Monetary Policy Shocks and the Employment of Young, Middle-Aged, and Old Workers*

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We study how monetary policy affects the labor status of people of different ages and genders, using Japanese data spanning the late 1990s to the late 2010s, with monetary policy shocks identified using high-frequency market data. We first demonstrate that expansionary monetary policy shocks reduce the number of unemployed of all ages in both genders by almost the same amount. We then show that the impacts of these shocks are starkly different across ages in terms of responses in the labor force and number of employed. Specifically, expansionary monetary policy shocks induce the young and elderly demographics who were previously outside the labor force to enter the labor market, thereby increasing the employed population within these age brackets while exerting lesser influence on the middle-aged cohort. These findings suggest that changes in the labor force participation rate could play an important role in determining the degree of labor market slack for specific ages, potentially leading to a relatively limited wage increase to expansionary monetary policy shocks through the composition effect.

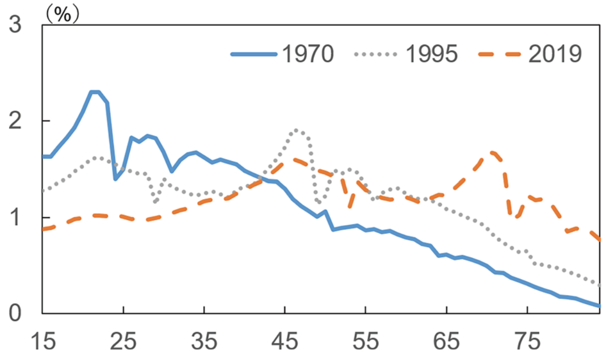
JEL Codes: E24, E32, E52.

1. Introduction

The demographic landscape of the Japanese economy has undergone significant transformations. Figure 1 shows the population

*We would like to thank Daisuke Miyakawa, Makoto Nirei, Toshitaka Sekine, Mototsugu Shintani, seminar participants at the Macroeconomic Workshop at Osaka University, and the staff of the Bank of Japan for their valuable comments and suggestions. The views expressed in this paper are those of the authors and do not necessarily represent the views of the Bank of Japan. Author e-mails: fumitaka.nakamura@boj.or.jp; nao.sudou@boj.or.jp; yuu.sugisaki@boj.or.jp.

Figure 1. Distribution of Population by Age in Japan



Note: This figure shows the distribution of population by age in Japan. The solid line, the dotted line, and the dashed line show the distribution in 1970, 1995, and 2019, respectively. The data come from the Ministry of Internal Affairs and Communications.

distribution in Japan across pivotal years, 1970, 1995, and 2019. In 1970, the distribution peaked around the 20s, with individuals younger than 30 constituting more than half of the population. In contrast, by 2019, this demographic segment accounted for less than 30 percent, while individuals aged over 60 represented one-third of the total population. Indeed, Japan is not an exception; to some degree, other advanced economies such as the United States, the United Kingdom, and Germany have also encountered analogous changes in their demographic structures in the last 50 years to comparable extents.

The effectiveness of macroeconomic policies is intricately linked to the demographic landscape, particularly in the context of labor market dynamics where individuals transition in and out of the workforce. Responses in labor force participation to policy changes across different stages of the life cycle significantly affect policy outcomes (see İmrohoroğlu and Kitao 2012 and Leahy and Thapar 2022). For example, younger demographics contemplating entry into the workforce and elderly individuals pondering retirement decisions are influenced by economic, social, and institutional factors. Monetary policy shocks can also expedite or delay these decisions by altering economic conditions, leading to heterogeneous responses of the individuals across age groups through affecting the factors involved in their decision-making process: some age cohorts may possess greater flexibility in adjusting their labor status compared to the other age cohorts. Because of the differences regarding the responses across age groups, the demographic composition can crucially affect monetary policy outcomes regarding total labor inputs, wage growth, and aggregate output. As illustrated in Figure 2, in Japan, younger and elderly individuals typically have earned lower wages compared to their middle-aged counterparts in the last 20 years, although the differences become slightly diminished in 2019 compared to 1999.[1] Consequently, other things being equal, an expansionary monetary policy shock may result in a limited nominal wage increase if it predominantly increases low-wage workers such as the young and the elderly relative to middle-aged workers. Therefore, it may also result in a moderate response of inflation as long as institutional arrangements in Japan that make both young and old workers responsive to these shocks remain in place.[2]

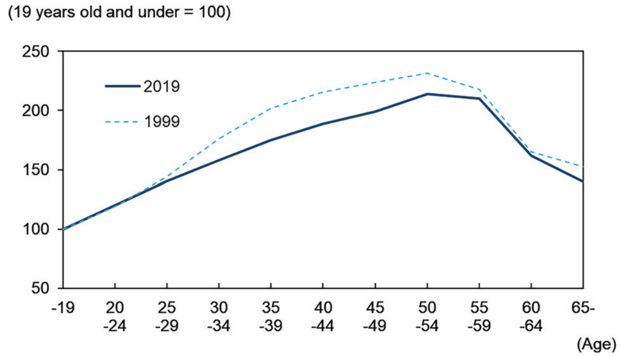
First, this paper investigates the response to monetary policy shocks of individuals with different ages concerning labor status.[3] To address this question, we utilize disaggregated data on employment, unemployment, and labor force participation by age and gender obtained from the Labor Force Survey in Japan, a country characterized by having one of the highest proportions of elderly citizens globally. We employ a vector autoregression (VAR) framework to estimate the responses of these disaggregated labor-related variables to monetary policy shocks. Our empirical specification closely follows the approach developed by Gertler and Karadi (2015) and identifies monetary policy shocks by instrumenting the one-year government

[1] Growing participation of the younger and elderly workers in the labor force may have suppressed wage growth during the recovery from the Global Financial Crisis. For example, for elderly workers, Mojon and Ragot (2019) and Bank of Japan (2023) highlight that active participation of old workers boosts the labor force despite the overall population declines, which contributes to a moderate increase in wages driven by the increased labor supply in the 2010s for Japan and OECD countries, respectively.

[2] This is consistent with Imam (2015), which shows the weakening effect of monetary policy shocks on the inflation rate due to aging.

[3] The importance of demographic change in monetary policy decision-making is also pointed out, for example, in Geneakoplos, Magill, and Quinzii (2004), Yellen (2014), Favero, Gozluklu, and Yang (2016), and Favero, Melone, and Tamoni (2022).

Figure 2. Hourly Nominal Earnings by Age in Japan



Note: This figure shows the average hourly nominal earnings by age in Japan. The data come from the Ministry of Health, Labour and Welfare.

bond yield with changes in Euroyen futures (Japanese short-term interest rate futures), following the methodology outlined by Nakamura, Sudo, and Sugisaki (2024).

We find that the number of unemployed falls significantly in response to an expansionary monetary policy shock, and the magnitude of the decline is quantitatively the same across ages and genders. In terms of changes in the labor force and number of employed, however, the impacts of a monetary policy shock are starkly different across ages. Specifically, both youth and elderly individuals experience a greater increase in labor force participation compared to the middle-aged demographic in response to expansionary monetary policy shocks, suggesting that a favorable macroeconomic labor market environment lowers the relative benefits of being a student or a retiree for individuals of these age cohorts. Moreover, the number of employed increases significantly for the youth and the elderly while that of the middle-aged does not respond significantly to the shocks. This observation suggests that a rise in firms' increased demand for labor inputs following expansionary monetary policy shocks is met, if not fully, by a rise in participation in the labor force among young and elderly individuals.

We further delve into the distinctive characteristics of Japan's labor market structure to illuminate the factors behind the pronounced increases in both young and older workers' responses to expansionary monetary policy shocks. Regarding young individuals, their labor force participation tends to be procyclical as they transition between students and workers; economic upswings encourage a greater number of students to enter the labor market, while recessions prompt a withdrawal. This procyclicality is also partially attributed to the fact that schooling options help youths choose better timing for employment. Under a system of simultaneous hiring and lifetime employment, young people have an incentive to be selective about the first company they work for as new graduates and the type of work they do, such as permanent or temporary employment from a long-term perspective. Regarding the elderly population, their labor force participation tends to be procyclical as they transition between retirees and workers. With a significant perception of inadequate pension support, coupled with high life expectancy and financial insecurity, the retired elderly rejoin the labor force when the labor market condition is favorable.

Second, we estimate the wage Phillips curve for different age groups to evaluate how the fluctuations in the labor force participation rate affect the labor market slack by altering the available labor supply within the economy. When the cyclicality of changes in the rate is age-specific, as evidenced in our study, variations in the slope of the wage Phillips curve are expected to be different across the age groups. Indeed, we find that the slope is steeper for the middle-aged compared to the slopes for the youth and the elderly. This observation further suggests that the aging of society has gone hand-in-hand with weak wage dynamics.[4] Our findings are consistent with the existing studies, for example, by Erceg and Levin (2014) and Elsby, Hobijn, and Şahin (2015): the shifts in labor force participation rate play a pivotal role in shaping nominal wage dynamics. Indeed, Erceg and Levin (2014), stressing the role of the labor force participation rate, showed theoretically that the slope of the wage Phillips curve becomes less steep when the labor force participation rate exhibits cyclical patterns.

[4]The flattening of the wage Phillips curve has been reported in the existing works in advanced countries, including Japan. See, for example, an empirical study conducted by Iwasaki, Muto, and Shintani (2021) and Hirata, Maruyama, and Mineyama (2020).

This paper is organized as follows. Section 2 describes the related literature. Section 3 presents the econometric framework we use for the empirical analysis. Section 4 describes the data set. Section 5 documents the results. Section 6 discusses the implications of our results for the wage Phillips curve. Section 7 concludes.

2. Literature Review

This paper is related to three strands of the literature. The first strand covers empirical works quantifying the heterogeneous effects of monetary policy shocks depending on the characteristics of each agent, including studies such as Coibion et al. (2017), Inui, Sudo, and Yamada (2017), Bahaj et al. (2019), Cloyne, Ferreira, and Surico (2020), Zens, Böck, and Zörner (2020), and Leahy and Thapar (2022). Among these studies, Bahaj et al. (2019) and Zens, Böck, and Zörner (2020) investigate the relationship between monetary policy shocks and the response to employment. Bahaj et al. (2019) focus on the collateral channel by exploiting the homes of firms' directors as a key source of collateral. The spatial separation of firms from their collateral enables them to separate the collateral channel from local demand effects. Zens, Böck, and Zörner (2020) find that the effects of monetary policy shocks on the unemployment rate differ depending on the occupational group. Compared to these papers, which focus on the characteristics of companies, this paper focuses on the heterogeneous effects of monetary policy shocks depending on differences in workers' age and gender. Moreover, Coibion et al. (2017) and Inui, Sudo, and Yamada (2017) investigate the relationship between consumption inequality and the transmission of monetary policy in the U.S. and in Japan, respectively. Inui, Sudo, and Yamada (2017) find that monetary policy shocks do not have statistically significant impacts across Japanese households in a stable manner in terms of their effects on income and consumption inequality. On the other hand, the present paper discusses the relationship between monetary policy and labor status and finds that impacts are starkly different across ages.[5]

[5]Regarding the relationship between monetary policy and inequality, Bernanke (2015) points out the possibility that quantitative easing can reduce inequality through promoting job creation since a stronger labor market benefits

The second strand of the literature covers empirical work quantifying the relationship between population aging and the business cycle, including the implications for monetary policy, such as Jaimovich and Siu (2009), Imam (2015), and Wong (2019).[6] Among these studies, Jaimovich and Siu (2009) document the relatively larger variation of employment among the youth and the elderly, and argue that the change in the age composition of the labor force accounts for a significant fraction of the cyclical fluctuation of business cycles in the U.S. We show that a similar pattern can be seen for employment variations conditional on monetary policy shocks in Japan as well as in the U.S., namely a larger response of the number of employed among the young and the old. Imam (2015) shows that there is a relationship between population aging and monetary policy in terms of inflation and unemployment by Bayesian estimation techniques, while this paper assesses the effect of monetary policy shocks on labor-related variables of different age groups.

The third strand of the literature consists of studies investigating the labor market slack and wage settings, including studies such as Erceg and Levin (2014), Blanchflower and Levin (2015), Elsby, Hobijn, and Şahin (2015), and Christiano, Trabandt, and Walentin (2021).[7] Erceg and Levin (2014) argue theoretically that monetary policy affects the labor force participation rate. Christiano, Trabandt, and Walentin (2021) construct a monetary model in which the labor force participation rate varies with the business cycle. Blanchflower and Levin (2015) and Elsby, Hobijn, and Şahin (2015) empirically point out the importance of labor force participation margin in explaining the hidden unemployment, which could put downward pressure on nominal wages. Since some workers who are not actively searching for a job can rejoin the workforce if the job

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the middle class. This paper clarifies the segments of the population who receive benefits from expansionary monetary policy shocks: such shocks lead to a greater increase in employment of young and old workers, whose wages are relatively low.

[6]Instead of monetary policy, some studies investigated the relationship between fiscal policy and demographic change, since age structure is closely related to the social security policy and taxation system. This includes Ríos-Rull (2001), Abel (2003), and İmrohoroğlu and Kitao (2012).

[7]Also, a lot of study has been dedicated to clarifying the cyclicality of employment and labor force participation. See, for instance, Ragan (1977), Shimer (2005), Campolmi and Gnocchi (2016), Chodorow-Reich and Karabarbounis (2016), and Cairo, Fugita, and Morales-Jimenez (2022).

market gets stronger, labor market slack exerts significant downward pressure on nominal wages. Compared to these studies, we argue that the slack is age-specific, larger for the young and the old, and smaller for other age groups, which, together with the shift in age composition in the population, may moderate a rise in the aggregate-level nominal wage in Japan in response to expansionary monetary policy shocks in Japan.

3. Econometric Framework

Our estimation procedure consists of two steps. First, we formulate a VAR that consists of macroeconomic variables of the sample period running from 1999:M1 to 2018:M12 and estimate the response of the variables to monetary policy shocks. We identify monetary policy shocks by using high-frequency data as external instruments following Gertler and Karadi (2015). Almost all of our sample period coincides with the period when the short-term interest rate was set close to zero and the Bank of Japan had launched various policy initiatives trying to reduce not only the current short-term nominal interest rate but also the expected short-term nominal interest rate and the term premium.[8] We therefore incorporate financial variables including the government bond rate instead of the short-term nominal interest rate in our VAR and isolate variations in the government bond rate that stem from the exogenous policy shocks thanks to high-frequency identification.[9] Second, we regress a disaggregated labor-related variable, such as the unemployment rate of males in their 30s, on macroeconomic variables and estimate the response of the variable of interest to monetary policy shocks. We assume a block

[8]Our data set includes the period in which the zero interest rate (ZIR), quantitative easing (QE), comprehensive monetary easing (CME), and quantitative and qualitative monetary easing (QQE) policies were in place. Note also that QQE includes QQE with a negative interest rate and QQE with yield curve control. ZIR runs from 1999:M2 to 2000:M8, QE runs from 2001:M3 to 2006:M3, CME runs from 2010:M10 to 2013:M4, and QQE runs from 2013:M4 to the present.

[9]External instruments are employed in a growing body of studies, including Stock and Watson (2012) and Mertens and Ravn (2013). High-frequency identification for Japan's monetary policy shocks used in the current paper are the same as those constructed in Nakamura, Sudo, and Sugisaki (2024).

recursive framework (see Lee and Ni 2002) so that a shock to disaggregated variables does not affect the dynamics of macrovariables in the VAR estimated in the first step.

3.1 Macrovariable Block

Our VAR contains N_x number of monthly series of macroeconomic variables and is expressed in the following structural form:

$$A_x X_t = A_x c_x + \sum_{j=1}^{p} A_x B_{xx,j} X_{t-j} + \varepsilon_{x,t}, \qquad (1)$$

where X_t is the N_x-dimensional vector of macroeconomic variables, $B_{xx,j}$ is the matrix of polynomials that represent the structural relationships among macroeconomic variables, A_x and c_x are coefficient matrices, and $\varepsilon_{x,t}$ is a vector of structural white noise shocks.[10] Multiplying each side of the equation by A_x^{-1} yields the reduced-form VAR model given by

$$X_t = c_x + \sum_{j=1}^{p} B_{xx,j} X_{t-j} + u_{x,t}, \qquad (2)$$

where $u_{x,t}$ is the reduced-form shock. The relationship between the reduced-form shock, $u_{x,t}$, and the structural shock, $\varepsilon_{x,t}$, is given by

$$u_{x,t} = S\varepsilon_{x,t}, \qquad (3)$$

with $S = A_x^{-1}$. The variance-covariance matrix of the reduced-form model Σ can be written as

$$E\left[u_{x,t}u'_{x,t}\right] = E\left[SS'\right] = \Sigma. \qquad (4)$$

Now, let r be the interest rate included as one of the macroeconomic variables in this VAR block, and let $X_{q,t}$ be macroeconomic variables other than r. We denote reduced-form residuals $u_{x,t}$ of r as $u_{r,t}$ and of $X_{q,t}$ as $u_{q,t}$. We define $\varepsilon_{r,t}$ and $\varepsilon_{q,t}$ similarly to $u_{r,t}$

[10] We use 12 lags, $p = 12$, in our baseline estimation. The results are little changed when other numbers of lags, $p = 6$ or 18, are used for the estimation.

and $u_{q,t}$. Regarding the component of the matrix S, s is defined as the column in matrix S corresponding to $\varepsilon_{r,t}$. To obtain the impulse response to the monetary policy shocks, we do not have to identify all of the coefficients in S. Specifically, we need to estimate the following equation:

$$X_t = c_x + \sum_{j=1}^{p} B_{xx,j} X_{t-j} + s\varepsilon_{r,t}. \tag{5}$$

In order to obtain the coefficient of the matrix $B_{xx,j}$, we can simply use the least-squares estimation in Equation (2). Since we focus on the case of Japan where the policy target rate is constrained by the effective lower bound, it is important for a policy indicator to include shocks to unconventional monetary policy such as forward guidance. Thus, we choose one-year and two-year rates as candidates for the policy indicator. To isolate movements of the policy indicator made by exogenous monetary policy shocks, we use instrument variable Z_t. The conditions of the instrument variables Z_t are

$$E\left[Z_t \varepsilon_{r,t}\right] = \rho, \tag{6}$$

$$E\left[Z_t \varepsilon_{q,t}\right] = 0. \tag{7}$$

These equations state that instruments Z_t are only correlated with monetary policy shocks $\varepsilon_{r,t}$, but they are orthogonal to other macroeconomic variables shocks $\varepsilon_{q,t}$. If we are able to obtain these instrument variables, s can be estimated as follows.

- From the instrument variables Z_t, and the residual u_t obtained from the VAR regression, estimate the following equation:

  $$u_{r,t} = \alpha_1 + \beta_1 Z_t + \xi_{1,t}, \tag{8}$$

  where α_1 and β_1 are coefficients and $\xi_{1,t}$ is the residual. From the equation, we can calculate the fitted value $\widehat{u}_{r,t}$.
- Using the fitted value $\widehat{u}_{r,t}$, estimate the following equation using the ordinary least squares (OLS):

  $$u_{q,t} = \alpha_2 + \beta_2 \widehat{u}_{r,t} + \xi_{2,t}. \tag{9}$$

The estimated coefficient β_2 corresponds to the ratio s_q/s_r, where s_r and s_q are elements of s and they correspond to the response of

$u_{r,t}$ and $u_{q,t}$ to a unit increase in the policy shocks $\varepsilon_{r,t}$. Finally, s_r can be obtained from the reduced-form variance-covariance matrix.[11]

Given these coefficients of s and $B_{xx,j}$, the impulse response to the monetary policy shocks can be estimated from the macrovariable block.

3.2 Segment-Variable Block

We denote the N_y-dimensional vector of segment variables at time t by Y_t. In this segment-variable block, the dynamics of macroeconomic variables do not depend on segment-level variables, while those of the segment variables depend on the macroeconomic variable block. Specifically, the reduced-form VAR can be described as follows:

$$Y_t = c_y + \sum_{j=0}^{q_1} B_{yx,j} X_{t-j} + \sum_{j=1}^{q_2} B_{yy,j} Y_{t-j} + u_{y,t}, \tag{10}$$

where $u_{y,t}$ is the reduced-form shocks of segment variables.[12] Here, we assume that the macroeconomic variables have contemporaneous effects on the segment variables. We can estimate the impulse response functions of the segment-variable block using the above relationship. Specifically, for the second term which corresponds to the behavior of the macroeconomic variables, we substitute an estimated impulse response function in the macroeconomic-variable block using the external instruments to obtain the impulse response functions.

The standard errors are calculated by the wild bootstrap following Mertens and Ravn (2013). The wild bootstrap generates valid confidence intervals under heteroskedasticity. We consider not only estimation errors related to macroeconomic and segment-level variables but also those related to instrument variables, by including all the steps of estimation for the bootstrap procedure.

[11] Details of the estimation of s_r are described in Gertler and Karadi (2015).

[12] In the baseline estimation, we use $q_1 = q_2 = 4$ on a quarterly basis since some of the segment-level variables are only available in quarters. Even if we change the number of lags to shorter (1 and 2) or longer (6) values, we obtain similar results.

3.3 Assumptions of VAR Model

Our specification of the VAR model is based on several assumptions. First, we assume that the instrument variables using high-frequency data can extract the exogenous component of monetary policy shocks. In other words, the price changes within the narrow window between monetary policy announcements are only due to the monetary policy, and do not contain other economic or financial news. The data we use are described in the next section, and the validity of the assumption is checked in Nakamura, Sudo, and Sugisaki (2024).

Second, we assume that macroeconomic variables are isolated from the segment-variable block, and that the dynamics of macroeconomic variables do not depend on the segment variables. In order to check the validity of this block recursive restriction on the lag coefficients as we do here, we use the single-equation F-test, following Lee and Ni (2002). The results show that segment variables are not significant in the macroeconomic-variable equations, which justifies our assumption.

4. Data

Our data sample consists of three groups of variables: aggregate data, disaggregated labor-related variables by age and gender, and high-frequency data used for the identification of monetary policy shocks.

4.1 Macroeconomic Variables and Disaggregated Labor-Related Variables

The set of macroeconomic variables used for estimating the VAR in Equation (2) includes the one-year government bond yield, corporate bond yield, consumer price index (CPI), capacity utilization, unemployment rate, and number of employed. They are all used in the VAR in the log level, except for the one-year government bond yield, corporate bond yield, and the unemployment rate. Financial data such as the one-year rate and corporate bond yield come from Bloomberg. CPI, unemployment rate, and number of employed are taken from statistics released by the Ministry of Internal Affairs and

Communications, and the capacity utilization rate is taken from the Indices of Industrial Production released by the Ministry of Economy, Trade and Industry. The disaggregated labor-related variables, including the employment status by age and gender, are taken from the Labor Force Survey released by the Ministry of Internal Affairs and Communications. The sample period is from 1999:Q1 to 2018:Q4.[13] The data series used for the estimation are shown in Figure 3.

4.2 High-Frequency Data

High-frequency data used as instrument variables are the key to our econometric framework.[14] We use tick-by-tick price data of interest rate futures.[15] The data we use are the three-month Euroyen interest rate futures (YE) with a variety of contract dates: 1 day to 3 months ahead (YE1), 3 to 6 months (YE2), 6 to 9 months (YE3), and 9 to 12 months (YE4). For the baseline estimation, following Nakamura, Sudo, and Sugisaki (2024), we use the primary factor extracted from changes in YE1 to YE4 (denoted YEF hereafter) over a 30-minute window around the announcement of the monetary policy meetings as the external instrument. These high-frequency data come from the Tokyo Financial Exchange Inc.[16]

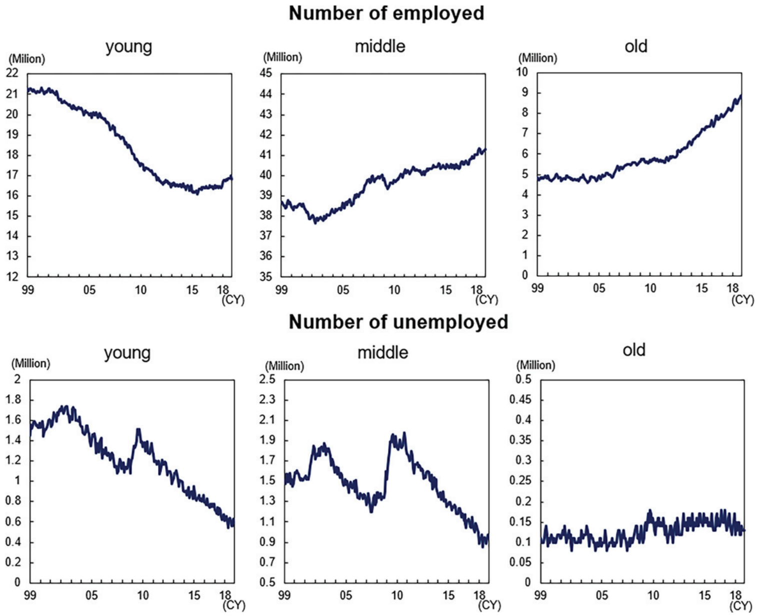
[13] Disaggregated labor-related variables are only available from 2002:Q1 onward. When estimating the response of these variables (namely Figure 6), we use the sample period that runs from 2002:Q1 to 2018:Q4. Partly because of this short sample period, Figure 6 shows larger standard errors, and thus we use a longer sample period for other baseline results. Even if we use a shorter sample period when estimating the impulse response of the number of employed, unemployed, and the labor force, the baseline results remain consistent, albeit with larger standard errors.

[14] The identification of monetary policy shocks using high-frequency financial data was first developed in the U.S. by studies such as Gürkaynak, Sack, and Swanson (2005), Gertler and Karadi (2015), and Nakamura and Steinsson (2018).

[15] Other widely used methods for the identification of monetary policy shocks include Romer and Romer (2004). Studies such as Coibion et al. (2017) and Nakamura (2019) use such methods for the identification for the empirical analysis in the U.S. using the sample period before the Global Financial Crisis. However, the same technique is not applicable to the period that includes the period when effective lower bound prevails, and therefore is not applicable for Japan in our sample period.

[16] We follow Munakata, Oi, and Ueno (2019) for the data cleaning regarding the high-frequency data.

Figure 3. Data Used for the Estimation by Age Group



Note: The data come from the Labor Force Survey. Young, middle, and old represent age groups of under 35, between 35 and 64, and 65 and over, respectively.

To check the validity of the extracted monetary policy shocks, we estimate the response of the financial variables. Specifically, we use the following equation:

$$\Delta R_t = \alpha + \beta \Delta i_t + \varepsilon_t, \tag{11}$$

where ΔR_t and Δi_t correspond to the change in asset return and the change in interest rate on the day that a policy announcement is made. We estimate this equation using the two-stage least squares by instrumenting YEF for a daily change in a policy indicator, Δi_t. Our identifying assumption is that the instrument variables (YEF changes) are orthogonal to the error term, and the instrument affects ΔR_t only through the policy indicator Δi_t. We estimate the regressions over the available 2003:M4–2017:M10 samples.

Table 1 shows the results of the two-stage regression. Each row represents a particular policy indicator. The coefficient represents

Table 1. Effects of Monetary Policy Shocks on Financial Markets

Policy Indicator	2 Year	5 Year	10 Year	USD/JPY
1 Year	0.1211***	0.1457***	0.1457**	–4.3118**
	(4.235)	(5.377)	(2.591)	(–2.069)
2 Year		0.1203***	0.1203**	–3.5592***
		(5.147)	(2.512)	(–2.762)

Note: Robust t-statistics in parentheses. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively.

the impact of a 10 basis point (bp) increase in a given policy indicator due to an exogenous monetary policy shock on a corresponding asset return. From the table, we can find that monetary policy easing shocks (in Japan) decrease 2- to 10-year government bond rates and depreciate the value of the Japanese yen, as expected. All of the results except for the 10-year bond rate and the exchange rate with 1-year government bonds as policy indicators are statistically significant at the 1 percent level, and all results are statistically significant at the 5 percent level.

As shown in Table 1, high-frequency data of monetary policy shocks indeed have a statistically significant impact on financial variables. This result indicates that YEF can be used as instruments when estimating the effects of monetary policy shocks. Then, the next issue is the choice of a policy indicator in the VAR specification: a financial variable whose shock corresponds to monetary policy innovation. As discussed in Gertler and Karadi (2015), traditional VARs use the same policy instruments and policy indicator, namely the overnight interest rate. This is because a structural shock to a policy indicator can be regarded as an exogenous monetary policy shock. On the other hand, we use the longer maturity rate of government bonds to capture shifts in unconventional monetary policy such as forward guidance. The longer-term government bond might incorporate various information other than monetary policy such as news on the economy reflecting the economic fundamentals. However, the high-frequency identification successfully eliminate the component of innovations in longer-term government bonds that is unrelated to monetary policy shocks.

Table 2. Effects of Instruments on the First-Stage Residuals

Policy Indicator	1 Year	2 Year
Coefficient	1.61***	1.85***
R^2	0.07	0.08
Robust F-statistic	13.11	12.01

Note: *** denotes significance at the 1 percent level.

When choosing the policy indicator, we need to avoid the weak instrument problem. Stock, Wright, and Yogo (2002) recommended that the F-statistic from the first-stage regression in the two-stage least squares should be above 10 in order to state that weak instrument problems are not present. Thus, we estimate the effects of high-frequency instruments on the first-stage residuals described in Equation (2). Table 2 shows the results. The left column shows the result when the one-year rate is the policy indicator, and the right column shows the case when the two-year rate is the policy indicator. The first row shows the estimates for the coefficient and the second row shows the R^2. The third row shows the robust F-statistic for each regression. From the table, we can see that monetary policy shocks denoted as YEF explain more than 5 percent of the monthly innovation of the two-year rate, and the associated robust F-statistic is around 13, which is above the threshold value, 10. On the other hand, although the robust F-statistic for the two-year rate is more than 10, the value for robust F-statistics is less than it is in the case for the one-year rate. Thus, we use the one-year rate as a policy indicator in our baseline estimation.[17]

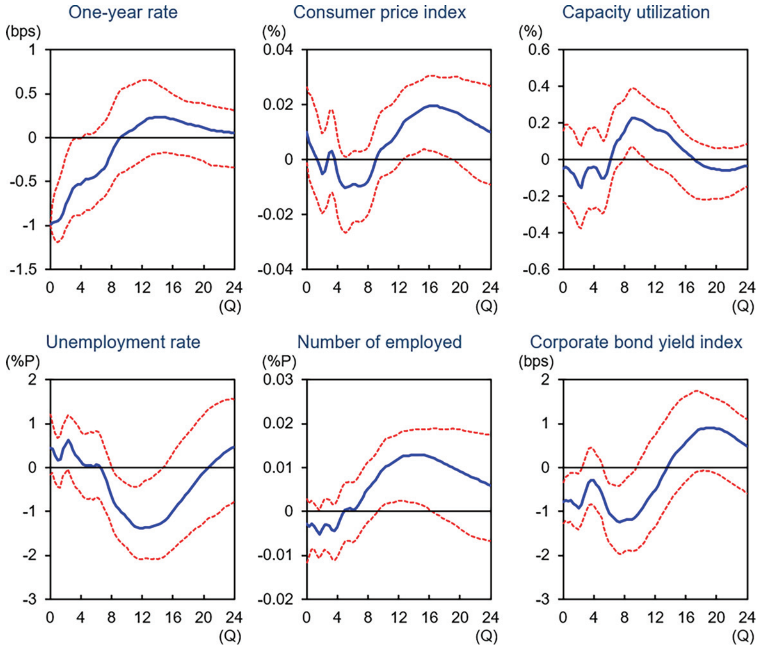
5. Empirical Results

5.1 Macroeconomic Variable Responses

Figure 4 shows the impulse response function of the macroeconomic variables to an expansionary monetary policy shock estimated using

[17]Even if we use the two-year rate as a policy indicator, we obtain almost the same results.

Figure 4. Macroeconomic Responses to a Monetary Policy Innovation



Note: This figure shows the responses of macroeconomic variables to an expansionary monetary policy shock. The shock is identified by high-frequency data of YEF and normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

the VAR in Equation (2). The size of the monetary policy shock is normalized so that the one-year rate declines by 1 basis point at the time of the impact, and the shock is identified by high-frequency data of YEF (factor of the Euroyen interest rate futures). Dashed lines show 90 percent confidence intervals. Consistent with the conventional view about the effects of an expansionary monetary policy shock, the CPI, capacity utilization, and number of employed all increase while the unemployment rate and corporate bond yield fall at a statistically significant level for all of the variables.[18]

[18] As for the variables used in the VAR analysis, we use the logarithmic scale in the CPI, capacity utilization, and number of employed for the estimation.

5.2 Segment-Variable Responses

5.2.1 Number of Unemployed

The upper charts of Figure 5 show the responses of the number of unemployed to an expansionary monetary policy shock by age. The number of unemployed does not respond in the first few quarters and starts to decline around two years after the shocks. The point estimates indicate that there is not much difference in terms of the timing and size of the decline across different age groups, while the declines of the unemployed for the old are muted, and the estimates are associated with larger confidence intervals. One potential reason why the response of the number of unemployed at and above 65 differs from that of the unemployment rate for other ages is the mandatory retirement age, which is now typically 60 in Japan.[19] Due to this retirement, old individuals tend to become non-labor force rather than unemployed when they quit their current position.[20]

5.2.2 Number of Employed

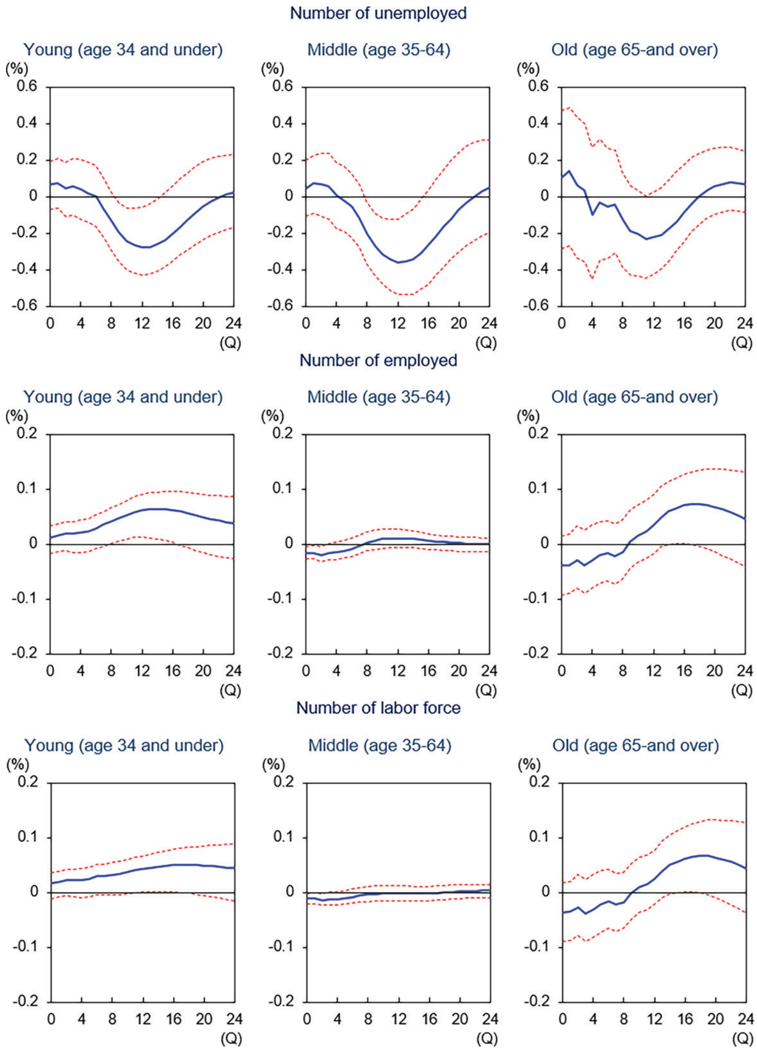
The middle charts in Figure 5 show the number of employed in response to an expansionary monetary policy shock.[21] From these

[19]The Act on Stabilization of Employment of Elderly Persons, revised in 2000, required firms to make efforts to employ workers until the age of 65. The law was then revised in 2013, requiring firms to guarantee the employment of all personnel seeking to remain employed until the age of 65 by 2025.

[20]We also check the impulse responses of the unemployment rate by age to an expansionary monetary policy shock, instead of the number of unemployed. We find that the results are unchanged qualitatively; however, we do not include them in this paper to conserve space. It is also possible to further examine the reason behind the changes in unemployment using the breakdown of unemployment reported in the Labor Force Survey. We decompose the unemployment into voluntary unemployment and involuntary unemployment. Note that involuntary unemployment refers to individuals who begin searching for a job due to factors attributable to their employer or business, whereas voluntary unemployment refers to those who leave their previous job for personal or family reasons. We find that the decline of the unemployment rate in response to an expansionary monetary policy shock is mainly due to the decrease in involuntary unemployment rather than voluntary unemployment.

[21]In this paper, the unemployed, the employed, and the total labor force population are divided into three mutually exclusive groups, and separate estimates are conducted for each group. On the other hand, the working paper version of this study employs a rolling sample approach to divide the

Figure 5. Employment Responses by Age



Note: This figure shows the responses of the number of unemployed, the number of employed, and the labor force to an expansionary monetary policy shock depending on the age given at the top of each graph. The shock is identified by high-frequency data of YEF and normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

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data into eight overlapping groups. The results indicate no substantial differences in age-specific responses to monetary policy shocks between the three-group and eight-group classifications. See Figures 6–8 in the following link: https://www.imes.boj.or.jp/research/abstracts/english/21-E-06.html.

charts, we find that the increase in response to an expansionary monetary policy shock is large in younger age groups and older age groups. More specifically, the number of employed young workers, who are under age 46, and the number of those age 65 and over increase.[22] On the other hand, the response of workers between the ages of 35 and 64 is close to zero over the six years after the shock.[23]

5.2.3 Labor Force

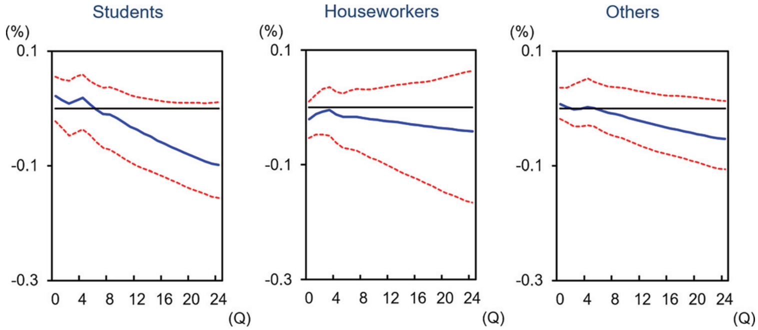
Generally, an increase in the number of employed occurs due to two reasons: a decrease in the number of unemployed, or an increase in the labor force. In our case, the former is unlikely to be the driving force, since the homogeneous impulse responses of the number of unemployed cannot account for the heterogeneous impulse responses of the number of employed. By contrast, as shown in the lower charts of Figure 5, we find evidence that the latter is the case: the age-specific shape of the response of labor force and that of the number of employed to a monetary policy shock are somewhat close. The size of the expansionary monetary policy shock is the same as in the previous figures. The figure reveals that young and old workers show larger responses. On the other hand, the response of workers between the ages of 35 and 64 does not increase after an expansionary monetary policy shock in the point estimate.

An increase in the number of labor force means that the number of non-labor force decreases. To explore the reason for this decrease, we decompose the non-labor force into students, homemakers, and others, following the definition in the Labor Force Survey. Figure 6

[22]By estimating which type of worker contributes to the increase in the number of employed following an expansionary monetary policy shock, we find that, for the younger worker, the main driving force of the increase is regular employment. On the other hand, non-regular employment including part-time job is the main contributor to the increase in the number of employed for the elderly.

[23]A large positive response of the youth following expansionary monetary policy shocks may contribute to alleviating the so-called scarring effect presented in, for example, Arulampalm, Booth, and Taylor (2000) and Arulampalm (2001) for the U.K. They argue that an individual's previous unemployment experience increases the probability of current unemployment and contributes to wage inequality or poverty. With respect to this scarring effect, our results show that expansionary monetary policy shocks increase the employment of the youth, which may reduce the risk of future unemployment, as younger workers accumulate human capital in their early stage of the work experiences.

Figure 6. Non-labor Force Responses

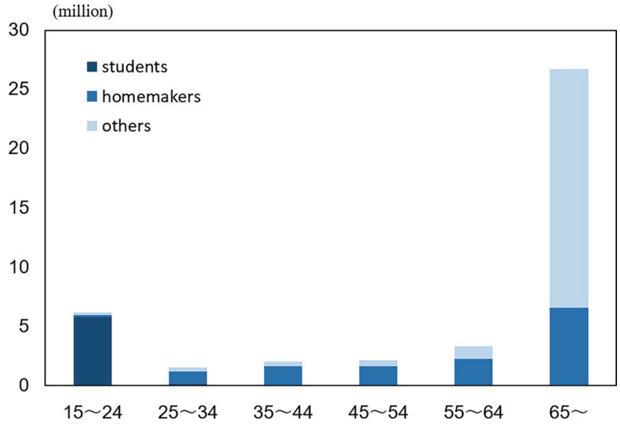


Note: This figure shows the responses of the non-labor force to an expansionary monetary policy shock. The shock is identified by high-frequency data of YEF and normalized so that the two-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

shows the impulse response of each component to an expansionary monetary policy shock. Although all the responses are not statistically significant at the 90 percent confidence interval, the point estimates indicate that the size of the decrease is the largest in students, and larger in others compared to homemakers. Figure 7 shows the breakdown of the number of non-labor force by age. It shows that the number of population that is not in labor force is high among individuals ages 15 to 24, as well as those over 65, particularly. Moreover, students constitute the dominant component of the non-labor force between the ages of 15 and 24. For ages between 30 to 54, most of the non-labor force consists of homemakers, and for the old, especially those older than 65, the percentage of others is large.

Figures 6 and 7 suggest the reasons behind the heterogeneous response of the labor force to monetary policy shocks. First, it is notable that among the youth, students constitute a significant segment of the non-labor force and the response of the youth is considered to be related to the observations made in existing studies that the labor force participation of the younger population tends to be procyclical as they transition between students and workers; economic upturns encourage more students to enter the labor market, while downturns deter such engagement (see Kondo 2007). These dynamics are partially attributed to the

Figure 7. Breakdown of Non-labor Force



Note: This figure shows the breakdown of the non-labor force by age. The data come from the Labor Force Survey.

simultaneous recruitment of new graduates and the lifetime employment system, where companies hire fresh graduates and retain them until retirement. Consequently, for younger generations, the initial job—secured immediately after graduation—is of considerable importance for their lifetime employment prospects, as pointed out by Oshio and Inagaki (2015). Thus, during recessions when fewer regular employment opportunities are anticipated, more students in Japan opt to continue their education rather than entering the labor force in pursuit of desirable positions.

Second, for older individuals, there is an increase in the proportion of those categorized as "others," including retirees making up a substantial part of the non-labor force. Their response is considered to be related to the observation that their labor force participation tends to be procyclical as they transition between workers and retirees. They may opt to reenter the workforce once the economy shows signs of improvement following an expansionary monetary policy shock. Given Japan's high life expectancy, aged individuals often believe that the benefits from the Japanese pension system may not suffice to cover their living expenses. Additionally, given the particularly extended life expectancy in Japan, all else being equal, the level of consumption for retired households could likely be diminished. These factors may contribute to a sense of financial insecurity among the Japanese elderly.[24] In summary, Japan's high life expectancy coupled with concerns that the benefits from the Japanese pension system may not adequately cover living expenses may have made Japanese elderly more responsive to labor market conditions compared with the case otherwise. This channel could work, reinforcing an outward shift of the labor supply curve when an expansionary monetary policy shock improves labor market conditions. Conversely, for those between the ages of 30 and 50, the majority of the non-labor force consists of homemakers, many of whom may be unable to seek employment even in an improved labor market condition due to childcare responsibilities.

5.2.4 Gender Differences

We also estimate the impulse response for each gender to check if the effects of monetary policy differ across gender. Figure 8 shows the responses for men and women to an expansionary monetary policy shock. Again, the shock is normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

From these results, we can conclude that the responses of employment, unemployment, and labor force are similar between men and women. Specifically, the chart clearly shows that an expansionary monetary policy shock reduces the number of unemployed, whereas it increases the number of employed and labor force statistically significantly. However, as we can see from the impulse response, the difference across the genders is not significant,[25] inter alia, compared

[24]This sentiment is corroborated by a survey conducted by the Cabinet Office of Japan. It reveals that a significant portion of the elderly do not feel financially secure, in contrast to their counterparts in the U.S. and European countries: over half of the elderly in Japan perceive their wealth as insufficient, whereas this figure is around or below 20 percent in the U.S. and Europe. Consequently, about 40 percent of the elderly express a desire to work, primarily due to inadequate financial resources—a proportion substantially higher than that in peer countries.

[25]Note that while the Bank of Japan (2018) indicates that the labor supply of women is more elastic than that of men, this paper finds that the response of the labor force to our identified monetary policy shocks is quite similar between the two genders. The Bank studies differences in the elasticity of labor supply reflecting various changes in the economic environment, including the Japanese government's policies that encourage the participation and advancement of

Figure 8. Responses by Gender

Note: This figure shows the responses of men and women to an expansionary monetary policy shock. The shock is identified by high-frequency data of YEF and normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

to the difference of impulse responses across age groups.[26] Also, to compare with the examples of other countries, results in the U.S. are explained in the appendix.

6. Implications for the Wage Phillips Curve

In the previous section, we show that the responses of the number of employed and the labor force to expansionary monetary policy shocks are larger among the young and old generations. This section studies an implication of these heterogeneous responses for nominal wage dynamics, using the concept of the wage Phillips curve.[27] Theoretically speaking, as Galí (2011) points out, the wage Phillips curve is flatter when the labor supply is elastic. Therefore, if the young and the old adjust their labor force inflow in response to a shock (as empirically shown in the previous section) to a greater degree, the wage Phillips curve for the young and the old, ceteris paribus, should be flatter than that for the middle-aged.[28]

In order to assess this argument quantitatively, we estimate the wage Phillips curve for each age group of workers. For this estimation, we need the unemployment rate and wage inflation rate of each age group. The data for unemployment rate are taken from the Labor Force Survey published by the Ministry of Internal Affairs and Communications. We use the deviation from the average unemployment rate in each group to estimate the slope of the wage Phillips

women in the labor force, whereas our paper investigates changes in the number of employed and labor force in response to monetary policy shocks identified using high-frequency market data.

[26]Even if we show the impulse response across the age decomposed by gender, the difference of the impulse response in gender is smaller compared to those of ages. We also check the response of unemployment rate instead of the number of unemployed, but the results are almost the same: the size of the reduction of the unemployment rate is almost the same between genders. These results are shown in the working paper version in the following link: https://www.imes.boj.or.jp/research/abstracts/english/21-E-06.html.

[27]The derivation of the wage Phillips curve is explained in, for example, Erceg, Henderson, and Levin (2000) and Galí (2011). The wage Phillips curve in Japan is estimated, for instance, by Muto and Shintani (2020) and Iwasaki, Muto, and Shintani (2021).

[28]Muto and Shintani (2020) point out that the slope of the wage Phillips curve is determined also by wage stickiness. Nonetheless, since wages for workers in Japan, regardless of age, are likely to be simultaneously revised in April by Shunto, it is reasonable to assume that wage stickiness is more or less the same across the ages.

curve.[29] The wage data come from the Basic Survey on Wage Structure published by the Ministry of Health, Labour and Welfare. Wage inflation rate is calculated from the baseline wage released in the Basic Survey on Wage Structure, scheduled salary in June excluding overwork salary.[30] The sample period is from 1999 to 2019.

Figure 9 shows the wage Phillips curve for each indicated age. Each circle corresponds to each data point, and the line shows the fitted curve obtained from the OLS in each age group. Also, we use the data of males and females separately to increase the number of data.[31] The horizontal axis corresponds to the deviation of the unemployment rate from the average. The vertical axis corresponds to the wage inflation rate. From the figure, we can see that all of the slopes are negative; a decrease in unemployment leads to a higher wage inflation. Furthermore, most importantly, the slope of the wage Phillips curve of middle-aged workers is the steepest.

In order to check the statistical significance, we use two regression equations. The first one is the simple regression,[32]

$$\pi_{w,t} = \alpha_0 + \alpha_1 unemp_t + \xi_t, \tag{12}$$

where $\pi_{w,t}$ is the wage inflation rate and $unemp_t$ is the unemployment rate. The α terms represent the regression coefficient, and ξ_t

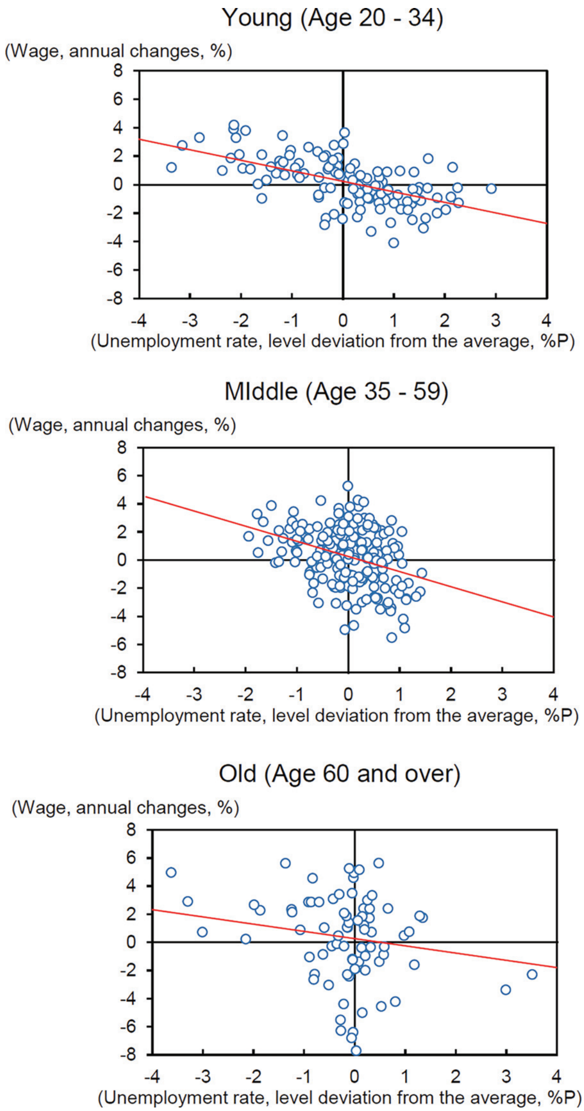
[29] We also detrend using a linear trend of time series of unemployment rate in each age. However, the method of calculating the deviation does not significantly change the results.

[30] Another definition of wage inflation rate used in estimating the wage Phillips curve is monthly total wage divided by monthly total working hours. We also estimate the results based on this definition, and obtain qualitatively similar results. Moreover, the hourly wage of short-time workers also gives similar results: the slope of the middle-aged worker is the steepest.

[31] Since we use the Basic Survey on Wage Structure, only the wage change on a yearly basis is available. Thus, we use male and female data separately to increase the number of data. To ensure robustness, we conduct the same exercises using the consolidated data and, again, obtain qualitatively similar results to the baseline ones.

[32] By assuming a simple autoregressive model for the determination of the unemployment rate, we can obtain the closed-form representation of the wage Phillips curve similar to Equation (12) rather than the standard forward-looking form of the New Keynesian wage Phillips curve, as described in Galí (2011). One may think that this simple specification cannot avoid the endogeneity problem. Indeed, several preceding studies such as Galí (2011) and Muto and Shintani (2020) control for inflation in estimating the wage Phillips curve. We also control this inflation rate as a robustness check, and obtain similar results; the wage Phillips curve for the young and the old is flatter.

Figure 9. The Wage Phillips Curve of Each Age Group



Note: This figure shows the wage Phillips curve of each age given at the top of each graph. The horizontal axis corresponds to the unemployment rate deviations from the average unemployment rate. The vertical axis corresponds to the wage inflation rate. Each circle corresponds to each data point, and the red lines show the fitted line from the OLS. The unemployment data come from the Ministry of Internal Affairs and Communications, and wage data come from the Ministry of Health, Labour and Welfare. The sample period is from 1999 to 2019.

Table 3. Wage Phillips Curve Depending on Age

Age	Unemployment Rate	Intercept
20–34	–0.74***	0.24*
(Robust-t)	(–7.96)	(1.95)
(90% CI)	[–0.89 –0.59]	
35–59	–1.08***	0.26*
(Robust-t)	(–6.09)	(1.96)
(90% CI)	[–1.37 –0.78]	
60–	–0.51***	0.27
(Robust-t)	(–2.59)	(0.87)
(90% CI)	[–0.84 –0.19]	

Note: ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively. Robust-t denotes robust t-statistics. 90% CI denotes 90 percent confidence interval.

is the regression error term. This equation corresponds to the most basic wage Phillips-curve estimation, and we estimate one for each age group. Table 3 shows the regression results of a wage Phillips curve for each age group. The table also shows the robust t-statistics and 90 percent confidence interval. These regression results are used to describe the fitted line in Figure 9. The results indicate that the slope of the coefficient is statistically significant at the 1 percent level for all age groups, and the slope of middle age is the steepest. Moreover, the point estimate of middle age is out of the 90 percent confidence interval of young and old workers.[33]

The second estimation is the pooled regression with age dummy variable written as

$$\pi_{w,t} = \alpha_0 + \alpha_1 unemp_t + \alpha_{2,x} dummy_{x,t} unemp_t + \xi_t. \tag{13}$$

[33]In this estimation of the wage Phillips curve, we use a slightly different age group compared to the VAR analysis. While we maintain the same threshold between young and middle-aged workers, the threshold between middle-aged and older workers is 65 for VAR analysis, whereas it is 60 for wage Phillips-curve estimation. This adjustment is due to the limited availability of wage data for older workers, which results in an insufficient sample size for estimating the wage Phillips curve if we use 65 years as the threshold. Consequently, it becomes infeasible to employ the exact same threshold as in the VAR analysis.

Table 4. Estimation of the Wage Phillips Curve with Dummy Variables

Age	u	u*dmy(20-34)	u*dmy(35-59)	u*dmy(60-)	Intercept
Case 1	–0.74***				0.25***
	(–7.19)				(2.58)
Case 2	–0.75***	0.01			0.25***
	(–4.10)	(0.07)			(2.59)
Case 3	–0.66***		–0.42**		0.26***
	(–6.34)		(–2.14)		(2.64)
Case 4	–0.84***			0.32	0.26***
	(–9.23)			(1.42)	(2.58)
Case 5	–1.08***	0.34*		0.56**	0.26***
	(–6.74)	(1.82)		(2.17)	(2.60)

Note: ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively. Robust t-statistics in parentheses.

Here, $dummy_{x,t}$ corresponds to the dummy variable, which takes a value of 1 at each age group described in Table 4. Table 4 shows the results. It reveals that all the coefficients for unemployment are statistically significant at the 1 percent level. Moreover, the point estimate of unemployment rate times dummy (35–59) is negative, while that with dummy (20–34) and dummy (60–) is positive. More importantly, in case 3, α_2 is statistically significant at the 5 percent level when dummy (35–59) is used; together with that in case 5, α_2 is significantly different from zero when dummy (20–34) and dummy (60–) are used simultaneously. These results confirm that the slope of the wage Phillips curve is the steepest for middle-aged workers, which is consistent with the VAR analysis obtained in the previous section.[34]

7. Conclusion

In this paper, we address the question of which age group of workers' employment, unemployment, and labor force is the most responsive to monetary policy shocks, and try to find the macroeconomic

[34]In addition, the appendix shows the results of estimating the wage Phillips curve in the U.S. We find that the slopes of the wage Phillips curve are similar across ages. This is consistent with the impulse response of the U.S. in the sense that the inflow of labor force does not differ across ages.

implications. Using the block recursive structure of the VAR model as well as monetary policy shocks identified by high-frequency data in Japan, we find that the responses of the number of employed to the shocks are large among young and old workers compared to the middle-aged workers, and the similar observations hold for the number in the labor force. On the other hand, the unemployment rate shows homogeneous impulse responses across all the age groups. These results suggest that there exists an added degree of underutilization of young and old workers before expansionary monetary shocks occur, which, other things being equal in turn, leads to the weak responses of wage inflation following shocks. Indeed, we find that the wage Phillips curve of middle-aged workers is steeper than those of young and old workers.

Appendix. Estimation Using U.S. Data

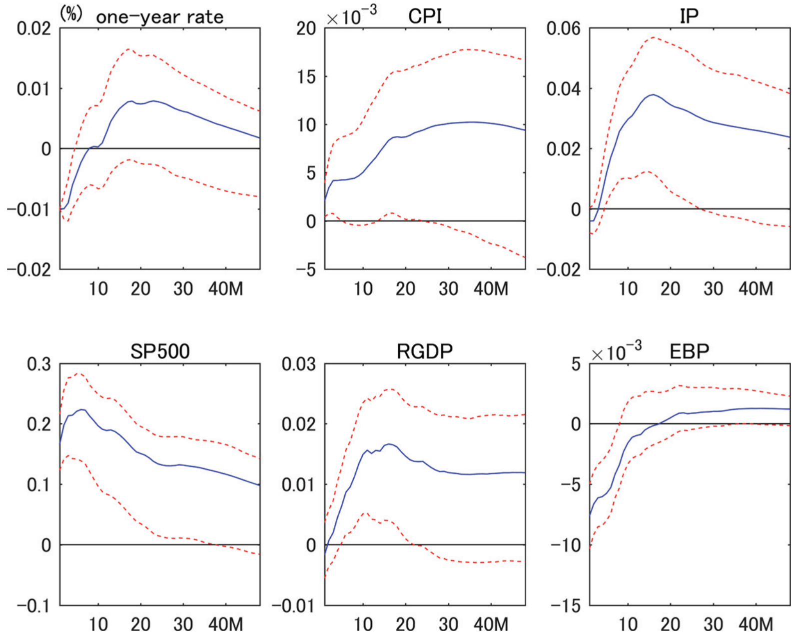
In this appendix, we present empirical results for the U.S., utilizing the same econometric framework as outlined in Section 3.

First, regarding the high-frequency data, which is used as the external instruments, we use the shocks in the three-month-ahead futures rate from Gertler and Karadi (2015). The one-year U.S. government bond rate is used as the policy indicator for the baseline analysis, but using the two-year bond rate gives very similar results. For the macroeconomic variables, we use the CPI, industrial production (IP), Standard and Poor's 500 index (SP500), real gross domestic product (RGDP), and excess bond premium (EBP), which is defined in Gilchrist and Zakrajšek (2012).[35] Regarding the segment variable of employment, we use the Current Population Survey (CPS) for the specific age groups of individuals over 15 years of age and older. The sample period is from 1979:M7 to 2016:M12.[36] The

[35] We use macroeconomic-variables data from Jarociński and Karadi (2020). In this data set, GDP is interpolated monthly following Stock and Watson (2010). Basically, it uses a Kalman filter to distribute the quarterly GDP across months using a data set of monthly variables that are closely related to economic activity. The robust F-statistic when estimating the effects of high-frequency instruments on the first-stage residuals is 12.7, which is above 10. This indicates that the weak instrument problem is not present.

[36] We use the 1979:M7 to 2016:M12 samples for the estimation of VAR coefficients. For the instruments variable, which is used to identify the monetary

Figure A.1. Macroeconomic Variable Responses in the U.S.



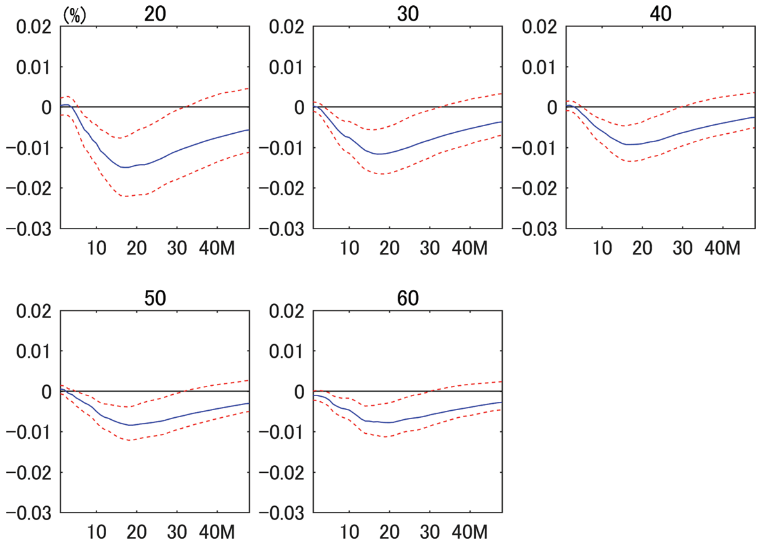
Note: This figure shows the responses of macroeconomic variables to an expansionary monetary policy shock in the U.S. The shock is normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

starting point coincides with the beginning of Paul Volker's tenure as Chairman of the Federal Reserve.

Figure A.1 shows the macroeconomic-variable responses to an expansionary monetary policy shock in the U.S. The shock is normalized so that the one-year bond rate decreases by 1 bp. We can see that in response to an expansionary monetary policy shock, the CPI, IP, and RGDP improve and SP500 rises, while the EBP, which is

policy shocks, we use the available 1991:M1–2012:M6 sample for the baseline two-step regression. We estimate the results excluding 2008:M7–2009:M6, which corresponds to the period of financial turbulence, but the results are very similar to the ones including the financial turbulence period.

Figure A.2. Unemployment Rate Responses in the U.S.

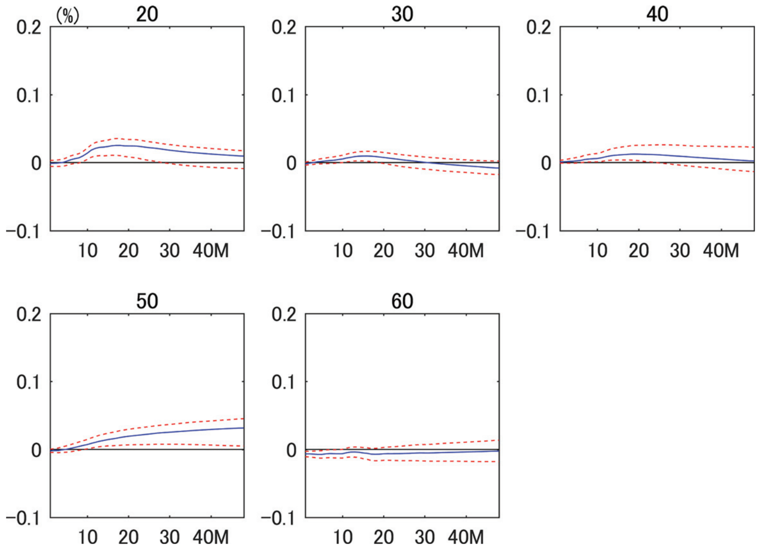


Note: This figure shows the responses of the unemployment rate to an expansionary monetary policy shock at the age given at the top of each graph. The shock is normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

an indicator of credit spreads, falls. The response is consistent with the high-frequency identification VAR analysis using U.S. macroeconomic data such as Gertler and Karadi (2015) and Jarociński and Karadi (2020).

Figure A.2 shows the responses of the unemployment rate to an expansionary monetary policy shock by age (given at the top of each graph). Each graph at age x is estimated using the sample between age $x - 5$ and $x + 5$. Dashed lines show 90 percent confidence intervals. Importantly, the responses of the unemployment rate are homogeneous across ages. On the other hand, Figure A.3 shows the results for the number of employed. The figure shows that the response of the number of employed in the U.S. is large at age 20 and age 50. Compared to these ages, each of the responses at age 30 and age 40 is weaker. Figure A.4 shows the results of labor force response. We can see that each of the responses at age 20 and age 50 is also larger compared to that

Figure A.3. Number of Employed Responses in the U.S.



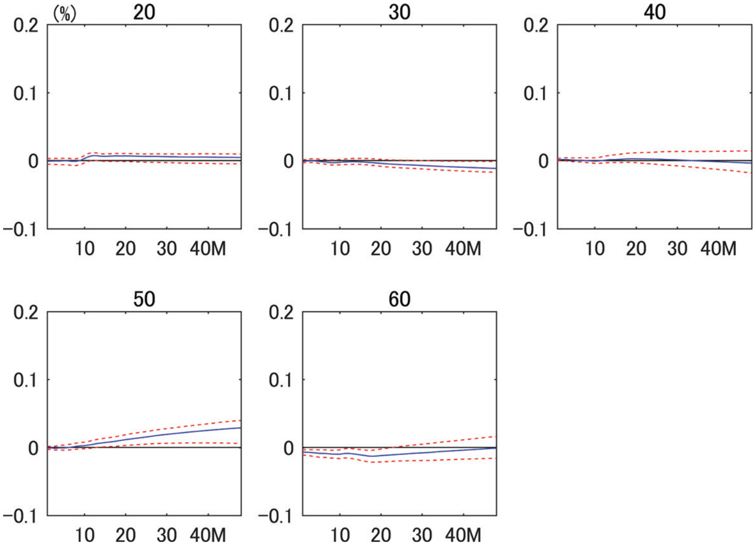
Note: This figure shows the responses of the number of employed to an expansionary monetary policy shock at the age given at the top of each graph. The shock is normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

of the middle-aged, which is similar to the number of employed case.[37]

Compared to the results of the estimation in Japan, we find a similar pattern in the results for the U.S. in two respects. First, the responses of the unemployment rate to a monetary policy shock are homogeneous across the age groups. Second, the number of employed and labor force shows heterogenous responses across ages including

[37]Compared to the empirical results in Japan, in which the response of the number of employed and that of labor force show similar results, the response of labor force in the U.S. is smaller overall than that of employed. This might be because the size of the response of employed is smaller than that in Japan, which means that a decrease in the number of unemployed contributes to an increase in the number of employed. Supporting this view, the response of the labor force is smaller than that of employed between 10 to 20 months after the shock, which corresponds to the period when the response of the unemployment rate is the smallest.

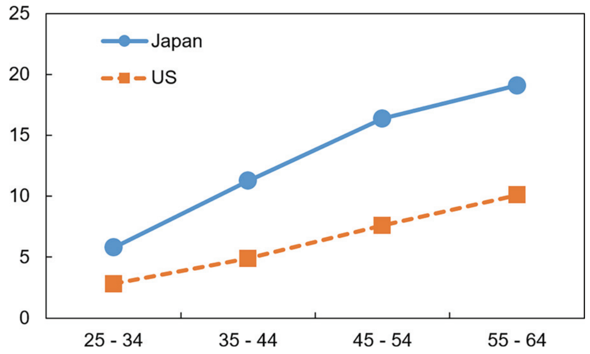
Figure A.4. Labor Force Responses in the U.S.



Note: This figure shows the responses of the labor force to an expansionary monetary policy shock at the age given at the top of each graph. The shock is normalized so that the one-year rate decreases by 1 bp. Dashed lines show 90 percent confidence intervals.

the pronounced increase in the people of their 20s and 50s for the number of employed and in the people of their 50s for the labor force. The difference between Japan and the U.S. is the response of the number of employed for middle-aged workers: a larger response can be observed in the U.S. results. This might arise from the difference in labor market structure between Japan and the U.S. As Owan (2004) points out, labor mobility is lower in Japan than in the U.S. Figure A.5 supports this argument. It shows the years of tenure with the current employer in Japan and the U.S. by age group. Older workers tend to have worked longer in their current job, but the key point is that workers in Japan show longer years of tenure with their current employer. For example, between ages 35 and 44, the job tenure in Japan is about 10 years, while it is 5 years in the U.S. Meanwhile, wages tend to be lower for young and old workers in the U.S. as well, as shown in Figure A.6. For all age groups, job tenure in

Figure A.5. Years of Tenure with Current Employer

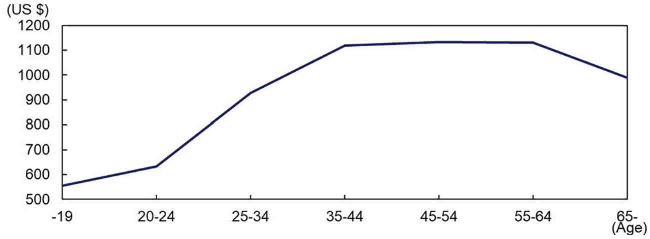


Note: This figure shows the years of tenure with the current employer in Japan and the U.S. for each age group in 2018. Japanese data come from the Ministry of Health, Labour and Welfare. The U.S. data come from the Bureau of Labor Statistics.

Japan is double that in the U.S.[38] Figure A.7 shows the number of job transfers and the job transfer rate by age group in Japan. More specifically, it shows the number of employed persons who changed jobs in the past one year (left axis, ten thousand), and the rate of employed persons who changed jobs in the past one year (right axis, percent). We can see that the youngest age group (between 15 and 24) shows a job transfer rate as high as 12 percent, while for older ages it is low, and above age 35 it is less than 5 percent. In sum, the job market is more liquid in the U.S. than it is in Japan, and the small response of the number of employed for the middle-aged workers to an expansionary monetary policy shock might be attributed to the low labor mobility in Japan, since middle-aged workers have

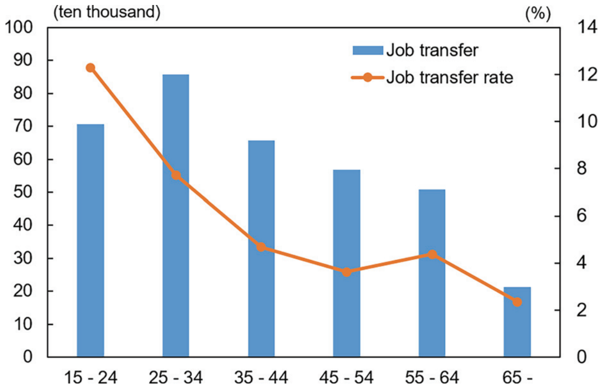
[38] We need to note that the definition of tenure is slightly different between Japan and the U.S. Specifically, in Japan, employee tenure is a measure of how long workers have been with their current employer, while in the U.S. it is a measure of how long wage and salary workers have been with their current employer at the time of the survey. Thus, employee tenure may be shorter in the U.S. However, promotion within the company is not so common in the U.S. compared to Japan, and thus this difference of definition might not significantly change the results.

Figure A.6. Weekly Earnings by Age in the U.S.



Note: This figure shows the median weekly earnings in 2021 in the U.S. The data come from the U.S. Bureau of Labor Statistics.

Figure A.7. Job Transfer Rate in Japan



Note: This figure shows the employed persons who changed jobs in the past one year (left axis, ten thousand), and the rate of employed persons who changed jobs in the past one year (right axis, percent). The data come from the Labor Force Survey.

relatively fewer job vacancy opportunities even if business conditions improve.

We estimate the wage Phillips curve for each age group of workers in the U.S. The unemployment data come from the Current Population Survey (CPS). The wage data come from the median usual

Table A.1. Wage Phillips Curve in the U.S.

Age	Unemployment Rate	Intercept
20	–0.11*	0.75***
(Robust-t)	(–1.71)	(3.81)
30	–0.16***	0.69***
(Robust-t)	(–4.54)	(10.59)
40	–0.11***	0.68***
(Robust-t)	(–3.82)	(14.36)
50	–0.10**	0.62***
(Robust-t)	(–2.62)	(10.84)

Note: ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively. Robust-t denotes robust t-statistics.

weekly earnings full-time wage.[39] The sample period is from 1996 to 2019.[40]

In order to check the statistical significance, we use two regression equations, the same as the regression in the main text. The first one is the simple regression,

$$\pi_{w,t} = \alpha_0 + \alpha_1 unemp_t + \xi_t, \tag{A.1}$$

where $\pi_{w,t}$ is the wage inflation rate and $unemp_t$ is the unemployment rate. The α terms represent the regression coefficient, and ξ_t is the regression error term. Table A.1 shows the regression results for the wage Phillips curve of each age group. The results indicate that the slope is similar across the ages.

The second estimation is the pooled regression with the age dummy variables,

$$\pi_{w,t} = \alpha_0 + \alpha_1 unemp_t + \alpha_{2,x} dummy_{x,t} unemp_t + \xi_t, \tag{A.2}$$

[39]Galí (2011) uses the average hourly earnings from the Establishment Survey, which is from the company data. On the other hand, we need the age information and use the data from the household side.

[40]To estimate the slope of the wage Phillips curve at age x, we use the age from $x - 5$ to $x + 4$.

Table A.2. Estimation of the Wage Phillips Curve with Dummy Variables in the U.S.

Age	u	u*dmy20	u*dmy30	u*dmy40	u*dmy50	Intercept
Case 1	–0.12**	0.01				0.71***
	(–2.42)	(0.10)				(8.61)
Case 2	–0.11**		–0.05			0.71***
	(–2.08)		(–0.48)			(8.61)
Case 3	–0.11***			0.00		0.71***
	(–3.29)			(0.00)		(8.61)
Case 4	–0.11***				0.01	0.71***
	(–2.26)				(0.12)	(8.61)

Note: ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent level, respectively. Robust t-statistics in parentheses.

where $dummy_{x,t}$ takes a value of 1 at age x.[41] For this regression, we use the sample between ages 16 and 54. Table A.2 shows the results. These show that none of the coefficients of the dummy variables is statistically significant. The results are consistent with the impulse response described in the main text. Namely, the impulse responses of the labor force in the U.S. are heterogeneous, but the differences between ages are not so distinctive compared to the results in Japan. Thus, the slope of the wage Phillips curve does not change with age in the U.S. regression.

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[41]Strictly speaking, the dummy variable takes a value of 1 when the data are from age $x - 5$ to $x + 4$.

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