Monetary Policy Analysis and Heterogeneous Unemployment Dynamics

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October 2024

Abstract

This paper examines the heterogeneous effects of unexpected expansionary monetary policy on unemployment rates for high- and low-skilled workers. Utilizing impulse response functions from time-series analysis, the results indicate that the unemployment rate for low-skilled workers is more sensitive to monetary policy shocks compared to that of high-skilled workers. To rationalize these empirical findings, a New Keynesian DSGE model with asymmetric search and matching (SAM) frictions is constructed, capturing the differentiated responses of low- and high-skilled unemployment rates to a nominal interest rate decrease. The model also demonstrates that the consumption responses of low- and high-skilled workers differ significantly, with low-skilled workers' consumption being more sensitive to monetary policy shocks compared to that of high-skilled workers. Additionally, the unemployment rate for low-skilled workers reacts more than twice as vigorously as that for high-skilled workers following a monetary policy shock. Due to the asymmetric search and matching (SAM) frictions, wages for low- and high-skilled workers increase disproportionately. These results highlight the importance of considering skill heterogeneity in the analysis of optimal monetary policy, potentially influencing the central bank's emphasis on inflation versus output stabilization..

Keywords: Monetary Policy, Unemployment, Heterogeneity, Search and Matching
JEL Codes: E24, E32, E52, J64

1 Introduction

Recently, the Federal Open Market Committee (FOMC) announced its unanimous decision to shift the policy focus concerning stronger labor markets. More precisely, FOMC made a concrete emphasis on low- and moderate-income communities.[1] Furthermore, according to FOMC, such shift of focus is important in the presence of zero lower bound when labor markets can't be stimulated without the cost of more inflation. A large body of research attributes much of income differences across people to differences in labor skills. The impact of monetary policy on income distribution involves several channels. For instance, changes in interest rates affect savers and borrowers differently, influencing the distribution of wealth (the savings-redistribution channel). Similarly, the reaction of asset prices to interest rate adjustments or inflation varies, affecting inequality among asset holders (the interest-sensitivity channel). Differences in household preferences and access to financial markets also lead to varied effects of monetary policy (the household heterogeneity channel). Moreover, an expansion in aggregate demand, driven by monetary easing, can have distinct effects on workers and capital owners, as wages and profits may adjust at different rates (the income composition channel). Employment and wages for various types of workers can also respond differently, influenced by factors such as unemployment risk, wage rigidity, and labor market institutions (the earnings heterogeneity channel).

Given these interacting forces, the overall effect on economic equality is not straightforward and requires quantitative analysis for a precise understanding. This paper aims to concentrate on one particular channel, that of labor earnings heterogeneity, while not addressing other types of heterogeneity, such as wealth distribution. Specifically, it explores how monetary policy interacts with labor market heterogeneity and search-and-matching (SAM) frictions in high- and low-skilled workers. The growing gap in labor income inequality, marked by increasing dispersion in wages and employment rates between high-skilled and low-skilled workers, is primarily linked to skill-biased technological change.[2] However, to my knowledge no study has yet explored the impact of asymmetric search and matching (SAM) frictions on the heterogeneous effects of monetary policy across different skill level unemployment dynamics throughout the business cycle.

To emphasize the empirical significance of the analysis, Figure 1 presents the empirical impulse responses of unemployment rates for low- and high-skilled workers

[1] source: https://www.federalreserve.gov/newsevents/speech/powell20210210a.htm

[2] See Heathcote et al. (2009), Elsby et al. (2010) and Díaz-Giménez et al. (2011)

following an identified monetary policy shock (i.e. an unexpected reduction of 0.25 percentage point in federal funds rate). One can notice that the unemployment rate of low-skilled workers is more sensitive to the monetary policy shock than that of high-skilled workers. Moreover, at its peak, the unemployment rate for low-skilled workers increases more than twice as much in response to the policy shock compared to that of high-skilled workers, and the recovery period for high-skilled workers is longer relative to low-skilled workers.

To rationalize the empirical results and study the heterogeneous dynamics of the labor markets, I construct a version of a two-agent New Keynesian model (TANK) that features skill heterogeneity. The interaction between firms and high- and low-skilled workers is modeled a la Diamond - Mortensen - Pissarides[3] (Blanchard and Galí (2010)) asymmetric search and matching model of unemployment. Instead of assuming a reduced-form wage inertia, an explicit modeling of labor market delivers a tractable framework that characterizes equilibrium wages for high- and low- skilled workers. Additionally, I assume that workers are ex-ante different across skills where there is no transition across the skill groups and then analyze how monetary policy interacts with skill-specific labor market variables.. Additionally, the model illustrates that the consumption responses of low- and high-skilled workers to monetary policy shocks differ markedly, with low-skilled workers' consumption being more sensitive. These findings emphasize on the importance of incorporating skill heterogeneity into the analysis of monetary policy, which may necessitate adjusting the central bank's focus on inflation versus output stabilization.

This paper contributes to a growing body of literature that outlines the interaction between monetary policy and worker heterogeneity. Most existing research merges an incomplete market framework with heterogeneous agents, as seen in Aiyagari, with New Keynesian models that include nominal rigidities, giving rise to what is commonly known as HANK models (for instance, see Kaplan et al. (2018); Ravn and Sterk (2021); Luetticke (2021)). In this vein, Nakajima (2013) enhances this framework by integrating SAM (search and matching) frictions, thereby linking unemployment risk directly to monetary policy actions. Their findings indicate that contractionary monetary shocks significantly increase income inequality, suggesting greater welfare costs than previously estimated. Nevertheless, these studies have not explored asymmetric SAM frictions among various skill levels. Dolado et al. (2021) present a New Keynesian DSGE model that includes asymmetric search-and-matching (SAM) fric-

[3]See Mortensen and Pissarides (1994) and Pissarides (1985)

tions and capital-skill complementarity (CSC) to investigate the distributive effects of monetary policy on labor income inequality between skill groups. Their analysis reveals how CSC leads to a greater demand for high-skilled labor following monetary policy expansions, thereby increasing wage and employment gaps between high- and low-skilled workers. This study lays an important groundwork by examining the interplay between monetary policy and labor market dynamics, especially highlighting CSC's role in amplifying the effects of policy shocks on labor income inequality.

Expanding upon Dolado et al. (2021), my paper enhances the model to explicitly account for the consumption responses of high- and low-skilled workers to monetary policy shocks, offering a deeper insight into the heterogeneous effects. Whereas Dolado et al. (2021) concentrate on wage and employment disparities following such shocks, our model further demonstrates the diverse sensitivity of consumption across skill groups, with low-skilled workers bearing a more substantial impact. Moreover, our empirical analysis shows that the unemployment rate for low-skilled workers is significantly more responsive to monetary policy shocks than that for high-skilled workers, highlighting the significance of incorporating skill heterogeneity into the monetary policy analysis. Through incorporating these elements, our study not only supports Dolado et al. (2021)'s observations regarding the increase in labor income inequality but also broadens the analysis by providing an alternative view of the wider economic effects, specifically on consumption patterns and unemployment rates across different skill levels.

The remainder of the paper is organized as follows: Section 2 provides the empirical evidence, analyzing how monetary policy shocks affect unemployment rates for low- and high-skilled workers. Section 3 introduces the theoretical model, explaining the structure of a New Keynesian DSGE model with asymmetric search and matching (SAM) frictions to study the impact of skill heterogeneity in the labor market. Section 4 details the aggregation and calibration of the model, describing how parameters are chosen to reflect the U.S. economy. Section 5 presents impulse response analysis, comparing model predictions with labor market responses to monetary policy shocks across skill levels. Section 6 concludes.

2 Monetary Policy and Heterogenous Unemployment: LP Empirical Evidence

In this section, I describe the empirical impulse response of unemployment rate to a monetary policy shock. The analysis is based on the local projections (LP) estimation approach proposed by Jordà (2005). The LP approach involves running a sequence of predictive regressions of a variable of interest on an identified shock for chosen prediction horizons. The impulse response is then captured by the sequence of regression coefficients of the shock.

To find the effect of the change in nominal interest rate (federal funds rate) on high- and low-skilled unemployment rates, first, I estimate the following equation

$$u_{j,t+h} = \alpha_h + \beta_j(h) s_t + \gamma_{j,h} u_{j,t+h-1} + \varepsilon_{j,t+h}$$

to capture the responses of two groups' unemployment rates on an identified monetary policy shock, where h is he length of horizon, $\varepsilon_{j,t+h}$ is a prediction error term with variance $\mathbb{V}(\varepsilon_{j,t+h}) = \sigma_h^2$, $u_{j,t+h}$ is quarterly unemployment rate for $j \in J = \{L, H\}$, s_t is the identified monetary policy shock (GK) [4] and $u_{j,t+h-1}$ represents one period lag of $u_{j,t+h}$.[5] The dynamic multiplier $\beta_j(h)$ captures the responses of unemployment rates on an identified monetary policy shock.

Moreover, I conducted joint hypothesis testing on the impulse responses to a monetary policy shock for both high- and low-skilled unemployment rates across 16 forecast horizons. In my analysis for the high-skilled unemployment rates, I found a chi-square statistic of 70.40 with a p-value of less than 0.0001. This indicates a statistically significant effect of the monetary policy shock on high-skilled unemployment at least at one of the horizons examined. Similarly, for low-skilled unemployment rates, the analysis yielded a chi-square statistic of 52.55 with a p-value of less than 0.0001, also strongly suggesting that all impulse responses are not jointly equal to zero. These findings highlight the differential impact of monetary policy shocks on unemployment across skill levels, demonstrating that both high- and low-skilled labor market segments exhibit statistically significant responses to policy changes at various points within the observed period.

To interpret dynamic multipliers of unemployment rates in terms of the responses

[4] GK Shock stands for Gertler and Karadi (2015) identified monthly (monetary policy) shocks, current futures.

[5] For more details about the data set see Appendix A

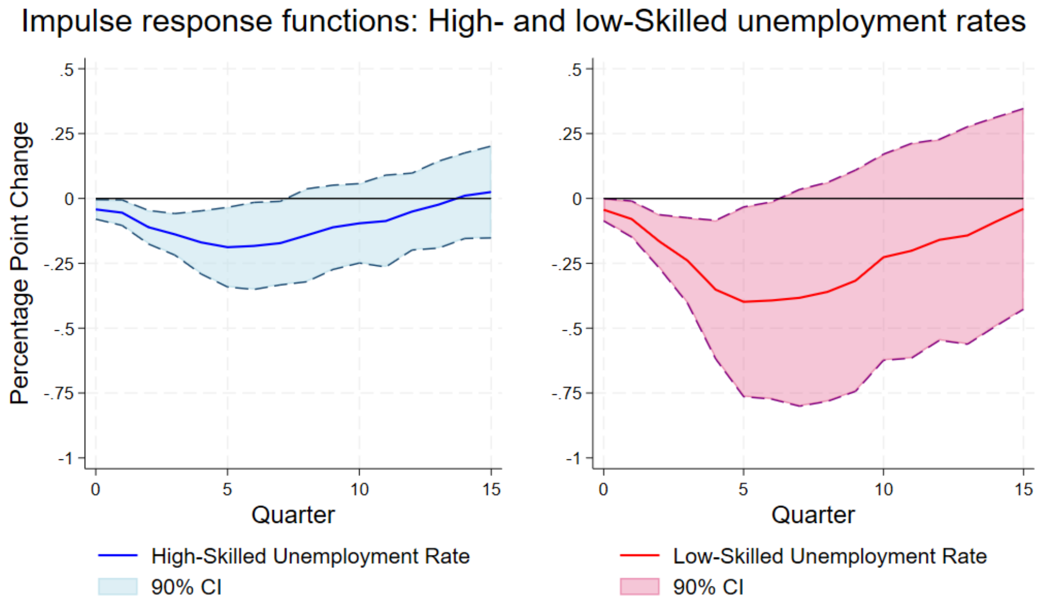

Figure 1. Impulse Responses of Low- and High-Skilled Unemployment Rates to a 0.25 p.p. decrease in FED funds rate (using GK)

to 0.25 percentage point decrease in fed funds rate, I use local projection estimation and run a sequence of regressions of a federal funds rate on the same identified monetary policy shocks

$$r_{t+h} = \alpha_{r,h} + \beta_r(h)\, s_t + \gamma_{r,h} r_{t+h-1} + \varepsilon_{r,t+h}$$

to get the dynamic multipliers of fed funds rate on the shock. After estimation, I normalize responses of high- and how-skilled unemployment rates ($\beta_j(h)\;\; j \in \{L, H\}$) by the factor $0.25/\beta_r(h = 0)$ to interpret the responses of different demographic groups to a 0.25 percentage point decrease in the fed funds rate on impact. Based on the local projections (LP) estimation results, a 0.25 percentage point reduction in the federal funds rate, reveals distinct sensitivities and recovery patterns within high- and low-skilled unemployment rates. The dynamic multipliers obtained from the LP methodology, indicates a more pronounced immediate response in the low-skilled unemployment rate ($u_{L,t}$), which undergoes a sharper decrease following the policy shock. This phenomenon suggests that low-skilled unemployment is more susceptible to changes in monetary policy, a finding that aligns with expectations given the typically higher cyclicality of low-skilled employment.

Conversely, as depicted in the Figure 1, high-skilled unemployment ($u_{H,t}$) exhibits a more moderate initial response, with the effect of the monetary policy shock attenuating more rapidly compared to its low-skilled counterpart. This attenuation of effects in the high-skilled labor market is demonstrated by the impulse response of high-skilled unemployment rate approaching zero faster compared to low-skilled unemployment rate. The peak responses observed in the data further corroborate these findings, with the low-skilled unemployment rate experiencing a more substantial deviation from baseline levels before the effect of the shock begins to weaken. This analysis not only highlights the variability in how different segments of the labor market respond to monetary policy changes but also points out the stability of high-skilled employment, which seem to recover more quickly after an unanticipated shock.

These empirical insights contribute to our understanding of labor market behavior, highlighting the differential impact of monetary policy on various skill groups. The faster recovery seen in high-skilled unemployment rates after a shock suggests a relative robustness and inherent steadiness of high skilled individuals, in contrast to the increased sensitivity and extended path to recovery observed in low-skilled unemployment rates.

3 Model

3.1 Households

3.1.1 High-Skilled Household

During each period $t = 0, 1, 2, ...$ high-skilled household maximizes the expected utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \left(C_{H,t} - b_H C_{H,t-1} \right) - \chi \frac{N_{H,t}^{1+\phi}}{1+\phi} \right] \tag{1}$$

where $C_{H,t}$ is consumption, $N_{H,t}$ is high-skill units of labor and β is the discount factor $0 < \beta < 1$.

A representative high-skilled household enters period t with bonds B_{t-1}. At the beginning of the period, the household receives nominal profits F_t from the intermediate-goods-producing firms. The household supplies $N_{H,t}$ units of labor and K_t units of capital at the wage rate $W_{H,t}$ and the capital remuneration rate Q_t, respectively, to each intermediate-goods-producing firm $i \in [0, 1]$ during period t. Then, the representative household's bonds mature, providing B_{t-1} additional units of currency. The household uses part of this additional currency to purchase B_t new bonds at nominal cost B_t/R_t, where R_t represents the gross nominal interest rate between t and $t+1$.

Moreover, household pays lump-sum tax $T_{H,t}$ each period in order to finance fixed unemployment benefit (z_H) of unemployed individuals in the household, and at the same time the pool of unemployed individuals pay job search costs (measured in terms of consumption goods) $c_{H,t}$, before hiring takes place.

The household uses its income for consumption, $C_{H,t}$, and investment, I_t, and job search costs, $c_{H,t}$, and carries B_t bonds into period $t+1$. Let P_t be the price level (the price index) associated to the final output Y_t, then the household budget constraint will be given by:

$$P_t C_{H,t} + P_t \Phi\left(I_t, I_{t-1}\right) + \frac{B_t}{R_t} + P_t U_{H,t} c_{H,t}\left(x_{H,t}\right) \\ = B_{t-1} + W_{H,t} N_{H,t} + Q_t K_t + F_t - P_t z_H U_{H,t} + T_{H,t} \tag{2}$$

for all $t = 0, 1, 2, ...$ By investing I_t units of output during period t, the household increases the capital stock K_{t+1} available during period $t+1$ according to

$$K_{t+1} = \left(1 - \delta_k\right) K_t + \Phi\left(I_t, I_{t-1}\right) \tag{3}$$

where the depreciation rate satisfies $0 < \delta_k < 1$ and the function Φ summarizes the technology which transforms current and past investment into installed capital for use in the following period. Investment adjustment cost is given by

$$\Phi\left(I_t, I_{t-1}\right) = \left(1 - Z\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{4}$$

where, $Z(1) = Z'(1) = 0$ and $\tau \equiv Z''(1) > 0$.[6] Therefore, the high-skilled household chooses $\left\{C_{H,t}, K_{t+1}, B_t\right\}_{t=0}^{\infty}$ to maximize the utility (1) subject to the budget constraint (2), capital accumulation equation (3) for all $t = 0, 1, 2, ...$ Letting $\Pi_t = P_t / P_{t-1}$ denote the gross inflation rate, $\Lambda_{H,t}$ the non-negative Lagrange multiplier on the budget constraint (2), and μ_t the non-negative multiplier on the law of

[6] If we assume that $S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$, then $S'\left(\frac{I_t}{I_{t-1}}\right) = \tau\left(\frac{I_t}{I_{t-1}} - 1\right)$ and $S''\left(\frac{I_t}{I_{t-1}}\right) = \tau$

capital accumulation (3), the first order conditions associated to this problem are

$$\Lambda_{H,t} = (C_{H,t} - b_H C_{H,t-1})^{-1} - \beta b_H \left(\mathbb{E}_t C_{H,t+1} - b_H C_{H,t}\right)^{-1} \tag{5}$$

$$q_t = \beta \mathbb{E}_t \left[\frac{\Lambda_{H,t+1}}{\Lambda_{H,t}} \left[\left(\frac{Q_{t+1}}{P_{t+1}} \right) + q_{t+1} (1 - \delta_k) \right] \right] \tag{6}$$

$$\Lambda_{H,t} = \beta R_t \mathbb{E}_t \left[\frac{\Lambda_{H,t+1}}{\Pi_{t+1}} \right] \tag{7}$$

and

$$1 = q_t \left[\left(1 - Z \left(\frac{I_t}{I_{t-1}} \right) \right) - Z' \left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right] + \beta \mathbb{E}_t \left[\frac{\Lambda_{H,t+1}}{\Lambda_{H,t}} q_{t+1} Z' \left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right] \tag{8}$$

where $q_t = \frac{\mu_t}{\Lambda_{H,t}}$ is the present discounted value of the rental rate on capital. According to equation (5), marginal utility of consumption equals to the Lagrange multiplier. Equation (6) is the Euler equation for capital, linking intertemporal marginal utility of consumption to the real remuneration rate of capital. Equation (7) describes high-skilled household's optimal consumption decision and lastly, equation (8) shows the optimal investment decision.

3.1.2 Low-Skilled Household

During each period $t = 0, 1, 2, ...$ low-skilled household maximizes the expected utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln (C_{L,t} - b_L C_{L,t-1}) - \chi \frac{N_{L,t}^{1+\phi}}{1+\phi} \right] \tag{9}$$

where $C_{L,t}$ is consumption, $N_{L,t}$ is low-skill units of labor and β is the discount factor $0 < \beta < 1$. A representative low-skilled household just consumes its labor income net of taxes (or transfers) each period, possibly (but not necessarily) because they do not have access to financial markets.The household pays lump-sum tax $T_{L,t}$ each period in order to finance fixed unemployment benefit (z_L) of unemployed individuals in the household. Moreover, I assume that low-skilled workers do not incur job search costs $c_{L,t} = 0$.

The household uses its income only for consumption, $C_{L,t}$, because they do not have the excess to the financial tools to smooth its consumption. Once again, letting

P_t be the price level (the price index) associated to the final output Y_t, then the household budget constraint will be given by:

$$P_t C_{L,t} = W_{L,t} N_{L,t} - P_t z_L U_{L,t} + T_{L,t} \tag{10}$$

for all $t = 0, 1, 2, ...$ Hence, the low-skilled household chooses $\{C_{L,t},\}_{t=0}^{\infty}$ to maximize the utility (9) subject to the budget constraint (10) for all $t = 0, 1, 2, ...$ Letting $\Lambda_{L,t}$ be the non-negative Lagrange multiplier on the budget constraint (10), the first order condition associated to this problem is

$$\Lambda_{L,t} = \left(C_{L,t} - b_L C_{L,t-1}\right)^{-1} - \beta b_L \left(\mathbb{E}_t C_{L,t+1} - b_L C_{L,t}\right)^{-1} \tag{11}$$

stating that marginal utility of consumption equals to the Lagrange multiplier.

3.2 Labor Market

During each period $t = 0, 1, 2, ...,$ in each intermediate-goods producing firm i, the flow into employment results from the number of workers who survive the exogenous separation and the number of new hires, $H_t(i)$ (which consists of low- $H_{L,t}(i)$ and high- $H_{H,t}(i)$ productivity type hires i.e. $H_t(i) = H_{L,t}(i) + H_{H,t}(i)$). Hence, employment evolves according to

$$N_{L,t}(i) = \left(1 - \delta_n^L\right) N_{L,t-1}(i) + H_{L,t}(i) \tag{12}$$

$$N_{H,t}(i) = \left(1 - \delta_n^H\right) N_{H,t-1}(i) + H_{H,t}(i) \tag{13}$$

where $N_{j,t}(i)$ and $H_{j,t}(i)$ with $j \in J = \{L, H\}$ represent the total number of high- and low-skilled workers employed and hired by firm i in period t, and δ_n^L and δ_n^H are the exogenous separation rates for low- and high-skilled labor respectively (with $0 < \delta_n^L < 1$ and $0 < \delta_n^K < 1$).

For all $t = 0, 1, 2, ...,$ the fraction of aggregate employment and hires supplied by the household must satisfy

$$N_{L,t} = \int_0^1 N_{L,t}(i)\, di \quad \text{and} \quad N_{H,t} = \int_0^1 N_{H,t}(i)\, di \tag{14}$$

$$H_{L,t} = \int_0^1 H_{L,t}(i)\, di \quad \text{and} \quad H_{H,t} = \int_0^1 H_{H,t}(i)\, di \tag{15}$$

respectively. Accounting for job destruction, the pool of household's members unemployed and available to work before hiring takes place is (assuming that workers' skills do not change)

$$U_{L,t} = L_L - \left(1 - \delta_n^L\right) N_{L,t-1} \tag{16}$$

$$U_{H,t} = L_H - \left(1 - \delta_n^H\right) N_{H,t-1} \tag{17}$$

where low- and high-skilled labor force is normalized to one, i.e $L_L = L_H \equiv 1$.

Also, it is convenient to represent the job creation rates, $x_{L,t}$ and $x_{H,t}$, by the ratio of new hires over the number of unemployed workers (for high- and low-skilled workers separately) such that

$$x_{L,t} = \frac{H_{L,t}}{U_{L,t}} \text{ and } x_{H,t} = \frac{H_{H,t}}{U_{H,t}} \tag{18}$$

with $0 < x_{L,t} < 1$ and $0 < x_{H,t} < 1$, given that all new hires represent a fraction of the pool of unemployed workers. The job creation rates $x_{L,t}$ and $x_{H,t}$, are also indices of *labor market tightness*, since it indicates the proportion of hires over the number of workers in search for a job.

The real cost of hiring a worker is equal to G_t and, as in Blanchard and Galí (2010), is a function of labor market tightness x_t:

$$G_{L,t} = A_L B_L x_{L,t}^{\alpha_L} \text{ and } G_{H,t} = A_H B_H x_{H,t}^{\alpha_H} \tag{19}$$

where α_L and α_H are the elasticities of labor market tightness with respect to hiring costs such that $\alpha_L \geq 0$ and $\alpha_H \geq 0$, B_j is a scale parameter such that $B_j \geq 0$, and A^L and A^H represent the different productivity terms of low- and high-skilled workers respectively. As pointed out in Rotemberg and Trigari (2006), this formulation expresses the idea that the tighter the labor market the more costly hiring may be.

Note that given the assumption of full participation, the unemployment rate, defined as the fraction of household members left without a job after hiring takes place, is

$$u_{L,t} = U_{L,t} - H_{L,t} \tag{20}$$

$$u_{H,t} = U_{H,t} - H_{H,t}. \tag{21}$$

Let $\mathcal{W}_{j,t}^N$ and $\mathcal{W}_{j,t}^U$ denote the marginal value of the expected income of an employed and unemployed worker, respectively. The employed worker earns a wage, suffers disutility from work, and might lose her job with probability δ_n^j. Hence, the marginal value of a new match for workers is

$$\mathcal{W}_{j,t}^N = \frac{W_{j,t}}{P_t} - \chi \frac{N_{j,t}^{\phi}}{\Lambda_{j,t}} + \beta \mathbb{E}_t \frac{\Lambda_{j,t+1}}{\Lambda_{j,t}} \left\{ \left[1 - \delta_n^j \left(1 - x_{j,t+1}\right)\right] \mathcal{W}_{j,t+1}^N + \delta_n^j \left(1 - x_{j,t+1}\right) \mathcal{W}_{j,t+1}^U \right\}. \tag{22}$$

This equation states that the marginal value of being hired is given by the wage minus the marginal disutility that the job produces to the worker and the expected-discounted net gain (where $\Lambda_{j,t} = 1/C_{j,t}$) from being either employed or unemployed.[7]

The unemployed worker expects to move into employment with probability x_t. Hence, the marginal value of unemployment is

$$\mathcal{W}_{j,t}^U = z_j - c_j \left(x_{j,t}\right) + \beta \mathbb{E}_t \frac{\Lambda_{j,t+1}}{\Lambda_{j,t}} \left\{ x_{j,t+1} \mathcal{W}_{j,t+1}^N + \left(1 - x_{j,t+1}\right) \mathcal{W}_{j,t+1}^U \right\} \tag{23}$$

such that $c_j \left(x_{j,t}\right)$ decreases in $x_{j,t}$. This equation states that the marginal value of unemployment is made up of the earnings without employment z_j, job searching cost $c_j \left(x_{j,t}\right) = D_j x_{j,t}^{\sigma_j}$ and the expected-discounted capital gain from being either employed or unemployed.[8]

The structure of the model guarantees that a realized job match yields some pure economic surplus. The share of this surplus between the worker and the firm is determined by the wage level, in addition to compensating each side for its costs from forming the job.

As in Pissarides (2000), the wage is set according to the Nash bargaining solution. The low- and high-skilled workers and the firm split the surplus of their matches with the absolute shares $0 < \eta_L < 1$ and $0 < \eta_H < 1$. During each period $t = 0, 1, 2, ...$ each intermediate-goods producing firm i negotiates wages with low- and high-skilled workers separately. The objective function of wage negotiation is defined by Nash product

$$\left(\mathcal{W}_{j,t}^N - \mathcal{W}_{j,t}^U\right)^{\eta_j} G_{j,t}^{1-\eta_j} \tag{24}$$

[7] In continuation value, the term $\delta_n^j \left(1 - x_{j,t+1}\right)$ corresponds to the fact that in the beginning of period $t+1$ an agent loses the job with probability δ_n^j and at the end of the period $t+1$ the agent cannot find job with the rate (probability) of $\left(1 - x_{j,t+1}\right)$. Since, probability of losing is independent from job finding rate, the product of $\delta_n^j \left(1 - x_{j,t+1}\right)$ shows that the agent lost a job and could not find one. And $1 - \delta_n^j \left(1 - x_{t+1,j}\right)$ shows that the agent either did not lose the job, or she lost the job and found another one at the end of the period.

[8] In job searching cost $\sigma_H < 0, D_L = 0$ and D_H is a scale parameter such that $D_H \geq 0$.

where the difference between $\mathcal{W}_{j,t}^{N}$ and $\mathcal{W}_{j,t}^{U}$ determines the worker's economic surplus, while firm's surplus is simply given by the real cost per hire, $G_{j,t}$, as in Blanchard and Galí (2010). Real cost per hire can be defined as a firm's surplus, since any current worker can be immediately replaced with someone who is unemployed by paying the hiring cost. Therefore, the total surplus from a match is the sum of the worker's and firm's surpluses

$$S_j = \left(\mathcal{W}_{j,t}^{N} - \mathcal{W}_{j,t}^{U}\right) + \left(G_{j,t}\right) \tag{25}$$

for all $t = 0, 1, 2, ...$, where S_j with $j \in J = \{L, H\}$ represents the total surplus to be shared among a firm and a j type worker. Hence, they choose $\left\{\mathcal{W}_{j,t}^{N} - \mathcal{W}_{j,t}^{U}, G_{t,j}\right\}_{t=0}^{\infty}$ to maximize the Nash product (24) subject to the total surplus (25) for all $t = 0, 1, 2, ...$ Letting $\xi_j = \frac{\eta_j}{1-\eta_j}$ (for $j \in J$) denote the relative bargaining powers of low- and high-skilled workers separately, then the Nash bargaining rule for match is

$$\xi_j G_{j,t} = \left(\mathcal{W}_{j,t}^{N} - \mathcal{W}_{j,t}^{U}\right). \tag{26}$$

Substituting equations (22) and (23) into the bargaining rule yields the agreed wages for high- and low- skilled workers separately

$$\begin{aligned}\frac{W_{H,t}}{P_t} &= \chi \frac{N_{H,t}^{\phi}}{\Lambda_{H,t}} + \left(z_H - c_H\left(x_{H,t}\right)\right) \\ &\quad + \xi_H \left[G_{H,t} - \beta\left(1 - \delta_n^H\right)\mathbb{E}_t \frac{\Lambda_{H,t+1}}{\Lambda_{H,t}}\left\{\left(1 - x_{H,t+1}\right)G_{H,t+1}\right\}\right]\end{aligned} \tag{27}$$

and

$$\frac{W_{L,t}}{P_t} = \chi \frac{N_{L,t}^{\phi}}{\Lambda_{L,t}} + z_L + \xi_L \left[G_{L,t} - \beta\left(1 - \delta_n^L\right)\mathbb{E}_t \frac{\Lambda_{L,t+1}}{\Lambda_{L,t}}\left\{\left(1 - x_{L,t+1}\right)G_{L,t+1}\right\}\right] \tag{28}$$

where wages for high- and low-skilled workers differ based on their asymmetric SAM friction. One should also note, that low- and high-skilled workers discount their future income streams with different discount factors.

3.3 The Goods Market

The production sector is comprised of a representative finished-goods-producing firm and a continuum of intermediate-goods-producing firms indexed by $i \in [0, 1]$, which is characterized by staggered price setting as in Rotemberg (1982).

During each period $t = 0, 1, 2, ...$, the representative finished-goods-producing firm uses $Y_t(i)$ units of each intermediate good $i \in [0,1]$, purchased at nominal price $P_t(i)$, to produce Y_t units of the finished product at a constant returns to scale technology

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\mu-1}{\mu}} di\right]^{\frac{\mu}{\mu-1}}. \tag{29}$$

where $\mu > 1$ is the elasticity of substitution among different goods. By maximizing its profits the final goods producing firm's demand for $Y_t(i)$ units of intermediate good i is

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\mu} Y_t \tag{30}$$

for all $i \in [0,1]$, where $P_t^{1-\mu} = \int_0^1 P_t(i)^{1-\mu} di$ for all $t = 0, 1, 2, ...$

During each period $t = 0, 1, 2, ...$, the representative intermediate-goods-producing firm hires $N_{t,j}(i)$ units of labor from the representative households ($j \in J = \{L, H\}$), in order to produce $Y_t(i)$ units of intermediate good i according to the constant returns to scale production technology

$$Y_t(i) = A_t K_t(i)^\theta \left(A_L N_{L,t}(i)^\rho + A_H N_{H,t}(i)^\rho\right)^{\frac{1-\theta}{\rho}} \tag{31}$$

where $1 < \theta < 0$ represents the capital share of production and ρ is a substitution parameter. A_t is the neutral technology shock, which follows the autoregressive process

$$\ln A_t = \rho_a \ln A_{t-1} + \varepsilon_{a,t}$$

with $0 < \rho_a < 1$ and zero-mean, serially uncorrelated innovation $\varepsilon_{a,t}$ that is normally distributed with standard deviation σ_a.

Since the intermediate goods are not perfect substitutes in the production of the final goods, the intermediate-goods-producing firm faces an imperfectly competitive market. During each period $t = 0, 1, 2, ...$ it sets the nominal price $P_t(i)$ for its output, subject to the representative finished-goods-producing firm's demand.

The intermediate-goods-producing firm faces a quadratic cost to adjusting nominal prices, measured in terms of the finished goods and is given by

$$\frac{\phi_p}{2}\left(\frac{P_t(i)}{\Pi P_{t-1}} - 1\right)^2 Y_t$$

where ϕ_p is the degree of adjustment cost and Π is the steady-state gross inflation rate. This relationship, as stressed in Rotemberg (1982), looks to account for the negative effects of price changes on customer–firm relationships. These negative effects increase in magnitude with the size of the price change and with the overall scale of economic activity, Y_t.

The problem for the firm is to maximize its total market value given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\beta^t \frac{\Lambda_{H,t}}{P_t} \right) F_t(i) \tag{32}$$

where $\beta^t \dfrac{\Lambda_{H,t}}{P_t}$ measures the marginal utility value to the representative household of an additional dollar in profits received during period t and

$$\begin{aligned} F_t(i) = {} & P_t(i) Y_t(i) - \sum_j W_{j,t} N_{j,t}(i) - K_t(i) Q_t \\ & - P_t \sum_j H_{j,t}(i) G_{j,t} - \frac{\phi_p}{2} \left(\frac{P_t(i)}{\Pi P_{t-1}(i)} - 1 \right)^2 Y_t P_t \end{aligned} \tag{33}$$

for all $t = 0, 1, 2, \ldots$. Therefore, the firm chooses $\{N_{j,t}(i), K_t(i), P_t(i)\}_{t=0}^{\infty}$ to maximize its profits $F_t(i)$ subject to the laws of employment accumulation for low- and high-skilled workers (equations (12) and (13)), the demand for intermediate goods (30), and the production technology (31) for all $t = 0, 1, 2, \ldots$. Letting Ξ_t denote the non-negative Lagrange multiplier on the production technology (31), the first-order conditions for this problem are

$$\frac{W_{j,t}}{P_t} = \frac{\Xi_t (1-\theta)}{\Lambda_{H,t}} \frac{Y_t(i) A^L N_{j,t}(i)^{\rho-1}}{A^L N_{L,t}(i)^{\rho} + A^H N_{H,t}(i)^{\rho}} - G_{j,t} + \beta \mathbb{E}_t \left[\frac{\Lambda_{H,t+1}}{\Lambda_{H,t}} \left(\left(1 - \delta_n^j\right) G_{j,t+1} \right) \right] \tag{34}$$

$$\frac{\Lambda_{H,t}}{P_t} Q_t(i) = \Xi_t \theta \frac{Y_t(i)}{K_t(i)} \tag{35}$$

and

$$\begin{aligned} \phi_p \left[\frac{\Pi_t(i)}{\Pi} - 1 \right] \frac{\Pi_t(i)}{\Pi} = {} & (1-\mu) \left(\frac{P_t(i)}{P_t} \right)^{-\mu} + C_t \Xi_t \mu \left(\frac{P_t(i)}{P_t} \right)^{-\mu-1} \\ & + \beta \phi_p \mathbb{E}_t \left[\frac{\Lambda_{H,t+1}}{\Lambda_{H,t}} \left(\left(\frac{\Pi_{t+1}(i)}{\Pi} - 1 \right) \frac{Y_{t+1}}{Y_t} \frac{\Pi_{t+1}(i)}{\Pi} \right) \frac{\Pi_{t+1}(i)}{\Pi_{t+1}} \right]. \end{aligned} \tag{36}$$

Equation (34) equates the wage to the marginal rate of transformation for $j \in J = \{L, H\}$. The marginal rate of transformation consists of three terms. The first term corresponds to the additional output produced by the marginal employed worker as in the model without labor market search. The second term, $G_{j,t}$, represents the cost of hiring an additional worker, and the third term captures the savings in hiring costs as a result of reduced hiring needs in period $t+1$. Equation (35) equates the remuneration rate of capital to the additional output generated by a marginal unit of capital. Lastly, Equation (36) represents nonlinearized New Keynesian Phillips curve.

3.4 The Central Bank

During each period $t = 0, 1, 2, ...$, the central bank conducts monetary policy using a modified Taylor rule

$$\ln\left(\frac{R_t}{R}\right) = \kappa_r \ln\left(\frac{R_{t-1}}{R}\right) + (1-\kappa_r)\left(\kappa_y \ln\left(\frac{Y_t}{Y}\right) + \kappa_\pi \ln\left(\frac{\Pi_t}{\Pi}\right)\right) + \ln e_{R,t} \tag{37}$$

where R, Y, and π are the steady-state values of the nominal interest rate, output, and gross inflation rate, respectively. The last term $\varepsilon_{MP,t}$ in Taylor rule captures a (persistent) monetary policy shock which follows an $AR(1)$ process

$$\ln e_{R,t} = \rho_r \ln e_{R,t-1} + \varepsilon_{r,t}$$

with $0 < \rho_r < 1$ and zero-mean, serially uncorrelated innovation $\varepsilon_{r,t}$ that is normally distributed with standard deviation σ_r.

3.5 Government

During each period $t = 0, 1, 2, ...$, the government receives lump-sum taxes $T_{H,t}$ and $T_{L,t}$ from both households in order to balance fixed unemployment benefits $P_t z_j U_{j,t}$ payed to unemployed household members. Hence, in each period $t = 0, 1, 2, ...$ government balances its budget according to the following equation:

$$T_t = T_{H,t} + T_{L,t} = P_t\left(z_L U_{L,t} + z_H U_{H,t}\right) \tag{38}$$

where $T_{j,t} = P_t z_j U_{j,t}$ in order to abstract from the transfers between high- and low-skilled households.

4 Aggregation and Calibration

In a symmetric, dynamic equilibrium, all intermediate goods-producing firms make identical decisions, so that $Y_t(i) = Y_t$, $N_{L,t}(i) = N_{L,t}$, $N_{H,t}(i) = N_{H,t}$, $H_{L,t}(i) = H_{L,t}$, $H_{H,t}(i) = H_{H,t}$, $F_t(i) = F_t$, and $P_t(i) = P_t$, for all $i \in [0,1]$ and $t = 0, 1, 2, ...$ In addition, the market clearing condition $B_t = B_{t-1} = 0$ must hold for all $t = 0, 1, 2, ...$

These conditions, together with the firm's profit (33), government budget (38) and households' budget constraints (2) and (10), will produce the aggregate resource constraint. Applying market clearing and equilibrium conditions produce the aggregate resource constraint

$$Y_t = (C_{H,t} + C_{L,t}) + U_{H,t} c_{H,t}(x_{H,t}) + \sum_j H_{j,t} G_{j,t} + \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 I_t + \frac{\phi_p}{2}\left(\frac{P_t}{\Pi P_{t-1}} - 1\right)^2 Y_t. \quad (39)$$

where $U_{H,t} c_{H,t}(x_{H,t})$ is the total job search cost of (high-skilled) unemployed household members and $\sum_j H_{j,t} G_{j,t}$ is the total hiring cost of intermediate goods producing firms. After substituting in the Lagrange multiplier, $\Lambda_{H,t}$, from equation (5) into equations (6), (7), (8), (27), (28), (34) for $j \in J$ and (36), equating the wages from equations (27) and (28) to equation (34) for $j \in J$, and equating the remuneration of capital from equation (6) to equation (35), the model describes the behavior of the 20 endogenous variables $\{Y_t, C_{j,t}, H_{j,t}, K_t, I_t, G_{j,t}, x_{j,t}, U_{j,t}, u_{j,t}, N_{j,t-1}, \Xi_t, R_t, \Pi_t\}$ for $j \in J$ and persistent autoregressive processes of the exogenous shocks $\varepsilon_{a,t}$, $\varepsilon_{r,t}$. Based on the set-up of the model, the equilibrium conditions do not have an analytical solution. Therefore, the system of equilibrium conditions is approximated by log-linearization around the (stationary) steady state.

The model is calibrated on quarterly frequencies using U.S. data. The values for all parameters are described below and presented in Table 1. In order to satisfy the Hosios condition (as in Blanchard and Galí (2010)) and ensure that the equilibrium of the decentralized economy is Pareto efficient, I impose that the relative bargaining power of the worker, ζ_j (for $j \in J$), is equal to the elasticity of labor market tightness with respect to hiring costs, α_j. The parameter of the capital share, θ, is set to 0.4 in line with studies such as King and Rebelo (1999) and Ireland (2004).

The asymmetry in SAM frictions is captured by skill-specific parameters. For exogenous separation rates, as in Blanchard and Galí (2010), I assume $\delta_H < \delta_L$,

Parameters		Values
$\alpha_L; \alpha_H$	Elasticity of labor market tightness (w.r.t. hiring cost)	$0.60; 2.27$
β	Discount factor	0.9
ϕ	Inverse of the Frisch intertemporal elasticity	1
$\delta_n^L; \delta_n^H$	Job destruction rate	$0.12; 0.04$
δ_k	Capital depreciation rate	0.025
θ	Capital share	0.4
ϕ_p	Degree of nominal price rigidities	35
μ	Degree of substitution among goods	10
κ_r	Interest rate reaction to inertia	0
κ_y	Interest rate reaction to output	0.5
κ_π	Interest rate reaction to inflation	1.5
ρ_a	Autoregressive coefficient, technological progress	0.85
ρ_r	Autoregressive coefficient, monetary policy shock	0.95
σ_H	Elasticity of labor market tightness (w.r.t. job search cost)	-0.07
$A_L; A_H$	Productivity terms of low and high-skilled workers	$2; 3$
$\eta_L; \eta_H$	Surplus share (bargaining powers of low and high skilled workers)	$0.38; 0.69$
$z_L = z_H$	Fixed unemployment benefit	0.2875
ρ	Substitution parameter	0.6
$b_L; b_H$	Habit formation parameters	$0.8; 0.8$

Table 1. Calibration - Parameter Values

meaning that low-skill labor market can be categorized as fluid and high-skilled labor market as a sclerotic market. Furthermore, one needs to set a value for B_j, that determines the steady-state share of hiring costs over total output, $G_j H_j / Y$. Since there does not exist an accurate empirical evidence on this parameter, in line with Blanchard and Galí (2010), I choose B_j (for $j \in J$) such that total hiring costs, $\sum_{j \in J} G_j H_j$, represent 5% of total output. Furthermore, I assume symmetry in the shares of hiring cost over total output, which in turn implies that $G_H H_H = G_L H_L = 2.5\%$.

As in Dolado et al. (2021), the bargaining power of low skilled workers, $\eta_L = 0.3740$ is smaller compared to high skilled workers $\eta_H = 0.6955$, meaning that low skilled workers capture smaller share of the surplus as a wage. These values are in line with structural estimates of these parameters provided by Cahuc et al. (2006). Also, in line with Dolado et al. (2021), both type of workers receive similar amount of unemployment benefit $z_L = z_H = 0.2875$. All other parameters are chosen in line with standard values in the literature. Lastly, as in Blanchard and Galí (2010), the disutility of labor, χ, is set to equal to 1.5.

5 Impulse Responses

In examining the responses of the economy to a contractionary monetary policy shock, particularly a 0.25 percentage point increase in the federal funds rate, this analysis explores both the aggregate impact and the differential effects on key economic variables, as depicted in Figures 2 and 3. The impulse responses of output (Y), capital (K), and investment (I) to the monetary policy shock highlight the effectiveness of such policy measures in stimulating economic activity. The observed increase in output is consistent with established economic theories that suggest an expansionary monetary policy facilitates economic growth by lowering borrowing costs, thereby encouraging investment and increasing demand for labor.

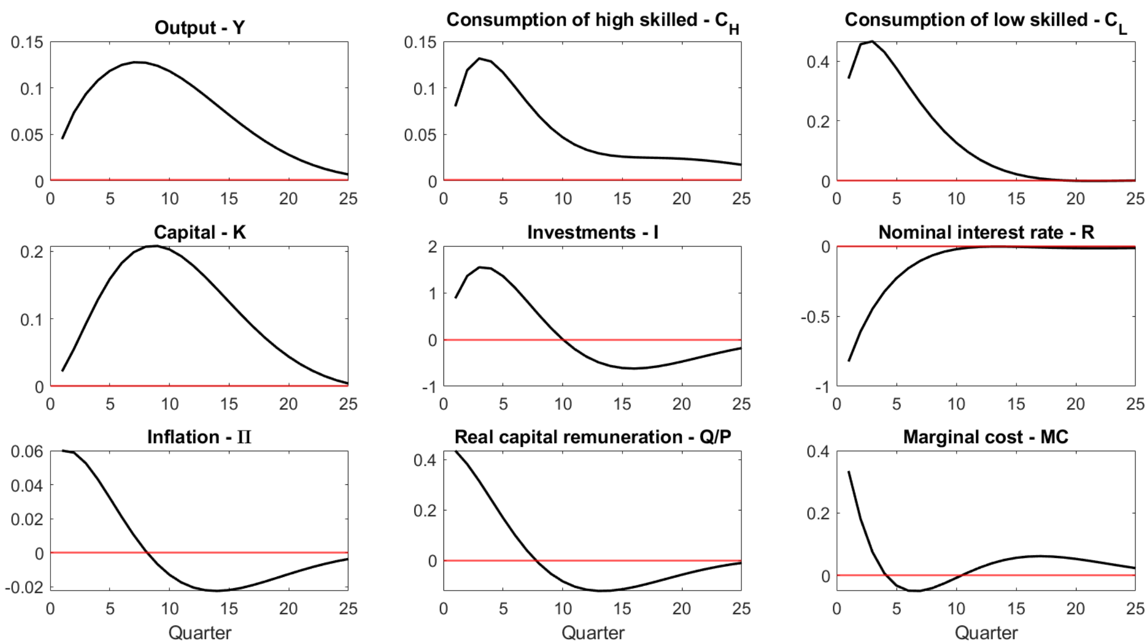

Figure 2. Impulse responses to a monetary policy shock (0.25 p.p.): y-axis for inflation and nominal interest rate in annual percentage points and for all other variables in percent.

The consumption dynamics between low- and high-skilled households reveal significant heterogeneity in the impact of monetary policy shocks. Low-skilled households exhibit a more pronounced increase in consumption (C_L), likely reflecting a higher marginal propensity to consume due to liquidity constraints (hand to mouth) and a more immediate benefit from reductions in unemployment. In contrast, high-skilled households (C_H) demonstrate a more moderate response, suggesting a buffer against monetary shocks provided by diversified income sources and access to financial markets. This differential consumption response is pivotal for understanding the broader economic implications of monetary policy adjustments.

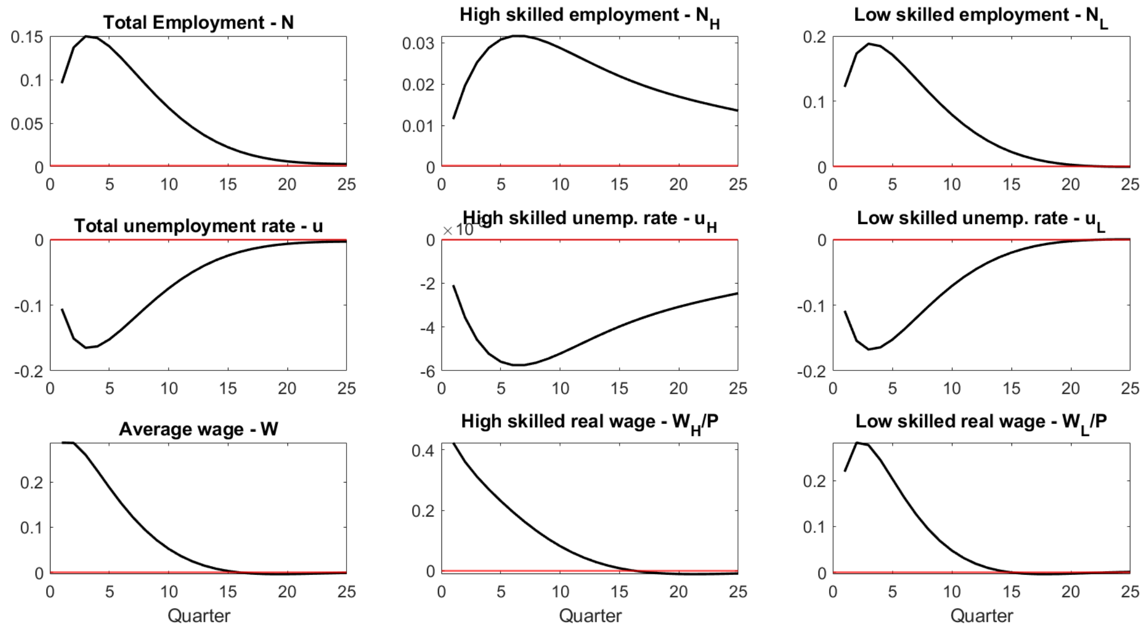

Figure 3. Impulse responses to a monetary policy shock (0.25 p.p.): y-axis for unemployment rate in percentage points, and for all other variables in percent.

The labor market responses further illustrate the model's capacity to reflect the diverse impacts across skill groups. Notably, the unemployment rate for low-skilled workers decreases more substantially than that for high-skilled workers, indicating the former's increased sensitivity to economic cycles and policy shifts. This observation aligns with empirical evidence, which shows that low-skilled workers are more adversely affected during economic downturns but also stand to gain more from policy-induced economic recoveries.

A decrease in the nominal interest rate triggers a series of economic changes. Reduced borrowing costs lead to an uptick in investment and capital accumulation, with firms reacting to the increased economic activity and better financing options. This surge in demand for labor, especially among low-skilled workers, results in a notable reduction in unemployment rates and a corresponding increase in wages. This process highlights how monetary policy is intricately linked with labor market outcomes and consumption behavior across households. Given these insights, it becomes evident that monetary policy has non-uniform effects across different demographic groups of

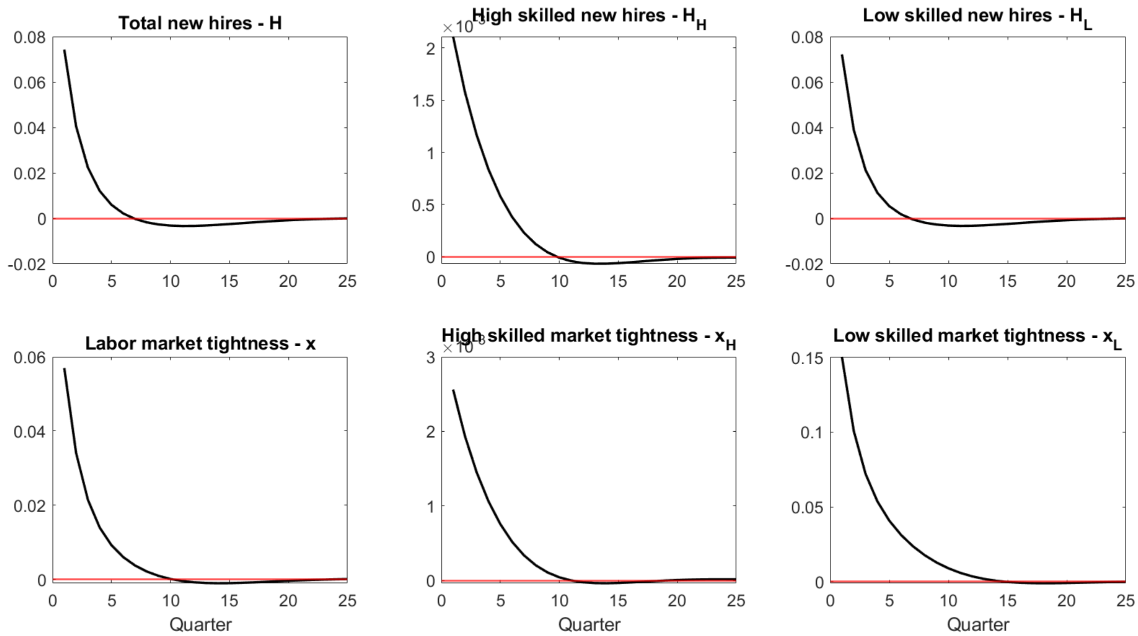

Figure 4. Impulse responses to a monetary policy shock (0.25 p.p.): y-axis for all variables in percentage point.

the economy.The analysis highlights the importance of taking into account labor market diversity in policy making and the possibility that policy interventions may lead to unexpected distributional effects. The different reactions of low- and high-skilled labor markets to monetary policy changes stress the need for a detailed and careful approach in policy analysis and implementation.

Given the observed heterogeneous effects, there is a compelling case for exploring optimal monetary policy that accounts for labor market disparities. Future research will focus on deriving a loss function that incorporates these heterogeneities, aiming to provide insights into how central banks might balance the trade-off between inflation targeting and output stabilization to achieve broader economic objectives. This exploration contributes to the growing body of literature on the implications of monetary policy in economies characterized by significant labor market heterogeneity. By extending the analysis to optimal policy formulation, the research aims to offer a comprehensive framework for understanding and navigating the complex interplay between monetary policy, labor market dynamics, and economic inequality.

6 Conclusion

This study explores the differential impacts of expansionary monetary policy on unemployment rates among high- and low-skilled workers, drawing upon empirical evidence and a detailed New Keynesian DSGE model that incorporates asymmetric search and matching frictions. The empirical analysis reveals that low-skilled workers are more adversely affected by shifts in monetary policy, a finding that is both statistically significant and economically meaningful. This empirical foundation underscores the relevance of labor market segmentation in the transmission mechanism of monetary policy.

Following the empirical foundation, the model's analysis further supports these empirical evidence by illustrating the distinct responses of high- and low-skilled unemployment rates to a reduction in the nominal interest rate. Notably, it demonstrates that consumption reactions to monetary policy shocks also diverge significantly between low- and high-skilled households. This distinction not only highlights the sensitivity of low-skilled workers to economic policies but also suggests a resilience within high-skilled employment groups to such shocks. The evidence presented thus advocates for a refined approach to monetary policy, one that recognizes the heterogeneous effects across different labor market segments. Future research directions will focus on optimizing monetary policy to account for these disparities, contributing to a more equitable economic environment. This next step aims to reconcile the central bank's dual objectives of inflation targeting and output stabilization in light of the labor market's diverse responses to policy changes.

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A Appendix

A.1 Data

The data consists of unemployment rate of individuals with at least bachelor's degree, unemployment rate of only high school graduates and non-graduates[9], and Gertler-Karadi's identified monetary policy shocks (GK). The data is given with quarterly frequency spanning from 03.01.1992 to 06.01.2012.

Unemployment rates are derived using the data (seasonally adjusted) available at Bureau of Labor Statistics. Unemployment rate of the individuals who have less than high school and only high school education is calculated according to

$$u_{L,t} = \frac{U_{HS,t} + U_{NHS,t}}{L_{HS,t} + L_{NHS,t}}$$

where $U_{HS,t}$ and $L_{HS,t}$ are unemployment level and labor force of only high school graduates (25 years and over) and $U_{NHS,t}$ and $L_{NHS,t}$ are unemployment level and labor force of individuals with less than a high school educational attainment (25 years and over).

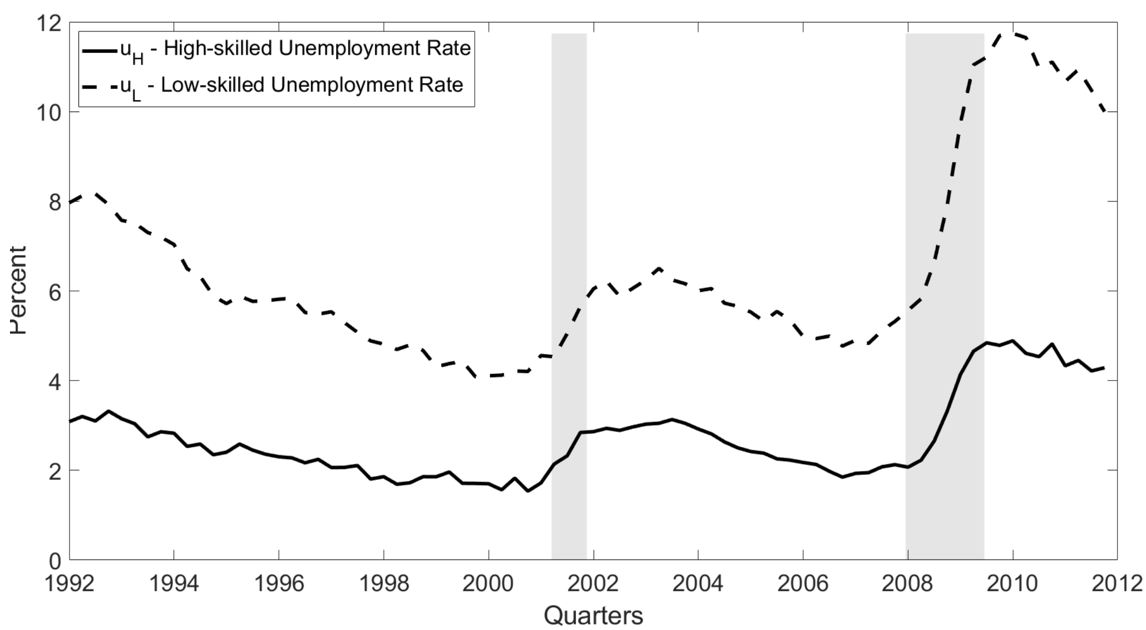

Figure 5. Low- and High-Skilled Unemployment Rates, with NBER Recessions (Grey Bars)

[9]Source: U.S. Bureau of Labor Statistics

The unemployment rate of individuals who own at least bachelor's degree is calculated by the same formula

$$u_{H,t} = \frac{U_{BA,t}}{L_{BA,t}}$$

where $U_{BA,t}$ and $L_{BA,t}$ stand for unemployment level and labor force of individuals who own at least bachelor's degree (25 years and over).

The data set spans from $1992 - Q1$ to $2012 - Q2$ and it covers three recession periods. Based on the time series, the levels of low- and high-skilled unemployment rate time series differ substantially ($\mathbb{V}(u_{H,t}) = 0.84$ and $\mathbb{V}(u_{L,t}) = 4.64$). One can notice that, the response of low-skilled labor force to the recessions is more sensitive compared to it's counterpart. More precisely, during recessions and recovery periods, low-skilled unemployment rate movement is steeper relative to high-skilled unemployment rate.