Capital-Task Complementarity and the Labor Income Channel of Monetary Policy

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Abstract

This paper examines how heterogeneity in worker substitutability with capital affects the labor income channel of monetary policy. Empirically, I show that workers performing routine tasks see smaller labor income gains than other workers following a monetary expansion and have higher marginal propensities to consume (MPC). I show that this relationship dampens the role that the labor market plays in monetary policy transmission. I embed capital-task complementarity in a medium-scale HANK model calibrated to match the respective capital-labor elasticities and labor shares of routine and non-routine workers. This worker heterogeneity reduces the size of the labor income channel 25 percent.

Keywords: Monetary Policy, Capital-Skill Complementarity, Heterogeneous Agents, New Keynesian, Labor Income Channel
JEL codes: E22, E24, E52, J24

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A growing literature is reexamining the conventional understanding of how monetary policy stimulates consumption. Instead of emphasizing *direct* transmission through intertemporal 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 models, consumption due to rising labor income in particular accounts for around half of the overall effect on consumption on impact. If the 'labor-income channel' is as important as this literature suggests, trends in the labor market may effect of 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 through general equilibrium increases in labor 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.

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 (2019) 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 more than those of 'routine' workers, while the opposite is true if capital is unresponsive

[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.

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 over the last 4 decades. I find that indeed, abstract workers' labor incomes increase significantly more than that of other workers and that routine labor incomes decline slightly. 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 embed capital-task complementarity 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 fraction of each occupation group that is 'hand-to-mouth' as well as each group's labor share 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, but that is otherwise identical. I find that capital-task complementarity reduces the size of the labor income channel by about 25 percent on impact.

Calibrating effective monetary policy requires a rigorous understanding of the relative importance of different transmission mechanisms and the ways in which they interact with other policies and macro-economic trends. Kaplan, Moll, and Violante (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 heterogeneity - 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. (2010) 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 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 I analyzes a variant of a simple TANK model with heterogeneity in workers' elasticities of substitution with capital. Section II presents my empirical results. Section III presents the medium-scale HANK model and quantitative results. Section IV concludes.

[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.

I. Worker Heterogeneity and the Labor Market Channel

In this section, I introduce heterogeneity in workers' elasticity of substitution with capital into an otherwise simple two-agent saver-spender model with fixed prices and capital adjustment costs (Mankiw, 2000). 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 attributable to rising wages - depends on both the responsiveness of capital to monetary policy and the covariance between a worker's 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 relatively high, firms are unwilling to increase capital and must instead disproportionately employ substitutable "routine" workers to increase output. When adjustment costs are relatively 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 to monetary policy. That is, when households who tend to consume new labor income don't see their labor income rise by very much, the crucial 'Keynesian Cross' feedback mechanism is dampened.

A. Simple Model

Households. Households differ along two dimensions: their access to financial markets and their occupation. Households can be either savers (sa) or spenders (sp) 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 with occupation 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:

$$U(C_t^{ij}, N_t^{ij}) = \frac{(C_t^{ij})^{1-\theta}}{1-\theta} - \psi \frac{(N_t^{ij})^{1+\nu}}{1+\nu}$$

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

$$\max_{C_t, B_{t+1}, N_t} \sum_{t=0}^{\infty} \beta^t E_0[U(C_t^{isa}, N_t^{isa})]$$

$$s.t.\ C_t^{isa} + \frac{B_{t+1}^{isa}}{1+r_t} \leq W_t^i N_t^{isa} + B_t^{isa} + T_t^{isa} + D_t^i \tag{1}$$

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

$$N_t^{isa} = \left(\psi^{-1} W_t^i (C_t^{isa})^{-\theta}\right)^{\frac{1}{\nu}} \tag{2}$$

$$1 = \beta(1+r_t)E_t\left(\frac{C_t^{isa}}{C_{t+1}^{isa}}\right)^{\theta} \tag{3}$$

Because constrained households have no access to the bond market, $C_t^{isp} = W^i N_t^{isp} + T_t^{isp}$. Labor supply for constrained households is analogous to that of unconstrained households. I consider the case where $\theta \to 0$, eliminating any income effects in the labor supply decision. This will allow me to solve for simple analytical expressions despite the introduction of worker heterogeneity, however the results do not depend on this assumption.

Firms. There is a continuum of goods producing firms subject to infinite price adjustment costs with the price level normalized 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 that it finances by issuing 1-period bonds with rates of return r_t. The fiscal authority's balanced budget constraint is given by $\frac{B_{t+1}}{1+r_t} = B_t + T_t$. Because prices are fixed, the monetary authority is able to set the real interest rate, r_t.

B. The Response of Labor Income to Output

Combining the firm's first order conditions with the households' labor supply condition and setting $\alpha_K = 1 - \alpha_R$ results in an expression for abstract labor as a function of routine labor in equilibrium.

$$N_t^A = \left(\frac{1-\sigma_A}{\sigma_A}\sigma_R N_t^{R-\nu-\frac{1}{\sigma_R}} f(N_t^R)\right)^{\frac{1}{-\nu-\frac{1}{\sigma_A}}}$$

$$f(N_t^R) = \left(\alpha_R N_t^{R\,\frac{\sigma_R-1}{\sigma_R}} + (1-\alpha_R)K_t^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}-1}$$

Plugging these expressions back into the production function gives an expression for routine labor (and therefore abstract labor) as a function of total output in equilibrium. Taking the derivative of N_t^A with respect to N_t^R give the *relative* response of abstract labor to routine labor. That is, by how much more/less do firms increase abstract labor demand relative to routine labor demand as they expand output? Assuming that ψ and ν are both bounded and greater than 0, and that $0 < \sigma_A < 1 < \sigma_R$, then for sufficiently low capital adjustment costs, μ abstract labor increases more than routine labor as output expands. As capital adjustment costs increase, the difference between the labor income response to output of the two types falls, and eventually reverses. These results are summarized in the following proposition.

PROPOSITION 1: If $\sigma_A < 1 < \sigma_R$, there exists a capital adjustment cost parameter μ^* such that $\frac{\partial N_t^A}{\partial N_t^R} > 1$ whenever $\mu < \mu^*$, and $\frac{\partial N_t^A}{\partial N_t^R} < 1$ whenever $\mu > \mu^*$. Furthermore, when $\mu < \mu^*$, $\frac{\partial^2 (N^A - N^R)}{\partial Y \partial \mu} < 0$.

The proof of this proposition can be found in Appendix 1. Intuitively, the parameter μ represents capital adjustment costs and governs the degree to which firms employ more capital as they expand production. As μ approaches 0, capital costs are diminishing and firms employ a large 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 demand following an expansionary monetary policy shock governs how both types of worker benefit from the expansion.

C. 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 savers C_t^{isa} is a function of their current income Y_t^{isa}, their expected future income, and the interest rate r_t. Consumption for spenders is simply equal to their income Y_t^{isp}. 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 at time 0. 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 Auclert et al. (2018), Patterson (2019), Bilbiie (2008), and others 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 the labor income response. A proof of this can be found in Appendix 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: Whenever $\mu < \mu^*$, the labor income channel Ω_L is decreasing in the proportion of spender households working in routine occupations, $\lambda_{sp,R}$.

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 spender households working in routine occupations increases, the covariance between MPC and the labor income response decreases. A proof of this proposition is given in Appendix 3. In the following section, I present evidence both that capital is sufficiently responsive to a monetary policy shock to benefit abstract workers more than routine workers, and that routine workers are likely to have higher MPCs than abstract workers.

II. Earnings Elasticities and Marginal Propensities to Consume

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, I argued that we should expect the labor income channel to be smaller if MPCs tend to covary with capital substitutability.

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

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 an exogeneous monetary policy shock. I find that the labor income of abstract workers is significantly more responsive than that of routine workers, whose response is actually slightly negative. 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 I 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.

Finally, I 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 less likely to be 'hand-to-mouth'. This suggests a *negative* covariance between the response of labor income to monetary policy and household MPC.

A. 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).

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.[7] 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. I extend this methodology to abstract and manual occupations as well. This conveniently divides the occupations into 3 disjoint groups of similar size.

TABLE 1

		1980			2007	
Abstract	Routine	Manual	Abstract	Routine	Manual	
Most Frequent Occupation	Manager, Sales, Accountant	Secretary Machine-operator	Truckdriver Laborer Health aide	Manager Sales-Supervisor	Secretary Machine-operator	Truckdriver 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.

[7] Crosswalks linking the CPS codes to Dorn's codes can be found on his website.

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 available in the public dataset, I grouped workers into the three occupation groups based on the aggregated occupation groups that were available in the public dataset.

In the 1995 SCF, abstract workers include managers and professionals. Routine occupations include machine operators, transportation workers, construction workers, and office and administrative workers. Technicians and sales are unfortunately grouped into this category as well. Manual workers include mechanics and repairmen, precision production workers, cleaners, security workers, and food preparation workers. Agricultural workers have been excluded.

In the 2007 SCF, abstract workers include managers and professionals. Routine workers include machine operators, transportation workers, technicians, and office and administrative workers (sales workers are also lumped into this broad category). Manual workers include repairmen, construction workers, precision production workers, protective service providers, personal care providers, cleaning workers, food workers, and other service workers. Agricultural workers have been excluded.

B. 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).[8] I first split the sample into abstract, routine and manual occupations

[8]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.

using Autor and Dorn's routine task intensity (RTI) score as described above. In addition to 12 lags of the left-hand-side variable, I control for 12 lags of the federal funds rate as well as a linear time trend. Ninety-percent confidence bands are calculated with Newey-West standard errors.

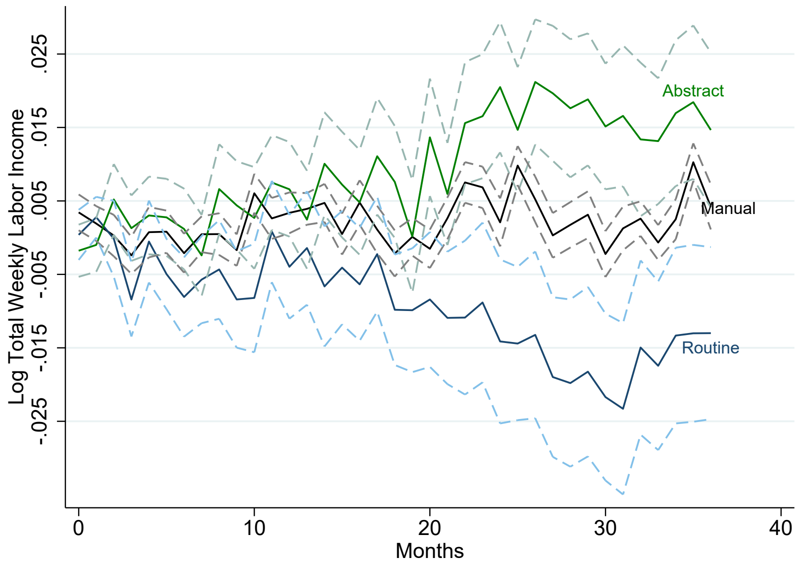


Figure 1:

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 wages 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 actually see a slight decline.

Because a group's total weekly labor earnings is the weighted sum of all 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 wages can largely be attributed to the extensive margin (increases in employment) rather than changes in the real wage. The response of hours is similarly modest, and can be found in Appendix X. Again, we can see substantial growth in the employment of abstract workers and a slight decline in the employment of routine workers.

These results are consistent with the mechanism outlined in the previous section. However, unlike in the simplified model, firms in the real world do not destroy capital when their borrowing costs increase. Therefore, we should not expect to see differences between the response of abstract labor income and routine labor income to contractionary shocks. To verify this, I rerun the specification from Figure 1 with a dummy variable for the sign of the shock. Results are presented in Appendix 4. When only expansionary shocks are considered, the differences between abstract and routine labor income are exaggerated. When only contractionary shocks are considered, the differences collapse.

Because I find that the primary margin through which monetary policy shocks affect labor income is employment, it is possible that the fall in routine employment and the rise in abstract employment following a monetary policy shock can partially be attributed to workers transitioning between routine and abstract occupations. To account for this, in Appendix A.5 I calculate an upper bound on the percent of the impulse response of each group that can be attributed to job-to-job transitions. I find that job-to-job transitions could explain at most only around half of the total response.

C. Earnings Elasticities by Industry

To test whether the mechanism described in Section I is indeed driving these results, I separate workers in the sample into industry subgroups depending on the responsiveness of capital in that industry to monetary policy shocks. According to Proposition 1, abstract and routine workers should see exaggerated differences in their labor income if they work in an industry in which capital increases significantly following a monetary policy shock. Conversely, workers in industries in which capital responds less to monetary policy should see little difference in their labor income responses. 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, so 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 to a 25 basis points expansionary monetary policy shock of log investment in equipment capital by capital type.[9] I record the peak impulse response for each capital type, and designate the

[9]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.

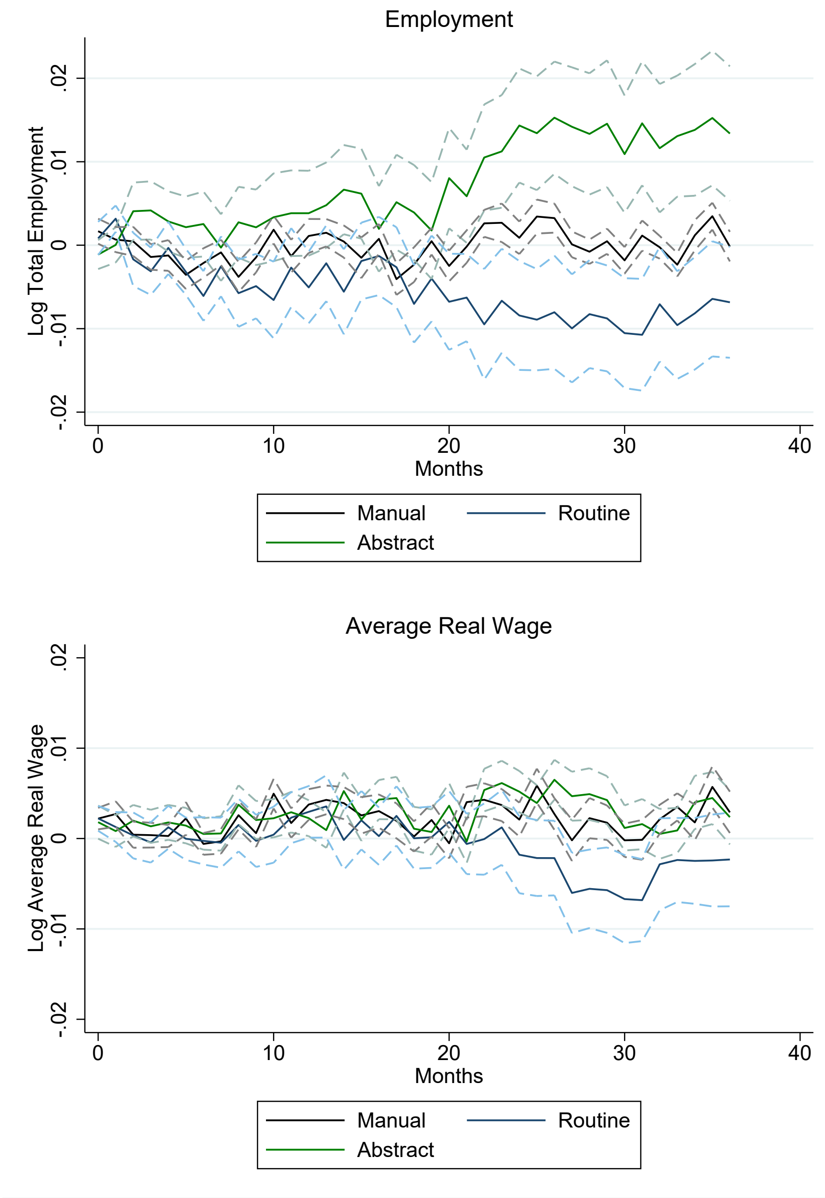


Figure 2:

Notes: This figure reports the impulse response of log total employment, log average real wages, and log average weekly hours 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.

top 25% most responsive types as 'responsive capital'. I then use the BEA's 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 (out of 15) were classified as 'responsive industries'.[10]

Appendix figure X reports the Jordá projections of log fixed investment in the most responsive equipment capital to a 25 basis point expansionary shock for all responsive capital types. Again, I use Romer and Romer shocks and control for 12 lags of both the left hand side 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.[11] 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.

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.

D. Relationship to Existing Literature

How do these results relate to existing findings on the incidence or sensitivity of a worker's labor income to fluctuations in aggregate output? 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 aggregate 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. estimate a similar specification using CPS data - where top earners are top-coded and dropped from their data set - they find that incidence is decreasing by earnings quantile.

[10]The responsive industries included construction, transportation, manufacturing, finance, and Mining

[11]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 non-responsive industry.

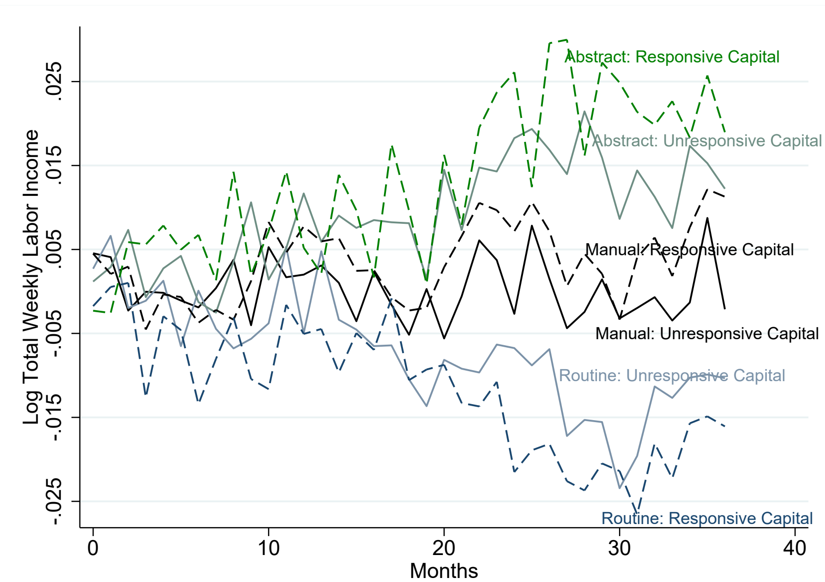


Figure 3: Weekly Labor Income by Industry Type

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 not very responsive. Confidence intervals have been omitted for ease of interpretation.

Similarly, Patterson (2019) 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 seem inconsistent with the results presented in Figures 2 and 3. I believe that two factors are likely responsible for these differences.

First, the occupation groups constructed above do not map neatly on to earnings quantiles. Specifically, both routine and manual workers tend to have lower earnings than abstract workers, but a considerable amount of earnings heterogeneity exists within each group. As shown in Table 1, the standard deviation of hourly earnings was nearly \$13 for the manual occupation group and almost \$9 for the routine group.

More importantly however, these studies all consider the sensitivity of individual earnings to fluctuations in GDP generally, without considering *what type of shock* generated the fluctuation. If two shocks affect the relative productivity or labor supply of two groups of workers in different ways, then we should not expect them to generate the same incidence patterns. For 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. A related point is that shocks may not necessarily have symmetric affects.[12] Therefore, if the fluctuations in aggregate output used in Alves et al. (2019), Guvenen et al. (2017), or Patterson (2019) were not generated by expansionary monetary policy shocks or were more negative on average than the monetary shocks used in this paper, then we would expect differences in the estimated incidence.[13]

E. Occupation and Marginal Propensity to Consume

So 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. As I argued in Section I, whether the labor income channel is amplified or dampened depends on the relationship between occupation type and MPC. The results above suggest that abstract workers are the primary beneficiaries of monetary stimulus. If these workers tend to have higher MPCs, we'd expect the labor income channel to play a significant role in the transmission of monetary policy, as the workers whose labor incomes go up are the ones who we would expect to quickly spend their newfound income. If abstract workers tended to have lower MPCs, the opposite would be true.

Using data from the Survey of Consumer Finances, Table 2 presents the median nominal value of liquid assets, total assets, non-financial income, and age for each of the three occupation groups, as well as each groups probability of being poor hand-to-mouth and wealthy hand-to-mouth. These variables were chosen because being young and having low levels of liquid wealth, total wealth, and income has been shown to be associated with 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.

[12] For example, if wages are sticky, a negative shock may decrease employment with no affect on wages, while a positive shock may increase wages.

[13] Both of these conditions are likely to be true. Monetary policy is unlikely to have driven a large portion of the fluctuations in aggregate output. Similarly, the Romer and Romer shock series used here is disproportionately positive.

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. The median liquid asset level for abstract household was $4,781 in 1995, more than double that of routine and manual households respectively. 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. Abstract households were about as likely as other groups to be wealthy hand-to-mouth in 1995, but by 2007 were 11 percentage points less likely to be wealthy hand-to-mouth than both routine and manual households. Abstract households were significantly less likely to be poor hand-to-mouth in both years.

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.

Taken together, these findings suggest that households headed by a worker with a routine or manual occupation may have higher MPCs than those headed by someone in an abstract occupation. This suggests that the covariance between the labor income response to monetary policy and MPC is negative.

III. Heterogeneous Agent New Keynesian Model

In this section, I present a medium-scale Heterogeneous Agent New Keynesian Model (HANK) model with heterogeneous labor in order to demonstrate that the mechanism outlined in Section I holds in a more complex setting and to quantify the effects of including heterogeneous labor on the size of the labor income channel. 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 I. I compare the deterministic response of consumption to a one-time negative (expansionary) monetary policy shock in economies with and without heterogeneous capital-labor elasticities. Both economies feature capital adjustment costs, so the relative size of the labor income channel in the homogeneous labor income model is similar to the analogous model in Alves et al. (2020).

A. 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 work in abstract occupations, while the remaining $1-\lambda$ work in routine occupations. The households' per-period utility function takes the following form.

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

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 (10) subject to their budget constraint (12).

$$\max_{c_{it}, n_{it}, b_{it}, a_{it}} \sum_{t=0}^{\infty} \beta^t E_0[u_j(c^{it}, n^{it})] \tag{10}$$

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 $\epsilon_{it} \sim N(0,1)$.

$$\log e_{it} = \rho_e \log e_{it-1} + \sigma_e \epsilon_{it} \tag{11}$$

Households also face a portfolio adjustment cost $\chi(a_{i,t-1}, a_t)$ (14) when making deposits into their illiquid account.

$$c_{it} + b_{it} + a_{it} + \chi_{it} \leq (1-t_t)e_{it}w_{it}n_{it} + (1+r^b_{t-1})b_{it-1} + (1+r^a_{t-1})a_{it-1} \tag{12}$$

$$b_{it} \geq \underline{\mathrm{b}} \tag{13}$$

$$\chi(a_{it}, a_{it-1}) = \frac{\chi_1}{\chi_2}\left| a_t - (1+r^a_t)a_{t-1} \right|^{\chi_2} [(1+r^a_t)a_{t-1} + \chi_0]^{-1} \tag{14}$$

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.[14]

$$u_c(c_{it})e_{it}(1-t_t)w_{it} = \psi_j n^{\nu}_{it} \tag{15}$$

$$u_b(c_{it}) = \mu_b + \beta E \partial_b V_{t+1}(z_{t+1}, b_t, a_t) \tag{16}$$

$$u_a(c_{it})[1 + \chi'(a_t, a_{t-1})] = \mu_a + \beta E \partial_a V_{t+1}(z_{t+1}, b_t, a_t) \tag{17}$$

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

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

[14] 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.

Each intermediate good firm produces according to a nested-CES production function (18) 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.[15]

$$y_{kt} = Z_t\left(\alpha_A {N_t^A}^{\frac{\sigma_A-1}{\sigma_A}} + (1-\alpha_A)\left(\alpha_R {N_t^R}^{\frac{\sigma_R-1}{\sigma_R}} + \alpha_K K_t^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}}\right)^{\frac{\sigma_A}{\sigma_A-1}} \tag{18}$$

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}, and investment adjustment costs c^I_{kt}. Firms maximize the infinite discounted stream of dividends, where the discount factor used each period is $1+r^a_t$, the rate of return on firm equity.[16]

$$\max_{y_{kt},n^a_{kt},n^r_{kt},i_{kt},p_{kt},k_{kt}} \sum_{t=0}^{\infty} \frac{1}{1+r^a_t}\left(\frac{p_{kt}}{P_t}y_{kt} - w^a_{kt}n^a_{kt} - w^r_{kt}n^r_{kt} - i_{kt} - c^p_{kt} - c^I_{kt}\right) \tag{19}$$

$$k_{kt} = (1-\delta)k_{kt-1} + i_{kt} \tag{20}$$

$$c^p_{kt} = \frac{\epsilon}{2\kappa_p}[log(1+\pi_{kt})]^2 Y_t \tag{21}$$

$$c^I_{kt} = \frac{1}{2\delta\epsilon_I}\left(\frac{k_{kt}-k_{kt-1}}{k_{kt-1}}\right)^2 k_{kt-1} \tag{22}$$

This problem is standard and symmetric for all firms, and leads to the following set of aggregate first order conditions. Here, Q_t is the multiplier on the investment adjustment cost constraint (22). Equation (23) is the Philips Curve, equation (24) governs firm valuation, and equations (25) and (26) are the demand equations for abstract and routine labor respectively.

$$log(1+\pi_{kt}) = \kappa_p\left(mc_t - \frac{1}{\mu+p}\right) + \frac{1}{r^a_{t+1}}\frac{Y_{t+1}}{Y_t}(1+\pi_{t+1}) \tag{23}$$

$$(1+r^a_t)Q_t = \alpha\frac{Y_{t+1}}{K_t}mc_{t+1} - \frac{K_{t+1}}{K_t} + (1-\delta) - \frac{(K_{t+1}-K_t)^2}{2\delta\epsilon_I K_t^2} + \frac{K_{t+1}Q_{t+1}}{K_t} \tag{24}$$

$$w^a_t = mc_t Y_t^{\Gamma_1}\alpha_A {N_t^A}^{\frac{-1}{\sigma_A}} \tag{25}$$

$$w^r_t = mc_t Y_t^{\Gamma_2}(1-\alpha_A)\left(\alpha_R {N_t^R}^{\frac{\sigma_R-1}{\sigma_R}} + \alpha_K K_t^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}-1} \alpha_R {N_t^R}^{\frac{-1}{\sigma_R}} \tag{26}$$

[15] 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.

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

Unions. Households in each occupation group provide a continuum of 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 formulation is identical to the one given in Adrien Auclert, Bence Bardóczy, Matthew Rognlie, Ludwig Straub (2021), and leads to the following wage Phillips Curve for each occupation type (27).

$$log(1+\pi_{jt}^w) = \kappa_w(\psi^j N_{d,t}^{j,1+\nu} - \mu_w N_{d,t}^{j,1+\nu}(1-t_t)w_t^j U_t^j) + log(1+\pi_{j,t+1}^w) \tag{27}$$

$$C_t^w = \frac{\mu_w}{1-\mu_w}\frac{1}{2\kappa_w}[log(1+\pi_{jt}^w)]^2 N_{d,t}^j \tag{28}$$

Finance. Following Auclert et al. (2021), 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

$$E_t[1+r_{t+1}^a] = E_t[\frac{d_t + p_{t+1}}{p_t}] = E_t[1+r_{t+1}^b] + \omega \tag{29}$$

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

$$1 + i_t = (1+\pi_t)(1+r_t^b) \tag{30}$$

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 $\phi > 1$.

$$i_t = \bar{r}_t + \phi\pi_t + \epsilon_t^m \tag{31}$$

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

$$G_t + r_t^b B_t^g = \tau_t(N_t^A w_t^A + N_t^R w_t^R) \tag{32}$$

B. Equilibrium

Let $D_t(a,b,e)$ be the distribution of households over the state. 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 $\{n^a_{kt}, n^r_{kt}, k_{kt}, \pi_t\}$, aggregate prices $\{p_t, w^a_t, w^r_t, r^a_t, r^b_t\}$, and policy variables $\{\tau_t, B^g_t, G_t, i_t\}$ 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.

$$p_t + B^g_t = A_t + B_t = \int_0^1 a dD_t(a,b,e) + \int b dD_t(a,b,e) \tag{33}$$

$$B^h_t = B_t = \int b dD_t(a,b,e) \tag{34}$$

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

$$N^A_t = \int e\, n(a,b,e)\, dD^A_t(a,b,e) \tag{35}$$

$$N^R_t = \int e\, n(a,b,e)\, dD^R_t(a,b,e) \tag{36}$$

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 $\chi = \int_0^1 \chi(a_t(a,b,e),a) dD_t(a,b,e)$.

$$Y_t = C_t + I_t + G_t + C^w_t + C^p_t + C^I_t + \chi_t \tag{37}$$

C. Calibration

When calibrating the model's parameters, I kept two general objectives in mind. First, the model should facilitate a comparison of the labor income channel a model with worker heterogeneity and the existing literature. 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, Moll, and Violante (2018), (KMV) and Auclert, Bardóczy, Rognlie, 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 I, 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 inverse elasticity of inter-temporal substitution to .5. 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. These values, along with equations 29 and 32, pin down the steady state values for the bond supply and illiquid asset supply. I set the slope of the price Phillips Curve to .1. Following ABRS, I set the steady state union markup to .1 and the slope of the wage Phillips Curve to .1. Finally, government spending is set to 20 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. A total labor share of .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.[17] With the relative 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 begin by considering the values of the elasticities of substitution between capital and labor σ_R and σ_A estimated in Krusell et al. (2000).[18] Later, I compare this case with a Cobb-Douglas production function. 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. Because the response of investment to monetary policy is a key determinant of the

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

[18]Here, the authors use a CES function with high-skilled (complementary) labor in the inner nest. This changes the symmetry of elasticities, but as should be clear from the Section I of this paper, does not affect the qualitative results.

labor income response, I calibrate capital adjustment costs in both the heterogeneous labor and the Cobb-Douglas models so that investment increases by .75% in response to a -.25% monetary policy shock.

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	0.46	0.47
Kurtosis	17.8	17.8	Wealthy HTM	0.29	0.29

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 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).

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).[19]

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.

[19]Kaplan et al. do not match the skewness of the distribution, as there are only 2 free parameters in the shock process.

D. The Labor Income Channel

To solve the model and estimate impulse response functions, I rely on the Sequence Space Jacobian method developed in Auclert, Bardóczy, Rognlie, and Straub (2019).[20] 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 state levels, $\bar{\tau}$, $\bar{r}_b$, $\bar{r}^a$. Here, $\bar{w}^i$ represents the steady state level of w^i.

$$\begin{aligned}\Omega = C_0\bigg(\{w_t^A\}^G, \bar{w^R}, \{N_t^A\}^A, \{N_t^R\}^A, \bar{r_b}, \bar{r^a}, \bar{\tau}\bigg) &+ \\ C_0\bigg(\bar{w^A}, \{w_t^R\}^G, \{N_t^A\}^R, \{N_t^R\}^R, \bar{r_b}, \bar{r^a}, \bar{\tau}\bigg) & \qquad (38)\end{aligned}$$

I start with the heterogeneous labor case. The lower labor share and relative wage of routine workers in steady state as well as the tighter borrowing constraint naturally generates a different distribution of assets between in the two groups and endogenously generates a different distribution of MPCs. Following Kaplan et al. (2018), a household's MPC is defined as the derivative of household consumption with respect to liquid assets, as liquid assets enter directly into income. 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 MPC for routine and abstract workers. The distributions are presented in Figure 4. Households with lower levels of liquid and illiquid wealth have higher MPCs as they have a higher chance of running up

[20] 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 4

Parameter		Value
Household		
β	Discount factor	0.965
σ	Inverse IES	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	-.01
ρ_e	Autocorrelation of earnings	0.94
σ_e	Standard deviation of earnings	1.3
ψ_A	Disutility of labor (abstract)	2.04
ψ_R	Disutility of labor (routine)	5.065
B^h	Total liquid assets	2.4
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	0.356
α_R	Coefficient on routine labor	0.671
Z	Aggregate TFP	1.29
δ	Depreciation rate	0.07
ϵ_I	Capital adjustment cost scale	6
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

against their borrowing constraint. Because abstract workers have higher labor income and asset levels in the steady state, they tend to have lower MPCs.

Simultaneously, their relative complementarity with capital results in their wages responding more to a monetary stimulus than that of routine workers. Figure 5 shows the response of wages for each type of worker to a 25 basis point negative monetary policy shock. The peak response of abstract wages increases while that of routine workers decreases. Increases in labor for both types of workers partially offset these differences, leading the labor income for both types of workers to increase, however abstract workers still see substantially larger labor income gains.

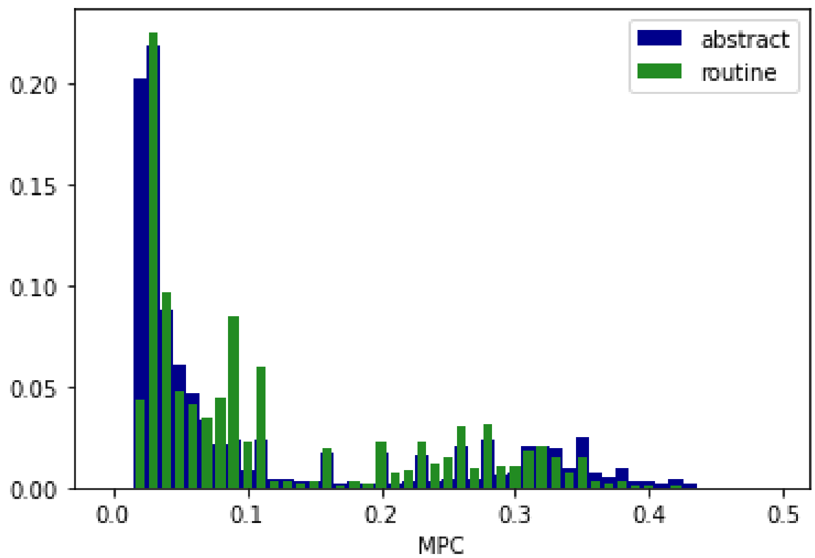


Figure 4:

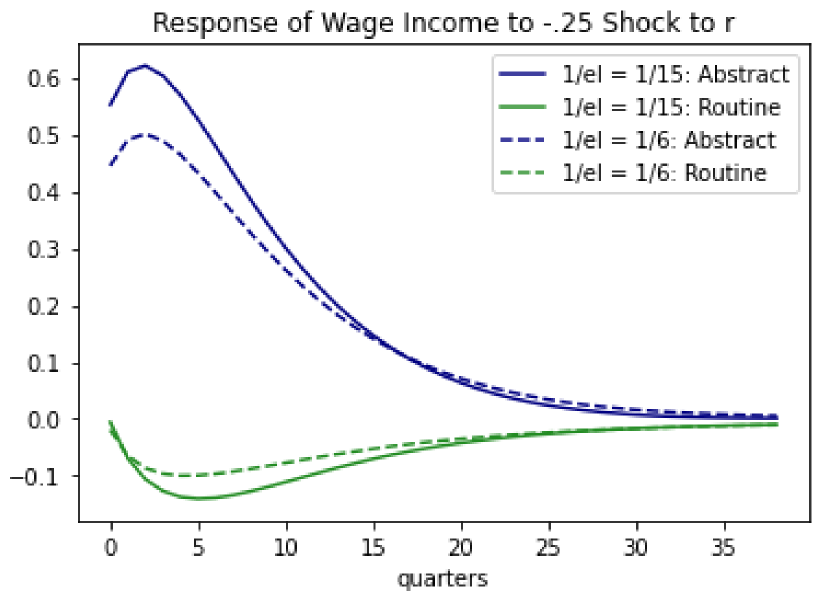
To see that the results from Proposition 1 hold in this model and that these differences are driven by the relative complementarity with capital of both types of workers, I estimate the wage response for abstract and routine workers for different levels of the capital adjustment cost, ϵ_I. Proposition 1 stated that, as adjustment costs were relaxed and capital become more responsive to monetary policy, we should see the difference between abstract and routine labor income responses to monetary policy increase. The results from this exercise can be found in Figure 6. Figure 6 reports the wage income response to the monetary policy shock of abstract workers and routine workers for different levels of ϵ_I. In my preferred specification, ϵ_I is set to 6. When ϵ_I is increased to 15, capital adjustment costs (equal to $\frac{1}{\epsilon_I}$) are reduced and capital becomes *more* responsive. Just as in the simple model, as capital becomes more responsive to monetary policy, the gap between the response of abstract and routine labor income widens.

Figure 5: Caption

It should be noted that while this model can generate differences in the labor income response to monetary policy of routine and abstract workers, the labor income response for both groups is driven largely by wage increases rather than hours or employment increases.[21], a finding which is inconsistent with the empirical results presented in Section II which show that hours and employment drive almost all of the response of labor income. This is the case in part because the model does not feature frictions that would generate unemployment. Additionally, the parameter for wage stickiness, taken from Autor, Rognlie, and Straub (2020), may be too low. To generate impulse response functions that more closely match those estimated in Section II, these two features would need to be considered more carefully. As shown in Proposition 2 however, the effect of capital-task complementarity on the labor income channel does not depend on whether the response of labor income to monetary policy is the result of the extensive or intensive margin.

What effect do the results presented in Figure 4 and 5 have on the size of the labor income channel? Figure 7 plots the labor income channel, calculated using equation (38), for both the standard homogeneous labor (Cobb-Douglas) model as well as my heterogeneous labor model that features capital-task complementarity. In the former, a -.25 monetary policy shock increases total labor income by about .45 percent. When capital-task complementarity is introduced, the response drops by about a quarter to around .33 percent on impact. Other than the production function, these models are otherwise the same; they feature households

[21]In the model, hours increase for both groups in response to monetary policy, but the increase is not as large as that of wages and is more similar for the 2 groups. The model does not feature unemployment.



with identical utility functions, target the same set of macroeconomic moments, and feature the same investment adjustment costs.[22] Therefore, I believe the dampening of the labor income channel can be largely attributed to a negative covariance between the response of labor income and household MPC.

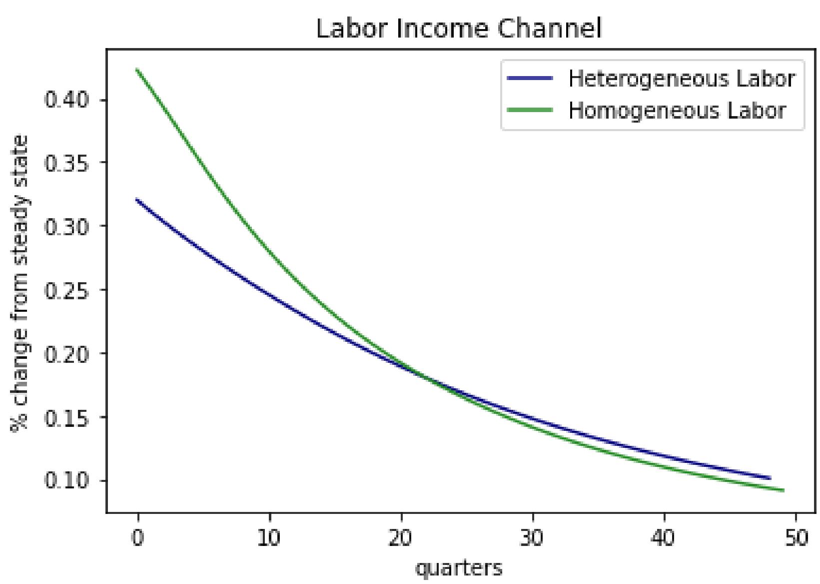


Figure 6:

[22]This is key. Auclert et al. (2020) and Bloesch and Weber (2021) have pointed out that the response of labor income to monetary policy depends on the responsiveness of investment.

IV. Conclusion

Disentangling the relative empirical importance of different channels of monetary policy transmission is still a new and growing area of research. By adding features like realistic MPCs and more complex financial markets into HANK models, researchers have demonstrated the importance of *indirect* increases in household incomes, and have exposed key interactions between monetary 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 raise wages equally for all workers, and that the size of the labor income channel depends on the response of capital to monetary policy, the relative 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 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 slightly. I show that these differences can largely be attributed to differences between workers 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 marginal propensities to consume, 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 about 25% 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., 2010, Braxton and Van Zandweghe, 2013, Bloesch and Weber (2021)). This paper provides a novel explanation to account for these trends.

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Appendix

A1. Prove that for μ sufficiently small, $\frac{\partial N_t^A}{\partial N_t^R} > 1$

Recall that combining the firm's first order conditions with the households' labor supply condition and letting $\alpha_K = 1 - \alpha_R$ gives you an expression for abstract labor as a function of routine labor in equilibrium.

$$N_t^A = \left(\frac{1-\sigma_A}{\sigma_A}\sigma_R N_t^{R-\nu-\frac{1}{\sigma_R}} f(N_t^R)\right)^{\frac{1}{-\nu-\frac{1}{\sigma_A}}} \tag{A.1}$$

$$f(N_t^R) = \left(\alpha_R N_t^{R\frac{\sigma_R-1}{\sigma_R}} + (1-\alpha_R)K_t(N_t^R)^{\frac{\sigma_R-1}{\sigma_R}}\right)^{\frac{\sigma_R(\sigma_A-1)}{(\sigma_R-1)\sigma_A}-1} \tag{A.2}$$

Assume that $0 < \sigma_A < 1 < \sigma_R$ and that ψ and ν are bounded and greater than 0. Recall that from equation (6) and equation (2) we have:

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

Rearranging and dropping time subscripts for simplicity gives you:

$$K = \left(\frac{\psi\sigma_K}{\mu\sigma_R}N^{R\frac{1}{\sigma_R}+\nu}\right)^{\frac{1}{\mu-1+\frac{1}{\sigma_R}}} \tag{A.3}$$

Taking the derivative with respect to N^R gives:

$$\frac{\partial K}{\partial N^R} = \frac{\frac{1}{\sigma_R}+\nu}{\mu-1+\frac{1}{\sigma_R}}\left(\frac{\psi\sigma_K}{\mu\sigma_R}N^{R\frac{1}{\sigma_R}+\nu}\right)^{\frac{1}{\mu-1+\frac{1}{\sigma_R}}-1}\frac{\psi\sigma_K}{\mu\sigma_R}N^{R(\frac{1}{\sigma_R}+\nu-1)} \tag{A.4}$$

Therefore, $\frac{\partial K}{\partial N^R} \to 0$ as $\mu \to \infty$. Intuitively, this makes sense. As capital adjustment costs get infinitely large, capital is less and less responsive as output (and therefore N^R) increases. This corresponds to the case of fixed capital. The opposite is true as $\mu \to 0$. As capital adjustment costs decrease, changing the capital stock becomes less and less difficult. If we take equation A.4 and set $\mu = 0$, we can see that $\frac{\delta K}{\delta N^R}$ explodes to ∞.

Returning to equations A.1 and A.2, we can find an expression for $\frac{\partial N_t^A}{\partial N_t^R}$ and solve for the case when $\mu = 0$ and when μ approaches ∞. First, taking the derivative of equation A.2 with respect to N_t^R gives you:

$$\frac{\partial f(N^R)}{\partial N^R} = \frac{\sigma_A - \sigma_R}{(\sigma_R - 1)\sigma_A} f(N^R)^{\Gamma_1} \left(\frac{\sigma_R - 1}{\sigma_R} (\alpha_R N^{R\frac{-1}{\sigma_R}} + \alpha_K K^{\frac{-1}{\sigma_R}} \frac{\partial K}{\partial N^R}) \right)$$

The derivative of equation A.1 with respect to N^R is given by:

$$\frac{-1}{\nu + \frac{1}{\sigma_A}} N^{A\Gamma_2} \sigma_R \frac{1-\sigma_A}{\sigma_A} \left(-(\nu + \frac{1}{\sigma_A}) N^{R-\nu-\frac{1}{\sigma_A}-1} f(N^R) + N^{R\nu-\frac{1}{\sigma_A}} \frac{\partial f(N^R)}{\partial N^R} \right)$$

$$= -\frac{\partial f(N^R)}{\partial N^R} C_1 + C_2 \tag{A.5}$$

Where C_1 and C_2 are positive constants.

Let $g(\mu) = \frac{\partial N^A}{\partial N^R}(\mu)$. Note that $\lim\limits_{\mu \to 0} g(\mu) = \infty$. To see this, note that when $\mu \to 0$, $\frac{\partial K}{\partial N^R} \to \infty$ and $\frac{\partial f(N^R)}{\partial N^R} \to -\infty$, because $\sigma_A < \sigma_R$. Then $g(\mu) \to \infty$ which can easily be seen from the first term of equation A.3. Here, the intuition is that, if capital costs approach 0 and firms expand capital aggressively as they expand output, their demand for complementary abstract workers relative to substitutable routine workers will explode as they employ almost no routine workers.

Define $g^l = \lim\limits_{\mu \to \infty} g(\mu)$.

Without having to solve for g^l, we can show that there exists a μ^* such that $\forall\, \mu < \mu^*$, $g(\mu) > 1$. First, note that because $g(\mu)$ is a continuous function, we can use the Intermediate Value Theorem to say that for any $u \in (g^l, \infty)$, $\exists$ a $\mu \in (0, \infty)$ such that $g(\mu) = u$. Pick some $u^* \in (g^l, \infty)$ such that $u^* \geq 1$. Then let μ^* be the μ such that $g(\mu) = u^*$.

Finally, we just need to show that $g(\mu)$ is monotonically decreasing in μ. To see that , note that $g(\mu) = \frac{\partial N^A}{\partial N^R}$ is *decreasing* in $\frac{\partial f(N^R)}{\partial N^R}$ which is *decreasing* in $\frac{\partial K}{\partial N^R}$ when $\sigma_A < \sigma_R$ and $\sigma_R > 1$ as we've assumed. This means that $g(\mu)$ is increasing in $\frac{\partial K}{\partial N^R}$. Finally, from the previous section we have that $\frac{\partial K}{\partial N^R}$ is decreasing in μ, meaning that $g(\mu)$ is also decreasing in μ.

Therefore, for all $\mu < \mu^*$, $\frac{\partial N_t^A}{\partial N_t^R} > 1$.

A2. The labor income channel can be expressed as:

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

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

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

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:

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

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

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

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

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

A3. Proof of Proposition 2, that if $\mu < \mu^*$ then Ω^L is decreasing the greater the share of routine workers who are spenders.

Recall that if $\mu < \mu^*$, then capital is sufficiently responsive such that $\frac{\partial N^R_t}{\partial Y_t} < \frac{\partial N^A_t}{\partial Y_t}$. Recall that we considered the case where $\theta = 0$ and therefore $W^i = \psi N_t^{ij\nu}$ and $N_t^{ij} = N_t^i$ for both spenders and savers.

Therefore $\frac{\partial Y^L_{Rt}}{\partial Y_t} = \frac{\partial \psi N_t^{R(1+\nu)}}{\partial Y_t} < \frac{\partial \psi N_t^{A(1+\nu)}}{\partial Y_t} = \frac{\partial Y^L_{At}}{\partial Y_t}$

In Section II, it was established that $\text{MPC}_{sp} = 1 \geq \text{MPC}_{sa}$. Assume the *total* proportion of routine workers $\lambda_{Rsp} + \lambda_{Rsa} = \lambda_R$, stays constant so that $d\bar{Y}^L$ stays constant, and the *total* proportion of spenders $\lambda_{Rsp} + \lambda_{Asp} = \lambda_{sp}$, stays constant so that $M\bar{P}C$ stays constant. Then if the proportion of routine workers who are spenders λ_{Rsp} increases, λ_{Rsa} and λ_{Asp} must decrease. Recall that Ω_L is given by:

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

When λ_{Rsp} 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_{Asp} and λ_{Rsa} 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_{Rsp}

A4. Expansionary vs. Contractionary Shocks.

In the main body of the paper, I present evidence that abstract and routine workers' labor incomes respond differently to expansionary monetary policy, and I argue that this is because firms invest in capital when borrowing costs are lower. However, firms do not uninstall capital when interest rates increase, and therefore we should not expect to see the same response to contractionary monetary policy. To confirm that the labor incomes of routine and abstract workers only respond differently to expansionary (negative) monetary policy shocks, I estimate impulse response functions using the following equation. Confidence intervals are calculated using Newey-West standard errors, and the controls X_t, are identical to those used in Section III Part B.

$$\log(L^i_{t+j}) = \alpha^j + \beta_0^{i,j}\min[0, e_t^{RR}] + \beta_1^{i,j}\max[0, e_t^{RR}] + X_t + e^i_{t+j} \tag{A.9}$$

Below, I report the coefficients for negative shocks (left) and positive shocks (right) separately.

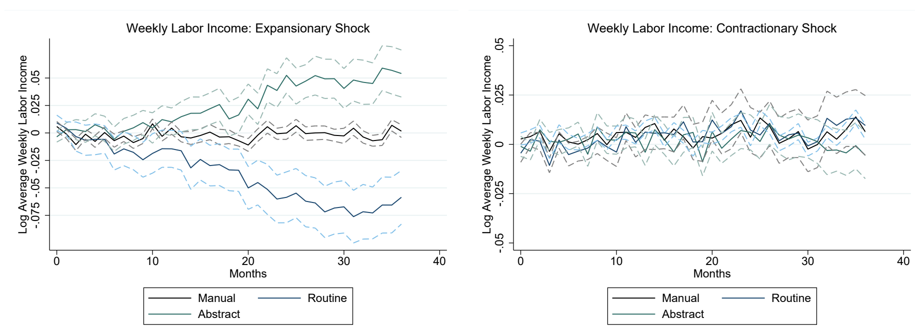

Figure 7: Effect of Expansionary vs. Contractionary Monetary Policy Shocks

From Figure 8, it is clear that the differences remain - and are exaggerated - when only negative shocks are considered and disappear when positive shocks are considered. This is consistent with firms adding capital when their borrowing costs decrease but not disposing of capital when their borrowing costs increase.

A5. Accounting for job-to-job transitions.

I find that the primary margin through which monetary policy shocks affect labor income is employment. Therefore, it is possible that the fall in routine employment and the rise in abstract employment can be partially attributed to workers transitioning between routine and abstract occupations. To account for this, I use CPS-MORG data containing detailed

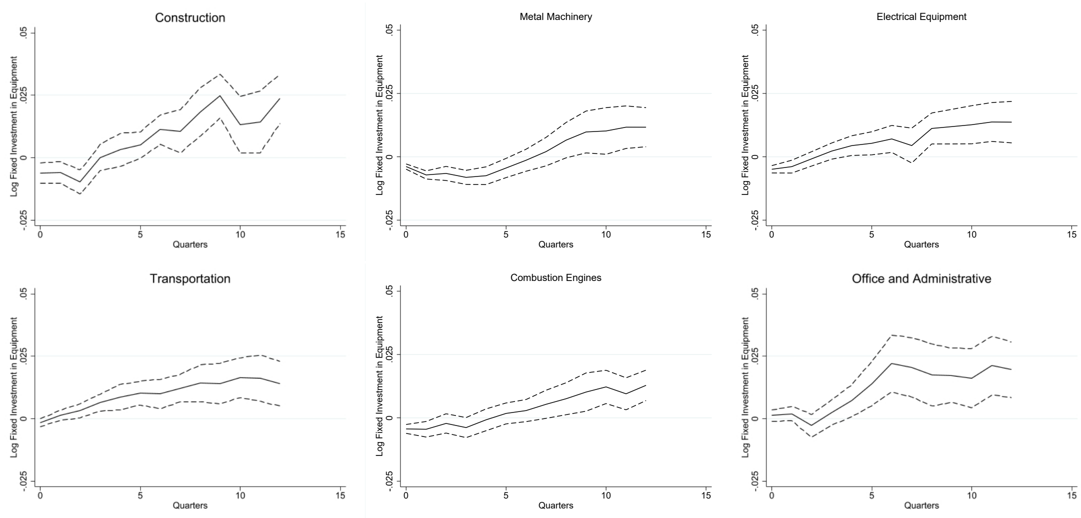

Figure 8: Response of Fixed Equipment Capital to Monetary Policy

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.

occupational information to calculate annual net transition levels from routine to abstract occupations, α_t. These net transition levels can be converted into the rate of growth of each occupation group attributable to net transitions from other groups. For example, dividing the number of workers who transitioned from routine to abstract occupations by the total number of abstract workers last year gives you the percent increase in abstract labor attributable to routine-to-abstract transitions.

I make the assumption that these annual percent increases are uniform over the year, and divide by 12 to get an approximate monthly rate of growth(or decline) that can be attributable to transitions. This allows me to compare these rates against the impulse responses calculated in Section II. If the largest monthly increase attributable to transitions is significantly smaller than the peak increase in labor income following a monetary policy shock, I can be confident that a large portion of the impulse response can not be attributed to transitions.

Respondents to the CPS are interviewed for 4 months, ignored for 8 months, and then interviewed again for 4 months. Their responses in the 4th and 8th interview (1 year apart) are included in the CPS-MORG extracts. I define the net transition level α_t as the total number of workers interviewed in a given month who transitioned from routine to abstract employment within the last year, less the number who transitioned from abstract to routine. Transitioning from routine to abstract within the last year means a worker reports working in an abstract occupation in their 8th interview, but reported working in a routine job in their 4th interview. Transitioning from abstract to routine is defined analogously. Abstract and routine jobs are defined as in Section III.

I then divide α_t by X^A_{t-12}, the total number of workers employed in abstract occupations in the previous year to calculate the *percent growth* in abstract employment over the year that can be attributed to job-to-job transitions. Finally, I divide α_t by X^R_{t-12}, the total number of workers employed in routine occupations in the previous year to get the percent decline in routine occupations attributable to transitions over the year. I make the assumption that this growth/decline was evenly spread over the year and divide these rates by 12 to get monthly growth rates.

These growth rates allow me to compare the growth in abstract employment that can be attributed to transitions to the growth in abstract employment caused by a monetary policy shock estimated in the paper. I take the largest monthly percent increase in abstract occupations and largest percent decrease in routine occupations and use this as an upper and lower bound for the percent increase in abstract occupations and percent decrease in routine occupations respectively. The largest monthly percent increase in abstract employment was 1.3%, around 60% of the peak impulse response. The maximum decline in routine employment was 1.2%, less than half of the peak impulse response.

These upper and lower bounds are the absolute maximum monthly growth rates that can be attributed to job-to-job transitions. The 95th percentile growth rate in abstract employment is .6%, less than 30% of the peak impulse response. The 95th percentile decline in routine employment was .55%, around a 5th of the peak impulse response.