Monetary Policy and Economic Inequality in the United States

By John Silvia, PhD, Chief Economist, Wells Fargo and Fellow, GIC Global Society of Fellows,
Olivier Coibion, Assistant Professor, College of William and Mary and Visiting Scholar, GIC Global Society of Fellows,
and Yuriy Gorodnichenko, PhD, Assistant Professor, University of California, Berkeley and Visiting Scholar, GIC Global Society of Fellows

Paper to be presented at the Inaugural Meeting of the Global Interdependence Center's Society of Fellows on March 26, 2012 at the Banque de France, Paris

March 26, 2012

Abstract

We study the effects and historical contribution of monetary policy shocks to consumption and income inequality in the United States. Contractionary monetary policy actions systematically increase inequality in labor earnings, total income, consumption and total expenditures. Furthermore, monetary shocks can account for a significant component of the historical cyclical variation in income and consumption inequality. Using detailed micro-level data on income and consumption, we document the different channels via which monetary policy shocks affect inequality, as well as how these channels depend on the nature of the change in monetary policy.

I Introduction

Recent popular demonstrations such as the Occupy Wall Street (OWS) movement have made it clear that the high levels of inequality in the United States remain a pressing concern for a large swath of the population. While such movements have primarily focused their ire on private financial institutions and their perceived contribution to inequality and the Great Recession, the Federal Reserve (Fed) has not remained immune to their criticism. Indeed, "End the Fed" and "Where's my bailout?" posters have been well-represented throughout these protests, giving the clear sense that the Federal Reserve has been a contributor to the rising income inequality in the United States.

This view is at odds, however, with the common wisdom among economists as to the source of this rising inequality. Skill-biased technological change (e.g. Bound and Johnson 1992), increased global trade (e.g. Feenstra and Hanson 2008) and changes in labor market institutions such as unionization (e.g. Card 2001) have long been the mechanisms which have received the most attention in the literature, while monetary policy is rarely mentioned as a likely candidate. However, the view that monetary policy has played a role in accounting for rising inequality is shared by more than just Ron Paul followers. James K. Galbraith (1998), for example, has argued

> "Rising wage inequality is neither inevitable nor mysterious nor necessary nor the dark side of a good thing, but was brought on, mainly, by bad economic performance… What caused bad economic performance? Economic policy, and very specifically monetary policy, changed. Beginning in 1970, the government abandoned the goal of full employment and instead turned its attention to a fight against inflation. For this purpose, only one instrument was deemed suitable: high interest rates brought into being by the Federal Reserve. There followed a repeated sequence of recessions… The high unemployment that these recessions produced generated the rise in inequality. For this, the Federal Reserve,

> under its reputable chairmen Arthur Burns, Paul Volcker and Alan Greenspan, stands primarily (though not solely) responsible."

Interestingly, while Galbraith suggests that disinflation will ultimately raise income inequality via the unequal income effects of the associated economic downturn, Austrian economists as well as Ron Paul suggest the opposite effect: income inequality will rise when the Fed engineers higher inflation. Their view is that the inflation will lower real wages, because wages are less flexible than prices, and therefore raise real profits. Because "the rich own a far higher proportion of stocks than they receive of labor income," inflationary monetary policy will ultimately increase income inequality.[1] Post-Keynesians like Galbraith and Austrian economists emphasized by Ron Paul therefore focus on different channels via which monetary policy can affect inequality, leading to conflicting conclusions about the ultimate effect of monetary policy actions on economic inequality.

There are, in principle, a number of different channels through which monetary policy could affect both income and consumption inequality. An unexpected change in interest rates or inflation will affect savers and borrowers differently, thereby generating different consumption responses which would likely increase consumption inequality (assuming savers are wealthier than borrowers). Second, heterogeneous agents with the same net wealth might hold portfolios with different asset shares so monetary policy actions would differentially affect wealth depending on the relative importance of each kind of financial asset in households' portfolios and the response of these assets to monetary policy shocks, and therefore alter the level of consumption inequality via wealth effects. Heterogeneous consumption responses from wealth effects could then translate into heterogeneous income effects via endogenous labor supply decisions. Third, the real wage effects of changes in monetary policy may differentially impact low and high income agents, as suggested by Galbraith. Carpenter and Rogers (2004), for example, document that contractionary monetary policy shocks disproportionately reduce employment for minorities, teenagers, and less-skilled individuals. Fourth, if households have systematically different income sources across the distribution, as suggested by the Austrians, and if each kind of income responds differently to shocks, then this channel could also lead monetary policy to affect income and consumption inequality. Finally, monetary policy has been found to have different effects across regions and

[1] The quote is from Austrian economist Karlsson (2011). Ron Paul advocates a similar chain of causation (http://www.ronpaul.com/on-the-issues/fiat-money-inflation-federal-reserve-2/).

industries (Carlino and DeFina 1998), yielding yet another mechanism via which monetary policy can affect both income and consumption inequality across households.

To assess whether U.S. monetary policy has significantly contributed to historical changes in consumption and income inequality in the U.S., we study the dynamic responses of measures of consumption and income inequality to monetary policy shocks identified as in Romer and Romer (2004). Our measures of inequality come from detailed household-level data from the Consumer Expenditures Survey (CEX) since 1980. These data are available on a higher frequency (quarterly) than other sources such as IRS data employed by Piketty and Saez (2003), with a high frequency being a necessary ingredient for analyzing the effects of monetary policy shocks. However, because of the survey nature of the data, it misses changes in the very upper end of the income distribution (i.e. the top 1%). The CEX data allow us to consider wage and total before-tax income inequality separately, as well as consumption and total expenditure inequality.[2] We document that monetary policy shocks have statistically significant effects on inequality: a contractionary monetary policy shock raises the observed inequality across households in income, labor earnings, expenditures and consumption, with the effects being largest for expenditure inequality. Furthermore, monetary policy shocks can account for a surprising amount of the historical cyclical changes in income and consumption inequality, particularly since the mid-1990s.

Because of the detailed micro-level data in the CEX survey, we can assess the sources of changing inequality after monetary policy shocks. For example, using data on the response of different percentiles of the salary income distribution, we show that monetary policy shocks are followed by higher labor earnings at the upper end of the distribution but lower earnings for those at the bottom, consistent with the channel emphasized by Galbraith. Strikingly, the long-run responses of salaries and consumption for each percentile line up almost one-for-one, consistent with the predictions of the Permanent Income Hypothesis. In contrast, we show that total income inequality seems to rise by less than salary inequality while total expenditures inequality rises by more. The more muted response of total income inequality reflects the fact that households in the bottom quintile of the distribution rely much less on salaries than those in higher echelons of the distribution: the share of total income coming from salary was approximately 38% in the 1990s for

[2] Tax information is not collected in a systematic enough manner to construct suitable after-tax income measures. As a result, we focus exclusively on pre-tax income. As discussed in section 2, expenditures in our data include consumption purchases plus a number of other expenditures such as mortgage payments, auto purchases, and education expenses among others.

the lowest quintile but over 75% for the top quintile. Instead, low-income households rely to a much larger extent on financial income –which rises significantly with higher interest rates– and other income sources (such as pensions and unemployment insurance) which change little in response to monetary policy shocks. In contrast, the response of total income by households at the 50th percentile and above is in line with the response of salary income. Thus, the more muted response of total income inequality relative to wage earnings inequality primarily reflects the smaller role played by labor income for those in the lower half of the income distribution. So while the composition of income varies across the income distribution, as suggested by the Austrians, the way in which it changes differs from their characterization: high-income households receive a larger share of their income from labor earnings than those at the bottom of the distribution, at least for those households surveyed by the CEX.

In contrast to the smaller response of income inequality relative to that of salary inequality after monetary policy shocks, total expenditure inequality increases much more strongly than consumption inequality. What lies behind this feature of the data is a disproportionate increase in expenditures by those at the upper end of the expenditure distribution: expenditures at the 90th percentile rise nearly 15% while consumption at the 90th percentile rises by less than 5%. Surprisingly, the strong response of expenditures does not appear to be driven by high-income households in general: we rank households by their levels of consumption of non-durables and services (as a proxy for permanent income) but find no systematic evidence of stronger expenditure responses by those in the highest quintile. Instead, we argue that the increased expenditure inequality likely reflects a wealth transfer from borrowers to savers: we define high and low net-worth households following the characterization of Doepke and Schneider (2006) and find much larger expenditure responses by high-net worth households than others despite the total income responses being similar across households. Since high net-worth households also tend to have high incomes, the wealth effect can account for much of the disproportionate increase in expenditure inequality relative to consumption inequality after monetary policy shocks.

Finally, we consider the sensitivity of these results to the nature of the monetary policy innovation. The Romer and Romer (2004) procedure identifies monetary policy shocks as innovations to the Federal Funds rate which are uncorrelated with the Fed's information set as represented by the Greenbook forecasts generated prior to each FOMC meeting. But as emphasized by Romer and Romer (2004), these innovations can reflect a number of factors such as

changes in the preferences or objectives of the central bank and political constraints. While some of these changes can be interpreted as transitory factors, others might best be thought of as systematic changes in the policy rule. Because transitory versus systematic innovations to policy rules would generally be expected to have different economic effects, we consider an alternative identification of monetary policy shocks. Following Boivin (2006) and Coibion and Gorodnichenko (2011), we estimate a Taylor-type (1993) reaction function for the Federal Reserve with time-varying coefficients, which allows us to distinguish innovations to the Fed's inflation target, innovations to the Fed's response to deviations of inflation from its target, and shocks to the policy rule. We show that changes in the Fed's inflation target played a limited role in income inequality changes in the early 1980s, but primarily affected expenditure and consumption inequality. Both rose significantly during this time period, and the Volcker disinflation can explain the simultaneous increase in both measures during this period and their persistently high level in the subsequent decade. Given the limited response of inequality measures to these policies, this suggests that changes in target inflation may have operated largely as a wealth shock, transferring resources from borrowers to savers as in Doepke and Schneider (2006).[3] Shocks to the Fed's systematic response to inflation, in contrast, can account for some of the historical changes in earnings and consumption inequality, but had little to no effect on expenditure or income inequality through this time period.

The results therefore suggest that monetary policy has played a more significant role in driving recent historical inequality patterns in the U.S. than one might have expected. These results are interesting for several reasons. First, the potential contribution of monetary policy to inequality has been largely ignored by the economics literature, despite the fact that many outside of mainstream economics emphasize a causal link between the two.[4] Understanding and quantifying the sources of inequality is a first step to determining what kinds of policies, if any, are most appropriate to address it. Second, the heterogeneity of consumption and income responses is of immediate relevance to monetary economists and policymakers for understanding the monetary transmission mechanism. In addition, some research has linked rising inequality to credit booms

[3] A caveat to this interpretation is that the effects of changes in the target rate of inflation on income and earnings inequality are sensitive to the measure of the inflation target. When we use Ireland's (2006) estimate of target inflation, we find that these policy changes can account for much of the size and persistence in the increase of income and earnings inequality of the early 1980s. We discuss this in section 5.

[4] One exception is Romer and Romer (1998) who focus on the effects of monetary policy on poverty. Another, Galbraith, Giovannoni and Russo (2007), relies on the term of structure of interest rates as a measure of exogenous policy actions to quantify the effects of monetary policy on earnings inequality.

and financial crises (Rajan 2010, Kumhof and Ranciere 2011), therefore suggesting a potential link from inequality to macroeconomic stability. Third, there is a growing macroeconomics literature emphasizing agent heterogeneity which is explicitly interested in the dynamics of consumption and income inequality, as well as the implications of heterogeneity across agents for optimal policy design. However, a recent survey of this literature (Heathcote, Storesletten, and Violante 2009) suggests that the issues surrounding monetary policy have not received much attention within this class of models. One interpretation of our results could be as providing a set of stylized facts about the conditional responses of income, earnings and consumption patterns across households in response to monetary policy shocks that can be used to calibrate and differentiate between different classes of heterogeneous agent models, in the same spirit as the use of monetary policy shocks by Christiano, Eichenbaum and Evans (2005) to estimate the parameters of New Keynesian models with a representative agent. In addition, recent work has emphasized both the strong cyclical component to economic inequality but also the variation in the behavior of inequality across business cycle episodes. With changes in monetary policy-making having been proposed as a potential contributor to the Great Moderation and its unique business cycle properties (e.g. Clarida, Gali and Gertler 2000), it is natural to consider it also as affecting cyclical inequality patterns.

The paper is structured as follows. Section 2 discusses the Consumer Expenditure Survey, the construction of inequality measures and their unconditional properties. Section 3 presents the main results on the effects of monetary policy shocks on income, labor earnings, expenditure and consumption inequality. Section 4 considers alternative measures of monetary policy shocks and section 5 includes some robustness checks. Section 6 concludes.

II Measuring Inequality

In this section, we briefly describe the Consumer Expenditure Survey and the construction of measures of inequality for total income, wage income, consumption and total expenditures.

2.1 The Consumer Expenditure Survey

The Consumer Expenditure Survey (CEX), which is provided by the Bureau of Labor Statistics (BLS), consists of two separate surveys, the Interview Survey and the Diary Survey. In this study we only use data from the Interview Survey since the Diary Survey covers only expenditures on small items

that are frequently purchased, mostly related to food. The Interview Survey provides information on up to 95% of the typical household's consumption expenditures.

The CEX is the most comprehensive data source on household consumption in the U.S. and is used for the construction of CPI weights.[5] The raw data of the Interview Survey can be accessed from the Inter-university Consortium for Political and Social Research (ICPSR) at the University of Michigan. The CEX is a monthly rotating panel, where households are selected to be representative of the US population, and is available on a continuous basis since 1980. About 1,500-2,500 households are surveyed in any given month. Each household is interviewed once per quarter, for at most five consecutive quarters, although the first interview is used for pre-sampling purposes and is not available for analysis. In each interview the reference period for expenditures covers the three months prior to the interview month. However, the within-interview variation is much lower than the between-interview variation, suggesting that many households provide average monthly expenditures instead. To reduce measurement error, we therefore aggregate the household's monthly expenditures to quarterly expenditures. Hence, "household time" is quarterly, but since the CEX is a monthly rotating panel, the overall sampling frequency of the expenditure data is monthly.

Non-durable consumption includes among others food, alcohol and tobacco, and gasoline and other fuel. Service consumption includes household utilities, household operations, service charges, recreational services, public transportation, and personal care services. Total expenditures adds non-durables, services, and expenditures on durable goods, e.g. furniture and furnishing, jewelry and watches, recreational goods, and personal care durables. We follow the literature and exclude housing services, health care and health insurance, and education services from the definition of non-durables and services, since these expenditures have characteristics of durable goods.[6]

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5 A household in the CEX refers to a so-called Consumer Unit (CU), which the BLS defines as "(1) all members of a particular household who are related by blood, marriage, adoption, or other legal arrangements; (2) a person living alone or sharing a household with others or living as a roomer in a private home or lodging house or in permanent living quarters in a hotel or motel, but who is financially independent; or (3) two or more persons living together who use their incomes to make joint expenditure decisions. Financial independence is determined by spending behavior with regard to the three major expense categories: Housing, food, and other living expenses. To be considered financially independent, the respondent must provide at least two of the three major expenditure categories, either entirely or in part." (http://www.bls.gov/cex/csxfaqs.htm#q3) Therefore, a household or CU can consist of more than one family.

6 The detailed aggregation of expenditures into non-durables, services, and durables is provided in the appendix.

We correct sample breaks due to slight changes in the questionnaire of the following variables: food at home ('82Q1-'88Q1), personal care services ('01Q2), and occupation expenditures ('01Q2). To further improve the quality of the data, we drop the following observations: interviews with more or less than three monthly observations; households reporting zero food or total expenditures; and observations with negative expenditures where there should not be any. As recommended by the BLS, we sum expenditures that occur in the same month but are reported in different interviews. Overall, this procedure eliminates about 7% of the observations in the initial sample. Income data is asked in the first and last interview (i.e. interviews 2 and 5 in CEX terminology), and financial data is only asked in the last interview. The reference period for income flows covers the twelve months before the interview. All nominal variables are deflated using the CPI-U. To make the results comparable across sub-samples and with studies that use aggregate data, we use survey sample weights.

The quality of the data in the CEX appears high, particularly for consumption measures. Bee, Meyer, and Sullivan (2012) compare reported consumption spending data in the CEX to comparable data from the national income accounts data and find that the CEX conform closely to aggregate data for large consumption categories, although previous work (e.g. Krueger et al. 2010) documents that the CEX underreports consumption relative to aggregate data. Heathcote, Perri and Violante (2010) compare income inequality data in the CEX with equivalent measures from the Panel Study of Income Dynamics (PSID) and the Current Population Survey (CPS). They find strong comovement among pre-tax earnings inequality measures from all three surveys. Attanasio (2003) and Attanasio, Battistin and Ichimura (2004) similarly document the consistency of wage inequality in the CEX and the CPS.

2.2 Measures of Inequality

Given the availability of household data on both consumption and income, the CEX allows us to study the behavior of both forms of inequality. To do so, we will focus on three measurements of inequality: Gini coefficients, cross-sectional standard deviations of log levels, and log differences between individual percentiles of the cross-sectional distribution. The Gini coefficient has long been used to measure inequality. It summarizes via a single number between 0 and 1 the extent to which a variable is equally allocated across different components of the distribution. In addition to Gini coefficients, we will also use the cross-sectional standard deviation of log values. Taking logs

allows us to diminish the sensitivity to outliers, but requires us to drop observations equal to zero, in contrast to the Gini coefficient. Finally, we will use the difference between the log of the 90th percentile and the log of the 10th percentile of each distribution. Like the cross-sectional standard deviation, the use of logs requires the elimination of observations with values of zero. But the advantages of the percentile differential are that it will conform more closely to the behavior of individual percentiles, which we will look at in subsequent sections, and that it is less sensitive to extreme observations in the tails of the distributions.

Given the detailed data in the CEX, we will consider two forms of inequality for income and consumption each. On the income side, we first construct measures of salary inequality across households. Given the survey nature of the data, the advantage of salaries is that they are likely to be known with the highest precision by households relative to other forms of income. The disadvantage is, of course, that salary is only one component of most households' income. As a result, we also construct measures of income inequality using total income for each household. Because individuals in the CEX are asked about their income only in the first and last quarters of their participation in the survey and the BLS imputes income for periods in between, we use only those individuals who are reporting their income in each survey to construct measures of inequality. Hence, the sample used to construct inequality measures each quarter is only a subset of the total population in the survey that period. Importantly, both total and salary incomes are pre-tax measures. Given the progressivity of the U.S. tax system, this means our measures of income inequality will tend to overestimate dispersion in income that is available for consumption for households in the survey. However, because of the survey nature of the data, the extreme upper end of the income distribution will be largely absent from the sample, i.e. our income inequality measures will tend to understate inequality relative to the total population. Another caveat is that there is no information on hours worked, so labor earnings data conflate changes in wages and hours.

Table 1 reports correlations among the different measures of inequality for both income and salary. The different measures of income inequality measures are highly correlated with one another, with correlations of 0.89 or above over the entire sample since 1980Q1. The correlation between the different measures of salary inequality is generally lower, particularly for the Gini coefficient. This reflects the fact that both the cross-sectional standard deviation and the 90th – 10th percentile measures include only households which report positive wage income, whereas the Gini

coefficient also takes into account those households reporting no wage income. The high correlation between the standard deviation and the $90^{th} - 10^{th}$ percentiles (0.85) is in line with those found for total income measures, which is consistent with the notion that the lower correlation of each with respect to the Gini coefficient reflects the differential treatment of individuals reporting no income.

Similarly, we construct both a narrow and broad measure of consumption inequality. The narrow measure, which we refer to as consumption inequality, includes the same categories as in Parker (1999). Consumption goods in this category include non-durables, services, and some durable goods (household appliances, entertainment goods like televisions, furniture) but do not include large durable purchases such as house and car purchases. However, we also define a broad measure of consumption, which we refer to as total expenditures, which includes the previous definition of consumption as well as mortgage payments, purchases of cars, medical supplies and services, and tuition and books for schooling among other items. In contrast to income measures, consumption and expenditure data for individuals in the survey is measured every period, so consumption and inequality measures use the entire population in the survey each period subject to the caveats discussed in section 2.1. For both consumption and expenditures, we first aggregate all reported purchases within each definition at the level of the household, then construct inequality measures across households.

Table 1 documents a high correlation across different measures of total expenditure inequality, ranging from 0.75 to 0.94. In contrast, correlations among the consumption measures are smaller, ranging from 0.80 down to 0.45. Table 1 also reports correlations across income and expenditure inequality measures as well as their volatilities. With respect to the latter, income and salary inequality measures have approximately the same volatility, while the volatility in expenditure inequality tends to be higher than that of consumption inequality. Correlations between different forms of inequality vary widely. For example, the correlation between income and salary inequality using Gini coefficients is very high at 0.82, while correlations between the two using either the standard deviation or the 90^{th}-10^{th} percentiles are much lower, at 0.22 and 0.12 respectively. Similar results obtain for the correlations of income with consumption and the correlations between salary and consumption. The correlation between expenditures and consumption is consistently very positive, as is that between salary and expenditure inequality.

2.3 Unconditional Properties of Inequality Measures

Figures 1 through 3 plot the historical inequality measures of income, labor earnings, expenditures and consumption inequality measures from the CEX based on the cross-sectional standard deviation (Figure 1), Gini coefficient (Figure 2) and the 90^{th} to 10^{th} percentile differential (Figure 3), averaged over the previous and subsequent quarter to illustrate more clearly business cycle and low-frequency variations. Consistent with results documented in the literature (Krueger and Perri 2005, Meyer and Sullivan 2010), our measures of total income inequality are all trending up over time. A similar pattern occurs for labor earnings inequality when measured using the Gini coefficient but not when measured using the cross-sectional standard deviation nor the 90^{th} – 10^{th} percentile differential. There is a sharp increase in all forms of inequality in the early 1980s. Income inequality rises over the course of the 1990s, while little such movement is apparent for consumption or expenditure inequality measures. Finally, there is a noticeable decline in expenditure inequality over the course of the 2000s despite there being no such decrease in income inequality.

The figures therefore reveal some evidence of cyclical behavior in inequality measures, consistent with Heathcote et al. (2010). Table 2 presents unconditional correlations between inequality measures and quarterly inflation, the unemployment rate and the Federal Funds rate. All series are HP-filtered prior to measuring correlations so that the latter primarily reflect business cycle fluctuations rather than trends. Correlations of different forms of inequality with the inflation rate are very small and somewhat negative. Similar results obtain with interest rate correlations. Labor earnings inequality are weakly positively correlated with the unemployment rate and negatively with inflation. Expenditure and consumption inequality are more strongly negatively correlated with the unemployment rate. This could be interpreted as being consistent with a wealth channel, whereby even if income inequality varies little with the business cycle, cyclical fluctuations in asset prices have significant effects on wealth holdings of individuals, leading to lower consumption and expenditures of the wealthy during recessions. Overall however, the unconditional correlations do not point toward very strong links between business cycles and inequality patterns.

III Effects of Monetary Policy Shocks on Inequality

In this section, we present baseline results for the effects of monetary policy shocks on measures of income inequality. We first discuss the construction of monetary policy shocks, then present results quantifying the effects of these shocks on different forms of inequality in the U.S.

3.1 The Identification of Monetary Policy Shocks

To characterize the effects of monetary policy on inequality in the U.S., we follow Romer and Romer (2004, RR henceforth) to identify innovations to monetary policy purged of anticipatory effects related to economic conditions. RR first construct a historical measure of changes in the target Federal Funds rate (FFR) at each FOMC meeting from 1969 until 1996. Using the real-time forecasts of the Fed staff presented in the Greenbooks prior to each FOMC meeting (denoted by *F*), RR construct a measure of monetary policy shocks defined as the component of policy changes from each meeting which is orthogonal to the Fed's information set, as embodied by the Greenbook forecasts. Specifically, they estimate

$$\Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i F_m \Delta y_{m,i} + \sum_{i=-1}^{2} \lambda_i (F_m \Delta y_{m,i} - F_{m-1} \Delta y_{m,i}) + \sum_{i=-1}^{2} \varphi_i F_m \pi_{m,i} + \sum_{i=-1}^{2} \theta_i (F_m \pi_{m,i} - F_{m-1} \pi_{m,i}) + \mu_i F_m ue_0 + \varepsilon_m \quad (1)$$

where *m* denotes the FOMC meeting, ffb_m is the target FFR going into the FOMC meeting, $F_m \Delta y_{m,i}$ is the Greenbook forecast from meeting *m* of real output growth in quarters around meeting *m* (-1 is previous quarter, 0 is current quarter, etc.), $F_m \pi_{m,i}$ are Greenbook forecasts of GDP deflator inflation, and $F_m ue_0$ are Greenbook forecasts of the current quarter's average unemployment rate. The estimated residuals $\hat{\varepsilon}_m$ are then defined by RR as monetary policy shocks.

We extend the RR dataset on monetary policy shocks until December 2008 as follows. First, we incorporate more recent changes in the target FFR decided upon at regular FOMC meetings. Second, we extend the Greenbook forecasts until December 2006, the most recent period through which the Federal Reserve has released them. Third, we use consensus forecasts from the Blue Chip Economic Indicators in place of Greenbook forecasts for the FOMC meetings in 2007 and 2008. The dataset therefore extends until the zero-bound on interest rates became binding in December 2008. Estimating the exact same specification as RR upon this extended dataset since January 1969 yields a sequence of monetary policy shocks at the frequency of FOMC meetings. We then

construct a quarterly measure of monetary policy shocks by averaging the orthogonalized innovations to the FFR from each meeting within a quarter. The resulting shock series are plotted in Figure 4, starting in 1980Q1. Consistent with the results documented in RR, the shocks are particularly large and volatile in the early 1980s during the Volcker disinflation. The shocks series also identify periods in which policy was distinctly more contractionary than usual conditional on real-time forecasts. For example, the "pre-emptive strike" against inflation in 1994-1995 is visible as a period of consistently positive MP shocks, as is the period of 2005-2006. The 2000-2004 period, on the other hand, suggests more expansionary policy than would have been typical given staff forecasts of macroeconomic conditions, consistent with Taylor (2007).

Appendix Figure 1 documents the effects of contractionary monetary policy shocks on a number of macroeconomic variables, using the exact same methodology as RR, using data from 1969:Q1 to 2008Q4. Contractionary monetary policy shocks lower real GDP, consumption and investment while raising unemployment. Both short-term and long-term interest rates rise immediately while inflation declines after a two-year lag. Prices of houses, the major financial asset for most households, decline gradually after one to years. Wages and business income decline temporarily, while financial income rises with higher interest rates. Transfers to households decline briefly before rising then tapering off. The heterogeneity in responses of different forms of income suggest one channel through which monetary policy could directly affect income inequality, namely different sources of income across agents. Consumption of durables declines quickly, but recovers quickly as well, whereas consumption of nondurables and services have more gradual, but shallow, declines. While most of these aggregate effects are well-known, we will take a new look at an old question by focusing primarily on household heterogeneity in income and consumption responses to monetary policy shocks.

3.2 The Effects of Monetary Policy Shocks on Inequality

To quantify the effects of monetary policy shocks on an economic variable *x*, we again follow RR and estimate

$$\Delta x_t = c + \sum_{j=1}^{J} \alpha_j \Delta x_{t-j} + \sum_{i=0}^{I} \beta_i \hat{\varepsilon}_{t-i} + v_t \qquad (2)$$

which allows monetary policy shocks to have contemporaneous effects on each variable. From the estimates of equation (2), we then construct accumulated impulse responses of the level of *x* to a monetary policy shock. We focus first on measures of income, salary, expenditure and consumption inequality, defined as in section 2. We estimate equation (2) for each form of inequality using three different measures of inequality for each: the cross-sectional standard deviation (of logged values), the Gini coefficient, and the difference between the (log) 90th percentile and the (log) 10th percentile.[7] Standard errors are as in Newey-West (1987). Confidence intervals are constructed using a bootstrap in which we draw repetitively from the estimated distribution of coefficients of equation (2) and construct impulse responses associated with each draw of coefficients. These yield a distribution of impulse responses which will characterize the uncertainty associated with impulse responses. While monetary policy shocks are generated regressors, Pagan (1984) shows that if the null hypothesis is that $\beta_i = 0 \; \forall i \in [0 \; I]$, then standard errors need no adjustment. Given the consensus view among mainstream economists that monetary policy has played little role in affecting economic inequality in the U.S., this is a reasonable prior to hold. Furthermore, because monetary policy shocks are the residuals from estimates of (1), they will be largely orthogonal to contemporaneous economic conditions and other factors in *v*, further justifying the use of unadjusted standard errors. In estimating equation (2), we consistently use a lag structure of $J = 4$ and $I = 8$ quarters.[8] This is a shorter lag structure than assumed by RR but is consistent with the results of Coibion (2012) which assesses the sensitivity in responses of monetary policy shocks a la RR to lag structure.

Figure 5 presents the accumulated impulse responses from estimates of equation (2) for each form of inequality (income, salary, expenditure and consumption) and measure of that inequality (standard deviation, Gini, and 90th to 10th percentile differential) using data from 1980Q1 until 2008Q4 and the associated one standard deviation confidence intervals.[9] The results for both income and salary inequality point to statistically significant effects of monetary policy shocks on

[7] In the case of 90th – 10th percentile differentials, we estimate equation (2) for changes in the 90th and 10th percentiles separately using seemingly-unrelated regressions (SUR), then construct the impulse response and standard errors of the difference between the two from the SUR estimates. This is done because, if each percentile has independent measurement error due to sampling, taking the difference between the two will increase the measurement error in the series and bias the estimation procedure.

[8] We investigate the sensitivity of our results to lag lengths in section V.

[9] Note that we include four lagged values of monetary policy shocks from 1979 to avoid shortening the time sample too much from the use of a long lag structure for monetary policy shocks.

inequality. In each case, the estimates point to higher long-run levels of income and salary inequality after contractionary monetary policy shocks, although the degree of statistical significance varies with the measure used. The results for consumption and expenditure inequality are even more supportive of an effect of monetary policy shocks on inequality, particularly for expenditure inequality. With expenditures, each measure of inequality points to a statistically significant and highly persistent increase in inequality after a contractionary monetary policy shock. Furthermore, the point estimates for expenditures are consistently larger than for other forms of inequality, pointing to monetary policy shocks having disproportionately large effects on expenditure inequality relative to other forms of economic inequality. In short, across all forms of inequality and the different ways of measuring each type of inequality, the impulse responses indicate that contractionary monetary policy shocks are associated with higher levels of economic inequality.

3.3 Distributional Effects Underlying Inequality Responses to Monetary Policy Shocks

To delve further into the potentially heterogeneous effects of monetary policy shocks on household incomes and expenditures, we present impulse responses of income, salary, expenditures and consumption for specific percentiles of their respective distributions using equation (2). Because of the nature of the survey data, the way these measures are constructed for incomes versus expenditures are different. In the case of both income and labor earnings, households are asked about their income and salaries over the last twelve months in only the first and fourth quarter in which they participate in the survey. Thus, measures of different percentiles of the salary and income distribution reflect a changing composition of households each quarter. Because consumption and expenditures are tracked each quarter, however, we can control for the potentially changing composition and ranking of households across periods when we measure the changes in consumption and expenditures by percentile each quarter. Specifically, in each quarter, we rank households according to either their consumption or expenditures. Then, we isolate those households at each percentile of interest (90^{th}, 75^{th}, 50^{th}, 25^{th} and 10^{th}) and construct the percent changes in their consumption and expenditures. Applying this procedure each quarter yields a time series of percent changes for each percentile which control for composition effects.

We show the effects of monetary policy shocks on different percentiles of the income, labor earnings, expenditure and consumption distribution in Figure 6. With respect to earnings responses, the results suggest that, after about two years, wage earnings for those in the upper end

of the salary income distribution rise while those at the lower end of the salary income distribution see their earnings fall. With the response of the 75th percentile being between that of the 90th and the 50th percentiles and the response of the 25th percentile being between that of the 10th and the 50th, these results point to contractionary monetary policy shocks having heterogeneous effects on earnings which raise salary incomes at the upper end of the distribution while lowering that of those at the bottom end of the distribution. However, because we cannot track the income of individual households over time in the CEX, this finding could be consistent with contractionary monetary shocks raising the labor incomes of high-earning individuals and lowering those of low-salary individuals but could also be consistent with significant churning in the positions of households across the salary distribution. Since the data do not decompose labor earnings into those components due to hours worked versus wage rates, significant reallocation of households across the distribution cannot be ruled out even if wage contracts are inflexible in the short-run. For example, job loss during the preceding twelve months could lead to significant changes in household labor earnings yet leave households reporting some positive labor income over this period in which case they would remain within the distribution.

The results with respect to total incomes are also suggestive of an effect of monetary policy shocks on income inequality but to a smaller extent than with wage income. The response of the 90th percentile of the income distribution is highest starting two years after the shock while that of the 10th percentile is lowest, but the difference between the two is only about half of that implied by salary differentials. Furthermore, unlike the responses of salary percentiles in which higher percentiles consistently saw higher earnings responses, the 25th percentile of the income distribution rises relative to both the 50th and 75th percentiles of the income distribution, so monetary policy shocks have less monotonic effects on the total income distribution than on wage incomes.

The reason why monetary policy shocks have more muted effects on total incomes of the 10th and 25th percentiles than might be expected from the response of their labor earnings lies in the different sources of their total incomes. Table 3 presents a decomposition of total income for each quintile (measured by consumption of nondurables and services as a proxy for permanent income) for the 1980s, 1990s and 2000s. The most striking result of this decomposition is the rising importance of salary as a share of total income at higher quintiles of the distribution. For example, in the 2000s, salary income accounted for over 80% of total income for the highest quintile, 74% for

the middle quintile, but only slightly over 40% for the bottom quintile, with the differences being even starker in previous decades. The reduced importance of salary income at the lower quintiles therefore suggests a natural interpretation for the results in Figure 5: total incomes of the bottom quintiles depend, to a much greater extent than in the rest of the distribution, on sources of income other than salaries.

Table 3 also documents that the largest contributor to total income (approximately 50%) for those in the bottom quintile of the distribution is the "other income" category, which includes unemployment insurance, Social Security and pension payments, welfare, worker's compensation, and other transfer programs. Even at the second quintile of the distribution, other income accounts for approximately 25% of total income, whereas this ratio is less than 10% for the top 2 quintiles. The financial income and business income shares vary much less across the distribution: the share of business income rises from 2% of total income for the bottom quintile to 5-9% for the top quintile while financial income falls from a share of 9-12% at the bottom quintile to approximately 7% for the top quintile.

Appendix Figure 1 documents that total transfers to households at the aggregate level fall very little after monetary policy shocks. Because lower income households rely more on this source of income than on wage income relative to other households, this mitigates the decline in their total income. In addition, households in the bottom of the income distribution receive a larger share of their income from financial assets. Income from this source rises significantly after monetary policy shocks, again mitigating the effects of declining labor income.[10] Thus, the difference between the response of labor income and total income for lower-income households reflects a composition of income shares which relies less on salary than more affluent households.

Turning to the responses of consumption by percentile, the results closely mirror those for salary inequality, with the main difference being that the differential behavior between high-consumption and low-consumption households is apparent much earlier than with respect to labor earnings. Most striking, however, is the fact that the long-run responses of consumption percentiles are almost identical to those found for salaries. For example, salary income at the 90th percentile rises by 4% as does consumption at the 90th percentile. Salary income at the 10th

[10] We also generated impulse responses of average financial income, business income, and "other" income for households ranked by quintile according to their consumption of non-durables and services. However, there was little heterogeneity in these responses and their patterns conformed closely to the dynamics of the aggregate series. Hence we do not report them, but they are available upon request.

percentile falls by 5% while consumption at the 10th percentile falls 6%. Results for the 25th, 50th and 75th percentiles of salary and consumption are all also remarkably close to one another. To the extent that labor earnings may most closely approximate permanent income, this result provides strong support for the Permanent Income Hypothesis, with the caveat that the labor earnings data are pre-tax.

Finally, responses of expenditures by percentiles similarly point to substantial heterogeneity in household responses to monetary shocks. The most striking result here is the very large increase in expenditures by those at the 90th percentile of the expenditure distribution relative to others. The magnitude of this increase dwarfs changes in income or salaries and likely explains the fact observed in Figure 4 that expenditure inequality rises so significantly and persistently after monetary policy shocks. One potential explanation for this, in the same spirit as for the behavior of total income of low-income households, could be that high income households (the 90th percentile) have much higher expenditures or a different composition of expenditures than other households. Table 4 therefore provides a decomposition of consumption and expenditures by households across quintiles, ranked by consumption of non-durables and services each quarter, as well as information about their relative expenditures on interest-sensitive expenditures.[11] While households in the upper end of the distribution consume relatively more durables and devote more of their spending to interest-sensitive expenditures like mortgage payments and auto purchases, the differences across quintiles are small. Furthermore, the ratio of spending on expenditures to consumption of non-durables and services is not rising. We constructed impulse responses of average spending for each of these categories for different quintiles, but found no evidence that households in the upper end of the distribution increased their expenditures more than other households after contractionary shocks. Hence, the greater response of expenditures for those at the 90th percentile of the expenditure distribution after monetary policy shocks cannot be explained via composition of spending across quintiles.

An alternative explanation might be wealth effects from the interest rate shocks as in Doepke and Schneider (2006): since contractionary policy shocks represent a transfer from borrowers to savers, one might expect to see disproportionate increases in the expenditures of borrowers. And to the extent that savers and borrowers are not uniformly within a quintile could

[11] Interest-sensitive expenditures are defined as mortgage payments, purchases of automobiles, spending on education, spending on repairing houses and other real estate, and durable consumption goods.

account for why we see no large differences in the response of expenditures across quintiles ranked by non-durables and services. Unfortunately, the CEX does not include reliable data on the net wealth position of households. Nonetheless, we can assess this possibility by restricting our attention to households with those characteristics identified by Doepke and Schneider (2006) as being closely associated with high net worth and low net worth households. Specifically, they argue that the main losers from inflation are "rich, old households" while the main winners are "young, middle-class households with fixed-rate mortgage debt." In the context of the CEX, we therefore split the sample into three groups: 1) low net-worth households are defined as aged 30-40 year-old white households with a male head in the household, no financial income, and positive mortgage payments, 2) high net-worth households are defined as aged 55-65 years white households with a male head in the household, positive financial income, and no mortgage payments, 3) everyone else with a white male head in the household. We restrict the first two categories to be white households with a male head in the household to limit the possible sources of differences between the two categories without unduly restricting the number of households in each group (as would be the case, for example, if we imposed restrictions on education levels).

For each set of households, we then construct measures of mean (log) income and expenditures as well as subcategories of each. Impulse responses for each group are constructed using equation (2) as before. The results, plotted in Figure 6, strongly support the redistribution of nominal wealth effect in generating heterogeneity in expenditures. High net-worth households experience large declines in labor earnings but these are offset by rising financial incomes. As a result, the response of the average total income for high net-worth households is no different from that of low net-worth households or other households in the CEX. At the same time, the high net-worth households display large increases in consumption and even more so total expenditures relative to other households. Low net-worth households, in contrast, reduce their consumption relative to others in the sample while their expenditures are no different from other households except those with high net-worth. Because high net-worth households are, on average, high-earning households due to their age profile, the increase in their expenditures can account for much of the increased expenditures at the high end of the distribution observed in Figure 4. Thus, the redistributive channel of monetary policy shocks appears to play a significant role in driving the disproportionate increases in expenditure inequality after contractionary monetary policy shocks.

3.3 Distributional Mobility

An important caveat to the responses of specific percentiles of income and consumption distributions to monetary policy shocks is that it is not clear to what extent households are moving across the distribution. For example, when the 90th percentile of the earnings distribution rises after a monetary policy shock, is it because high-income households are earning higher wages (or working more hours) or because some lower-income households received much higher labor incomes? To assess mobility across the distribution, we construct time-varying quarterly transition probabilities for each quintile of the consumption distribution. These are defined as the fraction of consumers within each quintile who, in the next quarter, end up in another quintile. Figure 7 plots these time-varying transition frequencies of moving from each quintile to each quintile of the consumption distribution from 1980Q1 until 2008Q4. One notable feature of these time series is that mobility has declined over time for each quintile other than the bottom one. For example, for the middle quintile, the frequency of remaining within that quintile from one quarter to the next has gone from approximately 35% in 1980 to nearly 45% in 2008. Furthermore, mobility at the bottom end of the distribution is limited: the frequency at which people in the lowest quintile move to the middle quintile or above has been approximately 5% each quarter over this time period.

To assess whether monetary policy shocks have significant effects on these transition frequencies, we estimate equation (2) in levels for each series and present impulse responses in Figure 8. One finding is that there is little persistence in the effects of monetary policy shocks on transition probabilities: after two years, almost all of the estimates are not different from zero. A second finding is that contractionary shocks cause some increased movement within the distribution: the frequency of households remaining within the same quintile declines for each of the top 4 quintiles. In contrast, the probability of remaining within the bottom quintile rises for much of the first year after a shock. These results suggest one reason why the impulse responses for different percentiles of the total income and labor earnings distribution appeared so volatile over the first two years: there is likely more movement within the distribution than in other periods. However, as this increased mobility fades after two years, the responses of the percentiles converge to more stable outcomes. Consistent with this, the responses for percentiles of the expenditures and consumption distributions, which control for composition effects, are much more stable through the first two years of impulse responses than are those of the earnings and income distributions.

3.4 Historical Contribution of Monetary Policy Shocks to U.S. Inequality

The impulse responses of inequality measures, and even more so the responses of different percentiles of each distribution, indicate that monetary policy shocks have heterogeneous effects on different households, such that contractionary policy shocks raise income and consumption inequality. To assess whether these responses are economically significant, we consider the extent to which monetary policy shocks since 1980 can account for the historical variation in U.S. income and consumption inequality. To do so, we use the predicted changes in income, salary, expenditure and consumption inequality due to monetary policy shocks from our estimates of equation (2), accumulate them over time and compare them to the actual evolution of inequality measures. We normalize both the predicted and actual series by the trend growth rate of each historical inequality measure to avoid assigning trend growth rates from estimated constants in equation (2) as a contribution of monetary policy shocks. In addition, we average both actual and predicted variables over the previous and subsequent quarter values. This is done to downplay very high-frequency variation in inequality measures and to emphasize business cycle variation in inequality. It is important to note that this averaging is done after the estimation.

Figure 9 presents the results using the cross-sectional standard deviation measures of inequality, with other measures yielding qualitatively similar results. First, monetary policy shocks appear to account for very little of the variation in income, earnings and expenditure inequality until the mid-1990s, with the exception of income inequality for which some of the higher frequency variation in the very early 1980s is consistent with movements induced by monetary policy shocks. Second, monetary policy shocks can account for some of the gradual changes in income and salary inequality, particularly since the mid-1990s, including the gradual reversion to trend that occurred until 2004, the increase in income and salary inequality in 2005-2006 during which monetary policy shocks were systematically contractionary, as well as the decline in income and salary inequality lasting into 2008 while monetary policy shocks were distinctly expansionary. The results are even more striking with consumption inequality: monetary policy shocks can account for many of the short-lived deviations from trend in the 1980s and can almost fully account for the trend behavior since the late 1990s. Interestingly, monetary policy shocks can account for very little of the variation in expenditure inequality over this time period, with the exception of the decline since 2005. For the rest of the time period, there is very little correlation between actual

movements in expenditure inequality and predicted changes due to monetary policy shocks. Nonetheless, the key feature of Figure 9 is the fact that monetary policy shocks can account for so much of the deviations of income, earnings, and consumption inequality from trend.

V Differentiating among Monetary Policy Shocks

In assessing the effects of monetary policy shocks on inequality, we have continually relied on the approach of Romer and Romer (2004). Indeed, their identification procedure has a number of advantages over previous attempts to do so. First, the use of changes in the FFR target decided upon specifically at FOMC meetings mitigates the possibility of including day-to-day changes in the FFR which have little to do with monetary policy. Second, policy changes are purged of anticipatory effects by controlling for the real-time forecasts of the staff of the Federal Reserve. The resulting shocks identify changes in policy which are not taken in response to economic conditions. As emphasized by RR, their procedure is not designed to characterize the reaction function of the Fed and therefore the identified innovations reflect a number of potential sources: the evolution of the Fed's operating procedures, policymakers' evolving beliefs about the workings of the economy, variation in the Fed's objectives, political pressures, and responses to other factors. Some of these changes could be interpreted as innovations to the central bank's policy rule (i.e. its systematic behavior) –for example if a new Chairman dislikes inflation more than a previous one– while others would more appropriately be characterized as transitory deviations from a policy rule (for example, political pressures at the time of an election). RR deliberately do not attempt to separate out these different sources to maintain as much variation in the shocks, but a caveat to this is that different sources of shocks may have yield very different economic responses.

As a result, we consider an alternative estimation of monetary policy shocks, still in the spirit of RR, which seeks to distinguish between some of these alternative sources of variation. Following Coibion and Gorodnichenko (2011), we first posit a reaction function for the central bank:

$$i_t = \left(1-\rho_{1,t}-\rho_{2,t}\right)\left[F_t rr_t^n + \varphi_{\pi,t}(F_t\pi_{t+1}-\bar{\pi}_t) + \varphi_{gy,t}(F_t gy_t - \overline{gy}) + \varphi_{x,t}x_t\right] + \rho_{1,t}i_{t-1} + \rho_{2,t}i_{t-2} + v_t \qquad (3)$$

according to which the central bank moves interest rates with its perception of the natural rate of interest $F_t rr_t^n$, and also responds to deviations of expected inflation $F_t\pi_{t+1}$ from its potentially time-varying target $\bar{\pi}_t$, deviations of expected output growth from its target $(F_t gy_t - \overline{gy})$, and the

output gap (x_t). In addition to allowing for time variation in the intercept, we allow for variation in the target level of inflation, in the response coefficients to macroeconomic conditions, and in the degree of interest-smoothing. Each time-varying coefficient is assumed to follow a random walk process as in Boivin (2006).

We estimate the coefficients of this reaction function as in Coibion and Gorodnichenko (2011) using data from 1969 to 2008 at the frequency of FOMC meetings using real-time forecasts of inflation, output growth and the output gap. Because Greenbook forecasts are only available until the end of 2006, we use consensus forecasts from Blue Chip Economic Indicators for FOMC meetings in 2007 and 2008. The latter do not include forecasts of the output gap but do include unemployment forecasts. We generate forecasts of the output gap for 2007 and 2008 by first constructing historical real-time Greenbook forecasts of the unemployment gap (the difference between GB forecasts of UE and GB estimates of the NAIRU) from 1997 to 2006, estimate the historical (linear) relationship between GB forecasts of the output gap and the unemployment gap, then use this version of Okun's Law embedded in GB forecasts to convert the unemployment gaps in BCEI forecasts (the consensus forecast of unemployment minus the real-time estimates of the NAIRU from the Survey of Professional Forecasters) into output gap forecasts.[12]

Figure 10 plots the estimated shock series for the target inflation rate and shocks to the inflation response coefficient. There are very large negative shocks to the inflation target in the very early 1980s, coinciding with the Volcker disinflation. Similarly, the shocks to the inflation response coefficients are systematically positive through the 1980s, but especially so in the very early 1980s. Both shocks point to changes in systematic monetary policy emphasizing lower inflation levels and volatility until the late 1990s. There is a brief reversal of this pattern in the early 2000s, during the prolonged period of low interest rates in light of deflation concerns. The mid-to-late 2000s, on the other hand, are associated with increasing responses to inflation deviations from the target but a simultaneous increase in the inflation target. The estimated residuals from the time-varying rule are highly correlated with the original Romer and Romer shocks from 1980Q1 to 2008Q4 (correlation of 0.60) and yield similar results as the benchmark RR shocks, so we focus on shocks to the inflation target and the systematic response to deviations of inflation from its target.

[12] See Coibion and Gorodnichenko (2011) for how we construct the dynamics of the real interest rate.

Figure 11 plots the effects of shocks to the target level of inflation and the systematic response to inflation deviations on the cross-sectional standard deviations of income, earnings, expenditure, and consumption inequality. Disinflationary shocks to the target rate of inflation are systematically associated with higher levels of all types of inequality, although the long-run effects are statistically significant only for expenditures and consumption. In contrast, an increase in the Fed's response to inflation deviations from its target is associated with temporary decreases in income and expenditure inequality, although the effects are only marginally statistically significant. The effects of expenditure and consumption inequality are reversed however, with stronger systematic responses to inflation being associated with persistently higher levels of consumption and expenditure inequality.

We also present estimates of the historical contribution of each kind of shock to inequality in Figure 11. Changes in the target rate of inflation have had very little quantitative impact on income or salary inequality, with the only notable contributions occurring in the early 1980s during the Volcker disinflation. However, consistent with the impulse responses, the effects were transitory. The results for consumption inequality are similar, with the decline in target inflation successfully accounting for much of the early 1980s spike in consumption inequality but little of the remaining variations. In contrast, shocks to the inflation target appear to have played a very large role in accounting for the persistent increase in expenditure inequality relative to trend. The changes in target inflation of the early 1980s can account for most of the concurrent increase in expenditure inequality as well as the subsequent persistence in these levels. Shocks to the systematic response to inflation account for very little of the historical variation in income and expenditure inequality. However, they seem to have played a non-trivial role in accounting for historical wage income inequality. These results therefore suggest that the historical dynamics of each form of economic inequality in the U.S. can be partially explained by monetary policy actions. The very large effects of the Volcker disinflation on expenditure and consumption inequality are particularly notable and again suggest a strong potential role for redistributive effects of monetary policy.

VI Robustness

In this section, we investigate the robustness of our results to several potential issues. First, we consider the use of longer lag lengths in the estimation of equation (2) for the construction of impulse responses to monetary policy shocks. Using insufficient lags can lead to severe bias in impulse responses, particularly for long-run behaviors. In addition, Romer and Romer (2004) use longer lag specifications than those used in our baseline results. As a result, we reproduce the impulse responses of percentiles of the income, salary, expenditure and consumption distributions using the same lag lengths as those employed by Romer and Romer (2004), namely 2 years of autoregressive lags ($J = 8$) and 3 years of monetary policy shocks ($I = 12$) and present the results in Appendix Figure 2. The impulse responses are very close to our baseline findings. For labor earnings, we continue to find a long-run increase in the 90th percentile while the 10th percentile falls approximately 5%. The relative responses of each percentile are as in the baseline, with labor earnings faring worse at each lower percentile level. Total income inequality rises by less than salary inequality, again due to smaller income declines for the 10th and 25th percentiles, reflecting the fact that labor income accounts for a smaller component of their total income than for higher income quintiles. The consumption and expenditure responses are also very similar to the benchmark results: consumption rises for the 90th percentile and falls significantly for the 10th percentiles, with the other percentile responses being in between. As before, the magnitudes of the consumption responses for each percentile are close to the changes in labor earnings. Expenditure inequality continues to increase strongly after contractionary monetary policy shocks, again displaying large increases in expenditures for the 90th percentile and, to a smaller extent, for the 75th percentile. Thus, there is little evidence of sensitivity in the response of inequality to longer lag lengths in the estimation of equation (2).

Second, we consider the sensitivity of these results to the inclusion of the Volcker disinflation. As highlighted in Figure 4, monetary policy shocks between 1979 and 1982 are much more volatile than in other periods. While some of this volatility may reflect the dramatic monetary policy actions of this time period, they could also reflect significant measurement error in monetary policy shocks. Because the Federal Reserve abandoned targeting the FFR during this period, movements in the FFR are more likely to be contaminated with endogenous market responses to economic conditions than in other periods. This feature of the data therefore suggests caution in interpreting results which hinge on the early Volcker period. To address this concern, we reproduce the responses of selected percentile of the income, salary, expenditure and consumption

distributions to monetary policy shocks, but restrict the time sample to begin in 1985Q1. The results are presented in Appendix Figure 3. Surprisingly, there appears to be almost no sensitivity of these responses to the Volcker disinflation period. There continues to be significant heterogeneity in labor earnings and consumption responses to monetary policy shocks, with the magnitudes remaining very close to the baseline findings. If anything, heterogeneity in consumption responses is slightly higher. The responses for income and expenditure percentiles are also broadly unchanged and point to very similar long-run effects as when using the entire time period. Thus, these results indicate that the Volcker disinflation period does not play a crucial role in identifying the response of inequality to monetary policy shocks.

A third robustness check that we consider is with respect to the identification of changes in the target level of inflation. Because the latter is unobserved, different identification schemes can potentially lead to very different results for both impulse responses and historical contributions. Our baseline measure of historical changes in the Federal Reserve's target level of inflation is drawn from estimation of the Fed's reaction function allowing for time-variation in the response coefficients. One advantage of this approach is that we can still use the real-time forecasts of the Federal Reserve to purge interest rate changes of anticipatory effects. But single-equation estimation of time-varying coefficients leads to significant uncertainty in the estimation of the time-variation and is less efficient than estimation using fully-specified model. As a result, we also consider the estimates of target inflation from Ireland (2006), who uses a fully-specified New Keynesian DSGE model to infer the target level of inflation on the part of the Federal Reserve. While Ireland's estimated path of the target path of inflation is qualitatively similar to our benchmark, the correlation in quarterly changes is very low: -0.28 from 1979Q1 until 2004Q2 (the last available date at which Ireland's measure is available). This low correlation in shocks suggests that the estimated effects of changes in the target level of inflation may be sensitive to the identification procedure.

To investigate the sensitivity of our results to identification of target inflation rates, we compare both the impulse responses of inequality measures (using the cross-sectional standard deviations) and the historical contributions of monetary policy shocks from our benchmark shocks to the target inflation rate and Ireland's estimates. The results, based on a common sample of 1980Q1 to 2004Q2, are presented in Appendix Figure 4. While the two shock measures yield different short-run dynamics for income and earnings inequality, the long-run responses are almost

identical for all inequality measures: increases in the target inflation rate lead to lower levels of income, salary, consumption and expenditure inequality levels. Appendix Figure 4 also presents estimates of the historical contribution of target inflation shocks to U.S. economic inequality. While the results for the two shock measures are indistinguishable for consumption and expenditure inequality, Ireland's estimate of target inflation changes points to a very significant contribution of target shocks in accounting for the large and persistent increase in earnings and total income inequality relative to trend in the early 1980s. Thus, Ireland's alternative measure of target inflation shocks points to an even more important monetary policy contribution to historical inequality fluctuations in the U.S. than in our baseline results.

VI Conclusion

Recent events have brought both monetary policy and economic equality to the forefront of policy issues. At odds with the common wisdom of mainstream macroeconomists, a tight link between the two has been suggested by a number of people, ranging widely across the political spectrum from Ron Paul and Austrian economists to Post-Keynesians such as James Galbraith. But while they agree on a causal link running from monetary policy actions to rising inequality in the U.S., the suggested mechanisms vary. Ron Paul and the Austrians emphasize inflationary surprises lowering real wages in the presence of sticky prices and thereby raising profits, leading to a reallocation of income from workers to capitalists. In contrast, post-Keynesians emphasize the *dis*inflationary policies of the Federal Reserve and their disproportionate effects of the wages of those at the bottom end of the income distribution.

We shed new light on this question by assessing the effects of monetary policy shocks on consumption and income inequality in the U.S. Contractionary monetary policy shocks appear to have significant long-run effects on inequality, leading to higher levels of income, labor earnings, consumption and total expenditures inequality across households, in contrast to the directionality advocated by Ron Paul and Austrian economists. Furthermore, while monetary policy shocks cannot account for the trend increase in income inequality since the early 1980s, they appear to have nonetheless played a significant role in cyclical fluctuations in inequality and some of the longer-run movements around the trends. This is particularly true for consumption inequality, which is likely the most relevant metric from a policy point of view, and expenditure inequality after

changes in the target inflation rate. To the extent that distributional considerations may have first-order welfare effects, our results point to a need for models with heterogeneity across households which are suitable for monetary policy analysis. While heterogeneous agent models with incomplete insurance markets have become increasingly common in the macroeconomics literature, little effort has, to the best of our knowledge, yet been devoted to considering their implications for monetary policy. In light of the empirical evidence pointing to non-trivial effects of monetary policy on economic inequality, this seems like an avenue worth developing further in future research.

Specifically, the dynamic responses to monetary policy shocks point toward two key channels that appear to be empirically important. First, monetary policy shocks have effects on labor earnings which vary systematically across the income distribution: labor income rises at the upper end of the distribution and falls at the lower end. Given that monetary policy shocks operate primarily through interest rates, this would suggest that modeling the complementarity/substitutability of capital with different forms of labor (such as skilled or unskilled) could go some way in accounting for these patterns. Alternatively, this heterogeneity could reflect different age profiles and associated labor supply elasticities or complementarities between labor and consumption. Identifying this causal link would be an important step in better understanding the relationship between monetary policy, income inequality, and economic outcomes.

Second, the disproportionate increase in expenditures for those at the upper end of the expenditure distribution relative to income changes suggests the possibility of significant wealth transfers via unexpected changes in interest rates and inflation. We document that the response of expenditures by high net-worth households is much larger than for other households in the data. Furthermore, the historical contribution of target inflation changes to expenditure inequality likely hinges on this mechanism. While the data limitations of the CEX make the identification of high net-worth households problematic, our results suggest that household balance sheets may play an important link in the monetary transmission mechanism.

Finally, the sensitivity of inequality measures to monetary policy actions points to even larger costs of the zero-bound on interest rates than is commonly identified in representative agent models. Nominal interest rates hitting the zero-bound while the central bank's systematic response to economic conditions calls for negative rates is conceptually similar to the economy being subject

to a prolonged period of contractionary monetary policy shocks. Given that such shocks appear to increase income and consumption inequality, our results suggest that standard representative agent models may significantly understate the welfare costs of zero-bound episodes.

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Figure 1: Cross-Sectional Standard Deviations of Total Income, Labor Earnings, Expenditures and Consumption in the United States.

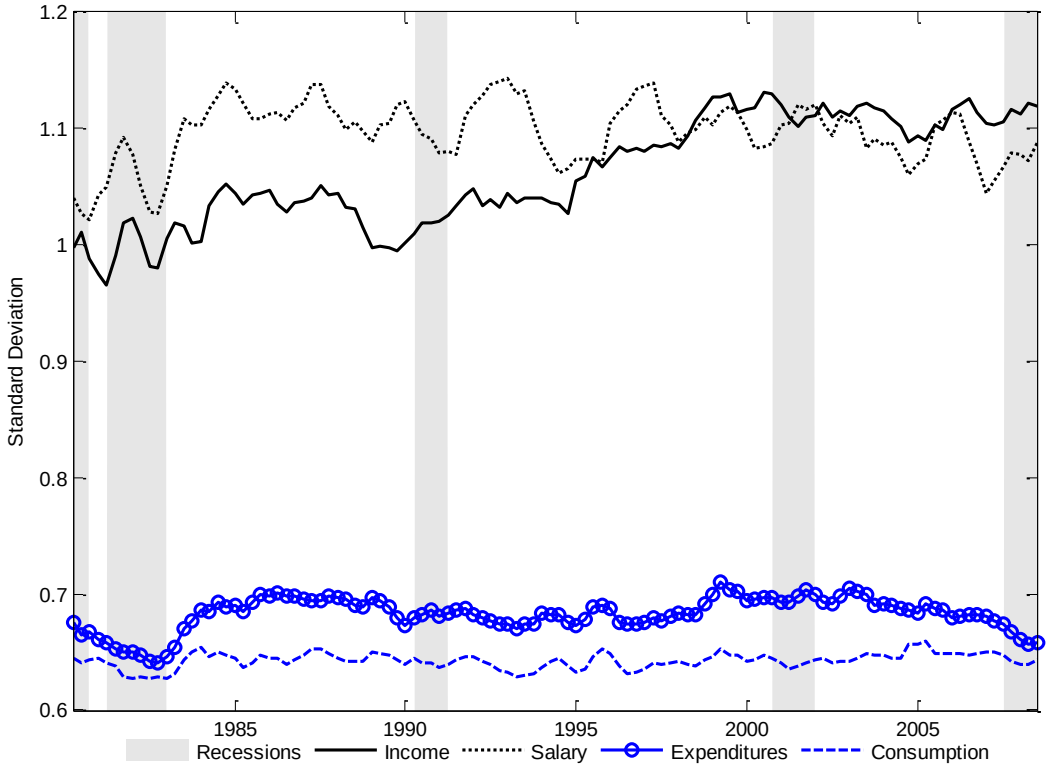


Figure 2: Gini Coefficients of Income, Labor Earnings, Expenditures and Consumption in the U.S.

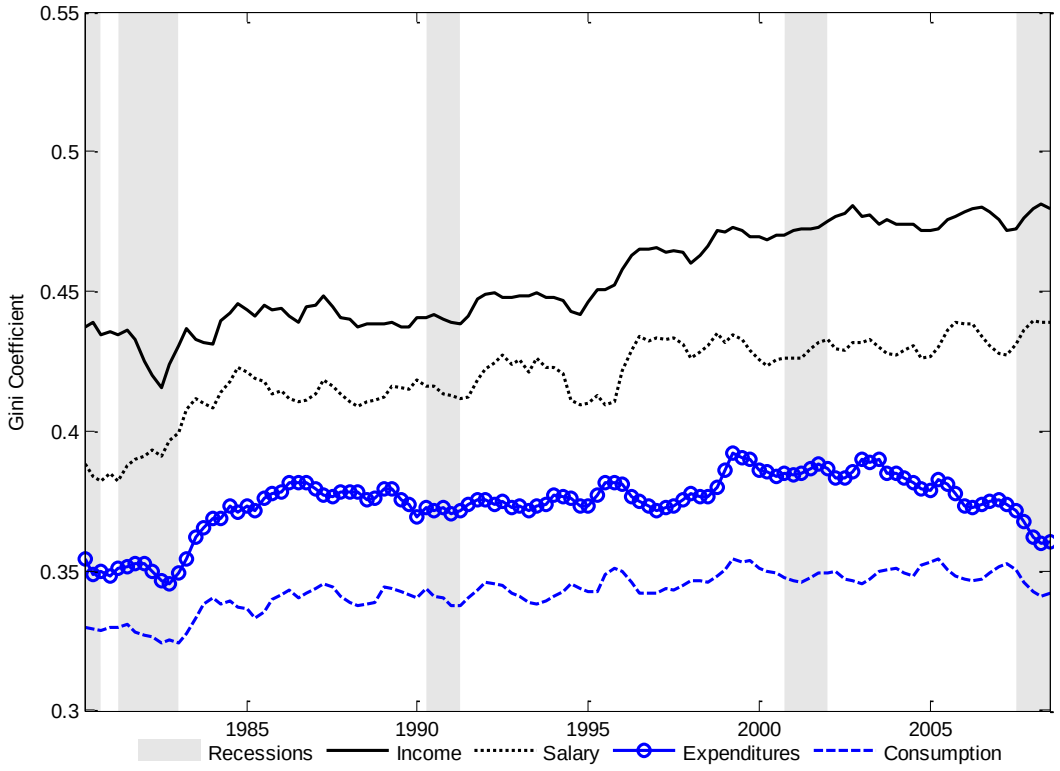
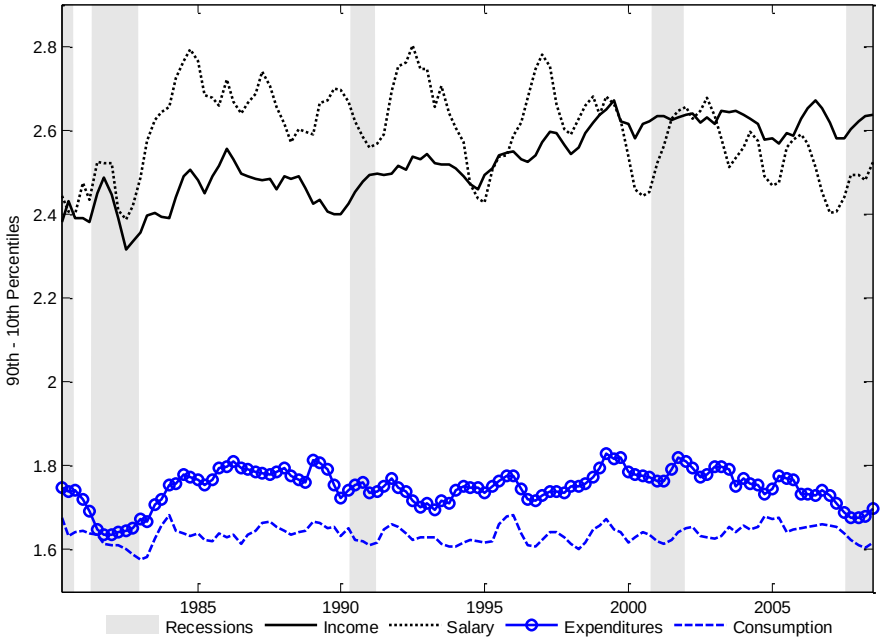
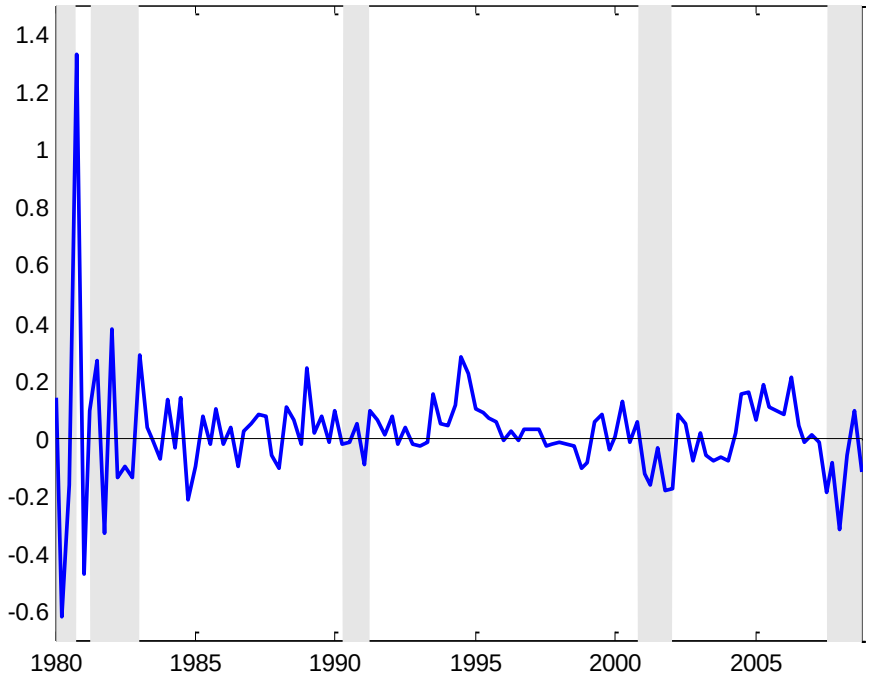


Figure 3: 90^{th} – 10^{th} Percentiles of Income, Labor Earnings, Expenditures and Consumption in the U.S.



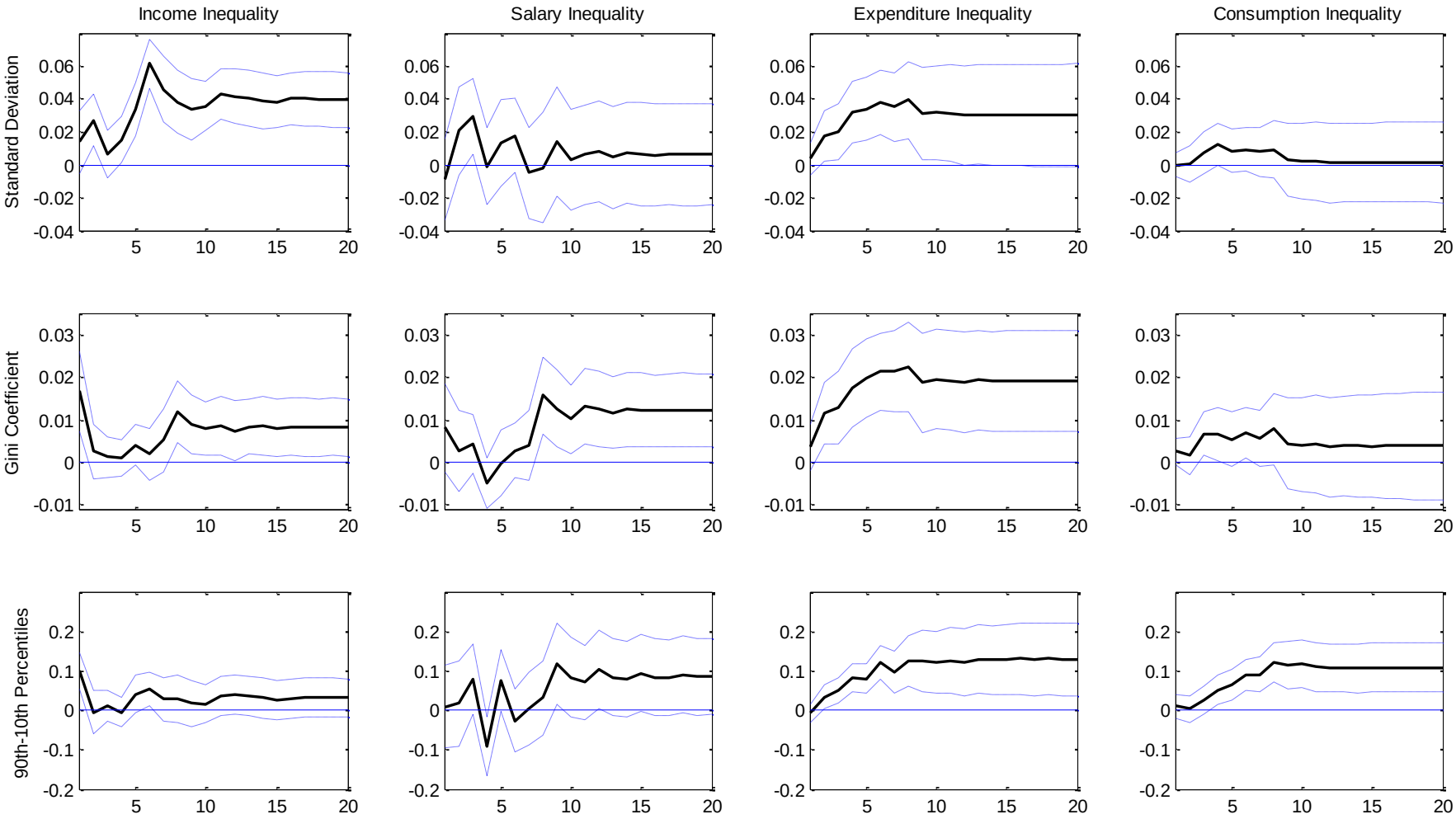
Note: In Figures 1-3, inequality measures are averaged over previous and subsequent quarters.

Figure 4: Monetary Policy Shocks



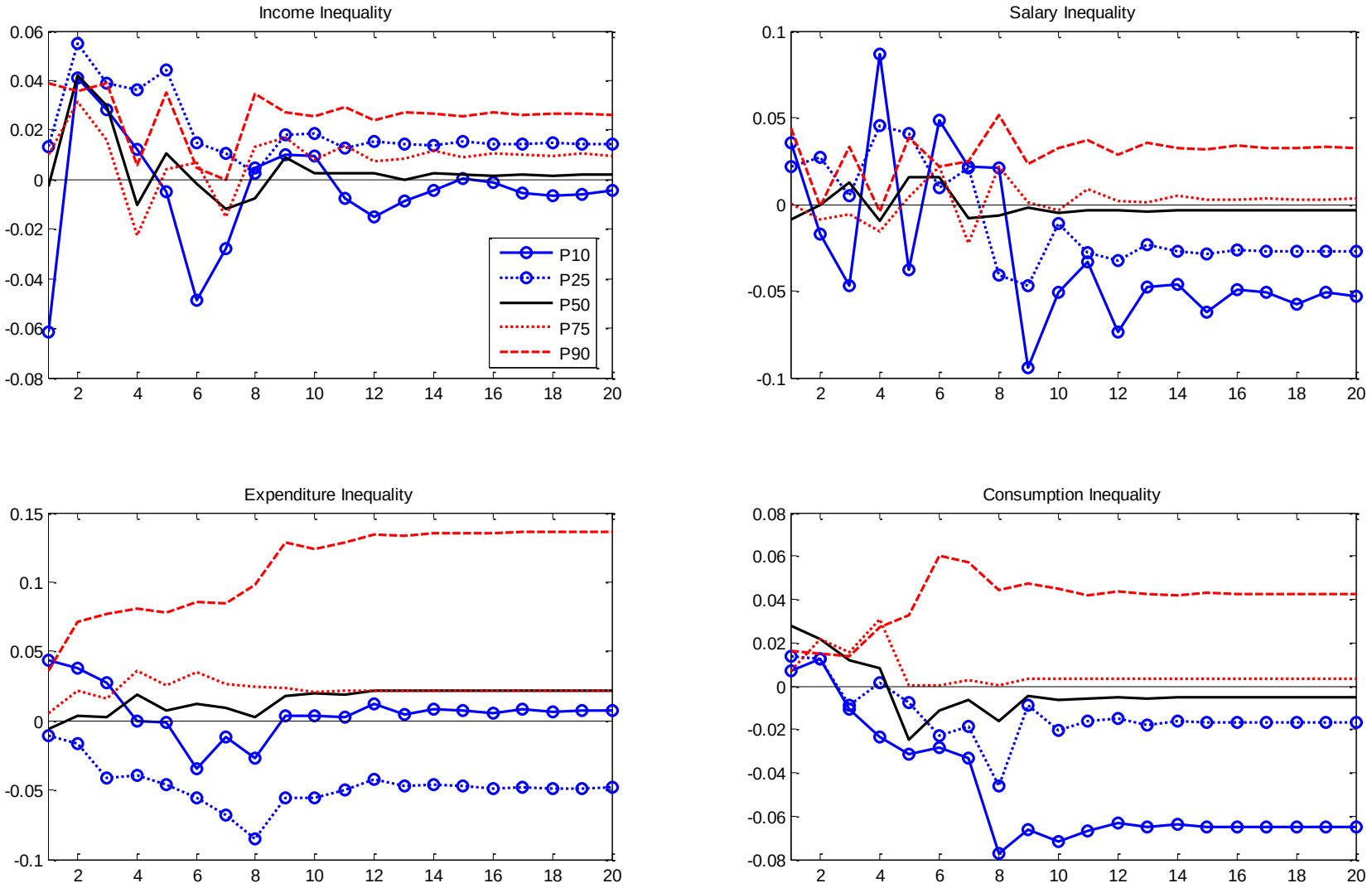
Note: The figure plots monetary policy shocks as identified in Romer and Romer (2004). See section 3.1 for details.

Figure 4: Response of Income, Labor Earnings, Expenditure and Consumption Inequality to a Contractionary Monetary Policy Shock



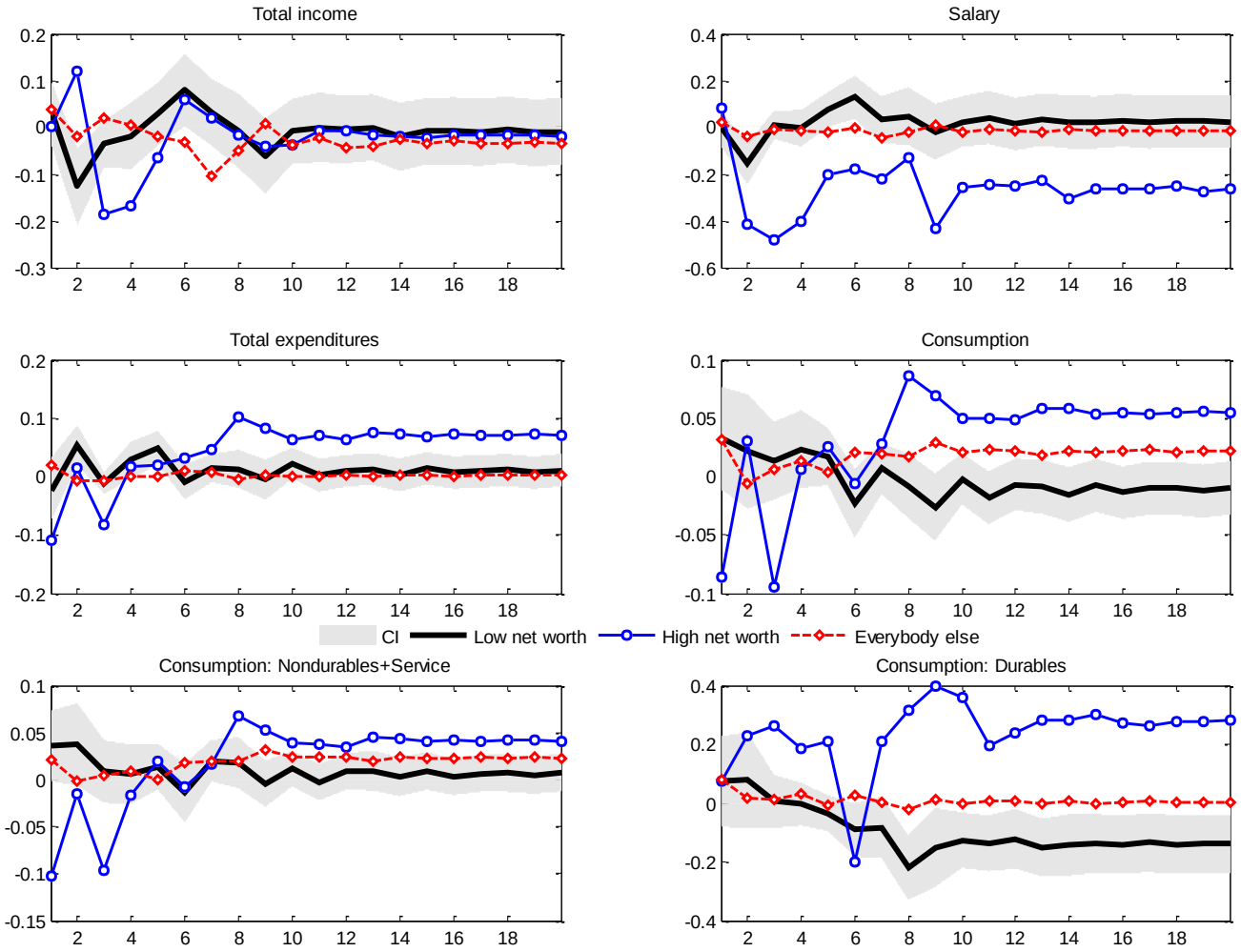
Notes: The figure plots impulse responses of inequality measures for total income (first column), salary income (second column), total expenditures (third column), and consumption (fourth column) in response to a contractionary monetary policy shock. Inequality is measured using the cross-sectional standard deviation (first row), Gini coefficient (second row), and the difference between the 90th and 10th percentiles of the cross-sectional distribution. One standard deviation confidence intervals are represented by the dashed lines. Impulse responses are at the quarterly frequency using data from 1980Q1:2008Q4. See section 3.2 for details.

Figure 5: Responses of Incomes, Earnings, Expenditures and Consumption by Percentile to Contractionary Monetary Policy Shocks



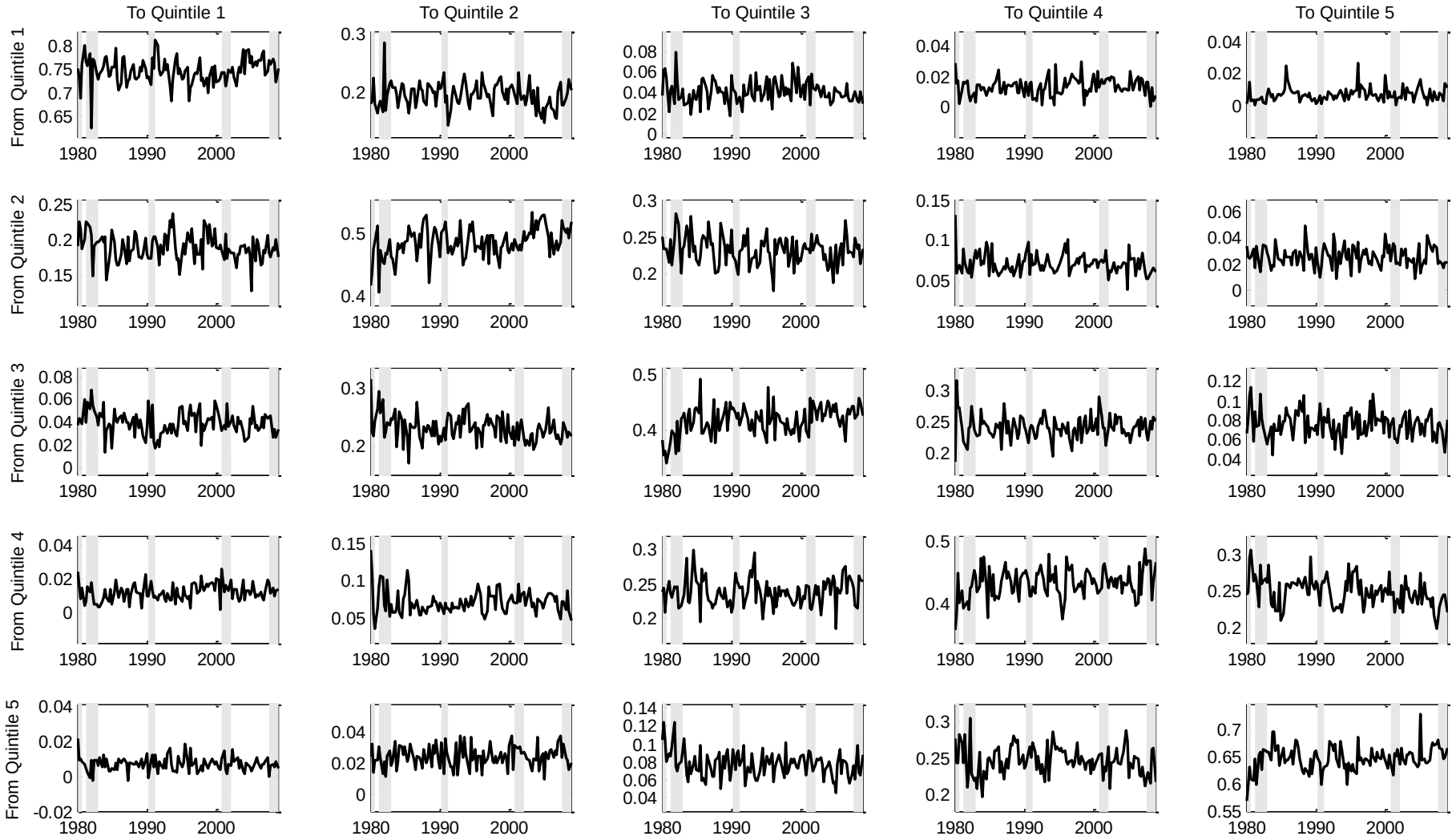
Notes: The figure plots the responses of each percentile of the income, salary, expenditure and consumption distributions of households in the CEX to contractionary monetary policy shocks using data from 1980Q1-2008Q4. P10 corresponds to the 10th (lowest) percentile of each distribution and equivalently for P25, P50, P75 and P90. See section 3.3 for details.

Figure 6: Mean Levels of Income and Spending across Quintiles in the Consumer Expenditure Survey



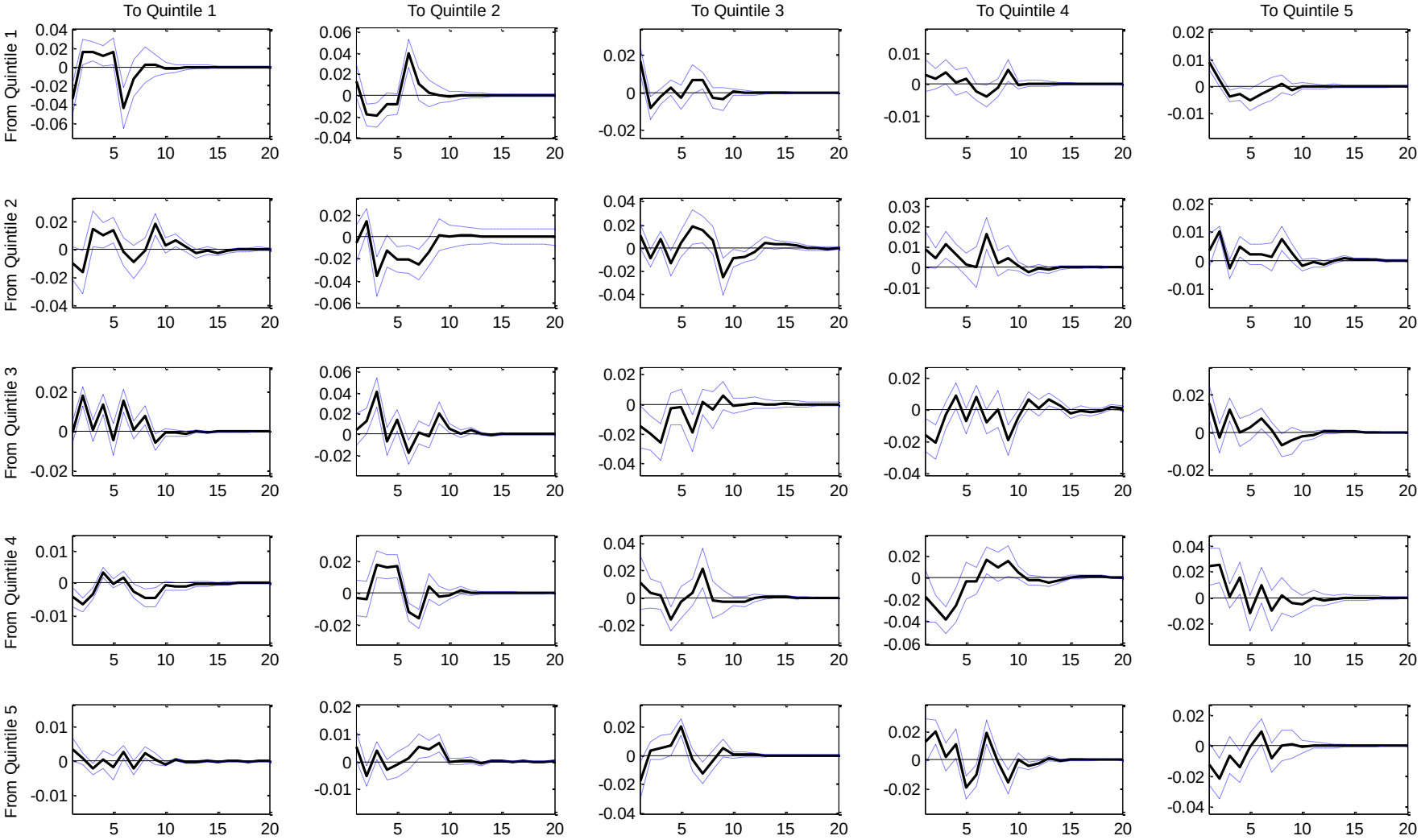
Note: The figure plots the impulse responses of mean measures for three groups of households to a contractionary monetary policy shock: low net-worth households (solid line with grey shaded area for confidence interval), high net-worth households (solid line with circles) and all other households. Definitions of low and high net worth households are in section 3.3 in the text.

Figure 7: Time-Varying Probabilities of Transitioning between Consumption Quintiles



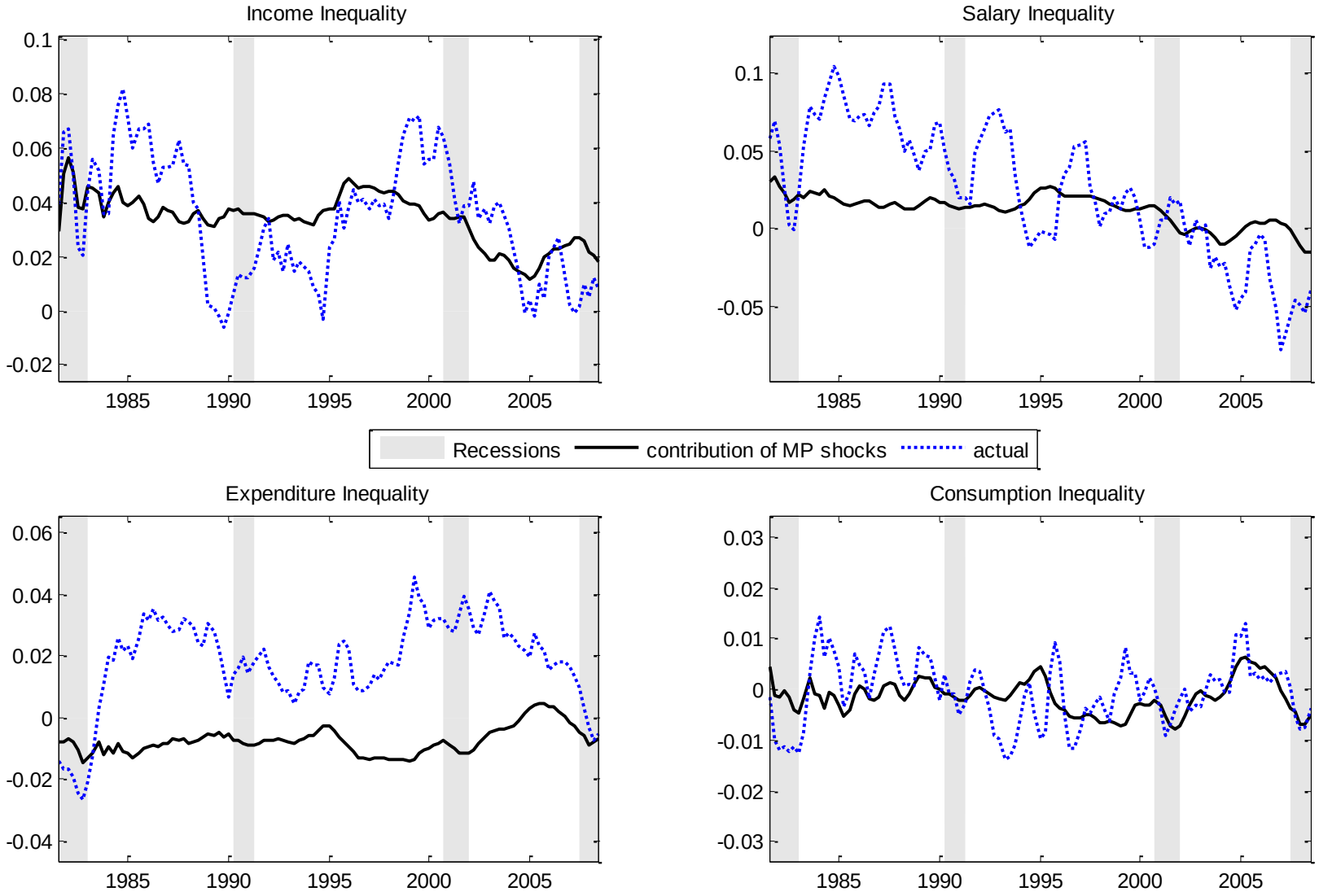
Note: The figure plots the frequency of moving from one quintile (rows) to another quintile (columns) of the consumption distribution in the CEX from 1980Q1 until 2008Q4. Grey shaded areas are U.S. recessions. See section 3.4 for details.

Figure 8: Response of Transition Probabilities to a Contractionary Monetary Policy Shock



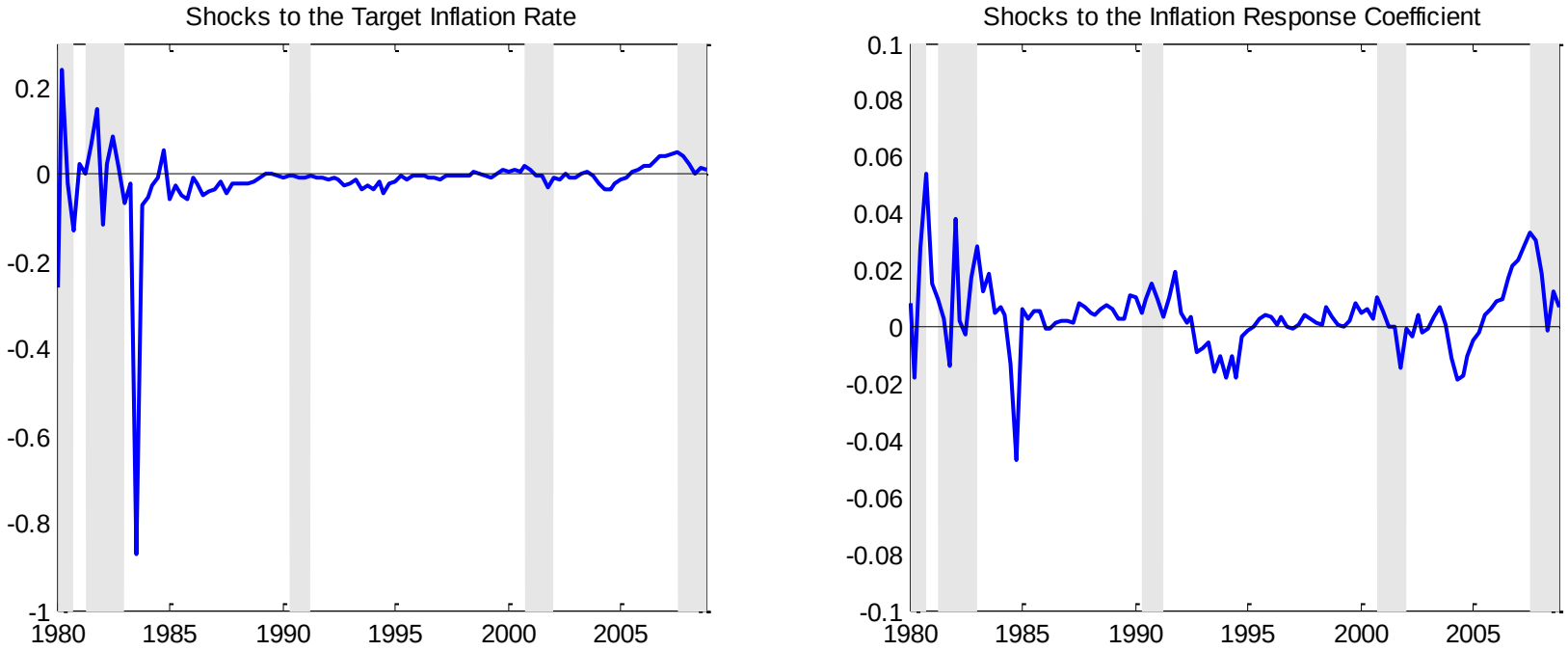
Notes: The figure plots the response of frequencies of moving from one quintile (rows) to another quintile (columns) of the consumption distribution in response to a contractionary monetary policy shock. One standard deviation confidence intervals are indicated by dashed blue lines. See section 3.4 for details.

Figure 9: The Contribution of Monetary Policy Shocks to Historical Variation in U.S. Inequality



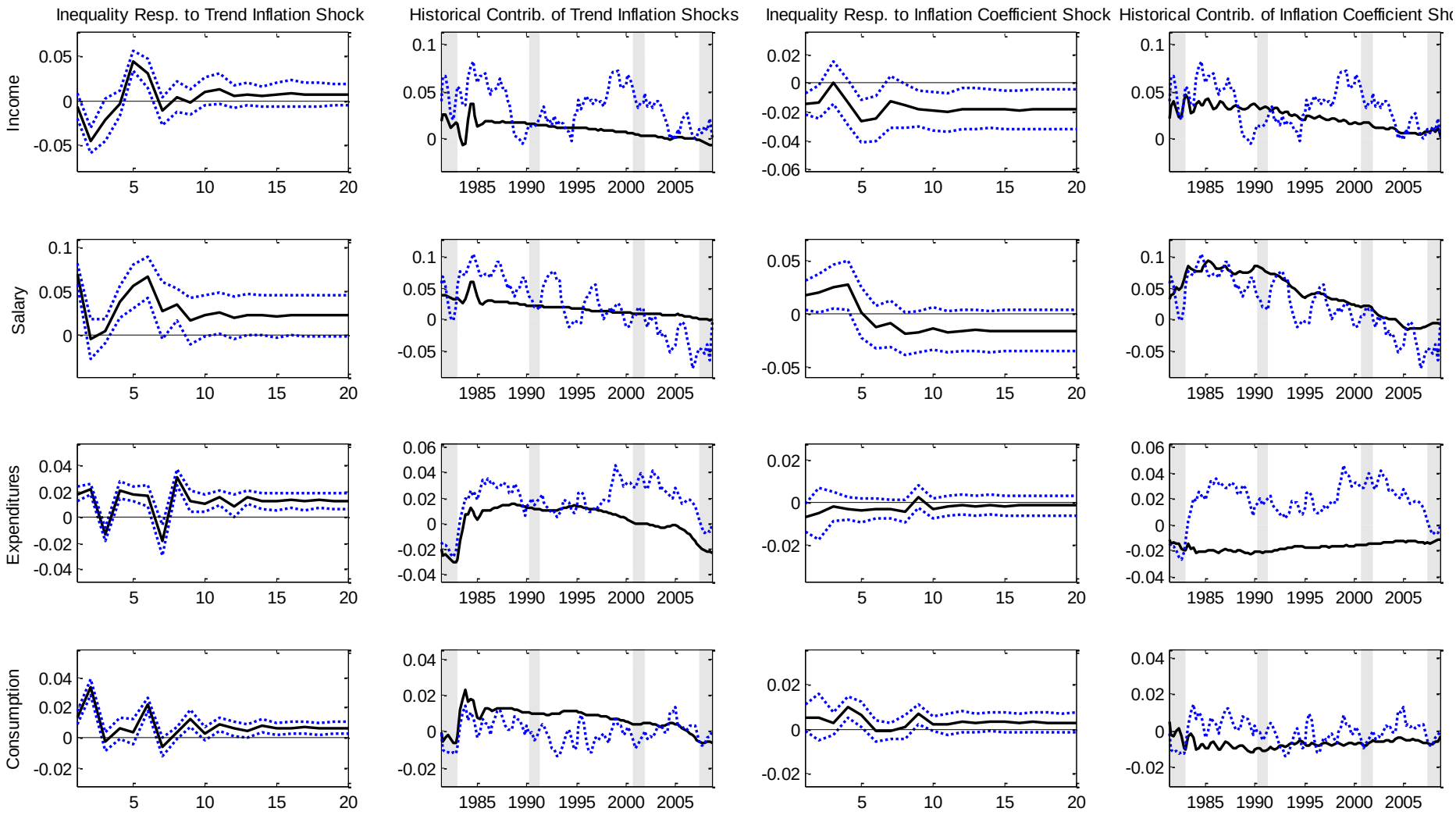
Notes: The figure plots the predicted path of different forms of U.S. inequality due only to monetary policy shocks (solid lines) versus the actual path of inequality measures (dotted lines). Inequality is measured using the cross-sectional standard deviation. Note that both actual and predicted series are normalized by the trend growth of each inequality series and are averaged over previous and subsequent quarter values.. See section 3.5 for details.

Figure 10: Shocks to the Systematic Component of Monetary Policy



Note: The left figure plots estimated shocks to the target rate of inflation while the right figure plots shocks to the central bank's estimated response to deviations of inflation from its target. Both shocks come from estimation of a Taylor rule with time-varying coefficients as in Coibion and Gorodnichenko (2011). See section 4 for details.

Figure 11: Response of Inequality to Alternative Measures of Monetary Policy Shocks



Note: The first and third columns plot impulse responses of inequality measures (standard deviations) to monetary policy shocks: decreases in the target level of inflation for column 1 and an increase in the response to deviations of inflation in column 3, with one standard deviation confidence intervals. The second and fourth columns show the historical contributions of each type of shock to inequality measures. See section 4 for details.

Table 1: Correlations and Volatilities of Inequality Measures

Panel A: Correlations across Inequality Measures			
	Corr(SD,Gini)	Corr(SD,90^{th}-10^{th})	Corr(Gini,90^{th}-10^{th})
Income Inequality	0.91	0.93	0.89
Salary Inequality	0.52	0.85	0.41
Expenditures Inequality	0.89	0.89	0.75
Consumption Inequality	0.63	0.80	0.45
Panel B: Correlations of Inequality in Income, Salary, Expenditures and Consumption			
	SD	Gini	90^{th} -10^{th}
Corr(Income, Salary)	0.22	0.82	0.12
Corr(Income, Expenditures)	0.32	0.50	0.23
Corr(Income, Consumption)	0.14	0.67	0.03
Corr(Salary, Expenditures)	0.26	0.55	0.23
Corr(Salary, Consumption)	-0.05	0.61	0.00
Corr(Expenditures, Consumption)	0.59	0.80	0.42
Panel C: Volatility of Inequality Measures			
	SD	Gini	90^{th} -10^{th}
Income Inequality	0.05	0.02	0.10
Salary Inequality	0.04	0.02	0.13
Expenditures Inequality	0.02	0.01	0.05
Consumption Inequality	0.01	0.01	0.03

Notes: Panel A presents correlation coefficients of inequality in income, salary, expenditures, and consumption across the different measures of each: SD denotes cross-sectional standard deviation, Gini denotes Gini coefficients, and 90^{th}-10^{th} denotes the difference between the 90^{th} and 10^{th} percentiles of the cross-sectional distribution. Panel B presents correlation coefficients between each pair of income, salary, expenditures, and consumption inequality for each approach (SD, Gini or 90^{th}-10^{th}) to measuring inequality. Panel C presents standard deviations of each measure of inequality. All data is from 1980Q1 to 2008Q4.

Table 2: Correlations of Inequality Measures with Macroeconomic Variables

Panel A: Correlation with the Quarterly Inflation Rate

	Corr(π,SD)	Corr(π,Gini)	Corr(π,90^{th}-10^{th})
Income Inequality	-0.12	0.02	-0.05
Salary Inequality	-0.07	-0.16	-0.11
Expenditures Inequality	-0.05	-0.09	-0.04
Consumption Inequality	0.06	0.03	0.03

Panel B: Correlation with the Unemployment Rate

	Corr(UE,SD)	Corr(UE,Gini)	Corr(UE,90^{th}-10^{th})
Income Inequality	0.01	-0.10	-0.02
Salary Inequality	0.00	0.07	0.08
Expenditures Inequality	-0.32	-0.25	-0.22
Consumption Inequality	-0.25	-0.25	-0.26

Panel C: Correlation with the Federal Funds Rate

	Corr(FFR,SD)	Corr(FFR,Gini)	Corr(FFR,90^{th}-10^{th})
Income Inequality	-0.12	-0.09	-0.08
Salary Inequality	-0.08	-0.19	-0.19
Expenditures Inequality	0.00	-0.02	-0.05
Consumption Inequality	0.11	0.09	0.11

Notes: The table presents correlations of income, labor earnings, expenditures and consumption inequality measures with the quarterly chained GDP Deflator inflation rate (π, Panel A), unemployment rate (UE, Panel B), and the Effective Federal Funds Rate (FFR, Panel C). Correlations are done with respect to inequality measured using the cross-sectional standard deviations (first column), the Gini coefficient (second column), and the difference between the 90^{th} and 10^{th} percentiles of the cross-sectional distribution (third column). All series are HP-filtered prior to measuring correlations. The measures of unemployment and the Federal Funds rate are averages over each quarter. All data is from 1980Q1 to 2008Q4.

Table 3: Decomposition of Income by Quintile

Quintiles by consumption of nondurables and services	Share of income source				Ratio of mean consumption of nondurables and services to mean consumption of nondurables and services in the 3rd quintile
	Salary	Business	Financial	Other	
	(1)	(2)	(3)	(4)	(5)
			Panel A: 1980s		
1	0.352	0.022	0.112	0.515	0.42
2	0.588	0.040	0.112	0.260	0.73
3	0.694	0.057	0.096	0.153	1.00
4	0.762	0.059	0.081	0.098	1.34
5	0.767	0.088	0.078	0.067	2.18
			Panel B: 1990s		
1	0.380	0.020	0.106	0.494	0.43
2	0.597	0.040	0.097	0.267	0.73
3	0.704	0.050	0.086	0.160	1.00
4	0.770	0.056	0.071	0.103	1.35
5	0.773	0.082	0.076	0.069	2.27
			Panel C: 2000s		
1	0.435	0.019	0.086	0.460	0.43
2	0.653	0.029	0.085	0.234	0.73
3	0.740	0.037	0.072	0.151	1.00
4	0.801	0.042	0.065	0.092	1.36
5	0.812	0.051	0.071	0.065	2.32

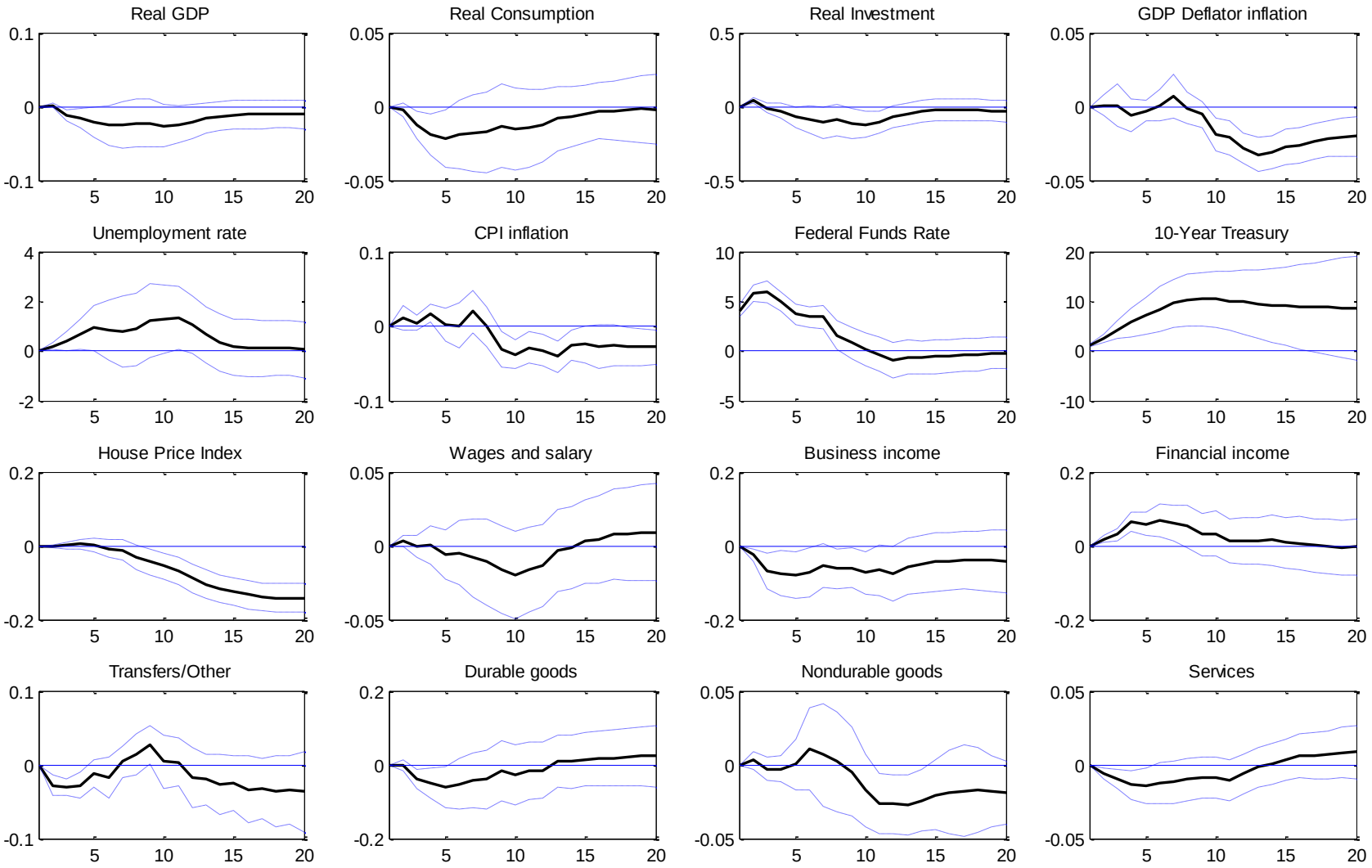
Note: The table presents a decomposition of sources of household income in the CEX by quintile. Households are sorted into quintiles using their consumption levels of nondurables and services. Income categories include labor earnings, business income, financial income, and other sources of income. See section 3.3 in the text for details.

Table 4: Decomposition of Expenditures and Consumption by Quintile

Quintiles by consumption of nondurables and services	Shares in consumption			Selected shares in total spending			Ratio of total spending to consumption of nondurables and services
	Nondurables	Durables	Services	Interest sensitive expenditures	Mortgage payments	Purchases of new vehicles	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Panel A: 1980s			
1	0.697	0.054	0.249	0.098	0.015	0.014	1.84
2	0.681	0.081	0.237	0.163	0.040	0.032	1.85
3	0.665	0.098	0.237	0.196	0.060	0.038	1.84
4	0.651	0.106	0.244	0.235	0.081	0.047	1.85
5	0.611	0.114	0.275	0.260	0.085	0.058	1.83
				Panel B: 1990s			
1	0.655	0.059	0.285	0.113	0.021	0.015	2.13
2	0.637	0.084	0.279	0.175	0.050	0.034	2.08
3	0.631	0.096	0.273	0.215	0.074	0.040	2.03
4	0.613	0.109	0.278	0.246	0.094	0.046	2.02
5	0.567	0.116	0.317	0.267	0.100	0.051	1.91
				Panel C: 2000s			
1	0.630	0.057	0.313	0.120	0.033	0.014	2.23
2	0.620	0.073	0.307	0.182	0.070	0.029	2.12
3	0.613	0.087	0.299	0.217	0.089	0.037	2.12
4	0.599	0.098	0.303	0.256	0.106	0.046	2.10
5	0.541	0.109	0.351	0.278	0.110	0.051	1.99

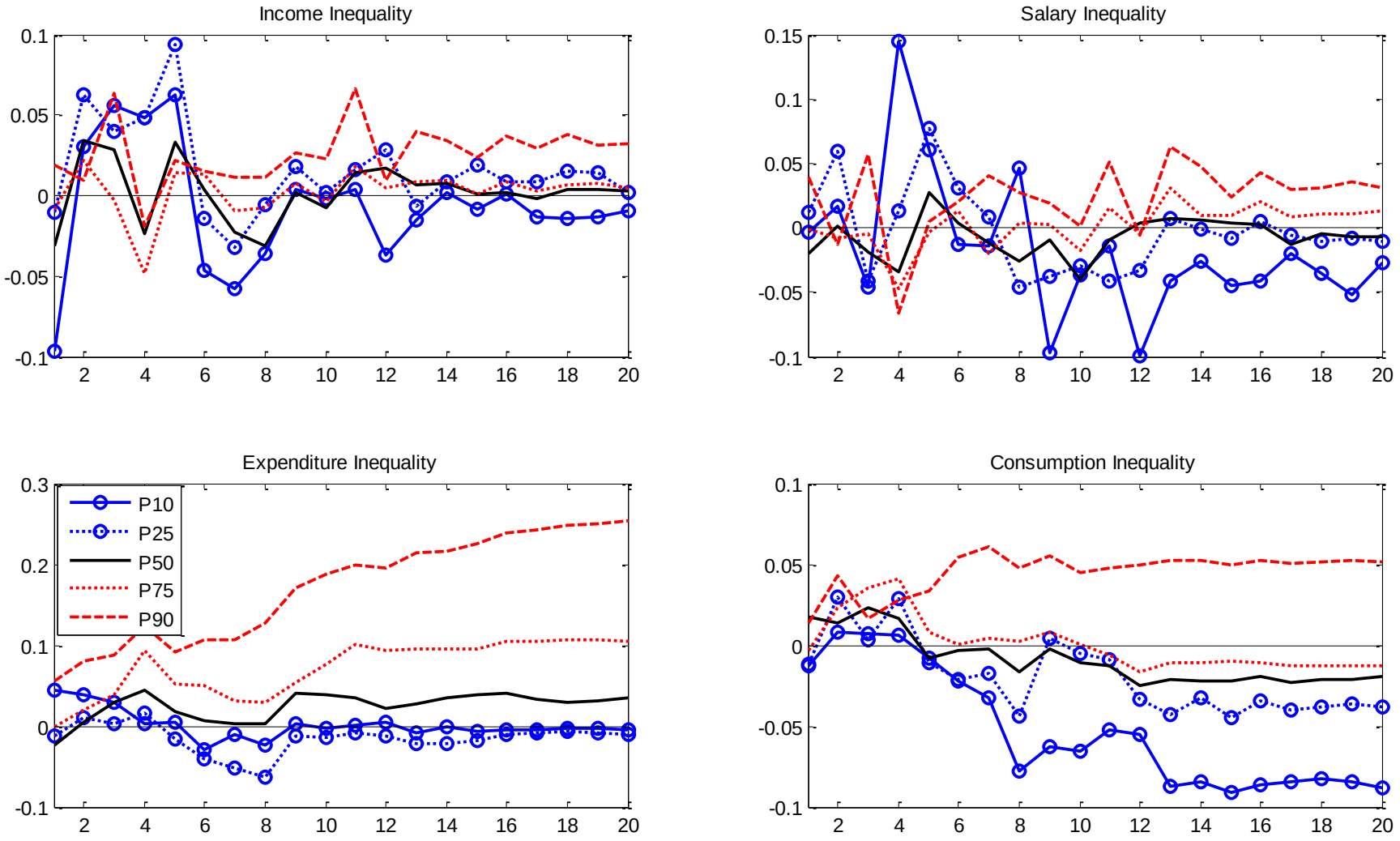
Note: The table presents a decomposition of consumption and expenditures in the CEX by quintile. Households are sorted into quintiles using their consumption levels of nondurables and services. Consumption includes nondurables, services and durables. Total spending is the sum of consumption and other expenditures, including auto purchases, mortgage payments among others. See section 3.3 in the text for details.

Appendix Figure A1: Effects of Monetary Policy Shocks on Macroeconomic Variables



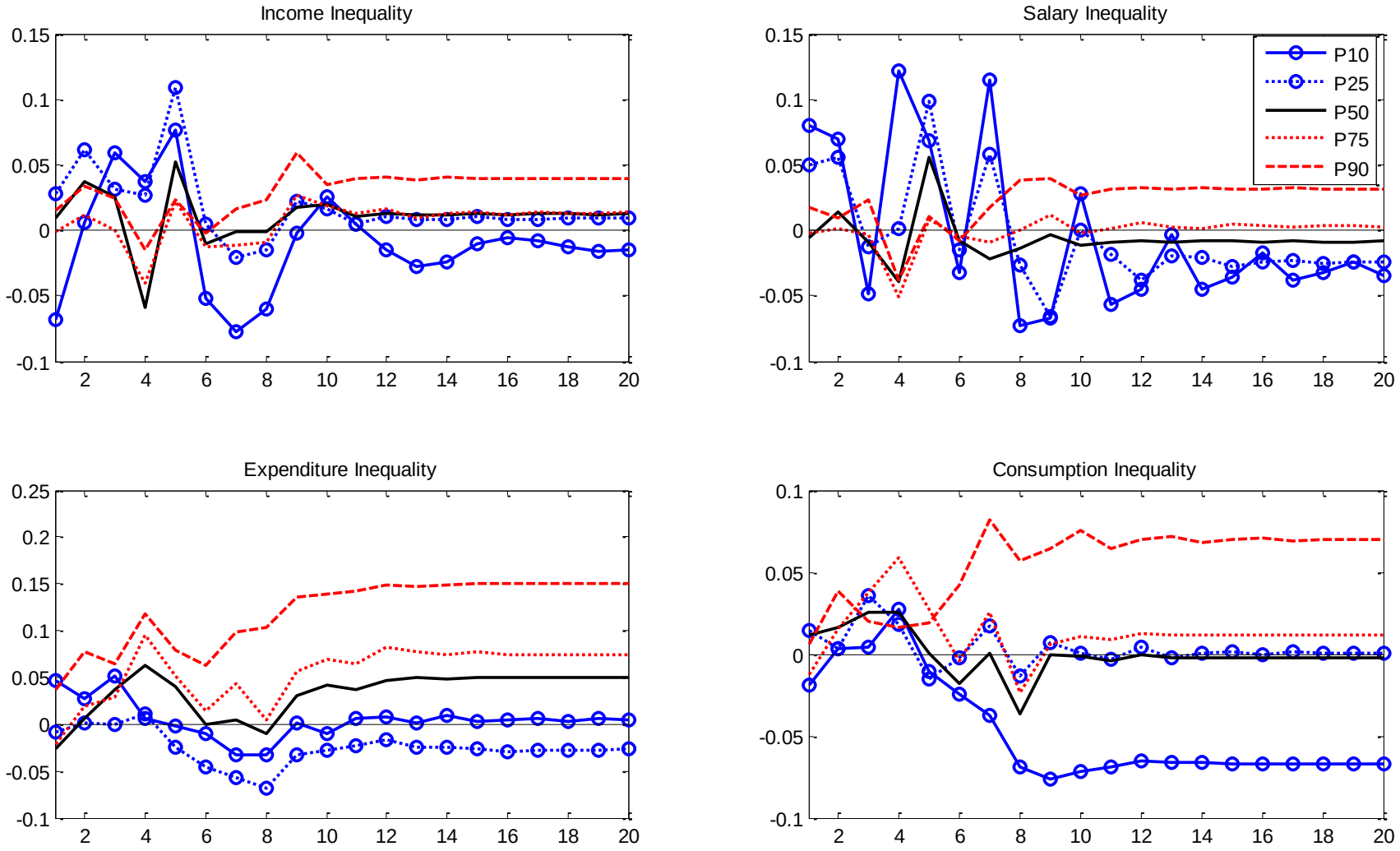
Note: The figure presents impulse responses of macroeconomic variables to monetary policy shocks from 1969Q1 until 2008Q4. One standard deviation bootstrapped confidence intervals are indicted by the dashed blue lines. See section 3.1 for details.

Appendix Figure 2: Robustness of Monetary Policy Shock Responses of Percentiles to Longer Lag Lengths



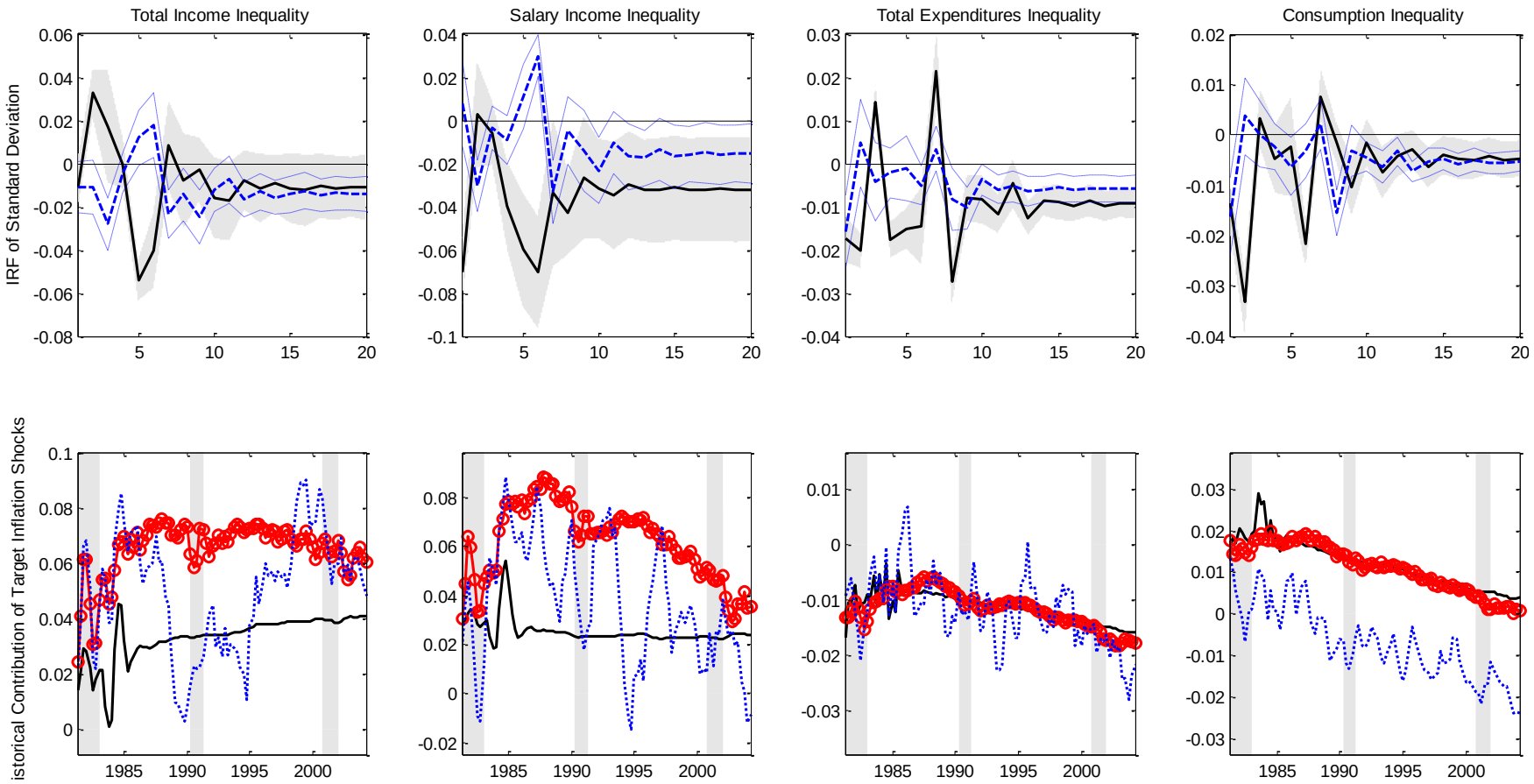
Note: The figure plots the responses of specific percentiles of the income, earnings, expenditure and consumption distributions of households in the CEX to contractionary monetary policy shocks using data from 1980Q1-2008Q4. P10 corresponds to the 10th (lowest) percentile of each distribution and equivalently for P25, P50, P75 and P90. See section 5 for details. Lag lengths are 2 years for AR component and 3 years for MP shocks.

Appendix Figure 3: Robustness of Monetary Policy Shock Responses of Percentiles to Dropping Volcker Disinflation



Note: The figure plots the responses of specific percentiles of the income, earnings, expenditure and consumption distributions of households in the CEX to contractionary monetary policy shocks using data from 1985Q1-2008Q4. P10 corresponds to the 10th (lowest) percentile of each distribution and equivalently for P25, P50, P75 and P90. See section 5 for details.

Appendix Figure 4: Robustness of Target Inflation Shock Responses to Measures of Target Inflation



Note: The top row plots impulse responses of inequality measured using the cross-sectional standard deviation to different measures of positive shocks to the target inflation rate. The solid line gives IRF's to target inflation shocks as in Coibion and Gorodnichenko (2011), with grey shaded areas corresponding to one standard deviation confidence intervals, while dashed lines indicate responses using target inflation shocks from Ireland (2006) with confidence intervals given by light dashed lines. The bottom row plots the estimated historical contribution of target inflation shocks to inequality. The black line is the estimated contribution using Coibion and Gorodnichenko (2011) shocks and the line with circles is the contribution using Ireland (2006) shocks. The dotted line is actual path. All series in bottom row are normalized by the mean growth rate of historical inequality and averaged over previous and subsequent quarter values. See section 5 for details.