Does Monetary Policy Work Through the Labor Market?

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November 11th, 2024

Abstract

This paper examines how heterogeneity in worker substitutability with capital affects the labor income channel of monetary policy. Empirically, workers performing routine tasks see smaller labor income gains than workers performing abstract tasks following a monetary expansion. At the same time, these workers' incomes and assets suggest they have higher marginal propensities to consume (MPC) than other workers. A back-of-the-envelope calculation implies that this relationship dampens the role that the labor market plays in monetary policy transmission by between 22 and 36 percent. I embed capital-task complementarity in a medium-scale HANK model, and find that the model can reproduce the qualitative patterns found in the data. In the model, capital-task complementarity reduces the size of the labor income channel by 25 percent compared to a model with homogeneous labor.

[*]I would like to thank Jennifer La'O and Émilien Gouin-Bonenfant for their continuous support and excellent feedback. I would like to also thank Hassan Afrouzi, Stephen Zeldes, Noémie Pinardon-Touati, several anonymous referees, Joseph Vavra, and seminar participants at Columbia University, the 2022 Econometrics Society North American Meeting, and the 2022 Society for Economic Dynamics Meeting for many helpful comments.

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1 Introduction

A growing literature is reexamining the conventional understanding of how monetary policy stimulates consumption. Instead of emphasizing *direct* transmission through inter-temporal substitution, this literature shows that when households have high marginal propensities to consume (MPC), monetary policy primarily acts *indirectly* by raising household incomes (Kaplan et al., 2018; Bilbiie, 2019 ; Auclert et al., 2020). In several leading quantitative models, consumption due to rising labor income in particular accounts for around half of the overall effect on consumption on impact. If this *labor-income channel* is as important as this literature suggests, trends in the labor market may affect the efficacy of monetary stimulus. In this paper, I explore how one major trend – capital-task complementarity – affects this channel. Specifically, I consider how the covariance between a worker's substitutability with capital and their MPC affects the strength of transmission of monetary policy through the labor market.

Monetary policy can raise workers' labor income both through general equilibrium increases in demand and by spurring capital investment and increasing workers' marginal products. The effect of higher capital is however, unlikely to affect all workers in the same way. Autor and Dorn (2013) argue that the falling cost of capital which automates 'routine' tasks and complements 'abstract' tasks can partially explain labor market polarization. In this context, workers in largely abstract occupations should see their labor income rise in response to monetary stimulus by more than that of workers in 'routine' occupations.[1] If high-MPC households tend to work in routine occupations, then the labor income channel will be dampened, as the households that would actually consume newfound labor income do not see their labor income increase by as much.

To demonstrate this point, I present a variant of a simple spender-saver model in which workers are employed in either abstract or routine occupations. Drawing on the Keynesian Cross-style arguments presented in Auclert (2019), as well as Patterson (2023) and Bilbiie (2019), I show that the size of the labor income channel depends not simply on the average size of income increases and average MPCs, but also on their covariance. I show that this covariance ultimately depends both on (i) the degree to which monetary policy stimulates capital and (ii) the proportion of high-MPC 'spender' households in each occupation group.[2] If capital is highly responsive to monetary policy, 'abstract' workers' labor incomes expand

[1]Using a similar logic, Dolado et al. (2021) introduce capital-skill complementarity into a rich HANK model with search and matching frictions and show that monetary policy can have significant distributional consequences.

[2]Auclert et al. (2020) and Bloesch and Weber (2021) highlight how the response of capital to monetary policy affects the overall labor income response for all workers. Unlike these papers, I consider how the response on capital affects the *difference* between the labor income responses of different workers.

more than those of 'routine' workers, while the opposite is true if capital is unresponsive to monetary policy. If capital is sufficiently responsive therefore, the covariance between labor income responses to monetary policy and MPC – and thus the size of the labor income channel – is decreasing in the fraction of high-MPC households working routine jobs.

Motivated by these predictions, I estimate impulse response functions of labor income to monetary policy shocks for different occupation groups using local projections. I find that, in response to a monetary stimulus, abstract workers' labor incomes increase significantly more than that of other workers and that routine labor incomes actually decline. To show that the mechanism outlined in the simple model is partly responsible for these results, I show that the differences are exaggerated in industries in which capital is highly responsive to monetary policy shocks, and muted in industries in which capital is less responsive. Given these findings, we should expect a relatively muted labor income channel if high-MPC households tend to work in routine occupations while low-MPC households work in abstract occupations. I present evidence that routine workers have lower liquid assets, total assets, and incomes on average. These characteristics are often associated with high MPCs, as households with low incomes and few liquid assets may face tighter borrowing constraints (Johnson et al., 2006; Blundell et al., 2008).

To quantify the effects of these findings on the size of the labor income channel, I use estimates of MPCs for financially constrained and unconstrained households from Kaplan et al. (2014), along with my own estimates of the labor income response to monetary policy by worker type and the share of each type that is financially constrained, to generate a back-of-the-envelope estimate of the size of the labor income channel. Relative to a case where all workers are assumed to experience the average increase in labor income, I find that the labor income channel falls by between 22 and 36 percent.

To show that capital-task complementarity can account for the patterns I observe in the data, I embed this channel into a medium-scale two-asset HANK model that features sticky-wages to ensure that profits, and therefore investments in capital, are pro-cyclical. I calibrate the model so that the incomes and asset positions of each occupation group match my estimates. As a result, routine workers in my model have higher MPCs on average. I calculate the size of the labor income channel in this environment, as well as in a standard two-asset HANK model with homogeneous labor that is otherwise identical. I find that capital-task complementarity reduces the size of the labor income channel by about 25 percent on impact.

Designing effective monetary policy requires understanding the relative strength of different transmission mechanisms and the ways in which they interact with other policies and macro-economic trends. Kaplan et al. (2018) find that RANK models, which rely primarily on 'direct' transmission mechanisms, miss crucial interactions between fiscal and monetary policy. Bloesch and Weber (2021) argue that secular changes in the composition of investment and globalization dampen the transmission of monetary policy to labor income and consumption. The aim of this paper is to highlight another important way in which a secular macroeconomic trend - growing capital-task complementarity - may affect monetary policy transmission. If high-MPC routine workers have become more substitutable with capital during the last several decades, monetary policy may have become less effective over time as a result.

This paper contributes to the literature studying monetary policy transmission in HANK models (McKay et al., 2016, Kaplan et al., 2018, Luetticke, 2018, Bilbiie, 2019, Hedlund et al., 2017). In particular, this paper furthers the small but growing literature examining the transmission of monetary policy through the labor market. Kaplan et al. (2018) and Auclert et al. (2020) explicitly decompose the impact of monetary policy into its component parts and find that the partial equilibrium response of consumption to higher wages makes up around half of the overall consumption response. In a subsequent paper, Alves et al. (2020) show that when capital adjustment costs are introduced, the labor income channel falls to about a third of the overall effect on consumption, still a significant contribution.[3] I show that accounting for capital-task complementarity has a significant impact on the size of this channel.

This paper also contributes to the substantial body of research that documents the presence and effects of heterogeneity in workers' elasticity of substitution with capital. Krusell et al. (2000) study the long-run growth of the wage premium for skilled labor in a model in which low-skill workers have a higher elasticity of substitution with capital equipment. Autor and Dorn (2013) present a model with heterogeneity in capital-labor substitutability based on an occupation's routine task content, rather than a worker's skill level, in order to explain the polarization of the US labor market. Eden and Gaggl (2018) also distinguish between routine and non-routine labor, and use a model with capital-task complementarity in order to explain the decline in the labor income share. I show that capital-task complementarity has short run implications for the efficacy of monetary policy in addition to long-run implications for the labor market.

Finally, this paper contributes to the literature studying whether the economy has become less responsive to traditional monetary policy shocks. Boivin et al. (2010a) document a more muted effect of monetary policy on real activity and inflation. Cao and Willis (2015) report that aggregate employment is less sensitive to monetary policy shocks. Bloesch and Weber (2021) show that changes in the composition of investment and a rising import share of

[3] In their paper, Alves et al. (2020) group together the effect of labor income and transfers, meaning that the labor income channel is likely less than a third of the overall effect.

investment goods dampen the transmission of monetary policy to domestic labor income. This paper offers a novel mechanism that may contribute to these trends.

The rest of the paper proceeds in the following way. Section 2 analyzes a variant of a simple two-agent model with heterogeneity in workers' elasticities of substitution with capital. Section 3 presents my empirical results. Section 4 presents the medium-scale HANK model and quantitative results. Section 5 concludes.

2 Simple Model

In this section, I introduce heterogeneity in workers' elasticity of substitution with capital into an otherwise very simple two agent model with fixed prices and capital adjustment costs. I solve for the demand of each type of labor as a function of total output, which gives an expression for how the labor income of both types of workers responds to an increase in output, a crucial ingredient when solving for the aggregate consumption response to a monetary policy shock (Auclert, 2019; Bilbiie, 2019). I show that the labor income channel - the portion of the consumption response to monetary policy attributable to rising labor income - depends on (i) the responsiveness of capital to monetary policy, and (ii) the covariance between a worker's marginal propensity to consume (MPC) and their substitutability with capital.

Intuitively, capital-labor substitutability determines how firms' demand for workers changes as they expand output. When capital adjustment costs are very high, firms are unable to increase capital and must instead disproportionately employ substitutable "routine" workers. When adjustment costs are very low, firms increase capital as they expand production, substituting out routine workers and increasing their relative demand for abstract workers. In contexts where capital is relatively responsive, the more high-MPC workers are concentrated in routine occupations, the smaller the labor income channel and the overall response of consumption. That is, when households who tend to consume new income don't see their labor income rise by very much as the economy expands, the crucial 'Keynesian Cross' feedback mechanism is dampened.

2.1 Environment.

Households. Households differ along two dimensions: their access to financial markets and their worker type. Households can be either unconstrained savers (u) or constrained spenders (c) and can work in either a routine (R) or an abstract (A) occupation. Savers own shares in the firm, receive dividends, and save in a one-period government issued bond, B_t with return

r_t. Spenders are fully financially constrained and therefore consume their entire income every period. I define λ_{ij} as the fraction of households of worker type i and financial market access j.

All households have the same separable utility function over consumption, c_t^{ij} and labor, n_t^{ij}. The per-period utility of a household with type ij is given by:

$$U(c_t^{ij}, n_t^{ij}) = \frac{(c_t^{ij})^{1-\theta}}{1-\theta} - \frac{(n_t^{ij})^{1+\nu}}{1+\nu}$$

Unconstrained savers all own proportional shares of the firm and choose consumption, labor, and bonds to maximize their infinite expected discounted stream of per-period utility subject to their budget constraint. The saver's problem is given by:

$$\max_{c_t, B_{t+1}, n_t} \sum_{t=0}^{\infty} \beta^t E_0[U(c_t^{iu}, n_t^{iu})]$$

$$s.t.\ c_t^{iu} + \frac{B_{t+1}^{iu}}{1+r_t} \leq w_t^i n_t^{iu} + B_t^{iu} + T_t^{iu} + D_t \tag{1}$$

Here T_t^{ij} is the lump-sum tax/transfer levied by the government on type-ij households and D_t is share of dividends issued by the firm to savers. The first order conditions for savers in occupation i are standard and are given by:

$$n_t^{iu} = \left(w_t^i (c_t^{iu})^{-\theta}\right)^{\frac{1}{\nu}} \tag{2}$$

$$1 = \beta(1+r_t) E_t \left(\frac{c_t^{iu}}{c_{t+1}^{iu}}\right)^{\theta} \tag{3}$$

Because constrained households have no access to the bond market, $c_t^{ic} = w^i n_t^{ic} + T_t^{ic}$. Labor supply for constrained households is analogous to that of unconstrained households. I consider the case where θ is equal to 0, eliminating any income effects in the labor supply decision and ensuring the same labor supply for all workers in a given occupation. This will allow me to solve for simple analytical expressions despite the introduction of worker heterogeneity, however the spirit of the results holds more generally in the larger model.

Firms. There are a continuum of firms who employ labor and capital and produce the consumption good. Firms set prices to maximize profit. However, firms are subject to infinite price adjustment costs, and therefore the firm's pricing decision is trivial and prices are constant. I normalize the price level to 1. Firms hire both abstract and routine labor and take their respective wages w_t^A and w_t^R, as given. Firms invest in capital subject to a per-period investment cost, K_t^μ. Capital can be used contemporaneously and fully depreciates every period. Because no inter-temporal pricing or investment decisions are present in this setting, the firms' per-period problem is simply given by:

$$\max_{N_t^A, N_t^R, K_t} y_t - w_t^R N_t^A - w_t^R N_t^R - K_t^\mu \tag{4}$$

Each firm has a nested CES production function in which the elasticity of substitution between capital and abstract labor (σ_A) is less than 1 while that of routine labor (σ_R) is greater than 1, meaning abstract labor is a gross complement to capital, while routine labor is a gross substitute.

$$y_t = Z_t\left(\alpha_A N_t^{A\frac{\sigma_A-1}{\sigma_A}} + (1-\alpha_A)\left(\alpha_R N_t^{R\frac{\sigma_R-1}{\sigma_R}} + \alpha_K K_t^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}}\right)^{\frac{\sigma_A}{\sigma_A-1}}$$

The firms' first order conditions are then given by:

$$\frac{w_t^R}{w_t^A} = (1-\alpha_A)\left(\alpha_R N_t^{R\frac{\sigma_R-1}{\sigma_R}} + \alpha_K K_t^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}-1} \frac{\alpha_R N_t^{R\frac{-1}{\sigma_R}}}{\alpha_A N_t^{A\frac{-1}{\sigma_A}}} \tag{5}$$

$$\frac{\mu K_t^{\mu-1}}{w_t^R} = \frac{\alpha_K}{\alpha_R}\left(\frac{N_t^R}{K_t}\right)^{\frac{1}{\sigma_R}} \tag{6}$$

Fiscal and monetary policy. The fiscal authority levies a lump-sum tax/transfer on households, T_t^{ij} that it finances by issuing 1-period bonds with rate of return r_t. The fiscal authority's balanced budget constraint is given by $\frac{B_{t+1}}{1+r_t} = B_t + \sum_{i,j} T_t^{ij}$. The monetary authority sets nominal interest rates, which are equivalent to real interest rates r_t, in this fixed-price context.

2.2 Capital and the Response of Labor Income to Output.

Combining the firm's first order conditions with the households' labor supply condition and letting $\alpha_K = 1 - \alpha_R$ results in an expression for abstract wages as a function of routine wages in equilibrium. Plugging these expressions back into the production function gives an expression for routine wages (and therefore abstract wages) as a function of total output in equilibrium. Taking the derivative of w_t^A with respect to w_t^R give the *relative* response of abstract labor to routine labor. Assuming that ν is both bounded and greater than 0, and that $0 < \sigma_A < 1 < \sigma_R$, results in the following proposition.

Proposition 1 *If $\sigma_A < 1 < \sigma_R$ and ν is bounded and positive, then there exists a capital adjustment cost parameter μ^* such that for all $\mu < \mu^* \rightarrow \frac{\partial w_t^A}{\partial w_t^R} > 1$ and abstract labor is more responsive to increases in output than routine labor. Furthermore, the difference between the labor income response of abstract and routine workers is decreasing in μ.*

The proof of this proposition can be found in Appendix A.1.1. Intuitively, the parameter μ represents capital adjustment costs and governs how responsive capital is to an increase in production. As μ approaches 0, capital costs decrease and firms employ a larger amount of new capital as they expand. This leads firms to demand disproportionately more complementary abstract labor. The opposite is true as μ increases. Therefore, the responsiveness of capital to increases in output following a monetary policy shock governs how both types of worker benefit from the expansion.

2.3 The Labor Income Channel.

Next, I derive an expression for the total effect of an interest rate shock on consumption Ω, and the labor income channel Ω_L. Aggregate consumption is simply the weighted sum of the consumption of the four household types. Consumption for unconstrained savers c_t^{iu} is a function of their current income y_t^{iu}, their expected future income, and the interest rate r_t. Consumption for constrained spenders is simply equal to their income y_t^{ic}. The total immediate effect of a one-time interest rate change on aggregate consumption $\frac{dC_0}{dr_0}$, can be decomposed into *direct* and *indirect* effects as in Kaplan et al. (2018) and Auclert (2019).

$$\Omega = dC_0 = \sum_{t=0}^{\infty} \frac{\partial C_0}{\partial Y_t} dY_t + \frac{\partial C_0}{\partial(-r_0)} dr_0 \tag{7}$$

The indirect effects can be further decomposed into the weighted sum of the effects attributable to each type of worker.

$$\frac{\partial C_0}{\partial Y_t} dY_t = \sum_i \sum_j \lambda_{ij} \frac{\partial c_0^{ij}}{\partial y_t^{ij}} \frac{\partial y_t^{ij}}{\partial Y_t} dY_t$$

Finally, I define the labor income channel Ω_L as the partial equilibrium effect of an interest rate change on consumption resulting from an increase in labor income only, keeping dividends, interest rates, and fiscal policy constant. For simplicity, I focus on the change in consumption resulting from a change in contemporaneous labor income, but the results below apply to changes in contemporaneous consumption resulting from changes in labor income at all horizons. Here, $\frac{\partial c_0^{ij}}{\partial y_0^{ij}}$ is the marginal propensity to consume for worker type ij.

For savers, this is small and approximately equal to $1-\beta$, whereas for spenders it is equal to 1 by construction.

$$\Omega_L = \sum_i \sum_j \lambda_{ij} \frac{\partial c_0^{ij}}{\partial y_0^{ij}} \frac{\partial w_0^i n_0^{ij}}{\partial Y_0} dY_0 \tag{8}$$

As several other papers have demonstrated, this expression can be written as the sum of the product of the average labor income response $d\bar{N}W$, and the average MPC, $M\bar{P}C$, and the *covariance* between MPC and $\frac{\partial w_t^i n_t^{ij}}{\partial Y_t}$ (Patterson (2023); Auclert (2019)). A proof of this can be found in Appendix A.1.2.

$$\Omega_L = M\bar{P}C\, d\bar{W}N + Cov\left(MPC^{ij}, \frac{\partial w^i n^{ij}}{\partial Y} dY\right) \tag{9}$$

Given Proposition 1, this leads to the following proposition.

Proposition 2 *When $\mu < \mu^*$, the labor income channel Ω_L is decreasing in the proportion of constrained households working in routine occupations, λ_{cR}.*

A proof of this proposition is given in Appendix A.1.3. Recall that when capital adjustment costs are sufficiently small, and therefore capital is sufficiently responsive, abstract workers benefit more than routine workers as firms expand output. Therefore, as the proportion of high-MPC constrained households working in routine occupations increases, the the covariance between MPC and the labor income response to monetary policy decreases, lowering the labor income channel.

3 Empirics

Several papers have documented heterogeneity in the elasticity of substitution between capital and labor.[4] In the previous section, I showed that workers who are relatively more complementary with capital will benefit more from an expansionary monetary policy shock than substitutable workers if capital is sufficiently responsive to the shock. If this is the case, we should expect the labor income channel to be smaller if MPCs tend to co-vary with capital substitutability.

I this section, I present evidence that both of these statements are supported by the data. First, I estimate the impulse response of the labor income of different types of workers to identified monetary policy shocks. I find that the labor income of abstract workers is significantly more responsive than that of routine workers, whose response is actually negative.

[4]For examples see Krusell et al. (2000) or Autor and Dorn (2013).

The labor income of manual workers - who are presumably neither strong substitutes nor complements to capital - appears to be unaffected by monetary stimulus.

To demonstrate that the mechanism outlined in Section 2 is partially responsible for this difference, I break each occupation group into 2 industry-based subgroups based on whether capital is highly responsive to monetary policy in that industry. I find that the difference between the response to monetary policy of the labor income of abstract and routine workers is exaggerated in industries in which capital is highly responsive, and muted in industries in which capital is less responsive, providing suggestive evidence in support of my mechanism.

I then use data from the Survey of Consumer Finances to calculate median liquid asset holdings, total asset holdings, household income, age, and the probability of being hand-to-mouth by the occupation group of the primary respondent.[5] These variables were chosen because each has been shown to predict a household's MPC. Low levels of liquid assets, total assets, and income, as well as being younger are associated with higher MPCs.[6] I find that while the median age of routine and manual workers is within a few years of the median age of abstract workers, liquid asset holdings, total asset holdings, and family income are significantly lower for routine and manual households when compared to abstract households. Abstract households were also significantly less likely to be 'hand-to-mouth'. This suggests a *negative* covariance between the response of labor income to monetary policy and household MPC.

Finally, I combine the estimates of the labor income response to monetary policy for each worker type and the share of each type which is hand-to-mouth with estimates of MPCs from Kaplan et al. (2014) to get a back-of-the-envelope estimate of the impact on the labor income channel.

3.1 Data

The Current Population Survey is a monthly household survey conducted by the Bureau of Labor Statistics. Each household is interviewed for 4 consecutive months then interviewed again after 8 months for another 4 consecutive months. In the 4th and 8th interview, households are asked specific questions related to earnings and hours. Extracts including these interviews are known as the 'Outgoing Rotation Groups' (ORG). I use CPS ORG data from 1979 through 2007. I restrict my sample to civilian non-farm workers between 25 and 65 who report being in the labor force. I drop self-employed workers and those working in the public sector, as presumably these workers face unique employment and earnings dynamics.

[5] Also known as the 'reference person' or 'household head'. The definition for hand-to-mouth comes from Kaplan et al. (2014).

[6] See Johnson et al. (2006) and Blundell et al. (2008). Here I define liquid assets as in Kaplan et al. (2014).

Additionally, I drop the last 3 months of 2002 and the first 3 months of 2003 from my sample, due to a large and unexplained spike in households who originally reported working in an abstract occupation in their 4th interview, then reporting a routine occupation in their 8th interview.[7]

The CPS-ORG has 3-digit occupation codes that are inconsistent over time. Crosswalks exist linking the codes across time, however the resulting groups are unbalanced in the sense that certain occupations (for example economics professors) migrate across groups over time (Dorn (2009), Autor (2015)). To correct for this, I use David Dorn's updated occupation classification.[8] My 3 dependent variables are real hourly wages (which the CPS imputes for salaried workers), total employment, and total weekly labor income, the product of total weekly hours and real hourly wages, summed across occupation group. All calculations use outgoing rotation group weights.

Following Autor and Dorn (2013), an occupation is considered routine if it falls into the top weighted third of the routine task intensity (RTI) score distribution. To construct the score, the log of an occupation's abstract and manual task content are subtracted from the log of its routine task content. Data for task content comes from David Dorn's website.[9] I extend this methodology to abstract and manual occupations as well. This conveniently divides the occupations into 3 disjoint groups of approximately similar size.

To construct the task content measures, Autor and Dorn (2013) merge job task requirements from the fourth edition of the US Department of Labor's Dictionary of Occupational Titles (DOT) (US Department of Labor 1977) to their corresponding Census occupation classifications to measure task content by occupation. The DOT provides 5 task definitions, summarized by Autor et al. (2003). They group these together into 3 summary measures following Autor et al. (2006). Their routine task measure is a simple average of an occupation's DOT score for "finger dexterity" and setting "limits, tolerances, and standards", both of which capture occupational tasks that may be easily automated. Summary statistics for each occupation group as well as the most frequent occupations in each group can be found in Table 1.

Data used to construct the financial variables comes from the Survey of Consumer Finances (SCF). The SCF is a triennial household survey with detailed information on household balance sheet information. Because the full dis-aggregated occupation codes are not

[7]While I explicitly consider the role of occupational transitions later in the paper, these months have transition rates into(out of) routine(abstract) employment that are between 5 and 6 times the average transition rate for the rest of the sample, suggesting they may be the result of a change in occupation classification rather than an occupational change.

[8]Crosswalks linking the CPS codes to Dorn's codes can be found on his website. See https://www.ddorn.net/data.htm for details.

[9]See https://www.ddorn.net/data.htm for details.

available in the public dataset, I grouped workers into occupation groups based on the aggregated occupation groups that were available in the public dataset. More details on this procedure are given below.

TABLE 1

	1980			2007		
	Abstract	Routine	Manual	Abstract	Routine	Manual
Most Frequent Occupation	Manager, Sales, Accountant	Secretary, Machine-operator	Truck driver, Laborer, Health aide	Manager, Sales-Supervisor	Secretary, Machine-operator	Truck driver, Laborer, Health aide
Average Real Wage	26.18 (16.01)	18.52 (8.75)	21.25 (12.71)	32.17 (22.22)	18.95 (11.04)	22.44 (15.66)
Average Age	41	40	40	43	42	42
Fraction College	0.36	0.08	0.14	0.51	0.14	0.23
Fraction Female	0.32	0.58	0.31	0.44	0.56	0.37
Observations	38,113	48,880	38,876	50,009	36,730	43,450

Note: this table reports summary statistics for the three occupation groups using the CPS MORG data. All statistics are calculated using outgoing rotation group sample weights. Real wages were calculated using 2019 dollars. Standard deviations are shown in parenthesis.

3.2 Estimating Earnings Elasticities

In order to test the hypothesis that the labor income of substitutable workers is less responsive to expansionary monetary policy, I estimate impulse response functions for log aggregate weekly labor income, log average real wages, and log total employment by occupation group, using Jordá projections and Romer and Romer shocks (Jordà, 2005; Romer and Romer, 2004).[10] To form the occupation groups, I split the sample into abstract, routine, and manual occupations using Autor and Dorn's routine task intensity (RTI) score as described above. In addition to 12 lags of the dependent variable, I control for 12 lags of the federal funds rate as well as a quadratic time trend. Ninety-percent confidence bands are calculated with Newey-West standard errors.

[10] Here I am using the updated version of the Greenboook forecast series from Wieland and Yang (2020) and following Coibion (2012), I estimate the shock series using GARCH.

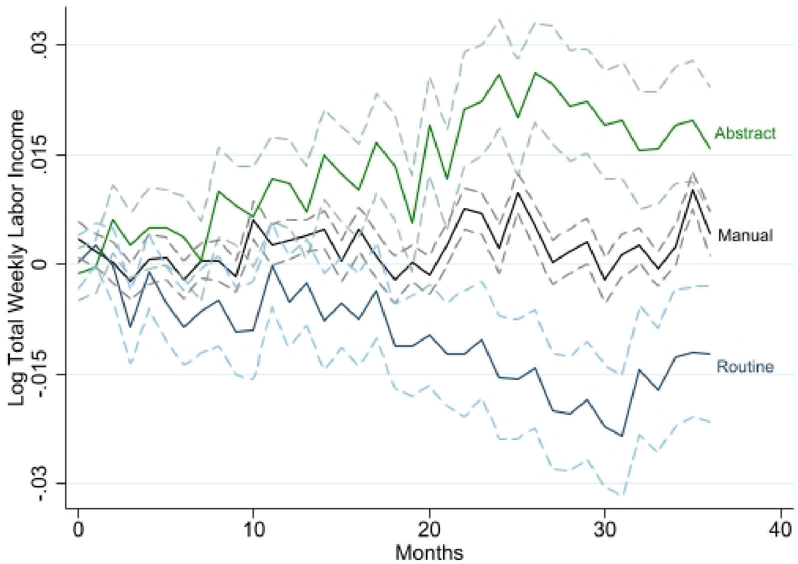

Figure 1: Response of Log Total Weekly Labor Income to Monetary Policy Shock

Notes: This figure reports the impulse response of log total average weekly labor income by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors.

The impulse response of log total weekly labor income to a 25 basis point expansionary (negative) exogenous monetary policy shock is reported in Figure 1. As is clear from the figure, abstract workers – those who are presumably gross complements with capital – see their total labor income increase starting at around 15 months after the shock and peaking at about 2.5 percent. Manual workers, see essentially zero change in their total labor income, while routine workers see a substantial decline.

Because a group's total weekly labor earnings is the weighted sum of all employed workers' labor earnings, changes in this variable capture both the extensive and intensive margin. To see the effects of the two separately, I estimate the impulse response of log real hourly wages and log employment. The results are reported in Figure 2. As is clear from the figure, the effect on total weekly labor income can largely be attributed to the extensive margin (changes in employment) rather than changes in the real wage, however routine workers do see a .8 percent peak decline in their average real wage, while abstract workers see a .8 percent peak increase. The response of hours are very modest for all workers, and can be found in Appendix A.2.

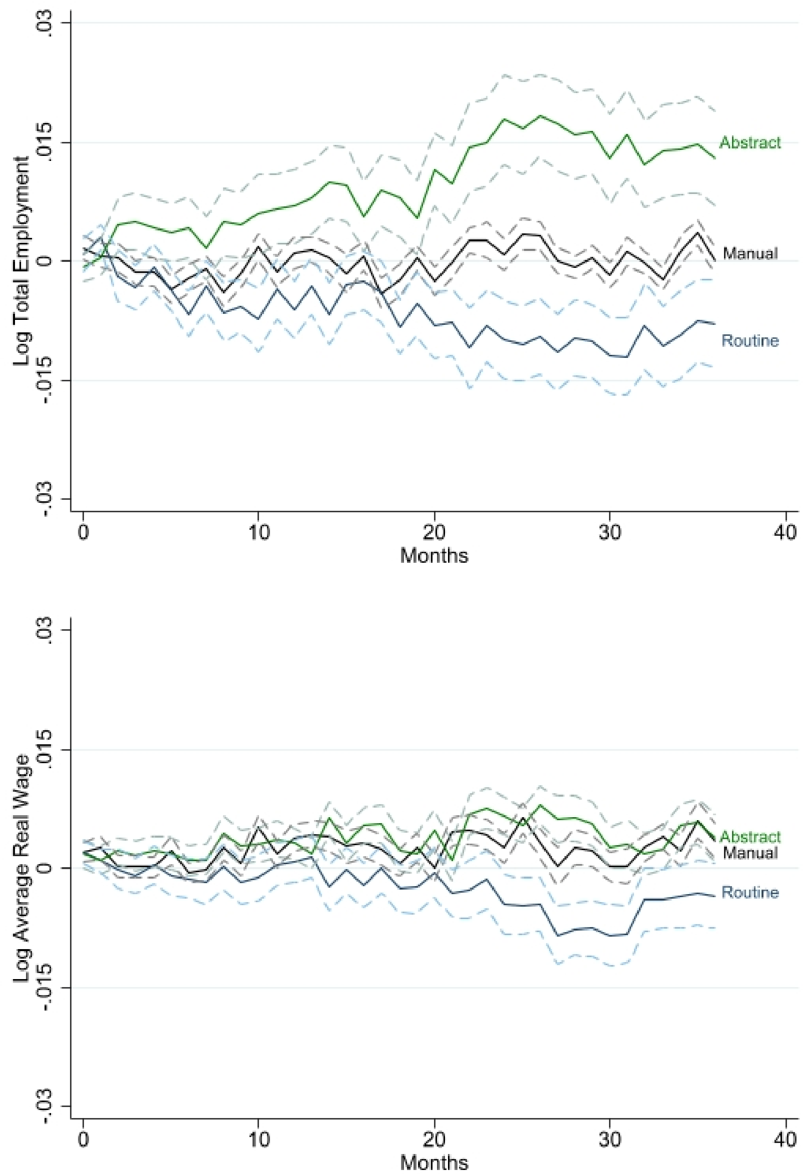

Figure 2: Log Total Employment (top) and Log Average Hourly Wage (bottom)

Notes: This figure reports the impulse response of log total employment and log average real wages to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors.

3.2.1 Robustness.

I perform a series of robustness checks to the main specification. The baseline results reported in Figure 1 may be sensitive to the assumed lag structure of both the shock and controls, as well as the time period being studied. In particular, Coibion (2012) finds that excluding the period between 1979 and 1982, in which the Federal Reserve abandoned federal funds rate targeting, can substantially alter impulse response functions estimated using Romer and Romer shocks.[11] Similarly, in her Handbook chapter, Ramey (2016) notes that Boivin et al. (2010b) find that the response of GDP to monetary policy tended to be smaller after 1984.

To address both of these points, I rerun the main specification, excluding the years before 1984. As an additional robustness check, I estimate versions of the impulse response functions in which I control for lags of the monetary shock in place of the Federal Funds Rate, as well as versions with 24 and 36 lags of all variables. These estimates are reported in Appendix Figures A.2 through A.7. As is clear from the figures, the finding that a monetary expansion increases abstract labor income, decreases routine labor income, and does not affect manual labor income are highly robust to the specification chosen and years included in the sample.[12]

As an additional robustness check, I consider the effect of monetary shocks in high interest rate environments and low interest rate environments separately. Intuitively, when faced with especially high capital costs, real-world firms have no reason to *remove* capital from the production process. That is, the lower bound on a firm's investment rate is zero, implying a lower bound of the growth rate of the capital stock equal to the negative depreciation rate. Therefore, monetary policy shocks should only generate differences in the rate of change of capital when capital costs are sufficiently low. As a result, differences between the labor income response of different occupation groups should be dampened in high interest rate environments.

Therefore, I re-run the baseline specification with indicators for whether the federal funds rate is higher or lower than the average level over my sample.[13] Specifically, I estimate equation (10) where y^i_{t+h} is log total weekly labor income for occupation group i at time $t+h$, ϵ_t is the estimated monetary policy shock, X_t is the same vector of controls used in the baseline specification, and D_t is an indicator variable for whether the shock occurred

[11] Coibion (2012) show that estimating the Taylor Rule reaction function using GARCH, as I do here, mostly eliminates these issues.

[12] This is potentially the result of using GARCH to estimate the monetary shocks, which Coibion et al. (2012) shows helps alleviate the vulnerability of impulse responses to the Volcker reforms and number of lags.

[13] This exercise is similar to the one performed in Tenreyro and Thwaites (2016). There the authors consider how the effects of monetary policy depend on the state of the business cycle.

alongside higher than average (high) or below average (low) interest rates.

$$y^i_{t+h} = \alpha_h + \beta^{i,h}_H D_t \epsilon_t + \beta^{i,h}_L (1 - D_t)\epsilon_t + \gamma' X_t + u_t \tag{10}$$

The $\beta^{i,h}_H$ coefficients are the impulse responses during periods with higher-than average interest rates, while the $\beta^{i,h}_L$ coefficients are the impulse responses for periods with lower than average interest rates. The results of this exercise are reported in Appendix A.3. Appendix Figure A.8 reports the impulse response of labor income by occupation group when the federal funds rate is comparatively high, while Appendix Figure A.9 reports the impulse response during low interest rates.

As predicted, when the federal funds rate - and presumably firm borrowing costs - are relatively high, monetary policy shocks appear to have little effect on labor income for any occupation group. In contrast, when interest rates are low, the differences between abstract and routine labor income are exaggerated. Intuitively, when interest rates are high, borrowing costs are more likely to be above the threshold at which firms will not invest. In this case, a monetary shock that moves interest rates slightly higher or lower will have no effect on investment rates, the rate of change of capital, and therefore the labor income of workers.

3.3 Impact on the Labor Income Channel.

Recall from Section 2 that the labor income channel, Ω_L can be expressed in the following way. Here, $d(N_i w_i)$ is the change in an occupation-i worker's labor income resulting from

$$\Omega_L = \sum_{i \in I} \sum_{j \in J} \lambda_{ij} d(N_i w_i) MPC_j$$

a monetary stimulus, MPC_j is the marginal propensity to consume out of transitory income changes for households with type-j financial constraints, and λ_{ij} is the share of type-i type-j households. The above expression can be restated in the following way.

$$\Omega_L = \sum_{i \in I} \sum_{j \in J} \lambda_{ij} (N_i w_i)(dlnN_i + dlnw_i) MPC_j \tag{11}$$

I use equation (11) along with the estimates from the previous subsection of $dlnN_i$ and $dlnw_i$ to generate a back-of-the-envelope estimate of the size of the labor income channel. I use the share of each type-i occupation that is hand-to-mouth and non-hand-to-mouth estimated in the following section using data from the Survey of Consumer Finances. Details on this estimation procedure can be found in Section 3.7. Finally, I use estimates for the MPC of hand-to-mouth and non-hand-to-mouth households from Kaplan et al. (2014).[14] To compare the labor income channel implied by my estimates to the case with homogeneous labor, I solve for the average percent change in employment and wages implied by the results in Figure 2. Appendix Table A.1 reports all of these values.

I find that incorporating heterogeneity in the labor income response to monetary policy decreases the labor income channel by 36 percent relative to the homogeneous labor case.

3.4 Occupational Transitions

In the preceding section, I found that a substantial amount of the difference between the effect of monetary policy shocks on the labor income of different occupations comes from differential effects on employment. It is possible that the fall in routine employment and the rise in abstract employment following a shock can partially be attributed to workers transitioning between routine and abstract occupations rather than transitioning into and out of unemployment.

In this subsection, I estimate the prevalence of transitions between the broad occupation groups and establish that they are as common as transitions between each occupation group and unemployment. As a result, this channel cannot be ruled out. I therefore repeat the simple back-of-the-envelope exercise above to determine how the size of the labor income channel would change if the changes in employment estimated in the previous subsection were attributed to occupational transitions rather than flows between employment and unemployment.

3.4.1 Estimating Occupational Transition Rates.

To estimate monthly transitions between the broad occupation groups, I use the longitudinal dimension of the basic CPS. Households are observed for 4 consecutive months, dropped from the sample for 8 months, and then observed for another 4 consecutive months. This allows me to calculate monthly growth rates for each occupation group attributable to inflows into each group from other occupation groups, g_O^{in}, outflows from each group into other groups, g_O^{out}, as well as inflows from unemployment, g_U^{in} and outflows into unemployment, g_U^{out}. Table 2 reports these growth rates.

[14] For non-hand-to-mouth (unconstrained) households, the average MPC reported in their Table 7 is 0.06. I take the average of their reported values for wealthy and poor hand-to-mouth, 0.395 for the hand-to-mouth (constrained) MPC.

TABLE 2

	Abstract	Routine	Manual
g_O^{in}	.052	.059	.054
g_O^{out}	.053	.058	.054
g_U^{in}	.016	.031	.030
g_U^{out}	.018	.033	.032

Note: this table reports the average monthly percent growth and decline of each occupation group attributable to inflows from and outflows to both other occupation groups and unemployment. Here I am using the basic monthly CPS and the corresponding sample weights.

Table 2 shows that average monthly flows into and out of each occupation group from and to other occupation groups are substantial and larger than the flows into and out of unemployment. Therefore, I cannot rule out occupational transitions as a partial explanation for the results in Figure 2.

3.4.2 Impact of Transitions on the Labor Income Channel.

To capture the impact of occupational transitions on the labor income channel, I define dN_a and dN_r as the change in routine and abstract employment attributable to flows from unemployment and dN_a^{tr} and dN_r^{tr} as the change attributable to occupation transitions. Therefore, $dN_a + dN_a^{tr} = dN_A$ and $dN_r + dN_r^{tr} = dN_R$, where dN_A and dN_R are the total change. I define $\phi = \frac{dN_r^{tr}}{dN_R}$, as the share of such transitions in the overall change in routine employment. From Figure 2 we see essentially no change in manual employment. Therefore, I assume that total transitions out of routine jobs $dN_r^{tr} = -dN_a^{tr}$, total transitions into abstract jobs. Using the assumptions above, I can rewrite equation (11) as a function of the transition share, ϕ. The difference in the labor income channel for 2 values of ϕ can be written as in equation (12).

$$\Omega_L(\phi') - \Omega_L(\phi) = (\phi' - \phi)\frac{dN_R}{N_R}\sum_{j\in J} MPC_j\Big(\lambda_{aj}N_a w_a - \lambda_{rj}N_r w_r\Big) \quad (12)$$

See Appendix A.4 for a derivation of equation (12). Intuitively, a higher ϕ implies a smaller increase in abstract employment along with a lower decrease in routine employment. This will decrease the negative covariance between MPC and the labor income response to monetary policy and, all else equal, increase the size of the labor income channel.

Using the same estimates for MPCs, average real wages, and the share of constrained and unconstrained households in each occupation group as in Section 3.3, I can calculate the impact of occupational transitions on the labor income channel. I find that if 100 percent of the decline in routine employment is attributable occupational transitions into abstract occupations, then the labor income channel drops by only 22 percent relative to a case with homogeneous labor. Put differently, assuming that the routine employment decline was entirely due to occupational transitions shrinks the gap between the labor income channel in the heterogeneous and homogeneous labor case by just over one third. To summarize, the possibility of occupational transitions lessen, but do not eliminate, the effects of capital-task complementarity on the labor income channel.

3.5 Earnings Elasticities by Industry

According to Proposition 1, abstract and routine workers should see greater differences in their labor income response to monetary policy if they work in an industry in which capital investment is particularly responsive to a monetary policy shock. Conversely, workers in industries in which capital responds less to monetary policy should see less of a difference in their labor income responses. To test whether my empirical results are consistent with the predictions of Proposition 1, I separate workers in the sample into industry subgroups depending on the responsiveness of capital in that industry to monetary policy shocks.

The most straightforward way to classify industries by the responsiveness of capital to monetary policy would be to estimate impulse response functions of capital investment by industry. Because data on fixed capital investment by industry is not available at a sufficient frequency, I classify industries using a simple 2-step procedure.

Fixed investment by *capital type* is available for all the years in my original sample at the quarterly frequency. I first identify what *types* of capital respond most strongly to monetary policy shocks. I then classify the industries for which these capital types make up the majority of their investment as 'responsive' industries. Specifically, I use data from the National Income and Product Accounts (NIPA) to estimate the impulse response of log investment in equipment capital to a 25 basis point expansionary monetary policy shock by capital type.[15] I record the peak impulse response for each capital type, and designate the top 25 percent most responsive types as 'responsive capital'. I then use the Bureau of Economic Analysis' unpublished Detailed Fixed Asset Tables and calculate the fraction of each industry's fixed assets that is made up of responsive capital. The 5 industries with the highest fraction were classified as 'responsive industries'.[16]

Appendix Figure A.10 reports the Jordá projections of log fixed investment for each type

[15] I chose to focus on equipment capital (rather than structures or intellectual property) as equipment capital has the clearest theoretical interpretation as capital for which some workers are substitutable and some are complementary.

[16] The responsive industries included construction, transportation, manufacturing, finance, and mining.

of responsive capital. Again, I use Romer and Romer shocks and control for 12 lags of both the dependent variable and the federal funds rate. I construct 90 percent confidence intervals using Newey-West standard errors.

This 2-step procedure creates 6 distinct groups.[17] Using this classification, I rerun the impulse response functions from Figure 1. The results are reported in Figure 3. For ease of interpretation, confidence intervals have been omitted. From this figure it is clear that restricting the sample to include only workers in industries in which capital is highly responsive to monetary policy (dashed lines) exaggerates the differences between abstract and routine workers.

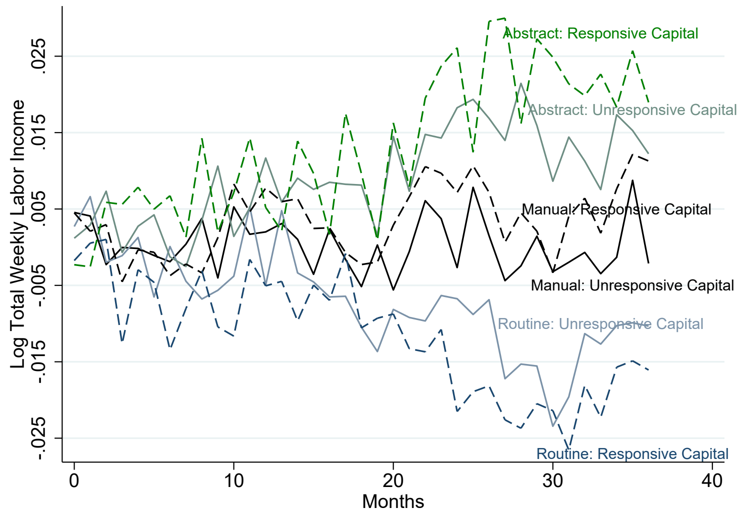

Figure 3: Weekly Labor Income by Industry Type

Notes: This figure reports the impulse response functions of weekly labor earnings to a 25 basis point negative monetary policy shock using Jordá projections and Romer and Romer shocks. The dashed lines correspond to workers in industries in which capital is very responsive to monetary policy, while the solid lines correspond to industries in which capital was less responsive. Confidence intervals have been omitted for ease of interpretation.

The difference in the response of weekly labor income between abstract, manual, and routine workers is noticeably more muted in industries in which capital is less responsive to monetary policy (solid lines). Intuitively, because these firms add relatively less capital to their production process as they expand, the marginal product (and thus the labor demand for) workers whose labor is complementary with capital increases by less, and the marginal product of substitutable workers falls by less.

[17] For example, a manager of a construction company is an abstract worker in a highly responsive industry, while a janitor at a hospital is a manual worker in a less-responsive industry.

One might be concerned that the high implied investment response to monetary policy for responsive industries simply reflects high depreciation rates. If capital in responsive industries depreciates at a higher rate than capital in less responsive industries, the results in Figure 3 may not imply that these industries are *adding more* capital in response to monetary stimulus, but instead are simply *replacing existing* capital. To address this, I calculate industry specific depreciation rates for equipment capital for each year between 1979 and 2007 using depreciation data from NIPA. I report these depreciation rates for all industries in Appendix Table A.2. Responsive industries had an average equipment capital depreciation rate of 13.5 percent, while less responsive industries had a slightly higher rate of 15 percent, suggesting that the greater investment response to monetary shocks likely reflects more capital being added to the production process.

3.6 Relationship to the Existing Literature

At first glance, these empirical results may seem puzzling given that policy makers generally view accommodative monetary policy as disproportionately helpful to the poor, who are hit hardest by recessions. The unequal incidence of downturns is often cited as a motivation for more aggressive stimulus. In a 2021 speech, Chairman Powell cited the uneven impact of the pandemic recession over the income distribution in a speech on the Federal Reserve's policy response.[18] How does this logic and the existing literature on the incidence of workers' labor income to fluctuations in aggregate output relate to my findings?

Guvenen et al. (2017) define a worker's 'beta' as the sensitivity of their labor income growth to aggregate income growth, and find that worker betas are decreasing in earnings percentile until approximately the 90th percentile, at which point they rise steeply. Using a similar formulation and the same data, Alves et al. (2020) estimate the sensitivity of income by permanent income quantile to aggregate income and find a similar pattern.

However, in both papers this u-shaped pattern is generated by top-earners. When Alves et al. (2020) estimate a similar specification using CPS data – where top earners are top-coded and dropped from their data set – they find that the incidence is monotonically decreasing by earnings quantile. Similarly, Patterson (2023) finds that the elasticity of earnings to GDP rises with MPC, which tends to be higher for lower income workers. As I am also using top-coded CPS data, these findings at first may appear inconsistent with my results.

The key difference between this paper and the studies mentioned above is that they consider the sensitivity of individual earnings to fluctuations in GDP generally, without conditioning on *what type of shock* generated the fluctuation. If two shocks affect the relative

[18] Here I am referencing the August 2021 Jackson Hole speech (Powell, 2021).

productivity or labor supply of two groups of workers in different ways, then we should not expect them to generate the same incidence patterns. As a simple example, a positive shock to low-skill labor productivity will generate a different incidence than a shock to high-skill labor productivity, even if they both generate an increase in output. Therefore, if the fluctuations in aggregate output used in Alves et al. (2020), Guvenen et al. (2017), or Patterson (2023) were not primarily generated by monetary policy shocks, then we should not necessarily be surprised to find differences in the estimated incidence.

In contrast to the papers mentioned above, Doniger (2019) explicitly estimates the impact of monetary shocks on wages and employment by education group. In particular, she uses data from the National Longitudinal Survey of Youth (NLSY) to construct a measure of the *allocative wage*, the firm's discounted forward-looking labor costs used when considering whether to begin or end an employment relationship, and estimates the effect of monetary shocks on this measure.

Doniger (2019) finds that the allocative wage of workers with a college education responds positively to a monetary stimulus, while the allocative wage of non-college educated workers does not respond. This appears inconsistent with my finding that the wage of abstract workers increases only slightly in response to a monetary stimulus, while the wage of routine workers declines. A likely explanation is her use of the estimated *allocative wage* rather than the reported *current* wage as the dependent variable. While such a measure is key to understanding the expected future costs of an employment relationship to a firm and the longer-term distributive consequences of monetary shocks, the current wage that households receive (and can spend now) is the correct variable when calculating the labor income channel.

Furthermore, Doniger (2019) uses CPS data to study the impact of monetary shocks on employment by education and initially finds a negative employment effect for less educated households following a monetary contraction. However, when she excludes the years of the Volker Reform (1979-1982), she finds no effect of monetary policy for employment for either education group. As mentioned in Section 3.2, my finding that an expansion increases abstract employment and decreases routine employment is robust to the exclusion of these years.

To explain the discrepancy between this zero result and the results above, it is important to note that the 3 *occupation* groups do not map cleanly into *education* groups. From Table 1, we see that at the start of my sample, 64 percent of abstract workers had no college degree, while 49 percent had no degree at the end of my sample. This suggests that the impulse response of employment by education group may average out the employment effects for different occupations within each education group, masking important heterogeneity needed to calculate the covariance between MPC and the labor income response to monetary policy, and ultimately the labor income channel.

3.7 Marginal Propensities to Consume by Occupation Group

Thus far, I have presented evidence that suggests that the response of labor income to monetary policy differs by occupation group, and that an occupation group's elasticity of substitution with capital may contribute to this difference. The results above suggest that abstract workers are the primary beneficiaries of monetary stimulus and that monetary policy may spur some households to transition into abstract occupations. Meanwhile, the wages of routine workers appear to fall and routine workers transition either into other occupations or unemployment. Monetary policy appears to have no effect on the labor income of manual workers.

According to Propositions 2, the implied effect of these results on the size of the labor income channel depends on the MPCs for each occupation group and for households who are potential occupation switchers. Existing research has shown that being young and having low levels of liquid wealth, total wealth, and income are associated with higher MPCs (Johnson et al., 2006; Blundell et al., 2008). Therefore, to get a sense of the relative size of the MPCs of workers in each occupation group. I estimate the income and wealth levels for each of these groups using data from the Survey of Consumer Finances (SCF). I use these estimates both in the back-of-the-envelope calculation as well as in the next section to calibrate the MPCs for households in the quantitative model.

In the publicly available SCF data, detailed occupation codes are unavailable, and households are instead put into more general occupation groups. For my purposes, I classify the group including managers, finance workers, professionals, scientists, and education workers as abstract occupations. The group including machine setters, operators, and tenders as well as transportation and material transport workers as routine, along with the group that includes sales workers, administrative support workers, and technicians. The two groups that include police and service workers as well as construction, extraction, and the skilled trades are classified as manual.

Table 2 presents the median nominal value of liquid assets, total assets, non-financial income, and age for each group, as well as each group's probability of being poor hand-to-mouth and wealthy hand-to-mouth, all of which predict higher MPCs (Johnson et al., 2006; Blundell et al., 2008). Here, liquid wealth is defined as in Kaplan et al. (2014) as the sum of checking and savings balances, mutual funds, stocks, and government and corporate bonds. Total assets is the sum of liquid assets, certificates of deposit, retirement accounts and pensions, the value of real estate assets less outstanding mortgages owed, and savings bonds. Monthly non-financial income includes wages and salaries, public transfers (SSI, unemployment, etc), and private transfers (alimony). A household is considered 'poor hand-to-mouth' if their liquid asset balances are less than half of their monthly income and they have illiquid asset balances under $1,000. A household is considered wealthy hand-to-mouth if they have illiquid assets over $1,000, but their liquid asset balances are less than half of their monthly income.

TABLE 2

	1980			2007		
	Abstract	Routine	Manual	Abstract	Routine	Manual
Liquid Assets	4781	1745	1383	11827	2884	2255
	(226)	(127)	(94)	(621)	(235)	(214)
Total Assets	80632	37393	21322	269487	105523	59687
	(5100)	(1668)	(2569)	(10666)	(7286)	(5428)
Monthly Income	4306	2995	2703	6462	4070	3973
	(98)	(50)	(129)	(130)	(122)	(83)
Average Age	43	41	39	45	45	42
	(0.50)	(0.47)	(0.40)	(0.39)	(0.62)	(0.48)
Wealthy	0.24	0.29	0.23	0.16	0.27	0.27
Hand-to-mouth	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Poor	0.06	0.18	0.28	0.06	0.17	0.20
Hand-to-mouth	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)

Note: this table reports summary statistics on household balance sheet items for the three occupation groups using the Survey of Consumer Finances (SCF). Medians for each variable are reported with standard deviations are shown in parenthesis. Due to the complicated survey design of the SCF, sample statistics are calculated using the replicate weight procedure outlined in the Survey's documentation. Households are grouped according to the occupation of the reference person.

From the table, one can see that in both years, households in which the reference person worked in an abstract occupation have substantially higher levels of liquid assets compared to other groups. The median liquid asset level for abstract household was $4,781 in 1995, more than double that of routine and manual households. By 2007, abstract households had around four times the level of liquid wealth of routine and manual households. A similar pattern emerges for total assets. Household heads who worked in an abstract occupation tended to be just a few years older on average, and made significantly more income than workers in other groups. Abstract households were about as likely as households in other groups to be wealthy hand-to-mouth in 1995, but by 2007 were just over half as likely to be wealthy hand-to-mouth than routine workers and manual households. Abstract households were significantly less likely to be poor hand-to-mouth in both years.

Taken together, these findings suggest that households headed by a worker in a routine or manual occupation may have higher MPCs than those headed by someone in an abstract occupation. These values are used in the next section to calibrate MPCs in the quantitative model.

4 Quantitative Model

In this section, I present a medium-scale Heterogeneous Agent New Keynesian Model (HANK) model with capital-task complementarity in order to demonstrate that the mechanism outlined in Section 2 holds in a more complex setting and generates patterns that are qualitatively consistent with the findings in Section 3.2. As is standard in HANK models, the economy features a unit mass of households who face un-insurable idiosyncratic labor productivity risk, sticky prices, and a monetary authority who follows a Taylor Rule. Following Kaplan et al. (2018), the economy features two assets households can use to self-insure, a liquid government bond and illiquid firm equity. The economy also features sticky wages in order to ensure pro-cyclical firm profits. As in Dolado et al. (2021) , I replace the standard Cobb-Douglas production function with the nested-CES production function from Section 2. I compare the deterministic response of consumption to a one-time negative (expansionary) monetary policy shock in otherwise identical economies with and without heterogeneous capital-labor elasticities. Both economies feature capital adjustment costs.

4.1 Model

Households. The economy is populated by a unit mass of heterogeneous households indexed by their occupation, asset holdings, and labor productivity. Time is discrete. As in the simple model, a fraction λ_A work in abstract occupations, while λ_R work in routine occupations. The households' per-period utility function takes the following form.

$$u_j(c_{it}, n_{it}) = \frac{(c_{it})^{1-\sigma}}{1-\sigma} - \psi_j \frac{(n_{it})^{1-\nu}}{1-\nu}$$

Households take their occupation's wage w_{jt}, rates of return on both assets, and taxes as given and choose their consumption c_{it}, labor supply n_{it}, liquid asset holdings b_{it}, and illiquid asset holdings a_{it} to maximize the infinite discounted sum of their utility (13) subject to their budget constraint (A.9).

$$\max_{c_{it}, n_{it}, b_{it}, a_{it}} \sum_{t=0}^{\infty} \beta^t E_0[u_j(c^{it}, n^{it})] \tag{13}$$

As is standard in HANK models, households face idiosyncratic shocks to their labor productivity e_{it}, and face a liquid borrowing constraint $\underline{b}_{it}$ preventing them from fully insuring these shocks. Idiosyncratic labor productivity is governed by the following AR(1) process, where $\epsilon_{it} \sim N(0,1)$.

$$\log e_{it} = \rho_e \log e_{it-1} + \sigma_e \epsilon_{it} \tag{14}$$

Households also face a portfolio adjustment cost $\chi(a_{i,t-1}, a_t)$ (A.11) when making deposits into their illiquid account as in Adrien Auclert, Bence Bardóczy, Matthew Rognlie, Ludwig Straub (2021). Details on the adjustment costs and household first order conditions are reported in Appendix A.6.

Firms. A competitive final goods producer aggregates a continuum of intermediate goods y_{kt} indexed by $k \in [0,1]$ into a single final good Y_t, where ϵ is the elasticity of substitution between goods.

$$Y_t = \left(\int y_{kt}^{\frac{\epsilon-1}{\epsilon}} dk \right)^{\frac{\epsilon}{\epsilon-1}}$$

The intermediate goods are produced by a continuum of monopolistically competitive firms. This is a standard problem whose solution implies that firm k's demand and the aggregate price level are given by the following expressions.

$$y_{kt} = \frac{p_{kt}^{-\epsilon}}{P_t} Y_t \qquad P_t = \left(\int p_{k,t}^{1-\epsilon} dk \right)^{\frac{1}{1-\epsilon}} \tag{15}$$

Each intermediate good firm produces according to a nested-CES production function (16) in which the elasticity of substitution between capital and abstract labor, σ_A is less than 1, while the elasticity between capital and routine labor, σ_R is greater than 1.[19]

$$y_{kt} = Z_t \left(\alpha_A {N_t^A}^{\frac{\sigma_A - 1}{\sigma_A}} + (1-\alpha_A) \left(\alpha_R {N_t^R}^{\frac{\sigma_R-1}{\sigma_R}} + \alpha_K K_t^{\frac{\sigma_R-1}{\sigma_R}} \right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}} \right)^{\frac{\sigma_A}{\sigma_A-1}} \tag{16}$$

Dividends are equal to revenues minus labor costs, $w^a_{kt} n^a_{kt} + w^r_{kt} n^r_{kt}$, investment i_{kt}, Rotemberg price adjustment costs c^p_{kt} (19), and investment adjustment costs c^I_{kt} (20). Firms maximize the infinite discounted stream of dividends, where the discount factor used each period

[19] This implies that capital and abstract labor are gross complements, while capital and routine labor are gross substitutes. Here, I use a production function of the same form as in Autor and Dorn (2013) in which abstract labor is in the outer nest. The results of this section however, do not depend on which type of labor is in the inner or outer nest of the function.

is $1 + r_t^a$, the rate of return on firm equity.[20] The firm's problem is to maximize equation (17) subject to equations (15), their production function, and equations (18)-(20).

$$\max_{y_{kt}, n_{kt}^a, n_{kt}^r, i_{kt}, p_{kt}, k_{kt}} \sum_{t=0}^{\infty} \frac{1}{1 + r_t^a} \left(\frac{p_{kt}}{P_t} y_{kt} - w_{kt}^a n_{kt}^a - w_{kt}^r n_{kt}^r - i_{kt} - c_{kt}^p - c_{kt}^I \right) \tag{17}$$

$$k_{kt} = (1 - \delta) k_{kt-1} + i_{kt} \tag{18}$$

$$c_{kt}^p = \frac{\epsilon}{2\kappa_p} [log(1 + \pi_{kt})]^2 Y_t \tag{19}$$

$$c_{kt}^I = \frac{1}{2\delta\epsilon_I} \left(\frac{k_{kt} - k_{kt-1}}{k_{kt-1}} \right)^2 k_{kt-1} \tag{20}$$

This problem is standard and symmetric for all firms. The firm's optimality conditions can be found in Appendix A.6.

Unions. Households in each occupation group provide a labor services to a labor union. Labor unions choose wages w_t^j, and hours $N_{d,t}^j$, to maximize the average utility of their workers U_t^j. Unions face quadratic wage adjustment costs, C_t^w. This leads to the following wage Phillips Curve for each occupation type (22).

$$C_t^w = \frac{\mu_w}{1 - \mu_w} \frac{1}{2\kappa_w} [log(1 + \pi_{jt}^w)]^2 N_{d,t}^j \tag{21}$$

$$log(1 + \pi_{jt}^w) = \kappa_w (\psi^j N_{d,t}^{j,1+\nu} - \mu_w N_{d,t}^{j,1+\nu} (1 - t_t) w_t^j U_t^j) + log(1 + \pi_{j,t+1}^w) \tag{22}$$

Finance. A financial intermediary invests household savings into either illiquid firm stock with price p_t or illiquid government bonds. The financial intermediary performs liquidity transformation at proportional cost ω, and offers an liquid asset with return r_t^b. The rate of return for both assets is given by

$$E_t[1 + r_{t+1}^a] = E_t[\frac{d_t + p_{t+1}}{p_t}] = E_t[1 + r_{t+1}^b] + \omega \tag{23}$$

The real interest rate on the government bond is determined by the Fisher equation.

$$1 + i_t = (1 + \pi_t)(1 + r_t^b) \tag{24}$$

The formulation for the union and financial intermediary are taken directly from Adrien Auclert, Bence Bardóczy, Matthew Rognlie, Ludwig Straub (2021).

[20] See Kaplan et al. (2018) for an explanation of this discount rate.

Government. A monetary authority sets the nominal interest rate on government bonds using a standard Taylor Rule in which $\epsilon_t^m = 0$ in steady state and $\phi > 1$.

$$i_t = \bar{r}_t + \phi \pi_t + \epsilon_t^m \tag{25}$$

The fiscal authority taxes labor income and issues bonds in order to finance government spending. The fiscal authority's budget constraint is given by the following.

$$G_t + r_t^b B_t^g = \tau_t (N_t^A w_t^A + N_t^R w_t^R) \tag{26}$$

4.2 Equilibrium

Let $D_t(a, b, e)$ be the distribution of households with illiquid assets a, liquid assets b, and productivity shock e. An equilibrium in this economy is defined as a sequence of individual decisions $\{a_{it}, b_{it}, n_{it}, c_{it}\}$ and distributions D_t, firm decisions $\{n_{kt}^a, n_{kt}^r, k_{kt}, \pi_t\}$, aggregate prices $\{p_t, w_t^a, w_t^r, r_t^a, r_t^b\}$, and policy variables $\{\tau_t, B_t^g, G_t, i_t\}$ such that households maximize their utility subject to their budget constraint and borrowing constraint, intermediate and final goods firms maximize profits subject to their respect constraints, unions maximize average utility of the workers subject their constraints, the fiscal authority adheres to its budget constraint, and all markets clear. The asset market clears when the total equity share value plus total government bonds equals total illiquid assets held by the households. Total liquid assets equal total liquid assets held by all households. The number of outstanding shares is normalized to 1.

$$p_t + B_t^g = A_t + B_t = \int_0^1 a dD_t(a, b, e) + \int b dD_t(a, b, e) \tag{27}$$

$$B_t^h = B_t = \int b dD_t(a, b, e) \tag{28}$$

I define $D_t^A(a, b, e)$ and $D_t^R(a, b, e)$ as the distribution over states of the abstract and routine workers respectively. The abstract and routine labor markets clear when

$$N_t^A = \int e\, n(a, b, e)\, dD_t^A(a, b, e) \tag{29}$$

$$N_t^R = \int e\, n(a, b, e)\, dD_t^R(a, b, e) \tag{30}$$

Finally, the goods market clears when output equals the sum of aggregate consumption $C_t = \int_0^1 c(a, b, e) dD_t$, aggregate investment, government spending, aggregate price and investment adjustment costs, and aggregate portfolio adjustment costs.

$$Y_t = C_t + I_t + G_t + C_t^w + C_t^p + C_t^I + \chi_t \tag{31}$$

4.3 Calibration

When calibrating the model's parameters, I kept two general objectives in mind. First, the model should facilitate a comparison of the size of labor income channel in a model with capital-task complementarity to that of a standard model with homogeneous labor. Towards that end, wherever possible I chose parameter values to match leading models in the existing HANK literature. In particular, I drew parameter values and functional forms from Kaplan et al. (2018), (KMV) and Adrien Auclert, Bence Bardóczy, Matthew Rognlie, Ludwig Straub (2021) (ABRS). Second, the model should provide a realistic quantification of the true labor income channel. With this second objective in mind, I pay particular attention to 3 sets of parameters: those that determine the stochastic labor productivity process, those that determine the distribution of steady state asset holdings, and those that determine the relative supply and demand for each type of labor. The first two sets of variables determine household MPCs, while the last set determines the labor income response of both types of workers to a monetary policy shock. As was shown in Section 2, the joint distribution of MPCs and labor income responses determines the size of the labor income channel.

Parameters drawn from the literature. Following KMV, I normalize quarterly GDP to 1 and set the interest rate on liquid assets to .005 so that the annual rate is 2 percent. I set the quarterly return on illiquid assets to 1.43 percent leading to an annual rate of .057. I set the elasticity of inter-temporal substitution to .4. Steady state inflation is set to 0, and the labor income tax is set to .35. I set the labor share to .6, investment to .29, and depreciation to .07. I set the slope of the price Phillips Curve to .1, and the steady state union markup to .1, and the slope of the wage Phillips Curve to .1, all following ABRS. Finally, government spending is set to 17 percent of GDP, the Taylor Rule coefficient on output is 0, and the Taylor Rule coefficient on inflation is 1.5.

Labor supply and demand. Setting the labor share to .6, GDP normalized to 1, and a unit mass of workers implies an average wage of .6. The proportion of each type of worker λ_A and λ_R, was chosen to target the relative wages and relative labor share of abstract and routine of workers in 2007, calculated using the final year of the CPS sample.[21] With the relative

[21] The relative labor share was calculated as the weighted sum of average earnings for abstract workers relative to routine workers.

quantity and price of abstract and routine labor pinned down, the scale parameters of the households' labor disutility ψ_A and ψ_R are calibrated to clear labor markets.

The firm's demand for each factor is determined by the parameters of their production function and the capital adjustment costs they face. I consider two sets of values for these parameters. For the *heterogeneous labor* version of the model, I choose the capital-labor elasticity parameters, $\{\sigma_R, \sigma_A\}$ so that impulse response functions of labor income reflect key characteristics of the empirically estimated impulse responses from Section 3. I calibrate the capital adjustment cost parameter to generate a 1 percent increase in capital investment on impact. In the *homogeneous labor* version of the model, I set both σ_R and σ_A to 1, and assume an equal labor share and wage across types.[22] I then use the firm's first order conditions for labor and set output equal to 1 to pin down α_A, α_R, and Z.

Stochastic labor productivity process. In heterogeneous agent models, a household's MPC is influenced by the risk of hitting their borrowing limit following a shock. Higher order moments of the income distribution affect consumption and savings behavior (Civale et al., 2015), and therefore targeting these moments is an important step in generating realistic MPCs. Following Kaplan et al. (2018), I choose ρ_e and σ_e such that the standard deviation and kurtosis of log income changes match those in Guvenen et al. (2015).[23] A comparison of the income process in the model and the data can be found in Table 3.

Asset Distribution. With the aggregate bond prices and quantities determined, I calibrate the parameters of the household's portfolio adjustment cost function, the discount rate, and the borrowing limit to clear bond markets and asset markets, and to target the fraction of each occupation group that are poor hand-to-mouth and wealthy hand-to-mouth estimated in the previous section. A comparison between the estimated fractions and those generated by the model can be found in Table 3.

A complete list of model parameters and their calibrated values can be found in Appendix Table A.3. To solve the model and estimate impulse response functions, I rely on the Sequence Space Jacobian method developed in Auclert et al. (2021).[24]

Note: The first column of the left panel reports estimated moments for changes in log earnings from Guvenen et al. (2015). The second column reports the analogous moments generated by the model. The first column

[22] In this case, all workers are neither gross compliments nor gross substitutes with capital.

[23] As in Kaplan et al. (2018), I do not match the skewness of the distribution, as there are only 2 free parameters in the shock process.

[24] The authors have created easy-to-use publicly available Python code that implements their method. I rely heavily on their code when solving the model.

TABLE 3

Distribution of changes of log labor income			Portion of each occupation group that are 'hand-to-mouth'		
	Model	Data		Model	Data
Mean	0	0	Abstract		
			Total HTM	0.27	0.30
Standard Deviation	0.48	0.48	Wealthy HTM	0.24	0.24
Skewness	0	-1.35	Routine		
			Total HTM	0.47	0.47
Kurtosis	17.8	17.8	Wealthy HTM	0.29	0.29

in the right panel reports the fraction of abstract and routine workers that are wealthy and poor hand-to-mouth at the mid-point in my sample (1995). The right column reports the analogous fractions generated by the model. A household is classified as poor hand-to-mouth if its liquid asset holdings are below half of its monthly income and its illiquid asset holdings are 'negligible' (less than $1,000 in the data and less than 7 in the model).

4.4 Labor Income Response: Model vs. Data

I consider the effect of a negative .25 percentage point monetary policy shock on the labor supply and wage of both types. Figure 4 shows the impulse response of wages to the monetary policy shock.[25] There are 3 key differences between the reduced form impulse responses and those generate by the model.

First, the model is unable to match the near-zero response of labor income - both labor supply and wages - on impact, and instead generates unrealistic initial jumps in both variables. Labor supply immediately increases by 1.25 percent for routine workers and 1.5 percent for abstract workers, while wages initially increase by .1 percent for routine workers and .4 percent for abstract workers. The inability of standard New Keynesian models to generate no initial effect as in empirically estimated impulse responses, without ingredients like habit formation, is well understood, and this model is no exception (Auclert et al., 2020). Labor income only begins to decline for routine types and increase further for abstract types *after* these initial jumps. However, because the homogeneous labor version of the model also features large initial jumps in labor supply and wages, the heterogeneous labor model still provides a useful comparison of the relative size of the labor income channel with and without capital-task complementarity.

Given this inherent limitation of the model, capital-labor elasticities for both types are chosen in order to match the roughly symmetric changes in labor income *after* the initial

[25] Appendix Figure A.11 shows the nearly identical response of labor supply.

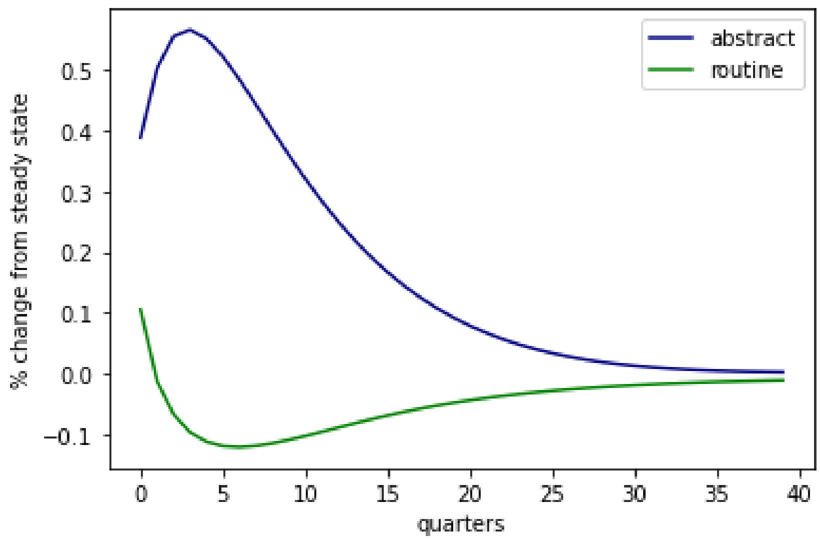

Figure 4: Response of Wages to Monetary Policy Shock

Notes: This figure reports the impulse response functions of wages for each occupation group to a 25 basis point negative monetary policy shock in the baseline heterogeneous labor model.

jump. At this point, the employment response has declined substantially to near zero for both types, while wages have *grown* by an additional .2 percent for abstract workers and *fallen* by an approximately equal amount for routine workers.

Second, unlike in the data, in the model the difference between the two types' labor income response comes more through wages, rather than through changes in hours or in employment as in the data. Generating changes in employment would require adding an ingredient such as search and matching frictions as in Dolado et al. (2021). However as in clear from equation (9), for the purposes of calculating the labor income channel, whether changes in labor income come from wages or labor supply does not matter.

Third, the changes in labor income after the initial jump generated by the model are only around 1/4 of the size of even the smaller of their empirical counterparts. This suggests that capital-task complementarity may only be a partial explanation for the empirical results. A possible explanation might be that, in addition to being more complementary with capital, abstract workers have greater bargaining power and are better able to capture a portion of firm profits through their labor income. Because abstract labor income grows more and routine labor income falls more in the data than in the model, the results in the next section can be interpreted as providing an upper bound on the covariance between the labor income response to monetary policy and workers' MPCs, and therefore an upper bound on the labor income channel.

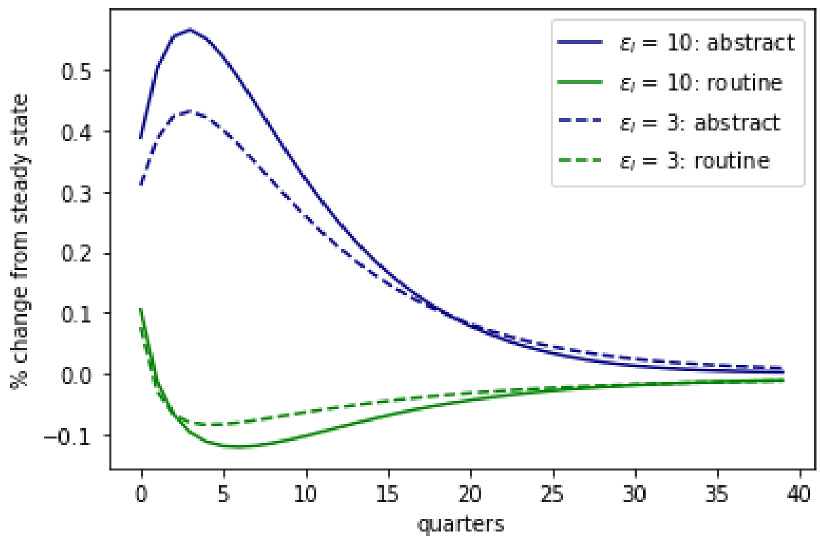

Figure 5: Wage Response for Different Capital Adjustment Costs

Notes: This figure reports the impulse response functions of wages for each occupation group to a 25 basis point negative monetary policy shock for various values of the capital adjustment cost. As ϵ_I grows, capital adjustment costs fall.

One feature of the data the model is able to match is how the impulse responses vary with the responsiveness of capital investment to the monetary policy shock. Figure 5 reproduces the pattern shown in Figure 3 by varying values of the capital adjustment parameter, ϵ_I. Recall that capital adjustment costs are *inversely* related to ϵ_I, so as ϵ_I increases, capital becomes more responsive. From Figure 5 it is clear that as capital becomes less responsive to monetary policy, the difference in the labor income response between the two types collapses. This directly reflects the results from Proposition 1 and the empirical results in Figure 3.

4.5 Marginal Propensities to Consume

Following Kaplan et al. (2018), a household's MPC is defined as the derivative of household consumption with respect to liquid assets. This allows me to use the policy functions for consumption to calculate MPCs for households at every state (a_{it}, b_{it}, e_{it}).

$$MPC_t = \frac{\partial c(a_{it}, b_{it}, e_{it})}{\partial b} \approx \frac{c(a_{it}, b_{it} + \epsilon, e_{it}) - c(a_{it}, b_{it}, e_{it})}{\epsilon}$$

Using the steady state policy functions and steady state joint distribution of productivity and assets for both types of workers, I calculate the distribution of MPCs for routine and abstract workers. Figure 6 reports this distribution.

The lower labor share and relative wage of routine workers in steady state naturally gen-

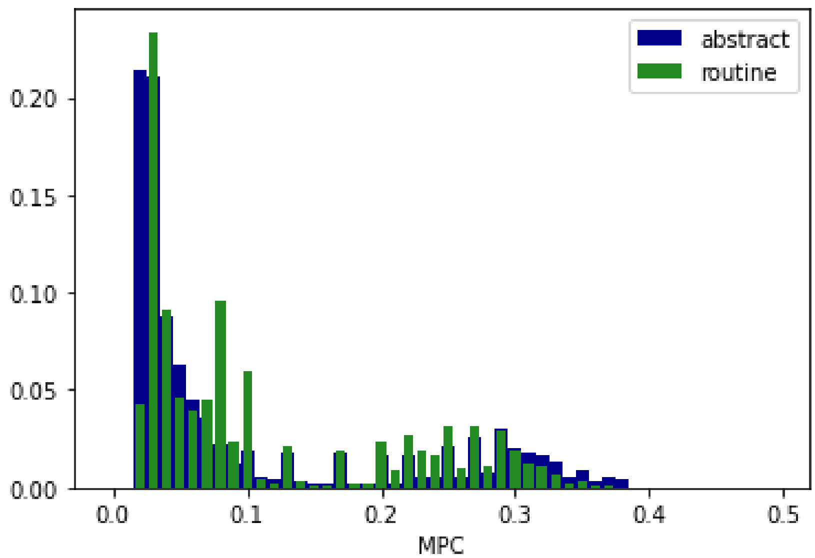

Figure 6: Marginal Propensities to Consume by Occupation Group

Notes: This figure reports the marginal propensities to consume out of liquid income for both occupation groups in the baseline heterogeneous labor model. See the text for a detailed description on calculating the MPCs.

erates a different distribution of assets between the two groups and endogenously generates a different distribution of MPCs. Households with lower levels of liquid and illiquid wealth have higher MPCs, as they have a higher chance of running up against their borrowing constraint. Because abstract workers have higher labor income and asset levels in the steady state, they tend to have lower MPCs.

4.6 The Labor Income Channel

I define the labor income channel as the sum of the partial equilibrium response of consumption to the general equilibrium path of abstract wages $\{w_t^A\}^G$, and routine wages $\{w_t^R\}^G$, following a monetary policy shock, holding r^b, r^a, and τ constant. Each general equilibrium path for wages, along with the equilibrium conditions for the firms and unions, generates a partial equilibrium path for labor hours. Let $\{N_t^j\}^m$ be this partial equilibrium path of hours for type j workers in response to the general equilibrium path $\{w_t^m\}^G$, holding all other prices constant. The labor income channel Ω, is simply the aggregate response of consumption on impact to this new path of labor income, holding taxes, r_b, and r_a constant at their steady

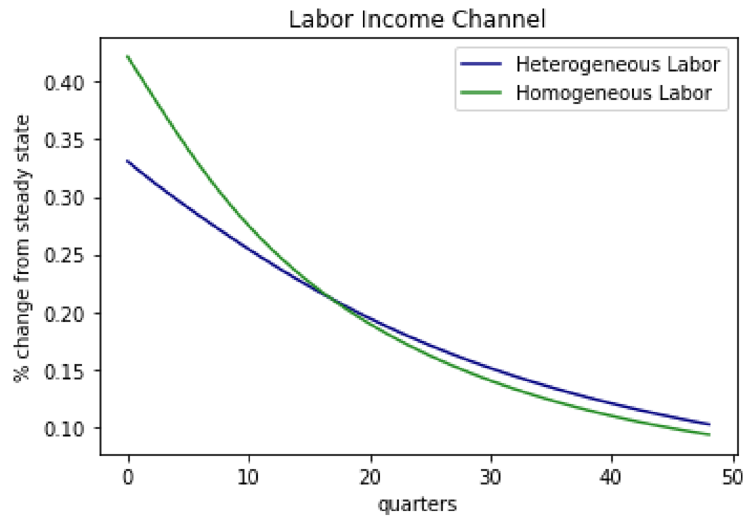

Figure 7: The Labor Income Channel

Notes: This figure reports the labor income channel for a 25 basis point negative monetary policy shock in the baseline heterogeneous labor model and the homogeneous labor model. See text for a detailed description of how the labor income channel is calculated.

state levels, $\bar{\tau}$, $\bar{r}_b$, $\bar{r}^a$. Here, $\bar{w}^i$ represents the steady state level of w^i.

$$\Omega = C_0\Big(\{w_t^A\}^G, \bar{w^R}, \{N_t^A\}^A, \{N_t^R\}^A, \bar{r_b}, \bar{r^a}, \bar{\tau}\Big) + \\ C_0\Big(\bar{w^A}, \{w_t^R\}^G, \{N_t^A\}^R, \{N_t^R\}^R, \bar{r_b}, \bar{r^a}, \bar{\tau}\Big) \tag{32}$$

I estimate the labor income channel for both the heterogeneous labor and homogeneous labor version of the model. The results are reported in Figure 7. As is clear from the figure, when capital-task heterogeneity is introduced into an otherwise identical model, the size of the labor income channel falls by about 25 percent on impact.

5 Conclusion

Disentangling the relative importance of different channels of monetary policy transmission remains a growing area of research. By adding features like realistic MPCs and more complex financial markets into New Keynesian models, researchers have demonstrated the importance of *indirect* increases in household incomes, and have exposed key interactions between monetary policy and other macroeconomic forces like fiscal policy and globalization. In particular, this literature has demonstrated the importance of assumptions about labor and financial markets for the transmission of monetary policy (Alves et al., 2020, Bloesch and Weber, 2021).

This paper furthers this research effort by considering a key feature of modern labor markets: heterogeneity in worker substitutability with capital. I argue that monetary policy is unlikely to increase labor income equally for all workers, and that the size of the labor income channel depends on the response of capital to monetary policy, the the degree of capital-task complementarity, and the covariance between how substitutable a worker is with capital and their marginal propensity to consume. As Dolado et al. (2021) emphasize, the distributional consequences of capital-task complementarity are important in their own right. I argue that these distributional consequences may also have implications for the aggregate *effectiveness* of monetary policy to stimulate consumption if the households who would spend their newfound labor income are not the households who see their labor incomes rise following a monetary stimulus.

I present empirical evidence that the total labor income of workers in occupations that perform abstract tasks rises significantly in response to monetary stimulus, while manual worker labor income does not respond and routine worker labor income declines. I show that these differences are larger in industries in which capital is especially responsive to monetary policy. Unsurprisingly, households in which the primary breadwinner works in a manual or routine occupation have lower household incomes, fewer assets, and less liquid savings than households in abstract occupations. This suggests a negative relationship between the response of household income to monetary stimulus and MPCs, and as a result, a dampened labor income channel. I embed this sort of capital-task complementarity into a medium-scale HANK model to quantify this dampening, and I find that the labor income channel is 26 percent smaller than in a standard model with homogeneous labor.

If the high-MPC households that drive monetary stimulus are concentrated in routine occupations, and routine occupations have become more substitutable with capital over the last half century, the size of the labor income channel has likely fallen and may continue to fall. Unless there is reason to think that other transmission mechanisms have grown, this implies that traditional levers of monetary policy may no longer be as effective. A growing body of research documents and attempts to explain the declining interest rate sensitivity of the US economy (Boivin et al., 2010a, Braxton and Van Zandweghe, 2013, Bloesch and Weber (2021)). This paper provides a novel explanation to account for these trends.

References

Adrien Auclert, Bence Bardóczy, Matthew Rognlie, Ludwig Straub. Using the sequence-space jacobian to solve and estimate heterogeneous-agent models. *Econometrica*, 89(5), 2021.

Felipe Alves, Greg Kaplan, Benjamin Moll, and Giovanni L. Violante. A further look at the propagation of monetary policy shocks in hank. *Journal of Money, Credit and Banking*, 52(S2):521–559, 2020.

Adrien Auclert. Monetary policy and the redistribution channel. *American Economic Review*, 109(6):2333–67, June 2019.

Adrien Auclert, Matthew Rognlie, and Ludwig Straub. Micro jumps, macro humps: Monetary policy and business cycles in an estimated hank model. Working Paper 26647, National Bureau of Economic Research, January 2020.

Adrien Auclert, Bence Bardóczy, Matthew Rognlie, and Ludwig Straub. Using the sequence-space jacobian to solve and estimate heterogeneous-agent models. *Econometrica*, 89(5): 2375–2408, 2021.

David H. Autor. Why are there still so many jobs? the history and future of workplace automation. *Journal of Economic Perspectives*, 29(3):3–30, September 2015.

David H. Autor and David Dorn. The growth of low-skill service jobs and the polarization of the us labor market. *American Economic Review*, 103(5):1553–97, August 2013.

David H. Autor, Frank Levy, and Richard J. Murnane. The Skill Content of Recent Technological Change: An Empirical Exploration. *The Quarterly Journal of Economics*, 118 (4):1279–1333, 2003.

David H. Autor, Lawrence F. Katz, and Melissa S. Kearney. The polarization of the u.s. labor market. *American Economic Review*, 96(2):189–194, May 2006.

Florin O. Bilbiie. The new keynesian cross. *Journal of Monetary Economics*, 2019.

Justin Bloesch and Jacob P. Weber. Structural Changes in Investment and the Waning Power of Monetary Policy. Technical report, Center for Open Science, March 2021.

Richard Blundell, Luigi Pistaferri, and Ian Preston. Consumption inequality and partial insurance. *American Economic Review*, 98(5):1887–1921, December 2008.

Federal Reserve Board. 1995,2007: Survey of consumer finances. https://www.federalreserve.gov/econres/scf-previous-surveys.htm.

Jean Boivin, Michael T Kiley, and Frederic S Mishkin. How has the monetary transmission mechanism evolved over time? Working Paper 15879, National Bureau of Economic Research, April 2010a.

Jean Boivin, Michael T. Kiley, and Frederic S. Mishkin. How Has the Monetary Transmission Mechanism Evolved Over Time? In Benjamin M. Friedman and Michael Woodford, editors, *Handbook of Monetary Economics*, volume 3 of *Handbook of Monetary Economics*, chapter 8, pages 369–422. Elsevier, 2010b.

John Carter Braxton and Willem Van Zandweghe. Has durable goods spending become less sensitive to interest rates? *Economic Review*, (Q IV):5–27, 2013.

Bureau of Economic Analysis. National Income and Product Accounts. Suitland, MD: 2022., 1979-2007.

Guangye Cao and Jonathan L. Willis. Has the U.S. economy become less interest rate sensitive? *Economic Review*, (Q II):5–36, 2015.

Simone Civale, Luis Diéz-Catalán, and Fatih Fazilet. Discretizing a process with non-zero skewness and high kurtosis. *SSRN Electronic Journal*, 01 2015.

Olivier Coibion. Are the effects of monetary policy shocks big or small? *American Economic Journal: Macroeconomics*, 4(2):1–32, April 2012.

Olivier Coibion, Yuriy Gorodnichenko, Lorenz Kueng, and John Silvia. Innocent bystanders? monetary policy and inequality in the u.s. Working Paper 18170, National Bureau of Economic Research, June 2012.

Juan J. Dolado, Gergo Motyovszki, and Evi Pappa. Monetary Policy and Inequality under Labor Market Frictions and Capital-Skill Complementarity. *American Economic Review: Macroeconomics*, forthcoming, 2021.

Cynthia Doniger. Do greasy wheels curb inequality? Finance and Economics Discussion Series 2019-021 1163, Washington: Board of Governors of the Federal Reserve System, 2019.

David Dorn. Essays on inequality, spatial interaction, and the demand for skills. *Dissertation University of St. Gallen*, (3613), September 2009.

Maya Eden and Paul Gaggl. On the welfare implications of automation. *Review of Economic Dynamics*, 29:15–43, 2018.

Fatih Guvenen, Fatih Karahan, Serdar Ozkan, and Jae Song. What do data on millions of u.s. workers reveal about life-cycle earnings risk? Working Paper 20913, National Bureau of Economic Research, January 2015.

Fatih Guvenen, Sam Schulhofer-Wohl, Jae Song, and Motohiro Yogo. Worker betas: Five facts about systematic earnings risk. *American Economic Review*, 107(5):398–403, May 2017.

Aaron Hedlund, Fatih Karahan, Kurt Mitman, and Serdar Ozkan. Monetary policy, heterogeneity, and the housing channel. Meeting Paper 1610, Society for Economic Dynamics, January 2017.

David S. Johnson, Jonathan A. Parker, and Nicholas S. Souleles. Household expenditure and the income tax rebates of 2001. *American Economic Review*, 96(5):1589–1610, December 2006.

Òscar Jordà. Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1):161–182, March 2005.

Greg Kaplan, Giovanni L Violante, and Justin Weidner. The wealthy hand-to-mouth. Working Paper 20073, National Bureau of Economic Research, April 2014.

Greg Kaplan, Benjamin Moll, and Giovanni L. Violante. Monetary policy according to hank. *American Economic Review*, 108(3):697–743, March 2018.

Per Krusell, Lee E. Ohanian, José-Víctor Ríos-Rull, and Giovanni L. Violante. Capital-skill complementarity and inequality: A macroeconomic analysis. *Econometrica*, 68(5): 1029–1053, 2000.

Ralph Luetticke. Transmission of Monetary Policy with Heterogeneity in Household Portfolios. Discussion papers, Centre for Macroeconomics (CFM), June 2018.

Alisdair McKay, Emi Nakamura, and Jón Steinsson. The power of forward guidance revisited. *American Economic Review*, 106(10):3133–58, October 2016.

Christina Patterson. The matching multiplier and the amplification of recessions. *American Economic Review*, 113(4):982–1012, April 2023.

Jerome Powell. Monetary Policy in the Time of COVID. economic policy symposium, Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, 2021.

V.A. Ramey. Chapter 2 - macroeconomic shocks and their propagation. volume 2 of *Handbook of Macroeconomics*, pages 71–162. Elsevier, 2016.

Christina D. Romer and David H. Romer. A new measure of monetary shocks: Derivation and implications. *American Economic Review*, 94(4):1055–1084, September 2004.

Sarah Flood, Miriam King, Renae Rodgers, Steven Ruggles, J. Robert Warren, Daniel Backman, Annie Chen, Grace Cooper, Stephanie Richards, Megan Schouweiler, Michael Westberry. IPUMS CPS: Version 11.0 Outgoing Rotation Groups. Minneapolis, MN: IPUMS, 2023., 1979-2007.

Silvana Tenreyro and Gregory Thwaites. Pushing on a string: Us monetary policy is less powerful in recessions. *American Economic Journal: Macroeconomics*, 8(4):43–74, October 2016.

Johannes F. Wieland and Mu-Jeung Yang. Financial Dampening. *Journal of Money, Credit and Banking*, 52(1):79–113, February 2020.

A Appendix

A.1 Appendix for Simple Model

A.1.1 Proof of Proposition 1.

The firm's first order conditions are given by equations (A.1) and (A.2).

$$\frac{w_t^R}{w_t^A} = (1-\alpha_A)\left(\alpha_R {N_t^R}^{\frac{\sigma_R-1}{\sigma_R}} + \alpha_K {K_t}^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}-1} \frac{\alpha_R {N_t^R}^{\frac{-1}{\sigma_R}}}{\alpha_A {N_t^A}^{\frac{-1}{\sigma_A}}} \tag{A.1}$$

$$\frac{\mu K_t^{\mu-1}}{w_t^R} = \frac{\alpha_K}{\alpha_R}\left(\frac{N_t^R}{K_t}\right)^{\frac{1}{\sigma_R}} \tag{A.2}$$

Because we have assumed that $\theta = 0$ - and therefore that there are no income effects in labor supply - total labor supply for type i-occupation households is given by equation (A.3), where $\lambda_i = \lambda_{iu} + \lambda_{ic}$.

$$N_{st}^i = \lambda_i {w_t^i}^{\frac{1}{\nu}} \tag{A.3}$$

Substituting (A.3) for both types into (A.1) and (A.2) gives you the following. For simplicity, I assume $\psi = 1$ and let $\hat{\alpha_R} = \alpha_R(\lambda_R)^{\frac{\sigma_R-1}{\sigma_R}}$.

$$\frac{w_t^R}{w_t^A} = (1-\alpha_A)\left(\hat{\alpha}_R {w_t^R}^{\frac{\sigma_R-1}{\nu\sigma_R}} + \alpha_K {K_t}^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}-1} \frac{\alpha_R {w_t^R}^{\frac{-1}{\nu\sigma_R}}}{\alpha_A {w_t^A}^{\frac{-1}{\nu\sigma_A}}} \frac{\lambda_A^{\frac{1}{\sigma_A}}}{\lambda_R^{\frac{1}{\sigma_R}}}$$

$$\frac{\mu K_t^{\mu-1}}{w_t^R} = \frac{\alpha_K}{\alpha_R}\left(\frac{w_t^R}{K_t}\right)^{\frac{1}{\nu\sigma_R}} \lambda_R^{\frac{1}{\sigma_R}}$$

Rearranging the second expression to get capital as a function of routine wages.

$$K_t = \left(\frac{\lambda_R^{\frac{1}{\sigma_R}} \alpha_K}{\alpha_R} (w_t^R)^{1+\frac{1}{\nu\sigma_R}}\right)^{\frac{1}{\mu-1+\frac{1}{\nu\sigma_R}}} = f(w_t^R) \tag{A.4}$$

Next, take the derivative of K_t with respect to w_t^R.

$$\frac{\partial K_t}{\partial w_t^R} = \frac{\alpha_K}{\alpha_R} \frac{1+\frac{1}{\nu\sigma_R}}{\mu-1+\frac{1}{\nu\sigma_R}} (w_t^R)^{\frac{1+\frac{1}{\nu\sigma_R}}{\mu-1+\frac{1}{\nu\sigma_R}}-1} \frac{1}{\mu}$$

From this expression, it is clear that, as μ decreases towards 0, $\frac{\partial K_t}{\partial w_t^R}$ approaches ∞. From equation (A.3 therefore, we also have that $\frac{\partial K_t}{\partial N_t^R} \to \infty$ as $\mu \to 0$. The converse is true when $\mu \to \infty$. The latter is the case of fixed capital. Intuitively, this makes sense. As capital adjustment costs get infinitely large, capital is less and less responsive as output (and therefore N^R) increases.

Plugging (A.4) and household labor supply into (A.1) gives the following expression for w_t^A as a function of w_t^R.

$$w_t^{A\frac{-1}{\nu\sigma_A}-1} = (1-\alpha_A)\left(\hat{\alpha}_R w_t^{R\frac{\sigma_R-1}{\nu\sigma_R}} + \alpha_K f(w_t^R)^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}-1} \frac{\alpha_R w_t^{R\frac{-1}{\nu\sigma_R}}}{\alpha_A w_t^R} \frac{\lambda_A^{\frac{1}{\sigma_A}}}{\lambda_R^{\frac{1}{\sigma_R}}} = g(w_t^R) \quad \text{(A.5)}$$

Solving for $\frac{\partial w_t^A}{\partial w_t^R}$ tells us whether abstract or routine workers' wages (and therefore also their labor supply) increases *more* as output expands. When $\frac{\partial w_t^A}{\partial w_t^R} = 1$, both wages increase proportionally. The derivative of g with respect to w_t^R for any arbitrary (positive) values of w_t^R and w_t^A will take the form where $\mathcal{C}_1$ and $\mathcal{C}_2$ are positive constants:

$$\frac{\partial w_t^A}{\partial w_t^R} = \mathcal{C}_1 f(w_t^R) + \mathcal{C}_2$$

We have already shown that as $\mu \to 0$, $\frac{\partial f(w_t^R)}{\partial w_t^R} \to \infty$. Therefore, because $\frac{\partial w_t^A}{\partial w_t^R}$ is a continuous function, we can employ the Intermediate Value Theorem and be confident that there exists some $\bar{\mu}$ such that if $\mu < \bar{\mu}$, then $\frac{\partial w_t^A}{\partial w_t^R} > 1$.

A.1.2 Derivation of Labor Income Channel

$$\Omega^L = \sum_i \sum_j \left(\lambda_{ij} MPC_{ij} d(N_{ij} w_i)\right) \quad \text{(A.6)}$$

For simplicity, I refer to $N_{ij}w_i$, a worker's labor income, as Y_{ij}^L. Rewriting equation (A.6) above and taking the derivative with respect to Y gives you:

$$\Omega^L = \sum_i \sum_j \left(\lambda_{ij} MPC_{ij} \frac{\partial Y_{ij}^L}{\partial Y} dY\right)$$

I define $d\bar{Y}^L$ as the average labor income response and $M\bar{P}C$ as the average MPC. This can be expanded out as:

$$= \sum_i \sum_j \lambda_{ij} \left(MPC_{ij} + M\bar{P}C - M\bar{P}C\right)\left(\frac{\partial Y_{ij}^L}{\partial Y} dY + d\bar{Y}^L - d\bar{Y}^L\right)$$

$$= Cov\left(MPC_{ij}, \frac{\partial Y_{ij}^L}{\partial Y} dY\right) + M\bar{P}C \sum_i \sum_j \lambda_{ij} \left(\frac{\partial Y_{ij}^L}{\partial Y} dY - d\bar{Y}^L\right) + \ ...$$

$$d\bar{Y}^L \sum_i \sum_j \lambda ij \left(MPC_{ij} - M\bar{P}C\right) + M\bar{P}C d\bar{Y}^L$$

It's easy to see that the middle two terms simplify to 0. Then you have:

$$\Omega^L = M\bar{P}C d\bar{Y}^L + Cov\left(MPC_{ij}, \frac{\partial Y_{ij}^L}{\partial Y} dY\right) \tag{A.7}$$

A.1.3 Proof of Proposition 2.

In Section A.1.1, I established that for a sufficiently low μ, the total derivative of abstract labor income in response to a monetary shock, dw_t^A was greater than dw^R. Because labor supply is an increasing function of the wage, $dn_t^A > dn_t^R$. By assumption, $w_t^A > w_t^R$ and therefore $n_t^A > n_t^R$. Therefore, $dY_{At}^L = w_t^A dn_t^A + dw_t^A n_t^A > dY_{Rt}^L$ for $\mu < \bar{\mu}$.

As stated in the Proposition, keep $\lambda_R = \lambda_{Ru} + \lambda_{Rc}$ - and therefore - $d\bar{Y}^L$ constant. Also, let λ_c, the total share of constrained households - and therefore $M\bar{P}C$ - constant. Then if the proportion of routine workers who are constrained λ_{Rc} increases, λ_{Ru} and λ_{Ac} must decrease. Recall that Ω_L is given by:

$$\sum_i \sum_j \lambda_{ij} \left(MPC_{ij} - M\bar{P}C\right)\left(\frac{\partial Y_{ij}^L}{\partial Y} dY - d\bar{Y}^L\right) + M\bar{P}C d\bar{Y}^L \tag{A.8}$$

When λ_{Rc} increases, more weight is given to a negative term as the MPC of spenders is above average but the earnings elasticity of routine workers is below average. Similarly, when λ_{Ac} and λ_{Ru} go down, less weight is given to positive terms. Both the MPC and earnings elasticity of abstract spenders is above average, and both the MPC and earnings elasticity of routine savers is below average.

Therefore, Ω_L is decreasing in λ_{Rc}.

A.2 Robustness Checks

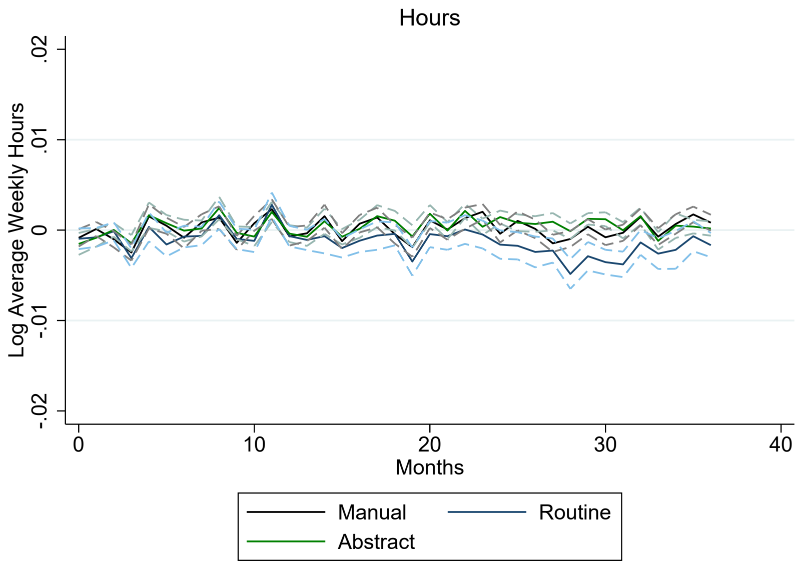

Figure A.1: Impulse response of log hours to a 25 basis point shock

Notes: This figure reports the impulse response of log average hours by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors.

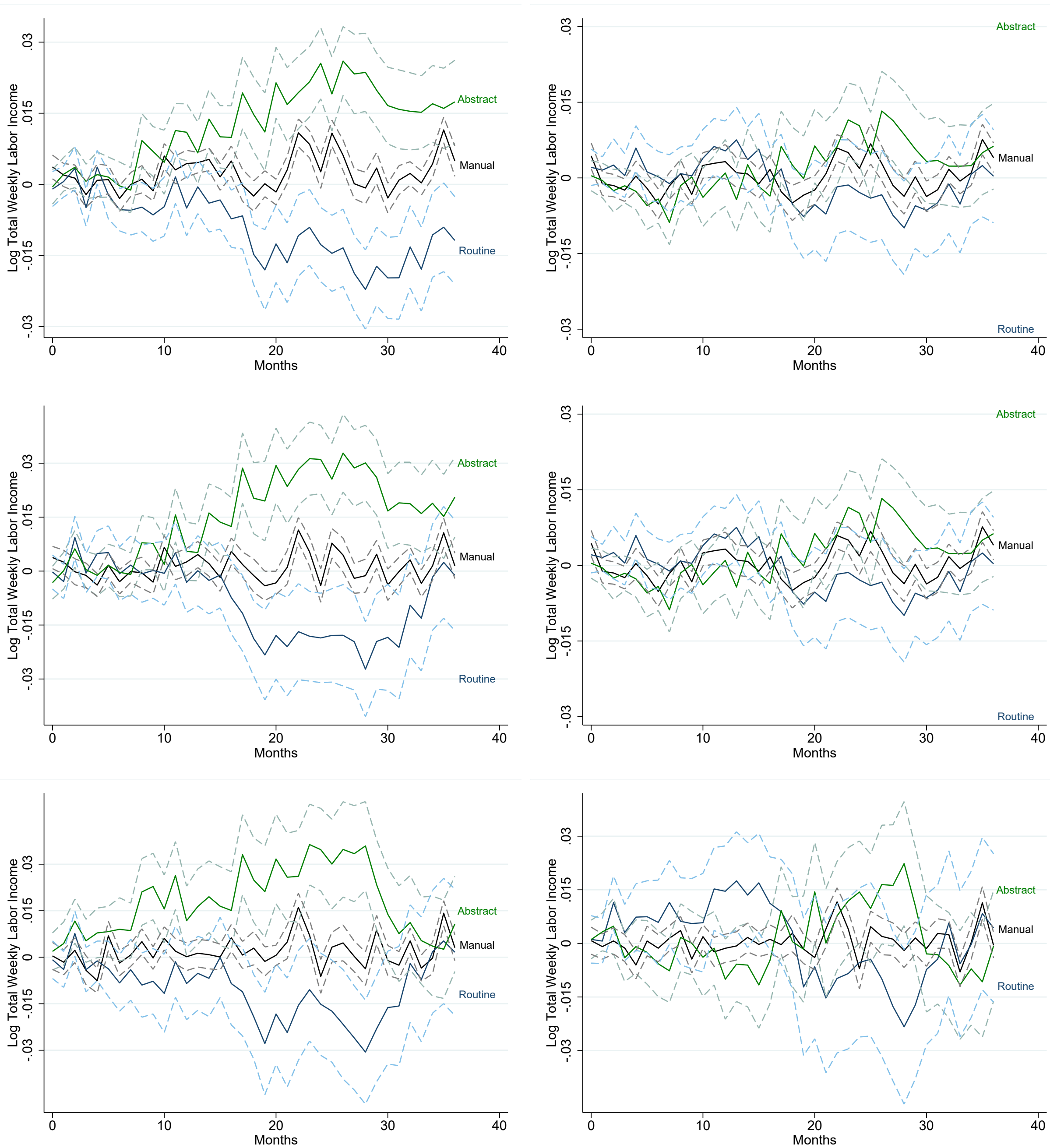

Figure A.2: Effect of Monetary Policy on Weekly Labor Income

Notes: This figure reports the impulse response of log total average weekly labor income by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors. The results on the left side of the figure control for lags of the federal funds rate, while the ride side controls for lags of the monetary shock. The top row includes 12 lags of the dependent variable and controls, the middle row includes 24 lags, and the bottom row includes 36 lags.

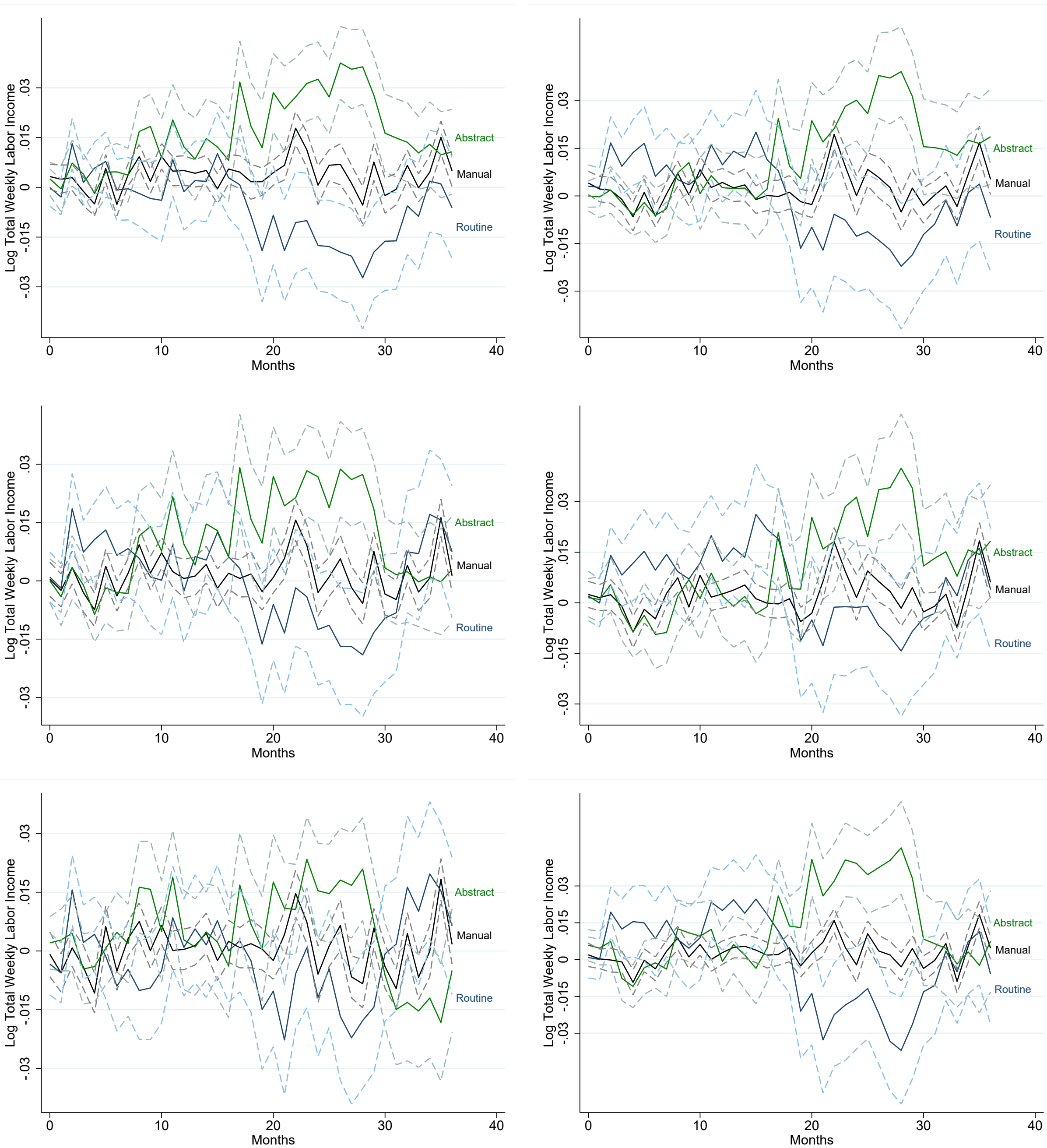

Figure A.3: Effect of Monetary Policy on Weekly Labor Income: Post 1984 Sample

Notes: This figure reports the impulse response of log total average weekly labor income by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks for the sample starting in 1984. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors. The results on the left side of the figure control for lags of the federal funds rate, while the ride side controls for lags of the monetary shock. The top row includes 12 lags of the dependent variable and controls, the middle row includes 24 lags, and the bottom row includes 36 lags.

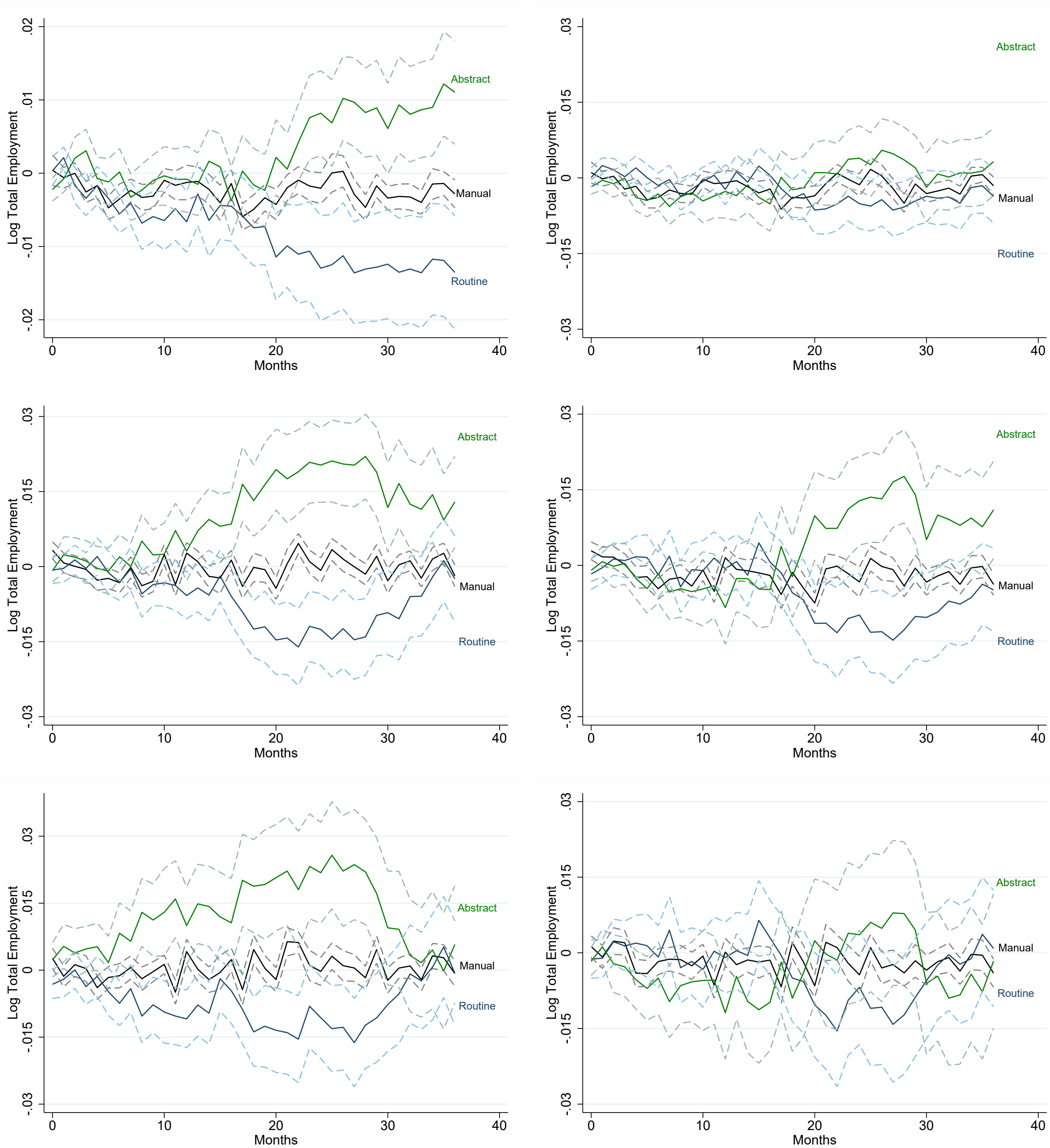

Figure A.4: Effect of Monetary Policy on Employment

Notes: This figure reports the impulse response of log total employment by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors. The results on the left side of the figure control for lags of the federal funds rate, while the ride side controls for lags of the monetary shock. The top row includes 12 lags of the dependent variable and controls, the middle row includes 24 lags, and the bottom row includes 36 lags.

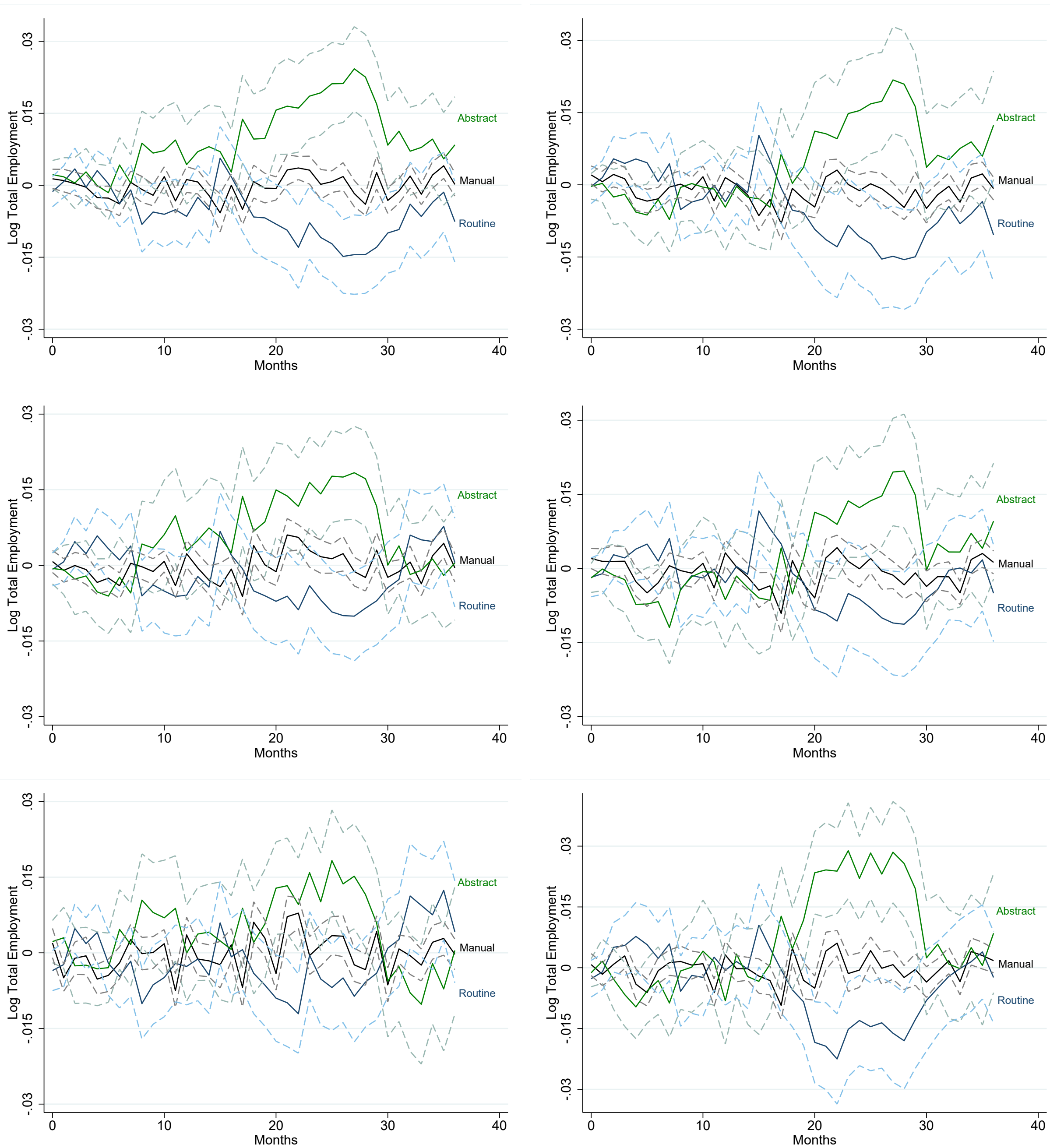

Figure A.5: Effect of Monetary Policy on Employment: Post 1984 Sample

Notes: This figure reports the impulse response of log total employment by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks for the sample starting in 1984. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors. The results on the left side of the figure control for lags of the federal funds rate, while the ride side controls for lags of the monetary shock. The top row includes 12 lags of the dependent variable and controls, the middle row includes 24 lags, and the bottom row includes 36 lags.

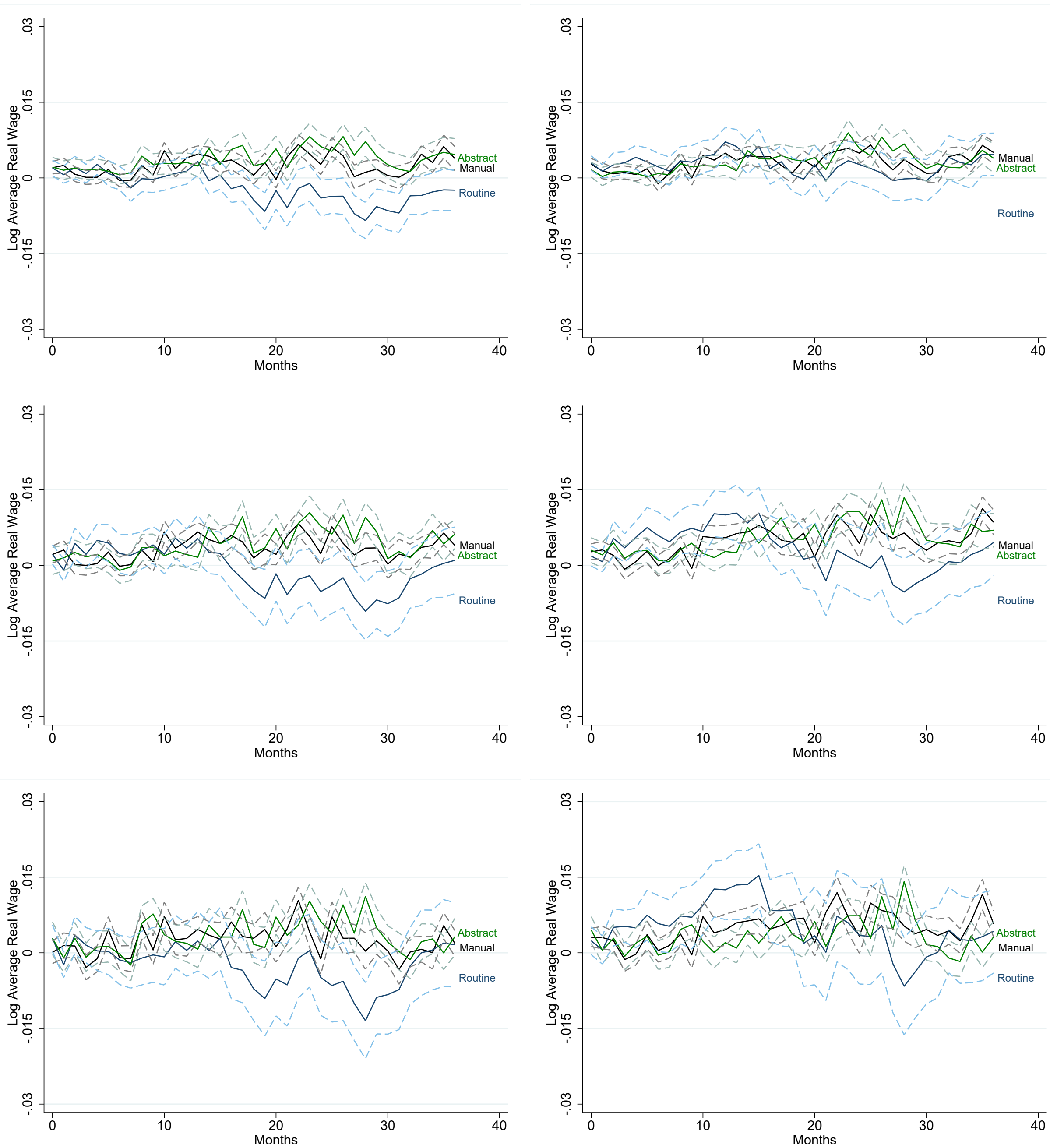

Figure A.6: Effect of Monetary Policy on the Real Wage

Notes: This figure reports the impulse response of the log average real wage by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors. The results on the left side of the figure control for lags of the federal funds rate, while the ride side controls for lags of the monetary shock. The top row includes 12 lags of the dependent variable and controls, the middle row includes 24 lags, and the bottom row includes 36 lags.

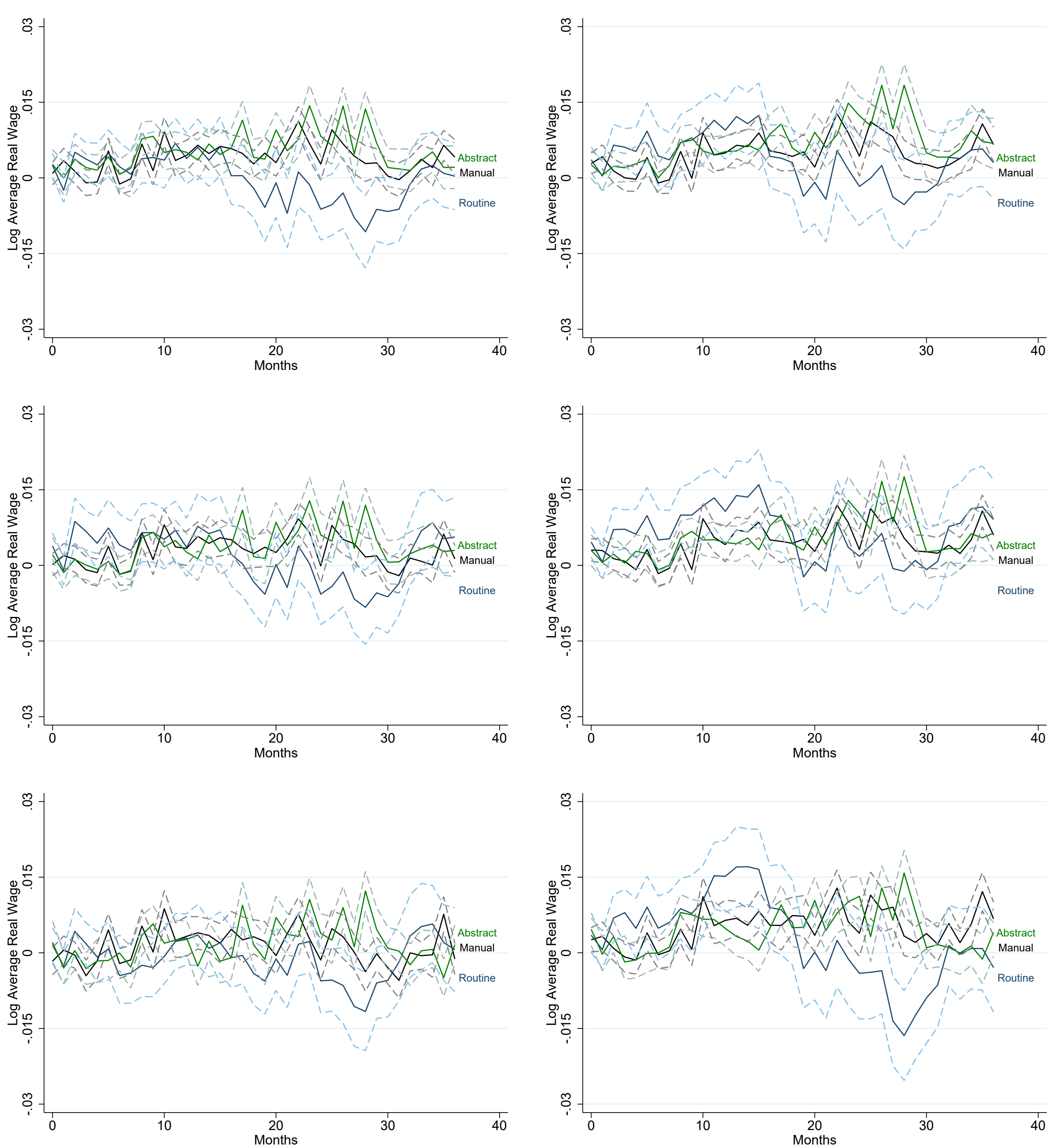

Figure A.7: Effect of Monetary Policy on the Real Wage: Post 1984 Sample

Notes: This figure reports the impulse response of log average real wages by occupation group to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks for the sample starting in 1984. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors. The results on the left side of the figure control for lags of the federal funds rate, while the ride side controls for lags of the monetary shock. The top row includes 12 lags of the dependent variable and controls, the middle row includes 24 lags, and the bottom row includes 36 lags.

A.3 High and Low Interest Rates

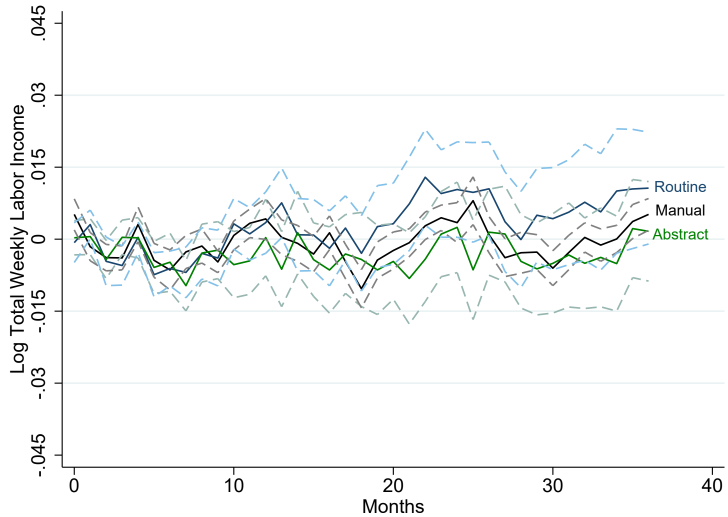

Figure A.8: Impulse response of log total weekly labor income: High Interest Rates

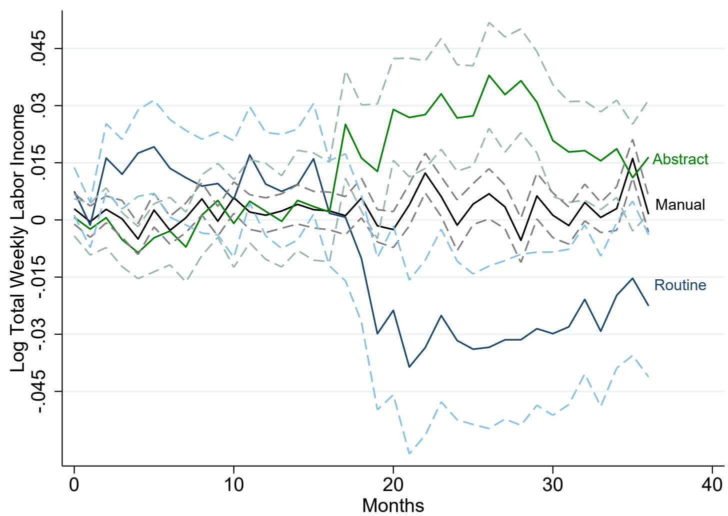

Figure A.9: Impulse response of log total weekly labor income: Low Interest Rates

A.4 Appendix for Back-of-the-Envelope Calculations.

Recall that the labor income channel can be written in the following way.

$$\Omega_L = \sum_{j \in J} MPC_j \Bigg(\lambda_{aj} N_a w_a \left(\frac{dN_A}{N_A} + \phi \frac{dN_R}{N_R} + \frac{dw_A}{w_A} \right) + \lambda_{rj} N_r w_r \left(\frac{dN_R}{N_R} - \frac{\phi dN_R}{N_R} + \frac{dw_R}{w_R} \right) + \lambda_{mj} N_m w_m \left(\frac{dN_M}{N_M} + \frac{dw_M}{w_M} \right) \Bigg)$$

In the case with occupational transitions, I define ϕ as the share of the change in routine occupation employment attributable to transitions into abstract occupations. Then the following holds.

$$dN_{fr}^{tr} = \phi dN_R = -dN_{fa}^{tr}$$

The total change in routine employment is $dN_R = dN_{fr}^{tr} + dN_r$. The total change in abstract employment is $dN_A = dN_{fa}^{tr} + dN_a$. I assume that $N_A = N_R = N_M$, as all task groups are roughly equal in size by construction.

From the empirical estimates, we have $\frac{dN_A}{N_A}$ and $\frac{dN_R}{N_R}$ which can be used to find expressions for the percent changes in employment for the other groups.

$$\frac{dN_A}{N_A} = \frac{dN_{fa}^{tr}}{N_A} + \frac{dN_a}{N_A} = \frac{dN_a}{N_A} - \frac{\phi dN_R}{N_R} = \frac{dN_a}{N_a} - \frac{\phi dN_R}{N_R}$$

Similarly, the following holds.

$$\frac{dN_R}{N_R} = \frac{dN_{fr}^{tr}}{N_R} + \frac{dN_r}{N_R} = \frac{\phi dN_R}{N_R} + \frac{dN_r}{N_r}$$

The difference between the labor income channel for 2 different values of ϕ is given by the following expression.

$$\Omega_L(\phi') - \Omega_L(\phi) = (\phi' - \phi) \frac{dN_R}{N_R} \sum_{j \in J} MPC_j \Big(\lambda_{aj} N_a w_a - \lambda_{rj} N_r w_r \Big)$$

Values used for the back-of-the-envelope calculation of the labor income channel, along with their source, are reported below in Table A.1.

TABLE A.1

Variable	Description	Value	Data Source
Peak Impulse Responses			
$dlnN_A$	Abstract Employment (% Change)	1.8	CPS MORG
$dlnN_R$	Routine Employment (% Change)	-1.4	CPS MORG
$dlnN_M$	Manual Employment (% Change)	0	CPS MORG
$dlnw_A$	Abstract Wages (% Change)	.8	CPS MORG
$dlnw_R$	Routine Wages (% Change)	-.8	CPS MORG
$dlnw_M$	Manual Employment (% Change)	0.6	CPS MORG
Average $dlnN$	Average Employment (% Change)	.12	Author's Calculation
Average $dlnw$	Average Wage (% Change)	.28	Author's Calculation
Hand-to-Mouth Shares			
λ_{ac}	Abstract Htm Share	.22	SCF
λ_{rc}	Routine Htm Share	.44	SCF
λ_{mc}	Manual Htm Share	.47	SCF
Average Wages			
$w_A/\bar{w}$	Abstract wage	1.18	CPS MORG
$w_R/\bar{w}$	Routine wage	.86	CPS MORG
$w_M/\bar{w}$	Manual wage	.95	CPS MORG
MPC			
MPC_u	Non-Hand-to-Mouth MPC	.06	Kaplan et al. (2014)
MPC_c	Hand-to-Mouth MPC	.395	Kaplan et al. (2014)

Note: This table reports the values used in the back of the envelope calculation of the labor income channel in Section 3.3 and Section 3.4. I report the peak impulse responses from Figure 2. The hand-to-mouth shares correspond to the estimated shares in 2007 from Section 3.7. Relative wages are generated using the summary statistics in Table 1. Marginal propensities to consume come from the first row of Table 7 in Kaplan et al. (2014). The hand-to-mouth MPC is the average of the wealth and poor hand-to-mouth.

A.5 Investment by Industry

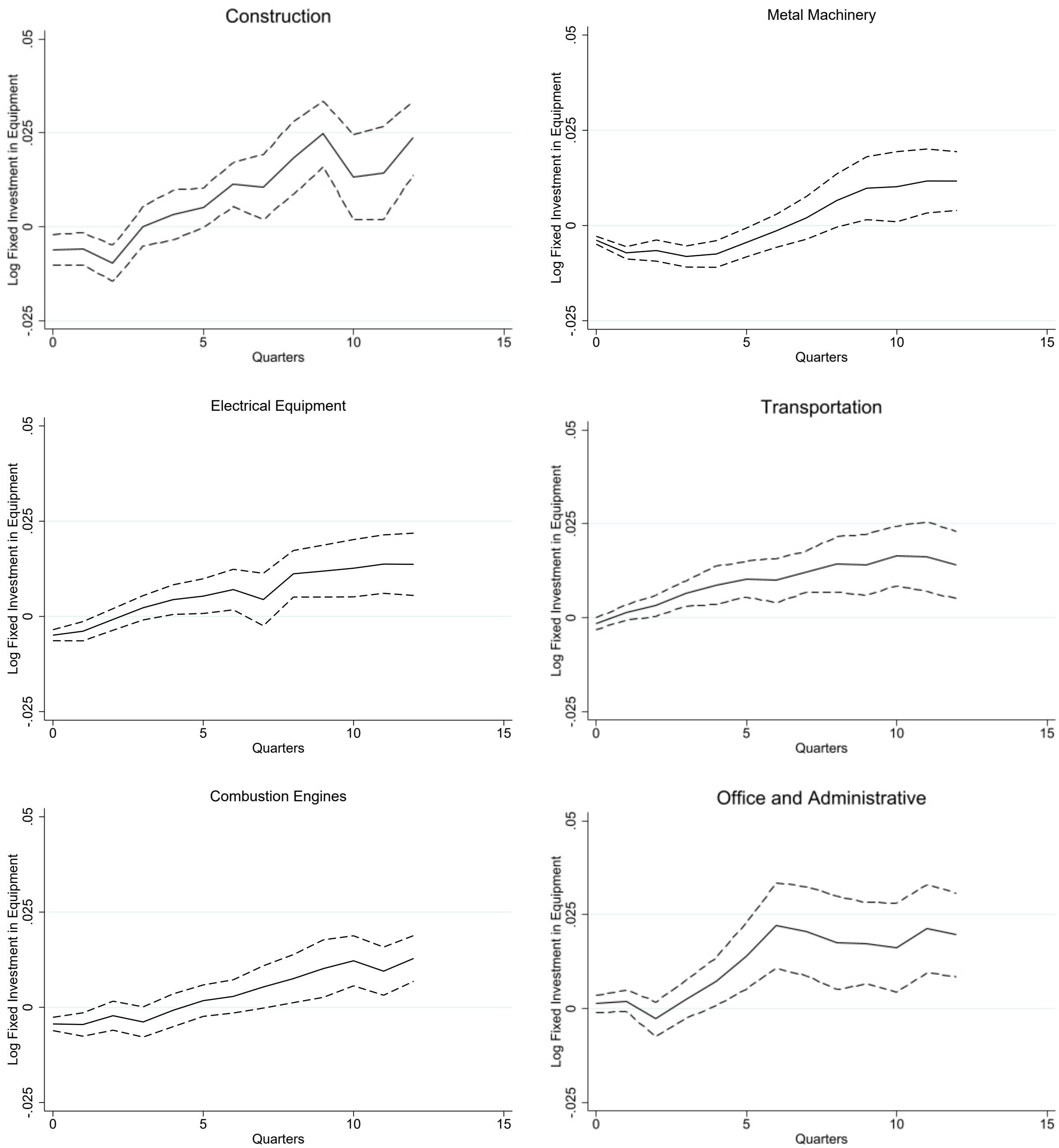

Figure A.10: Response of Fixed Equipment Capital to Monetary Policy

Notes: This figure reports the impulse response of log fixed investment in equipment capital for different capital types to an exogenous 25 basis point monetary policy shock using Jordá projections and Romer and Romer shocks. 90 percent confidence intervals are shown (dashed lines) and were constructed with Newey-West standard errors.

TABLE A.2

Industry	1979	2007	Average
Responsive Industries			
Manufacturing	0.104	0.112	0.112
Finance and insurance	0.134	0.167	0.157
Construction	0.161	0.166	0.164
Mining	0.143	0.124	0.139
Transportation and warehousing	0.088	0.111	0.103
Responsive average	0.126	0.136	0.135
Less-Responsive Industries			
Professional, scientific, and technical services	0.150	0.186	0.174
Real estate and rental and leasing	0.150	0.150	0.160
Administrative and waste management services	0.138	0.167	0.155
Utilities	0.089	0.078	0.095
Management of companies and enterprises	0.128	0.159	0.151
Accommodation and food services	0.143	0.149	0.148
Retail trade	0.149	0.155	0.155
Educational services	0.152	0.170	0.166
Information	0.117	0.137	0.127
Agriculture, forestry, fishing, and hunting	0.135	0.139	0.142
Wholesale trade	0.169	0.160	0.169
Arts, entertainment, and recreation	0.138	0.152	0.151
Health and social assistance	0.152	0.161	0.159
Less-Responsive Average	0.139	0.151	0.150

Note: This table reports annual depreciation rates for equipment capital between 1979 and 2007 calculated using data from the National Income and Product Accounts.

A.6 Quantitative Model Details

Equation A.9 is the households' budget constraint. Equation A.10 is the borrowing constraint and A.11 is the portfolio adjustment cost.

$$c_{it} + b_{it} + a_{it} + \chi_{it} \leq (1 - t_t)e_{it}w_{it}n_{it} + (1 + r^b_{t-1})b_{it-1} + (1 + r^a_{t-1})a_{it-1} \tag{A.9}$$

$$b_{it} \geq \underline{\mathrm{b}} \tag{A.10}$$

$$\chi(a_{it}, a_{it-1}) = \frac{\chi_1}{\chi_2}\left|a_t - (1 + r^a_t)a_{t-1}\right|^{\chi_2}\left[(1 + r^a_t)a_{t-1} + \chi_0\right]^{-1} \tag{A.11}$$

The functional form for the portfolio adjustment costs is taken from Adrien Auclert, Bence Bardóczy, Matthew Rognlie, Ludwig Straub (2021) and is bounded, differentiable, and convex in a_t. The household's first order conditions are given by the following 3 equations where V_t is the household's value function, μ_b is the multiplier on the liquid asset constraint (13) and μ_a is the multiplier on the illiquid asset constraint.[26]

$$u_c(c_{it})e_{it}(1-t_t)w_{it} = \psi_j n_{it}^{\nu} \tag{A.12}$$

$$u_b(c_{it}) = \mu_b + \beta E \partial_b V_{t+1}(z_{t+1}, b_t, a_t) \tag{A.13}$$

$$u_a(c_{it})[1+\chi'(a_t, a_{t-1})] = \mu_a + \beta E \partial_a V_{t+1}(z_{t+1}, b_t, a_t) \tag{A.14}$$

The firm's optimality conditions are the following. Here, Q_t is the multiplier on the investment adjustment cost constraint (20). Equation (A.15) is the Philips Curve, equation (A.16) governs firm valuation, and equations (A.17) and (A.18) are the demand equations for abstract and routine labor respectively.

$$log(1+\pi_{kt}) = \kappa_p \left(mc_t - \frac{1}{\mu + p} \right) + \frac{1}{r_{t+1}^a} \frac{Y_{t+1}}{Y_t}(1+\pi_{t+1}) \tag{A.15}$$

$$(1+r_t^a)Q_t = \alpha \frac{Y_{t+1}}{K_t} mc_{t+1} - \frac{K_{t+1}}{K_t} + (1-\delta) - \frac{(K_{t+1}-K_t)^2}{2\delta\epsilon_I K_t^2} + \frac{K_{t+1}Q_{t+1}}{K_t} \tag{A.16}$$

$$w_t^a = mc_t Y_t^{\Gamma_1} \alpha_A N_t^{A\frac{-1}{\sigma_A}} \tag{A.17}$$

$$w_t^r = mc_t Y_t^{\Gamma_2}(1-\alpha_A) \left(\alpha_R N_t^{R\frac{\sigma_R - 1}{\sigma_R}} + \alpha_K K_t^{\frac{\sigma_R - 1}{\sigma_R}} \right)^{\frac{\sigma_R(\sigma_A - 1)}{(\sigma_R - 1)\sigma_A} - 1} \alpha_R N_t^{R\frac{-1}{\sigma_R}} \tag{A.18}$$

[26]To solve the households' problem, I rely heavily on Auclert et al. (2020) and their endogenous grid point algorithm. Clear instructions for how to implement the algorithm are available in their paper's appendix.

TABLE A.3

Parameter		Value
Household		
β	Discount factor	0.966
$1/\sigma$	Elasticity of Intertemporal Substitution	0.4
χ_0	Portfoloio adj. cost pivot	0.25
χ_{1A}	Abstract portfoloio adj. cost scale	25.49
χ_{1R}	Routine portfoloio adj. cost scale	8
χ_2	Portfoloio adj. cost curve	2
$\underline{\text{b}}$	Borrowing limit	0
ρ_e	Autocorrelation of earnings	0.94
σ_e	Standard deviation of earnings	1.37
ψ_A	Disutility of labor (abstract)	2.0
ψ_R	Disutility of labor (routine)	5.1
B^h	Total liquid assets	3.47
ν	Inverse Frisch Elasticity	1
Firms		
σ_A	Abstract substitution elasticity	0.67
σ_R	Routine substitution elasticity	1.67
α_A	Coefficient on abstract labor	0.36
α_R	Coefficient on routine labor	0.67
Z	Aggregate TFP	1.29
δ	Depreciation rate	0.07
ϵ_I	Inverse capital adjustment cost	10
κ_p	Slope of price Phillips Curve	0.1
μ_p	Steady state markup	1.05
Labor Unions		
μ_w	Steady state markup	1.1
κ_w	Slope of wage Phillips Curve	0.1
Policy		
G	Government Spending	0.17
τ	Labor income tax	0.35
B^g	Bond supply	2.8
ϕ_y	Taylor rule output coeffi.	0
ϕ_π	Taylor rule inflation coeffi.	1.5

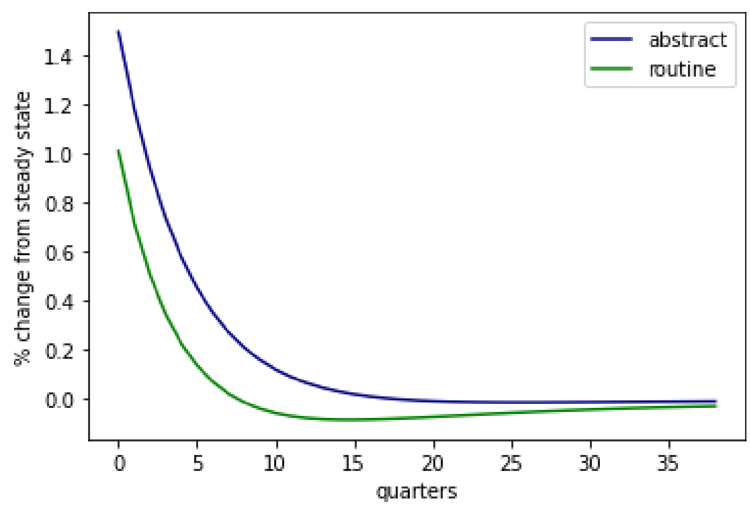

Figure A.11: Model: Response of Employment to Monetary Policy