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State Dependency in Price and Wage Setting*

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Abstract

The frequency of nominal wage adjustments varies with macroeconomic conditions. Existing macroeconomic analyses exclude such state dependency in wage setting, assuming exogenous timing and constant frequency of wage adjustments under time-dependent setting (e.g., Calvo- and Taylor-style setting). To investigate how state dependency in wage setting influences the transmission of monetary shocks, this paper develops a New Keynesian model in which the timing and frequency of wage changes are endogenously determined in the presence of fixed wage-setting costs. I find that state-dependent wage setting reduces the real impacts of monetary shocks compared to time-dependent setting. Further, with state dependency, monetary nonneutralities decrease with the elasticity of demand for differentiated labor, while the opposite holds under time-dependent setting.

Next, this paper examines the empirical importance of state dependency in wage setting. To this end, I augment the model with habit formation, capital accumulation, capital adjustment costs, and variable capital utilization. When parameterized to reproduce the fluctuations in wage rigidity observed in the U.S. data, the state-dependent wage-setting model shows a response to monetary shocks quite similar to that of the time-dependent counterpart. The result suggests that for the U.S. economy, state dependency in wage setting is largely irrelevant to the monetary transmission.

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1 Introduction

The transmission of monetary disturbances has been an important issue in macroeconomics. Recent studies using a dynamic general equilibrium model, such as Huang and Liu (2002) and Christiano, Eichenbaum, and Evans (2005), show that nominal wage stickiness is one of the key factors in accounting for the monetary transmission. However, existing studies establish the importance of sticky wages under Calvo (1983)- and Taylor (1980)-style setting. Such time-dependent setting models are extreme in that because of the exogenous timing and constant frequency of wage setting, wage adjustments occur only through changes in the intensive margin. In contrast, there is evidence that the extensive margin also matters, i.e., evidence for state dependency in wage setting. For example, reviewing empirical studies on micro-level wage adjustments, Taylor (1999) concludes that "the frequency of wage setting increases with the average rate of inflation." Further, according to Daly, Hobijn, and Lucking (2012) and Daly and Hobijn (2014), the fraction of wages not changed for a year rises in recessions in the U.S.[1] How does the impact of monetary shocks differ under state- and time-dependent wage setting? Is state dependency in wage setting relevant for the U.S. monetary transmission?

To answer these questions, the present paper constructs a New Keynesian model with state-dependent price and wage setting, building on the seminal state-dependent pricing model of Dotsey, King, and Wolman (1999).[2] The price-setting side of the model is essentially

[1] In addition to these empirical supports, state-dependent wage-setting models are theoretically attractive for policy analysis because the timing and frequency of wage adjustments could change with policy.

[2] The framework of Dotsey, King, and Wolman (1999) is widely used for analyzing aggregate price dynamics. Bakhshi, Kahn, and Rudolf (2007) derive the New Keynesian Phillips curve for the model. Landry (2009, 2010) develop a two-country model with state-dependent pricing and analyze exchange rate movements. Dotsey and King (2005, 2006) analyze the impact of various real-side features on the monetary transmission. Nakov and Thomas (2014) analyze optimal monetary policy.

the same as that of Dotsey, King, and Wolman (1999). Firms change their price in a staggered manner because fixed costs for price adjustments differ across firms. However, since all firms face the identical sequence of marginal costs and price-setting costs are independently distributed over time, adjusting firms set the same price as in typical time-dependent pricing models, making the price distribution tractable. The wage-setting side of the present model departs from the flexible-wage setting of Dotsey, King, and Wolman (1999). Specifically, as in Blanchard and Kiyotaki (1987) and Erceg, Henderson, and Levin (2000), households supply a differentiated labor service and set the wage for their labor. Further, I introduce fixed wage-setting costs that differ across households and evolve independently over time.[3] Hence, households adjust their wage in a staggered way. Since adjusting households set the same wage under assumptions commonly made for time-dependent setting, the wage distribution is also tractable. Therefore, the present model with state dependency in both price and wage setting can be solved with the method developed by Dotsey, King, and Wolman (1999).

This paper finds that compared to the time-dependent counterpart, the state-dependent wage-setting model shows smaller real impacts of monetary shocks.[4] Further, these two wage-setting regimes imply opposite relationships between monetary nonneutralities and the elasticity of demand for differentiated labor services, which is a key parameter for wage setting. Specifically, nonneutralities decrease with the elasticity under state-dependent wage setting, but as shown by Huang and Liu (2002), nonneutralities increase under time-dependent setting.

To understand the impacts of state dependency in wage setting described above, consider an expansionary monetary shock. In the presence of nominal rigidity, the aggregate price, consumption, and labor hours all increase, decreasing real wages and raising the marginal rate of substitution of leisure for consumption. Because the timing of wage adjustments is

[3] Blanchard and Kiyotaki (1987) also assume fixed wage-setting costs. In contrast, Kim and Ruge-Murcia (2009) introduce convex wage-adjustment costs.

[4] Following the convention of the state-dependent pricing literature, under time-dependent setting, the timing and frequency of wage adjustments are fixed to those at the steady state of the state-dependent wage-setting model.

endogenous, the fraction of households raising their wage increases under state-dependent setting. In contrast, the fraction remains unchanged under time-dependent setting. Further, the resetting wage, which is common to all adjusting households, rises more quickly under state- than time-dependent setting. The key to this result is that under monopolistic competition, the demand for households' labor hours increases as the aggregate wage rises relative to their wage. This implies that since more households raise their wage, adjusting households find it optimal to raise their wage more substantially under state- than time-dependent setting. In response, firms raise their price more quickly. Hence, state-dependent wage setting facilitates nominal adjustments following monetary disturbances and reduces nonneutralities compared to time-dependent setting.[5]

The relative wage concern also governs the relationship between monetary nonneutralities and the elasticity of demand for differentiated labor. Under a higher elasticity, households' labor hours more elastically decrease as their wage rises relative to the aggregate wage. Hence, when wage setting is time dependent, adjusting households raise their wage less substantially under a higher elasticity, which implies that monetary nonneutralities increase with the elasticity, as shown by Huang and Liu (2002). This relationship is overturned under state-dependent setting. Under a higher elasticity, labor hours of nonadjusting households increase more substantially and therefore more households raise their wage. In response, adjusting households tend to set a higher wage when the elasticity is higher. As a result, under state-dependent setting, wage adjustments occur more quickly and monetary nonneutralities become smaller when the elasticity is higher.

Next, this paper investigates the empirical importance of state dependency in wage setting for the transmission of monetary shocks. As Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007) show, the real side of a model also plays a crucial role in the monetary transmission. Hence, I augment my model with capital accumulation,

[5] Because adjustment decisions are endogenous under state-dependent setting, adjusting households could shift to those who raise their wage substantially. In the present model, households who conduct a large wage increase are those who fixed their wage for a long period of time. Such a selection effect is weak in the present model, and as shown later, it is consistent with data.

capital adjustment costs, habit formation, and variable capital utilization. Further, I choose the distribution of wage-setting costs so that the model reproduces the fluctuations in the fraction of wages not changed for a year, specifically the variation in the 'Wage Rigidity Meter' released by the Federal Reserve Bank of San Francisco.[6]

I find that the distribution of wage-setting costs is similar to the Calvo-type distribution. More specifically, in any given period, most households draw costs close to zero or the maximum, implying small fluctuations in the extensive margin. As a result, the state-dependent wage-setting model shows a response to monetary shocks quite similar to that of the time-dependent counterpart. For example, the cumulative response of output decreases by less than 10% when wage setting switches from time to state dependent. The result indicates that state dependency in wage setting plays a minor role in the U.S. monetary transmission and time-dependent wage setting models describe the responses to monetary disturbances reasonably well.

This paper is related to the literature that studies how various features of wage setting influence the transmission of monetary shocks. Olivei and Tenreyro (2007, 2010) show that in data, the output response to a monetary shock depends on when the shock occurs and the finding can be explained by the difference in the frequency of wage changes across quarters. Dixon and Le Bihan (2012) show that the heterogeneity in wage spells observed in micro-level data helps accounting for the persistent response of output and inflation to a monetary shock. Although these studies analyze important patterns of wage setting, their models assume time-dependent wage setting. The present paper contributes the literature by examining state dependency in wage setting, which is another feature of wage adjustments.

This paper is also related to the literature on state-dependent price setting. Following Caplin and Spulber (1987) and Caplin and Leahy (1991), more recent contributions analyze how state-dependent pricing influences the monetary transmission in a dynamic stochastic

[6] Such long-term rigid wages are key to generating the persistent response to monetary shocks in New Keynesian models (Dixon and Kara (2010)). Further, as discussed in footnote 5, in the present model, the selection effect mainly works through changes in the fraction of those rigid wages.

general equilibrium model. Examples include Dotsey, King, and Wolman (1999), Dotsey and King (2005, 2006), Devereux and Siu (2007), Golosov and Lucas (2007), Gertler and Leahy (2008), Klenow and Kryvtsov (2005, 2008), Midrigan (2011), and Nakamura and Steinsson (2010). While these studies describe price setting in a rich way, they assume flexible wages. The contribution of the present paper is to construct a full-blown model with state-dependent price and wage setting, which is comparable to the state-of-the-art models with time-dependent price and wage setting developed by Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007).

The rest of this paper is organized as follows. Section 2 introduces the benchmark model with state-dependent price and wage setting, and Section 3 determines the parameter values for the model. Section 4 analyzes the impact of state dependency in wage setting on the transmission of monetary disturbances. Section 5 develops the full model with various real-side features and investigates the relevance of state dependency in wage setting to the U.S. monetary transmission. Section 6 concludes.

2 Benchmark Model

This section introduces state dependency in price and wage setting into a simple New Keynesian model. To this end, I assume fixed costs for price and wage changes and thereby consider endogenous timing of price and wage adjustments.

2.1 Firms

There is a continuum of firms of measure one.[7] Each firm produces a differentiated good indexed by $z \in [0, 1]$. The production function is

$$y_t(z) = k_t(z)^{1-\alpha} n_t(z)^{\alpha}, \tag{1}$$

[7] This subsection closely follows the explanation by Dotsey, King, and Wolman (1999).

where $\alpha \in [0,1], y_t(z)$ is output, $k_t(z)$ is capital, and $n_t(z)$ is the composite labor, which is defined below.[8] As in Dotsey, King, and Wolman (1999) and Erceg, Henderson, and Levin (2000), households own capital, and the total amount of capital is fixed.[9] Firms rent capital and the composite labor in competitive markets. Cost minimization implies the following first-order conditions:

$$\alpha mc_t[\frac{k_t(z)}{n_t(z)}]^{1-\alpha} = w_t \tag{2}$$

and

$$(1-\alpha)mc_t[\frac{k_t(z)}{n_t(z)}]^{-\alpha} = q_t, \tag{3}$$

where mc_t is the real marginal cost, w_t is the real wage for the composite labor, and q_t is the real rental rate of capital.

Each firm sets the price of its product $P_t(z)$, and the demand for each product $c_t(z)$ is given by

$$c_t(z) = [\frac{P_t(z)}{P_t}]^{-\epsilon^p} c_t, \tag{4}$$

where $\epsilon^p > 1$ and P_t is the aggregate price index, which is defined as

$$P_t = [\int_0^1 P_t(z)^{1-\epsilon^p} dz]^{\frac{1}{1-\epsilon^p}}, \tag{5}$$

and c_t is the demand for the composite good. The composite good is defined by

$$c_t = [\int_0^1 c_t(z)^{\frac{\epsilon^p-1}{\epsilon^p}} dz]^{\frac{\epsilon^p}{\epsilon^p-1}}. \tag{6}$$

[8] I found that the result of this paper is robust to including aggregate TFP shocks, such as those in Cooley and Prescott (1995). Hence, for simplicity, I assume constant aggregate TFP.

[9] The full model in Section 5 introduces capital accumulation and variable capital utilization. I also solved the model with no capital ($\alpha = 1$) and found that the result of this paper did not change.

Firms produce the quantity demanded: $y_t(z) = c_t(z)$.

Firms infrequently change their price because price adjustments incur fixed costs. Specifically, in each period, each firm draws a fixed price-setting cost $\xi_t^p(z)$, denominated in the composite labor, from a continuous distribution $G^p(\xi^p)$. These costs are independently and identically distributed across time and firms. Since firms face the identical marginal cost of production, the resetting price P_t^* is common to all adjusting firms, as under typical time-dependent price setting. Consequently, at the beginning of any given period before drawing current price-setting costs, firms are distinguished only by the last price adjustment and a fraction $\theta_{j,t}^p$ of firms charge $P_{t-j}^*, j = 1, ..., J$. The price distribution, including the number of price vintages J, is endogenously determined. Since inflation is positive and price-setting costs are bounded, firms eventually change their price and J is finite.

Let $v_{0,t}^p$ denote the real value of a firm that resets its price in the current period and $v_{j,t}^p, j = 1, ..., J-1$, denote the real value of a firm that keeps its price unchanged at P_{t-j}^*. No firm keeps its price to P_{t-J}^*. Each firm changes its price if

$$v_{0,t}^p - v_{j,t}^p \geq w_t \xi_t^p(z). \tag{7}$$

The left-hand side is the benefit of changing the price, while the right-hand side is the cost. For each price vintage, the fraction of firms that change their price is given by

$$\alpha_{j,t}^p = G^p(\frac{v_{0,t}^p - v_{j,t}^p}{w_t}), \tag{8}$$

$j = 1, ..., J-1$, and $\alpha_{J,t}^p = 1$. This is also the probability of price adjustments before firms draw their current price-setting cost. The fraction and probability of price changes increase as the benefit of price adjustments increases.

The value of a firm that adjusts its price is

$$v^p_{0,t} = \max_{P^*_t}\{(\frac{P^*_t}{P_t} - mc_t)(\frac{P^*_t}{P_t})^{-\epsilon^p}c_t$$
$$+\beta E_t\frac{\lambda_{t+1}}{\lambda_t}[(1-\alpha^p_{1,t+1})v^p_{1,t+1} + \alpha^p_{1,t+1}v^p_{0,t+1} - w_{t+1}\Xi^p_{1,t+1}]\}, \tag{9}$$

where E_t is the conditional expectation and λ_t is households' marginal utility of consumption. The first line is the current profit. The second line is the present value of the expected profit. With probability $(1-\alpha^p_{1,t+1})$, the firm keeps P^*_t in the next period. With probability $\alpha^p_{1,t+1}$, the firm resets its price again in the next period. The last term is the expected next-period price-setting cost, and $\Xi^p_{j,t+1}$, $j = 1, ..., J$, is defined by

$$\Xi^p_{j,t+1} = \int_0^{\bar{\xi}^p_{j,t+1}} xg^p(x)dx, \tag{10}$$

where g^p denotes the probability density function of price-setting costs. Note that $\bar{\xi}^p_{J,t+1} = B^p$, where B^p is the maximum cost.

The value of a firm that keeps its price is

$$v^p_{j,t} = [(\frac{P^*_{t-j}}{P_t} - mc_t)(\frac{P^*_{t-j}}{P_t})^{-\epsilon^p}c_t$$
$$+\beta E_t\frac{\lambda_{t+1}}{\lambda_t}[(1-\alpha^p_{j+1,t+1})v^p_{j+1,t+1} + \alpha^p_{j+1,t+1}v^p_{0,t+1} - w_{t+1}\Xi^p_{j+1,t+1}], \tag{11}$$

$j = 1, ..., J-2$, and

$$v^p_{J-1,t} = [(\frac{P^*_{t-(J-1)}}{P_t} - mc_t)(\frac{P^*_{t-(J-1)}}{P_t})^{-\epsilon^p}c_t + \beta E_t\frac{\lambda_{t+1}}{\lambda_t}[v^p_{0,t+1} - w_{t+1}\Xi^p_{J,t+1}]. \tag{12}$$

The optimal resetting price P^*_t satisfies the first-order condition for (9):

$$(\frac{P^*_t}{P_t})^{-\epsilon^p}\frac{c_t}{P_t} - \epsilon^p(\frac{P^*_t}{P_t} - mc_t)(\frac{P^*_t}{P_t})^{-\epsilon^p-1}\frac{c_t}{P_t} + \beta E_t\frac{\lambda_{t+1}}{\lambda_t}(1-\alpha^p_{1,t+1})\frac{\partial v^p_{1,t+1}}{\partial P^*_t} = 0. \tag{13}$$

Replacing the terms $\partial v^p_{j,t+j}/\partial P^*_t, j = 1, ..., J-1$, using (11) and (12) yields

$$P^*_t = \frac{\epsilon^p}{\epsilon^p - 1} \frac{E_t \sum_{j=0}^{J-1} \beta^j \left(\frac{\omega^p_{j,t+j}}{\omega^p_{0,t}}\right) \left(\frac{\lambda_{t+j}}{\lambda_t}\right) P^{\epsilon^p-1}_{t+j} c_{t+j} P_{t+j} mc_{t+j}}{E_t \sum_{j=0}^{J-1} \beta^j \left(\frac{\omega^p_{j,t+j}}{\omega^p_{0,t}}\right) \left(\frac{\lambda_{t+j}}{\lambda_t}\right) P^{\epsilon^p-1}_{t+j} c_{t+j}}, \tag{14}$$

where $\omega^p_{j,t+j}/\omega^p_{0,t} = (1-\alpha^p_{j,t+j})(1-\alpha^p_{j-1,t+j-1}) \cdots (1-\alpha^p_{1,t+1}), j = 1, ..., J-1$, is the probability of keeping P^*_t until $t+j$. The probability is invariant under typical time-dependent setting. In contrast, in the present model, the probability endogenously evolves reflecting state dependency (see (8)). However, as under time-dependent setting, the optimal price is a constant markup times the weighted average of the current and expected future nominal marginal costs ($P_{t+j} mc_{t+j}$).

2.2 Households

There is a continuum of households of measure one. Each household supplies a differentiated labor service, which is indexed by $h \in [0,1]$. A household's preference is

$$E_t \sum_{l=0}^{\infty} \beta^l [\ln c_{t+l}(h) - \chi n_{t+l}(h)^\zeta], \tag{15}$$

where $\beta \in (0,1), \chi > 0, \zeta \geq 1$, $c_t(h)$ is consumption of the composite good, and $n_t(h)$ is hours worked.

Each household sets the wage rate for its labor service $W_t(h)$ and supplies labor hours demanded $n_t(h)$. As in Erceg, Henderson, and Levin (2000), a representative labor aggregator combines households' labor services, and all firms hire the composite labor from the aggregator. The composite labor is defined as

$$n_t = [\int_0^1 n_t(h)^{\frac{\epsilon^w-1}{\epsilon^w}} dh]^{\frac{\epsilon^w}{\epsilon^w-1}}, \tag{16}$$

where $\epsilon^w > 1$. Cost minimization by the labor aggregator implies the demand for each labor service:

$$n_t(h) = [\frac{W_t(h)}{W_t}]^{-\epsilon^w} n_t, \tag{17}$$

where W_t is the aggregate wage index, which is defined as

$$W_t = [\int_0^1 W_t(h)^{1-\epsilon^w} dh]^{\frac{1}{1-\epsilon^w}}. \tag{18}$$

Households infrequently adjust their wage because wage setting incurs fixed costs. Similar to price setting, in each period, each household draws a fixed wage-setting cost $\xi_t^w(h)$, denominated in the composite labor, from a continuous distribution $G^w(\xi^w)$. These costs are independently and identically distributed over time and across households.

As in typical New Keynesian models, there exists a complete set of nominal contingent bonds, implying that a household faces the budget constraint:

$$q_t k_t(h) + \frac{W_t(h) n_t(h)}{P_t} + \frac{M_{t-1}(h)}{P_t} + \frac{B_{t-1}(h)}{P_t} + \frac{D_t(h)}{P_t} = c_t(h) + \frac{\delta_{t+1,t} B_t(h)}{P_t} + \frac{M_t(h)}{P_t} + w_t \xi_t^w(h) I_t(h), \tag{19}$$

where $k_t(h)$ is capital holding, $M_t(h)$ is money holding, $B_{t-1}(h)$ is the quantity of the contingent bond given the current state of nature, $D_t(h)$ is nominal profits paid by firms, $\delta_{t+1,t}$ is the vector of the prices of contingent bonds, $B_t(h)$ is the vector of those bonds purchased, and $I_t(h)$ is the indicator function that takes one if households reset their wage in the period and zero otherwise. Assuming that households have identical initial wealth and the utility function is separable between consumption and leisure, households have identical consumption as a result of perfect insurance: $\lambda_t(h) = \lambda_t$.[10]

The existence of perfect insurance for consumption implies that the optimal wage W_t^* is

[10] As in Khan and Thomas (2014), I assume nominal bonds contingent on both aggregate and idiosyncratic shocks. Another setting that leads to perfect insurance for consumption is a representative household with a large number of workers, as in Huang, Liu, and Phaneuf (2004). Relaxing the assumption of perfect consumption insurance needs keeping track of the joint distribution of wages and wealth across households. I leave it to future research.

common to all adjusting households, as under standard time-dependent setting. Accordingly, at the start of any given period, a fraction $\theta^w_{q,t}$ of households charge $W^*_{t-q}, q = 1, ..., Q$. The wage distribution, including the number of wage vintages Q, is endogenously determined. Under positive inflation and bounded wage-setting costs, households eventually change their wage and Q is finite.

Let $v^w_{0,t}$ denote the utility of a household (relating to wage-setting decisions) that resets its wage in the current period and $v^w_{q,t}, q = 1, ..., Q-1$, denote the utility of a household that keeps its wage unchanged at W^*_{t-q}. No household keeps its wage at W^*_{t-Q}. Each household changes its wage if

$$v^w_{0,t} - v^w_{q,t} \geq w_t \lambda_t \xi^w_t(h). \tag{20}$$

The left-hand side is the benefit of changing the wage, while the right-hand side is the cost. For each wage vintage, the fraction of adjusting households is given by

$$\alpha^w_{q,t} = G^w(\frac{v^w_{0,t} - v^w_{q,t}}{w_t \lambda_t}), \tag{21}$$

$q = 1, ..., Q-1$, and $\alpha^w_{Q,t} = 1$. This is also the probability of wage adjustments before households draw their current wage-setting cost. The fraction and probability of wage changes increase with the value of adjusting wages.

The utility of a household adjusting its wage is

$$\begin{aligned} v^w_{0,t} \quad = \quad & \max_{W^*_t}\{\lambda_t \frac{W^*_t}{P_t}(\frac{W^*_t}{W_t})^{-\epsilon^w} n_t - \chi[(\frac{W^*_t}{W_t})^{-\epsilon^w} n_t]^\zeta \\ & +\beta E_t[(1-\alpha^w_{1,t+1})v^w_{1,t+1} + \alpha^w_{1,t+1} v^w_{0,t+1} - \lambda_{t+1} w_{t+1} \Xi^w_{1,t+1}]\}. \end{aligned} \tag{22}$$

The first line is the current utility. The second line is the present value of the expected utility. With probability $(1 - \alpha^w_{1,t+1})$, the household keeps W^*_t in the next period. With probability $\alpha^w_{1,t+1}$, the household resets its wage again in the next period. The last term is the present value of the expected next-period wage-setting cost, and $\Xi^w_{q,t+1}, q = 1, ..., Q$, is defined by

$$\Xi^w_{q,t+1} = \int_0^{\bar{\xi}^w_{q,t+1}} x g^w(x) dx, \tag{23}$$

where g^w denotes the probability density function of wage-setting costs. Note that $\bar{\xi}^w_{Q,t+1} = B^w$, where B^w is the maximum cost.

The utility of a nonadjusting household is

$$\begin{aligned} v^w_{q,t} &= [\lambda_t \frac{W^*_{t-q}}{P_t} (\frac{W^*_{t-q}}{W_t})^{-\epsilon^w} n_t - \chi[(\frac{W^*_{t-q}}{W_t})^{-\epsilon^w} n_t]^\zeta \\ &\quad + \beta E_t[(1 - \alpha^w_{q+1,t+1}) v^w_{q+1,t+1} + \alpha^w_{q+1,t+1} v^w_{0,t+1} - \lambda_{t+1} w_{t+1} \Xi^w_{q+1,t+1}], \end{aligned} \tag{24}$$

$q = 1, ..., Q - 2$, and

$$v^w_{Q-1,t} = [\lambda_t \frac{W^*_{t-(Q-1)}}{P_t} (\frac{W^*_{t-(Q-1)}}{W_t})^{-\epsilon^w} n_t - \chi[(\frac{W^*_{t-(Q-1)}}{W_t})^{-\epsilon^w} n_t]^\zeta + \beta E_t[v^w_{0,t+1} - \lambda_{t+1} w_{t+1} \Xi^w_{Q,t+1}]. \tag{25}$$

The optimal wage W^*_t satisfies the first-order condition for (22):

$$\begin{aligned} &\frac{\lambda_t}{P_t} (\frac{W^*_t}{W_t})^{-\epsilon^w} n_t - \epsilon^w \lambda_t \frac{W^*_t}{P_t} (\frac{W^*_t}{W_t})^{-\epsilon^w - 1} \frac{n_t}{W_t} + \epsilon^w \chi \zeta (\frac{W^*_t}{W_t})^{-\epsilon^w \zeta - 1} \frac{n^\zeta_t}{W_t} \\ &+ \beta E_t (1 - \alpha^w_{1,t+1}) \frac{\partial v^w_{1,t+1}}{\partial W^*_t} = 0. \end{aligned} \tag{26}$$

Replacing the terms $\partial v^w_{q,t+q} / \partial W^*_t$, $q = 1, ..., Q - 1$, using (24) and (25), this equation can be written as

$$E_t \sum_{q=0}^{Q-1} \beta^q (\frac{\omega^w_{q,t+q}}{\omega^w_{0,t}}) \left\{ \frac{\epsilon^w - 1}{\epsilon^w} \frac{W_t^*}{P_{t+q}} \lambda_{t+q} - \chi\zeta[(\frac{W_t^*}{W_{t+q}})^{-\epsilon^w} n_{t+q}]^{\zeta-1} \right\} (\frac{W_t^*}{W_{t+q}})^{-\epsilon^w} n_{t+q} = 0, \qquad (27)$$

where $\omega^w_{q,t+q}/\omega^w_{0,t} = (1-\alpha^w_{q,t+q})(1-\alpha^w_{q-1,t+q+1})...(1-\alpha^w_{1,t+1}), q = 1, ..., Q-1$, denotes the probability of keeping W_t^* until $t+q$. Because of state dependency, the probability endogenously varies over time, as indicated by (21). However, as under typical time-dependent setting, households set the wage equating the discounted expected marginal utility of labor income with the discounted expected marginal disutility of labor.

2.3 Money Demand

The money demand function is given by

$$\ln \frac{M_t}{P_t} = \ln c_t - \eta R_t, \qquad (28)$$

where M_t is the quantity of money and R_t is the net nominal interest rate, which is defined by

$$\frac{1}{1+R_t} = \beta E_t(\frac{\lambda_{t+1}}{\lambda_t} \frac{P_t}{P_{t+1}}) = \beta E_t(\frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\Pi_{t+1}}). \qquad (29)$$

Here, Π_{t+1} is the gross inflation rate.

3 Parameter Values

Parameter	Description	Value	
		Benchmark	Full
β	discount factor	0.99	same
ζ	exponent on labor	2.0	same
χ	disutility of labor	2.46	8.94
α	elasticity of output with labor	0.64	same
ϵ^p	elasticity of demand for goods	6.0	same
ϵ^w	elasticity of demand for labor services	6.0	same
η	interest semi-elasticity of money demand	4.0	same
$\bar{\Pi}$ ($\bar{\mu}$)	steady-state inflation (money growth) rate	$1.03^{0.25}$	same
(B^p, b^p, d^p)	distribution of price-setting cost	(0.0027,16,2)	(0.0020,360,35)
(B^w, b^w, d^w)	distribution of wage-setting cost	(0.0334,16,2)	(0.0289,110,9.5)
δ	capital depreciation rate	NA	0.025
b	habit parameter	NA	0.65
σ_a	capital utilization costs	NA	0.01
ψ	capital adjustment costs	NA	3.5
ρ_μ	money growth persistence	NA	0.68
σ_μ	money growth volatility	NA	0.008

Table 1: Parameter values.

The third column of Table 1 lists the parameter values for the benchmark model. The values are similar to those used in previous studies, such as Huang and Liu (2002) and Christiano, Eichenbaum, and Evans (2005). The length of a period is one quarter. The annual real interest rate is 4% and $\beta = 0.99$. The exponent of labor ζ is 2.0, implying a Frisch labor supply elasticity of 1.0. The composite labor supplied at the steady state n^{ss} is 30% of the total time endowment (normalized to one), which implies $\chi = 2.46$. The elasticity of output with labor α is 0.64. The elasticity of demand for differentiated goods ϵ^p and that for differentiated labor services ϵ^w are 6.0, generating 20% markup rates under flexible prices and wages.[11] The interest semi-elasticity of money demand η is 4.0, implying that one percentage point increase in the *annualized* nominal interest rate leads to one percent reduction in real money balances, which is in line with the estimate by Christiano,

[11] Huang and Liu (2002) set $\epsilon^p = 10$, whereas Christiano, Eichenbaum, and Evans (2005) estimate $\epsilon^p = 6$ in their benchmark model. For ϵ^w, Huang and Liu (2002) use 2–6, whereas Christiano, Eichenbaum, and Evans (2005) set 21.

Eichenbaum, and Evans (2005).[12] I assume 3% annual inflation at the steady state, which is close to the average inflation for the last two decades in the U.S. Thus, the quarterly steady-state inflation rate $\bar{\Pi}$ and money growth rate $\bar{\mu}$ are $1.03^{0.25}$.

As for the distribution of price-setting costs, I follow Dotsey, King, and Wolman (1999) in assuming a flexible distributional family:

$$\xi^p(x) = B^p \frac{\arctan(b^p x - d^p \pi) + \arctan(d^p \pi)}{\arctan(b^p - d^p \pi) + \arctan(d^p \pi)}, \tag{30}$$

where $x \in [0, 1]$ and ξ^p is the inverse of G^p. For illustrative purposes, the benchmark model uses a shape similar to that assumed by Dotsey, King, and Wolman (1999) ($b^p = 16$ and $d^p = 2$, Figure 1). The maximum cost B^p is adjusted to produce the average price duration of 3.0 quarters at the steady state.[13] The degree of price rigidity is similar to that observed in micro-level data and that estimated using aggregate data.[14] At the steady state, 32.9% of prices are adjusted in any given quarter. This quarterly frequency of price changes is comparable to the monthly frequency of price changes of 9–12% reported by Nakamura and Steinsson (2008).

For the benchmark model, the shape of the distribution of wage-setting costs is the same as that of the distribution of price-setting costs (Figure 1). Specifically, the distribution of wage-setting costs is

$$\xi^w(x) = B^w \frac{\arctan(b^w x - d^w \pi) + \arctan(d^w \pi)}{\arctan(b^w - d^w \pi) + \arctan(d^w \pi)}, \tag{31}$$

[12] I also solved the model with a higher interest semi-elasticity, $\eta = 17.65$, which is the value used by Dotsey, King, and Wolman (1999). The result of the present paper did not change.

[13] The steady state is found by solving nonlinear equations for equilibrium conditions. As in Dotsey, King, and Wolman (1999), the number of price vintages J is endogenously determined so that all the firms in the Jth price vintage choose to change their price. Similarly, the number of wage vintages Q is determined so that all the households in the Qth wage vintage choose to reset their wage. At the steady state, $J = 6$ and $Q = 9$.

[14] Analyzing micro-level data, Nakamura and Steinsson (2008) find that the mean (median) price duration is about 11–13 (8–11) months for 1988–2005 in the U.S, whereas Bils and Klenow (2004) report a median duration of 5.5 months for 1995–1997. Estimating a New Keynesian model with the U.S. aggregate data, Christiano, Eichenbaum, and Evans (2005) find the average price spell of 2.3 quarters for 1965–1995, while Smets and Wouters (2007) find that it is 3.7 quarters for 1981–2004.

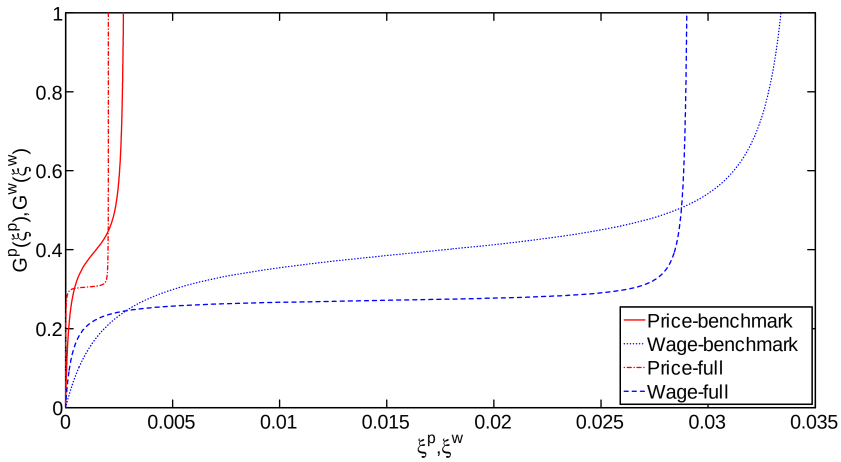

Figure 1: Distributions of price- and wage-setting costs.

where $x \in [0, 1]$, ξ^w is the inverse of G^w, $b^w = 16$, and $d^w = 2$. The maximum cost B^w is adjusted to generate the average wage spell of 3.8 quarters at the steady state, which is in line with the estimates using micro- and macro-level data.[15] At the steady state, 26.6% of wages are adjusted in any given quarter. This quarterly frequency of wage changes is in line with that estimated by Barattieri, Basu, and Gottschalk (2014) (21.1%–26.6%).[16]

4 Impulse Responses to Monetary Shocks

This section compares the response to monetary shocks under state- and time-dependent wage setting and examines how state dependency influences the transmission of monetary disturbances.[17] State- and time-dependent wage setting have the identical steady state, but

[15] Examining micro-level data, Barattieri, Basu, and Gottschalk (2014) report that the average wage duration is 3.8–4.7 quarters in the U.S. for 1996–1999. Using the U.S. aggregate data, Smets and Wouters (2007) estimate that the average wage duration is about 3.8 quarters for 1981–2004. In contrast, Christiano, Eichenbaum, and Evans (2005) estimate that the average wage duration is 2.8 quarters for 1965–1995. I calibrated my model to this lower wage stickiness and found that the result of the present paper did not change.

[16] The implied price- and wage-setting costs are small. At the the steady state, 0.04% and 0.25% of total labor are used for price and wage adjustments, respectively.

[17] Following Dotsey, King, and Wolman (1999), I first linearize the model around the steady state and then use the method of King and Watson (1998, 2002). I am grateful to the authors for making their computer codes available.

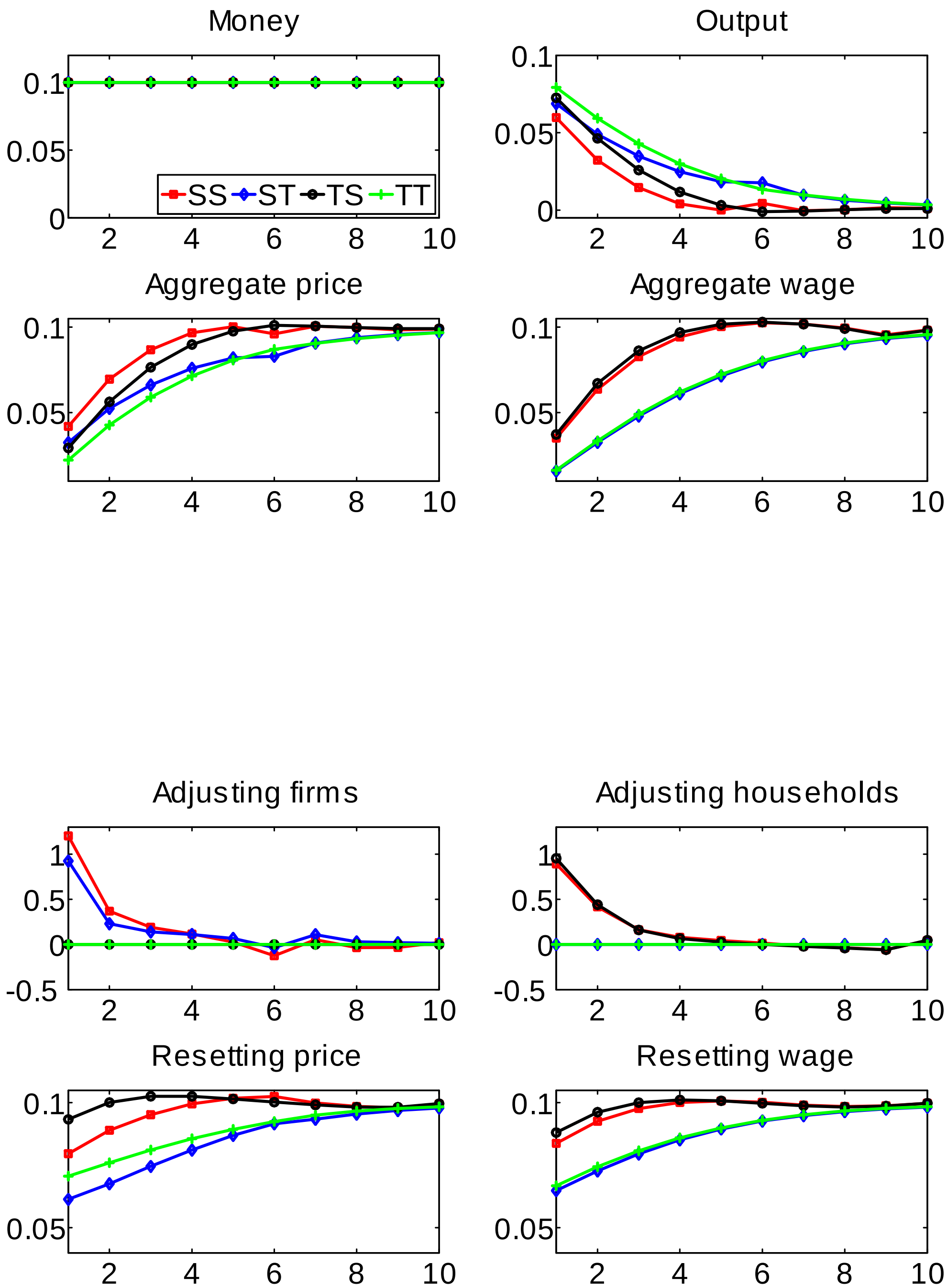

Figure 2: Permanent increase in money - benchmark model. The vertical axis is the percent deviation (the percentage point deviation for adjusting firms and households) from the steady state.

they respond to monetary disturbances in different ways. Under state-dependent setting, households optimally change the timing of wage adjustments in response to monetary shocks. Hence, there are endogenous movements in the frequency of wage adjustments. In contrast, under time-dependent setting, households cannot change when to adjust their wage and must follow the steady-state timing. Therefore, the frequency of adjustments remains unchanged at its steady-state level.

I assume that a shock occurs in period 1 and that the quantity of money M_t increases by 0.1% permanently, as shown in the upper-left panel of Figure 2. In order to analyze the role of price setting, I compare state- and time-dependent wage setting under both state- and time-dependent pricing, defining state- and time-dependent pricing in a way parallel to wage setting. Therefore, the following four cases are compared: 1) state-dependent price setting and state-dependent wage setting (SS); 2) state-dependent price setting and time-dependent wage setting (ST); 3) time-dependent price setting and state-dependent wage setting (TS); and 4) time-dependent price setting and time-dependent wage setting (TT).

As shown in Figure 2, under both state- and time-dependent wage setting, output increases temporarily following the expansionary monetary shock, as in typical New Keynesian models with nominal wage stickiness (see Huang and Liu (2002) and Christiano, Eichenbaum, and Evans (2005)). However, state dependency in wage setting reduces the increase in output compared to time-dependent setting. As an example, compare the two under state-dependent pricing (SS versus ST). Under SS, output increases by 0.06% in period 1 and returns to almost the pre-shock level by period 4. Hence, the real impact of the monetary shock almost disappears within a year. In contrast, the increase in output is larger and more persistent under ST. Output increases by 0.07% initially and remains above the pre-shock level for more than two years. The similar pattern is observed under time-dependent pricing (TS versus TT).

Next, in order to understand the impact of state dependency in wage setting shown above, micro-level wage adjustments are examined. Since all adjusting households choose the same wage in the present model, micro-level wage adjustments are largely described by the fraction of households adjusting their wage and the resetting wage chosen by those households.

The two lower-right panels of Figure 2 present the responses of these two dimensions of wage adjustments. Following the expansionary monetary shock, the aggregate price, consumption, and labor hours increase. If households do not raise their wage, their real wage falls, while the marginal rate of substitution of leisure for consumption rises. Hence, the fraction of households raising their wage increases under state-dependent setting. For example, under SS, the fraction rises by 0.89 of a percentage point in period 1. In contrast, by construction, the fraction does not increase under time-dependent setting (ST). Adjusting households also set a higher wage under state- than time-dependent setting. The resetting wage rises by 0.084% under SS, whereas it rises only by 0.065% under ST.

Why does state dependency in wage setting raise the resetting wage? State dependency increases the number of wage increases, and hence the aggregate wage rises more quickly under state- than time-dependent setting. The quicker rise in the aggregate wage has two opposing effects on the resetting wage, as indicated by (27). On one hand, adjusting households must raise their wage more substantially because their hours increase with the aggregate wage, as shown in (17). On the other hand, firms raise their price more quickly in response to the higher aggregate wage. This reduces the increases in consumption and aggregate labor hours, dampening the rise in the resetting wage. Under parameter values commonly used in the literature, the relative wage effect dominates. Hence, the resetting wage is higher under state- than time-dependent wage setting.

Since more households raise their wage and those households set a higher wage, the aggregate wage rises more quickly and firms also raise their price more quickly under state- then time-dependent wage setting. As a result, state dependency in wage setting reduces the real impacts of monetary shocks.

The relative wage effect is also the key to the relation between money nonneutralities and the elasticity of demand for differentiated labor services. Figure 3 presents impulse responses to the expansionary monetary shock introduced above for three values of the elasticity: ϵ^w= 3, 6 (benchmark), and 8.[18] The left panel shows the result when both price- and wage setting are state dependent (SS), while the right one shows the result when only wage setting switches to time dependent (ST).[19]

Under time-dependent wage setting (ST), monetary nonneutralities increase as the elasticity of demand for differentiated labor ϵ^w rises. This result is the same as that under conventional time-dependent wage setting, such as Taylor-style setting (e.g. Huang and Liu (2002)). When ϵ^w is high, households' labor hours quickly decrease with their wage relative to the aggregate wage, and adjusting households find it optimal to raise their wage mildly. Hence, the rise in the resetting wage is decreasing in ϵ^w. Since the fraction of households raising their wage does not change under time-dependent setting, under a higher ϵ^w, the aggregate wage rises more slowly and money nonneutralities become larger.

The relationship is overturned under state-dependent wage setting (SS), and the response of output decreases as the elasticity of demand for differentiated labor ϵ^w rises. If households do not raise their wage under a high ϵ^w, their labor hours and thus the marginal rate of substitution of leisure for consumption substantially increase. Hence, more households choose to raise their wage under a higher ϵ^w. As for the resetting wage, two effects compete. On one hand, when ϵ^w is higher, households find it optimal to raise their wage more mildly relative to the aggregate wage. On the other hand, the aggregate wage rises more quickly because a larger fraction of households raise their wage. Under the parameter values considered here, the resetting wage first decreases and then increases with ϵ^w. Overall, under a higher ϵ^w, the aggregate wage rises more quickly and monetary nonneutralities become smaller.

To summarize, state dependency in wage setting decreases the real impacts of monetary disturbances compared to time-dependent setting. Further, monetary nonneutralities decrease with the elasticity of demand for differentiated labor services under state-dependent

[18] Other parameters keep their benchmark values, except that the maximum wage-setting cost B^w and the disutility of labor χ are adjusted to maintain the average wage duration (3.8 quarters) and the composite labor supplied at the steady state n^{ss} (0.3).

[19] The result does not change significantly when price setting is time dependent (TS versus TT).

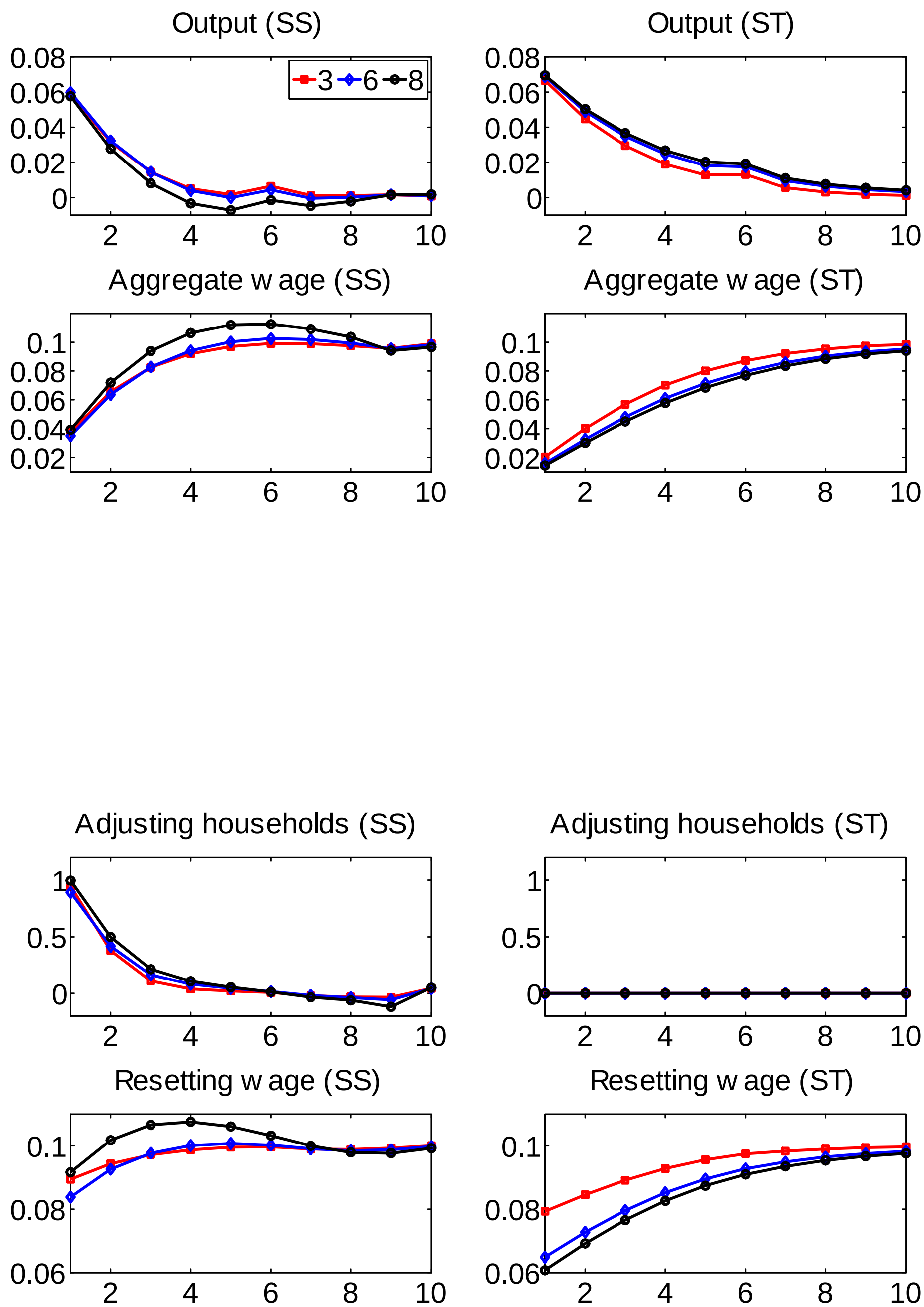

Figure 3: Elasticity of demand for differentiated labor - benchmark model. The vertical axis is the percent deviation (the percentage point deviation for adjusting firms and households) from the steady state.

wage setting, while the opposite relation holds under time-dependent setting.

5 State Dependency in Wage Setting in the U.S.

This subsection quantifies the impact of state dependency in wage setting on the transmission of monetary shocks in the U.S. To this end, I modify the benchmark model with various real-side features and calibrate the distributions of price- and wage-setting costs to the patterns of price and wage adjustments observed in the U.S. micro-level data.

5.1 Full Model

The firm side of the model is essentially the same as that of the benchmark model, except that in the full model, $k_t(z)$ is capital services and q_t is the real rental rate of capital services.

The household side is modified as follows. Households' preference includes habit formation, and the momentary utility function is given by $\ln[c_t(h) - bc_{t-1}(h)] - \chi n_t(h)^{\zeta}$, where $b \in [0,1]$. There is capital accumulation, and as in Huang and Liu (2002), households choose the amount of capital that they carry into the next period $\bar{k}_{t+1}(h)$ subject to quadratic adjustment costs $\psi[\bar{k}_{t+1}(h) - \bar{k}_t(h)]^2/\bar{k}_t(h)$, where $\psi > 0$. Further, households choose the amount of capital services that they supply $k_t(h) = u_t(h)\bar{k}_t(h)$ by choosing capital utilization rate $u_t(h)$ subject to costs $a(u_t(h))\bar{k}_t(h)$, as in Christiano, Eichenbaum, and Evans (2005). Hence, households face the budget constraint:

$$\begin{aligned}
& q_t k_t(h) + \frac{W_t(h)n_t(h)}{P_t} + \frac{M_{t-1}(h)}{P_t} + \frac{B_{t-1}(h)}{P_t} + \frac{D_t(h)}{P_t} \\
& = c_t(h) + \bar{k}_t(h) - (1-\delta)\bar{k}_{t-1}(h) + \psi\frac{[\bar{k}_{t+1}(h) - \bar{k}_t(h)]^2}{\bar{k}_t(h)} + a(u_t(h))\bar{k}_t(h) \\
& + \frac{\delta_{t+1,t}B_t(h)}{P_t} + \frac{M_t(h)}{P_t} + w_t\xi_t^w(h)I_t(h),
\end{aligned} \tag{32}$$

where $\delta \in [0,1]$ is the capital depreciation rate.

The growth rate of money ($\mu_t = M_t/M_{t-1}$) follows

$$\ln \mu_t = (1-\rho_\mu) \ln \bar{\mu} + \rho_\mu \ln \mu_{t-1} + \varepsilon_{\mu,t}, \tag{33}$$

where $\rho_\mu \in [0, 1)$ and $\varepsilon_{\mu,t}$ is a monetary shock that is independently and identically distributed with $N(0, \sigma_\mu^2)$.

5.2 Parameter Values

The last column of Table 1 lists parameter values for the full model. The parameters appeared in the benchmark model inherit their original values, except for the disutility of labor χ, which is adjusted to maintain the steady-state labor ($n^{ss} = 0.3$) and the parameters on the distributions of price- and wage-setting costs. The capital depreciation rate δ is 0.025. I set the habit parameter $b = 0.65$, which is the estimate by Christiano, Eichenbaum, and Evans (2005). For the capital utilization cost, I follow Christiano, Eichenbaum, and Evans (2005) in assuming that $\bar{u} = 1, a(1) = 0$, and $\sigma_a = a''(1)/a'(1) = 0.01$, and other information is not needed. As in Dotsey and King (2006), I choose the parameter on the capital adjustment cost ψ so that the initial response of investment to a money growth shock is about twice that of output, which is consistent with the result in Christiano, Eichenbaum, and Evans (2005). For the money growth process, I use the values in Huang, Liu, and Phaneuf (2004): $\rho_\mu = 0.68$ and $\sigma_\mu = 0.008$.

The distribution of price-setting costs is chosen targeting three features on micro-level price adjustments. First, the average price spell is 3.0 quarters. Second, the quarterly frequency of price adjustments is about 33% at the steady state. These two targets are in line with those found in Nakamura and Steinsson (2008). In addition, I target the finding by Klenow and Kryvtsov (2005, 2008). They find that the volatility of the U.S. inflation is mostly driven by the volatility of the average price change and the volatility of the fraction of price changes plays a minor role. As Figure 1 shows, the selected distribution is very similar to the Calvo-type distribution and almost all firms draw either zero or the maximum price-setting costs (infinite in the case of Calvo).

	U.S. data	Model
Average wage spell (quarters)	3.8	3.7
Fraction of wages not changed for a year (%)	25	23
$\sigma_{fraction}/\sigma_y$	4.5	4.4

Table 2: Calibration of the distribution of wage-setting costs.

Similarly, the distribution of wage-setting costs is chosen targeting three statistics on micro-level wage adjustments shown in Table 2. First, the average wage duration is 3.8 quarters at the steady state, which is consistent with the finding of Barattieri, Basu, and Gottschalk (2014). The other two targets involve the fraction of wages not changed for a year. I focus on the variable because wage data are typically collected annually and most available evidence for state dependency in wage setting is about the fraction of those long-term rigid wages.[20] Hence, the second target is the fraction of 25% at the steady state, which is in line with the finding of Barattieri, Basu, and Gottschalk (2014).[21] The third target is the volatility of the fraction of wages not changed for a year. I compute the actual volatility using the 'Wage Rigidity Meter' of the Federal Reserve Bank of San Francisco between 1997Q3 and 2013Q4. The volatility is 4.5 times as large as the output volatility.[22]

Figure 1 shows the selected distribution. The distribution is similar to the Calvo-type distribution in that a large number of households draw either small or large costs. However,

[20] An example is Card and Hyslop (1997). For the U.S., a notable exception is Barattieri, Basu, and Gottschalk (2014), which compute the quarterly frequency of wage adjustments. However, their data is relatively short (1996–1999) and it is hard to compute the volatility of the quarterly frequency of wage adjustments.

[21] The 'Wage Rigidity Meter' released by the Federal Reserve Bank of San Francisco implies a lower fraction: it is about 13% between August 1997 and December 2013. Given the average wage duration of about a year, it is hard to reproduce it in the model. Hence, I use the finding of Barattieri, Basu, and Gottschalk (2014) as a target.

[22] The meter is released monthly and I take the number of the middle month of a quarter as the quarterly number. The meter is discontinuous in 1997Q2. The series is taken log and detrended using the Hodrick-Prescott filter of a smoothing parameter of 1,600. The data is for all workers. The volatility does not change very significantly when computed separately for hourly and nonhourly workers (4.3 for hourly and 6.0 for nonhourly workers).

there are some households drawing intermediate costs and their adjustment decisions vary with economic states, generating some state dependency in wage setting. Accordingly, as Table 2 shows, the model with the distribution reasonably reproduces the data moments.[23] In contrast, if the distribution of the benchmark model is assumed, the fraction of wages not changed for a year shows a counterfactually high volatility (about 25). If the shape of the price-setting costs is assumed, then the volatility becomes too low (0.3) compared to the data value.

5.3 Impulse Responses to Monetary Shocks

I assume a one standard deviation shock to money growth ($\sigma_\mu = 0.008$) and thus the quantity of money M_t increases gradually, as shown in the upper-left panel of Figure 4. As in the benchmark model, the four price- and wage-setting regimes are compared: SS, ST, TS, and TT.

As shown, the state- and time-dependent wage setting models show quite similar responses to the monetary shock. Although state dependency reduces monetary nonneutralities, the impact is relatively small. For example, the cumulative response of output for 10 quarters after the shock decreases only by 8% as wage setting switches from time to state dependent. Other real and nominal aggregate variables move in a similar way between state- and time-dependent wage setting.[24]

As for micro-level wage adjustments, the fraction of adjusting households increases by around 7.6 percentage points at the onset of the shock under state-dependent wage setting. The increase is small relative to the increase in output of 2.7%.[25] Because of the small increase in the extensive margin, the resetting wage is also only slightly higher under state- than time-dependent setting. As a result, the rises in the aggregate wage are quite similar

[23] The 'Wage Rigidity Meter' is the 12-month moving average of the fraction of wages not changed for a year. Therefore, to keep the comparability, for the model statistic, I take the five-quarter moving average.

[24] The result is available upon request.

[25] In the benchmark model, the fraction of adjusting households increases by 0.9 percentage points under SS, while output increases by 0.1%.

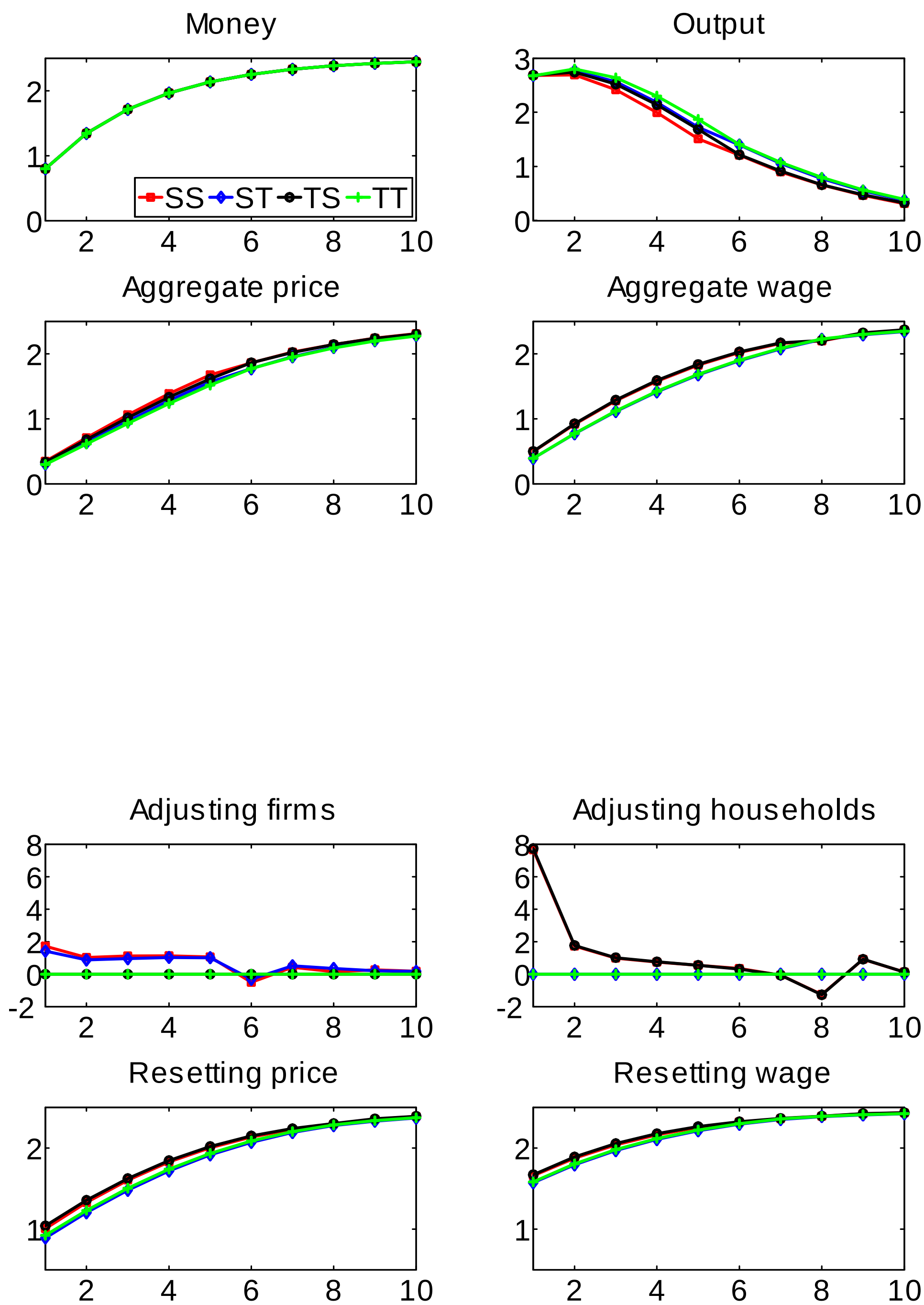

Figure 4: Money growth shock - full model. The vertical axis is the percent deviation (the percentage point deviation for adjusting firms and households) from the steady state.

between the two wage-setting regimes.[26]

The result of this section implies that state dependency in wage setting is largely irrelevant for the response to monetary disturbances in the U.S. and time-dependent wage setting models describe the impact of nominal wage stickiness on the U.S. monetary transmission reasonably well.

6 Conclusion

Although there is evidence that the timing and frequency of wage adjustments vary with economic states, existing macroeconomic analyses overlook such state dependency in wage setting and exclusively assume time-dependent setting. To fill this gap, the present paper has constructed a New Keynesian model including fixed wage-setting costs and has analyzed how state dependency in wage setting influences the transmission of monetary shocks. This paper has found that the real impacts of monetary shocks are reduced by state dependency in wage setting. However, when parametrized to reproduce the observed variation in wage rigidity in the U.S. data, the state-dependent wage-setting model shows a response to monetary shocks quite similar to that of the time-dependent model. This result indicates that state dependency in wage setting is largely irrelevant for the transmission of monetary shocks in the U.S.

There are several directions for future research. First, it would be interesting to examine the empirical relevance of state dependency in wage setting for countries other than the U.S. In particular, there are a large number of studies on micro-level wage adjustments in European countries, and the present model can be calibrated to their findings.[27] Second, the present model is a natural framework to consider optimal monetary policy. In particular, since Nakov and Thomas (2014) analyze optimal monetary policy under state-dependent

[26] A further analysis shows that state dependency in wage setting becomes largely irrelevant in the benchmark model under the distribution of wage-setting costs assumed in the full model.

[27] Some examples are Le Bihan, Montornes, and Heckel (2012), Fabiani, Kwapil, Room, Galuscak, and Lamo (2010), and Walque, Krause, Millard, Jimeno, Bihan, and Smets (2010).

pricing, it would be interesting to examine how their result changes under state dependency in both price and wage setting.

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