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Monopsonistic Wage-setting and Monetary Policy*

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Abstract

Research in labor economics has documented evidence of labor market monopsony. Nevertheless, macroeconomic studies routinely consider households' wage-setting under monopolistic competition. We introduce *firms'* wage-setting under *monopsonistic* competition in an otherwise standard sticky-price model. This substantially alters the implications for wage dynamics, welfare, and policy. Compared to its counterpart model with monopolistic wage-setting, our model indicates that the wage Phillips curve includes the wage markdown as its main driver and has a steeper slope generated by *strategic substitutability* in wage-setting, and that the second-order approximation to households' utility functions is of the same form but with a smaller welfare weight on wage growth variability. Consequently, a welfare-maximizing policy features stabilizing inflation rather than wage growth.

JEL Classification: E24, E52, J42

Keywords: Labor market monopsony, Wage markdown, Strategic substitutability, Staggered wage-setting, Timeless-perspective policy, Inflation stabilization

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1 Introduction

Research in labor economics has documented evidence of monopsony power in labor markets.[1] With such power, firms facing workers' upward-sloping labor supply curves can reduce their wages below their marginal product of labor. Staiger et al. (2010), for example, show evidence that labor supply is inelastic, Yeh et al. (2022) present estimates of substantial markdowns of wages from the marginal product of labor, and Benmelech et al. (2022) provide evidence that employer concentration lowers wages. In light of the evidence, Langella and Manning (2021) observe that research interest has shifted from documenting the presence of monopsony power in labor markets to analyzing its consequences. Nevertheless, many macroeconomic studies routinely assume wage-setting by households under monopolistic competition. Since the analogy made by Erceg et al. (2000) with the monopolistic price-setting of Calvo (1983), monopolistic wage-setting has been used in seminal work by Christiano et al. (2005) and Smets and Wouters (2007) and presented in graduate macroeconomics textbooks, such as Galí (2015), Walsh (2017), and Woodford (2003).

In this paper we introduce wage-setting by *firms* under *monopsonistic* competition in an otherwise standard sticky-price model and compare the model to its counterpart model with monopolistic wage-setting of the sort developed by Erceg et al. (2000).[2] An implication of monopsonistic wage-setting for wage (growth) dynamics is that the main driver of the wage Phillips curve is the wage markdown (i.e., the gap between the real wage and the marginal product of labor) in our model, in contrast to the wage markup (i.e., the gap between the real wage and the marginal rate of substitution between consumption and labor) in the counterpart model. Moreover, in the latter model a finite elasticity of households' supply of differentiated labor generates strategic complementarity in households' wage-setting and hence real rigidity in relative wages, while in our model a CES aggregator of households' supply of differentiated labor used in, for example, Berger et al. (2022) gives rise to *strategic substitutability* in firms' wage-setting and thus partially offsets nominal wage rigidity

[1] See, e.g., Manning (2021), Card (2022), and Azar and Marinescu (2024) for reviews of the literature.

[2] To model labor market monopsony, our paper takes a similar approach to, for example, Bhaskar et al. (2002) and Berger et al. (2022), who consider heterogeneity in workers' preferences for jobs. Another modeling approach involves search frictions in labor markets (e.g., Burdett and Mortensen, 1998; Postel-Vinay and Robin, 2002). Trottner (2025) demonstrates an equivalence between the two approaches.

induced by staggered wage-setting. As a consequence, the slope on the main driver of the wage Phillips curve is steeper than that in the counterpart model. Thus, in wage-setting, monopolistic competition causes households to respond conservatively to the wage markup, whereas monopsonistic competition induces firms to respond aggressively to the wage markdown.

We investigate the welfare implications of monopsonistic wage-setting by deriving a welfare function of the model economy as a second-order approximation to a representative household's utility function. Compared to the counterpart model with monopolistic wage-setting, the welfare function in our model is of the same form, consisting of variability of inflation, wage growth, and the output gap, but with a distinct weight on wage growth variability depending inversely on the slope of the wage Phillips curve. As a consequence, the steeper slope of the wage Phillips curve implies a smaller welfare weight on wage growth variability than that in the counterpart model. This inverse relationship between the Phillips curve slope and the corresponding welfare weight is in line with the relationships shown in Erceg et al. (2000) and the graduate macroeconomics textbooks.

We use the welfare function to examine the implications of monopsonistic wage-setting for monetary policy. Our model shows that a welfare-maximizing policy—the timeless-perspective policy advocated by Woodford (1999)—features inflation stabilization and that stabilizing inflation is a better policy strategy than stabilizing wage growth, in contrast to the features of the welfare-maximizing policy with monopolistic wage-setting demonstrated by Erceg et al. (2000). In models with sticky prices and nominal wages, the adjustments of real wages to shocks inevitably entail a welfare cost because prices, nominal wages, or both have to adjust subject to their rigidities. In the counterpart model with monopolistic wage-setting, real wages adjust preferably through a change in prices rather than a change in nominal wages in response to shocks that alter the natural rate of the real wage, that is, the real wage that would prevail under flexible prices and nominal wages. Thus, the welfare-maximizing policy features wage growth stabilization. In our model with monopsonistic wage-setting, by contrast, real wages adjust preferably through a change in nominal wages. Therefore, the welfare-maximizing policy features inflation stabilization. These distinct policy implications can be ascribed to the smaller weight on wage growth variability of the welfare function in our model, which reduces the welfare loss incurred by that variability. In this way, accounting for monopsony power in labor markets aligns the policy implications of sticky prices and nominal wages with the mandates of actual central banks for price stability or inflation stabilization rather than wage growth stabilization.

In related literature, our results are fundamentally consistent with those of Aoki (2001). That paper analyzes welfare and policy implications in a model with two types of goods, one with flexible prices and the other with sticky prices, and finds that variability of the inflation rate of sticky prices induces a welfare loss and thus stabilizing such an inflation rate is a desirable policy strategy. Aoki's (2001) findings imply that variability of either the inflation rate of prices or the growth rate of wages with higher total rigidity—which is the sum of nominal and real rigidities and can be measured by the size of the slope of a price or wage Phillips curve—generates a larger welfare loss than that with lower total rigidity. Therefore, stabilizing the inflation or wage growth rate with higher total rigidity is a more desirable policy strategy than stabilizing either of those rates with lower total rigidity. In our model with monopsonistic wage-setting, the total rigidity of prices is higher than that of wages and therefore a welfare-maximizing policy features inflation stabilization. By contrast, in the counterpart model with monopolistic wage-setting, the reverse holds: the total rigidity of wages is higher than that of prices and thus a welfare-maximizing policy conditional on productivity and preference shocks features wage growth stabilization, in line with the result of Erceg et al. (2000).[3] Galí (2011) conducts an analysis closely related to ours. The paper develops a model with staggered price- and wage-setting, unemployment, and labor force participation, which is based on labor market search and wage bargaining between workers and firms, and examines a welfare-maximizing policy conditional only on technology shocks. Labor market frictions that give rise to unemployment and nonparticipation in the model lead wage growth variability to induce a lower welfare cost than inflation variability when both workers and firms have equal bargaining power. The welfare-maximizing policy is then well characterized by an interest-rate feedback rule that puts weight on inflation stabilization but not on wage growth stabilization.

The remainder of the paper proceeds as follows. Section 2 introduces firms' monopsonistic wage-setting in an otherwise standard sticky-price model and derives a wage Phillips

[3]For wage markup shocks that directly affect wage growth, we find that a welfare-maximizing policy features inflation stabilization.

curve to analyze the implications for wage dynamics. Section 3 investigates policy trade-offs by deriving a welfare function. Section 4 parameterizes the model. Section 5 examines a welfare-maximizing policy. Section 6 concludes. Throughout the paper, the implications of monopsonistic wage-setting are compared to those of monopolistic wage-setting.

2 Model

In this section we introduce firms' wage-setting under monopsonistic competition in an otherwise standard sticky-price model. Economic agents in the model are a representative household with its members (i.e., workers), a representative wholesale firm, retail firms, a representative composite-good-producing firm, and a monetary authority. A notable feature of the model is that the household provides an aggregate of all members' supply of differentiated labor for the wholesale firm, which sets their individual wages subject to their labor supply curves and produces its output using the aggregate labor supply. Retail firms then produce differentiated goods from the output and set their product prices subject to the composite-good-producing firm's demand curves. The remaining part of the model is standard in the literature. The behavior of each economic agent is described in what follows.

2.1 Households

The representative household has a large number of members $m \in [0, 1]$. The household's preferences over composite-good consumption C_t and its members' labor supply $\{l_t(m)\}$ are represented as the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t \exp \varepsilon_{c,t} - \int_0^1 \frac{1}{1+\frac{1}{\chi}} \left(l_t(m)\right)^{1+\frac{1}{\chi}} dm \right), \tag{1}$$

where E_t is the expectation operator conditional on information available in period t, $\varepsilon_{c,t}$ is a shock to consumption preferences, $\beta \in (0, 1)$ is the subjective discount factor, and $\chi > 0$ is the elasticity of each household member's labor supply. The household purchases one-period (riskless) bonds B_t and its budget constraint is

$$P_t\,C_t + B_t = \int_0^1 P_t W_t(m)\,l_t(m)\,dm + r_{t-1}\,B_{t-1} + T_t\,, \tag{2}$$

where P_t is the price of composite goods, r_t is the interest rate on the bonds and is assumed to coincide with the monetary policy rate, $W_t(m)$ is household member m's real wage, and T_t consists of lump-sum taxes and transfers as well as firms' profits received.

The household chooses composite-good consumption C_t, its members' labor supply $\{l_t(m)\}$, and bond holdings B_t so as to maximize the utility function (1) subject to the budget constraint (2). In the presence of complete contingent claims for consumption, the first-order conditions for utility maximization lead to

$$\Lambda_t = \frac{\exp \varepsilon_{c,t}}{C_t}, \tag{3}$$

$$1 = E_t\left(\frac{\beta\,\Lambda_{t+1}}{\Lambda_t}\frac{r_t}{\pi_{t+1}}\right), \tag{4}$$

$$l_t(m) = (\Lambda_t\,W_t(m))^{\chi} \quad \forall m \in [0,1]\,, \tag{5}$$

where Λ_t is the marginal utility of consumption and $\pi_t = P_t/P_{t-1}$ is the inflation rate of the composite goods' price. Eq. (5) describes each household member's labor supply curve.

The household provides wholesale firms with an aggregate of all members' supply of differentiated labor $\{l_t(m)\}$. Aggregate labor supply is of the form used in, for example, Berger et al. (2022):

$$l_t = \left[\int_0^1 (l_t(m))^{\frac{1+\theta_{wd}}{\theta_{wd}}}\,dm\right]^{\frac{\theta_{wd}}{1+\theta_{wd}}}, \tag{6}$$

where $\theta_{wd} > 0$ denotes the (negative of the) elasticity of substitution between household members' labor supply (i.e., $d\log\left(l_t(m')/l_t(m)\right)/d\log\left(W_t(m)/W_t(m')\right) = -\theta_{wd}$) and shows that an increase in the relative wage of a household member leads to a decrease in another member's relative labor supply.[4] This labor supply aggregator implies an aggregate wage index

$$P_t W_t = \left[\int_0^1 (P_t W_t(m))^{1+\theta_{wd}}\,dm\right]^{\frac{1}{1+\theta_{wd}}}, \tag{7}$$

which leads to $P_t W_t\,l_t = \int_0^1 P_t W_t(m)\,l_t(m)\,dm$. The marginal contribution of individual labor

[4] The aggregator (6) yields each member's relative labor supply curve $l_t(m)/l_t = [(P_t W_t(m))/(P_t W_t)]^{\theta_{wd}}$.

to aggregate labor l_t increases with individual labor supply $l_t(m)$, as

$$\frac{d\log\left(dl_t/dl_t(m)\right)}{d\log\left(l_t(m)/l_t\right)} = \frac{1}{\theta_{wd}} > 0.$$

Thus, the labor supply aggregator (6) can be viewed as succinctly capturing the notion that high earners not only work longer hours—following their individual labor supply curves—but are also more productive than low earners—by contributing more to the aggregate labor supply. Kuhn and Lozano (2008) document for the US labor market that the top 20 percent of earners were twice as likely to work at least 50 hours per week as the bottom 20 percent in 2006, and such long hours were much more common for college graduates (who are relatively more productive) than for less educated workers (who are less productive). The productivity gain associated with paying a worker more, embedded in the labor supply aggregator (6), gives rise to strategic substitutability in wholesale firms' wage-setting, as shown later.

2.2 Wholesale firms

A representative wholesale firm produces output $Y_{w,t}$ using the technology

$$Y_{w,t} = \left(A_t \exp \varepsilon_{a,t}\right) l_t^{\alpha}, \tag{8}$$

where $A_t \exp \varepsilon_{a,t}$ represents the (economy-wide) productivity level, its deterministic component A_t is governed by

$$\log A_t = \log g + \log A_{t-1}, \tag{9}$$

the stochastic component $\varepsilon_{a,t}$ denotes a productivity shock, and $\alpha \in (0,1]$ is the labor elasticity of production.

The wholesale firm's profit is represented as

$$E_0 \sum_{t=0}^{\infty} Q_{0,t} \left(P_t mc_t \, Y_{w,t} - \int_0^1 \left(1-\tau_{wd}\right) P_t W_t(m) \, l_t(m) \exp \tilde{\varepsilon}_{wd,t} \, dm \right),$$

where $Q_{t,t+j}$ is the (nominal) stochastic discount factor between period t and period $t+j$, $P_t mc_t$ denotes wholesale goods' price, $\tilde{\varepsilon}_{wd,t}$ is a shock to the wage markdown explained later, and $\tau_{wd} \in [0,1)$ denotes a subsidy for the wholesale firm's payment for each worker's wage.

Given the output price $P_t mc_t$, the wholesale firm sets individual workers' wages $\{P_t W_t(m)\}$ on a staggered basis as in Calvo (1983). In each period, a fraction $\xi_w \in (0,1)$ of wages are indexed to the steady-state rate π_w of the aggregate wage growth rate

$$\pi_{w,t} \equiv \frac{P_t W_t}{P_{t-1} W_{t-1}} = \pi_t \, \frac{W_t}{W_{t-1}} \, , \tag{10}$$

while the remaining fraction is set identically so as to maximize relevant profit

$$E_t \sum_{j=0}^{\infty} \xi_w^j \, Q_{t,t+j} \left(P_{t+j} mc_{t+j} \, Y_{w,t+j} - (1-\tau_{wd}) \, P_t W_t(m) \pi_w^j \, l_{t+j|t}(m) \exp \tilde{\varepsilon}_{wd,t+j} \right)$$

subject to the production technology (8), the labor supply aggregator (6), and the individual labor supply curve

$$l_{t+j|t}(m) = \left(\Lambda_{t+j} \, \frac{P_t W_t(m) \pi_w^j}{P_{t+j}} \right)^{\chi} .$$

By defining the marginal product of labor as

$$MPL_t \equiv \alpha \, mc_t \, \left(A_t \exp \varepsilon_{a,t} \right) l_t^{\alpha-1} = \alpha \, mc_t \, \frac{Y_{w,t}}{l_t} \tag{11}$$

and the marginal rate of substitution between consumption and labor as

$$MRS_t \equiv \frac{l_t^{\frac{1}{\chi}}}{\Lambda_t}, \tag{12}$$

the first-order condition for wages is written as

$$\begin{aligned} 0 = E_t \sum_{j=0}^{\infty} \left(\beta \xi_w \right)^j \Lambda_{t+j} l_{t+j|t}(m) \exp \tilde{\varepsilon}_{wd,t+j} \Bigg[w_t^* \prod_{k=1}^{j} \frac{\pi_w}{\pi_{t+k}} - \frac{\mu_{wd} \exp(-\tilde{\varepsilon}_{wd,t+j})}{1-\tau_{wd}} \, \frac{MPL_{t+j}}{W_{t+j}} \\ \times \left(\frac{W_{t+j}}{MRS_{t+j}} \, w_t^* \prod_{k=1}^{j} \frac{\pi_w}{\pi_{w,t+k}} \right)^{\frac{\chi}{\theta_{wd}}} \prod_{k=1}^{j} \frac{W_{t+k}}{W_{t+k-1}} \Bigg], \end{aligned} \tag{13}$$

where the equilibrium condition for the discount factor $Q_{t,t+j} = (\beta^j \Lambda_{t+j}/\Lambda_t)(P_t/P_{t+j})$ is used, $w_t^* \equiv W_t^*/W_t$, W_t^* is the real wage optimized by the wholesale firm in period t, and $\mu_{wd} \equiv \chi/(1+\chi)$ is the steady-state wage markdown. It is worth noting that if all wages are flexible (i.e., $\xi_w = 0$), the first-order condition (13) can be reduced to

$$w_t^* = \left[\frac{\mu_{wd} \exp(-\tilde{\varepsilon}_{wd,t})}{1-\tau_{wd}} \frac{MPL_t}{W_t} \left(\frac{W_t}{MRS_t} \right)^{\frac{\chi}{\theta_{wd}}} \right]^{\frac{1}{1-\chi/\theta_{wd}}},$$

where the term $1/(1-\chi/\theta_{wd})$ represents strategic substitutability in the wholesale firm's wage-setting, which is caused by the productivity gain from the increasing individual labor supply observed in the labor supply aggregator $1/\theta_{wd}$, as noted above, along with the elasticity of individual labor supply χ.

Under staggered wage-setting, the aggregate wage (7) can be rewritten as

$$1 = \xi_w \left(\frac{\pi_w}{\pi_{w,t}} \right)^{1+\theta_{wd}} + (1-\xi_w)(w_t^*)^{1+\theta_{wd}}. \tag{14}$$

Using the individual labor supply curves (5) and the marginal rate of substitution (12), the aggregate labor supply (6) can also be rewritten as

$$\left(\frac{MRS_t}{W_t} \right)^{\frac{\chi(1+\theta_{wd})}{\theta_{wd}}} = \xi_w \left(\frac{MRS_{t-1}}{W_{t-1}} \frac{\pi_w}{\pi_{w,t}} \right)^{\frac{\chi(1+\theta_{wd})}{\theta_{wd}}} + (1-\xi_w)(w_t^*)^{\frac{\chi(1+\theta_{wd})}{\theta_w}}. \tag{15}$$

Eqs. (13)–(15) imply that if all wages are flexible (i.e., $\xi_w = 0$), then we have

$$\frac{W_t}{MPL_t} = \frac{\mu_{wd} \exp(-\tilde{\varepsilon}_{w,t})}{1-\tau_{wd}},$$

so a positive wage markdown shock $\tilde{\varepsilon}_{w,t}$ indeed increases the markdown of wages from the marginal product of labor.

2.3 Composite-good-producing firms

A representative composite-good-producing firm combines individual differentiated goods $\{Y_t(f)\}$ supplied by a continuum of retail firms $f \in [0,1]$ to produce its output Y_t using the aggregation technology $Y_t = \left[\int_0^1 (Y_t(f))^{(\theta_p-1)/\theta_p} df \right]^{\theta_p/(\theta_p-1)}$, where $\theta_p > 1$ represents the elasticity of substitution between the composite-good-producing firm's demand for individual goods. The firm maximizes profit $P_t Y_t - \int_0^1 P_t(f) Y_t(f) df$ subject to the technology, given composite goods' price P_t and individual goods' prices $\{P_t(f)\}$. The first-order condition for profit maximization yields the firm's demand curve for each individual good

$$Y_t(f) = Y_t \left(\frac{P_t(f)}{P_t} \right)^{-\theta_p}, \tag{16}$$

and thus the technology or, equivalently, the goods demand aggregator leads to composite goods' price

$$P_t = \left[\int_0^1 \left(P_t(f) \right)^{1-\theta_p} df \right]^{\frac{1}{1-\theta_p}}. \tag{17}$$

The output of the firm is equal to the household's consumption demand:

$$Y_t = C_t \,. \tag{18}$$

2.4 Retail firms

Each retail firm $f \in [0, 1]$ produces an individual differentiated good $\{Y_t(f)\}$ from wholesale goods and sets its product price $P_t(f)$ on a staggered basis as in Calvo (1983), given the composite-good-producing firm's demand curve (16) and wholesale goods' price $P_t mc_t$.

In each period, a fraction $\xi_p \in (0, 1)$ of retail firms index their product prices to the steady-state inflation rate π, while the remaining fraction identically sets the price $P_t(f)$ so as to maximize relevant profit

$$E_t \sum_{j=0}^{\infty} \xi_p^j \, Q_{t,t+j} \big((1 + \tau_p) P_t(f) \pi^j - P_{t+j} mc_{t+j} \big) \, Y_{t+j} \left(\frac{P_t(f) \pi^j}{P_{t+j}} \right)^{-\theta_p},$$

where $\tau_p \in [0, 1)$ is a subsidy for each retail firm's output of a differentiated good.

The first-order condition for profit maximization is written as

$$0 = E_t \sum_{j=0}^{\infty} (\beta \xi_p)^j \, \Lambda_{t+j} Y_{t+j} \left(p_t^* \prod_{k=1}^{j} \frac{\pi}{\pi_{t+k}} \right)^{-\theta_p} \left(p_t^* \prod_{k=1}^{j} \frac{\pi}{\pi_{t+k}} - \frac{\mu_p}{1 + \tau_p} mc_{t+j} \right), \tag{19}$$

where $p_t^* \equiv P_t^* / P_t$, P_t^* is the price optimized by retail firms in period t, and $\mu_p \equiv \theta_p / (\theta_p - 1)$ is the steady-state price markup. Under staggered price-setting, eq. (17) can be rewritten as

$$1 = \xi_p \left(\frac{\pi}{\pi_t} \right)^{1-\theta_p} + (1 - \xi_p) (p_t^*)^{1-\theta_p}. \tag{20}$$

The output of the wholesale firm is equal to the sum of retail firms' demand:

$$Y_{w,t} = \int_0^1 Y_t(f)\, df = Y_t \Delta_t \,, \tag{21}$$

where Δ_t represents the relative price distortion:

$$\Delta_t \equiv \int_0^1 \left(\frac{P_t(f)}{P_t} \right)^{-\theta_p} df \,,$$

which evolves under staggered price-setting as

$$\Delta_t = \xi_p \, \Delta_{t-1} \left(\frac{\pi}{\pi_t} \right)^{-\theta_p} + (1-\xi_p)(p_t^*)^{-\theta_p} \,. \tag{22}$$

2.5 Monetary authority

The monetary authority adjusts its policy rate in response to inflation, wage growth, and the output gap. Specifically, the policy rate is set according to a rule of the sort proposed by Taylor (1993):

$$\log r_t = \log r + \phi_p(\log \pi_t - \log \pi) + \phi_w(\log \pi_{w,t} - \log \pi_w) + \phi_y(\log Y_t - \log Y_t^n) + \varepsilon_{r,t} \,, \tag{23}$$

where Y_t^n is the natural rate of output that would prevail in the absence of price and nominal wage rigidities (i.e., $\xi_p = \xi_w = 0$) and the wage markdown shock $\varepsilon_{wd,t}$, given by

$$Y_t^n = (A_t \exp \varepsilon_{a,t}) \, (\alpha \exp \varepsilon_{c,t})^{\frac{\alpha}{1+1/\chi}} \,, \tag{24}$$

r is the steady-state policy rate, $\varepsilon_{r,t}$ is a monetary policy shock, and ϕ_p, ϕ_w, ϕ_y are the degrees of monetary policy responses to inflation, wage growth, and the output gap, respectively.

2.6 Equilibrium conditions

The equilibrium conditions of the model consist of eqs. (3), (4), (8)–(15), (18)–(23), and (24), along with stationary processes of the four shocks $\varepsilon_{c,t}$, $\varepsilon_{a,t}$, $\tilde{\varepsilon}_{wd,t}$, and $\varepsilon_{r,t}$. We consider an efficient steady state and thus assume that the subsidies cancel out the steady-state wage markdown and price markup, that is, $\tau_{wd} = 1 - \mu_{wd}$ and $\tau_p = \mu_p - 1$. Then, the equilibrium conditions are detrended using the productivity level A_t and are log-linearized around the efficient steady state.

In the log-linearized equilibrium conditions, aggregate labor $\hat{l}_t$ is determined to meet the labor supply condition

$$\hat{w}_t = \hat{mrs}_t \,, \tag{25}$$

while the aggregate wage growth rate $\hat{\pi}_{w,t}$ is determined according to the wage Phillips curve

$$\hat{\pi}_{w,t} = \beta\, E_t \hat{\pi}_{w,t+1} - \kappa_{wd}\, \hat{\mu}_{wd,t} - \varepsilon_{wd,t} \,, \tag{26}$$

where hatted variables denote log-deviations from steady-state values, $\mu_{wd,t}$ is the wage markdown, $\varepsilon_{wd,t} \equiv \kappa_{wd}\, \tilde{\varepsilon}_{wd,t}$ is a rescaled shock to the markdown, and the slope is $\kappa_{wd} \equiv (1 - \xi_w)(1 - \beta\xi_w)/[\xi_w(1 - \chi/\theta_{wd})]$. This wage Phillips curve is novel in the literature in the following two points. First, wage growth is driven by the wage markdown, that is, the gap between the real wage and the marginal product of labor:

$$\hat{\mu}_{wd,t} = \hat{w}_t - \hat{mpl}_t \,. \tag{27}$$

Second, in the slope κ_{wd}, the term $1/(1 - \chi/\theta_{wd})$ represents strategic substitutability in the wholesale firm's wage-setting as noted above and thus partially offsets nominal wage rigidity captured by the term $(1 - \xi_w)(1 - \beta\xi_w)/\xi_w$. The substitutability implies that when the wholesale firm raises wages by one unit in response to a decrease in the wage markdown, workers increase individual labor supply $l_t(m)$ by χ and thus the aggregate labor supply l_t increases by χ/θ_{wd}, which in turn incentivizes the firm to further raise wages. Therefore, given the condition $\chi < \theta_{wd}$, the larger the productivity gain from increasing the individual labor supply observed in the labor supply aggregator $1/\theta_{wd}$ or the elasticity of the individual labor supply χ is, the more aggressively the wholesale firm responds to the wage markdown in wage-setting.

The remaining log-linearized equilibrium conditions are standard in the literature:

$$\hat{\lambda}_t = \, - \hat{y}_t + \varepsilon_{c,t} \,, \tag{28}$$

$$\hat{\lambda}_t - E_t\hat{\lambda}_{t+1} = \hat{r}_t - E_t\hat{\pi}_{t+1}\,, \tag{29}$$

$$\hat{mrs}_t = \frac{1}{\chi}\,\hat{l}_t - \hat{\lambda}_t\,, \tag{30}$$

$$\hat{y}_t = \alpha\,\hat{l}_t + \varepsilon_{a,t}\,, \tag{31}$$

$$\hat{mpl}_t = \hat{mc}_t + \hat{y}_t - \hat{l}_t\,, \tag{32}$$

$$\hat{\pi}_t = \beta\,E_t\hat{\pi}_{t+1} - \kappa_p\,\hat{\mu}_{p,t}\,, \tag{33}$$

$$\hat{\mu}_{p,t} = \,-\,\hat{mc}_t\,, \tag{34}$$

$$\hat{\pi}_{w,t} = \hat{\pi}_t + \hat{w}_t - \hat{w}_{t-1}\,, \tag{35}$$

$$\hat{y}^n_t = \frac{\alpha}{1+1/\chi}\,\varepsilon_{c,t} + \varepsilon_{a,t}\,, \tag{36}$$

$$\hat{r}_t = \phi_p\,\hat{\pi}_t + \phi_w\,\hat{\pi}_{w,t} + \phi_y\,(\hat{y}_t - \hat{y}^n_t) + \varepsilon_{r,t}\,, \tag{37}$$

where $\mu_{p,t}$ is the price markup and the slope of the price Phillips curve (33) is $\kappa_p \equiv (1-\xi_p)(1-\beta\xi_p)/\xi_p$.

2.7 Counterpart model with monopolistic wage-setting

In a counterpart model with monopolistic wage-setting of the sort developed by Erceg et al. (2000), a representative household sets its members' wages subject to a representative wholesale firm's demand curves for their labor, while the firm produces its output using an aggregate of its demand for all individual differentiated labor $\{l_t(m)\}$:

$$l_t = \left[\int_0^1 (l_t(m))^{\frac{1-\theta_{wu}}{\theta_{wu}}}\,dm\right]^{\frac{\theta_{wu}}{1-\theta_{wu}}}\,, \tag{38}$$

where $\theta_{wu} > 1$ denotes the elasticity of substitution between the firm's demand for individual differentiated labor and also represents the (negative of the) elasticity of labor demand. This aggregator leads to the firm's demand curve for each individual labor $l_t(m) = l_t\,[(P_tW_t(m))/(P_tW_t)]^{-\theta_{wu}}$ and hence an aggregate wage index

$$P_tW_t = \left[\int_0^1 (P_tW_t(m))^{1-\theta_{wu}}\,dm\right]^{\frac{1}{1-\theta_{wu}}}.$$

The household sets its members' wages $\{P_tW_t(m)\}$ on a staggered basis as in Calvo

(1983): in each period, a fraction $\xi_w \in (0,1)$ of wages are indexed to the steady-state wage growth rate π_w, while the remaining fraction is chosen identically so as to maximize relevant utility

$$E_t \sum_{j=0}^{\infty} (\beta \xi_w)^j \left[-\frac{1}{1+\frac{1}{\chi}} \left(l_{t+j|t}(m) \right)^{1+\frac{1}{\chi}} + \frac{\Lambda_{t+j}}{P_{t+j}} (1+\tau_{wu})\, P_t W_t(m) \pi_w^j\, l_{t+j|t}(m) \exp(-\tilde{\varepsilon}_{wu,t+j}) \right]$$

subject to the wholesale firm's labor demand curve

$$l_{t+j|t}(m) = l_{t+j} \left(\frac{P_t W_t(m) \pi_w^j}{P_{t+j} W_{t+j}} \right)^{-\theta_{wu}},$$

where $\tau_{wu} \in [0,1)$ is a subsidy for each household member's labor supply and $\tilde{\varepsilon}_{wu,t}$ is a wage markup shock.

In the equilibrium conditions of the counterpart model, the following three equations are included instead of eqs. (13)–(15):

$$\begin{aligned}
0 &= E_t \sum_{j=0}^{\infty} (\beta \xi_w)^j\, \Lambda_{t+j} l_{t+j|t}(m) \exp\left(-\tilde{\varepsilon}_{wu,t+j}\right) \left[w_t^* \prod_{k=1}^{j} \frac{\pi_w}{\pi_{t+k}} - \frac{\mu_{wu} \exp \tilde{\varepsilon}_{wu,t+j}}{1+\tau_{wu}} \frac{MRS_{t+j}}{W_{t+j}} \right. \\
&\quad \left. \times \left(w_t^* \prod_{k=1}^{j} \frac{\pi_w}{\pi_{w,t+k}} \right)^{-\frac{\theta_{wu}}{\chi}} \prod_{k=1}^{j} \frac{W_{t+k}}{W_{t+k-1}} \right], \qquad (39) \\
1 &= \xi_w \left(\frac{\pi_w}{\pi_{w,t}} \right)^{1-\theta_{wu}} + (1-\xi_w) (w_t^*)^{1-\theta_{wu}}, \qquad (40) \\
W_t &= MPL_t, \qquad (41)
\end{aligned}$$

where $\mu_{wu} = \theta_{wu}/(\theta_{wu}-1)$ is the steady-state wage markup. We assume $\tau_{wu} = \mu_{wu} - 1$ to cancel out the steady-state wage markup and consider an efficient steady state of the model. Note that if all wages are flexible (i.e., $\xi_w = 0$), the first-order condition (39) can be reduced to

$$w_t^* = \left(\frac{\mu_{wu} \exp \tilde{\varepsilon}_{wu,t}}{1+\tau_{wu}} \frac{MRS_t}{W_t} \right)^{\frac{1}{1+\theta_{wu}/\chi}},$$

where the term $1/(1+\theta_{wu}/\chi)$ represents strategic complementarity in the household's wage-setting, which stems from the elasticity of the marginal disutility of labor $1/\chi$ along with the elasticity of individual labor demand $-\theta_{wu}$.

Moreover, in the log-linearized equilibrium conditions of the counterpart model, the following three equations (42)–(44) are included instead of eqs. (25)–(27). Aggregate labor $\hat{l}_t$ is determined to meet the labor demand condition

$$\hat{w}_t = \hat{mpl}_t \,, \tag{42}$$

while the aggregate wage growth rate $\hat{\pi}_{w,t}$ is determined according to the wage Phillips curve

$$\hat{\pi}_{w,t} = \beta\, E_t \hat{\pi}_{w,t+1} - \kappa_{wu}\, \hat{\mu}_{wu,t} + \varepsilon_{wu,t} \,, \tag{43}$$

where $\mu_{wu,t}$ is the wage markup, $\varepsilon_{wu,t} \equiv \kappa_{wu}\, \tilde{\varepsilon}_{wu,t}$ is a rescaled shock to the markup, and the slope is $\kappa_{wu} \equiv (1-\xi_w)(1-\beta\xi_w)/[\xi_w(1+\theta_{wu}/\chi)]$. In this wage Phillips curve, wage growth is driven by the wage markup, that is, the gap between the real wage and the marginal rate of substitution between consumption and labor:

$$\hat{\mu}_{wu,t} = \hat{w}_t - \hat{mrs}_t \,. \tag{44}$$

Moreover, in the slope κ_{wu}, the term $1/(1+\theta_{wu}/\chi)$ represents strategic complementarity in the household's wage-setting as noted above and thus induces real rigidity in relative wages. The larger the elasticity of the marginal disutility of labor $1/\chi$ or the elasticity of individual labor demand θ_{wu} is, the more conservatively the household responds to the wage markup in wage-setting.

Before proceeding to the welfare implications of firms' monopsonistic wage-setting compared to households' monopolistic wage-setting, it is worth emphasizing that the slope κ_{wd} of the wage Phillips curve in our model is distinct from the one κ_{wu} in the counterpart model, reflecting the difference between monopsonistic and monopolistic competition in labor markets. In particular, the slope $\kappa_{wd} \equiv (1-\xi_w)(1-\beta\xi_w)/[\xi_w(1-\chi/\theta_{wd})]$ under monopsonistic wage-setting is steeper than the one $\kappa_{wu} \equiv (1-\xi_w)(1-\beta\xi_w)/[\xi_w(1+\theta_{wu}/\chi)]$ under monopolistic wage-setting as long as the condition $\chi < \theta_{wd}$ is met. This condition holds under empirically plausible values of the elasticity of individual workers' labor supply χ and the elasticity of substitution between individual workers' labor supply θ_{wd}, including the values we adopt for the quantitative analysis presented later. The following proposition summarizes the finding.

Proposition 1 *Let $\chi < \theta_{wd}$. Then, the slope of the wage Phillips curve (26) in our model with firms' monopsonistic wage-setting is steeper than that of (43) in the counterpart model with households' monopolistic wage-setting, i.e., $\kappa_{wd} > \kappa_{wu}$.*

3 Policy Trade-offs

In this section we derive a welfare function from the model and investigate policy trade-offs in the welfare function by comparing them with those in the counterpart model with monopolistic wage-setting.

A welfare function of the model economy is derived as a second-order approximation to the representative household's utility function (1). As shown in Appendix A, the utility function (1) can be approximated up to the second order as

$$\begin{aligned} & E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t \exp \varepsilon_{c,t} - \int_0^1 \frac{1}{1+1/\chi} \left(l_t(m) \right)^{1+\frac{1}{\chi}} dm \right) \\ & \approx -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\theta_p}{\kappa_p} \hat{\pi}_t^2 + \frac{\chi \alpha}{\kappa_{wd}} \hat{\pi}_{w,t}^2 + \frac{1+1/\chi}{\alpha} \left(\hat{y}_t - \hat{y}_t^n \right)^2 \right] + tip \,, \end{aligned} \tag{45}$$

where tip stands for terms independent of policy. Based on this function, welfare W_d is measured as

$$\begin{aligned} W_d &= (1-\beta)\, E \left[E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t \exp \varepsilon_{c,t} - \int_0^1 \frac{1}{1+1/\chi} \left(l_t(m) \right)^{1+\frac{1}{\chi}} dm \right) \right] \\ & \approx -\frac{1}{2} \left[\frac{\theta_p}{\kappa_p} Var\left(\hat{\pi}_t \right) + \frac{\chi \alpha}{\kappa_{wd}} Var\left(\hat{\pi}_{w,t} \right) + \frac{1+1/\chi}{\alpha} Var\left(\hat{y}_t - \hat{y}_t^n \right) \right] + tip \,. \end{aligned} \tag{46}$$

The welfare function demonstrates inverse relationships between the weight θ_p/κ_p on inflation variability and the slope κ_p of the price Phillips curve (33) and between the weight $\chi\alpha/\kappa_{wd}$ on wage growth variability and the slope κ_{wd} of the wage Phillips curve (26).

In the counterpart model with monopolistic wage-setting, a derivation similar to that in Appendix A yields a second-order approximation to the utility function (1):

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t \exp \varepsilon_{c,t} - \int_0^1 \frac{1}{1+1/\chi} \left(l_t(m)\right)^{1+\frac{1}{\chi}} dm \right)$$
$$\approx -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\theta_p}{\kappa_p} \hat{\pi}_t^2 + \frac{\theta_{wu}\alpha}{\kappa_{wu}} \hat{\pi}_{w,t}^2 + \frac{1+1/\chi}{\alpha} \left(\hat{y}_t - \hat{y}_t^n\right)^2 \right] + tip\,, \tag{47}$$

and the welfare measure W_u:

$$W_u = (1-\beta)\, E \left[E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t \exp \varepsilon_{c,t} - \int_0^1 \frac{1}{1+1/\chi} \left(l_t(m)\right)^{1+\frac{1}{\chi}} dm \right) \right]$$
$$\approx -\frac{1}{2} \left[\frac{\theta_p}{\kappa_p} Var\left(\hat{\pi}_t\right) + \frac{\theta_{wu}\alpha}{\kappa_{wu}} Var\left(\hat{\pi}_{w,t}\right) + \frac{1+1/\chi}{\alpha} Var\left(\hat{y}_t - \hat{y}_t^n\right) \right] + tip\,. \tag{48}$$

The welfare function shows an inverse relationship between the weight $\theta_{wu}\alpha/\kappa_{wu}$ on wage growth variability and the slope κ_{wu} of the wage Phillips curve (43).

As noted above, the slope κ_{wd} of the wage Phillips curve in our model is steeper than the one κ_{wu} in the counterpart model under the condition $\chi < \theta_{wd}$. Then, the inverse relationship implies that the weight $\chi\alpha/\kappa_{wd}$ on wage growth variability of the welfare function in our model is smaller than the one $\theta_{wu}\alpha/\kappa_{wu}$ in the counterpart model if the condition $\chi \leq \theta_{wu}$ is additionally met. This additional condition also holds under empirically plausible values of the elasticity of individual labor supply χ and the elasticity of substitution between individual labor demand θ_{wu}, including the values we adopt for the quantitative analysis presented later. The following proposition summarizes the finding.

Proposition 2 *Let $\chi < \theta_{wd}$ and $\chi \leq \theta_{wu}$. Then, the weight on wage growth variability of the welfare function* (46) *in our model with firms' monopsonistic wage-setting is smaller than that of the welfare function* (48) *in the counterpart model with households' monopolistic wage-setting, i.e., $\chi\alpha/\kappa_{wd} < \theta_{wu}\alpha/\kappa_{wu}$.*

4 Model Parameterization

We parameterize the model by calibrating its structural parameters and estimating the remaining parameters.

4.1 Calibration of structural model parameters

We calibrate structural model parameters that are common between our model and its counterpart model with monopolistic wage-setting. In the calibration we follow Erceg et al. (2000) to facilitate the comparison of quantitative results. Table 1 presents the quarterly calibration of the structural model parameters. We set the subjective discount factor at $\beta = 0.99$, the elasticity of each worker's labor supply at $\chi = 2/3$, the labor elasticity of production at $\alpha = 0.7$, the elasticity of substitution between demand for individual goods at $\theta_p = 4$, the degree of price rigidity at $\xi_p = 0.75$, and the degree of nominal wage rigidity at $\xi_w = 0.75$.[5] These parameter values imply that the slope of the price Phillips curve is $\kappa_p = 0.086$. We also choose the monetary policy responses to inflation, wage growth, and the output gap at $\phi_p = 1.5$, $\phi_w = 0$, and $\phi_y = 0.5/4$, respectively, as in Taylor (1993).

Table 1: Calibration of structural parameters in the quarterly model.

Parameter	Description	Value
β	Subjective discount factor	0.99
χ	Elasticity of each worker's labor supply	2/3
α	Labor elasticity of production	0.7
θ_p	Elasticity of substitution between demand for individual goods	4
ξ_p	Degree of price rigidity	0.75
ξ_w	Degree of nominal wage rigidity	0.75
ϕ_p	Monetary policy response to inflation	1.5
ϕ_w	Monetary policy response to wage growth	0
ϕ_y	Monetary policy response to output gap	0.5/4

4.2 Estimation of remaining model parameters

We estimate the remaining model parameters, those of the labor aggregator and the four shock processes. We assume a stationary first-order autoregressive process for each of the four shocks. Given the calibration of the common structural model parameters presented in Table 1, we obtain values of the remaining model parameters using full-information Bayesian estimation. The model has four shocks—the consumption preference shock $\varepsilon_{c,t}$, the produc-

[5] In our model, the elasticity of labor supply faced by firms in wage-setting is represented as χ. Research in labor economics documents that the elasticity of firm-specific labor supply is around 3 (e.g., Caldwell et al., 2025). In Appendix B, we use a larger value of $\chi = 3$ than our calibration of $\chi = 2/3$ that follows Erceg et al. (2000), and confirm the robustness of our results.

tivity shock $\varepsilon_{a,t}$, the wage markdown shock $\varepsilon_{wd,t}$, and the monetary policy shock $\varepsilon_{r,t}$—and thus the estimation uses four US quarterly time series on output growth, labor, the wage growth rate, and the interest rate during the sample period of 1984:Q1 to 2007:Q4.[6] The data on the four time series are the same as in Smets and Wouters (2007) and are demeaned using their respective sample averages.

The prior distributions for the parameters to be estimated are presented in Table 2. As seen in the upper panel of the table, we set the prior for the elasticity of substitution between individual workers' labor supply θ_{wd} to be the gamma distribution with mean 4 and standard deviation 1.5. The priors for the shock processes are based on Smets and Wouters (2007), that is, the beta distributions with mean 0.5 and standard deviation 0.2 for the shock persistence parameters ρ_i, $i = c, a, wd, r$, and the inverse gamma distributions with mean 0.1 and standard deviation 2 for the shock innovations' standard deviations σ_i, $i = c, a, wd, r$.

We also estimate the elasticity of substitution between individual labor demand θ_{wu} and parameters of the four shock processes (ρ_i, σ_i), $i = c, a, wu, r$ in the counterpart model with monopolistic wage-setting. For these parameters, we set similar prior distributions to those in our model, as displayed in the lower panel of Table 2.

Table 2 also reports each parameter's posterior mean and 90 percent highest posterior density interval.[7] It is worth noting that the data are in favor of our model with monopsonistic wage-setting rather than the counterpart model with monopolistic wage-setting. Indeed, the log marginal data density is -257 for our model, which is larger than -313 for the counterpart model.

In what follows, we choose the values of the estimated parameters at their posterior mean estimates. Specifically, in our model, we set $\theta_{wd} = 5.875$, $\rho_c = 0.937$, $\rho_a = 0.941$, $\rho_{wd} = 0.488$, $\rho_r = 0.074$, $\sigma_c = 1.043$, $\sigma_a = 0.450$, $\sigma_{wd} = 0.622$, and $\sigma_r = 1.198$.[8] In the counterpart model, we set $\theta_{wu} = 2.863$, $\rho_c = 0.932$, $\rho_a = 0.989$, $\rho_{wu} = 0.136$, $\rho_r = 0.514$, $\sigma_c = 0.955$, $\sigma_a = 0.447$, $\sigma_{wu} = 0.685$, and $\sigma_r = 0.345$.

[6]Because the sample period ends before the nominal interest rate reached its effective lower bound, the nonlinearity arising from the lower bound is not a critical issue for the estimation strategy used.

[7]In the estimation, $200,000$ draws are generated and the first $100,000$ draws are discarded. The scale factor for the jumping distribution in the Metropolis-Hastings algorithm is adjusted so that the acceptance rate is approximately 24 percent.

[8]Our estimate of $\theta_{wd} = 5.875$ is smaller than the corresponding parameter's value of 10.85 in Berger et al. (2022). In Appendix B, we use their value and confirm the robustness of our results.

Table 2: Prior and posterior distributions for model parameters of labor aggregator and shock processes.

	Prior distribution			Posterior distribution	
Parameter	Distribution	Mean	St. dev.	Mean	90% interval
(a) *Model (with monopsonistic wage-setting)*					
θ_{wd}	Gamma	4	1.5	5.875	$[3.375, 8.268]$
ρ_c	Beta	0.5	0.2	0.937	$[0.923, 0.951]$
ρ_a	Beta	0.5	0.2	0.941	$[0.922, 0.960]$
ρ_{wd}	Beta	0.5	0.2	0.488	$[0.427, 0.550]$
ρ_r	Beta	0.5	0.2	0.074	$[0.048, 0.100]$
σ_c	Inv. gamma	0.1	2	1.043	$[0.896, 1.186]$
σ_a	Inv. gamma	0.1	2	0.450	$[0.396, 0.502]$
σ_{wd}	Inv. gamma	0.1	2	0.622	$[0.540, 0.704]$
σ_r	Inv. gamma	0.1	2	1.198	$[1.033, 1.358]$
(b) *Counterpart model with monopolistic wage-setting*					
θ_{wu}	Gamma	4	1.5	2.863	$[1.051, 4.605]$
ρ_c	Beta	0.5	0.2	0.932	$[0.903, 0.963]$
ρ_a	Beta	0.5	0.2	0.989	$[0.979, 0.999]$
ρ_{wu}	Beta	0.5	0.2	0.136	$[0.035, 0.231]$
ρ_r	Beta	0.5	0.2	0.514	$[0.444, 0.586]$
σ_c	Inv. gamma	0.1	2	0.955	$[0.751, 1.152]$
σ_a	Inv. gamma	0.1	2	0.447	$[0.396, 0.501]$
σ_{wu}	Inv. gamma	0.1	2	0.685	$[0.571, 0.801]$
σ_r	Inv. gamma	0.1	2	0.345	$[0.298, 0.392]$

Using these parameter values and the calibrated values of the common structural model parameters reported in Table 1, we compute the slope of the wage Phillips curve (26) as $\kappa_{wd} = 0.097$ and the weight on wage growth variability of the welfare function (45) as $\chi\alpha/\kappa_{wd} = 4.820$ in our model. In the counterpart model with monopolistic wage-setting, we calculate the slope of the wage Phillips curve (43) as $\kappa_{wu} = 0.016$ and the weight on wage growth variability of the welfare function (47) as $\theta_{wu}\alpha/\kappa_{wu} = 123.604$. Therefore, we can see that under the model parameter values, the slope of the wage Phillips curve is steeper in our model than in the counterpart model, that is, Proposition 1 holds, and thus the welfare weight on wage growth variability is an order of magnitude smaller, that is, Proposition 2 holds.

4.3 Impulse responses to shocks

We analyze the properties of the model using impulse responses to shocks. Figure 1 plots the responses of the real wage $\hat{w}_t$, the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, output $\hat{y}_t$, and the interest rate $\hat{r}_t$ to one-standard-deviation positive innovations to the consumption preference shock $\varepsilon_{c,t}$, the productivity shock $\varepsilon_{a,t}$, the wage markdown shock $\varepsilon_{wd,t}$, and the monetary policy shock $\varepsilon_{r,t}$ in the model. The panels for the real wage $\hat{w}_t$ also include its natural rate

$$\hat{w}_t^n = -\frac{1-\alpha}{1+1/\chi}\,\varepsilon_{c,t} + \varepsilon_{a,t}\,, \tag{49}$$

and those for output contain its natural rate $\hat{y}_t^n$ as well. These natural rates are displayed as dotted lines in the panels.[9]

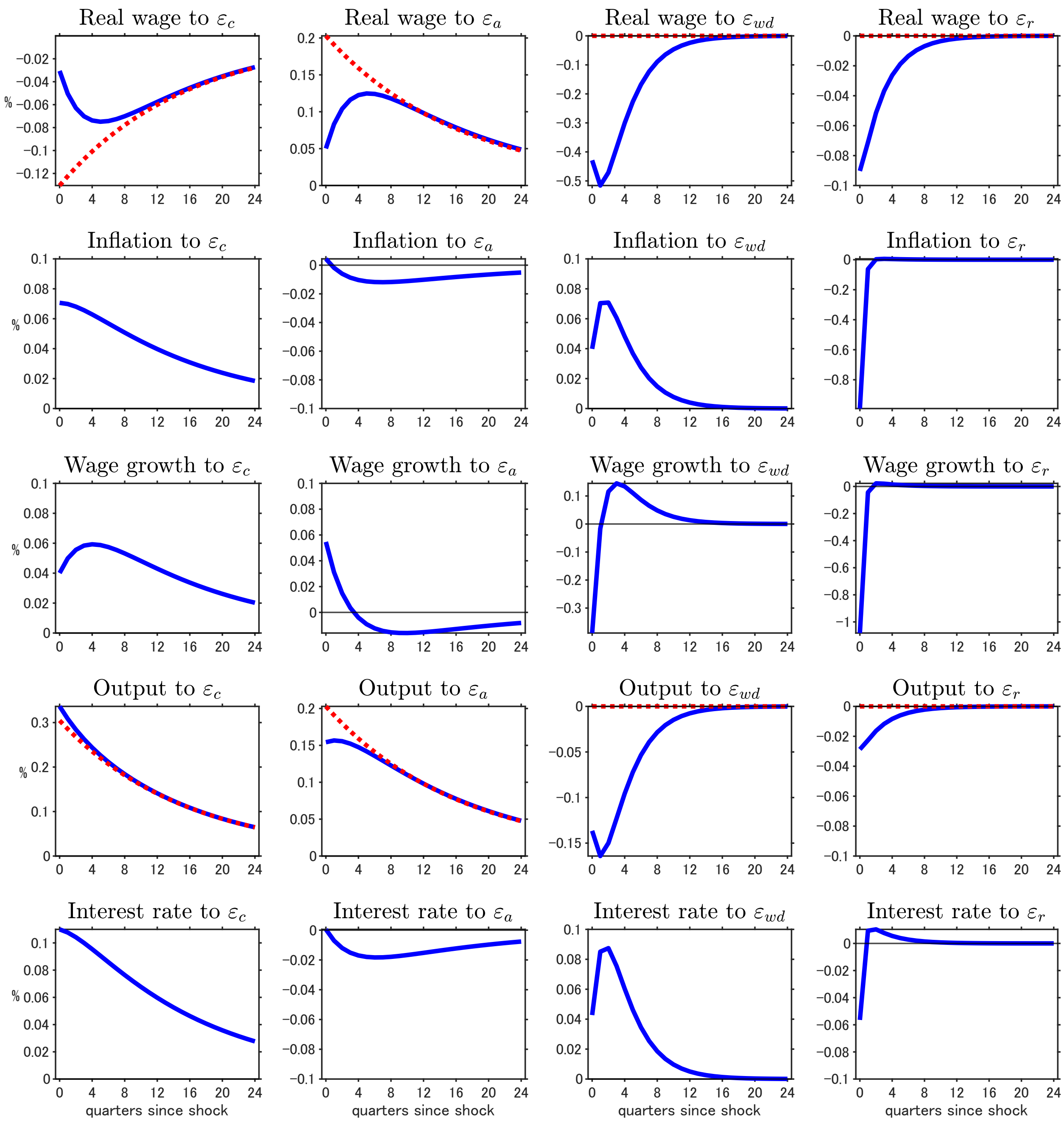
Starting in the first column of the figure, a positive consumption preference shock $\varepsilon_{c,t}$ raises the natural rate of output $\hat{y}_t^n$ while reducing the natural rate of the real wage $\hat{w}_t^n$. The shock decreases the marginal rate of substitution between consumption and labor and hence the real wage in monopsonistically competitive labor markets, which leads the wage growth rate to rise less than the inflation rate. The shock also increases consumption, output, and the inflation rate and hence the interest rate under the Taylor-type policy rule. These responses align qualitatively with evidence of the responses to demand shocks from VARs.

The second column displays the impulse responses to a positive productivity shock $\varepsilon_{a,t}$, which increases both the natural rates of output and the real wage. This shock raises output, which increases the marginal rate of substitution and hence the real wage. The shock also leads the marginal product of labor to increase more than the real wage, which reduces the wage markdown and thus raises the wage growth rate on impact of the shock. Although the productivity shock tends to reduce the inflation rate by lowering the real marginal cost, the price level rises slightly on impact of the shock to reconcile the sluggish increase in the real wage and the initial hike in the wage growth rate given the steep wage Phillips curve (26). Such movements in the inflation rate lead the interest rate to decline. These responses are qualitatively consistent with VAR evidence (e.g., Christiano et al., 2015).

The third column presents the impulse responses to a positive wage markdown shock

[9] The consumption preference and productivity shocks affect the natural rates of output and the real wage, whereas the wage markdown and monetary policy shocks do not.

Figure 1: Impulse responses to shocks in the model.



Notes: The panels in each column display the impulse responses of the real wage $\hat{w}$ and its natural rate $\hat{w}^n$ (first row), the inflation rate $\hat{\pi}$ (second row), the wage growth rate $\hat{\pi}_w$ (third row), output $\hat{y}$ and its natural rate $\hat{y}^n$ (fourth row), and the interest rate $\hat{r}$ (fifth row), respectively, to one-standard-deviation positive innovations to the consumption preference shock z_c (first column), the productivity shock z_a (second column), the wage markdown shock z_{wd} (third column), and the monetary policy shock z_r (fourth column) in the model. In the panels for the real wage and output, their natural rates are also plotted as dotted lines. All responses are expressed as percentages. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

$\varepsilon_{wd,t}$. The shock reduces the wage growth rate on impact, which prompts the real wage to fall below its steady-state level. The ensuing reduction in the labor supply that is needed to lower the marginal rate of substitution leads output to fall and the inflation rate to rise. The latter effect further dampens the real wage, although it is mitigated by the positive interest rate response to the inflation rise. When the effects of the shock decay, a temporary increase in the wage growth rate ensures that the real wage, output, and the inflation rate return to their steady-state levels.

The fourth column illustrates the impulse responses to a contractionary monetary policy shock $\varepsilon_{r,t}$. This shock directly puts upward pressure on the interest rate and thus reduces output, the real wage, and the wage growth and inflation rates. Since the shock is estimated to have little persistence, the interest rate tracks the inflation rate by declining on impact of the shock and rising afterwards.

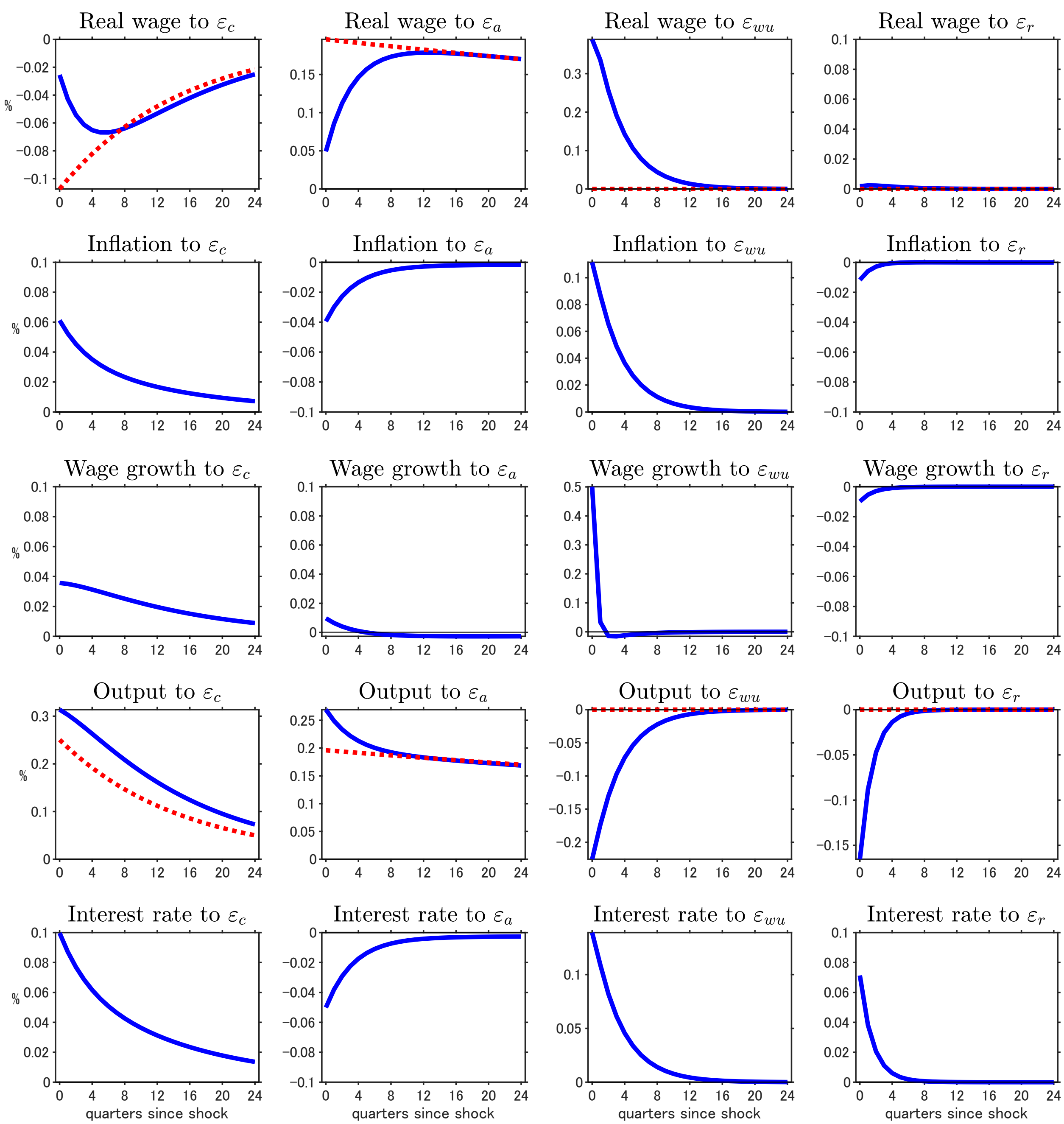
To compare the impulse responses in our model to those in the counterpart model with monopolistic wage-setting, Figure 2 plots the latter responses.

In the first column of the figure, we can see qualitatively the same responses to a positive consumption preference shock $\varepsilon_{c,t}$ as those in our model. Quantitatively, the responses of the wage growth, inflation, and interest rates are smaller in the counterpart model, since the positive shock reduces the marginal rate of substitution between consumption and labor and thus raises the wage markup, which dampens increases in the wage growth, inflation, and interest rates.

The second column shows the impulse responses to a positive productivity shock $\varepsilon_{a,t}$, which are somewhat different from those in our model. In the counterpart model, the productivity shock raises the marginal product of labor and hence the real wage in monopolistically competitive labor markets. At the same time the shock increases output and hence the marginal rate of substitution, thus mitigating the rise in the wage markup and dampening the increase in the wage growth rate. Moreover, it reduces the real marginal cost and hence the inflation rate, which leads the interest rate to decline under the Taylor-type policy rule.

The third column displays the impulse responses to a positive wage markup shock $\varepsilon_{wu,t}$. This shock leads the wage growth rate to rise much more than the inflation rate on impact, which increases the real wage and reduces output. The rise in the inflation rate leads the interest rate to increase.

Figure 2: Impulse responses to shocks in the counterpart model with monopolistic wage-setting.



Notes: The panels in each column display the impulse responses of the real wage $\hat{w}$ and its natural rate $\hat{w}^n$ (first row), the inflation rate $\hat{\pi}$ (second row), the wage growth rate $\hat{\pi}_w$ (third row), output $\hat{y}$ and its natural rate $\hat{y}^n$ (fourth row), and the interest rate $\hat{r}$ (fifth row), respectively, to one-standard-deviation positive innovations to the consumption preference shock z_c (first column), the productivity shock z_a (second column), the wage markup shock z_{wu} (third column), and the monetary policy shock z_r (fourth column) in the counterpart model with monopolistic wage-setting. In the panels for the real wage and output, their natural rates are also plotted as dotted lines. All responses are expressed as percentages. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

The fourth column illustrates the impulse responses to a contractionary monetary policy shock $\varepsilon_{r,t}$. The shock raises the interest rate and thus reduces output. The inflation rate declines slightly more than the wage growth rate, which leads to a small decline in the real wage. The interest rate rises despite the feedback from lower inflation and output, unlike in our model, reflecting the greater persistence of the estimated policy shock.

5 Policy Implications

In this section we investigate a welfare-maximizing policy in the model and compare it to that in the counterpart model with monopolistic wage-setting.

5.1 Timeless-perspective policy

The welfare-maximizing policy we analyze is the timeless-perspective policy developed by Woodford (1999). To derive the policy, the log-linearized equilibrium conditions (25)–(28), (30)–(36), and (49) can be reduced to[10]

$$\hat{\pi}_t = \beta\, E_t \hat{\pi}_{t+1} + \kappa_p \left[\frac{1 + 1/\chi}{\alpha} \left(\hat{y}_t - \hat{y}_t^n \right) - \hat{\mu}_{wd,t} \right], \tag{50}$$

$$\hat{\pi}_{w,t} = \hat{\pi}_t + \hat{w}_t^n - \hat{w}_{t-1}^n + \frac{\alpha + 1/\chi}{\alpha} \left[\left(\hat{y}_t - \hat{y}_t^n \right) - \left(\hat{y}_{t-1} - \hat{y}_{t-1}^n \right) \right]. \tag{51}$$

Comparing the price Phillips curves (33) and (50), we have the relationship

$$\hat{\mu}_{p,t} = \hat{\mu}_{wd,t} - \frac{1 + 1/\chi}{\alpha} \left(\hat{y}_t - \hat{y}_t^n \right), \tag{52}$$

which influences how the monetary authority is able to balance inflation, wage growth, and the output gap, as the price markup $\hat{\mu}_{p,t}$ and the wage markdown $\hat{\mu}_{wd,t}$ are, respectively, the drivers of inflation and wage growth in the price and wage Phillips curves (33) and (26). The timeless-perspective policy can be derived by maximizing the welfare function (45) subject to the price Phillips curve (50), the wage Phillips curve (26), and the wage growth definition (51). The policy is composed of the following equations that combine the first-order conditions for the welfare-maximization problem:

[10] In the model the real wage gap (i.e., the gap between the real wage and its natural rate) is proportional to the output gap, i.e., $\hat{w}_t - \hat{w}_t^n = [(\alpha + 1/\chi)/\alpha]\,(\hat{y}_t - \hat{y}_t^n)$. This relationship arises from the fact that workers are wage takers in monopsonistically competitive labor markets and thus that their labor supply satisfies the condition (25).

$$\hat{\pi}_t = -\frac{\kappa_p}{\theta_p}(\lambda_{pd,t} - \lambda_{pd,t-1} - \lambda_{dd,t}), \tag{53}$$

$$\hat{\pi}_{w,t} = \frac{\kappa_p}{\chi\alpha}(\lambda_{pd,t} - \lambda_{pd,t-1}) - \frac{\kappa_{wd}}{\chi\alpha}\lambda_{dd,t}, \tag{54}$$

$$\hat{y}_t - \hat{y}_t^n = \kappa_p\,\lambda_{pd,t} + \frac{\alpha + 1/\chi}{1 + 1/\chi}(\lambda_{dd,t} - \beta\,E_t\lambda_{dd,t+1}), \tag{55}$$

where $\lambda_{pd,t}$ and $\lambda_{dd,t}$ are Lagrange multipliers on (50) and (51), respectively. In the absence of nominal wage rigidity, the timeless-perspective policy is reduced to

$$\hat{\pi}_t = -\frac{1}{\theta_p}\left[(\hat{y}_t - \hat{y}_t^n) - \left(\hat{y}_{t-1} - \hat{y}_{t-1}^n\right)\right], \tag{56}$$

as presented in graduate macroeconomics textbooks, such as Galí (2015), Walsh (2017), and Woodford (2003).

As for the counterpart model with monopolistic wage-setting, the log-linearized equilibrium conditions (28), (30)–(34), (36), (42)–(44), and (49) can be reduced to

$$\hat{\pi}_t = \beta\,E_t\hat{\pi}_{t+1} + \kappa_p\left[\frac{1-\alpha}{\alpha}(\hat{y}_t - \hat{y}_t^n) + (\hat{w}_t - \hat{w}_t^n)\right], \tag{57}$$

$$\hat{\pi}_{w,t} = \beta\,E_t\hat{\pi}_{w,t+1} + \kappa_{wu}\left[\frac{\alpha + 1/\chi}{\alpha}(\hat{y}_t - \hat{y}_t^n) - (\hat{w}_t - \hat{w}_t^n)\right] + \varepsilon_{wu,t}, \tag{58}$$

as in Erceg et al. (2000). Comparing the price Phillips curves (33) and (57) as well as the wage Phillips curves (43) and (58), we have

$$\hat{\mu}_{p,t} = -\hat{\mu}_{wu,t} - \frac{1 + 1/\chi}{\alpha}(\hat{y}_t - \hat{y}_t^n), \tag{59}$$

which again influences the ability of the monetary authority to balance inflation, wage growth, and the output gap, as the price markup $\hat{\mu}_{p,t}$ and the wage markup $\hat{\mu}_{wu,t}$ are the drivers of inflation and wage growth in the price and wage Phillips curves (33) and (43), respectively. The timeless-perspective policy can be derived by maximizing the welfare fuction (47) subject to the price Phillips curve (57), the wage Phillips curve (58), and the wage growth definition (35). The policy is composed of the following equations that combine the first-order conditions for the welfare-maximization problem:

$$\hat{\pi}_t = -\frac{\kappa_p}{\theta_p}(\lambda_{pu,t} - \lambda_{pu,t-1} - \lambda_{du,t}), \tag{60}$$

$$\hat{\pi}_{w,t} = -\frac{\kappa_p}{\theta_{wu}\alpha}(\lambda_{pu,t} - \lambda_{pu,t-1}) - \frac{\kappa_{wu}}{\theta_{wu}\alpha}\lambda_{du,t}$$
$$- \frac{1}{\theta_{wu}\alpha}[(\lambda_{du,t} - \beta E_t\lambda_{du,t+1}) - (\lambda_{du,t-1} - \beta E_{t-1}\lambda_{du,t})], \quad (61)$$

$$\hat{y}_t - \hat{y}_t^n = \kappa_p \lambda_{pu,t} + \frac{\alpha + 1/\chi}{1 + 1/\chi}(\lambda_{du,t} - \beta E_t\lambda_{du,t+1}), \quad (62)$$

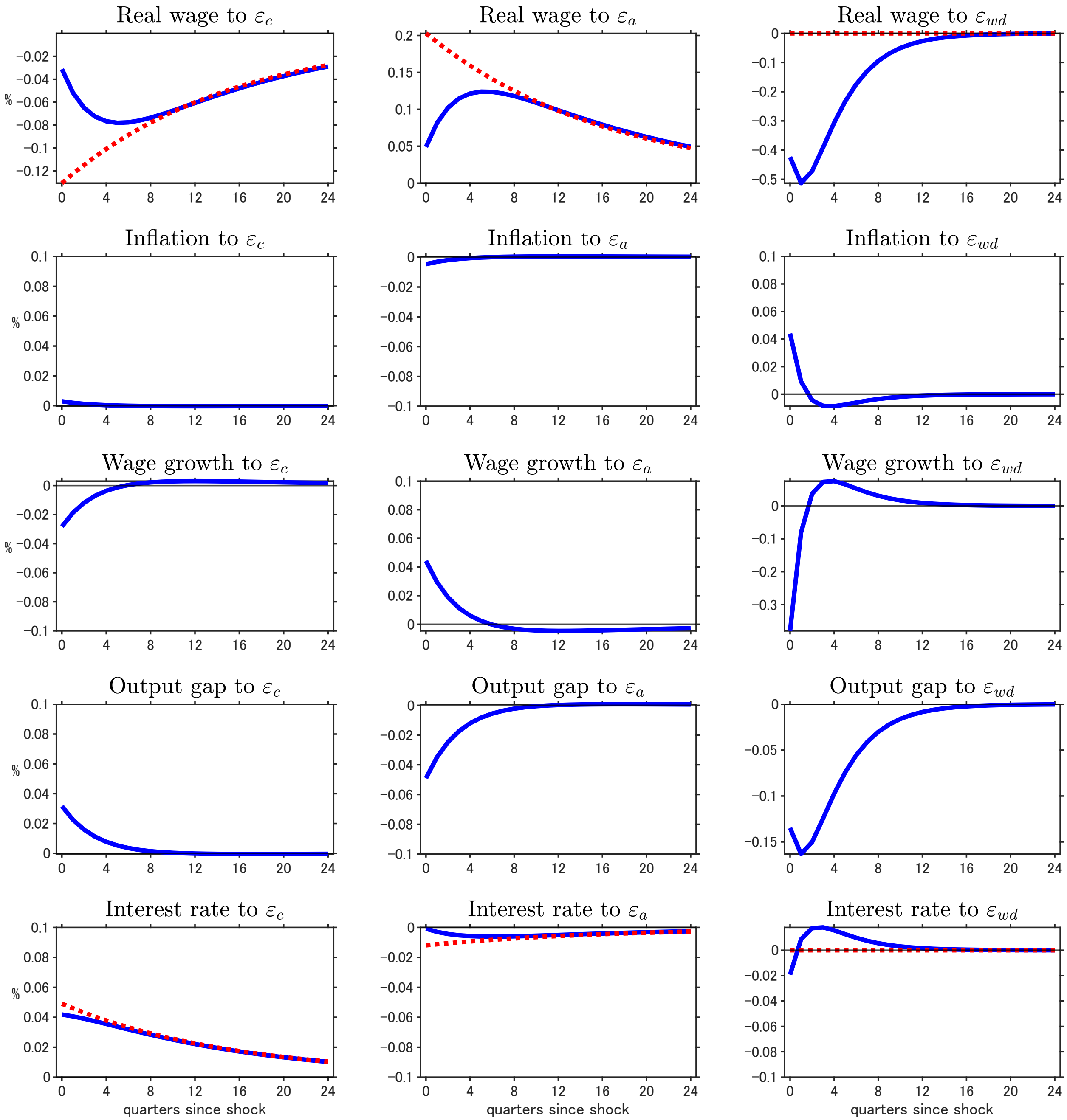
where $\lambda_{pu,t}$ and $\lambda_{du,t}$ are Lagrange multipliers on (57) and (35), respectively. This policy is reduced to (56) in the absence of nominal wage rigidity.

5.2 Impulse responses to shocks under timeless-perspective policy

We investigate the properties of the timeless-perspective policy using the impulse responses to shocks. The responses under the policy (53)–(55) in our model are displayed in Figure 3. This figure plots how the real wage $\hat{w}_t$, the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, the output gap $\hat{y}_t - \hat{y}_t^n$, and the interest rate $\hat{r}_t$ respond to one-standard-deviation positive innovations to the consumption preference shock $\varepsilon_{c,t}$, the productivity shock $\varepsilon_{a,t}$, and the wage markdown shock $\varepsilon_{wd,t}$ under the timeless-perspective policy. In the panels for the real wage and the interest rate, their natural rates are also shown as dotted lines. Under the parameterization of the model reported in Tables 1 and 2, the weights on variability of inflation, wage growth, and the output gap in the welfare function (45) are calculated as $\theta_p/\kappa_p = 46.602$, $\chi\alpha/\kappa_{wd} = 4.820$, and $(1 + 1/\chi)/\alpha = 3.571$, respectively. Thus, the weight on inflation variability is about an order of magnitude larger than those on the variability of wage growth and the output gap.

We discuss the impulse responses to each of the three shocks, starting with those to a positive consumption preference shock $\varepsilon_{c,t}$ presented in the first column of the figure. This shock reduces the natural rate of the real wage while raising the natural rate of output. The timeless-perspective policy then aims to close the output gap and the real wage gap subject to price and nominal wage rigidities. To that end the policy leads output to rise and the real wage to decline by decreasing the wage growth rate along with a small increase in the inflation rate. The reliance on the wage growth rate more than on the inflation rate arises because the weight on inflation variability is larger than that on wage growth variability in the welfare function (45) under the parameterization of the model, as seen above. The shock also increases the natural rate of interest

Figure 3: Impulse responses under timeless-perspective policy in the model.



Notes: The figure displays the impulse responses under the timeless-perspective policy in the model. The panels in each column plot how the real wage $\hat{w}$ and its natural rate $\hat{w}^n$ (first row), the inflation rate $\hat{\pi}$ (second row), the wage growth rate $\hat{\pi}_w$ (third row), the output gap $\hat{y} - \hat{y}^n$ (fourth row), and the interest rate $\hat{r}$ (fifth row) respond to, respectively, one-standard-deviation positive innovations to the consumption preference shock ε_c, the productivity shock ε_a, and the wage markdown shock ε_{wd}. In the panels for the real wage and the interest rate, their natural rates are also shown as dotted lines. All responses are expressed as percentages. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

$$\hat{r}_t^n = \left(1 - \frac{\alpha}{1 + 1/\chi}\right)(\varepsilon_{c,t} - E_t \varepsilon_{c,t+1}) - (\varepsilon_{a,t} - E_t \varepsilon_{a,t+1}),$$

which raises the policy rate along with the rises in the output gap and the inflation rate through the Euler equation for the output gap:

$$\hat{y}_t - \hat{y}_t^n = E_t \left(\hat{y}_{t+1} - \hat{y}_{t+1}^n\right) - (\hat{r}_t - E_t \hat{\pi}_{t+1} - \hat{r}_t^n). \tag{63}$$

The second column of the figure displays the impulse responses to a positive productivity shock $\varepsilon_{a,t}$. This shock increases both the natural rates of the real wage and output. To close the real wage gap, the timeless-perspective policy leads the real wage to rise by increasing the wage growth rate along with a small decrease in the inflation rate. The small response of the inflation rate compared to that of the wage growth rate corresponds with the responses to the consumption preference shock presented above. To attain these responses, the policy lets output rise less than its natural rate and thus reduces the output gap. The shock also decreases the natural rate of interest, which slightly lowers the policy rate along with the decreases in the output gap and the inflation rate through the output gap Euler equation (63).

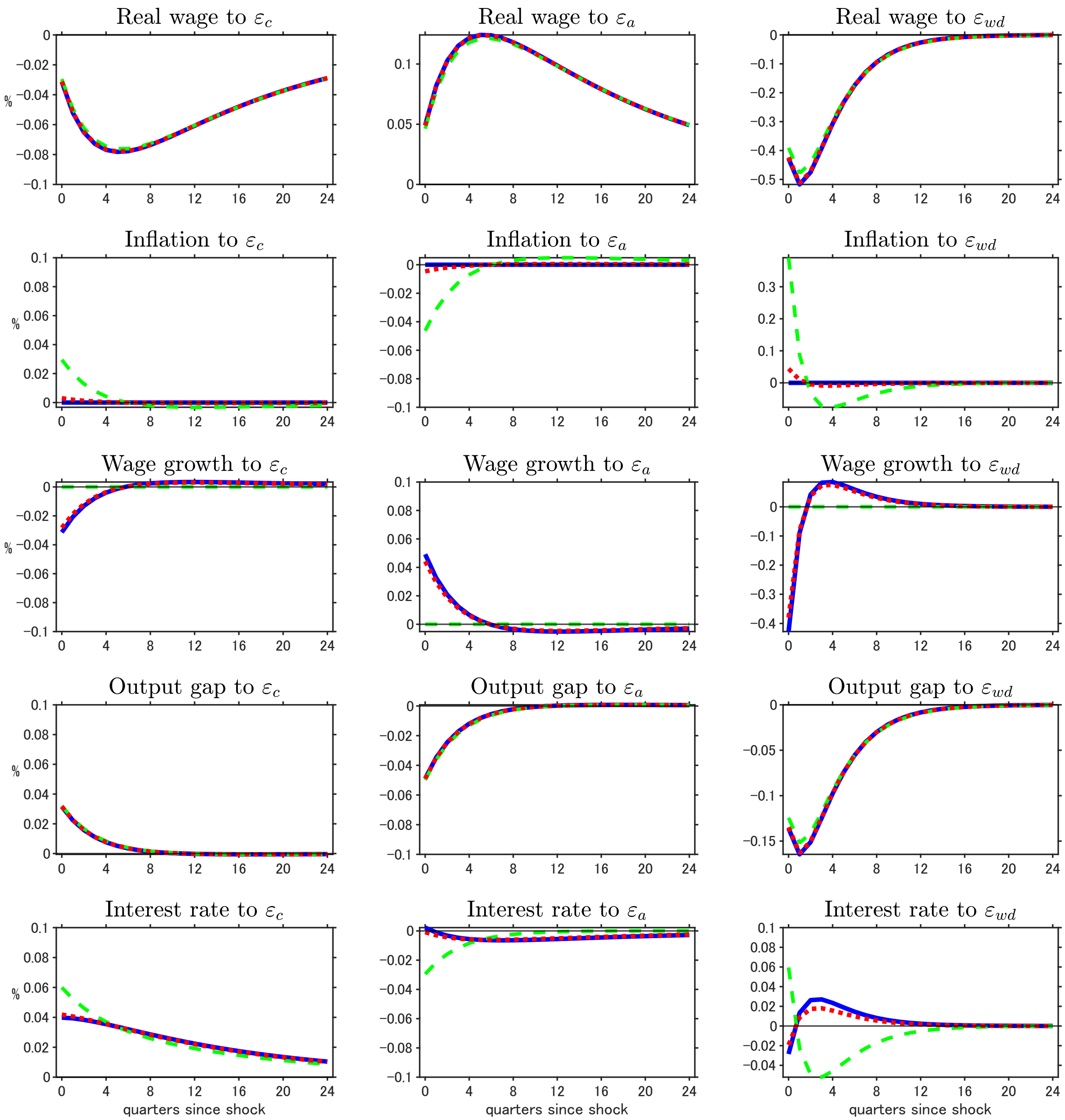
The third column plots the impulse responses to a positive wage markdown shock $\varepsilon_{wd,t}$. This shock makes no changes in the natural rates of the real wage, output, and interest and decreases the wage growth rate on impact. Then, the real wage declines under price rigidity, which reduces the marginal rate of substitution between consumption and labor in monopsonistically competitive labor markets and thus decreases the labor supply and hence (the) output (gap). The decline in the real wage also reduces the wage markdown and hence the price markup through the relationship (52) and thus generates a small rise in inflation. The response of the inflation rate is once again small relative to that of the wage growth rate. The decrease in the output gap enlarges first before it diminishes, so that the interest rate declines slightly on impact of the shock and rises slightly afterwards through the output gap Euler equation (63).

These three columns show that the inflation responses are much smaller than the wage growth responses. This difference reflects the fact that the weight on inflation variability is larger than that on wage growth variability in the welfare function (45) under the parameterization of the model reported in Tables 1 and 2. Thus the impulse responses suggest that the timeless-perspective policy features inflation stabilization. To confirm this, we compare the impulse responses under the timeless-perspective policy (53)–(55) to those under full inflation stabilization (i.e., $\hat{\pi}_t = 0$ in each period t) and under full wage growth stabilization (i.e., $\hat{\pi}_{w,t} = 0$ in each period t). This comparison is displayed in Figure 4. For each of the three shocks (i.e., the consumption preference shock $\varepsilon_{c,t}$, the productivity shock $\varepsilon_{a,t}$, and the wage markdown shock $\varepsilon_{wd,t}$), the responses of the real wage and the output gap under the timeless-perspective policy are almost the same as those under each of the other two policy strategies. However, the responses of the inflation, wage growth, and interest rates under the timeless-perspective policy are almost the same as those under full inflation stabilization but are different from those under full wage growth stabilization, which indeed induces a larger response of inflation to each of the three shocks and hence a larger welfare loss based on the relatively large inflation weight in the welfare function (45) than the timeless-perspective policy does. Therefore, inflation stabilization is an important feature of the timeless-perspective policy in the model.

We turn next to the timeless-perspective policy in the counterpart model with monopolistic wage-setting. Under the parameterization of the model reported in Tables 1 and 2, the weight on wage growth variability in the welfare function (47) is calculated as $\theta_{wu}\alpha/\kappa_{wu} = 123.604$ and is an order of magnitude larger than that of $\chi\alpha/\kappa_{wd} = 4.820$ in our model, as noted above, while the weights on variability of inflation and the output gap stay at $\theta_p/\kappa_p = 46.602$ and $(1 + 1/\chi)/\alpha = 3.571$. Thus, in the counterpart model, the weight on wage growth variability is much larger than those on the variability of inflation and the output gap.

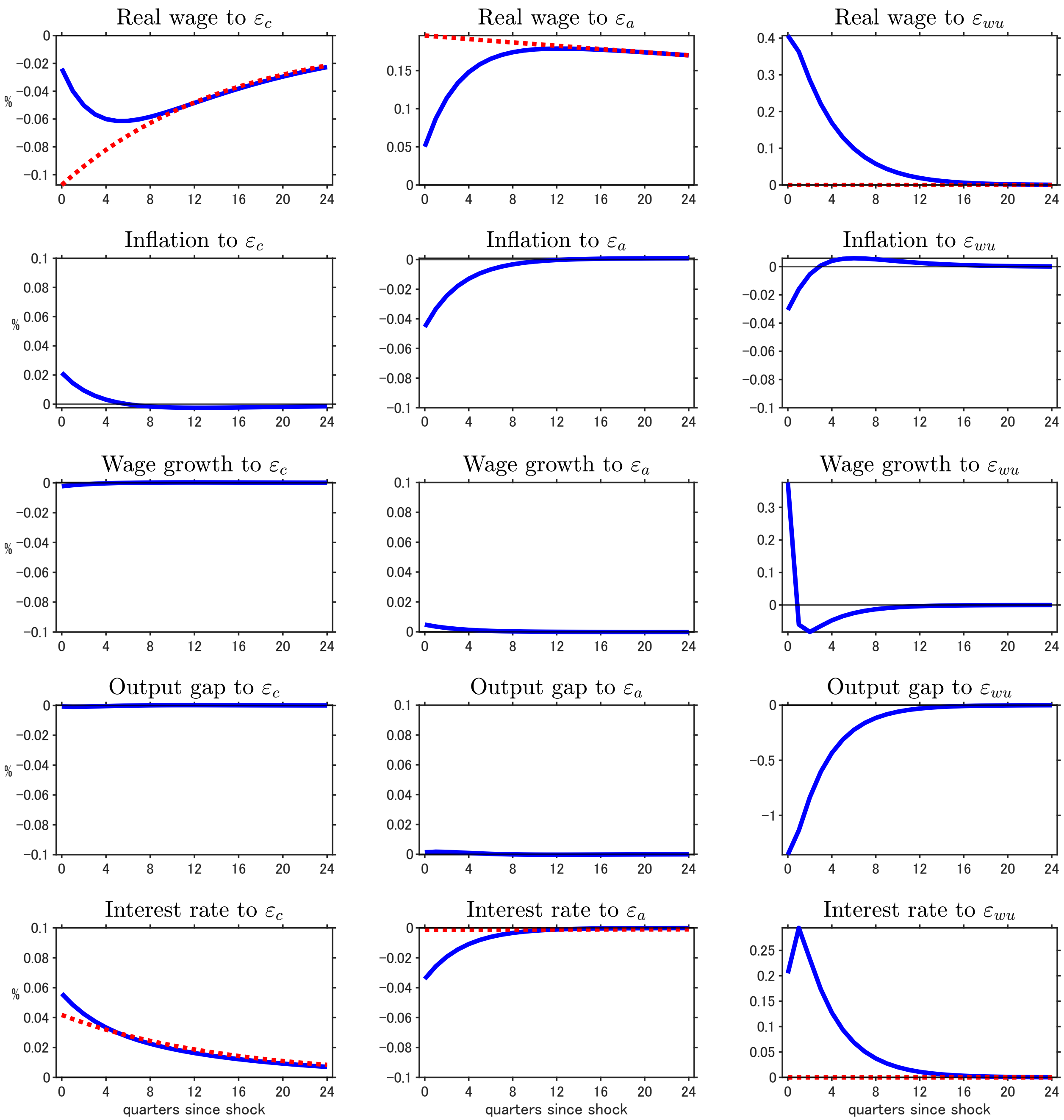
Figure 5 displays the impulse responses under the timeless-perspective policy (60)–(62). In the first column of the figure, a positive consumption preference shock $\varepsilon_{c,t}$ reduces the natural rate of the real wage while raising the natural rate of output. To close the output gap and the real wage gap subject to price and nominal wage rigidities, the policy leads output to rise slightly less than its natural rate and the real wage to decline by increasing the inflation rate along with a small decrease in the wage growth rate. The combination of the increase in the inflation rate and the small decrease in the wage growth rate is due to the fact that the weight on wage growth variability is larger than that on inflation variability in the welfare function (47) under the parameterization of the counterpart model reported in

Figure 4: Impulse responses under full inflation stabilization and full wage growth stabilization in the model.



Notes: The figure displays the impulse responses of the model under full inflation stabilization as solid lines, those under full wage growth stabilization as dashed lines, and those under the timeless-perspective policy as dotted lines. The panels in each column plot how the real wage $\hat{w}$, the inflation rate $\hat{\pi}$, the wage growth rate $\hat{\pi}_w$, the output gap $\hat{y} - \hat{y}^n$, and the interest rate $\hat{r}$ respond to, respectively, one-standard-deviation positive innovations to the consumption preference shock ε_c, the productivity shock ε_a, and the wage markdown shock ε_{wd}. All responses are expressed as percentages. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

Figure 5: Impulse responses under timeless-perspective policy in the counterpart model with monopolistic wage-setting.



Notes: The figure displays the impulse responses under the timeless-perspective policy in the counterpart model with monopolistic wage-setting. The panels in each column plot how the real wage $\hat{w}$ and its natural rate $\hat{w}^n$ (first row), the inflation rate $\hat{\pi}$ (second row), the wage growth rate $\hat{\pi}_w$ (third row), the output gap $\hat{y} - \hat{y}^n$ (fourth row), and the interest rate $\hat{r}$ (fifth row) respond to, respectively, one-standard-deviation positive innovations to the consumption preference shock ε_c, the productivity shock ε_a, and the wage markup shock ε_{wu}. In the panels for the real wage and the interest rate, their natural rates are also shown as dotted lines. All responses are expressed as percentages. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

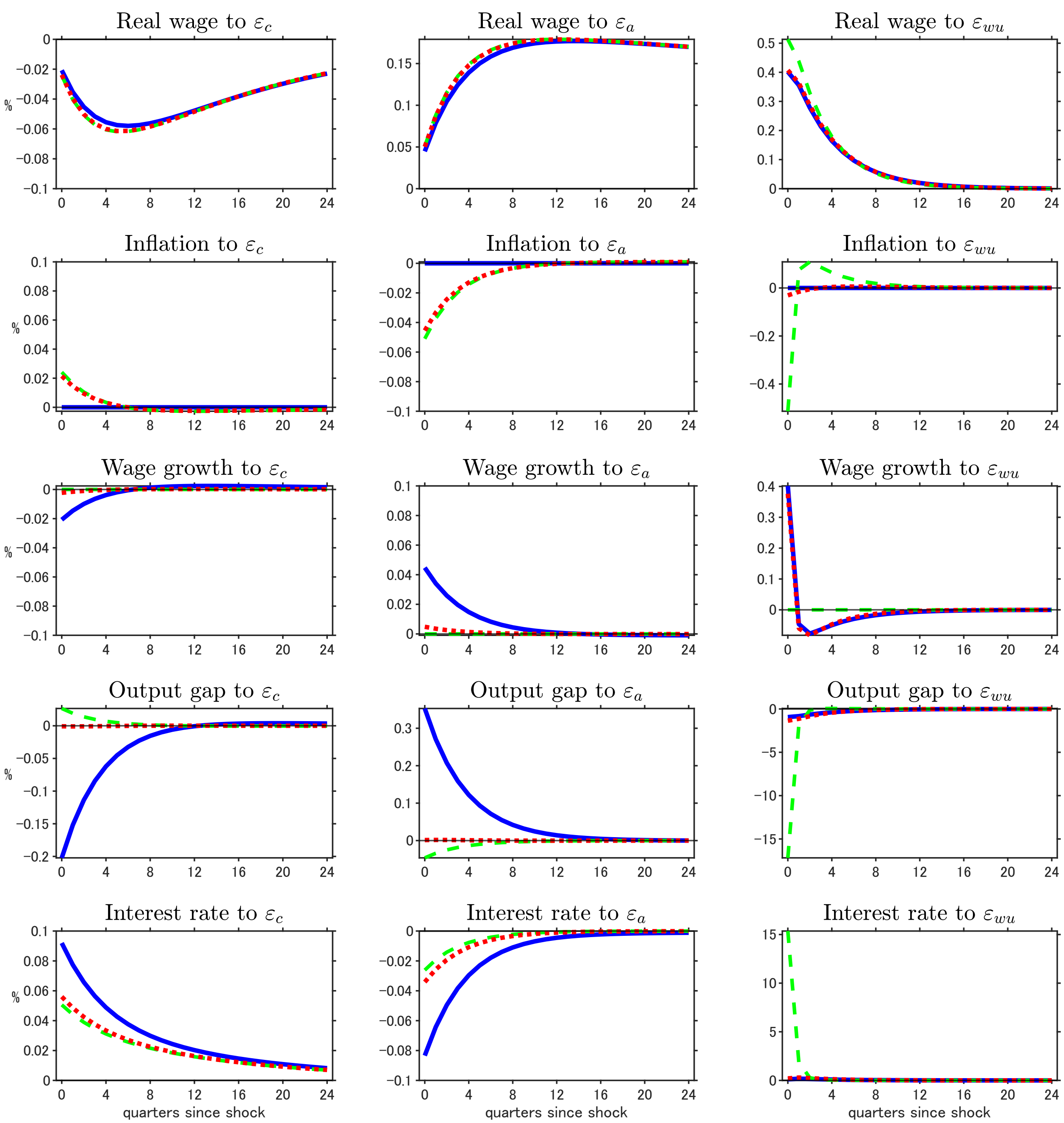
Tables 1 and 2. The shock also raises the natural rate of interest and hence the policy rate along with the increases in the inflation rate and the output gap through the output gap Euler equation (63).

The second column of the figure displays the impulse responses to a positive productivity shock $\varepsilon_{a,t}$. This shock increases the natural rates of the real wage and output. To close the output and real wage gaps, the timeless-perspective policy leads output to rise slightly more than the natural rate of output and the real wage to rise by decreasing the inflation rate along with a small increase in the wage growth rate. The small response of the wage growth rate compared to that of the inflation rate corresponds with the responses to the consumption preference shock presented above. The shock decreases the natural rate of interest slightly, which lowers the policy rate along with the decrease in the inflation rate through the output gap Euler equation (63).

The third column plots the impulse responses to a positive wage markup shock $\varepsilon_{wu,t}$. This shock does not change the natural rates of the real wage, output, and interest and directly increases the wage growth rate, so the timeless-perspective policy cannot prevent the increase. Therefore, the real wage rises under price rigidity, which raises the marginal product of labor in the presence of monopolistically competitive labor markets by reducing (the) output (gap) under decreasing returns to scale. When the effects of the shock decay, the decrease in the output gap is mitigated, so that the interest rate rises through the output gap Euler equation (63).

The first two columns show that the responses of wage growth to consumption preference and productivity shocks are much smaller than the responses of inflation, and suggest that the timeless-perspective policy conditional on the two shocks features wage growth stabilization in the model with monopolistic wage-setting, as also pointed out by Erceg et al. (2000). These authors find that stabilizing wage growth is a more desirable policy strategy than stabilizing inflation in response to shocks to firms' productivity and to households' preferences over consumption and leisure. To revisit their finding, Figure 6 compares the impulse responses under the timeless-perspective policy (60)–(62) to those under full inflation stabilization (i.e., $\hat{\pi}_t = 0$ in each period t) and under full wage growth stabilization (i.e., $\hat{\pi}_{w,t} = 0$ in each period t). For each of the three shocks (i.e., the consumption preference shock $\varepsilon_{c,t}$, the productivity shock $\varepsilon_{a,t}$, and the wage markup shock $\varepsilon_{wu,t}$), the real wage displays a similar response under

Figure 6: Impulse responses under full inflation stabilization and full wage growth stabilization in the counterpart model with monopolistic wage-setting.



Notes: The figure displays the impulse responses of the counterpart model with monopolistic wage-setting under full inflation stabilization as solid lines, those under full wage growth stabilization as dashed lines, and those under the timeless-perspective policy as dotted lines. The panels in each column plot how the real wage $\hat{w}$, the inflation rate $\hat{\pi}$, the wage growth rate $\hat{\pi}_w$, the output gap $\hat{y} - \hat{y}^n$, and the interest rate $\hat{r}$ respond to, respectively, one-standard-deviation positive innovations to the consumption preference shock ε_c, the productivity shock ε_a, and the wage markup shock ε_{wu}. All responses are expressed as percentages. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

each of the three policy strategies. To achieve the real wage response, the timeless-perspective policy and full wage growth stabilization generate almost the same responses of the inflation and wage growth rates and the output gap to the consumption preference shock and the productivity shock. In contrast, full inflation stabilization induces larger responses of the wage growth rate and the output gap to each of the two shocks and hence a larger welfare loss based on the weights on variability of wage growth and the output gap in the welfare function (47) than the timeless-perspective policy does. Thus, wage growth stabilization is an important feature of the timeless-perspective policy conditional on the preference and productivity shocks.

However, such a feature is not observed in the timeless-perspective policy conditional on the wage markup shock. The positive shock puts upward pressure on the wage growth rate on impact, which full wage growth stabilization cancels out through the wage Phillips curve (58) by severely dampening (the) output (gap) as well as the inflation rate to raise the real wage (gap). These large drops in the inflation rate and the output gap induce a larger welfare loss than do their small changes under the timeless-perspective policy, even though the latter policy reduces welfare due to the large increase in the wage growth rate and the large weight on wage growth variability in the welfare function (47). For the wage markup shock, full inflation stabilization generates almost the same responses of the real wage, the output gap, and the inflation, wage growth, and interest rates as those under the timeless-perspective policy. Therefore, the timeless-perspective policy conditional on the wage markup shock features inflation stabilization, which extends the understanding of the policy beyond Erceg et al. (2000).

5.3 Quantitative welfare comparison of policy strategies

In the preceding subsection we have indicated that the timeless-perspective policy in our model features inflation stabilization. In this subsection we dig deeper into this feature by conducting a quantitative welfare comparison of different policy strategies. Two sets of policy strategies are considered. The first set consists of fully stabilizing the inflation rate (i.e., $\hat{\pi}_t = 0$), the wage growth rate (i.e., $\hat{\pi}_{w,t} = 0$), and the output gap (i.e., $\hat{y}_t - \hat{y}_t^n = 0$) in each period t. The second set consists of following the interest-rate feedback rule (37) with responses to the inflation or wage growth rate as well as the output gap.

We quantify the welfare loss from adopting a policy strategy by comparing the welfare cost incurred under the policy strategy to that under the timeless-perspective policy. Let $W_{d,tpp}$ and $W_{d,aps}$ represent the levels of welfare (46) under the timeless-perspective policy and under an alternative policy strategy in question, respectively, and let δ denote the permanent consumption loss from adopting the policy strategy as a fraction of consumption under the timeless-perspective policy. This welfare loss depends on the two welfare levels as follows:

$$\delta = 1 - \exp\left(W_{d,aps} - W_{d,tpp}\right).$$

Table 3 presents the variances of the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, and the output gap $\hat{y}_t - \hat{y}_t^n$ generated by each policy strategy and the permanent consumption loss δ from adopting the policy strategy compared to the timeless-perspective policy (53)–(55) in our model with the parameter values reported in Tables 1 and 2. Panels (a)–(c) show the cases of only the consumption preference shock $\varepsilon_{c,t}$, only the productivity shock $\varepsilon_{a,t}$, and only the wage markdown shock $\varepsilon_{wd,t}$, respectively, and panel (d) considers the case in which the three shocks occur independently.

The table highlights three points for each of the three shocks and for their combination. First, full inflation stabilization $\hat{\pi}_t = 0$ achieves almost the same welfare level as the timeless-perspective policy does. This confirms that the timeless-perspective policy features inflation stabilization in our model, as indicated above. Second, full inflation stabilization attains a better welfare level than those under full wage growth stabilization $\hat{\pi}_{w,t} = 0$ and under full output gap stabilization $\hat{y}_t - \hat{y}_t^n = 0$. Thus stabilizing the inflation rate is a more desirable policy strategy than stabilizing the wage growth rate, as implied in Figure 4, and stabilizing the output gap.[11] Third, the interest-rate feedback rule with responses to the inflation rate of $\phi_p = 1.5$ gives rise to a better welfare level than that with responses to the wage growth rate of $\phi_w = 1.5$. Because the inflation weight is about an order of magnitude larger than the other weights in the welfare function (45) as emphasized above, a policy strategy that generates a smaller variance of the inflation rate tends to be more desirable.

The quantitative welfare comparison of different policy strategies in the counterpart

[11] Fully stabilizing the output gap induces a large welfare cost in our model, because such a policy strategy requires that the price and wage markups coincide according to (52). Consequently, inflation and wage growth have offsetting effects on the real wage, which increases their variability.

Table 3: Welfare losses from adopting different policy strategies in our model.

	$Var\,(\hat{\pi}_t)$	$Var\,(\hat{\pi}_{w,t})$	$Var\,(\hat{y}_t - \hat{y}_t^n)$	δ
Welfare weight	46.602	4.820	3.571	—
(a) *Consumption preference shock* $\varepsilon_{c,t}$				
Timeless-perspective	0.000	0.001	0.002	—
$\hat{\pi}_t = 0$	0.000	0.002	0.002	0.000
$\hat{\pi}_{w,t} = 0$	0.002	0.000	0.002	0.000
$\hat{y}_t - \hat{y}_t^n = 0$	1.074	1.366	0.000	0.283
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.054	0.049	0.002	0.014
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.063	0.053	0.002	0.016
(b) *Productivity shock* $\varepsilon_{a,t}$				
Timeless-perspective	0.000	0.004	0.005	—
$\hat{\pi}_t = 0$	0.000	0.005	0.005	0.000
$\hat{\pi}_{w,t} = 0$	0.004	0.000	0.005	0.001
$\hat{y}_t - \hat{y}_t^n = 0$	2.588	3.293	0.000	0.680
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.002	0.008	0.005	0.001
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.011	0.002	0.005	0.003
(c) *Wage markdown shock* $\varepsilon_{wd,t}$				
Timeless-perspective	0.002	0.174	0.104	—
$\hat{\pi}_t = 0$	0.000	0.221	0.106	0.001
$\hat{\pi}_{w,t} = 0$	0.184	0.000	0.094	0.038
$\hat{y}_t - \hat{y}_t^n = 0$	44.629	44.629	0.000	10.835
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.021	0.233	0.104	0.006
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.238	0.015	0.094	0.051
(d) *Combination of three shocks* $\varepsilon_{c,t}$, $\varepsilon_{a,t}$, *and* $\varepsilon_{wd,t}$				
Timeless-perspective	0.002	0.179	0.111	—
$\hat{\pi}_t = 0$	0.000	0.227	0.113	0.001
$\hat{\pi}_{w,t} = 0$	0.190	0.000	0.101	0.039
$\hat{y}_t - \hat{y}_t^n = 0$	48.291	49.288	0.000	11.691
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.077	0.290	0.110	0.020
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.312	0.070	0.101	0.069

Notes: The second line of the table displays the values of the weights on variability of the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, and the output gap $\hat{y}_t - \hat{y}_t^n$ in the welfare function (45) in our model. The second to fourth columns then respectively present the variances of the inflation rate, the wage growth rate, and the output gap generated by the policy strategies listed in the first column. The last column shows the permanent consumption loss δ from adopting each of the policy strategies, as a percentage of consumption under the timeless-perspective policy. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

model with monopolistic wage-setting is presented in Table 4. The first two panels of the table show the following three points for both the consumption preference shock $\varepsilon_{c,t}$ and the productivity shock $\varepsilon_{a,t}$. First, full wage growth stabilization $\hat{\pi}_{w,t} = 0$ achieves almost the same welfare level as the timeless-perspective policy does, conditional on the consumption preference and productivity shocks. Second, full wage growth stabilization is a better policy strategy than full inflation stabilization $\hat{\pi}_t = 0$, conditional on the two shocks, as in Erceg et al. (2000) and implied in Figure 6. Third, the interest-rate feedback rule (37) with responses to the wage growth rate of $\phi_w = 1.5$ is a more desirable policy strategy than that with responses to the inflation rate of $\phi_p = 1.5$, conditional on the consumption preference shocks. Because the weight on the wage growth rate is much larger than the other weights in the welfare function (45) as emphasized above, a policy strategy that generates a smaller variance of the wage growth rate tends to be more desirable. Moreover, full output gap stabilization $\hat{y}_t - \hat{y}_t^n = 0$ is a relatively good policy strategy, as pointed out by Erceg et al. (2000).[12] In contrast, the third and fourth panels suggest that full wage growth stabilization is the worst policy strategy among those considered, conditional on the wage markup shock and on the combination of the three shocks. Although the variance of the wage markup shock implied by the estimates in Table 2 is small relative to the other shock variances, a shock to the wage markup directly shifts the wage growth rate, which makes its stabilization very costly. As a consequence, inflation stabilization works best on average over the three shocks.

Before proceeding to the conclusion, we conduct robustness exercises regarding the degree of nominal wage rigidity ξ_w, the elasticity of each worker's labor supply χ, and the elasticity of substitution between individual workers' labor supply θ_{wd}. In particular, we consider larger values of $\xi_w = 0.875$, $\chi = 3$, and $\theta_{wd} = 10.85$, because they all increase the weight on wage growth variability in the welfare function (45) and hence the welfare loss incurred by that variability. Indeed, a rise from $\xi_w = 0.75$ to 0.875, from $\chi = 2/3$ to 3, and from the estimate of $\theta_{wd} = 5.875$ to the value of 10.85 used in Berger et al. (2022) increases the wage growth weight of the welfare function (45) from $\chi\alpha/\kappa_{wd} = 4.820$ to 21.652, 11.973,

[12] In contrast to our model with monopsonistic wage-setting, fully stabilizing the output gap implies a trade-off between the price and wage markups according to (59) in the counterpart model with monopolistic wage-setting. Consequently, inflation and wage growth move in opposite directions, which requires less variability in them to attain desired changes in the real wage.

Table 4: Welfare losses from adopting different policy strategies in the counterpart model with monopolistic wage-setting.

	$Var(\hat{\pi}_t)$	$Var(\hat{\pi}_{w,t})$	$Var(\hat{y}_t - \hat{y}_t^n)$	δ
Welfare weight	46.602	123.604	3.571	—
(a) *Consumption preference shock* $\varepsilon_{c,t}$				
Timeless-perspective	0.001	0.000	0.000	—
$\hat{\pi}_t = 0$	0.000	0.001	0.063	0.002
$\hat{\pi}_{w,t} = 0$	0.001	0.000	0.001	0.000
$\hat{y}_t - \hat{y}_t^n = 0$	0.001	0.000	0.000	0.000
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.024	0.020	0.036	0.018
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.019	0.015	0.054	0.014
(b) *Productivity shock* $\varepsilon_{a,t}$				
Timeless-perspective	0.003	0.000	0.000	—
$\hat{\pi}_t = 0$	0.000	0.007	0.199	0.007
$\hat{\pi}_{w,t} = 0$	0.006	0.000	0.005	0.000
$\hat{y}_t - \hat{y}_t^n = 0$	0.004	0.000	0.000	0.000
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.003	0.001	0.009	0.001
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.007	0.000	0.016	0.001
(c) *Wage markup shock* $\varepsilon_{wu,t}$				
Timeless-perspective	0.000	0.162	1.156	—
$\hat{\pi}_t = 0$	0.000	0.150	1.651	0.001
$\hat{\pi}_{w,t} = 0$	0.087	0.000	86.973	1.442
$\hat{y}_t - \hat{y}_t^n = 0$	0.040	0.267	0.000	0.053
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.023	0.231	0.088	0.029
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.058	0.277	0.289	0.069
(d) *Combination of three shocks* $\varepsilon_{c,t}$, $\varepsilon_{a,t}$, *and* $\varepsilon_{wu,t}$				
Timeless-perspective	0.004	0.163	1.157	—
$\hat{\pi}_t = 0$	0.000	0.158	1.913	0.010
$\hat{\pi}_{w,t} = 0$	0.093	0.000	86.979	1.442
$\hat{y}_t - \hat{y}_t^n = 0$	0.045	0.267	0.000	0.053
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.050	0.252	0.133	0.047
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.084	0.292	0.358	0.084

Notes: The second line of the table displays the values of the weights on variability of the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, and the output gap $\hat{y}_t - \hat{y}_t^n$ in the welfare function (47) in the counterpart model with monopolistic wage-setting. The second to fourth columns then respectively present the variances of the inflation rate, the wage growth rate, and the output gap generated by the policy strategies listed in the first column. The last column shows the permanent consumption loss δ from adopting each of the policy strategies, as a percentage of consumption under the timeless-perspective policy. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2.

and 5.103, respectively. We then confirm the robustness of our results (as can be seen in Tables A1–A3 of Appendix B). Full inflation stabilization $\hat{\pi}_t = 0$ generates almost the same welfare level as the timeless-perspective policy does for the consumption preference shock $\varepsilon_{c,t}$, the productivity shock $\varepsilon_{a,t}$, and the wage markdown shock $\varepsilon_{wd,t}$ and for the combination of these three shocks. Therefore, the timeless-perspective policy features inflation stabilization in our model. Full inflation stabilization also achieves a higher welfare level than full wage growth stabilization $\hat{\pi}_{w,t} = 0$ for each of the three shocks and for their combination. Thus, stabilizing inflation is a more desirable policy strategy than stabilizing wage growth in our model.[13]

6 Conclusion

We have introduced firms' wage-setting under monopsonistic competition in an otherwise standard sticky-price model and indicated that it substantially alters the implications for wage growth dynamics, welfare, and policy. Compared to its counterpart model with monopolistic wage-setting, our model implies that the wage Phillips curve includes the wage markdown as its main driver and has a steeper slope generated by strategic substitutability in wage-setting, and thus the second-order approximation to the representative household's utility function is of the same form but with a smaller welfare weight on wage growth variability. Therefore, we demonstrate in our model that the timeless-perspective policy features inflation stabilization and that stabilizing inflation is a more desirable policy strategy than stabilizing wage growth.

In this paper we assume either monopsonistically or monopolistically competitive labor markets. We could consider the coexistence of these two types of labor markets in the model economy. Specifically, some households supply labor in monopsonistically competitive labor markets, while the others do so in monopolistically competitive labor markets. A two-agent model of this sort would be useful to analyze the distributional effects of monetary policy, which is a possible agenda for future research.

Another possible agenda is to extend our model by introducing worker entry into and exit

[13] The results of the counterpart model also hold qualitatively for the larger values of $\xi_w = 0.875$ and $\chi = 3$, as these parameter values make the wage growth weight of the welfare function (47) even larger.

from the labor force along the lines of Kurozumi and Van Zandweghe (2025). We could then analyze the implications of an extensive margin of labor for wage growth dynamics, welfare, and policy. In particular, we could examine how monetary policy should be conducted in terms of inflation and employment stabilization.

Appendix

A Derivation of Welfare Function

In this appendix we derive a second-order approximation to the utility function (1). The period consumption utility function can be approximated up to the second order as

$$\log C_t \exp \varepsilon_{c,t} \approx \hat{y}_t + \hat{y}_t \, \varepsilon_{c,t} + tip.$$

Therefore, the second-order approximation to the consumption part of the utility function yields

$$E_0 \sum_{t=0}^{\infty} \beta^t \log C_t \exp \varepsilon_{c,t} \approx E_0 \sum_{t=0}^{\infty} \beta^t \left(\hat{y}_t + \hat{y}_t \, \varepsilon_{c,t} \right) + tip. \tag{64}$$

Next, the period labor disutility function can be reduced to

$$\int_0^1 \frac{1}{1+1/\chi} \left(l_t(m) \right)^{1+\frac{1}{\chi}} dm = \frac{1}{1+1/\chi} \left(\frac{y_t \, \Delta_t}{\exp \varepsilon_{a,t}} \right)^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)} \left(\frac{mrs_t}{w_t} \right)^{-(1+\chi)} \Delta_{wd,t}, \tag{65}$$

where $\Delta_{wd,t}$ represents the relative wage distortion:

$$\Delta_{wd,t} \equiv \int_0^1 \left(\frac{P_t W_t(m)}{P_t W_t} \right)^{1+\chi} dm,$$

which can be reduced under staggered wage-setting to

$$\Delta_{wd,t} = \xi_w \, \Delta_{wd,t-1} \left(\frac{\pi_w}{\pi_{w,t}} \right)^{1+\chi} + (1-\xi_w) \left(w_t^* \right)^{1+\chi}. \tag{66}$$

Log-linearizing the composite goods' price (20) yields

$$\hat{p}_t^* \approx \frac{\xi_p}{1-\xi_p} \, \hat{\pi}_t. \tag{67}$$

Moreover, the second-order approximation to (20) leads to

$$\hat{p}_t^* \approx \frac{\xi_p}{1-\xi_p} \left(\hat{\pi}_t + \frac{\theta_p - 1}{2(1-\xi_p)} \, \hat{\pi}_t^2 \right). \tag{68}$$

Log-linearizing the relative price distortion's law of motion (22) yields $\hat{\Delta}_t \approx 0$ and thus Δ_t is of second order. Using this as well as (67) and (68), the second-order approximation to (22) leads to

$$\hat{\Delta}_t \approx \xi_p \, \hat{\Delta}_{t-1} + \frac{\theta_p \xi_p}{2(1-\xi_p)} \, \hat{\pi}_t^2 = \sum_{j=0}^{t} \xi_p^{t-j} \frac{\theta_p \xi_p}{2(1-\xi_p)} \, \hat{\pi}_j^2 + tip,$$

and therefore

$$\sum_{t=0}^{\infty} \beta^t \hat{\Delta}_t \approx \sum_{t=0}^{\infty} \beta^t \sum_{j=0}^{t} \xi_p^{t-j} \frac{\theta_p \xi_p}{2(1-\xi_p)} \, \hat{\pi}_j^2 + tip$$
$$= \sum_{t=0}^{\infty} \beta^t \frac{\theta_p \xi_p}{2(1-\xi_p)(1-\beta\xi_p)} \, \hat{\pi}_t^2 + tip = \sum_{t=0}^{\infty} \beta^t \frac{1}{2} \frac{\theta_p}{\kappa_p} \, \hat{\pi}_t^2 + tip. \tag{69}$$

Log-linearizing the aggregate wage (14) yields

$$\hat{w}_t^* \approx \frac{\xi_w}{1-\xi_w} \, \hat{\pi}_{w,t}, \tag{70}$$

and then the second-order approximation to (14) leads to

$$\hat{w}_t^* \approx \frac{\xi_w}{1-\xi_w} \left(\hat{\pi}_{w,t} - \frac{1+\theta_{wd}}{2(1-\xi_w)} \, \hat{\pi}_{w,t}^2 \right). \tag{71}$$

The log-linearized aggregate labor supply (25) implies that mrs_t/w_t is of second order. Using (25), (70), and (71), the second-order approximation to the aggregate labor supply (15) yields

$$\hat{mrs}_t - \hat{w}_t \approx \xi_w \left(\hat{mrs}_{t-1} - \hat{w}_{t-1} \right) + \frac{(1+\theta_{wd})\xi_w}{2(1-\xi_w)} \left(\frac{\chi}{\theta_{wd}} - 1 \right) \hat{\pi}_{w,t}^2$$
$$= \sum_{j=0}^{t} \xi_w^{t-j} \frac{(1+\theta_{wd})\xi_w}{2(1-\xi_w)} \left(\frac{\chi}{\theta_{wd}} - 1 \right) \hat{\pi}_{w,j}^2 + tip,$$

and therefore

$$\sum_{t=0}^{\infty} \beta^t \left(\hat{mrs}_t - \hat{w}_t \right) \approx \sum_{t=0}^{\infty} \beta^t \sum_{j=0}^{t} \xi_w^{t-j} \frac{(1+\theta_{wd})\xi_w}{2(1-\xi_w)} \left(\frac{\chi}{\theta_{wd}} - 1 \right) \hat{\pi}_{w,j}^2 + tip$$
$$= \sum_{t=0}^{\infty} \beta^t \frac{(1+\theta_{wd})\xi_w}{2(1-\xi_w)(1-\beta\xi_p)} \left(\frac{\chi}{\theta_{wd}} - 1 \right) \hat{\pi}_{w,t}^2 + tip. \tag{72}$$

Moreover, log-linearizing the relative wage distortion's law of motion (66) leads to $\hat{\Delta}_{wd,t} \approx 0$ and thus $\Delta_{wd,t}$ is of second order. Using this as well as (70) and (71), the second-order approximation to (66) yields

$$\hat{\Delta}_{wd,t} \approx \xi_w \, \hat{\Delta}_{wd,t-1} + \frac{\theta_{wd}(1+\chi)\xi_w}{2(1-\xi_w)} \left(\frac{\chi}{\theta_{wd}} - 1 \right) \hat{\pi}_{w,t}^2 = \sum_{j=0}^{t} \xi_w^{t-j} \frac{\theta_{wd}(1+\chi)\xi_w}{2(1-\xi_w)} \left(\frac{\chi}{\theta_{wd}} - 1 \right) \hat{\pi}_{w,j}^2 + tip,$$

and therefore

$$\sum_{t=0}^{\infty}\beta^t\hat{\Delta}_{wd,t} \approx \sum_{t=0}^{\infty}\beta^t\sum_{j=0}^{t}\xi_w^{t-j}\frac{\theta_{wd}(1+\chi)\xi_w}{2(1-\xi_w)}\left(\frac{\chi}{\theta_{wd}}-1\right)\hat{\pi}_{w,j}^2 + tip$$
$$= \sum_{t=0}^{\infty}\beta^t\frac{\theta_w(1+\chi)\xi_w}{2(1-\xi_w)(1-\beta\xi_w)}\left(\frac{\chi}{\theta_{wd}}-1\right)\hat{\pi}_{w,t}^2 + tip. \tag{73}$$

Since Δ_t, mrs_t/w_t, and $\Delta_{wd,t}$ are of second order as noted above, the period labor disutility function (65) can be approximated up to the second order as

$$\int_0^1 \frac{1}{1+1/\chi}\left(l_t(m)\right)^{1+\frac{1}{\chi}}dm$$
$$\approx \frac{1}{1+1/\chi}\left(y\Delta\right)^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)}\left(\frac{mrs}{w}\right)^{-(1+\chi)}\Delta_{wd}\left\{1+\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)(\hat{y}_t-\varepsilon_{a,t})\right.$$
$$\left. + \frac{1}{2}\left[\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\right]^2(\hat{y}_t-\varepsilon_{a,t})^2 + \frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{\Delta}_t - (1+\chi)\left(\hat{mrs}_t - \hat{w}_t\right) + \hat{\Delta}_{wd,t}\right\},$$

and therefore it follows from (69), (72), and (73) that

$$E_0\sum_{t=0}^{\infty}\beta^t\int_0^1 \frac{1}{1+1/\chi}\left(l_t(m)\right)^{1+\frac{1}{\chi}}dm$$
$$\approx E_0\sum_{t=0}^{\infty}\beta^t\left(\frac{1}{1+1/\chi}\left(y\Delta\right)^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)}\left(\frac{mrs}{w}\right)^{-(1+\chi)}\Delta_{wd}\left\{1+\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)(\hat{y}_t-\varepsilon_{a,t})\right.\right.$$
$$\left.\left. + \frac{1}{2}\left[\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\right]^2(\hat{y}_t-\varepsilon_{a,t})^2 + \frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{\Delta}_t - (1+\chi)\left(\hat{mrs}_t - \hat{w}_t\right) + \hat{\Delta}_{wd,t}\right\}\right)$$
$$= \frac{1}{\alpha}\left(y\Delta\right)^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)}\left(\frac{mrs}{w}\right)^{-(1+\chi)}\Delta_{wd}\,E_0\sum_{t=0}^{\infty}\beta^t\left[\frac{1}{2}\frac{\theta_p}{\kappa_p}\hat{\pi}_t^2 - \frac{1}{2}\frac{\chi\alpha(1+\theta_{wd})\xi_w}{(1-\xi_w)(1-\beta\xi_p)}\left(\frac{\chi}{\theta_{wd}}-1\right)\hat{\pi}_{w,t}^2\right.$$
$$\left. + \frac{1}{2}\frac{\chi\alpha\theta_{wd}\xi_w}{(1-\xi_w)(1-\beta\xi_p)}\left(\frac{\chi}{\theta_{wd}}-1\right)\hat{\pi}_{w,t}^2 + \frac{1}{2}\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t^2 + \hat{y}_t - \frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t\,\varepsilon_{a,t}\right] + tip$$
$$= \frac{1}{\alpha}\left(y\Delta\right)^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)}\left(\frac{mrs}{w}\right)^{-(1+\chi)}\Delta_{wd}\,E_0\sum_{t=0}^{\infty}\beta^t\left[\frac{1}{2}\frac{\theta_p}{\kappa_p}\hat{\pi}_t^2 + \frac{1}{2}\frac{\chi\alpha\xi_w(1-\chi/\theta_{wd})}{(1-\xi_w)(1-\beta\xi_p)}\hat{\pi}_{w,t}^2\right.$$
$$\left. + \frac{1}{2}\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t^2 + \hat{y}_t - \frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t\,\varepsilon_{a,t}\right] + tip$$
$$= \frac{1}{\alpha}\left(y\Delta\right)^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)}\left(\frac{mrs}{w}\right)^{-(1+\chi)}\Delta_{wd}\,E_0\sum_{t=0}^{\infty}\beta^t\left[\frac{1}{2}\frac{\theta_p}{\kappa_p}\hat{\pi}_t^2 + \frac{1}{2}\frac{\chi\alpha}{\kappa_{wd}}\hat{\pi}_{w,t}^2 + \frac{1}{2}\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t^2 + \hat{y}_t\right.$$
$$\left. - \frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t\,\varepsilon_{a,t}\right] + tip$$

In an efficient steady state of the model we have

$$\frac{1}{y} = \frac{1}{\alpha}\, y^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)-1} \Delta^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)} \left(\frac{mrs}{w}\right)^{-(1+\chi)} \Delta_{wd} \Leftrightarrow 1 = \frac{1}{\alpha}\,(y\Delta)^{\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)} \left(\frac{mrs}{w}\right)^{-(1+\chi)} \Delta_{wd}.$$

Thus we have

$$E_0 \sum_{t=0}^{\infty} \beta^t \int_0^1 \frac{1}{1+1/\chi}\,(l_t(m))^{1+\frac{1}{\chi}}\, dm$$

$$\approx E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{2}\frac{\theta_p}{\kappa_p}\,\hat{\pi}_t^2 + \frac{1}{2}\frac{\chi\alpha}{\kappa_{wd}}\,\hat{\pi}_{w,t}^2 + \frac{1}{2}\frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t^2 + \hat{y}_t - \frac{1}{\alpha}\left(1+\frac{1}{\chi}\right)\hat{y}_t\,\varepsilon_{a,t}\right] + tip. \quad (74)$$

Therefore, from (64) and (74), the second-order approximation to the utility function (1) yields the welfare function (45).

B Results of Robustness Exercises

In this appendix we present the results of the robustness exercises regarding the degree of nominal wage rigidity ξ_w, the elasticity of each worker's labor supply χ, and the elasticity of substitution between individual workers' labor supply θ_{wd}. We consider values of $\xi_w = 0.875$, $\chi = 3$, and $\theta_{wd} = 10.85$, larger than our calibrated values reported in Tables 1 and 2, because all of them increase the weight on wage growth variability in the welfare function (45) and hence the welfare loss incurred by that variability. Indeed, a rise from $\xi_w = 0.75$ to 0.875, from $\chi = 2/3$ to 3, and from $\theta_{wd} = 5.875$ to 10.85 increases the wage growth weight of the welfare function (45) from $\chi\alpha/\kappa_{wd} = 4.820$ to 21.652, 11.973, and 5.103, respectively.

Focusing first on the degree of nominal wage rigidity, Table A1 presents the variances of the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, and the output gap $\hat{y}_t - \hat{y}_t^n$ generated by each policy strategy and the permanent consumption loss δ from adopting the policy strategy compared to the timeless-perspective policy (53)–(55) in our model with the parameter values reported in Tables 1 and 2, except for $\xi_w = 0.875$. Table A1 confirms the robustness of our results with respect to the degree of nominal wage rigidity. Full inflation stabilization $\hat{\pi}_t = 0$ generates almost the same variances of the inflation rate, the wage growth rate, and the output gap and hence almost the same welfare level as the timeless-perspective policy does for the consumption preference shock $\varepsilon_{c,t}$, the productivity shock $\varepsilon_{a,t}$, and the wage markdown shock $\varepsilon_{wd,t}$ and for the combination of these three shocks. Therefore, the

Table A1: Welfare losses from adopting different policy strategies in our model: robustness exercise with respect to ξ_w.

	$Var\,(\hat{\pi}_t)$	$Var\,(\hat{\pi}_{w,t})$	$Var\,(\hat{y}_t - \hat{y}_t^n)$	δ
Welfare weight	46.602	21.652	3.571	—
(a) *Consumption preference shock* $\varepsilon_{c,t}$				
Timeless-perspective	0.000	0.000	0.004	—
$\hat{\pi}_t = 0$	0.000	0.001	0.004	0.000
$\hat{\pi}_{w,t} = 0$	0.002	0.000	0.002	0.000
$\hat{y}_t - \hat{y}_t^n = 0$	0.031	0.002	0.000	0.007
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.059	0.050	0.009	0.019
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.123	0.058	0.018	0.035
(b) *Productivity shock* $\varepsilon_{a,t}$				
Timeless-perspective	0.000	0.001	0.010	—
$\hat{\pi}_t = 0$	0.000	0.001	0.011	0.000
$\hat{\pi}_{w,t} = 0$	0.004	0.000	0.005	0.001
$\hat{y}_t - \hat{y}_t^n = 0$	0.076	0.005	0.000	0.018
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.001	0.003	0.013	0.000
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.024	0.001	0.001	0.005
(c) *Wage markdown shock* $\varepsilon_{wd,t}$				
Timeless-perspective	0.006	0.365	0.447	—
$\hat{\pi}_t = 0$	0.000	0.400	0.398	0.002
$\hat{\pi}_{w,t} = 0$	3.720	0.000	1.889	0.848
$\hat{y}_t - \hat{y}_t^n = 0$	1.304	1.304	0.000	0.395
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.058	0.443	0.482	0.021
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	3.592	0.329	0.792	0.834
(d) *Combination of three shocks* $\varepsilon_{c,t}$, $\varepsilon_{a,t}$, *and* $\varepsilon_{wd,t}$				
Timeless-perspective	0.006	0.366	0.460	—
$\hat{\pi}_t = 0$	0.000	0.402	0.413	0.002
$\hat{\pi}_{w,t} = 0$	3.726	0.000	1.897	0.849
$\hat{y}_t - \hat{y}_t^n = 0$	1.411	1.310	0.000	0.420
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.118	0.496	0.504	0.041
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	3.740	0.389	0.811	0.875

Notes: The second line of the table displays the values of the weights on variability of the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, and the output gap $\hat{y}_t - \hat{y}_t^n$ in the welfare function (45) in our model. The second to fourth columns then respectively present the variances of the inflation rate, the wage growth rate, and the output gap generated by the policy strategies listed in the first column. The last column shows the permanent consumption loss δ from adopting each of the policy strategies, as a percentage of consumption under the timeless-perspective policy. The values of model parameters used are those reported in Table 1, except for $\xi_w = 0.875$, and the posterior mean estimates reported in Table 2.

timeless-perspective policy features inflation stabilization. Full inflation stabilization also achieves a higher welfare level than full wage growth stabilization $\hat{\pi}_{w,t} = 0$ does for each of the three shocks and for their combination. Thus, fully stabilizing inflation is a more desirable policy strategy than fully stabilizing wage growth. Moreover, the interest-rate feedback rule (37) with responses to the inflation rate of $\phi_p = 1.5$ is a better policy strategy than that with responses to the wage growth rate of $\phi_w = 1.5$, since the former attains a higher welfare level than the latter for each of the three shocks and for their combination.

We next turn to the elasticity of each worker's labor supply χ. Table A2 presents the results of the robustness exercise that uses the values of model parameters reported in Tables 1 and 2, except for $\chi = 3$. In the welfare function (45), a rise from $\chi = 2/3$ to 3 increases the weight on wage growth variability from $\chi\alpha/\kappa_{wu} = 4.820$ to 11.973 and decreases the weight on output gap variability $(1 + 1/\chi)/\alpha = 3.571$ to 1.905. Table A2 confirms that for the consumption preference shock $\varepsilon_{c,t}$, the productivity shock $\varepsilon_{a,t}$, and the wage markdown shock $\varepsilon_{wd,t}$ and for the combination of these three shocks, full inflation stabilization $\hat{\pi}_t = 0$ achieves almost the same welfare level as the timeless-perspective policy does and is a more desirable policy strategy than full wage growth stabilization $\hat{\pi}_{w,t} = 0$. As for the interest-rate feedback rule (37), the rise in χ not only increases the wage growth weight but also decreases the output gap weight in the welfare function, and thus raises the welfare loss incurred by wage growth variability and lowers that incurred by output gap variability. As a consequence, the interest-rate rule with responses to the wage growth rate of $\phi_w = 1.5$ is a better policy strategy than that with responses to the inflation rate of $\phi_p = 1.5$.

Last, we show the results of the robustness exercise regarding the elasticity of substitution between individual workers' labor supply. The results, presented in Table A3, use the values of model parameters reported in Tables 1 and 2, except for $\theta_{wd} = 10.85$. A rise from $\theta_{wd} = 5.875$ to 10.85 increases the wage growth weight of the welfare function (45) from $\chi\alpha/\kappa_{wu} = 4.820$ to 5.103. As with the robustness exercise on the degree of nominal wage rigidity ξ_w, Table A3 confirms that for each of the three shocks and for their combination, full inflation stabilization $\hat{\pi}_t = 0$ achieves almost the same welfare level as the timeless-perspective policy does and is a more desirable policy strategy than full wage growth stabilization $\hat{\pi}_{w,t} = 0$. Moreover, the interest-rate feedback rule (37) with responses to the inflation rate of $\phi_p = 1.5$ is a better policy strategy than that with responses to the wage growth rate of $\phi_w = 1.5$.

Table A2: Welfare losses from adopting different policy strategies in the model: robustness exercise with respect to χ.

	Var $(\hat{\pi}_t)$	*Var* $(\hat{\pi}_{w,t})$	*Var* $(\hat{y}_t - \hat{y}_t^n)$	δ
Welfare weight	46.602	11.973	1.905	—
(a) *Consumption preference shock* $\varepsilon_{c,t}$				
Timeless-perspective	0.000	0.005	0.023	—
$\hat{\pi}_t = 0$	0.000	0.011	0.019	0.000
$\hat{\pi}_{w,t} = 0$	0.006	0.000	0.031	0.001
$\hat{y}_t - \hat{y}_t^n = 0$	0.057	0.237	0.000	0.027
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.017	0.034	0.014	0.005
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.019	0.008	0.034	0.005
(b) *Productivity shock* $\varepsilon_{a,t}$				
Timeless-perspective	0.000	0.004	0.015	—
$\hat{\pi}_t = 0$	0.000	0.007	0.013	0.000
$\hat{\pi}_{w,t} = 0$	0.005	0.000	0.021	0.001
$\hat{y}_t - \hat{y}_t^n = 0$	0.039	0.163	0.000	0.018
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.003	0.020	0.008	0.002
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.005	0.000	0.022	0.001
(c) *Wage markdown shock* $\varepsilon_{wd,t}$				
Timeless-perspective	0.010	0.044	0.174	—
$\hat{\pi}_t = 0$	0.000	0.143	0.224	0.004
$\hat{\pi}_{w,t} = 0$	0.053	0.000	0.114	0.007
$\hat{y}_t - \hat{y}_t^n = 0$	0.672	0.672	0.000	0.190
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.042	0.146	0.159	0.013
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.062	0.001	0.105	0.009
(d) *Combination of three shocks* $\varepsilon_{c,t}$, $\varepsilon_{a,t}$, *and* $\varepsilon_{wu,t}$				
Timeless-perspective	0.011	0.054	0.212	—
$\hat{\pi}_t = 0$	0.000	0.161	0.257	0.004
$\hat{\pi}_{w,t} = 0$	0.064	0.000	0.167	0.009
$\hat{y}_t - \hat{y}_t^n = 0$	0.767	1.071	0.000	0.235
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.062	0.200	0.182	0.020
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.086	0.009	0.161	0.014

Notes: The second line of the table displays the values of the weights on variability of the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, and the output gap $\hat{y}_t - \hat{y}_t^n$ in the welfare function (45) in our model. The second to fourth columns then respectively present the variances of the inflation rate, the wage growth rate, and the output gap generated by the policy strategies listed in the first column. The last column shows the permanent consumption loss δ from adopting each of the policy strategies, as a percentage of consumption under the timeless-perspective policy. The values of model parameters used are those reported in Table 1, except for $\chi = 3$, and the posterior mean estimates reported in Table 2.

Table A3: Welfare losses from adopting different policy strategies in the model: robustness exercise with respect to θ_{wd}.

	$Var\,(\hat{\pi}_t)$	$Var\,(\hat{\pi}_{w,t})$	$Var\,(\hat{y}_t - \hat{y}_t^n)$	δ
Welfare weight	46.602	5.103	3.571	—
(a) *Consumption preference shock* $\varepsilon_{c,t}$				
Timeless-perspective	0.000	0.001	0.002	—
$\hat{\pi}_t = 0$	0.000	0.002	0.002	0.000
$\hat{\pi}_{w,t} = 0$	0.002	0.000	0.002	0.000
$\hat{y}_t - \hat{y}_t^n = 0$	4.105	4.660	0.000	1.069
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.054	0.049	0.002	0.014
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.064	0.053	0.002	0.016
(b) *Productivity shock* $\varepsilon_{a,t}$				
Timeless-perspective	0.000	0.004	0.005	—
$\hat{\pi}_t = 0$	0.000	0.004	0.005	0.000
$\hat{\pi}_{w,t} = 0$	0.004	0.000	0.005	0.001
$\hat{y}_t - \hat{y}_t^n = 0$	9.893	11.230	0.000	2.558
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.002	0.008	0.005	0.001
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.011	0.002	0.005	0.003
(c) *Wage markdown shock* $\varepsilon_{wd,t}$				
Timeless-perspective	0.002	0.180	0.111	—
$\hat{\pi}_t = 0$	0.000	0.227	0.112	0.001
$\hat{\pi}_{w,t} = 0$	0.207	0.000	0.105	0.043
$\hat{y}_t - \hat{y}_t^n = 0$	170.595	170.595	0.000	35.658
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.022	0.241	0.111	0.006
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.269	0.017	0.105	0.058
(d) *Combination of three shocks* $\varepsilon_{c,t}$, $\varepsilon_{a,t}$, *and* $\varepsilon_{wu,t}$				
Timeless-perspective	0.002	0.185	0.118	—
$\hat{\pi}_t = 0$	0.000	0.233	0.119	0.001
$\hat{\pi}_{w,t} = 0$	0.212	0.000	0.112	0.044
$\hat{y}_t - \hat{y}_t^n = 0$	184.592	186.485	0.000	37.975
$(\phi_p, \phi_w, \phi_y) = (1.5, 0, 0.5/4)$	0.078	0.298	0.118	0.020
$(\phi_p, \phi_w, \phi_y) = (0, 1.5, 0.5/4)$	0.344	0.072	0.112	0.077

Notes: The second line of the table displays the values of the weights on variability of the inflation rate $\hat{\pi}_t$, the wage growth rate $\hat{\pi}_{w,t}$, and the output gap $\hat{y}_t - \hat{y}_t^n$ in the welfare function (45) in our model. The second to fourth columns then respectively present the variances of the inflation rate, the wage growth rate, and the output gap generated by the policy strategies listed in the first column. The last column shows the permanent consumption loss δ from adopting each of the policy strategies, as a percentage of consumption under the timeless-perspective policy. The values of model parameters used are those reported in Table 1 and the posterior mean estimates reported in Table 2, except for $\theta_{wd} = 10.85$.

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