014), we further restrict the sample of transactions to: (i) Houses where the number of square meters is between 25 and 750; (ii) Transactions with sales price between DKK 100,000 and DKK 25,000,000; (iii) Transactions with sales prices per square meter between DKK 1,000 and DKK 200,000.

For the transactions satisfying these criteria, we calculate the sales price per square meter and the tax value per square meter and winsorize both metrics at the percentiles 2.5 and 97.5 within each year.

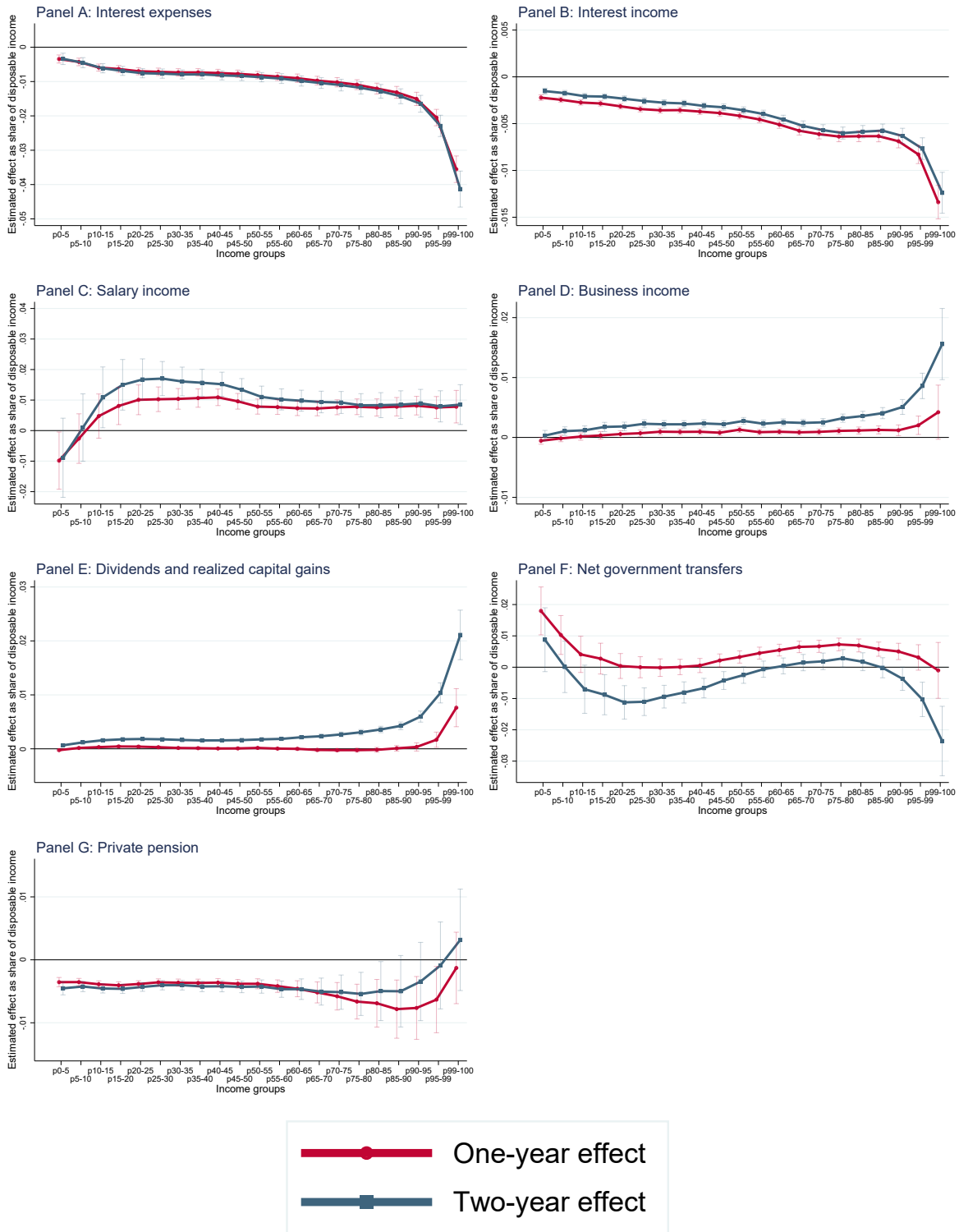
Within each municipality and each year, we calculate the average sales price per square meter, which we define to be the *price level* in the municipality-year. We also calculate an *adjustment factor* within each municipality and each year as the sum of sales price per square meter divided by the sum of the tax values per square meter. The adjustment factor serves to approximate the market value of non-traded properties based on tax values.

Finally, based on the series of price levels, we construct a municipality-specific house price index. To compute the change in the asset value of a given property, we apply the index to the estimated market value of the property, which is the tax value stepped up with the adjustment factor.

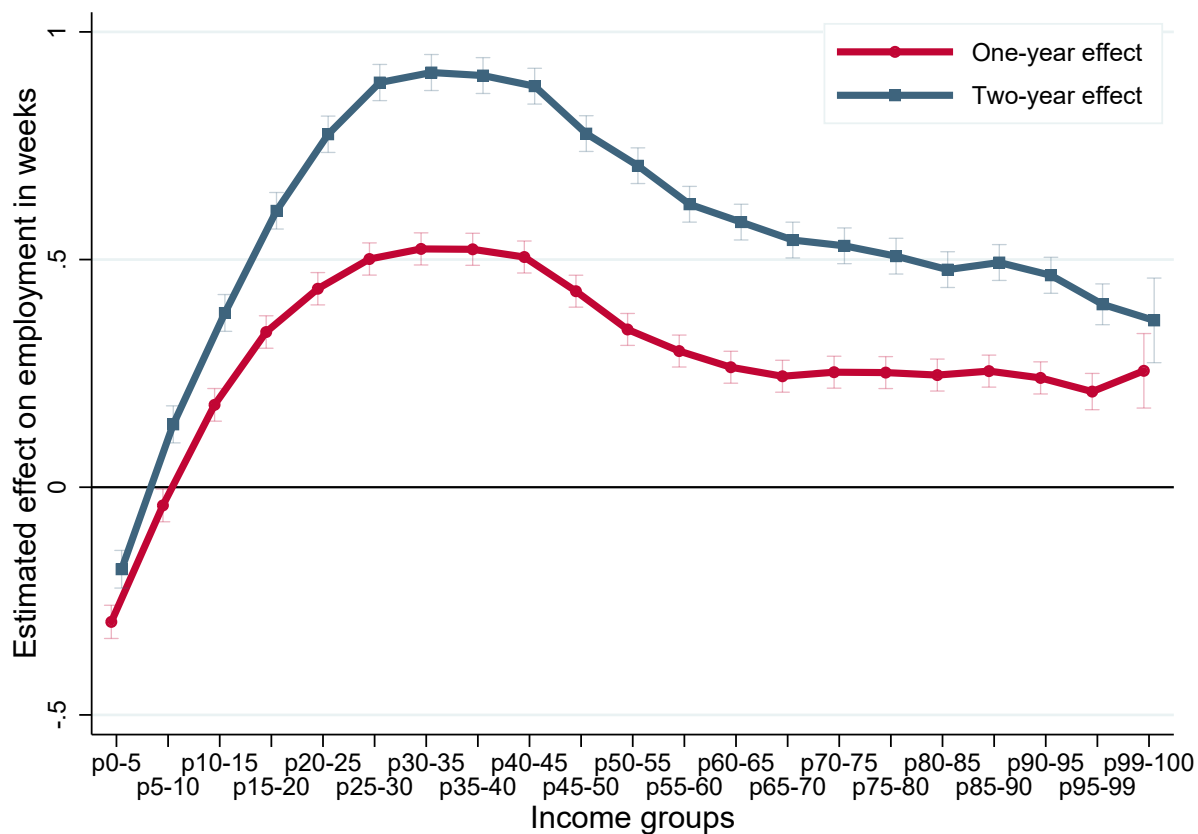
For example, assume that a property in municipality  $m$  has tax value 80 at the end of year  $t$ ; that the adjustment factor for municipality  $m$  in year  $t$  is 1.25, and that the price index indicates an increase in the price level of properties in municipality  $m$  between year  $t$  and year  $t + 1$  of 10%. The estimated market value of the property at the end of year  $t$  is then 100, the tax value of 80 stepped up by the adjustment factor 1.25, and the estimated increase in the value of the property over year  $t + 1$  is 10, i.e. the 10% price increase applied to the estimated market value of 100.

The available micro-data allows is to calculate price levels and adjustment factors for the period 1992-2013. In the few sample years outside of this period, we use the national house price index from Abildgreen (2018) instead of the municipality-specific price index. Moreover, we apply the adjustment factor for 1992 and 2013 to years before 1992 and after 2013 respectively.

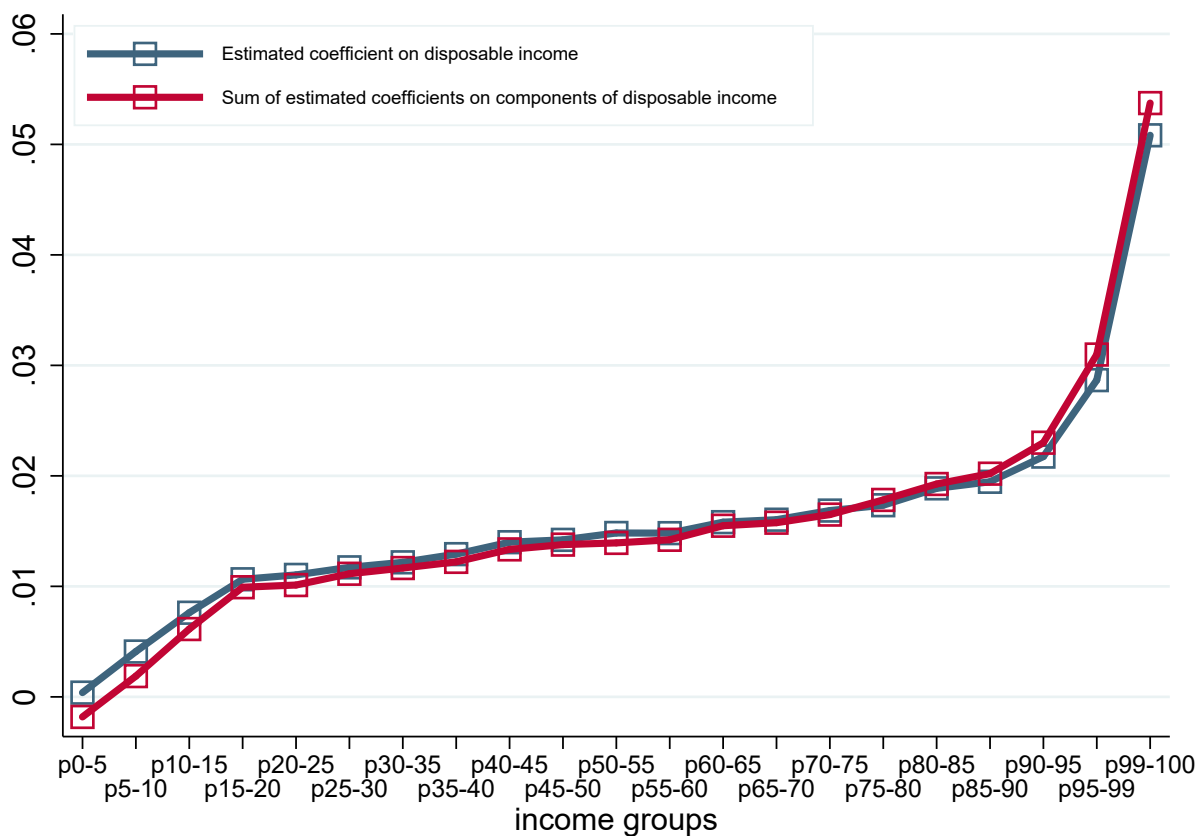
**Figure A1: Heterogeneous effects of monetary policy on income components.** The figure shows the estimated two-year effect of a one percentage point decrease in the monetary policy rate on the components of disposable income at different positions in the income distribution and over different time horizons: one year after the policy rate is changed (red squares) and two years after the policy rate is changed (blue squares).



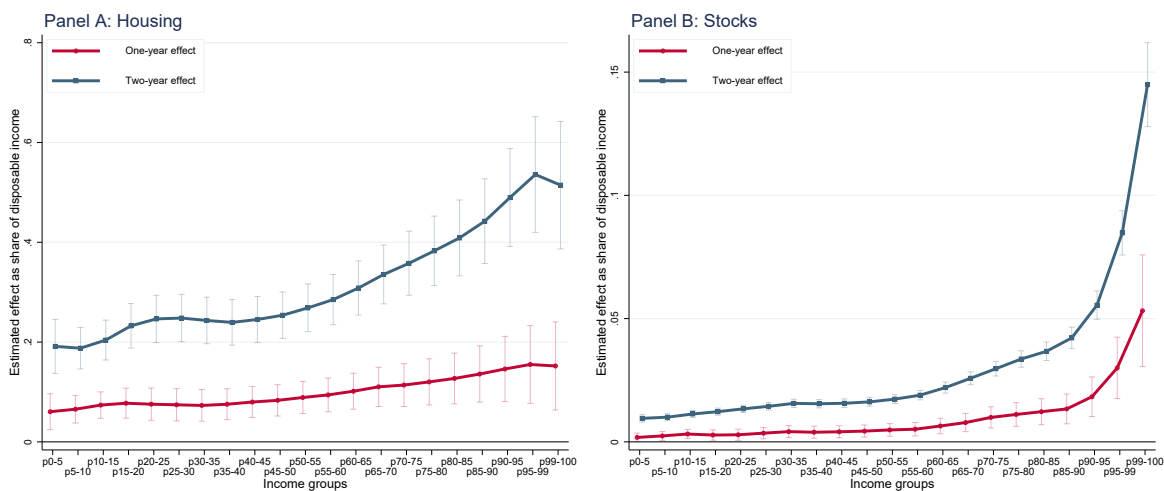
**Figure A2: Employment effects.** The figure shows the estimated effects of a one percentage point decrease in the monetary policy rate on employment (in weeks) at different positions in the income distribution and over different time horizons: one year after the policy rate is changed (red squares) and two years after the policy rate is changed (blue squares).



**Figure A3: Adding up the estimated effects on components of disposable income.**  
The figure compares, at each position in the income distribution, the estimated two-year effect of a one percentage point decrease in the policy rate on disposable income (Figure 4) to the sum of the estimated effects on the components of disposable income (Figure 5).

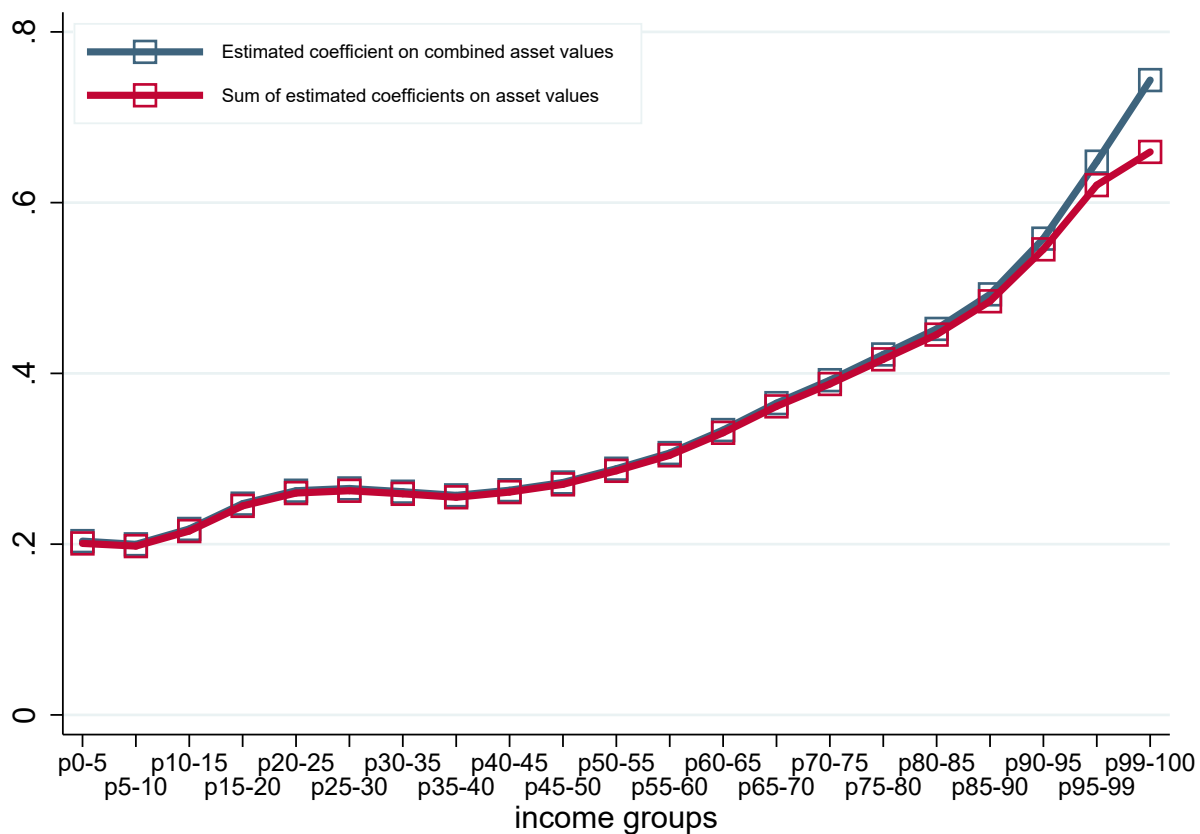


**Figure A4: Heterogeneous effects of monetary policy on asset values.** The figure shows the estimated "price effect" of a one percentage point decrease in the policy rate on the components of wealth at different positions in the income distribution and over different time horizons: one year after the policy rate is changed (red squares) and two years after the policy rate is changed (blue squares).

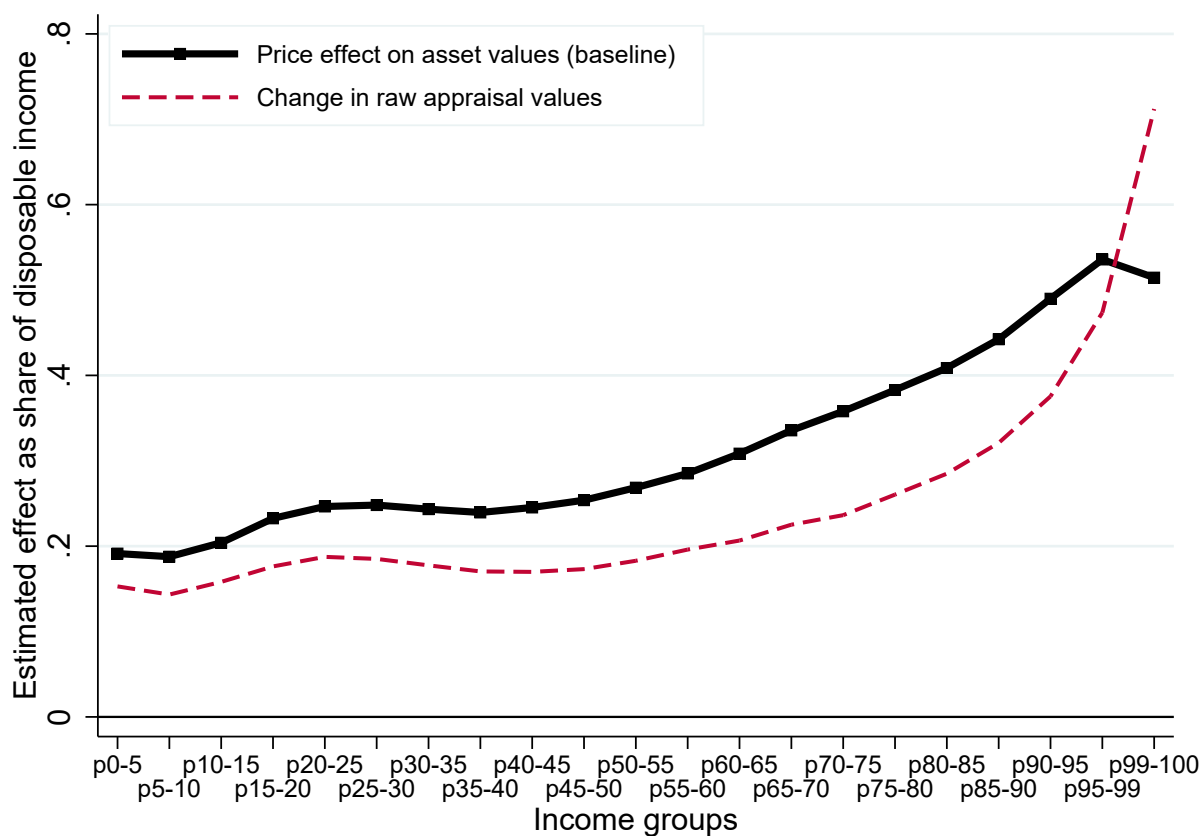




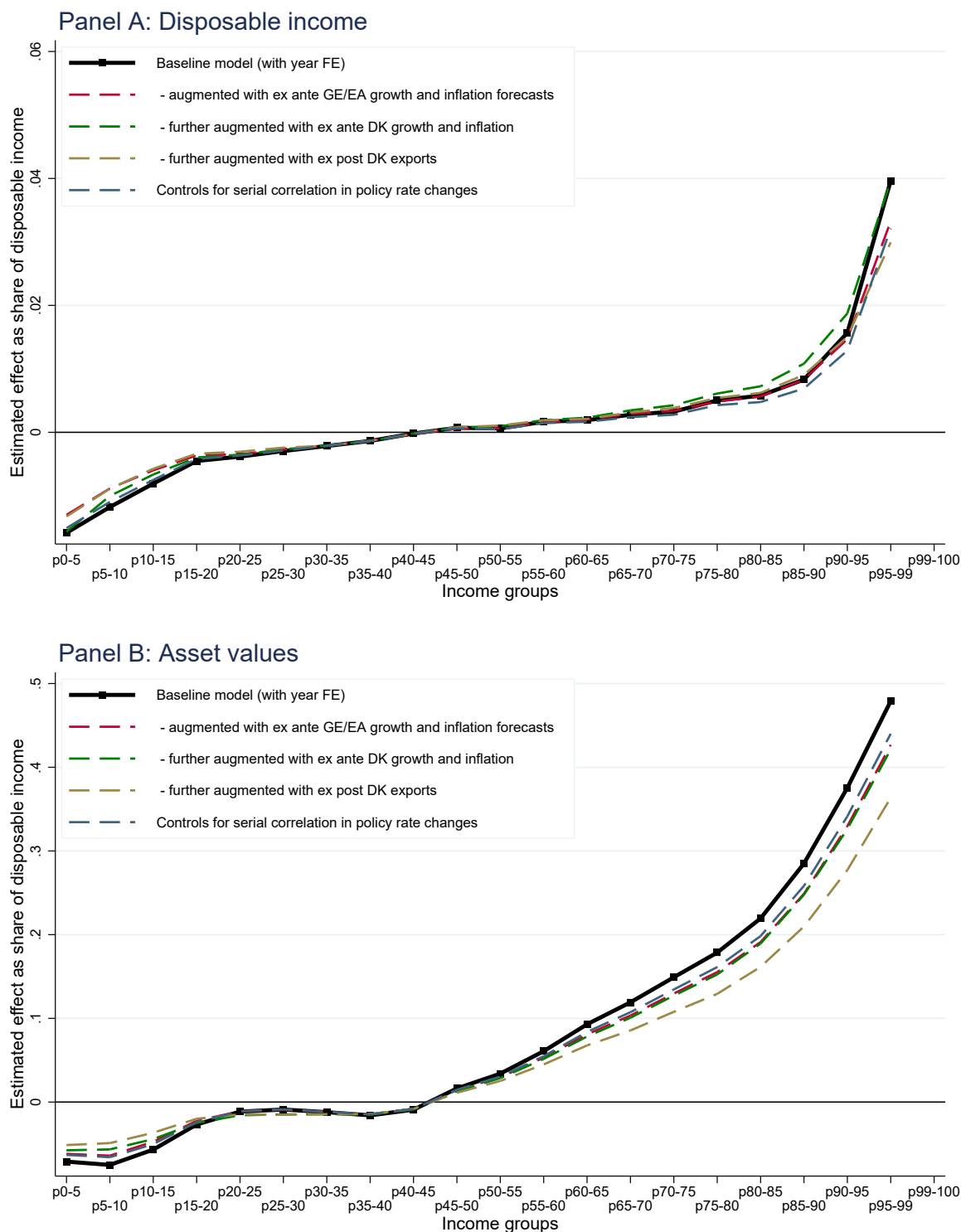
**Figure A5: Adding up the estimated effects on asset values.** The figure compares, at each position in the income distribution, the estimated two-year price effect of a one percentage point decrease in the policy rate on combined asset values (Figure 7) to the sum of the estimated effects on the individual asset values (Figure 8)



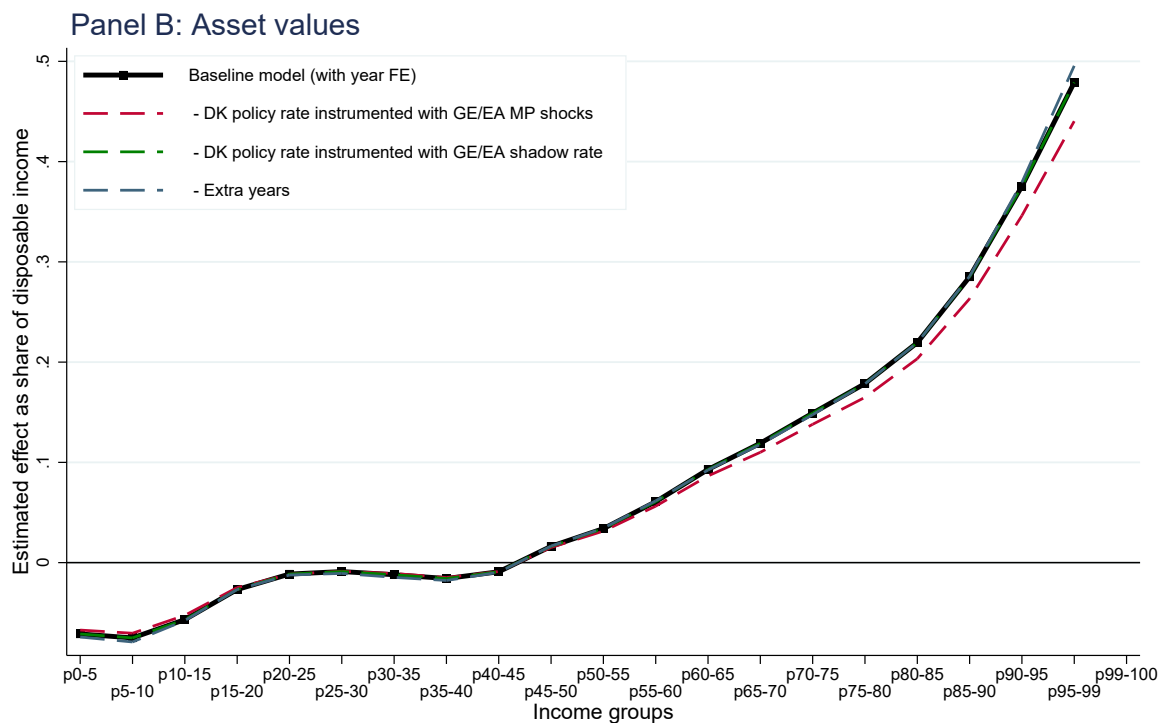
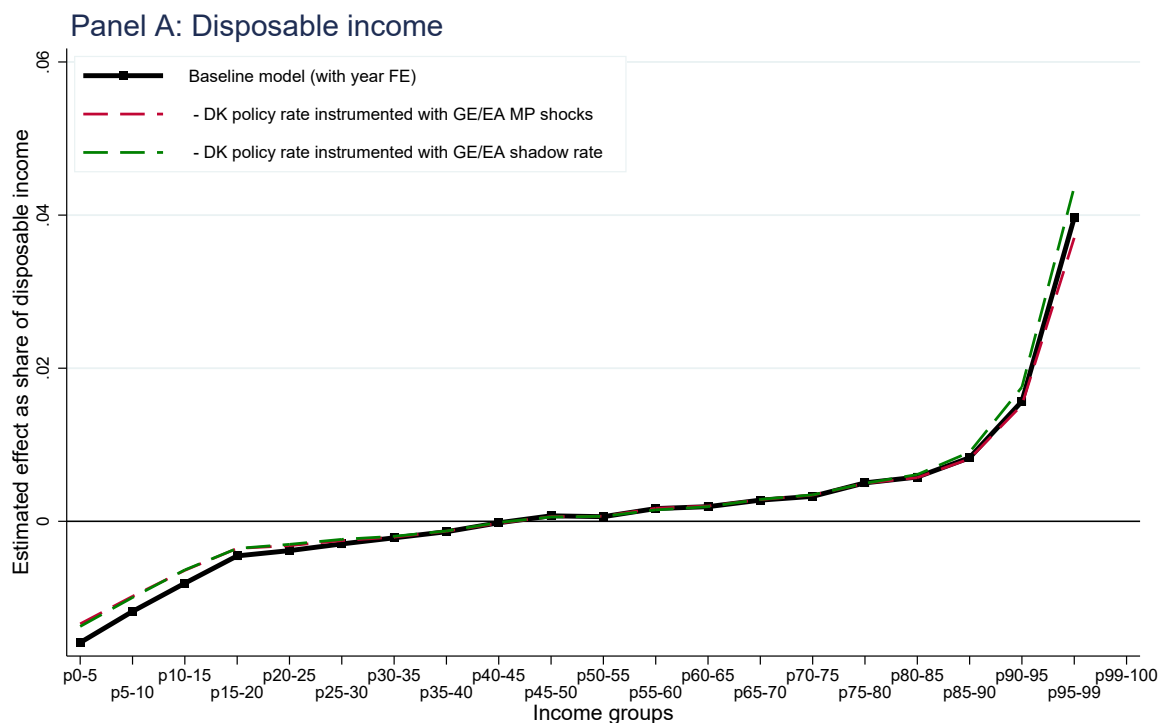
**Figure A6: Robustness of heterogenous effects on housing values.** The figure compares the estimated "price effect" of a one percentage point decrease in the policy rate on housing wealth (black line - baseline also reported in Figure 8) to the effect on the raw change in the appraisal values of housing (red line).



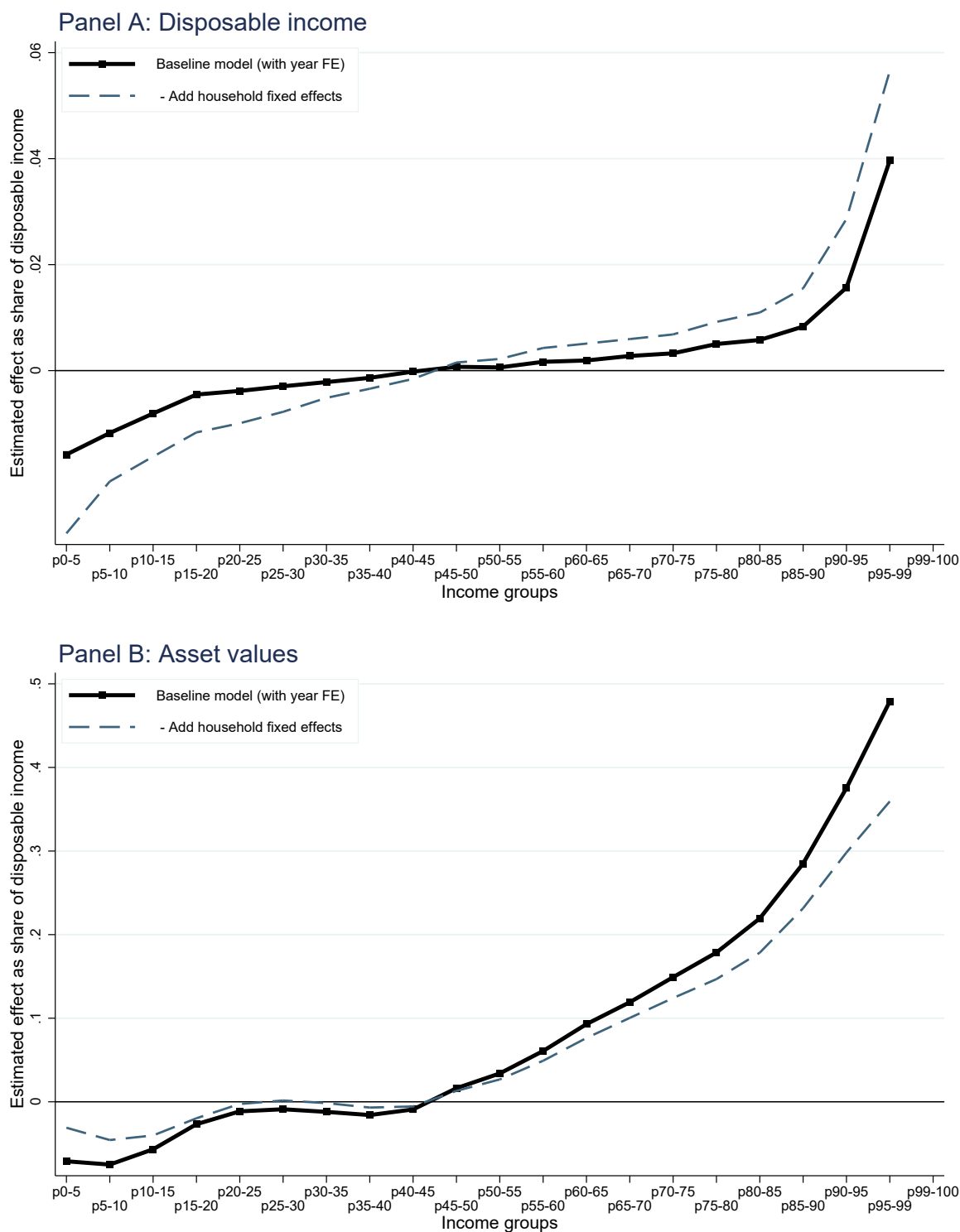
**Figure A7: Sensitivity to macro controls.** The figure shows the income gradient in the effect of monetary policy on disposable income (Panel A) and asset values (Panel B) estimated with different sets of macro controls. The lines indicate the two-year effect of a one percentage point decrease in the policy rate relative to the effect at the median income level (p45-50). Departing from the baseline model with year fixed effects (black line), the models sequentially add: *ex ante* forecasts of GDP growth inflation in GE/EA (red line); *ex ante* realizations of GDP growth and inflation in Denmark (green line); *ex post* realizations of exports from Denmark (light brown line). The final model includes controls for the leaded monetary policy shock (blue line). All the new controls are interacted with a full vector of income group indicators.



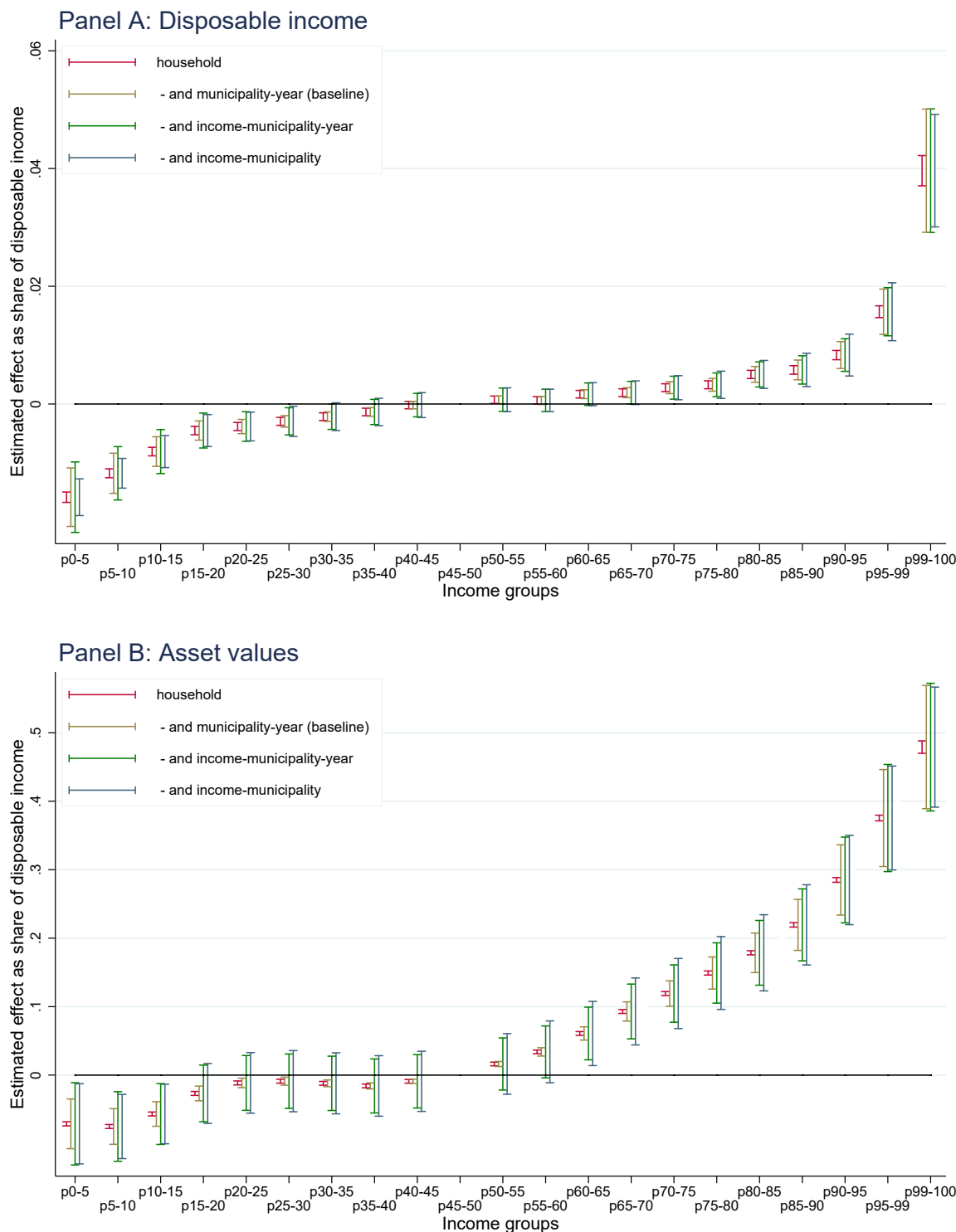
**Figure A8: Sensitivity to estimation procedure, measurement and sample.** The figure shows the income gradient in the effect of monetary policy on disposable income (Panel A) and asset values (Panel B) estimated with an alternative model, measurement and sample period. The lines indicate the two-year effect of a one percentage point decrease in the policy rate relative to the effect at the median income level (p45-50). Departing from the baseline model with year fixed effects (black line), the model is modified so that changes in the Danish policy rate are instrumented with residual variation in the GE/EA policy rates (red line); measurement is modified so that the German/Euro monetary policy stance is captured by the shadow rate rather than the policy rate (green line); and the sample is extended to include years 2015-2017 in the asset price model (blue line).



**Figure A9: Sensitivity to household fixed effects.** The figure shows the income gradient in the effect of monetary policy on disposable income (Panel A) and asset values (Panel B) estimated with the baseline model augmented with household fixed effects. The lines indicate the two-year effect of a one percentage point decrease in the policy rate relative to the effect at the median income level (p45-50).



**Figure A10: Sensitivity to clustering.** The figure shows the 95% confidence levels around the two-year effects of a one percentage point decrease in the monetary policy rate on disposable income (Panel A) and asset values (Panel B) under different clustering schemes: one-dimensional clustering at the level of household (red line); two-dimensional clustering at the level of households and municipality-years (brown line); two-dimensional clustering at the level of households and income-municipality-years (green line); two-dimensional clustering at the level of households and income-municipalities (blue line). The model includes year fixed effects so the effects are measured relative to the effect at the median income level (p45-p50).



**Table A1: Owners of Danish mortgage bonds.** The table allocates outstanding Danish mortgage bonds to the sector of the owners over the period 1999-2014.

Non-financial firms	5.5%
Financial firms	42.4%
Insurance companies and pension funds	26.4%
Public Sector	4.6%
Households	6.3%
Foreign investors	12.1%
Unallocated	1.4%

**Table A2: Descriptive statistics by age** The table shows describes the composition of disposable income and net wealth by age groups. Panel A describes the components of disposable income: salary income, business income, stock income (i.e. dividends and realized capital gains), interest income, transfer income (i.e. government transfers net of taxes), other income and interest expenses. All the income components are expressed as a fraction of disposable income and thus sum to 100%. Panel B describes the components of net wealth: deposits (including bonds), stocks, housing wealth, debt and net wealth (i.e. assets net of debt). All the net wealth components are expressed as a fraction of disposable income. Panel C describes 6 binary indicators: whether the individual is a net creditor (i.e. has positive net wealth); has any debt; owns any stocks; owns any real estate; is at least partly self-employed; and buys a new car.

	25-35 years	35-45 years	45-55 years	55-65 years	65-75 years	>75 years
<b>Panel A: income components (% of disposable income)</b>						
salary income	140%	144%	141%	111%	27%	2%
business income	6%	12%	16%	16%	9%	3%
stock market income	1%	2%	3%	5%	5%	4%
interest income	1%	1%	2%	3%	6%	9%
net government transfers	-32%	-41%	-46%	-28%	23%	49%
interest expenses	18%	20%	19%	14%	9%	4%
private pension	0%	0%	1%	6%	36%	34%
other income	1%	1%	2%	2%	3%	3%
<b>Panel B: net wealth components (% of disposable income)</b>						
deposits	31%	39%	58%	95%	175%	241%
stocks	6%	8%	14%	26%	53%	81%
housing	256%	373%	426%	496%	570%	448%
debt	264%	316%	292%	247%	187%	79%
net wealth	29%	105%	206%	371%	611%	690%
<b>Panel C: descriptive indicators</b>						
is net creditor	47%	58%	69%	80%	90%	96%
has no debt	12%	9%	10%	16%	35%	65%
holds stocks	22%	27%	33%	39%	43%	39%
owns real estate	44%	61%	67%	69%	62%	44%
is self-employed	8%	13%	17%	16%	10%	5%
buys new car	3%	4%	5%	4%	3%	1%