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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. We use administrative household-level data covering the entire population in Denmark over the period 1987-2014 and exploit a long-standing currency peg as a source of exogenous variation in monetary policy. We consistently find that gains from softer monetary policy in terms of income, wealth and consumption are monotonically increasing in the ex-ante income level. The distributional effects reflect systematic differences in exposure to the various channels of monetary policy, especially non-labor channels (e.g. leverage and risky assets). Our estimates imply that softer monetary policy increases income inequality.

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

Keywords: Monetary policy, Inequality, Household heterogeneity, Risky assets, Leverage

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1 Introduction

Recent theory highlights the role of heterogeneous households in monetary policy transmission through direct and indirect channels (Kaplan, Moll and Violante, 2018). When households differ in terms of balance sheets and occupations, monetary policy may 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 these gains and losses across income groups is crucial for at least two reasons. First, it determines how monetary policy affects inequality in society (Bernanke, 2015; Draghi, 2016). Second, it matters for the aggregate effects of monetary policy as the marginal propensity to consume varies systematically with income (Auclert, 2019).

Despite the importance of the distributional effects of monetary 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). This paper breaks new ground by using rich, administrative micro-data to analyze how monetary policy affects income, wealth and a proxy for consumption of durables for households at different positions in the income distribution. We also 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 overall gains and losses at each income level, and we summarize the implications for inequality by quantifying how monetary policy affects income shares through the 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 link the tax records to the auto register with comprehensive information on car purchases, an important component of durable consumption. This granular information allows us to estimate how monetary policy differentially affects the income, wealth and consumption dynamics of households at different income levels.

Our empirical strategy addresses the endogeneity of monetary policy 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 maintain a fixed exchange rate and at the same time use it to pursue other policy objectives (Mundell, 1963; Fleming, 1962), so Denmark generally imports its monetary policy stance from Frankfurt. We show that this source of exogenous variation in Danish monetary policy rates can be harnessed in a simple local projections framework to deliver plausible estimates of monetary policy transmission to economic aggregates (e.g. output, prices and consumption).

In our main analysis, we use household-level data to estimate how the effect of monetary policy varies over the income distribution. The dependent variable is 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 comparisons across outcomes. The main explanatory variable is the change in the Danish monetary policy rate interacted with indicators of the households' position in the ex ante income distribution. We restrict the identifying variation in monetary policy to the component that is plausibly exogenous by instrumenting the change in the Danish monetary policy rate with the change in the German/Euro Area monetary policy rate while controlling for lagged, current and projected values of German/Euro Area output growth and inflation (all interacted with income group indicators). Further, we add income group indicators that control for long-run changes in household outcomes at different positions in the income distribution and thus ensure that our results are not confounded by secular trends in inequality. Finally, we add time fixed effects that control for the average effect of all potentially confounding shocks. This implies that our main estimates are *differential effects*: The effect of monetary policy at a given position in the income distribution over and above the effect for the reference group of households around the median income level. The differential effects are ultimately what matters for inequality. At the cost of stronger identifying assumptions, we also estimate the *absolute effects* of monetary policy for each income group by dropping the time fixed effects.

Our first set of results documents a striking income gradient in the effect of monetary policy on disposable income: When the monetary policy rate is lowered by one percentage point, the two-year effect on disposable income is around 3 percentage points larger for the top 1% of households than for the reference group in the middle of the income distribution and around

1 percentage point smaller for the households at the lowest income levels.[1] Varying the time horizon, we find that the income gradient is steepest over horizons of two and three years.

We explore the economic channels underlying this key result by estimating the model for each component of disposable income separately. Consistent with theory and the perception of policymakers (e.g. Draghi, 2016), softer monetary policy has the largest effect on salary income for households at the low end of the income distribution, reflecting a sizeable increase in employment for this group. However, most other components of disposable income contribute to a positive income gradient. Importantly, gains in the form of business income and stock market income are highly concentrated at the top of the income distribution. We document that the income gradient in the effects of monetary policy is partly, but not entirely, due to systematic differences in the composition of income and balance sheets. For instance, households with higher incomes benefit more from lower interest expenses when the monetary policy rate is lowered and this reflects both a higher level of debt relative to disposable income and a higher pass-through rate given the level of debt.

Our second set of results shows a positive income gradient in the effect of monetary policy on the value of households' assets through changes in property prices and stock prices. Over a two-year horizon, the effect on asset values, measured in units of disposable income, is around 40 percentage points larger for the top 1% than for households around the median income level and around 5 percentage points smaller for households with the lowest incomes. The gradient reflects that households with higher income hold more assets relative to their disposable income, but also that the average asset returns created by softer monetary policy are higher for high-income households. Comparing to the first set of results, these findings suggest that the differential effects of monetary policy through changes in asset prices are much stronger than the effects through changes in disposable income.[2]

The key identifying assumptions are that German/Euro Area monetary policy shocks, first, do not coincide with other shocks that affect Danish households differentially over the income distribution and, second, do not themselves have such differential effects other than by moving Danish policy rates. A range of robustness tests support these assumptions. To absorb confounding shocks, we add more ex ante controls (i.e. evaluated before or in the same period as the

[1] This result is related to earlier evidence that high-income households are more exposed to aggregate fluctuations in the economy (Parker and Vissing-Jorgensen, 2009).

[2] Expressed relative to total asset values, our estimates imply capital gains of around 4% at the bottom and around 6% at the top when the monetary policy rate is lowered by one percentage point. The results for individual asset classes are broadly consistent with the literature on the effects of monetary policy on house prices (e.g. Taylor, 2007) and on stock prices (e.g. Rigobon and Sack, 2004).

monetary policy shock): We control for ex ante macroeconomic conditions in Denmark and for ex ante changes in the global financial cycle. We also take alternative approaches to identifying monetary policy shocks, using methods developed by Romer and Romer (2004) and Jarocinski and Karadi (2020). To shut down alternative channels through which monetary policy in Frankfurt could affect outcomes in Denmark, we sequentially add ex post controls (i.e. evaluated after the monetary policy shock): We control for ex post changes in exports and imports, for ex post changes in foreign assets and liabilities and ultimately, accounting as broadly as possible for business cycle spillovers, for ex post German/Euro Area macro outcomes (i.e. stock prices, GDP growth and inflation). The main results remain qualitatively unchanged through all these robustness tests. Finally, investigating the external validity of our analysis, we show that our findings are not driven by the relatively high levels of household debt in Denmark. The main results remain similar when we weight the observations in our Danish sample to match, within income groups, household debt in the United States or the Euro Area.

As a first extension of the core analysis, 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 policy, whether in the form of higher disposable income or capital gains on assets, must be either consumed or added to the household's wealth. However, by changing market interest rates, monetary policy also affects consumption and savings through intertemporal substitution. Accounting for both of these channels of monetary policy as well as others (e.g. changes in asset holdings and leverage), we re-estimate the model using household-level changes in car purchases and net wealth as outcomes. The results indicate that the gains of softer monetary policy in terms of consumption as well as net wealth increase in income. The effects on net wealth are similar to the estimated price effects on asset values, which is consistent with an important role for "saving by holding" (Fagereng et al., 2019).

Second, we investigate the role of household debt in the transmission of monetary policy. Debt matters directly for exposure to several channels of monetary policy and may further shape consumption responses to the extent that it represents a financial constraint. We therefore estimate an augmented model where the effect of changes in the policy rate is allowed to vary with ex ante leverage at each income level. Within income groups, we find that the estimated effects on disposable income, housing wealth and consumption increase almost monotonically with leverage. Within groups with similar leverage, the income gradient is generally weaker than in the full sample. While these results point to an important role of debt in shaping the distributional effects of monetary policy, significant heterogeneity remains after accounting for

leverage. Notably, the top-1% stands out with larger gains from softer monetary policy than any other income group at each level of leverage. Stock market gains are particularly large for households with high incomes and no debt.

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. We find that effects on disposable income are hump-shaped in age, largest for the middle-aged and smaller 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 monetary 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 less 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.

It is important for the interpretation of our results that we restrict the identifying variation in monetary policy to the exogenous component (e.g. lowering the policy rate to keep the exchange rate fixed). Strictly speaking, we cannot be sure that the distributional effects are the same for the endogenous component (e.g. lowering the policy rate to support aggregate demand). A similar caveat applies to the large empirical literature that identifies the effect of monetary policy from exogenous shocks by controlling for the expected response of monetary policy to the business cycle or by isolating monetary policy surprises.

Our paper mainly contributes to the emerging empirical literature on monetary policy and inequality (Coibon et al., 2017; Mumtaz and Theophilopoulou, 2017; Ampudia et al., 2018; Amberg et al., 2021). This theme attracts 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). Compared

to our main result, Coibon et al. (2017) find that lower policy rates are associated with less income inequality. This may partly reflect differences in methodologies. 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 consider the effect on disposable income, accounting for tax payments and interest expenses, rather than total income. As our results agree with Coibion et al. (2017) that monetary policy has little or no effect on inequality in earnings, the difference is mainly about the effect on inequality in financial income. Our results indicate that softer monetary policy raises inequality through this channel because of differences in portfolio composition: Overall financial income increases for high-income groups, who hold many equities and therefore gain more through higher stock market income than they lose through lower interest income, while it decreases for low-income groups who mainly hold deposits.[3] Consistent with our results, Amberg et al. (2021) find that a lower monetary policy rate creates the largest income gains at the top of the income distribution, driven mainly by increases in financial income; however, their results, unlike ours, also point to relatively large income gains at the bottom, driven by increases in labor income. To our knowledge, our paper is the first in this literature to study the effect of monetary policy on asset values, the most important source of differential gains and losses according to our results, and net wealth accumulation using administrative data.

Our results also inform theory models about the direct and indirect channels of monetary policy (Kaplan, Moll and Violante, 2018; Auclert, 2019; Slacalek, Tristani and Violante, 2020; Alves, Kaplan, Moll and Violante, 2020). In these models, the effect of monetary policy on macroeconomic aggregates depends importantly on how shocks to the household budget pass through to consumption. As the marginal propensity to consume varies systematically over the income distribution, reflecting partly the correlation with wealth and liquidity, it is of crucial importance whether the gains and losses accrue to high-income or low-income households.[4] Our results also highlight that non-labor channels (e.g. leverage, dividends, risky assets) contribute importantly to both the aggregate and distributional effects of monetary policy. This resonates with recent developments of the HANK framework highlighting asset prices as an important

[3]Coibion et al. (2017) also find that softer monetary policy reduces consumption inequality, which is consistent with predictions from the model by Auclert, Rognlie and Straub (2020). These results are not directly comparable to ours, as we do not study consumption inequality but the effect on consumption at different positions in the income distribution. Another related paper is Gornemann et al. (2021) who study theoretically the distributional effects of systematic monetary policy.

[4]Auclert (2019) formally demonstrates the existence of a redistributive channel in monetary transmission if the distribution of gains and losses correlates with marginal propensities to consume. Luetticke (2021) shows that monetary policy transmission also depends on marginal propensities to invest in real assets.

transmission mechanism (Alves, Kaplan, Moll and Violante, 2020; Auclert, Rognlie and Straub, 2020) and with theoretical work on monetary policy in the macro-financial tradition (Brunnermeier and Sannikov, 2012).

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; Di Maggio et al., 2020b; Flodén et al., 2019; Cloyne et al., 2019). Most similar in terms of the empirical approach is a paper that analyzes the heterogeneous effects of monetary policy using micro-data from Norway (Holm et al., 2021). The two papers differ in the fundamental research question: While they study heterogeneity by household *liquidity* to learn about the role of financial frictions for monetary policy transmission, we study heterogeneity by household *income* to understand the interplay between monetary policy and inequality. The flavor of the results is also different: while they find that the effect on disposable income varies non-monotonically with liquidity, we find a perfectly monotonic relation with income and a crucial role for leverage and risky assets.

The paper proceeds as follows. Section 2 describes the data. Section 3 introduces the model. Sections 4-6 present the results. Section 7 concludes.

2 Data

The main analysis uses micro-data on income, wealth and consumption from different administrative registers.[5] In this section, we specify the sample, describe the data sources and provide summary statistics of the key variables.

2.1 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 (Kleven et al., 2011) and therefore only to a limited extent prone to under-reporting by the taxpayers themselves (Alstadsæter et al., 2019).

[5]We also use standard macro-data on aggregate prices, output, consumption and so on for both Denmark and Germany/Euro Area.

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 sole 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 components are taxes and interest expenses. We define *disposable income* as the sum of the income components minus interest expenses and tax liabilities.[6]

The tax register also contains information about important categories of assets and liabilities. 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 indeces, which allows us to approximate capital gains on real estate, including on properties that do not change hands in a given period, at market value (see details in Online Appendix B). 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.[7]

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., 2021).[8] However, the approach also has limitations. We cannot account

[6]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.

[7]Since the abolition of the net wealth tax in 1997 (Jakobsen et al., 2021), taxpayers are not required to complement the information reported by domestic banks with self-reported information on loans from other sources nor to provide estimated values of unlisted stocks. Tax favored pension accounts are similar to 401ks in the U.S: 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.

[8]Consumption can be imputed 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). There are two reasons why we do not adopt this measure. First, a recent paper shows that the imputation procedure may be associated with significant measurement error at the tails

for purchases of used cars and, as information on purchase prices is not available, we cannot distinguish between more and less expensive new cars.

Finally, the population register provides information on age and place of residence and defines 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. Younger households with low incomes are often students with high life-time incomes receiving considerable financial support from their parents (Andersen et al., 2020a), 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.[9]

2.2 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 I. For 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

(Abildgren et al., 2018). This is particularly problematic for studies with a distributional perspective like ours. Second, changes in market interest rates create (unobserved) capital gains and losses on mortgage loans, which introduces measurement error in the imputed consumption measure. If we were to use imputed consumption as an outcome, the measurement error would cause a systematic bias as it correlates with the dependent variable (changes in monetary policy rates). In principle, it may be possible to mitigate these measurement problems with exhaustive information about all household assets and liabilities, including information about within-year transactions, but such data is not available in our setting.

[9]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.

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%).

Panel A provides a sense of the baseline inequality in Denmark during our sample period by showing each income group's disposable income measured relative to disposable income in the middle income group (p40-60). This metric ranges from 66% in the bottom group to 432% in the top 1%. The distribution of disposable income is much more equal than the distribution of market income, by accounting for government transfers and taxes as well as interest expenses.

Panel B 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 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 show below, that household leverage tends to increase with income.

The differences in income composition are 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 - everything else equal - create the largest relative increases in disposable income for the middle class; and if it increases business 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, for instance wage rates may increase more 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, for instance unemployed workers may find jobs and start earning salary income when the business cycle is improving. Our regression results generally

account for heterogeneous price and non-price effects.

Panel C summarizes the value of the various types of assets and liabilities by income group. 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. 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 composition of the balance sheet is suggestive of how monetary policy may affect households differentially through asset prices. For instance, 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; and if it increases stock prices uniformly across income groups, 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 high-income areas than in low-income areas, it will contribute to the heterogeneity in gains and losses across households belonging to different income groups. Our regression results capture this source of heterogeneity by accounting for local price variation.

Panel D 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 more households buying new cars, but fewer households with no debt at all.

Finally, to assess whether our results are likely to extend to other settings, we compare the

structure of household balance sheets in Denmark to the United States and the Euro Area in dimensions that are key to the transmission of monetary policy: homeownership, stock market participation, debt market participation and debt-income ratios. Using tabulations from the Survey of Consumer Finance for the United States and the Household Finance and Consumption Survey for the Euro Area, Figure A1 in the Online Appendix shows that both the United States and the Euro Area exhibit an overall positive income gradient in all four dimensions that is qualitatively similar to what we observe in the Danish sample. Moreover, as shown in Figure A2 in the Online Appendix, the household debt structure has evolved in a qualitatively similar fashion in Denmark and the United States over the sample period. Overall, Denmark mainly stands out by households having relatively elevated debt-income levels. We will explore the implications of this difference by estimating the effects of monetary policy in our Danish sample re-weighted so that it resembles households in the United States and the Euro Area in terms of debt structure.

3 Empirical design

The aim of the analysis is to estimate how monetary policy differentially affects the income, wealth and consumption dynamics of households at different income levels. The key methodological challenge is the endogeneity of monetary policy. In this section, we first briefly describe the long-standing Danish currency peg; then show how the peg can be used to isolate plausibly exogenous variation in Danish monetary policy; and finally use a model that exploits this variation to estimate differential effects of monetary policy over different time horizons.

3.1 The currency peg

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 other Scandinavian countries (Taylor, 1993). Since 1987, the Danish Krone has been pegged to the German Mark and the Euro, and exchange rate stability remains 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."[10]

This currency peg is useful for identification by creating a plausibly exogenous source of variation in Danish monetary policy. Theory tells us that to keep the exchange rate fixed in an

[10]Speech at the Danish Bankers Association on 4 December 2002, quoted in Abildgren (2010).

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). In normal times, Denmark therefore 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.

Figure 1 illustrates precisely this point. After a convergence period in the 1980s, Danish monetary authorities have generally followed the interest rate decisions made in Frankfurt; only in rare periods with turmoil in global markets, they have temporarily adjusted the interest rate spread to defend the exchange rate. In the Online Appendix, we provide more details about the currency peg (Appendix C) and document that the exchange rate of Danish Kroner relative to German Mark (1987-1998) and Euro (from 1999) has indeed been extremely stable in line with the policy objective (Figure A3).

To be clear, the currency peg does not imply that the monetary policy stance imported from Frankfurt is orthogonal to economic conditions in Denmark. As business cycles are positively correlated, the imported policy will generally be closer to the one appropriate for the Danish business cycle than a random draw.[11] However, the business cycle correlation is far from perfect, which means that the exogenous component of monetary policy will be much stronger under a currency peg than if inflation and output growth were the objectives of the Danish central bank. In brief, our estimation strategy uses the variation in Danish monetary policy created by the currency peg while absorbing the potentially confounding effect of correlated business cycles with a comprehensive set of macro controls.

3.2 Aggregate effects of monetary policy

We exploit the currency peg to isolate exogenous variation in Danish monetary policy and use this variation to estimate the effect of monetary policy on a range of macro aggregates (see Jorda et al., 2020). This preliminary step serves to assess the plausibility of the identification

[11] As shown in Figure A4 in the Online Appendix, the correlation coefficient between macro outcomes in Denmark and Germany/Euro Area is around 0.3 and 0.4 for quarterly GDP growth and inflation respectively, which is lower than the corresponding correlation coefficients of around 0.45 and 0.55 for Denmark and the United States. The correlation between macro outcomes in Denmark and Germany was essentially zero in the subperiod with a peg to the German Mark, which encompasses the German reunification (coefficients of around 0.1 and -0.1 for GDP growth and inflation) while the correlation between Denmark and the Euro Area was stronger in the subperiod with a peg to the Euro (coefficients of around 0.5 and 0.6). The correlation between macro outcomes in Denmark and the United States is suggestive of the importance of global shocks.

strategy before adapting the model to household-level outcomes. To make the macro-analysis fully equivalent to the micro-analysis, it uses the same sample period and the same annual frequency.

The explanatory variable of interest is the change in the Danish monetary policy rate between period $t-1$ and period t (Δi_t). To address the potential endogeneity of this variable, we instrument it with the change in the German/Euro Area monetary policy rate (Δi_t^*) and include a set of control variables that captures the current macroeconomic conditions as well as the outlook over future periods in Germany/Euro Area (X_t^*).[12] The dependent variable (Y) is the change in some Danish macro variable between period $t-1$ and some future period $t+h$ where h denotes the time horizon over which the effects of monetary policy are estimated (Jordà , 2005). Formally, we thus estimate the following local-projections model:

$$\frac{Y_{t+h} - Y_{t-1}}{Y_{t-1}} = \alpha_h + \beta_h(-\Delta i_t) + \phi_h X_t^* + \mu_t \tag{1}$$

where the vector X^* includes actual GDP growth and inflation in periods $t-1$ and t as well as forecasts of GDP growth and inflation for period $t+1$ and the lagged dependent variable.[13] The currency peg ensures that the instrument is highly relevant while the set of control variables effectively restricts the identifying variation to the German/Euro Area monetary policy shocks (i.e. the variation in Δi_t^* that is orthogonal to X_t^*).[14] As the change in the policy rate enters the model with a negative sign, the estimated coefficients measure the effect of lowering the monetary policy rate by one percentage point, a *softening* of monetary policy.

Figure 2 illustrates the estimated effects of a 1 percentage point decrease in the monetary policy rate. The effect on the Danish monetary policy itself exhibits some persistence but dies out over the full four-year horizon (Figure 2A). The estimated effect on GDP reaches around 2.5% over a three-year time horizon, after which it starts to dissipate (Figure 2B). By contrast, the effect on prices is small both in the short and the medium term (Figure 2C). Aggregate consumption follows a pattern similar to GDP although with a slightly lower peak and a more pronounced reversal at the end of the estimation period (Figure 2D). Aggregate car purchases are

[12]The results are the same if we first estimate the German/Euro Area monetary policy shock as the residual variation in Δi_t^* after regressing it on X_t^*, and use this shock as an instrument in equation (1). Figure A5 compares the German/Euro Area monetary policy shocks (blue bars) to the actual change in the German/Euro Area policy rate (red line) and in the Danish policy rate (green line). The controls absorb a lot of the variation suggesting that German/Euro Area monetary policy is highly endogenous to local conditions. For instance, the largest negative change in the German/Euro Area policy rate occurred in 2009 just after the financial crisis, but after purging for the effect of the macro environment, the monetary policy shock is slightly positive.

[13]Macro variables for Denmark are from Statistics Denmark; macro variables for Germany and the Euro Area are from the OECD, the World Bank and Eurostat; forecasts are from OECD Economic Outlook.

[14]In the first stage, the F-statistic on the excluded instrument is around 36.

qualitatively similar; however, the effects are larger by almost an order of magnitude, highlighting that cars constitute a volatile component of aggregate consumption (Figure 2E). Aggregate labor income appears to be more sluggish with the effect of monetary policy emerging and dissipating somewhat slower than the effects on GDP and consumption (Figure 2F). The results are broadly consistent with the empirical literature on the macroeconomic effects of monetary policy shocks (e.g. Jorda et al., 2020).

3.3 Distributional effects of monetary policy

In the main analysis, we employ an equivalent empirical framework to estimate the heterogeneous effects of monetary policy on income dynamics using household-level data. The explanatory variable of interest remains the change in the Danish policy rate, which is now interacted with income group indicators to allow for heterogeneous effects. The dependent variable is the change in some household-level outcome y, such as disposable income, measured over varying horizons and scaled by ex ante household disposable income. Formally, we estimate the following model where j, t, k and h denote the household, the calendar year, the income group and the time horizon, respectively:

$$\frac{y_{j;t+h} - \overline{y}_{j;<t}}{\overline{d}_{j;<t}} = \sum_{k=1}^{21} \mathbb{1}[j \in k] \Big[\alpha_h^k + \beta_h^k(-\Delta i_t) + \gamma_h^k X_t^* \Big] + \theta_t + \varepsilon_{j,t} \tag{2}$$

On the left-hand side, $\overline{d}$ expresses the *ex ante* level of disposable income, that is the level before the policy rate change in year t, which we capture by the average taken over the three years before year t to reduce the effect of transitory shocks in a single year, and $\overline{y}$ expresses the ex ante level of the outcome defined analogously.[15] On the right-hand side, $\mathbb{1}[j \in k]$ indicates if household j belongs to income group k whereas X^* denotes the vector of German/Euro Area macro variables as defined above and θ_t is a vector of time fixed effects. The change in the Danish policy rate Δi_t is instrumented with the change in the German/Euro Area policy rate Δi_t^*. We estimate the model using household-level data for the period 1987-2014 and report standard errors that are clustered at the level of households and year-municipality.

The identification strategy in the household-level analysis is equivalent to the macro-level analysis above. We effectively use German/Euro Area monetary policy shocks, the variation in monetary policy that remains after conditioning on the macro environment (X^*), as a source of exogenous variation in the Danish monetary policy rate. The macro controls are now interacted

[15] To be precise, we construct the ex ante level of disposable income and the outcome by taking the average over year $t-3$, $t-2$ and $t-1$, but the results are not sensitive to simply using the value in $t-1$.

with income group indicators to allow for a heterogeneous correlation between business cycles and the outcome across different income groups. However, as we are ultimately interested in inequality and thus how monetary policy affects income groups differentially, we go one step further and include time fixed effects in the model. This absorbs the macro effect of any potentially confounding aggregate shock, but it also means that we can only identify the effects of monetary policy relative to the effects for a reference group, which we choose to be the middle income group (p45-50). It therefore implies that the estimates delivered by the baseline model with time fixed effects are *differential effects* measuring the effect of monetary policy at a given position in the income distribution relative to the effect around the median income level. We sometimes also report results from models without time fixed effects. The estimates from such models capture the absolute effects of monetary policy for each group rather than the differential effects relative to the reference group. The estimates of the absolute effects mainly serve to better understand the differential effects and check their plausibility. Importantly, they also rely on stronger identifying assumptions, that is that the change in the German/Euro Area monetary policy rate does not correlate with other shocks affecting aggregate income conditional on the controls, which are not necessary to estimate the differential effects.

We address a number of identification concerns with the baseline model itself and in further robustness tests. First, one may wonder whether our results could be confounded by long-run trends in inequality (Piketty, 2014). All our models, including the baseline, control flexibly for such trends with income group fixed effects (α^k) that absorb differences in average income growth at different positions in the income distribution. Second, one may be concerned that our baseline model does not isolate exogenous monetary policy shocks but uses variation that is endogenous to confounding differential shocks. We address this concern by adding ex ante controls (i.e. evaluated at time $t-1$ and t) for the Danish macro environment and for the global financial cycle. We also probe the robustness of our results to using alternative series of monetary policy shocks, based on the methodologies of Romer and Romer (2004) and Jarocinski and Karadi (2020), as detailed in Appendix D. Third, one may worry that our estimates are effectively picking up spillover effects of the monetary policy conducted in Germany/Euro Area going through changes in the demand for Danish exports or assets. Such spillover effects do not affect our baseline estimates if they affect all income groups in the same way, but could bias our results if, say, increased demand for Danish exports induced by expansionary monetary policy in Frankfurt raises the incomes of high-income business owners more than it raises the incomes of low-income workers. We purge our estimates from such differential spillovers by augmenting

the model with a range of ex post controls (i.e. evaluated at time $t+h$). Some of these controls - such as changes in Danish exports, imports, external assets and external liabilities - aim to capture specific types of spillovers while others - such as German/Euro Area stock prices, output growth and inflation - aim to shut down foreign business cycle spillovers more broadly.

We investigate the *channels* through which disposable income is affected by monetary policy by applying the model separately to each of its positive and negative components: salary income, business income, stock market income, interest income, private pension income, net government transfers and interest expenses. In these regressions, we continue to scale with disposable income on the left-hand side (rather than the ex-ante level of the income component itself). This delivers an approximate decomposition of the total effect on disposable income and allow us to assess which income components contribute most to the overall distributional effect.

In addition to the effects on disposable income, we also estimate the differential gains and losses created by monetary policy through its effect on asset prices. Our analysis focuses on two major asset classes, stocks and housing assets, and uses a slightly modified framework.[16] 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). By holding ex ante 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.

The practical implementation varies slightly for the two types of assets due to data differences. 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.[17] 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 differences in the effects of monetary policy working through systematic differences in portfolio sizes, but not through differences in portfolio composition (Calvet et al,

[16]Mortgage loans with a fixed rate are also a potentially important source of capital gains and losses in Denmark. Like in the United States, borrowers have an option to repay mortgage loans at the market price of the underlying bonds and the market value of existing loans therefore varies inversely with the market interest rate. However, we are unable to include mortgage loans in the analysis of price effects, as we cannot distinguish capital gains on loans from loan repayments in the available data (Andersen et al., 2020b).

[17]Formally, the approximation is $(P_{j,t-1}Q_{j,t-1})((\Pi_{t+n} - \Pi_{t-1})/\Pi_{t-1})$ where Π is the national stock price index.

2007; 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 Online Appendix B). 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 differential effects of monetary policy working through systematic differences in the value of housing assets across income groups, as well as through systematic differences in the responsiveness of house prices to monetary policy.

Finally, we study the differential effects of monetary policy on wealth accumulation and consumption across the income distribution. Concretely, we estimate the effect of monetary policy on wealth accumulation by using the change in net wealth (scaled by ex ante 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 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.

4 Main results

4.1 Disposable income

Income gradient

Figure 3 shows the differential effects of a one percentage point reduction in the policy rate on disposable income over a two-year horizon. The estimated effects exhibit a striking income gradient: The gains created by a softer monetary policy in the form of disposable income are increasing monotonically in the baseline level of income. Relative to the middle of the income distribution, the effect is around 3 percentage points larger for the top 1% and around 1 percentage point smaller for the lowest income levels.

Figure 4 illustrates how these estimates at selected positions in the income distribution vary with the time horizon. The income gradient emerges already with a short horizon of one year, but gets noticeably stronger when the horizon is extended to two years. At longer horizons of three and four years, the differential gains are roughly stable with some signs that they start

dissipating, notably at the bottom and the middle of the income distribution. Motivated by these patterns, the rest of the analysis focuses on the two-year horizon.

Channels

We explore the channels of monetary policy and how each of them contributes to the overall income gradient highlighted in Figure 3 by applying our model to each component of disposable income in turn. In this case, we use a model *without* time fixed effects, which produces estimates of the effects of monetary policy in absolute rather than differential terms. This is useful because it allows us to make a quantitative comparison across income components and thus assess which channels of monetary policy are more important at each position in the income distribution. Moreover, it allows us to verify that the main result, the income gradient in the effect on overall disposable income, is based on a set of plausible estimates of the absolute effect for a range of income components. However, it comes at the cost of stronger identifying assumptions, as discussed above. The results are reported in the eight panels of Figure 5, each with the same scale on the y-axis to make magnitudes directly comparable.

The first results indicate that softer monetary policy tends to increase disposable income by raising salary income (Figure 5A). The gain is largest for households at the 25th percentile of the income distribution where a one percentage point decrease in the policy rate increases salary income by almost 1% of disposable income; smaller above the median income level where the estimated effect drops to around 0.5% of disposable income; and close to zero at the bottom. Conceptually, the estimates may reflect either quantity effects or price effects: salary income may go up because employees work more hours or because the hourly wage rate goes up. In Figure A6 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. Overall, these results are consistent with the 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.

Moreover, softer monetary policy increases disposable income by raising income earned by self-employed through their own businesses (Figure 5B). While this effect is positive at all positions in the income distribution it increases monotonically with the baseline level of income: a one percentage point decrease in the policy rate increases business income by 0.1-0.2% of

disposable income in the middle of the income distribution and by more than 1% of disposable income at the top. This pattern, at least partly, reflects that the propensity to be self-employed is increasing in income, as shown in Table I. However, the strong non-linearity in the estimated effects also suggests that self-employed at different positions in the income distribution may be differentially exposed to monetary policy.

The next set of results show that monetary policy has opposing effects on interest income (Figure 5C) and stock market income in the form of dividends and realized capital gains (Figure 5D). A decrease in the policy rate generally lowers interest income, suggesting pass-through to interest rates on bank deposits and bonds,[18] but at the same time raises stock market income, which is consistent with a stimulating effect of monetary policy on corporate profits and stock prices. Both effects increase monotonically in the baseline level of income: households with higher incomes lose more interest income but also gain more stock market income when the policy rate is lowered. However, the net impact varies with the position in the income distribution. At high income levels, the gains in stock market income dominates the loss of interest income and, for the top income group, the net effect of a one percentage point decrease in the policy rate is an increase in overall financial income of around 1% of disposable income. At lower income levels, the net impact on financial income is negative.

Further, a decrease in the policy rate generally increases disposable income by lowering interest payments (Figure 5E), suggesting pass-through to interest rates on bank loans.[19] 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. Specifically, a one percentage point decrease in the policy rate reduces interest expenses by more than 3% of disposable income in the top income group compared to less than 1% around the middle and less than 0.5% at the bottom. The income gradient in the estimates is consistent with the increasing ratio of debt to disposable income documented in Table I.[20]

While private pension payments are largely unaffected by monetary policy (Figure 5F), we find sizeable and non-monotonic effects on government transfers and taxes (Figure 5G). The

[18] In the middle of the income distribution, with an estimated effect of around -0.25% of disposable income and deposits of around 60% of disposable income, the estimates suggest a pass-through rate of around 0.4.

[19] In the middle of the income distribution, with an estimated effect of around 0.75% of disposable income and debt amounting to 230% of disposable income, the estimates suggest a pass-through rate of around 0.35.

[20] One may wonder how the reduction in households' interest expenses can be larger than the reduction in their interest income at all income levels. This is because only a small fraction of outstanding mortgage bonds, the majority of total lending, is held by households whereas the vast majority is held by banks, insurance companies, pension funds and foreign investors (see Table AI in the Appendix). The indirect effect on households of a reduction in the interest income of financial intermediaries is captured in the analysis of households' stock market income (Figure 5D) and stock portfolio values (Figure 9B).

income gains created by a softening of monetary policy are generally subject to taxation and affect the eligibility to social transfers, but the estimates may, in principle, also reflect that the government attempts to offset the effects of monetary policy shocks on aggregate economic activity with changes in fiscal policy. Consistent with the former channel, we find the most negative effect on net government transfers for the top income group where the overall income gain is largest and around the 25th percentile where the large employment gains reduce net government transfers through higher tax payments as well as well through lower unemployment benefits.[21] In other parts of the income distribution the effects on net transfers are smaller. In Figure A7 in the Online Appendix, we show formally that the differential effect of monetary policy on *market disposable income*, that is measured before government transfers and payments, exhibits an even steeper income gradient between high and low incomes than the baseline results, suggesting that the fiscal system in fact attenuates the distributional effects of monetary policy.

Lastly, we also report the effect on overall disposable income that emerges from the model without time fixed effects (Figure 5H).[22] The income gradient is the same as in Figure 3, but the estimates now reflect the absolute effects of monetary policy rather than differential effects. The results imply that a one percentage point decrease in the policy rate increases disposable income by around 1% in the middle of the disposable income, which compares to more than 4% for the top income group and almost precisely zero for the lowest incomes.

Decomposition

Our analysis shows that the effects of monetary policy are highly heterogeneous and the question arises whether this is mainly due to the systematic differences in income composition and balance sheets highlighted in Table I or to monetary policy creating different incentives and inducing different behavioral responses across the income distribution. A couple of examples serve to illustrate the distinction. First, the gradient in the effect of monetary policy on interest expenses may simply reflect that high-income households have more debt relative to their disposable income but also that they more often take advantage of opportunities to refinance mortgage loans when interest rates change (Andersen et al., 2020b). Second, the large effect of monetary policy on salary income for low-income households may be because salaries make up a large share of their overall disposable income so that they benefit more from a proportional increase

[21] The combined marginal tax rate on labor income is particularly high for unemployed who transition into low-wage employment as they lose generous unemployment benefits and pay high marginal taxes on the modest income gain.

[22] As shown in Figure A8 in the Online Appendix, the income gradient in the components of disposable income add up to the income gradient in disposable income almost perfectly.

in wage rates or hours, or because they work in occupations or industries more sensitive to monetary policy. Third, the large effect of monetary policy on stock market income (i.e. the sum of dividends and realized gains) for high-income households may merely reflect that they hold more stocks relative to their disposable income, but also that they hold stocks with different dividend policies and risk characteristics (Fagereng et al., 2020) and exhibit different propensities to realize capital gains over the business cycle (Hoopes et al., 2016).

We make a simple decomposition of the differential effects of monetary policy in the part that can be explained by systematic differences in income structure and balance sheets and the part that is unexplained by such differences and therefore reflects heterogeneous effects of monetary policy on incentives and behavior. The decomposition is obtained in the following way. For each income component, we isolate the distributional effects of monetary policy explained by compositional differences by scaling the effect estimated at the median at each position in the income distribution. For instance, debt in the top income group is 40% higher than debt at the median (relative to disposable income) and the balance sheet structure therefore predicts that the effect on interest expenses in the top income group is 40% higher than the effect estimated at the median. We use balance sheets to decompose the effect on capital income (stock market income, interest income, interest expenses) and the income structure to decompose the effect on non-capital income (salary income, business income, private pension, net government transfers). Summing these predictions across all income components, we obtain an estimate of what can be explained by compositional differences and, by subtracting this from the total effect on disposable income, an estimate of what is unexplained.

The results are mixed, as shown in Figure 6. On the one hand, they suggest that most of the large effect of monetary policy at the top can be explained by the particular income structure and balance sheets of high-income households. On the other hand, they suggest that the gradient elsewhere in the distribution, notably at the bottom, to a much lesser extent reflects such factors. To provide a deeper understanding of these patterns, we show the decomposition separately for each income component in Figure A9 in the Online Appendix. For some income components, the income gradient in the estimates mirrors the income structure and balance sheets almost perfectly, for instance interest income, stock market income and business income. For other income components, there is a substantial unexplained part. For instance, the income gradient in the effect on interest expenses is not fully explained by the income gradient in leverage, suggesting an important role for differences in loan characteristics and refinancing behavior. Moreover, the unexplained part of the effect on salary income is strongly negative

at the bottom of the income distribution but strongly positive for incomes around the 25th percentile, suggesting that the employment gains are very small for the former group and large for the latter.

4.2 Asset values

Income gradient

Figure 7 shows the differential effects of a one percentage point reduction in the policy rate on asset values over a two-year horizon, measured relative to ex ante disposable income. The estimates capture the "price 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 results exhibit a clear income gradient: The gains created by a softer monetary policy in the form of higher asset values increase in household income. Relative to the middle of the income distribution, the effect is around 40% percentage points larger for the top 1% and around 5 percentage points smaller for the lowest income levels.

Figure 8 illustrates how these estimates vary with the time horizon at selected positions in the income distribution. The income gradient is discernible already when the effects are estimated over a one-year horizon and gradually becomes more pronounced when the horizon is extended to longer horizons. The results are consistent with a lagged effect of monetary policy on asset prices also identified in previous studies. For instance, Coibion et al. (2017) find that the effect of monetary policy on housing prices continues to increase over a horizon of 4 years.

Channels

We explore the channels underlying the estimated effect on overall asset values by showing the contribution from housing assets and stocks respectively. Like in the case of disposable income, we use the model *without* fixed effects to quantify the channels so that the estimates can be interpreted in absolute rather than differential terms.

The first results indicate that softer monetary policy generally increases the value of housing assets at all income levels (Figure 9A). The magnitude of the effect increases roughly monotonically in income: a one percentage point decrease in the policy rate creates a gain through this channel of around 15% of disposable income at the bottom of the income distribution and around 40% of disposable income at the top. Given the ratios of housing assets to disposable income, these estimates are equivalent to an increase in the value of housing assets of around

4% at the bottom of the income distribution and almost 7% at the top.[23] Thus, the income gradient reflects both that high-income households own more housing assets relative to their disposable income and that housing prices exhibit a differential sensitivity to interest rates over the income distribution. In a robustness test reported in Figure A10 in the Online Appendix, we show that using the raw changes in the appraisal values of property rather than the imputed changes in market values gives similar results, although with a steeper slope at the very top of the income distribution.

The next results shows that a lower monetary policy generally increases the value of household portfolios of stocks, but that these gains are highly concentrated at the top of the income distribution (Figure 9B). The estimated gain created by a one percentage point decrease in the policy rate is around 15% of disposable income in the top income group and entirely negligible below the median income level. As we use the same index return to impute stock market gains for all the income groups, the income gradient in these estimates reflects the overwhelming concentration of stock ownership in the highest income groups. Given the value of stock portfolios relative to disposable income, the estimate for the top income group is equivalent to an increase the value of stocks of around 6%.[24]

The final results show the effect on total asset values delivered by the model without time fixed effects (Figure 9C).[25] While the income gradient is the same as in Figure 7, these estimates now capture the absolute rather than the differential effects of monetary policy. The estimated effects are positive at all income levels as softer monetary policy boosts asset prices. Specifically, the estimates suggest that a one percentage point decrease in the policy rate increases asset values by around 15% of disposable income at the bottom of the income distribution and by around 60% of disposable income at the top. This suggests that the gains in the form of higher asset values are substantially larger than the gains in the form of higher disposable income. Given the ratio of asset values to disposable income (Table I), the estimated effects are equivalent to an increase in asset values of around 4% at the bottom and around 6% at the top. Thus, the income gradient in the figure reflects that high-income households have more assets relative to their disposable income and that the prices of the assets they hold are more sensitive to monetary policy.

[23]This is similar to the estimates of the elasticity of house prices with respect to the monetary policy rate of around 8-9% often cited in the literature (e.g. Taylor, 2007).

[24]This is close to the widely cited estimate of the elasticity of stock prices with respect to the monetary policy rate of 6.8% (Rigobon and Sack, 2004).

[25]As shown in Figure A11 in the Online Appendix, the income gradient in the components of total asset values add up to the income gradient in total asset values almost perfectly.

Our analysis of asset values is incomplete in the sense that there are balance sheet components that it does not cover. First, monetary policy may create gains and losses on mortgage debt. In Denmark, mortgage bonds are traded on a public market and mortgage borrowers can repay their loans at market value at any point in time. A softening of monetary policy increases the price of existing bonds, which means that the market value of outstanding debt increases and borrowers incur a capital loss. Unfortunately, the size of these losses depends on loan characteristics and borrower behavior that are unobservable in the data (e.g. variable vs. fixed rate, time to maturity, refinancing choices) and we are therefore unable to include this channel in the analysis. Second, monetary policy creates gains and losses on assets held in tax-favored pension accounts. These assets have grown significantly over the sample period, from near zero in the early 1990s to a level of around 300% of GDP (Greenwood and Vissing-Jørgensen, 2018). Unfortunately, as micro-data on pension accounts only exists from 2014, we are unable to include these assets in the analysis. However, based on data for 2014 where pension assets increase with income in roughly the same way as non-pension assets except at the very top of the income distribution (Figure A12), we conjecture that including pension assets in the analysis may accentuate rather than attenuate the income gradient in the effects of monetary policy on assets values.[26]

4.3 Robustness, Inference and External validity

We conduct a range of additional tests in order to probe the robustness of our main results, revisit the statistical inference under alternative sets of assumptions and explore the external validity of the findings. We report the results in Figures A13-A18 in the Online Appendix.

First, we add controls for Danish macroeconomic conditions and the global financial cycle and address confounders in the form of serially correlated monetary policy shocks and non-conventional monetary policy. Specifically, we augment the set of macro controls with GDP growth and inflation in Denmark in periods t and $t-1$ (red line), to control for a possibly differential importance of local economic conditions on households in different income groups, and with the change in the U.S. VIX index in period t (blue line) to control for global financial shocks (Rey, 2013). We also add policy rate changes in period $t+1$ (green line) to account for any serial correlation in the monetary policy interventions that biases our estimates of monetary

[26] In a recent paper, Catherine, Miller and Sarin (2020) argue that future social security benefits should be considered an asset for the purposes of studying wealth inequality. In this vein, one could study how monetary policy affects asset values at different positions in the income distribution through its effect on the net present value of future public pensions. We do not pursue this type of analysis in the present paper.

policy in period t. Each of these new controls is interacted with a full vector of income group indicators. Further, we adopt an alternative measure of Euro/German monetary policy namely changes in the shadow rate, which account for the zero lower bound (brown line). The shadow rate is not bounded at zero and captures the effect of both conventional and unconventional monetary policy measures (Wu and Xia, 2016). As shown in Figure A13, these changes to the model barely have any effect on the estimates.

Second, we sequentially add a number of ex post controls (i.e. changes from period $t-1$ to period $t+h$) that absorb the direct effect of monetary policy in Frankfurt on economic outcomes in Denmark through other channels than the Danish policy rate. Specifically, we add (i) the ex post change in exports from Denmark (red line) to control for the effect on external demand for Danish goods and services and, analogously, the ex post change in imports to Denmark (green line); (ii) the ex post change in foreign liabilities (brown line) to control for the effect on external demand for Danish assets and, analogously, ex post foreign assets (blue line); and (iii) the ex post stock price returns in Germany /Euro Area (orange line) and ex post GDP growth and inflation in Germany /Euro Area (gray line) to control for any other spillover effects of foreign business cycles. Again, all the additional controls are interacted with a full vector of income group indicators. As shown in Figure A14, the results are robust to these additional controls. In the most saturated model that adds controls for ex ante GDP growth and inflation in Denmark, ex post changes in trade and foreign assets and liabilities and ex post stock market returns, GDP growth and inflation in Germany/Euro Area, decreasing the policy rate by one percentage point creates a differential gain of disposable income for the top income group of 4.3 percentage points (compared to 3.3 percentage points in the baseline model) and a differential increase in asset values of 20% of disposable income (compared to 38% in the baseline model).

Third, we take two alternative approaches to identifying German/Euro Area monetary policy shocks drawing on the work by Romer and Romer (2004) and Jarocinski and Karadi (2020). The former approach estimates shocks at the frequency of the monetary policy meetings at the ECB, controlling for the information set available to members of the Governing Council. The latter approach identifies monetary policy shocks from high-frequency movements in interest rates and stock prices around the time of monetary policy announcements by the ECB. In both cases, we collapse the estimated monetary shocks to the annual frequency and use the resulting annual series to instrument for changes in the Danish monetary policy rate. More details on the construction of the alternative series of monetary policy shocks are available in Online Appendix D. As shown in Figure A15, the results are similar when we use these alternative approaches to

identification. Specifically, the differential effects on disposable income are slightly larger than the baseline results with either of the two alternative approaches whereas the differential effects on asset values are somewhat larger than the baseline results with the Romer-Romer approach and somewhat smaller with the Jarocinski-Karadi approach.

Fourth, we estimate a version of the baseline model augmented 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, which absorbs a significant amount of variation. As shown in Figure A16, the results are qualitatively robust to this demanding extension of the model. The gradient in the income gains is steeper than in the baseline, with estimated income gains to the top-1% exceeding gains to the median income group by more than 5 percentage points, whereas the gradient in the gains of asset values is moderately flatter than in the baseline model.

Fifth, we probe the sensitivity of the standard errors to assumptions about the correlation structure in the error term and illustrate the results in Figure A17 in the Online Appendix. Specifically, we display the baseline results 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; Abadie et al., 2017). We also report confidence intervals based on the Driscoll-Kraay standard errors that are robust to very general forms of cross-sectional and temporal correlation (Driscoll and Kraay, 1998) and are employed by some of the most closely related papers (e.g. Coibion et al., 2017). The income gradient continues to be statistically significant in all cases.

Finally, we investigate whether the baseline results are driven by particularities in the balance sheets of Danish households and, in particular, we ask how the results might have looked like if Danish households were similar to households in other economies in terms of their exposure to debt markets. We address this question by re-estimating our baseline model while weighting the observations so that our Danish sample effectively matches households in the United States and the Euro Area, within each income group and each year, in terms of the share participating in the debt market and the median debt-income ratio for those with positive debt. More details on the weighting approach are available in Online Appendix E. As shown in Figure A18, the results

from the re-weighted sample are very similar to the baseline, suggesting that the relatively high levels of debt in Denmark are not a major driver of the estimated *differential* effects of monetary policy and thus strengthening the case for external validity of our results.[27]

5 Further results

5.1 Net 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 through intertemporal 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 10A shows the differential effects of a one percentage point reduction in the monetary policy rate on wealth accumulation over a two-year horizon, measured relative to ex ante disposable income. There is a clear income gradient in the estimates: The wealth gains created by softer monetary policy are systematically larger at higher income levels. Relative to the middle of the income distribution, the effect on net wealth is around 40% percentage points larger at the top and around 5 percentage points smaller at the bottom. These estimates are strikingly similar to the estimated "price effects" on asset values (Figure 9). The similarity 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., 2020a; Andersen et al, 2021). It is 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 mortgage loans (Andersen and Leth-Petersen, 2019).

[27] Variable rate loans were introduced in Denmark in 1998 and have co-existed with fixed rate loans on the mortgage loan market since then. It would have been useful to distinguish between loans with fixed and variable rates in the empirical analysis; however, we do not observe loan characteristics in the data. Andersen et al. (2020) argue that the Danish mortgage system is similar to the US system in that long-term fixed-rate mortgages are common and can be refinanced without penalties, but differs in that Danish households are free to refinance at any time.

Figure 10B shows the analogous estimates for new car purchases. 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 effect of monetary policy on car consumption tends to increase with household income, at least through the upper half of the income distribution. Relative to the median income level, the effect of a one percentage point reduction in the monetary policy rate is larger in the top income group by around 0.002 cars (equivalent to around 3% of the baseline new car purchases in this group). 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. However, we cannot be sure that this conclusion is robust to using a broader measure of consumption, as cars may account for a larger share of marginal consumption at higher income levels.

5.2 Leverage

We now investigate the role of household leverage in shaping the distributional effects of monetary policy. 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.[28] 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). We opt for the version of the model without time fixed effects, which produces estimates in absolute rather than differential terms and thus allows us to make quantitative comparisons across income groups, leverage groups and outcomes.

We start by considering how leverage mediates the effect of monetary policy on interest expenses. Specifically, Figure 11A 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. Comparing within income groups, these gains increases monotonically in leverage. Comparing within leverage groups, the gains are 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.[29]

[28] We also include a full set of three-way interactions between macro controls, income group indicators and leverage indicators.

[29] 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 exploit opportunities to refinance mortgage loans with a fixed rate. Alternatively, it may be the case that households in the top income group have higher

As shown in Figure 11B, 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 other channels than lower interest expenses. 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 non-debt channels.

Next, we study how the effect of monetary policy on wealth through asset prices varies with leverage. Specifically, Figures 11C-11D show the "price effect" on the value of housing assets and stock portfolios for households with different income and leverage. The patterns for the two asset classes are strikingly different. On the one hand, leverage can account for most of the income gradient in the effect on housing assets: when comparing households with the same 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 accounts for 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, both in the full sample and within income groups.

Finally, we consider how leverage mediates the effect of monetary policy on wealth accumulation and car consumption. Figure 11E shows that the effect on wealth accumulation is roughly similar to the combined "price effects" on housing and stocks for all income and leverage groups. Figure 11F shows that the effect of monetary policy on new car purchases exhibits a striking

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. The gains estimated for households with no debt likely reflect the extensive margin of borrowing: 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).

monotonicity in leverage: the estimated effect is growing in leverage within each income group. This pattern reflects that households with more leverage reap larger gains from a softening of monetary policy in terms of disposable income and housing values (as shown above), but it is also consistent with leveraged households having a higher marginal propensity to consume because they are more financially constrained.

5.3 Age

While our analysis until now has focused on the differential effects of monetary policy across income groups, this section investigates differential effects 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 AII 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. The omitted category is the youngest age group (below age 35) so the age-specific estimates of the effect of monetary are measured relative to this age group.

Figure 12 illustrates the estimated differential effects on disposable income (Panel A) and asset values (Panel B). There is a hump-shaped relation between the effects on disposable income and age: The effects are larger for the middle-aged (35-65 years) than for the young (below age 35) and the elderly (above age 75). By contrast, the effect on asset values is almost monotonically increasing in age. These relationships reflect that exposure to the various direct and indirect channels of monetary policy change markedly over the life cycle (Table AII). Importantly, the middle-aged have most debt relative to disposable income and therefore benefit most from lower interest expenses when the policy rate is lowered and the elderly 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.

6 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 without time fixed effects (Figure 5H), 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 almost 1.5% for the bottom income group.[30] Hence, our results suggest that monetary policy, through a range of direct and indirect channels, makes the distribution of disposable income significantly 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 5G, 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, shown in Figures 9 and 10.

7 Conclusion

In this paper, we study the *distributional effects* of monetary policy across income groups. Our results document a strong income gradient in the gains from expansionary monetary policy: A lower policy rate creates relatively larger gains to households at higher income levels in the form

[30] If the income share of the top-1% is initially 10%, the results suggest that lowering the policy rate by one percentage point increases this share to 10.3%.

of disposable income, asset values, net wealth and durable consumption. 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.

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Table I: Descriptive statistics The table shows describes the composition of disposable income (Panel B) and net wealth (Panel C) and describes some important behavioral margins (Panel D) by income groups. Note that the category *deposits* also includes bonds. 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 B and C, we aggregate each income and wealth element within each income group over the entire sample period and divide with disposable income aggregated in the same way. In Panel B, *disposable income* sums salary income, business income, stock market income, interest income, private pension income, other income and net government transfers and subtracts interest expenses. In Panel C, *net wealth* sums deposits, stocks and housing and subtracts debt.

	p0-20	p20-40	p40-60	p60-80	p80-90	p90-99	p99-100
Panel A: Level of disposable income (in % of middle group)							
	66%	85%	100%	115%	132%	170%	432%
Panel B: Composition of disposable income (each component in % of overall disposable income)							
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%
private pension	4%	5%	6%	10%	15%	17%	11%
other income	1%	1%	1%	1%	2%	3%	7%
net government transfers	58%	5%	-18%	-35%	-51%	-67%	-80%
interest expenses	8%	13%	15%	16%	18%	21%	23%
disposable income	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Panel C: Composition of balance sheets (each component in % of overall disposable income)							
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%**	**670%**
Panel D: Descriptive indicators							
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 1: Monetary policy rates. The figure shows the 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 (Euro Area). The dashed lines indicate major events affecting monetary policy rates. The bold dashed line marks the beginning of the peg to the German Mark.

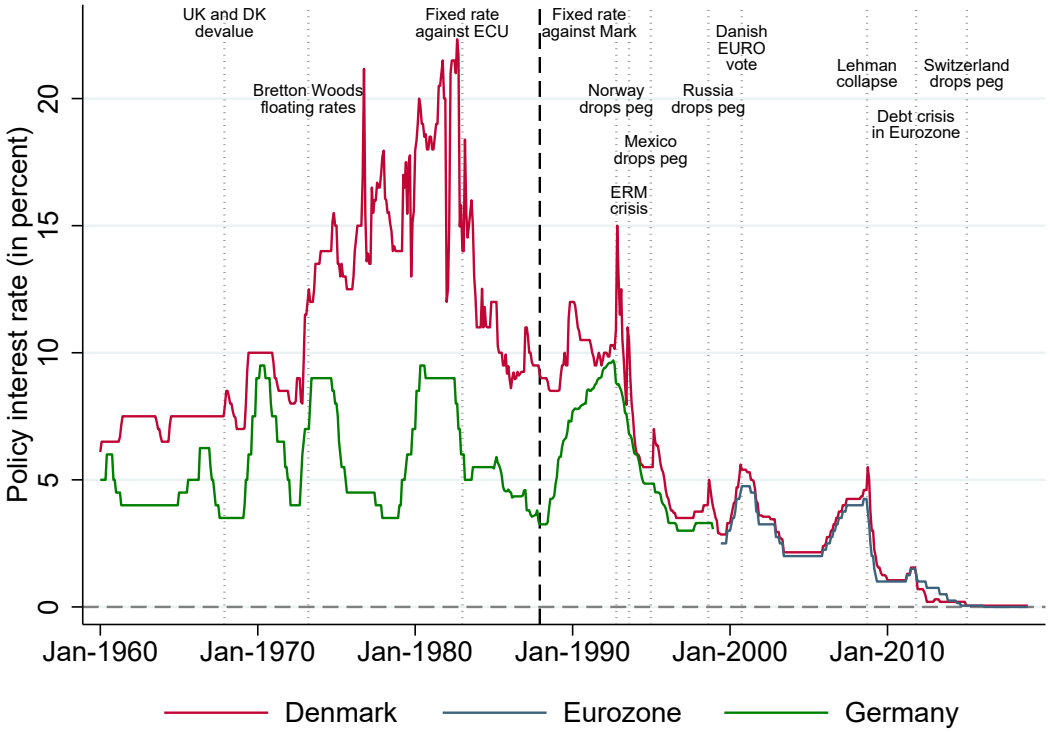


Figure 2: Macro effects of monetary policy shocks. The figure shows the estimated dynamics in Danish macro variables associated with a one percentage decrease in the Danish monetary policy rate (in period 0). The estimates come from a local projections framework that instruments changes in the Danish monetary policy rate with changes in the German/Euro Area monetary policy and controls for lagged, current and projected German/Euro Area output growth and inflation. The outcomes are the monetary policy rate (Panel A), the level of GDP (Panel B), the price level (Panel C), aggregate consumption (Panel D), aggregate car purchases (Panel E) and aggregate labor income (Panel F). The figure shows point estimates (blue line) and confidence bounds based on one standard error (dark gray) and two standard errors (light gray) respectively.

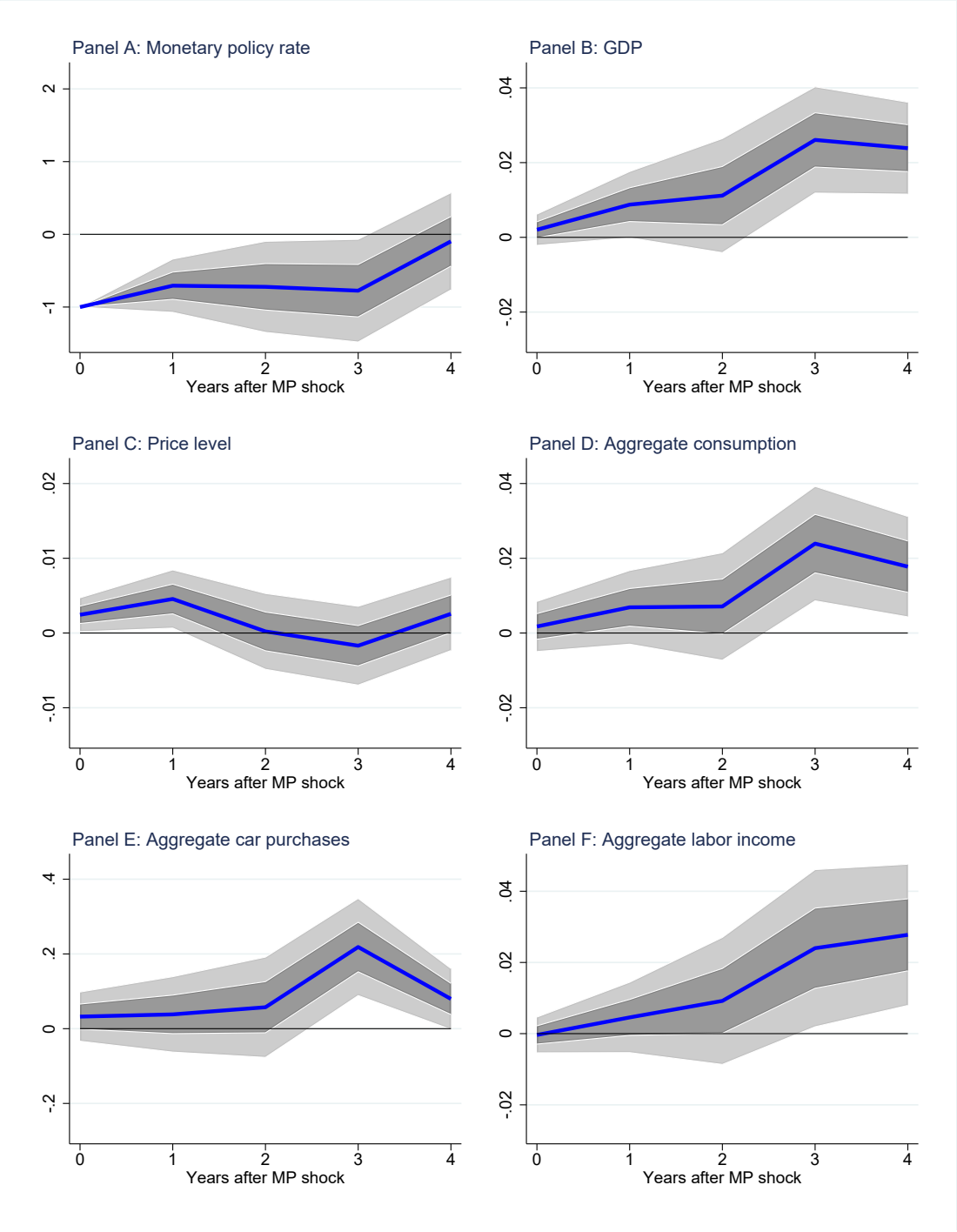


Figure 3: Differential effects of monetary policy on disposable income. The figure shows the estimated differential effect of a one percentage point decrease in the monetary policy rate on disposable income at different positions in the income distribution over a two-year horizon. The estimates are relative to the median group (p45-50).

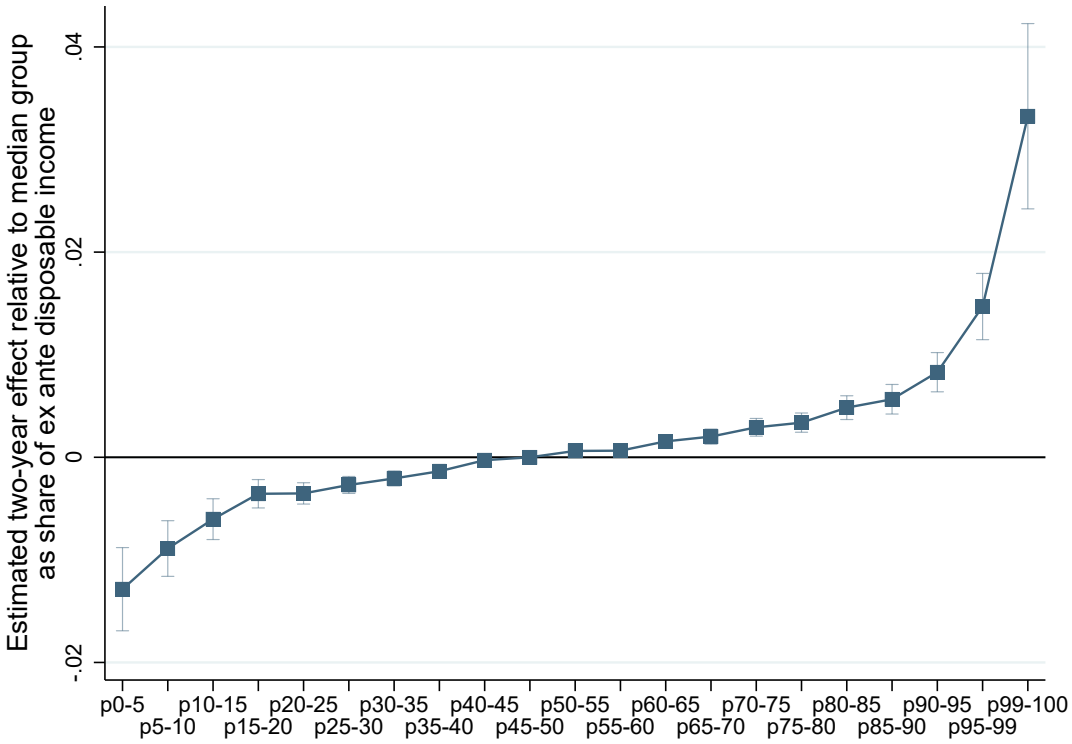


Figure 4: Differential effects on disposable income by time horizon. The figure shows the estimated differential effect of a one percentage point decrease in the monetary policy rate on disposable income at selected positions in the income distribution over a one-year, two-year, three-year and four-year horizon. The estimates are relative to the median group (p45-50).

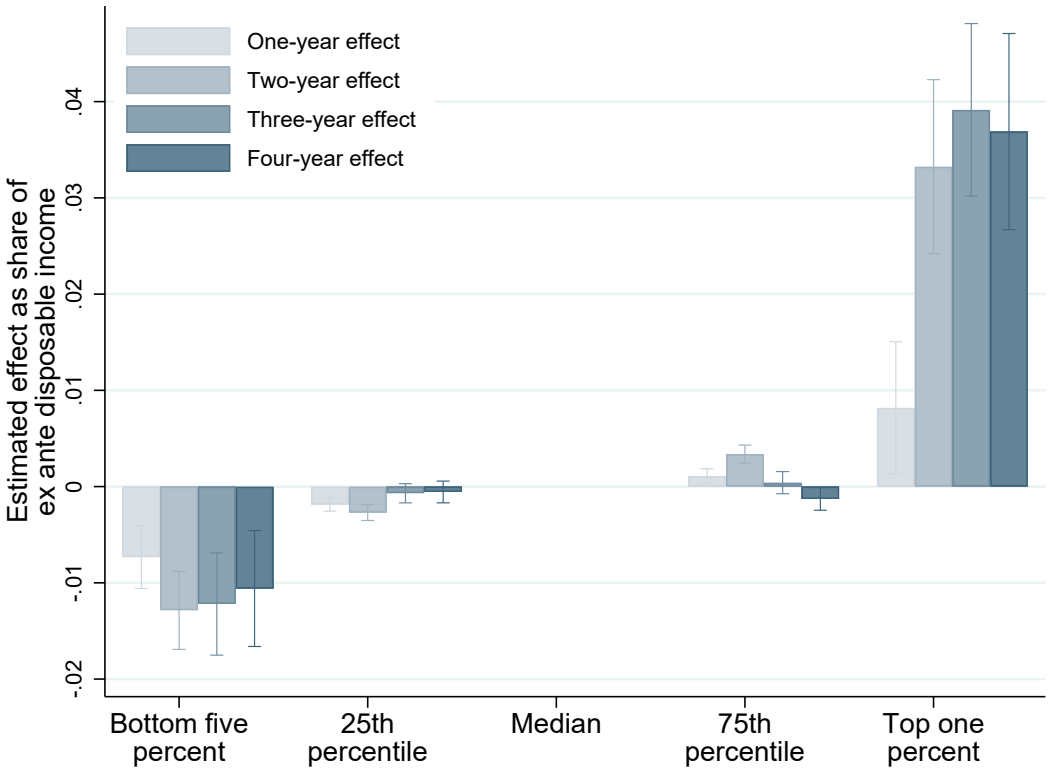


Figure 5: Heterogeneous effects on disposable income by component. The figure shows the estimated two-year effect of a one percentage point decrease in the monetary policy rate on the components of disposable income (Panels A-G) and on overall disposable income (Panel H) at different positions in the income distribution.

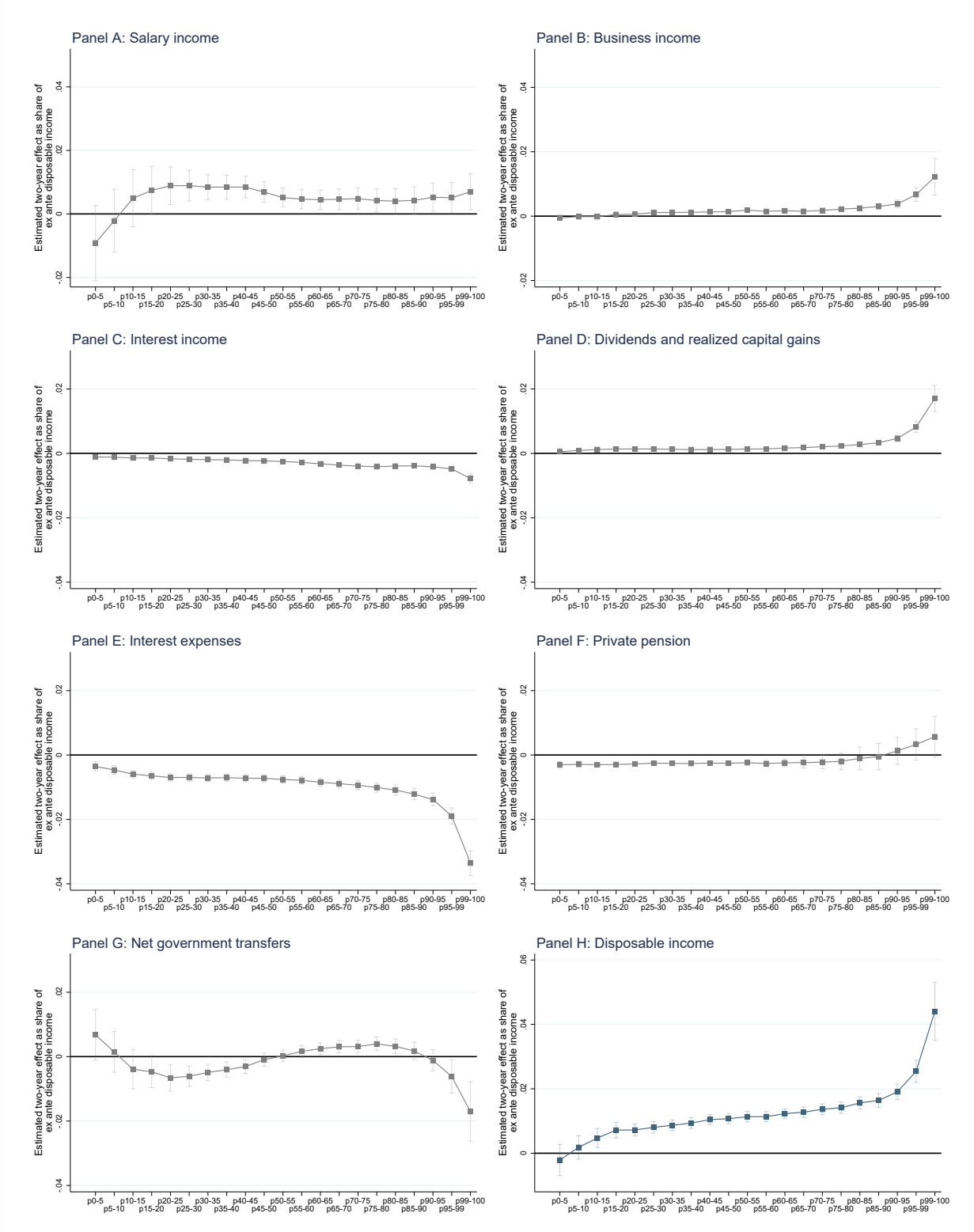


Figure 6: The role of income and balance sheet composition. The figure shows the estimated two-year effect on disposable income of a one percentage point decrease in the monetary policy rate at selected positions in the income distribution decomposed into a part that is explained by differences in the composition of income and balance sheets (light blue bars) and a part that is unexplained by compositional differences (dark blue bars). The estimates are relative to the median group (p45-50).

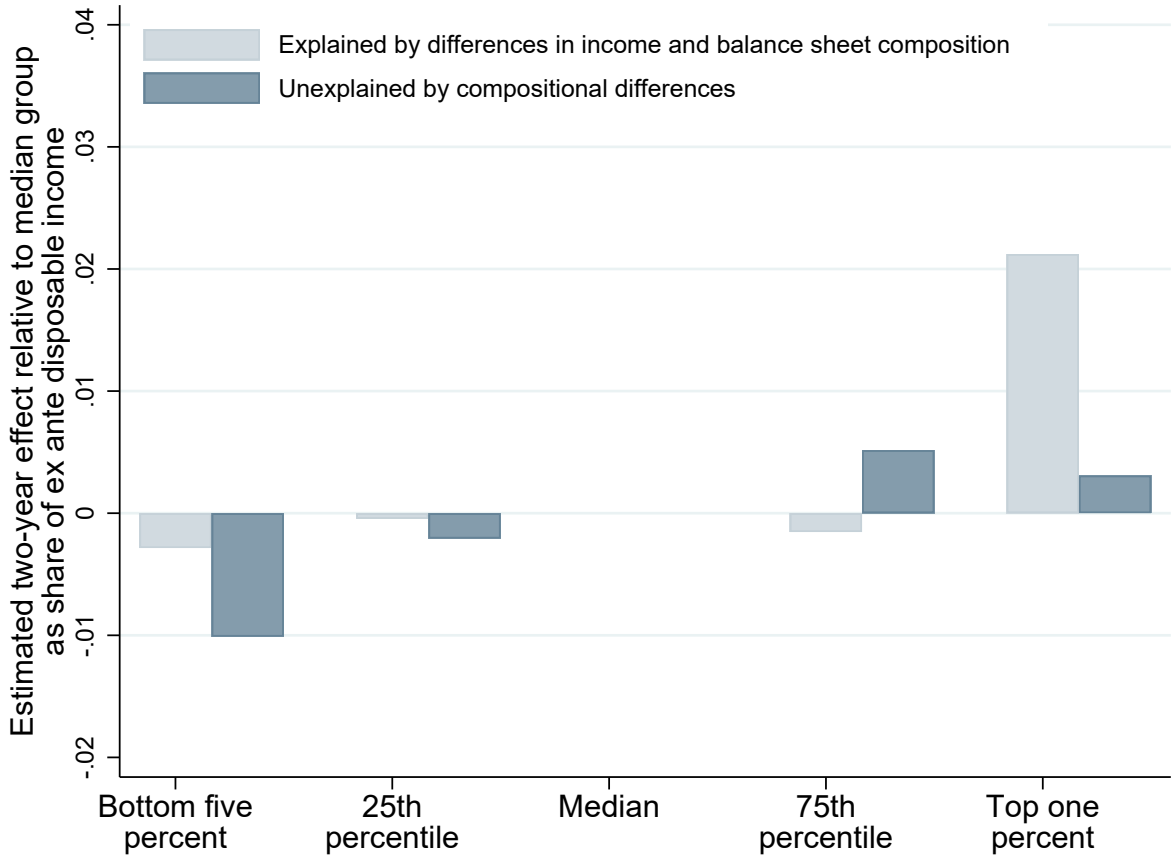


Figure 7: Differential effects of monetary policy on asset values. The figure shows the estimated differential "price effect" of a one percentage point decrease in the policy rate on the combined value of housing assets and stock portfolios at different positions in the income distribution over a two-year horizon. The estimates are relative to the median group (p45-50).

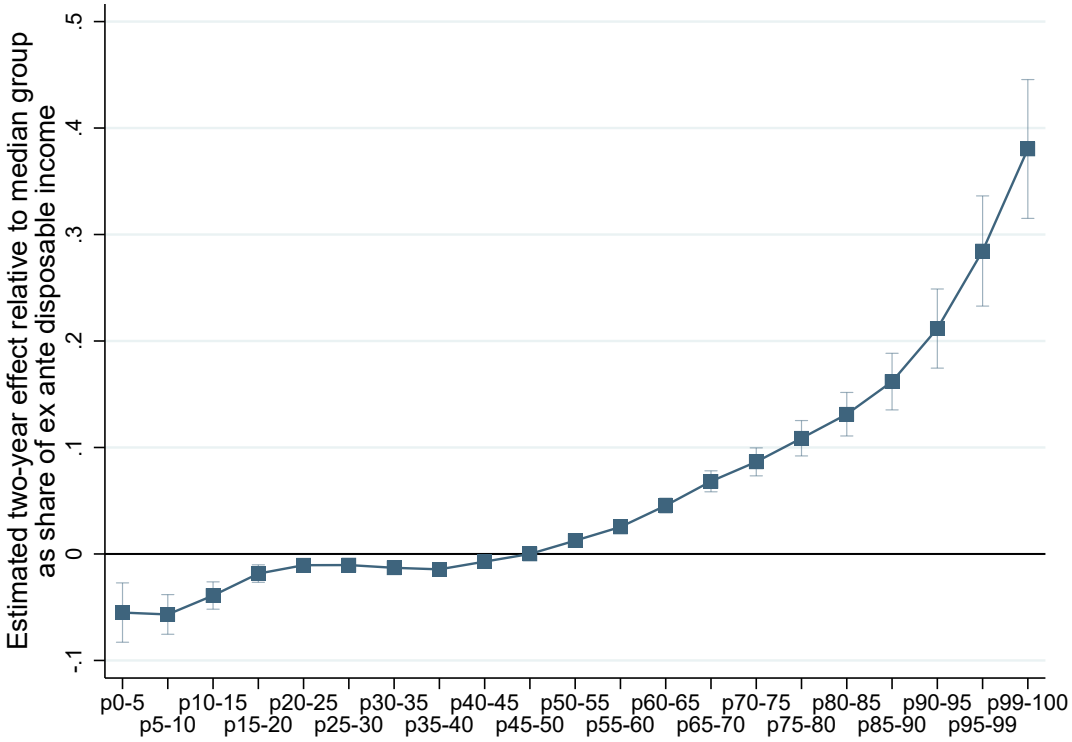


Figure 8: Differential effects on asset values by time horizon. The figure shows the estimated differential "price effect" of a one percentage point decrease in the monetary policy rate on the combined value of housing assets and stock portfolios at selected positions in the income distribution over a one-year, two-year, three-year and four-year horizon. The estimates are relative to the median group (p45-50).

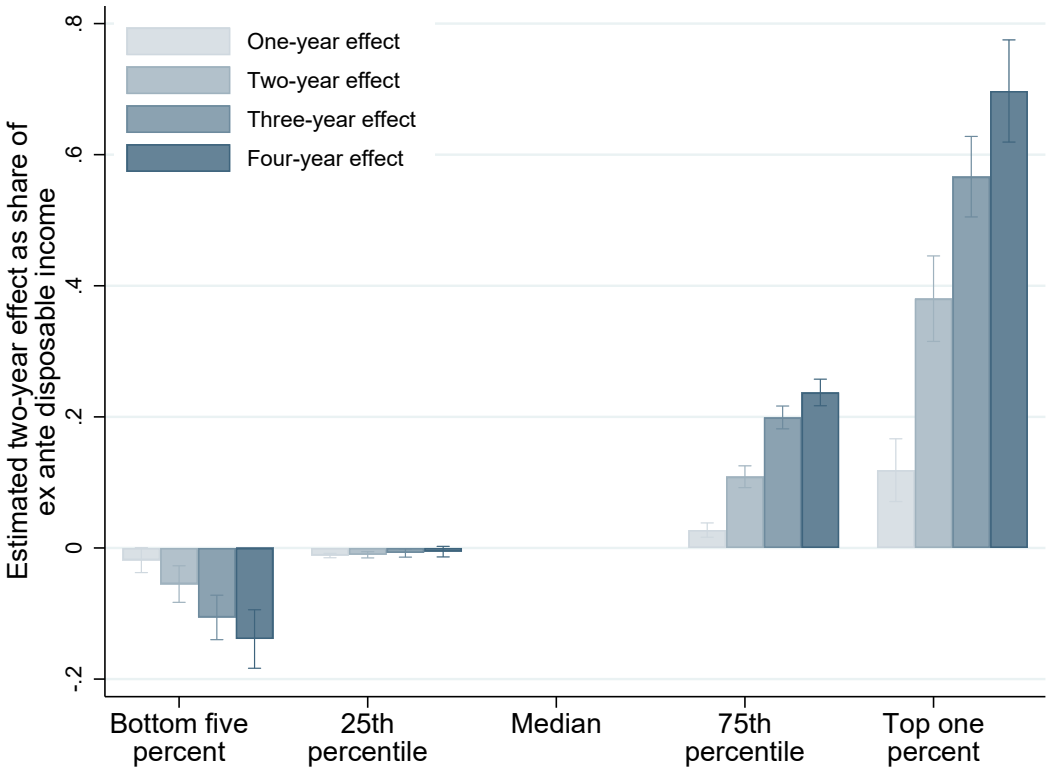


Figure 9: Heterogeneous effects on asset values by asset categories. The figure shows the estimated two-year "price effect" of a one percentage point decrease in the monetary policy rate on the value of housing assets and stock portfolios respectively (Panels A-B) and the combined value of these asset categories (Panel C) at different positions in the income distribution.

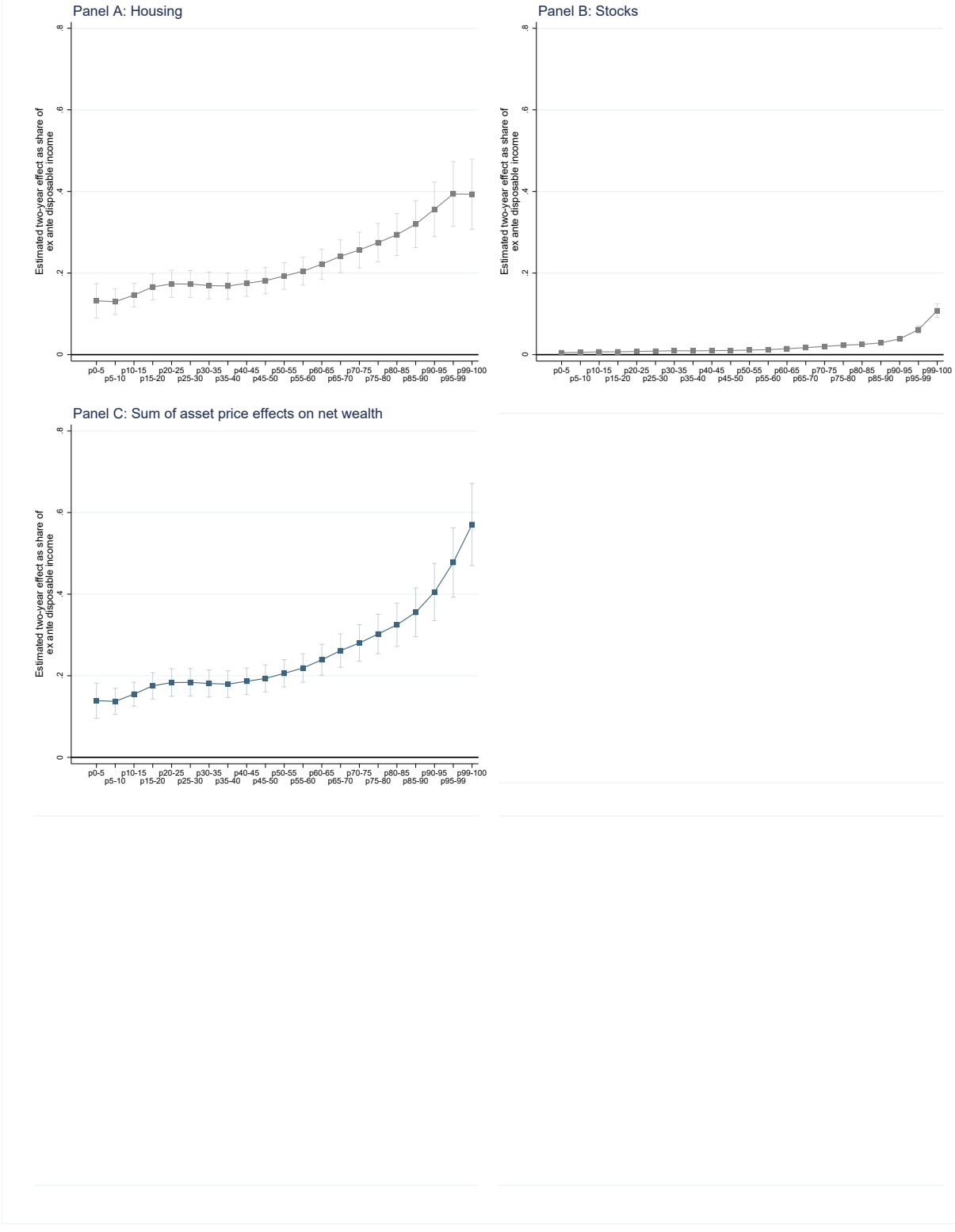


Figure 10: Implications for wealth accumulation and consumption. The figure shows the estimated differential effect of a one percentage point decrease in the policy rate on the change in net wealth (Panel A) and the number of newly registered cars (Panel B) at different positions in the income distribution over a two-year horizon. The estimates are relative to the median group (p45-50).

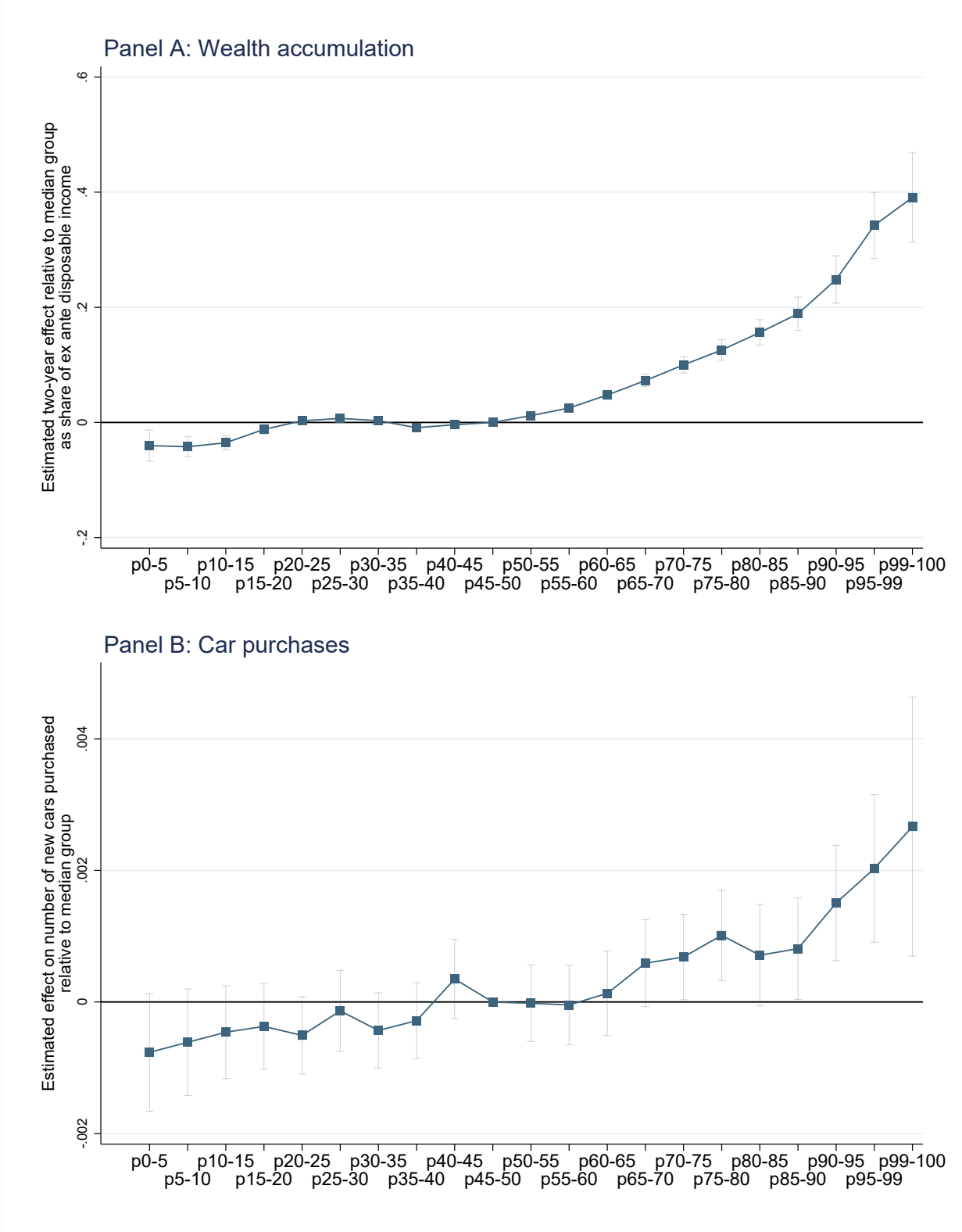


Figure 11: The mediating role of leverage. The figure shows the estimated two-year gain created by a one percentage point decrease in the monetary policy rate through lower interest expenses (Panel A), higher overall disposable income (Panel B), appreciation of housing assets (Panel C), appreciation of stock portfolios (Panel D), the change in net wealth (Panel E), and the number of newly registered cars (Panel F) at selected 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").

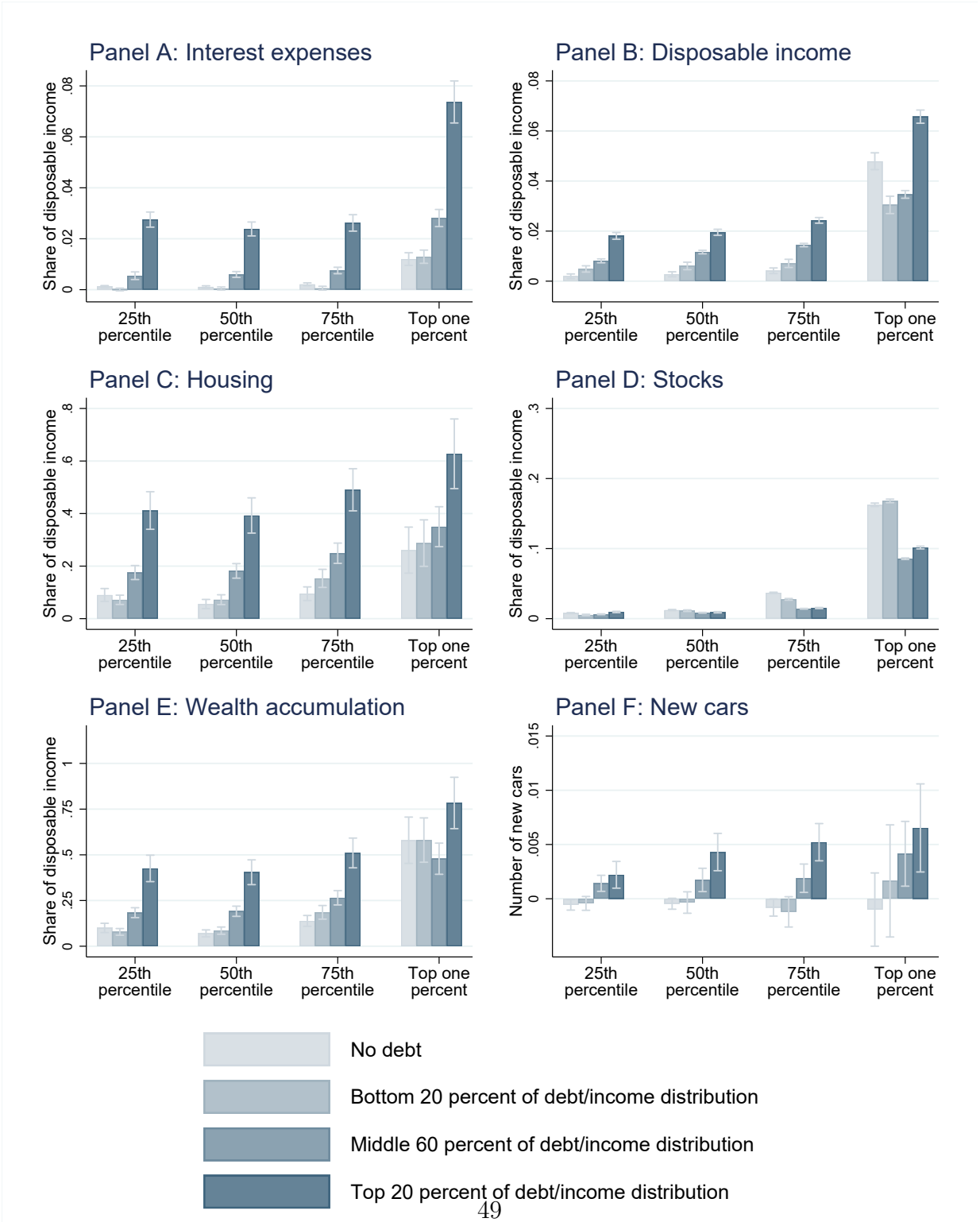


Figure 12: The differential effect of monetary policy by age. The figure shows the estimated differential effect of a one percentage point decrease in the policy rate on disposable income (Panel A) and asset values (Panel B) for different age groups over a two-year horizon. The estimates are measured relative to the youngest group (25-35 years).

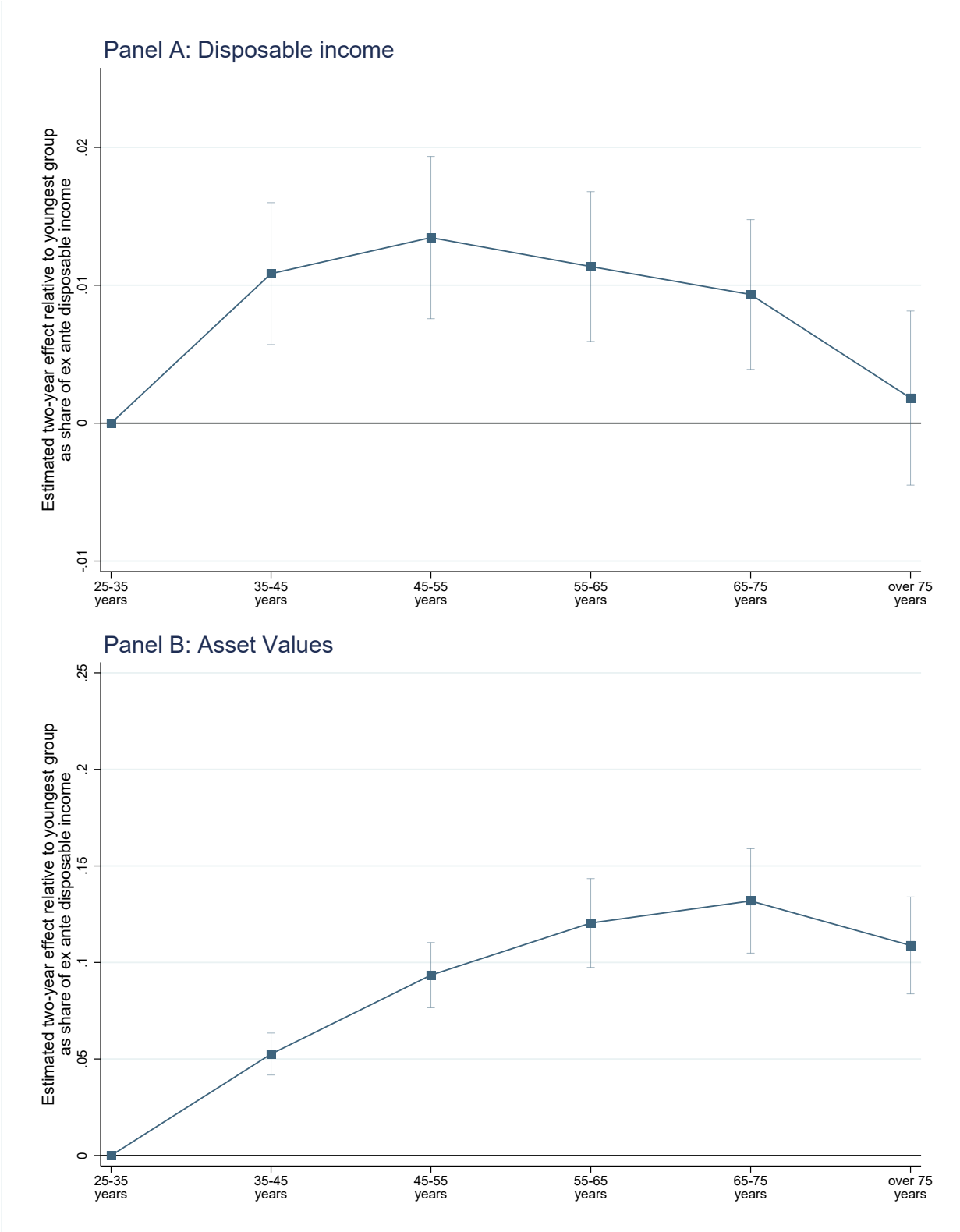
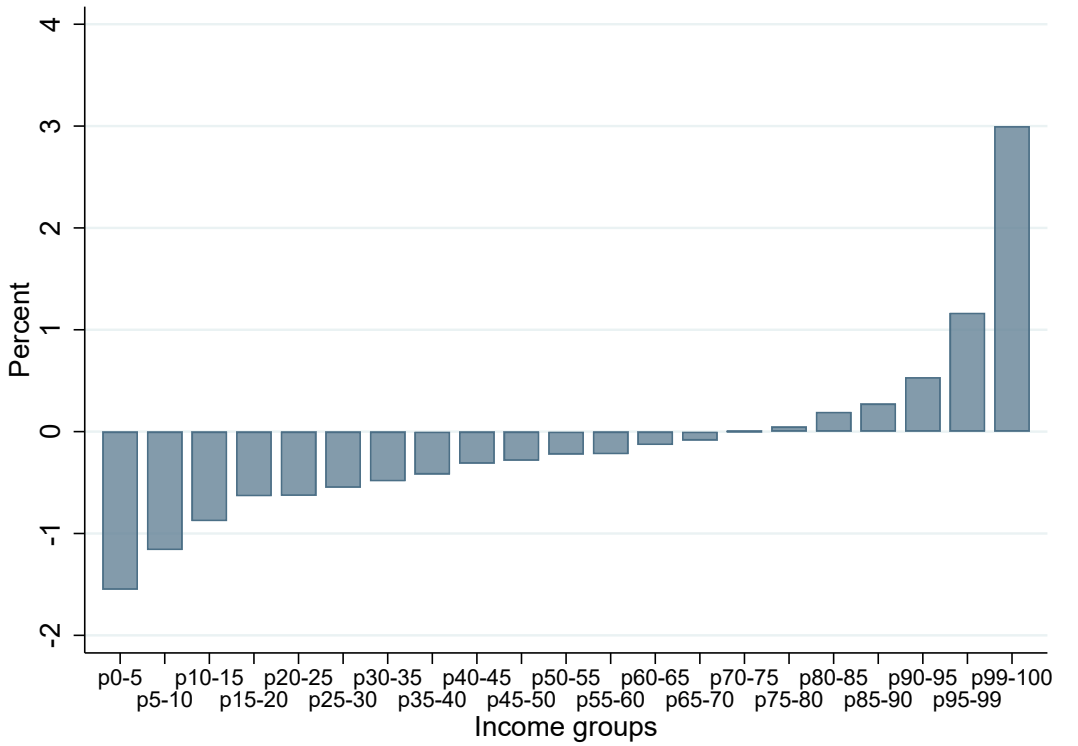


Figure 13: Implications for income inequality. The figure shows the simulated percentage change in each income group's share of total disposable income resulting from a one percentage point decrease in the policy rate. Applying the two-year coefficients from Figure 4, the simulation first computes the 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.



Internet Appendix for "Monetary Policy and Inequality"

Internet Appendix A: Extra Results

Figure A1: Household financial characteristics by income and economy. The figure shows how a range of household financial characteristics vary by income in Denmark (black lines), the United States (red lines) and the Euro Area (blue lines) in 2013-2014: The share of households owning their primary residence (Panel A), the share of households owning any stocks (Panel B), the share of households with any debt (Panel C) and the ratio of median debt to median income (Panel D). Sources: The figures for the United States are based on the Survey of Consumer Finance, 2013, Tables 1, 7, 9 and 13. The figures for the Euro Area are based on the Household Finance and Consumption Survey, 2014, Tables B3, C5, E5, E6 and I1. The figures for Denmark are computed using micro-data for 2014.

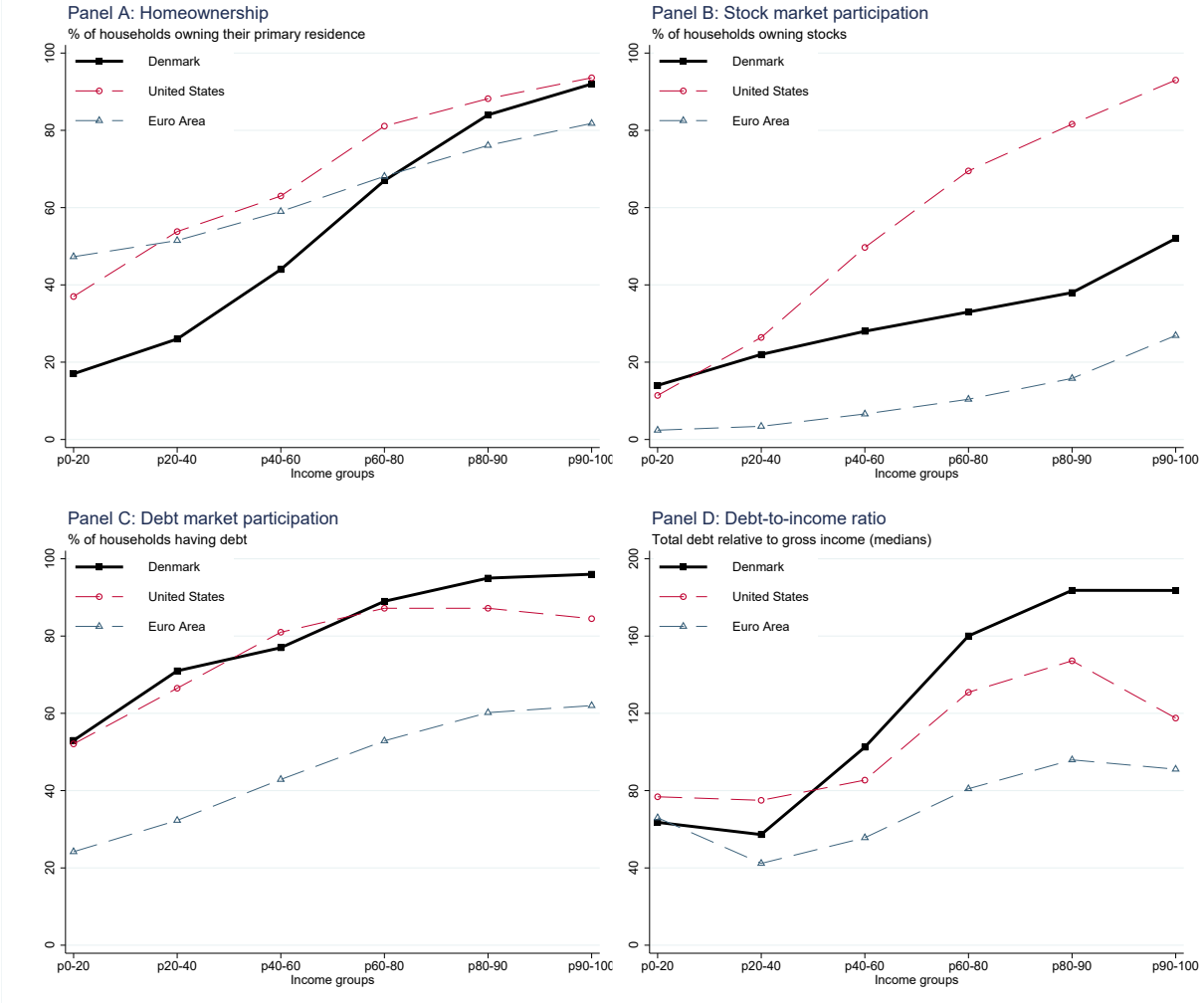


Figure A2: Household debt by income, economy and over time. The figure shows how the extensive and intensive margin of debt market participation vary by income and over time in Denmark (blue lines) and the United States (red lines): The share of households with any debt (Panels A-B)and the ratio of median debt to median income (Panels C-D). Sources: The figures for the United States are based on the Survey of Consumer Finance, 2013, Tables 1 and 13. The figures for Denmark are computed using micro-data.

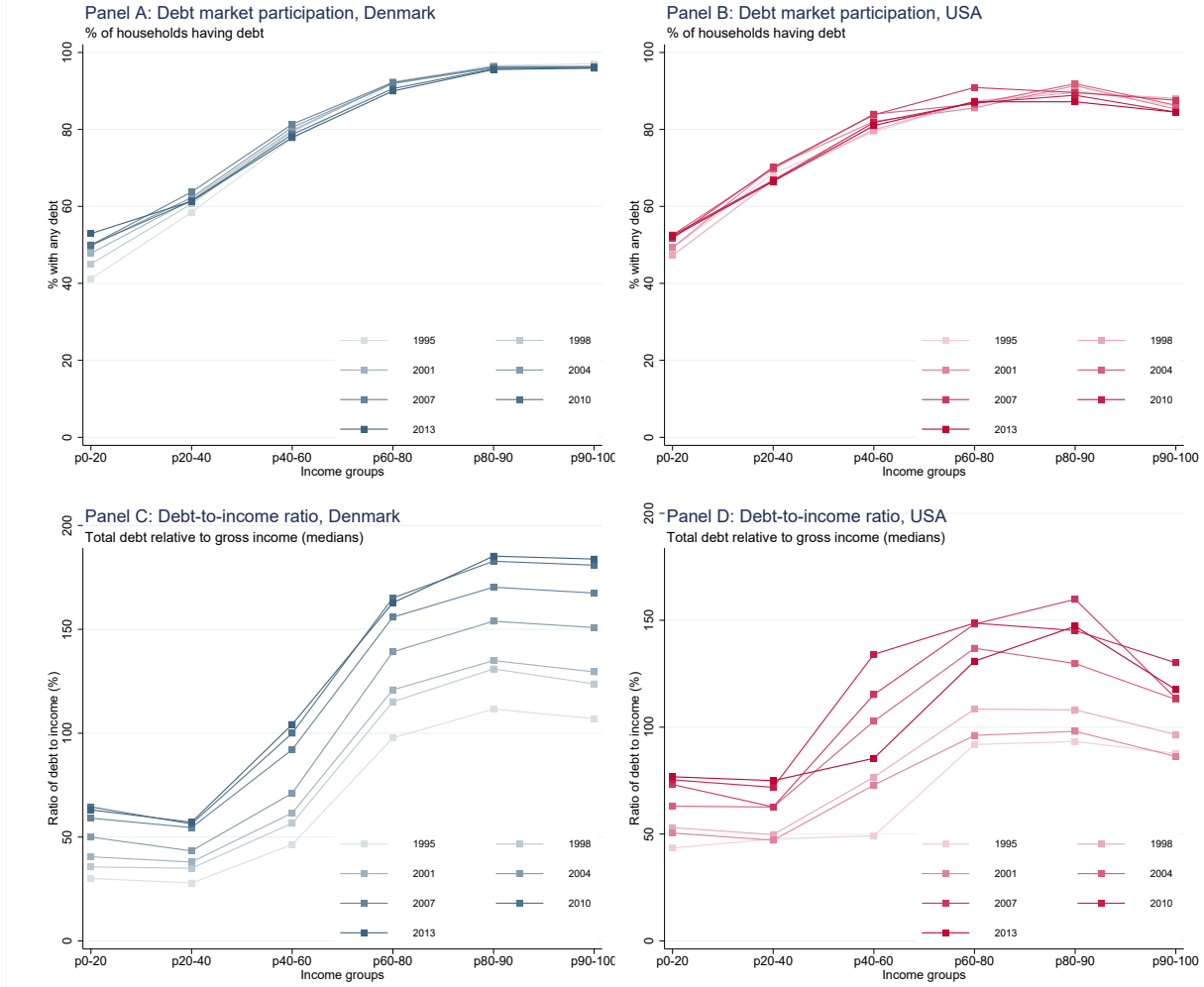


Figure A3: Exchange rates. Notes: The figure shows the following daily exchange rates: Danish Kroner per German Mark (1/1-1960-31/12-1998); Danish Kroner per Euro (1/1-1999-31/12-2018) and Danish Kroner per US Dollar (1/1-1960-31/12-2018). The dashed lines indicate major events affecting exchange rates.

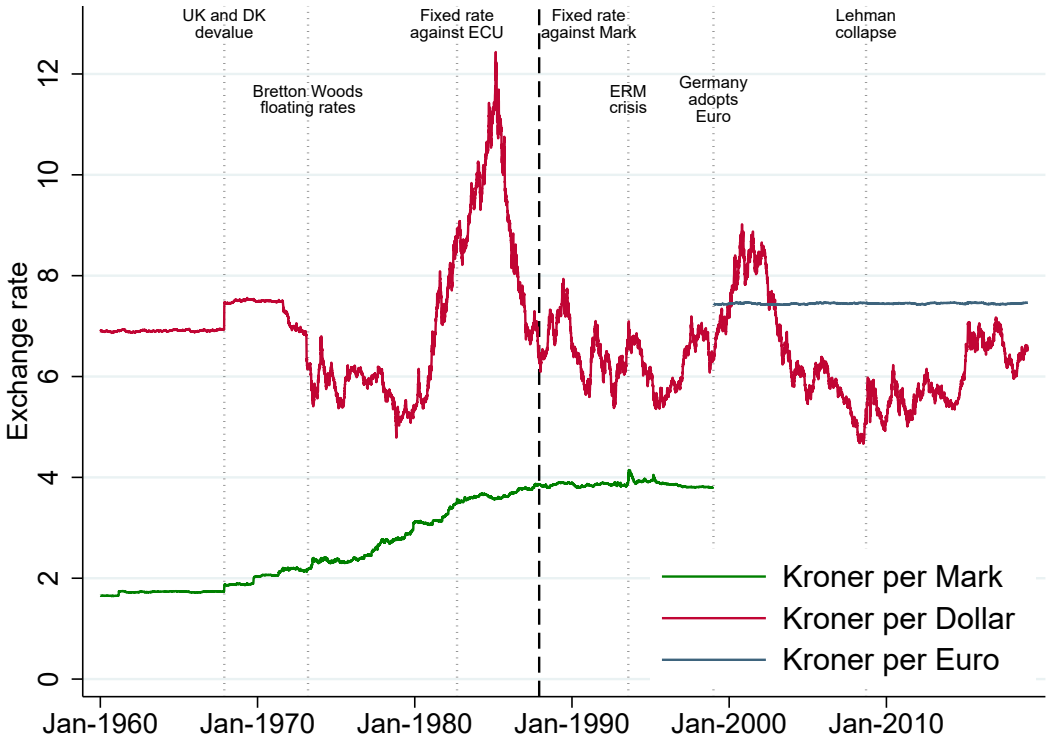


Figure A4: Cross-country correlations in macro outcomes The figure shows the correlation in GDP growth rates (Panel A) and inflation rates (Panel B) between Denmark and Germany/Euro Area (red dots) and between Denmark and the United States (blue dots).

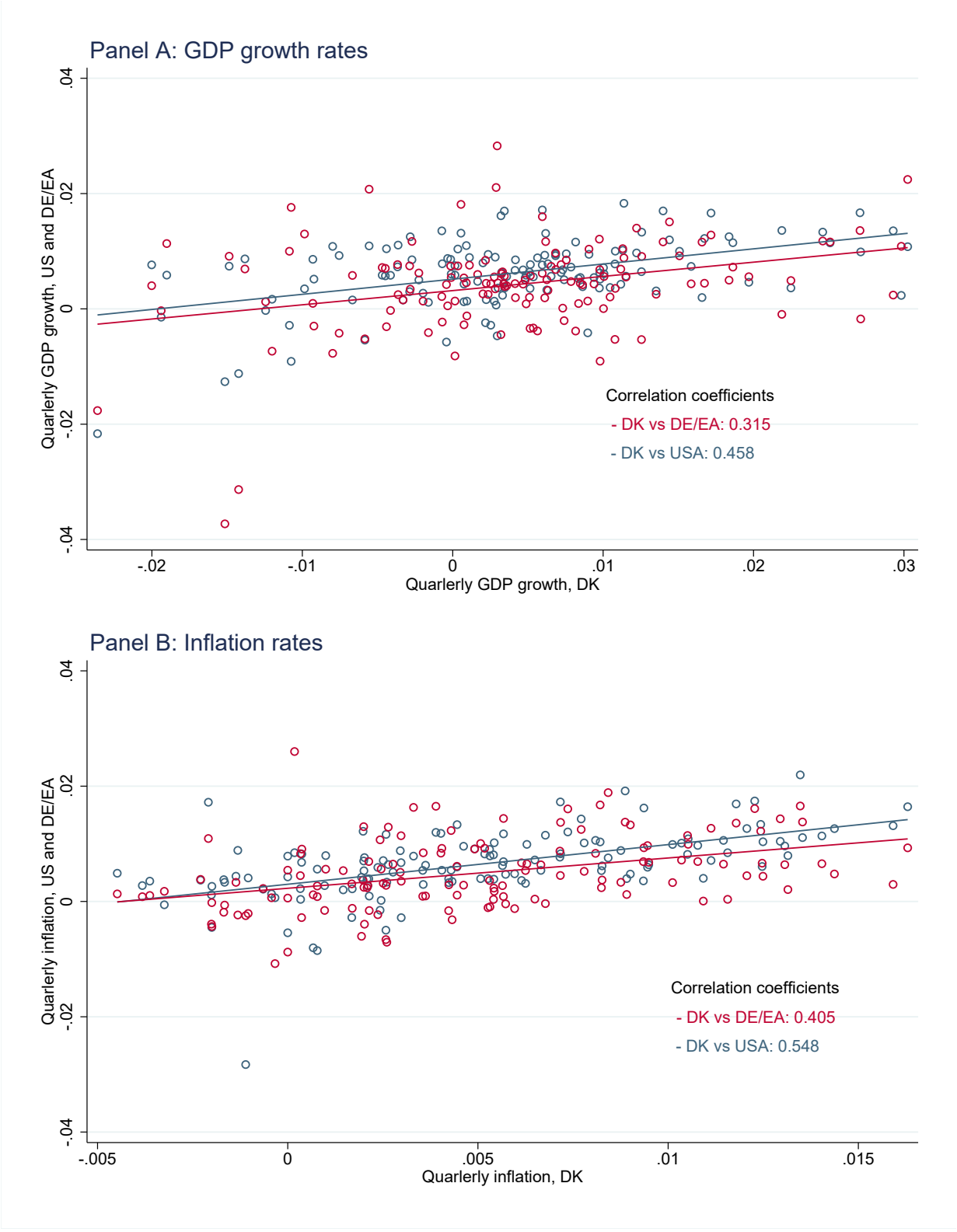


Figure A5: Monetary policy shocks. The figure shows the annual change in the policy rate in Germany / Euro Area (red line); the annual change in the policy rate in Denmark (black line); and the residual variation in the policy rate in Germany / Euro Area after regressing on the macro-controls in the baseline model, i.e. contemporaneous and lagged values of GDP growth and inflation and forecasts for GDP growth and inflation (blue bars).

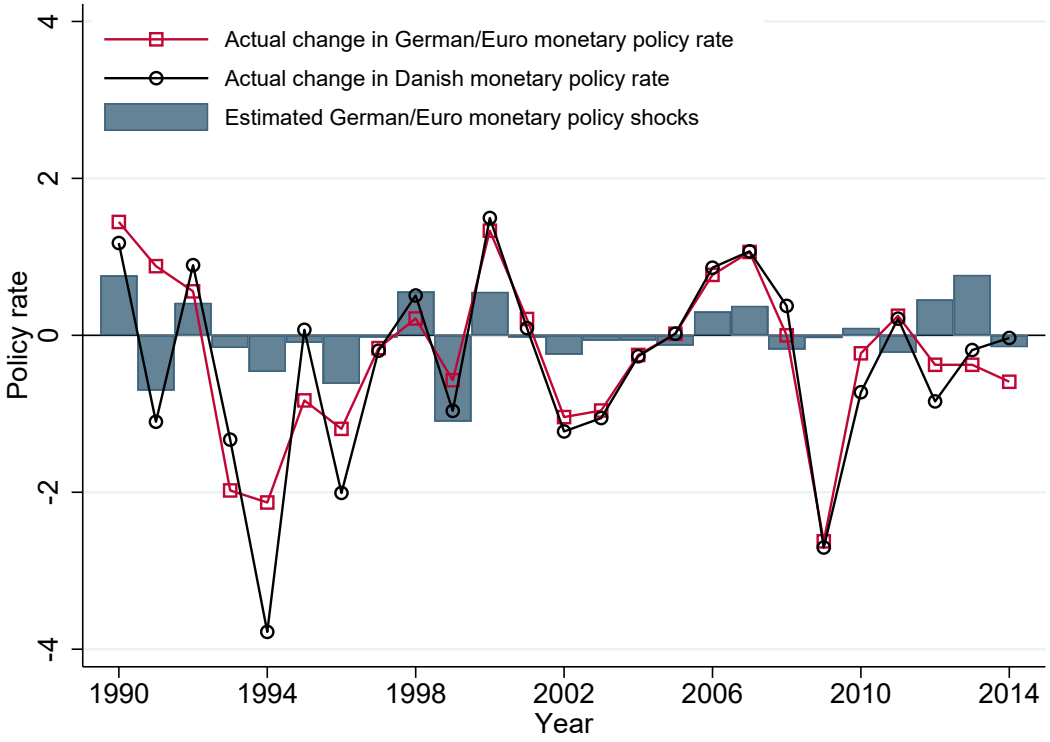


Figure A6: Heterogeneous effects on employment. The figure shows the estimated effect of a one percentage point decrease in the monetary policy rate on employment (in weeks) at different positions in the income distribution over a two-year horizons.

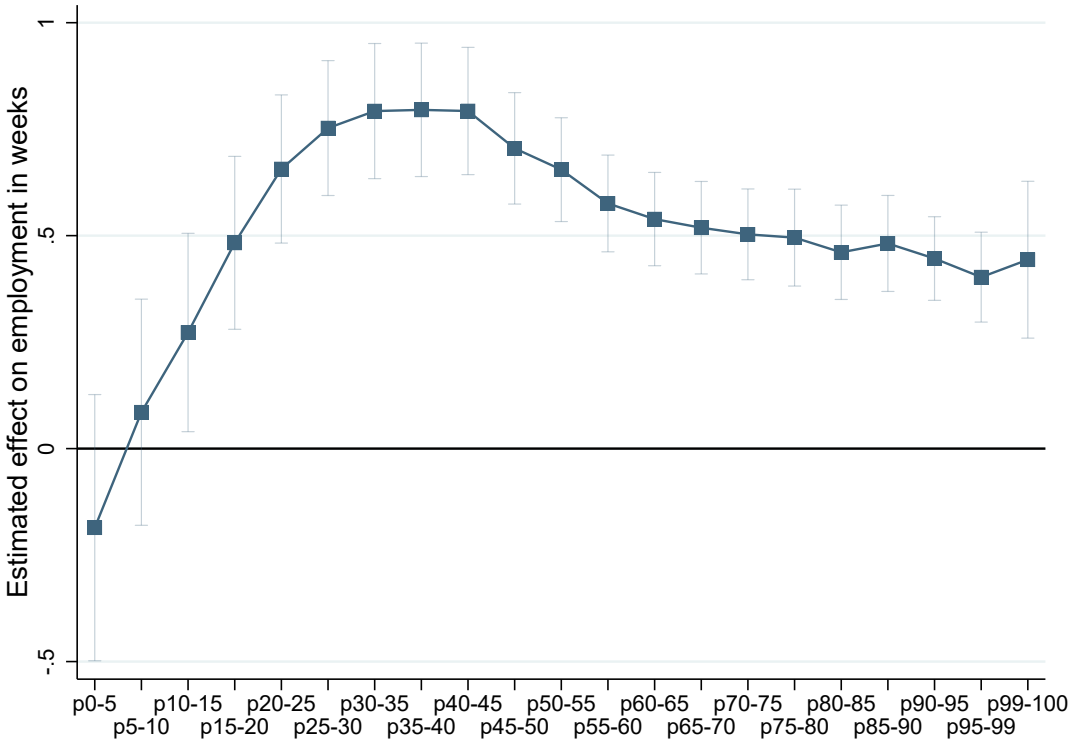


Figure A7: Market disposable income. The figure shows the estimated two-year effects of a one percentage point decrease in the monetary policy rate on disposable income (full black line) and market disposable income, i.e. measured before government transfers and taxes, (dashed red line).

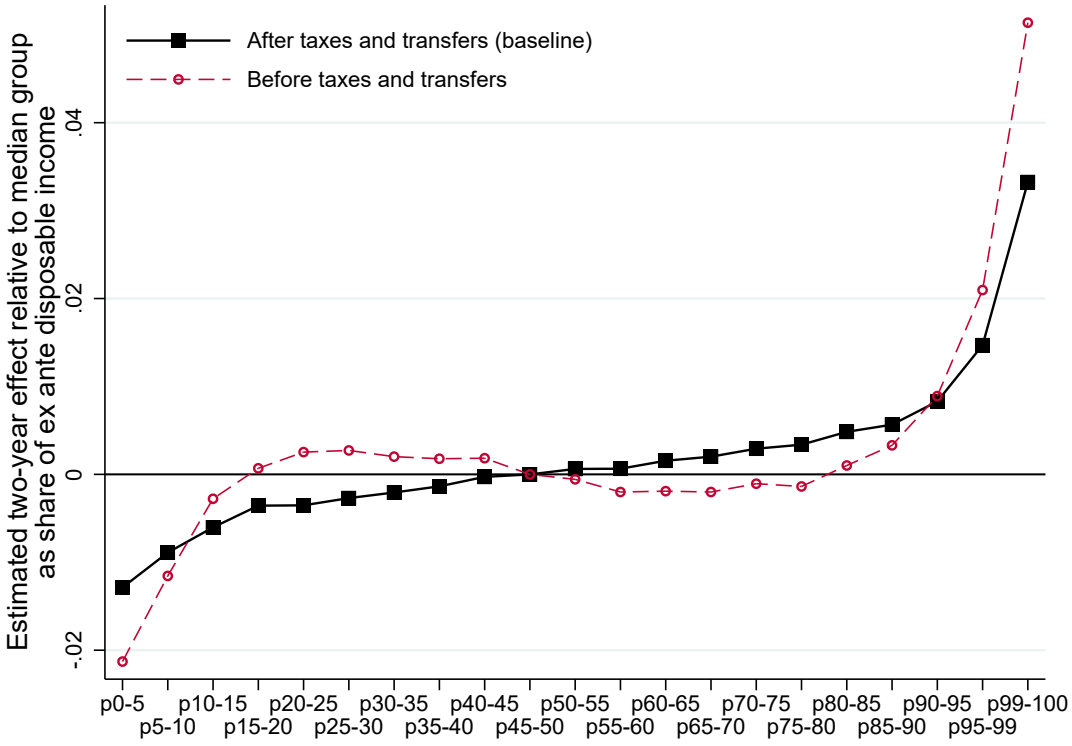


Figure A8: Adding up effects on disposable income. The figure compares, at each position in the income distribution, the estimated two-year effect of a one percentage point decrease in the policy rate on disposable income (full black line) to the sum of the estimated effects on the components of disposable income (dashed red line).

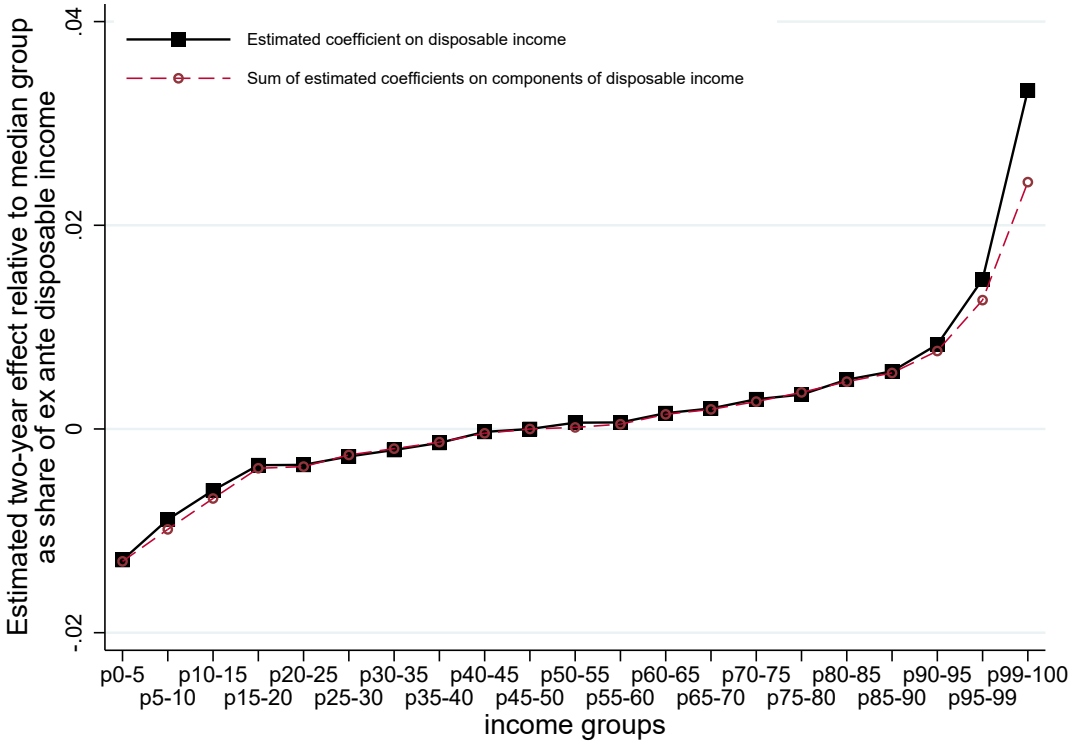


Figure A9: The role of income and balance sheet composition. The figure shows, for each component of disposable income (Panels B-H) and for disposable income itself (Panel A), the estimated two-year effect of a one percentage point decrease in the monetary policy rate (full lines) and the part of the effect that is explained by differences in the composition of income and balance sheets (red dotted lines).

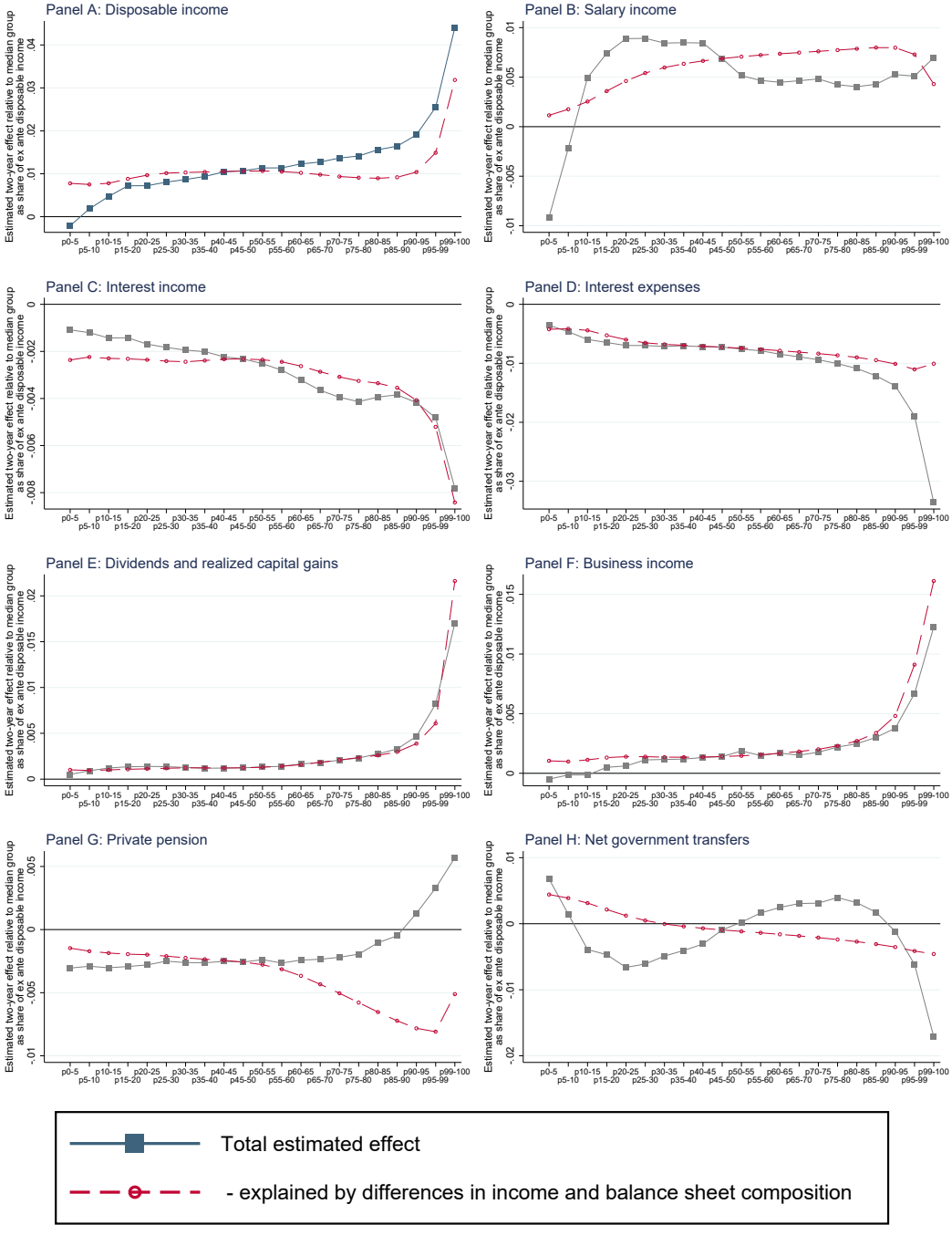


Figure A10: Robustness of heterogenous effects on housing values. The figure compares the estimated "price effect" of a one percentage point decrease in the policy rate on housing wealth (full black line) to the effect on the raw change in the appraisal values of housing (dashed red line).

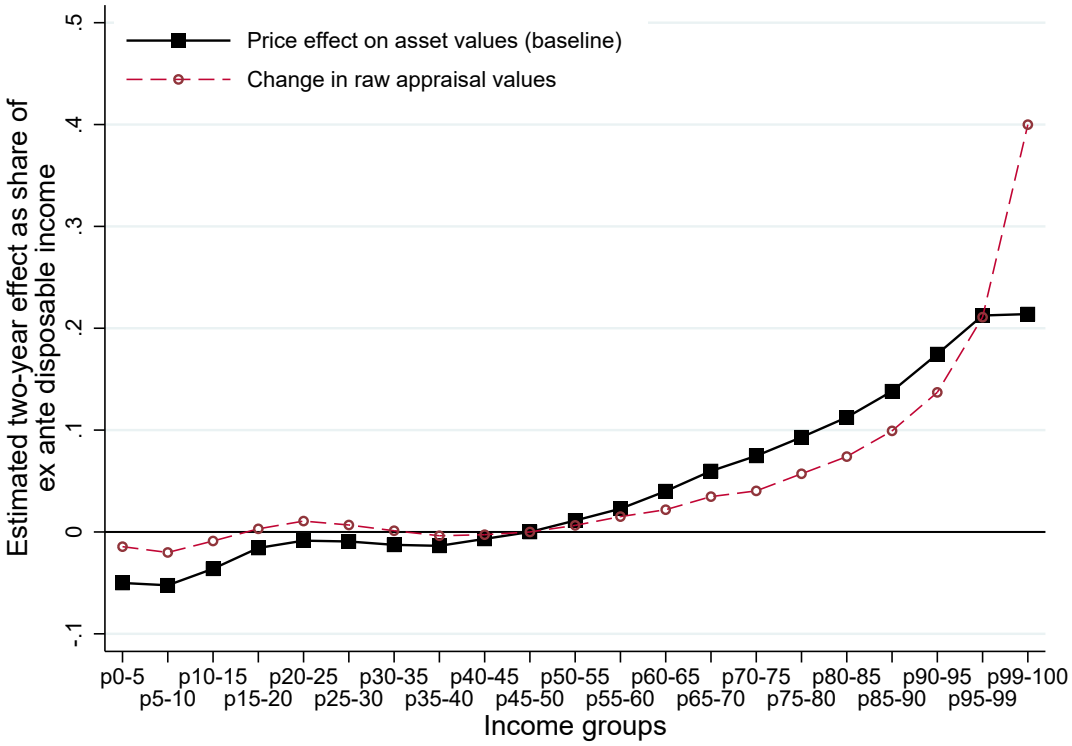


Figure A11: Adding up effects on asset values. The figure compares, at each position in the income distribution, the estimated two-year price effect of a one percentage point decrease in the policy rate on combined asset values (full black line) to the sum of the estimated effects on the individual asset values (dashed red line)

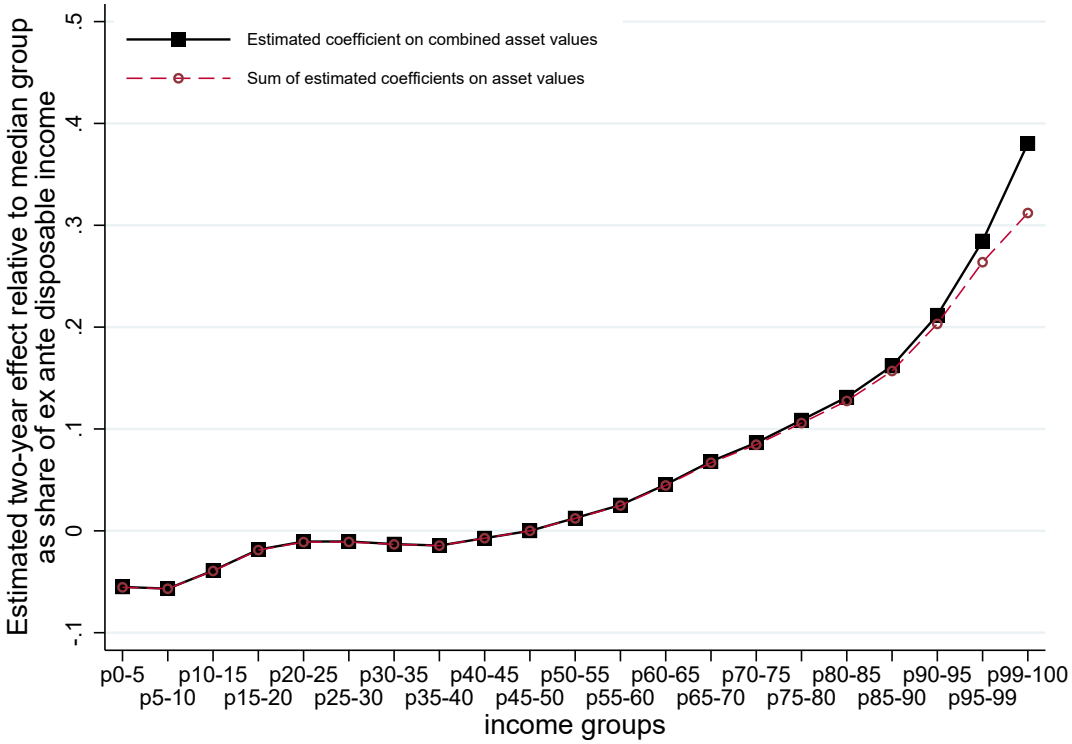


Figure A12: Pension wealth. The figure shows the ratio of assets to disposable income in 2014 at each position in the income distribution while distinguishing between assets outside of tax-favored pension schemes (full black line) and asses within tax-favored pension schemes (dashed red line).

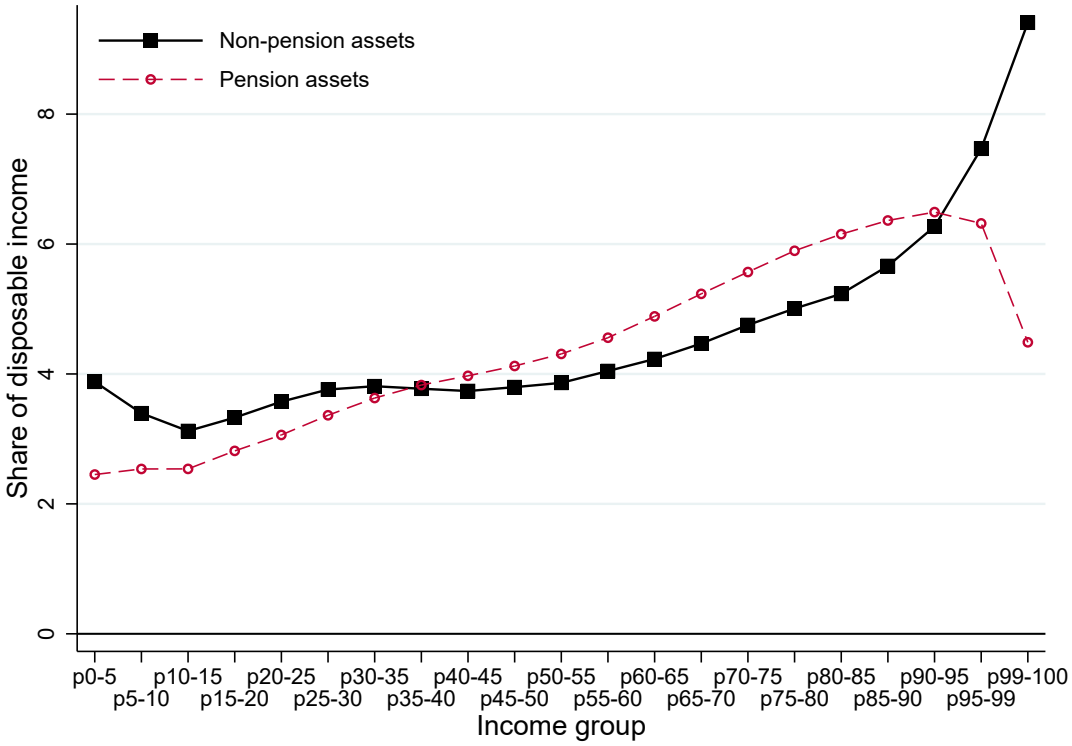


Figure A13: Sensitivity to additional macro controls and measurement. The figure shows the estimated differential effect of a one percentage point decrease in the monetary policy rate on disposable income (Panel A) and asset values (Panel B) at different positions in the income distribution over a two-year horizon obtained from models with additional macro controls and with alternative measurement and sample period. Starting from the baseline results (black line), the figure compares to the results from a model that further controls for ex ante GDP growth and inflation in Denmark (red line); controls for the ex ante change in the VIX index (blue line); accounts for serial correlation in monetary policy rates by controlling for the leaded monetary policy shock (green line); captures the German/Euro monetary policy stance with the shadow rate rather than the policy rate (brown line). All the additional controls are interacted with a full vector of income group indicators. The estimates are relative to the median group (p45-50).

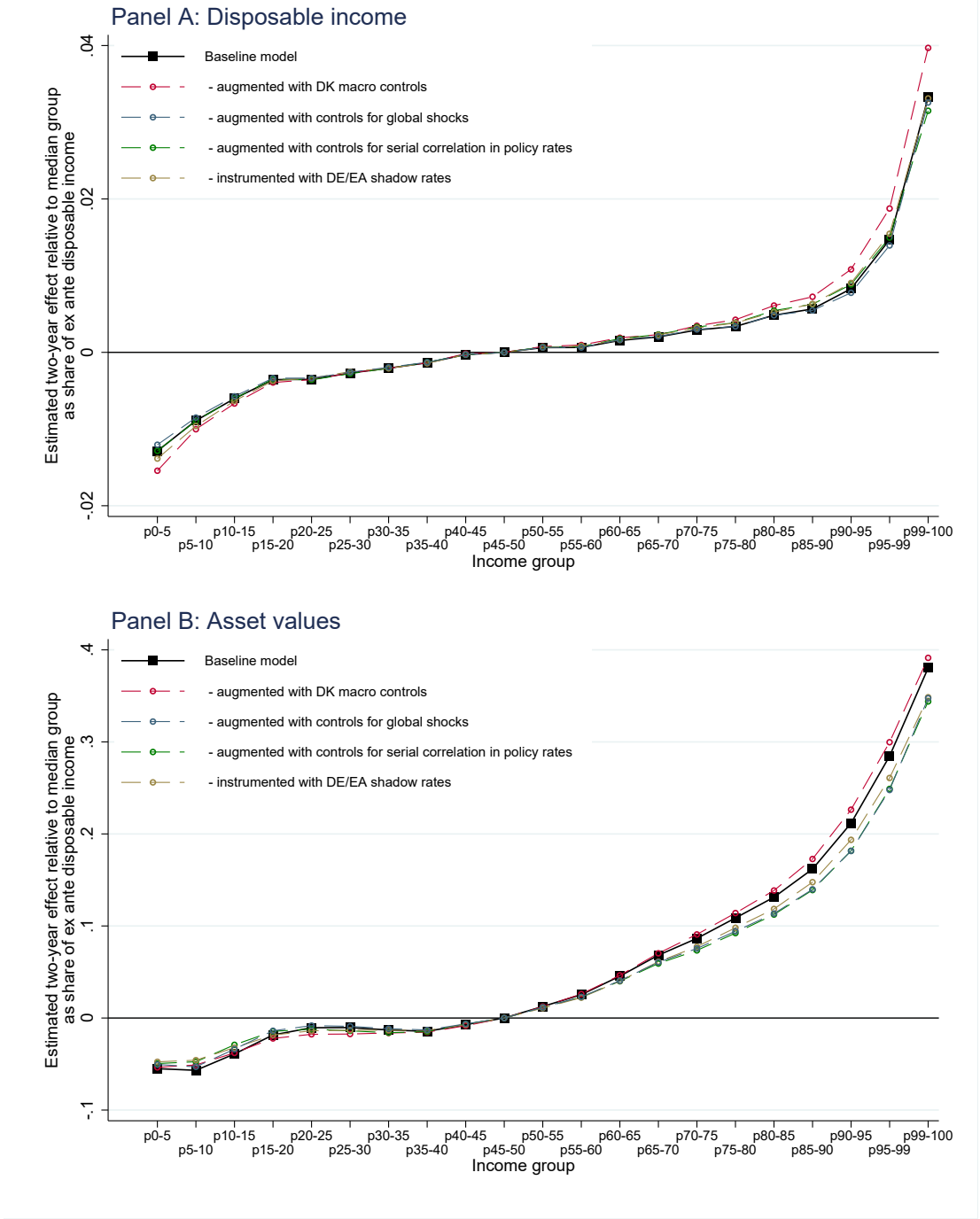


Figure A14: Sensitivity to EX POST macro controls. The figure shows the estimated differential effect of a one percentage point decrease in the monetary policy rate on disposable income (Panel A) and asset values (Panel B) at different positions in the income distribution over a two-year horizon obtained from models with ex post macro controls (i.e. evaluated after the monetary policy shock). Starting from the baseline results (black line), the figure compares to models that all include controls for ex ante GDP growth and inflation in Denmark and sequentially add the following variables: ex post exports from Denmark (red line); ex post imports to Denmark (green line); ex post Danish foreign liabilities (brown line); ex post Danish foreign assets (blue line); ex post realizations of the stock market index in Germany / Euro Area (orange line); and ex post realizations of GDP growth and inflation in Germany / Euro Area (gray line). All the additional controls are interacted with a full vector of income group indicators. The estimates are relative to the median group (p45-50).

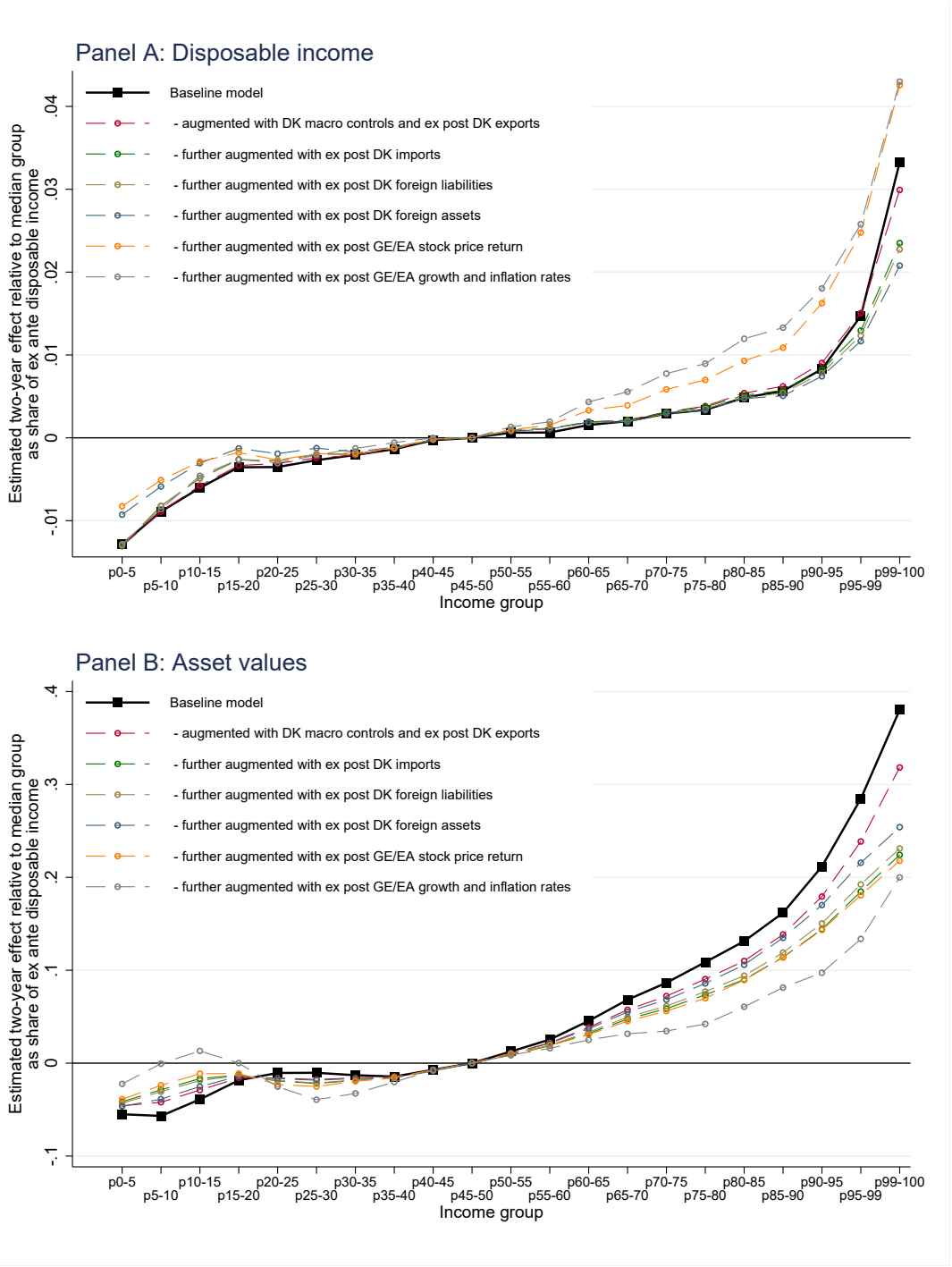


Figure A15: Sensitivity to identification of monetary policy shocks. The figure shows the estimated differential effect of a one percentage point decrease in the monetary policy rate on disposable income (Panel A) and asset values (Panel B) at different positions in the income distribution over a two-year horizon obtained from models using different series of monetary policy shocks. Starting from the baseline results (full black line), the figure compares to models that identify monetary policy shocks in the spirit of Romer-Romer (dashed blue line) and Jarocinski-Karadi (dashed red line). More details about the exact estimation strategy are available in the Appendix.

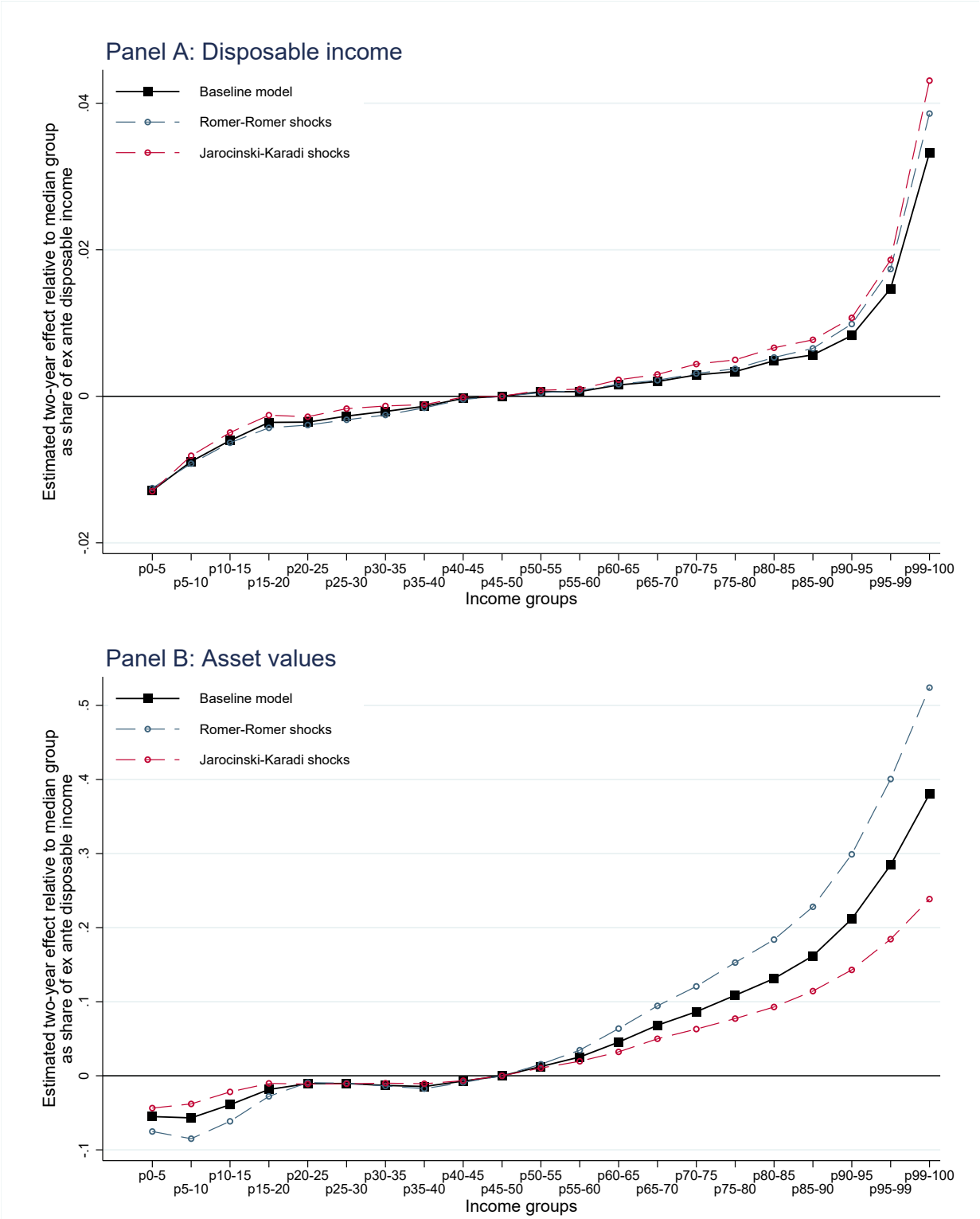


Figure A16: Sensitivity to household fixed effects. The figure shows the estimated differential effect of a one percentage point decrease in the monetary policy rate on disposable income (Panel A) and asset values (Panel B) at different positions in the income distribution over a two-year horizon obtained from the baseline model (full black line) and a model augmented with household fixed effects (dashed red line). All The estimates are relative to the median group (p45-50).

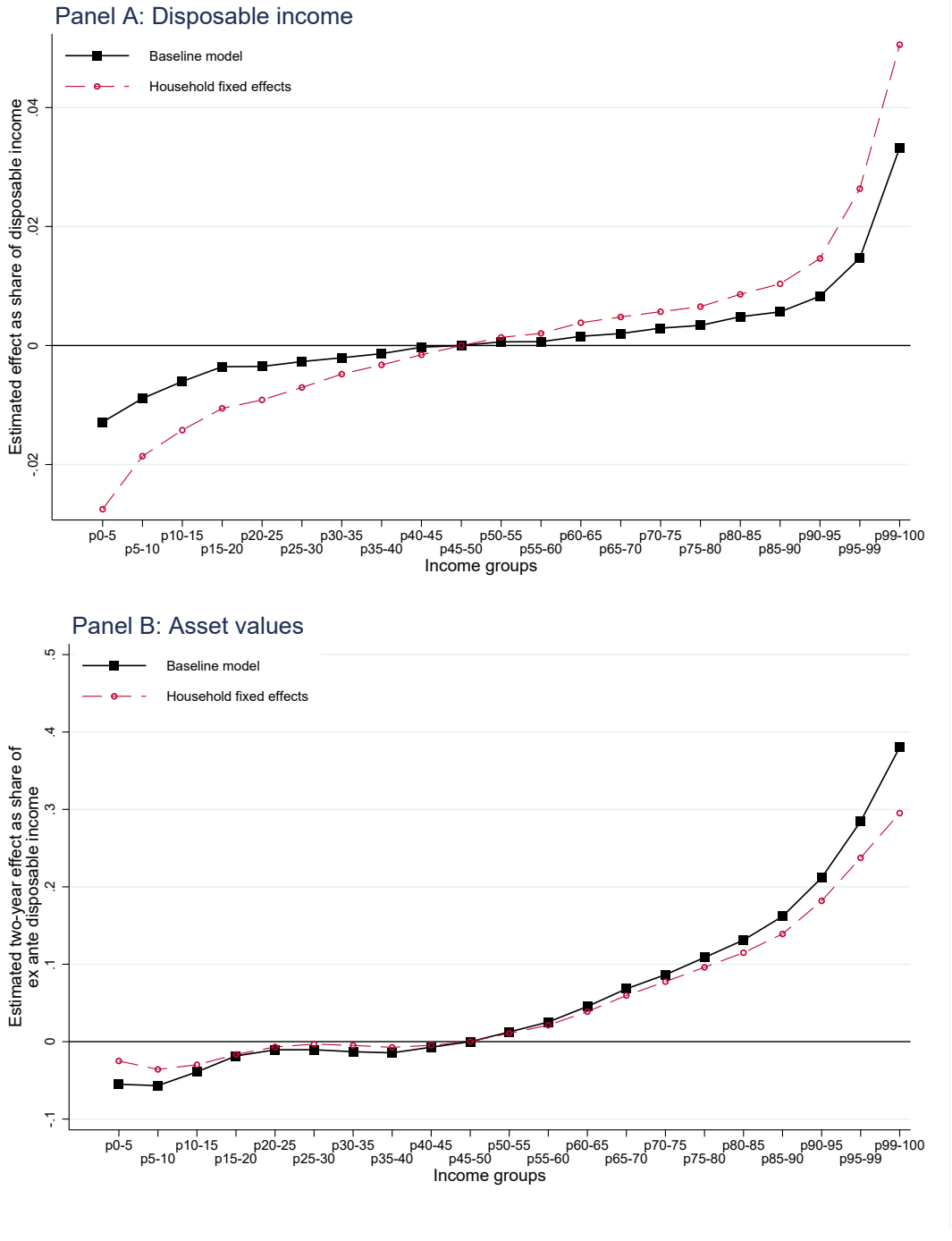


Figure A17: Sensitivity to clustering. The figure shows the 95% confidence levels around the two-year differential effects of a one percentage point decrease in the monetary policy rate on disposable income (Panel A) and asset values (Panel B) under different assumptions: one-dimensional clustering at 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); Driscoll-Kraay standard errors (orange line).

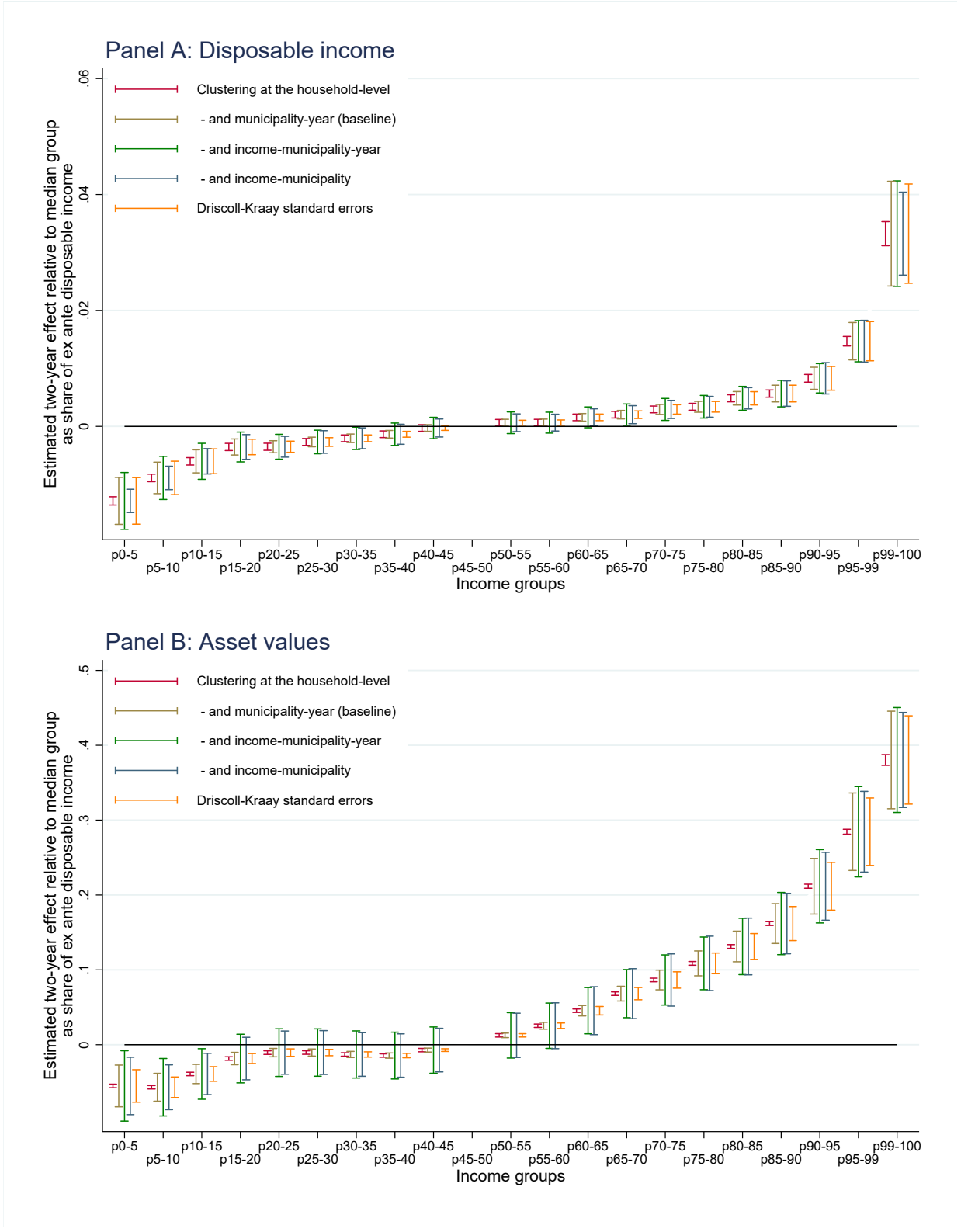


Figure A18: Sensitivity to re-weighting of observations. The figure shows the estimated differential effect of a one percentage point decrease in the monetary policy rate on disposable income (Panel A) and asset values (Panel B) at different positions in the income distribution over a two-year horizon obtained from models using different weighting schemes. Starting from the baseline results (full black line), the figure compares to models that re-weight observations so as to achieve, within each broad income group, the same fraction of households with any debt and the same median debt-income ratio for households with debt as in the United States (dashed red line) and the Euro Area (dashed blue line). The estimates are relative to the median group (p45-50).

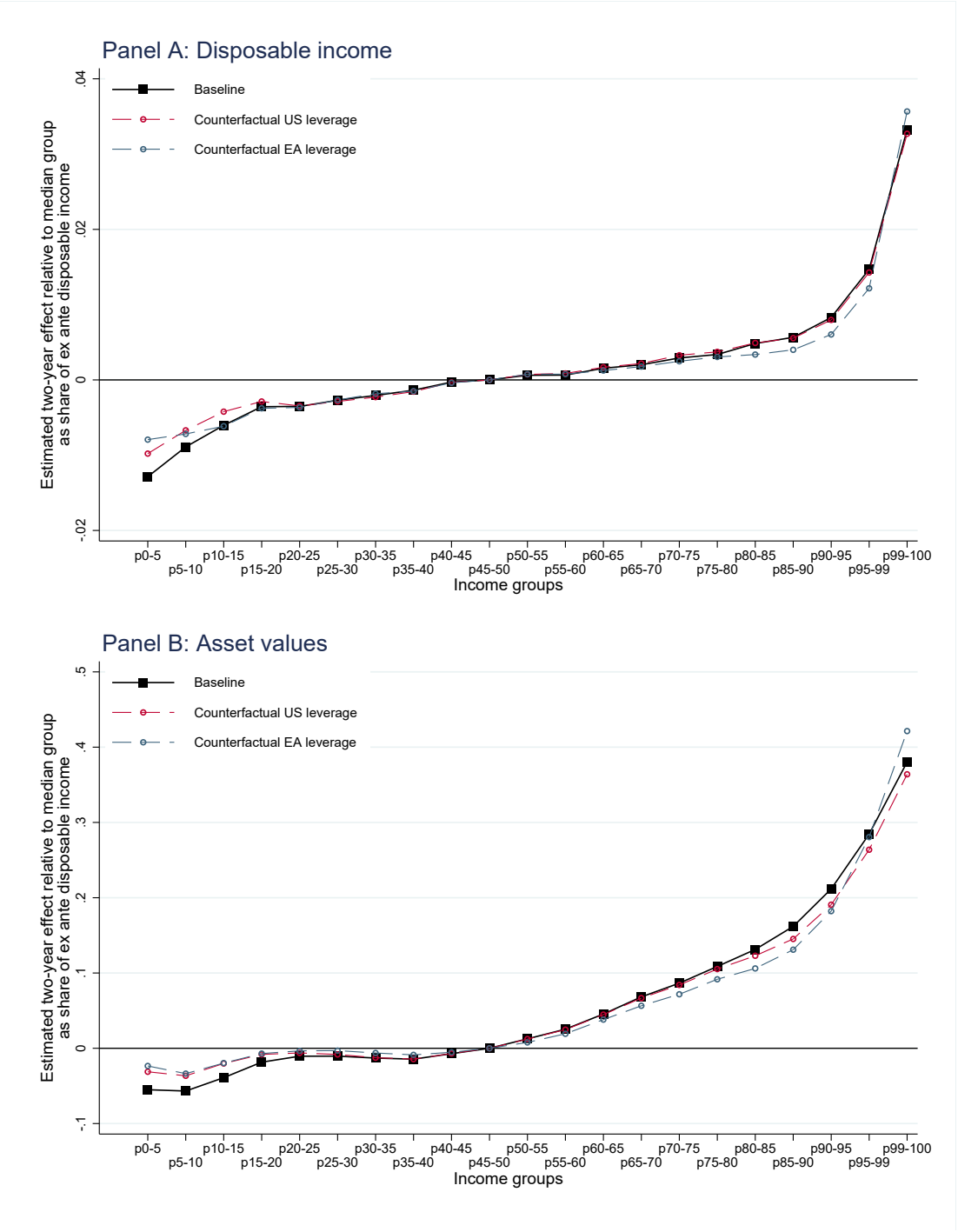


Figure A19: Weighting scheme. The figure shows the weights on Danish observations, by income group and year, necessary to match the fraction with zero debt and the median ratio of debt to income for those with positive debt observed for U.S. households. The weights vary across households with no debt (Panel A), households with positive debt and a ratio of debt to income below the U.S. median in the relevant year and income group (Panel B), households with positive debt and a ratio of debt to income above the U.S. median in the relevant year and income group (Panel C).

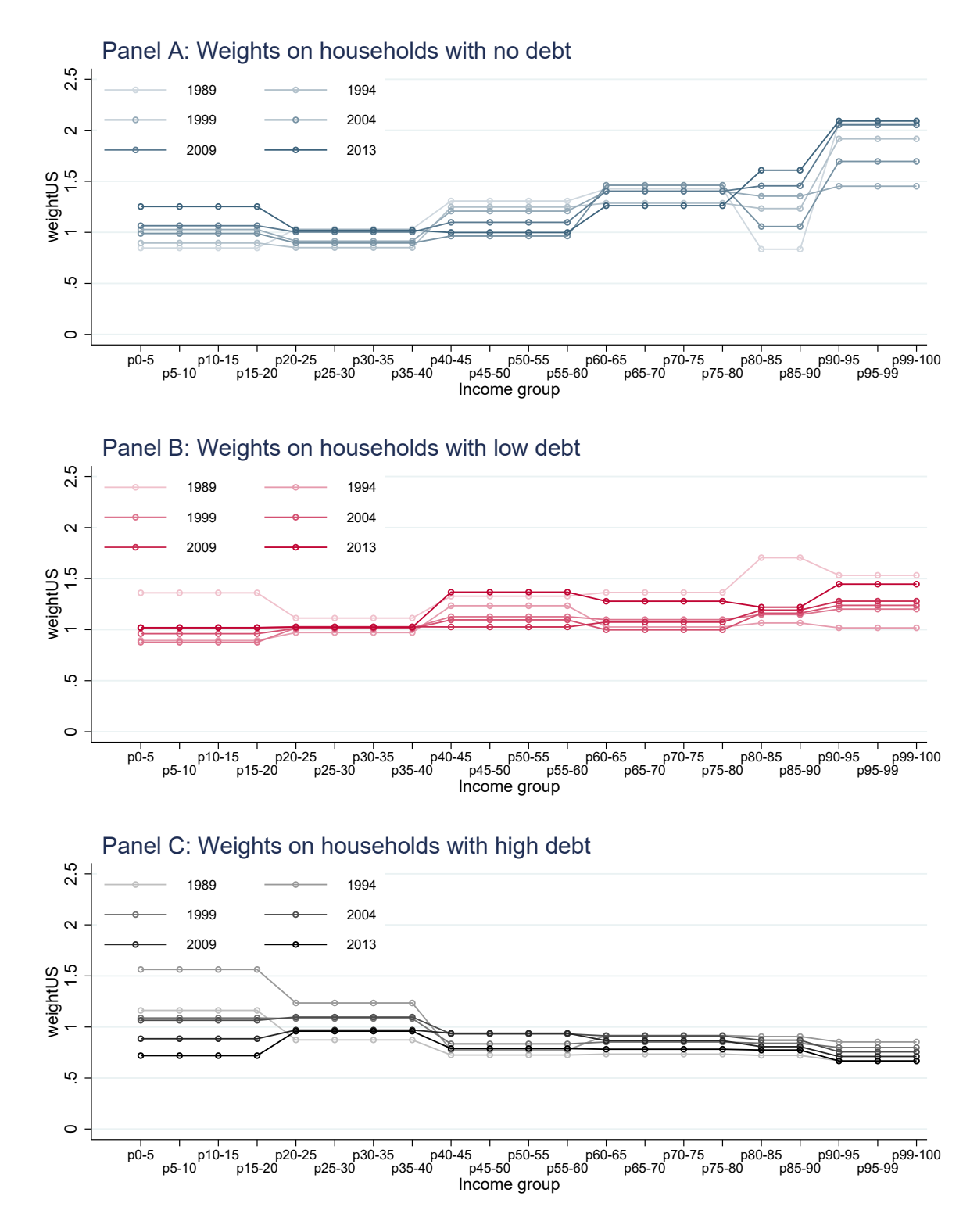


Table AI: Owners of Danish mortgage bonds. The table allocates outstanding Danish mortgage bonds to the sector of the owners over the period 1999-2014.

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 AII: Descriptive statistics by age 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 age groups. Note that the category *deposits* also includes bonds. All income and wealth elements are expressed as a fraction of disposable income. To construct Panels A and B, we aggregate each income and wealth element within each age group over the entire sample period and divide with disposable income aggregated in the same way. In Panel B, *disposable income* sums salary income, business income, stock market income, interest income, private pension income, other income and net government transfers and subtracts interest expenses. In Panel C, *net wealth* sums deposits, stocks and housing and subtracts debt.

	25-35 years	35-45 years	45-55 years	55-65 years	65-75 years	>75 years
Panel A: Composition of disposable income (each component in % of overall disposable income)						
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%
private pension	0%	0%	1%	6%	36%	34%
other income	1%	1%	2%	2%	3%	3%
net government transfers	-32%	-41%	-46%	-28%	23%	49%
interest expenses	18%	20%	19%	14%	9%	4%
disposable income	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Panel B: Composition of balance sheets (each component in % of overall disposable income)						
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%**
Panel C: Descriptive indicators						
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%

Table AIII: Romer-Romer monetary policy shocks The table shows the results from regression at the frequency of meetings in the ECB monetary policy committee where the dependent variable is the change in the monetary policy rate from before the meeting to after the meeting. We present more details in Online Appendix D

	Change in policy rate
Policy rate before meeting	-0.0548***
	(0.0114)
GDP growth, one-year-ahead forecast	0.123***
	(0.0287)
Inflation, one-year-ahead forecast	0.224***
	(0.0531)
GDP growth, forecast innovation	0.102
	(0.0568)
Inflation, forecast innovation	-0.0218
	(0.0779)
GDP growth, nowcast	-0.0221
	(0.0141)
Inflation, nowcast	-0.0312
	(0.0260)
GDP growth, nowcast innovation	0.0622
	(0.0465)
Inflation, nowcast innovation	-0.0205
	(0.0961)
Constant	-0.391***
	(0.0782)
Observations	225

Internet Appendix B: 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 Abildgren (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.

Internet Appendix C: Monetary policy in Denmark

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.

Figure A3 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.[31] In the past two decades (1999-2020), Kroner has been pegged to Euro and the exchange rate between the two currencies has been

[31] 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.

almost completely fixed. The highly volatile exchange rate of Kroner against US Dollar over the past 50 years serves as a useful comparison.

Figure A1 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 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.

Internet Appendix D: Alternative monetary policy shocks series

We estimate a series of monetary policy shocks for the Euro area in the spirit of Romer and Romer (2004). The series is estimated at the frequency of the ECB's Governing Council monetary policy meetings, which take place once a month in most years. Meeting dates are available on ECB's website. For each meeting, we record the change in the policy rate from the day before the meeting to the day after. To proxy for the information set available to policymakers at the time of the meeting, we use data from the most recent Macroeconomic Projections publication produced by either ECB or Eurosystem staff. If the most recent staff projections are more than 30 days old at the time of the meeting, we instead rely on the ECB Survey of Professional Forecasters (if more recent).

From these sources, we construct meeting-frequency series on nowcasts and one-year forecasts of annual inflation and real GDP growth in the Euro area. We then regress the change in the policy rate on the forecast and nowcast variables and their innovations, defined as the change in projections for a given calendar year since the previous meeting. The level of the policy rate before the meeting is also included as an explanatory variable. Table AIII shows output from this regression. The one-year forecasts of GDP growth and inflation correlate positively and significantly with policy rate changes, while the coefficients on the nowcast and innovation variables are numerically small and statistically insignificant.

The residuals from the regression constitute a series of estimated monetary policy shocks, measured at the monetary policy meeting frequency. We convert this to an annual series by summing residuals within each calendar year. Unfortunately, this series only covers the period since the establishment of the ECB in 1999. To the best of our knowledge, the data required for constructing a similar series for the early part of our analysis period, during which the Danish krone was pegged to the German Mark, are not available. We therefore combine our series of Romer-Romer shocks with a series of "baseline" shocks covering the early years. These are constructed as the residuals from a regression of the annual change in German/Euro Area policy rate on the same macroeconomic controls as in our baseline specification (lagged, current and forecast values of GDP growth and inflation), using annual data for our full analysis period. We then use the combined series to instrument for the change in the Danish policy rate in equation (2). If we restrict the analysis to the subperiod where the Romer-Romer shocks are available, this alternative series of shocks still produces results that are similar to the baseline model.

We also use Jaricinski-Karadi monetary policy shocks for the Euro Area. These are identified from high-frequency movements in interest rates and stock prices around the time of monetary policy announcements, as explained in Jarocinski and Karadi (2020). We collapse the original series to annual frequency by summing within each calendar year. As in the Romer-Romer case, the resulting series only goes back to 1999, so we combine it with our series of "baseline" shocks for the early part of our analysis period. We then use this combined series to instrument for the Danish policy rate change in equation (2). Again, if we restrict the analysis to the subperiod where the Jaricinski-Karadi shocks are available, this alternative series of shocks still produces results that are similar to the baseline model.

Online Appendix E: Reweighting observations to investigate external validity

To investigate the external validity of our main results, we re-estimate the baseline model while re-weighting the observations so that, within each income group and each year, the fraction of Danish households with any debt and the median debt-to-income ratio of Danish households with positive debt match households in the United States and the Euro Area.

We obtain statistics on household debt in the United States from the Survey of Consumer Finance. Table 13 indicates the fraction of households with any debt as well as the median value of debt for households with any debt in six income groups (p0-20, p20-40, p40-60, p60-80, p80-90, p90-100) while Table 1 indicates median pre-tax income in the same income groups. We compute the median debt-to-income ratio as the ratio of median debt to median income in each income group and year. The data is available for every third year since 1989 (i.e. 1989, 1992, 1995 and so on). For years where no data is available we use the value for the closest year (we use the 1989 value for 1990, the 1992 value for 1991 and so on).

We obtain statistics on household debt in the Euro Area from the Household Finance and Consumption Survey, 2014, Tables B3, C5, E5, E6 and I1. Table E5 indicates the fraction of households with any debt in six income groups (p0-20, p20-40, p40-60, p60-80, p80-90, p90-100); Table E6 indicates the median value of debt for households with any debt in the same income groups; and Table I1 indicates median pre-tax income in the same income groups. We compute the median debt-to-income ratio as the ratio of median debt to median income in each income group. Historical data is not available so we construct values back in time by assuming that all debt metrics have followed the same historical trend as we observe in the Danish micro-data within each income group. For instance, to construct the share of EA households in the lowest income group with any debt in 2010, we assume that this fraction grew at the same rate between 2010 (unobserved) and 2014 (observed) as in the Danish micro data (both values observed).

We construct weights that make the sample of Danish households match households in the United States within each year and each income group, in terms of household debt. Let $A^i_{t,g}$ denote the fraction with any debt and $m^{US}_{t,g}$ denote the median debt-to-income ratio for those with positive debt where g indicates the income group; t the year; and i either Denmark (DK) or United States (US). For Danish households in income group g with no debt, we apply the weight $w_{t,g} = A^{US}_{t,g}/A^{DK}_{t,g}$. Further, we let $B^{US}_{t,g}$ and $B^{DK}_{t,g}$ denote the fraction of U.S. and Danish households respectively with positive debt and a debt-income ratio below the U.S. median $m^{US}_{t,g}$. For Danish households in income group g with positive debt and a debt-income ratio below the U.S. median, we apply the weight $w_{t,g} = B^{US}_{t,g}/B^{DK}_{t,g}$. Finally, we let $C^{US}_{t,g}$ and $C^{DK}_{t,g}$ denote the fraction of U.S. and Danish households respectively with positive debt and a debt-income ratio above the U.S. median $m^{US}_{t,g}$. For Danish households in income group g with positive debt and a debt-income ratio above the U.S. median, we apply the weight $w_{t,g} = C^{US}_{t,g}/C^{DK}_{t,g}$. Intuitively, the weights ensure that the sample of Danish households, within each income group and year, has the same share with no debt, the same share with positive debt below the U.S. median and the same share with positive debt above the U.S. median as U.S. households. For instance, if there are 25% more Danish households with no debt than in the United States in a given

income group at a given time, we apply the weight 0.8 to these observations in our weighted regressions. We follow the exact same procedure to produce another set of weights that makes Danish households match households in the Euro Area.

Figure A19 in the Online Appendix illustrate the weights that match our sample to households in the United States on debt. In the early years, there are more low-income households with no debt in Denmark than in the United States (weight¡1), but this pattern reverses over time (weight¿1). At higher income levels, there are less households with no debt in Denmark than in the United States throughout the sample period - the difference is particularly pronounced at the top of the income distribution in the most recent years (weight ≈ 2). By contrast, there are generally more Danish households with high ratios of debt to income, notably at high income levels and in more recent years.