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Abstract

We consider a matching model of employment with flexible wages for new hires, but sticky wages within matches. Unlike most models of sticky wages, we allow effort to respond if wages are too high or too low. In the Mortensen-Pissarides model, employment is not affected by wage stickiness in existing matches. But it is in our model. If wages of matched workers are stuck too high, firms require more effort, lowering the value of additional labor and reducing hiring. We find that effort's response can greatly increase wage inertia and the volatility of employment relative to that in measured productivity.

Keywords: Effort, Employment, Sticky Wages, Wage Inertia

JEL Classification: E32, E24, J22

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1 Introduction

There is much evidence that wages are sticky within employment matches.[1] On the other hand, wages earned by new hires show greater flexibility. Pissarides (2009), for example, surveys eleven studies that distinguish between wage cyclicality for workers in continuing jobs versus those in new matches, seven based on U.S. data and four on European.[2] All find that wages for new matches are more procyclical than for those in continuing jobs. Reflecting such evidence, we consider a Mortensen-Pissarides model of employment with wages that are flexible for new hires while sticky within matches. But we depart from the sticky-wage literature by allowing that firms and workers bargain, at least implicitly, over worker effort more frequently than wage rates. To an extent, this renders wages flexible within matches despite nominal rigidities. Suppose that after a negative shock a worker's wage, if flexible, would fall. If the wage is stuck too high, our model predicts that the firm will require the worker to produce more, yielding some decline in the *effective* wage. For salaried workers this extra effort could be viewed as spending more hours at work or taking work home. For hourly-paid workers it could be viewed as increasing the pace of work. In both cases the key is that the extra effort is not directly accompanied by any wage compensation.

Relaxing constant effort has three important implications for how sticky wages affect business cycle fluctuations. For one, while Shimer (2004) and others illustrate that wage stickiness in existing matches does not matter for employment in the Mortensen-Pissarides model, it does matter if effort responds. Consider a negative shock to aggregate productivity. If existing jobs exhibit sticky wages, then firms will ask more of these workers. In turn this lowers the marginal value of adding labor, lowering vacancies and hiring. This is a purely general equilibrium force. By moving the economy along a downward sloping aggregate labor demand schedule, higher effort by current workers reduces demand for new hires.

Second, wage setting places much less weight on future desired wage rates if effort can respond. The intuition is as follows. Suppose that the bargained wage is above anticipated

[1] Barattieri, Basu, and Gottschalk (2014), based on the Survey of Income and Program Participation, estimate an expected duration of nominal wages within matches of greater than a year. See also LeBow, Sachs, and Wilson (2003).

[2] Earlier papers stressing greater wage cyclicality for new hires include Bils (1985) and Beaudry and DiNardo (1991). Studies since Pissarides' survey, including Kudlyak (2014) and Basu and House (2016) on NLSY data and Haefke, et al. (2013) on CPS data, similarly find greater wage cyclicality for new hires. Topel and Ward (1992), among others, show that life-cycle wage changes also project heavily on job changes.

future desired wage rates. Under fixed effort this creates pressure to lower the bargained wage to maintain the bargained division of match rents. But, if effort responds, then the too-high future wage will be partly offset by higher effort. So it exerts less sway for lowering the bargained wage today. In this sense, bargaining discounts the future as though wages are more flexible. It is often argued that New-Keynesian models generate too little price inertia because of forward-looking wage and price setting. This motivates adding ingredients such as sticky information or dropping rational expectations in favor of a "hybrid" Phillips curve.[3] Our model weakens the forward-looking element of wage setting and generates much more inertia in aggregate wages, even though we maintain fully forward looking rational expectations.

Third, effort's response raises productivity in recessions driven by a drop in labor demand, such as from a negative productivity shock. So it can help explain why labor productivity has shown little cyclicality (e.g., Van Zandweghe, 2010).[4] Directly related, effort's response under sticky wages considerably increases volatility of employment relative to that in productivity–we show that it can capture much of the Shimer puzzle even if the replacement rate is fairly low. This reflects partly that employment responds more to labor demand shocks, but also that measured productivity becomes less procyclical.[5]

We consider two versions of our model. We first allow firms to require different effort levels across workers of all vintages, as dictated by Nash bargaining. This may require very different effort levels across workers. During a recession the efficient contract for new hires dictates low effort at low wage while matched workers, whose wages do not adjust, work at an elevated pace. Alternatively, we impose a technological constraint that workers of differing vintages must operate at a similar pace. The latter model generates especially strong wage inertia and greater employment volatility. Again consider a negative shock to productivity.

[3] Fuhrer (2006) and Mankiw and Reis (2002), among others, argue that data show more price inertia than predicted by New-Keynesian models, including that inflation lags measures of the output gap or monetary shocks. To add inertia Mankiw and Reis introduce sticky information; Gali and Gertler introduce the hybrid information Phillips curve; Christiano, Eichenbaum, and Evans (2005) introduce backward-looking indexing.

[4] In particular, during the seven quarters of the NBER-defined Great Recession hours declined by 10 percent compared to only a 7 percent decline in real output. For the prior recession (beginning 2001.I) labor productivity similarly increased by 4 percent. (Data are from BLS program on multifactor productivity.)

[5] We consider negative shocks to labor supply (preference shocks), as well as productivity shocks. Predicted responses for wages and productivity are remarkably similar across these differing shocks if effort responds. We view this as consistent with much smaller cyclical movements in wages and productivity than in employment or output, as is typical of U.S. recessions.

Firms can require higher effort from past hires with stuck high wages. But, if new hires must work the same pace, this implies high effort for them as well. For reasonable parameters firms distort the contract for new hires rather than give rents (high wages without high effort) to its current workers. This produces a great deal of aggregate wage inertia. The sticky wage for past hires drives up their effort and thereby the effort of new hires. Reflecting this, the bargained wages for new hires, though flexible, will be higher as well. This dynamic continues in subsequent periods. High wages for new hires drives up their subsequent effort, driving up effort and wages for the next cohort of hires, and so forth. Thus producing a great deal of wage inertia.[6]

There is only sparse direct evidence on cyclicality of worker effort. Anger (2011) studies paid and unpaid overtime hours in Germany for 1984 to 2004. She finds that unpaid overtime (extra) hours are highly countercyclical, in sharp contrast to cyclicality in paid overtime hours. Quoting the paper: "Unpaid hours show behavior that is exactly the opposite of the movement of paid overtime." Lazear, Shaw, and Stanton (2013) examine data on productivity of individual workers at a large (20,000 workers) service company for the period June 2006 to May 2010, bracketing the Great Recession. At this company a computer keeps track of worker productivity. They find that effort is highly countercyclical, with an increase in the local unemployment rate of 5 percentage points associated with an increase in effort of 3.75 percent.[7] There is evidence, as well many anecdotes, that firms required more of workers during the Great Recession. (Low hiring as the economy emerged from that recession was often also ascribed to this elevated effort.) For instance, in a survey of a random sample of 600 U.S. workers, conducted during July 2011, 55 percent stated that their responsibilities had increased as a result of the recession–27 percent said that their duties had doubled. Similarly, from a survey of 571 professional bankers, lawyers and accountants, conducted in London in early 2010, 70 percent of respondents stated they had "stepped up" to the more

[6]Gertler and Trigari (2009), among others, assume that new hires receive the existing sticky-bargained wage. Although this adds inertia, its effect on aggregate wages is much more limited because the new hires are few relative to the flow of workers bargaining over wages (about 14 percent for our calibration below). Furthermore, wage setters do not downweight future target wage rates, as we show is the case if effort can respond.

[7]Schor (1987) reports cyclicality of physical activity (effort) for piece-rate workers in U.K. manufacturing for 1970 to 1986. These data show effort to be modestly procyclical. But for piece-rate workers higher effort does not reduce the effective wage rate. Thus these data do not address how effort of hourly or salaried paid workers will respond under wage stickiness.

demanding responsibilities because colleagues had been displaced.[8]

Our paper proceeds as follows. Section 2 presents our model of employment under sticky wages and endogenous effort. The models are then calibrated in Section 3. Section 4 characterizes wage dynamics, especially how effort's response reduces forward looking and adds inertia to wage setting. Section 5 examines how the model economies respond to aggregate shocks that affect labor demand (i.e., productivity) or labor supply (preferences) and compares U.S. data moments to those simulated from the models. The model with a common effort response does much better than the competing models in matching the acyclicality in wages and productivity relative to that in employment or output. Section 6 explores whether we see, as suggested by the model, less cyclical wages and more cyclical employment in industries with work rules tied across workers. Industries with more restrictive work schedules, our proxy for tied work rules, do display less cyclical wages and more cyclical hours. The last section concludes then discusses from lens of our model why effort, and so productivity, may have become less procyclical.

2 Model

Transitions between employment and unemployment are modeled with matching between workers and firms in a Diamond-Mortensen-Pissarides (DMP) framework, but allowing for a choice of labor effort at work.

2.1 Environment

- **Workers:** There is a continuum of identical workers whose mass is normalized to one. Each worker has preferences defined by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Big\{ c_t + \psi \frac{(1-e_t)^{1-1/\gamma} - 1}{1 - 1/\gamma} \Big\},$$

  where c_t denotes consumption in period t and e_t the effort level at work. The time discount factor is denoted by β. The market equates $(\frac{1}{1+r})$, where r is the rate of return on consumption loans, to this discount factor; so consumers are indifferent to

[8]The U.S. survey was conducted for the publication Workforce Management. It covered workers from a variety of industries, including retail, financial services, manufacturing and health care. The London survey was conducted for the financial services recruiting firm Joslin Rowe.

consuming or saving their wage earnings. Each period, an individual worker is either employed or unemployed. When employed (or matched with a firm), a worker is paid wage w_t and exerts effort e_t. The parameter γ reflects the worker's willingness to substitute effort levels over time. When unemployed, a worker engages in job search and is entitled to collect unemployment insurance benefits b. An unemployed worker's labor effort is set equal to zero.

- **Firms:** There is a continuum of identical firms. A matched firm produces output according to a constant-returns-to-scale Cobb-Douglas production technology:

$$y_t = z_t e_t^{\alpha} (k_t e_t)^{1-\alpha},$$

where z_t denotes the aggregate productivity, k_t capital per effort so that $k_t e_t$ is the total amount of capital employed by a matched firm.

The capital market is perfectly competitive, with the aggregate capital stock, K, owned by workers. We treat capital as mobile across firms, with no adjustment costs. At the optimum, given the constant-returns-to-scale production technology, capital-labor ratio k_t is common across all matches and satisfies:

$$r_t + d = (1-\alpha) z_t k_t^{-\alpha} e.$$

d denotes the capital depreciation rate; hence $r_t + d$ is the rental rate of capital.

- **Staggered Wage Contracts:** Wages for a match are determined through Nash bargaining between the worker and firm at the first period employed. Wage stickiness is introduced through wage contracts *à la* Calvo (1983). Each period, provided a match survives the exogenous match separation shocks, the wage is renegotiated with probability $1-\lambda$. Since the match wage remains unchanged with probability λ, λ is a measure of wage stickiness; and average wage duration $1/(1-\lambda)$. We denote the probability distribution function of wages by $G(w)$.

- **Choice of Labor Effort:** In addition to wages, effort level is also determined through Nash bargaining given the contracted wage. Unlike wage bargaining, a match determines the effort level each period. Two versions of the model are considered: (i) each worker-firm pair chooses effort individually and (ii) choice of common effort across workers (say, due to required coordinating of workers in production). These cases are discussed at length below.

We see it as reasonable that the pace of work, or hours of work for those salaried, can change without accompanying wage bargaining. Above we cited evidence that workers were assigned a wider range of tasks during the Great Recession as separated workers were not replaced. Those occurrences do not seem tied to explicit wage bargains.

An important assumption here is that the firm and worker cannot commit future effort choices. We presume that workers could credibly threaten quits or firms credibly threaten layoffs if effort moved far from that what could be garnered by bargaining, so that committing to future effort levels is not credible. As a by-product, this assumption eliminates any problem that workers or firms will choose to dissolve a match that has positive joint value–so we do not need to assume any commitment by workers or firms to avoid inefficient separations.[9]

- **Aggregate Output:** Thanks to the constant-returns-to-scale production technology, aggregate output (Y_t) also exhibits constant returns to scale in aggregate capital K_t, and labor L_t:

$$Y_t = n_t \int z_t k_t^{1-\alpha} e_t(w)\, dG_t(w) = z_t k_t^{1-\alpha} L_t = z_t \bar{K}^{1-\alpha} L_t^{\alpha}.$$

Here n_t denotes the total number of employed workers (or matches), $\overline{e}_t = \int e_t \, dG(w)$ the average effort level, and $L_t = n_t \overline{e}_t$ sums efforts of all workers to give total efficiency units of labor input. It is important to distinguish between effective labor input in the model, L_t, and labor input as measured in the data, which corresponds to n_t.[10]

[9]If bargaining could commit future effort levels to mimic choices under flexible wages, it is quite feasible that ex post the present value of the match to either the worker or firm could go negative, even though the joint value stays positive. For instance, in response to a negative productivity shock, the flexible-wage effort choice declines, reinforcing the impact of wage stickiness to reduce rents to the firm.

[10]In our model variations in n_t reflect only employment, as there is no intensive margin corresponding to the paid workweek. By ignoring variations in paid hours we implicitly assume that pay for extra hours (including any overtime premium) just matches that required to compensate workers for their disutility. If, instead, it overcompensates then that would push the bargained effort, describe below, to increase when paid hours expand. If it under-compensates, then it would push bargained effort lower.

For simplicity, we treat investment adjustment costs as prohibitive at the aggregate level, with the aggregate capital stock fixed with respect to cyclical fluctuations at $\bar{K}$. Capital's role here is to provide a convenient channel so that labor's marginal product is decreasing in aggregate effective units of labor–that is, so the aggregate demand for labor is downward sloping. From the firm's view, aggregate movements in the output to capital ratio are reflected via the competitive rental rate of capital.

- **Matching Technology:** Each period new matches are formed through a constant returns to scale aggregate matching technology:

$$M(u_t, v_t) = \chi u_t^{\eta} v_t^{1-\eta},$$

where u_t denotes the total number of unemployed workers and v_t the total number of vacancies. Thanks to the CRTS property of the matching function, the matching probabilities for an unemployed worker, denoted by p, and for a vacancy, q, can be described as a function of only labor market tightness θ $(= v/u)$: $p(\theta_t) = \chi\theta_t^{1-\eta}$ and $q(\theta_t) = \chi\theta_t^{-\eta}$. Finally, we assume that each period existing matches break at the exogenous rate δ and that firms posts vacancies at unit cost κ to recruit workers.

2.2 Value Functions and Choices for Wages and Labor Effort

For simplicity time subscripts are omitted: variables are understood to refer to time period t, unless marked with a prime ($'$) denoting period $t+1$ (or by $''$ for $t+1$). Let $\mathbf{s}$ conveniently denote the set of aggregate state variables, which includes the productivity shock, z, and the probability distribution of wages for workers, $G(w)$. Let $W(w, \mathbf{s})$ denote the utility value for a worker who is employed (matched) at wage w under aggregate state $\mathbf{s}$:

$$\begin{aligned} W(w, \mathbf{s}) = w + \psi \frac{(1-e)^{1-1/\gamma} - 1}{1 - 1/\gamma} \\ + \beta\Big\{(1-\delta)\mathbb{E}\Big[\big\{\lambda W(w, \mathbf{s}') + (1-\lambda)W(w^{*\prime}, \mathbf{s}')\big\}\big|\mathbf{s}\Big] + \delta\mathbb{E}\big[U(\mathbf{s}')|\mathbf{s}\big]\Big\}. \end{aligned} \tag{1}$$

$w^{*\prime}$ denotes next period's wage provided the match is given opportunity to renegotiate. Effort level e is determined through Nash bargaining, which is described below in detail. Let $U(\mathbf{s})$

In presenting data results below, we distinguish whether measures are for employment or total hours (employment times average paid workweek). All productivity measures, e.g., TFP, are based on total hours.

denote the value for an unemployed worker for state is $\mathbf{s}$:

$$U(\mathbf{s}) = b + \beta\Big\{p(\theta)\mathbb{E}\big[W(w^{*\prime}, \mathbf{s}')\big|\mathbf{s}\big] + \big(1 - p(\theta)\big)\mathbb{E}\big[U(\mathbf{s}')\big|\mathbf{s}\big]\Big\}, \tag{2}$$

where b denotes unemployment insurance benefits (or simply the value of leisure when not working). Using the values of employed and unemployed worker the worker's match surplus $H(w, \mathbf{s})$ is defined as follows:

$$\begin{aligned} H(w, \mathbf{s}) &= W(w, \mathbf{s}) - U(\mathbf{s}) \\ &= w - b + \psi\frac{(1-e)^{1-1/\gamma} - 1}{1 - 1/\gamma} + \beta(1-\delta)\lambda\mathbb{E}\big[H(w, \mathbf{s}') - H(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big] \\ &+ \beta\big(1 - \delta - p(\theta)\big)\mathbb{E}\big[H(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big]. \end{aligned} \tag{3}$$

Analogously, let $J(w, \mathbf{s})$ denote the value of a matched firm whose worker is contracted at wage w when the aggregate state is $\mathbf{s}$:

$$J(w, \mathbf{s}) = \alpha z k^{1-\alpha} e - w + \beta(1-\delta)\lambda\mathbb{E}\big[J(w, \mathbf{s}') - J(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big] + \beta(1-\delta)\mathbb{E}\big[J(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big]. \tag{4}$$

Note that firm's output net of rental cost of capital is $y - (r + d)k = \alpha z k^{1-\alpha} e$.

Firms post vacancies, v, such that the expected value of hiring a worker equals the cost of vacancy (i.e., the value of vacancy $V(\mathbf{s}) = 0$):

$$\kappa = \beta q(\theta)\mathbb{E}\big[J(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big]. \tag{5}$$

The wage is determined by Nash bargaining between a worker and firm when matches are newly formed as well as for the fraction λ each period of ongoing matches that renegotiate a wage.

$$w^*(\mathbf{s}) = \underset{w}{\operatorname{argmax}}\, H(w, \mathbf{s})^{\eta} J(w, \mathbf{s})^{1-\eta}. \tag{6}$$

We have imposed that the firm's bargaining parameter coincides with the relative importance of vacancies in the matching function so that the Hosios condition holds.

The first order condition for the Nash-bargained wage $w^*(\mathbf{s})$ is:

$$\eta J(w^*, \mathbf{s})\partial H(w^*, \mathbf{s})/\partial w - (1-\eta)H(w^*, \mathbf{s})\partial J(w^*, \mathbf{s})/\partial w = 0. \tag{7}$$

Under fixed effort an increase in the wage is a pure transfer from firm to worker, so $\partial H(w^*, \mathbf{s})/\partial w = -\partial J(w^*, \mathbf{s})/\partial w$. In turn, we have $J(w^*, \mathbf{s})/H(w^*, \mathbf{s}) = (1-\eta)/\eta$. More generally, if effort is chosen to maximize joint surplus, as our model implies under flexible wages, then an envelope condition still implies that $J(w^*, \mathbf{s})/H(w^*, \mathbf{s}) = (1-\eta)/\eta$. Under sticky wages, our model does not necessarily deliver the joint wealth maximizing effort choice. A marginally higher bargained wage, by increasing subsequent effort choice, can marginally increase or decrease joint surplus. Nevertheless, we have, for the log-linearized decisions analyzed below, $\partial H(w^*, \mathbf{s})/\partial w \approx -\, \partial J(w^*, \mathbf{s})/\partial w$. Therefore, across the model variations we consider, we have:[11]

$$\frac{J(w, \mathbf{s})}{H(w, \mathbf{s})} \approx \frac{1-\eta}{\eta}. \tag{8}$$

Given the bargained wage, each period the firm and its matched workers must bargain over effort. We consider two alternatives. First, we treat effort as bargained by the firm separately for each individual worker. Second, we consider the firm as bargaining over a common effort level jointly with all its matched workers. We refer to the former as the "individual effort model," the latter as the "common effort model".

Effort level in the individual effort model, given the contracted wage w and the aggregate state $\mathbf{s}$, is determined through Nash bargaining between the firm and each worker:

$$e^*(w, \mathbf{s}) = \underset{e}{\operatorname{argmax}}\, H(w, \mathbf{s})^{\eta} J(w, \mathbf{s})^{1-\eta}$$

This yields the following first order condition for $e^*(w, \mathbf{s})$:

$$\frac{\alpha z k^{1-\alpha}}{\psi(1-e^*)^{-1/\gamma}} = \frac{\eta}{(1-\eta)} \frac{J(w, \mathbf{s})}{H(w, \mathbf{s})}, \tag{9}$$

where $e^*(w, \mathbf{s})$ is also reflected in the surpluses of worker and firm, $H(w, \mathbf{s})$ and $J(w, \mathbf{s})$. Under a flexibly-chosen wage, since $J(w^*, \mathbf{s})/H(w^*, \mathbf{s}) = (1-\eta)/\eta$, this reduces to $\alpha z k^{1-\alpha} = \psi(1-e^*)^{-1/\gamma}$. Intuitively, under flexible wages the marginal product of effort equals its marginal disutility, as needed to maximize joint surplus. But under a sticky wage that will not generally be true. For instance, if the wage is stuck above its flexible counterpart, so $J(w^*, \mathbf{s})/H(w^*, \mathbf{s}) < (1-\eta)/\eta$, then the marginal product of effort gets pushed below its marginal disutility.[12] This reflects that, under the sticky wage, effort choice must serve the

[11] Please see the appendix for additional detail.

[12] At the outset of a sticky wage contract we have from (8) that $H(w^*, \mathbf{s})/J(w^*, \mathbf{s}) \approx \eta/(1-\eta)$. So, at that point, $\psi(1-e^*)^{-1/\gamma} \approx \alpha z k^{1-\alpha}$, with effort "close" to its flexible wage counterpart. But that will not generally be true over the duration of the sticky-wage.

purpose of dividing match surplus, not just maximizing match surplus.[13]

Of course, it may not be realistic for a firm to vary work rules so freely across its employees. For instance, consider workers operating on the same assembling line. It is impractical to have the assembly line speed up and slow down as it passes workers with wages bargained at differing dates. More generally, it is presumably difficult for any employer engaging workers in team production to assign expectations of effort and performance that differ so dramatically across coworkers. For this reason, we also consider the common effort model, which is our preferred benchmark.

We assume this common effort level is also determined through bargaining. But, unlike wage bargaining and the individual effort bargaining above, this common effort bargaining involves all workers at the firm. Moreover, because the contracted wages of these matched workers differ, the surpluses accruing to the parties are heterogeneous. To capture this environment we employ a multi-party bargaining protocol. Specifically, $e^*(\mathbf{s})$ is chosen according to the Nash bargain:

$$e^*(\mathbf{s}) = \underset{e}{\operatorname{argmax}} \left[\prod \left(H(w,\mathbf{s})\right)^{dG(w)}\right]^{\eta} \left[\int J(w,\mathbf{s})dG(w)\right]^{1-\eta}. \tag{10}$$

Workers are stratified by their bargained wage w. We assume all workers receive equal weight in bargaining; so for a wage group of share $dG(w)$, the bargaining share is $dG(w)$.[14] The first-order condition for choosing the common effort $e^*(\mathbf{s})$ is:

$$\frac{\alpha z k^{1-\alpha}}{\psi(1-e^*)^{-1/\gamma}} = \frac{\eta}{(1-\eta)} \left[\int J(w,\mathbf{s})dG(w)\right] \left[\int \frac{1}{H(w,\mathbf{s})}\, dG(w)\right]. \tag{11}$$

The two bracketed terms on the right side are, respectively, arithmetic mean of firm surplus per worker and the harmonic mean of surplus across workers. In steady-state, or under flexible wages, the right-hand side reduces to 1, with effort's marginal product equated to its

[13] Our model predicts higher effort if relative rents for the worker, $H(w,\mathbf{s}) - J(w,\mathbf{s})$, deviates above its flexible-wage counterpart. This resembles efficiency-wage models with imperfect monitoring that relate effort to worker rents in the job (e.g, Uhlig and Xu, 1996). But there are important differences from those settings. We assume effort is observable. There are no a priori rents, or queuing, in our model, even with sticky wages. We have Nash bargaining, whereas the efficiency wage is typically defined to minimize the firm's labor cost. Put in the context of Nash bargaining, that corresponds to putting all weight on the firm's objective. To the extent this is generalized, the efficiency wage model predictions for effort are weakened (Strand, 2003).

[14] Nash bargaining guarantees positive surplus for the firm and for each worker, provided total surplus is positive. Under the common effort choice, it is conceivable for the firm to experience negative surplus for some workers, with this cross-subsidized by more profitable (lower wage) matches. But this will not occur for sufficiently small shocks, given we calibrate realized matches to have surplus in steady state.

marginal disutility. But under sticky wages, predetermined according to (6), the marginal product of effort will be pushed below its marginal disutility if the wage is stuck too high.[15]

In addition to the wage and effort levels, a key variable for the model dynamics is the vacancy-unemployment ratio (θ). Combining (4) and (5) yields the forward-looking difference equation for θ:

$$\frac{\kappa}{q(\theta)} \approx \beta\mathbb{E}\left[\alpha y' - \beta(1-\delta)\lambda\mu(\mathbf{s}'')(w^{*\prime} - w^{*\prime\prime}) + (1-\delta)\frac{\kappa}{q(\theta')}\Big|\mathbf{s}\right]. \tag{12}$$

where $-\mu(\mathbf{s}'')(w^{*\prime} - w^{*\prime\prime})$ is a first-order Taylor approximation to $J(w^{*\prime}, \mathbf{s}'') - J(w^{*\prime\prime}, \mathbf{s}'')$. This expression for the dynamics of θ holds for both the individual effort and the common effort models. However, due to the differences in the first-order condition for effort described above, cyclicality of the vacancy-unemployment ratio differs considerably across the two models.

3 Calibration: Benchmark

Imposed Parameters The period is a quarter. The discount factor, β is set to 0.99, implying an annualized real interest rate of 4 percent. The real interest rate (1 percent), combined with the capital depreciation rate, $d = 2.5$ percent, yields a steady-state quarterly rental rate of capital (marginal product of capital), $r + d$, of 3.5 percent. The elasticities for u_t and v_t in the matching function, η and $1 - \eta$, are each set to one half, partly for convenience, but also to be roughly consistent with empirical estimates (e.g., Rogerson and Shimer, 2010).

Key parameters for the impact of wage stickiness on hiring are the duration of wage contracts, the Frisch elasticity of labor effort, and labor's share in production. We set the average duration of wage contracts to one year, which implies $\lambda = 3/4$. This is a typical choice for calibrating wage stickiness in the literature. It is supported by our analysis of wages in the SIPP data in Section 6.

[15] Under both individual and common effort choices we treat the wage as Nash bargained at the individual match level, dividing rents over that match. Under common effort we assume workers treat subsequent effort choices as independent of their bargained wage, as they are trivially small relative to the firm's workforce. For the firm there potentially exists an incentive to bargain upward the wages of new hires, in order to push up the effort of other workers. This represents a form of "cheating" on bargains previously negotiated. We exclude such cheating by assuming that the firm can commit to negotiate individual wages on the basis of dividing individual match surplus as in (6). Because negotiated wages anticipate future common effort levels, but do not attempt to influence these choices, wage choices under common effort reflect $\frac{J(w,\mathbf{s})}{H(w,\mathbf{s})} = \frac{1-\eta}{\eta}$ exactly, not just approximately.

The Frisch elasticity of labor effort, $\gamma\frac{1-e}{e}$, reflects both parameter γ and the level of effort. We first normalize effort, by choice of ψ, so that $e = 0.5$ in steady state.[16] This implies the Frisch elasticity is γ. This elasticity is difficult to calibrate, given that effort is typically not observed. We set $\gamma = 0.5$ so that the Frisch elasticity for effort is 0.5. Comparing this choice to estimates of the Frisch elasticity for the workweek margin, it is in the range surveyed by Hall (2009). For salaried workers we might anticipate a larger elasticity for effort than the workweek, as effort movements in our model would reflect movements in their workweek as well as intensity per hour. For hourly paid workers, we might anticipate a smaller elasticity for effort than for the workweek.[17]

Labor's share, under Cobb-Douglas production, dictates the elasticity of the labor demand schedule. In turn, this dictates the degree that higher effort from existing workers will crowd out hiring. We set the labor share parameter in production, α, to 0.64. This implies aggregate labor demand is very elastic, with elasticity of $\frac{1}{1-\alpha} = 2.78$, yielding only modest crowding out effects. But other factors could be introduced that limit the short-run elasticity of labor demand, further magnifying effort's impact on hiring.[18]

Targeted Parameters Other parameters are chosen to match the following steady-state targets. The labor-market tightness ($\theta = v/u$) is normalized to one. The match efficiency ($\chi = 0.6$) is chosen so that the job finding rate, $p(\theta) = \chi\theta^{1-\eta}$, is 60 percent in steady state given an elasticity of the matching function with respect to unemployment, η, of 1/2. The job separation rate ($\delta = 4$ percent) is chosen so that the steady-state unemployment rate is 6.25 percent. The vacancy posting cost (κ) is chosen to satisfy the free entry condition in (5). Given the steady-state wage ($\widetilde{w}$), the unemployment benefit (b) is chosen so that the

[16] The steady state effort level reflects the utility parameter ψ, and other calibrated parameters, according to: $e = 1 - \left(\frac{\psi}{\alpha}\right)^{\gamma}\left(\frac{r+\delta}{1-\alpha}\right)^{\frac{\gamma(1-\alpha)}{\alpha}}$.

[17] Schor (1987) reports a time-series for physical activity of 131,500 piece-rate workers in a standing panel of 171 British factories for years 1970 to 1986. The measure represents the ratio between actual effort and a standard level of intensity as defined by "time and motion" men. Schor regresses effort on hours per week in British manufacturing as well as additional variables. The estimated elasticity of effort with respect to the workweek varies from 0.52 to 0.60 across five specifications (with standard errors of about 0.14). Bils and Cho (1994) take this as an estimate of the relative Frisch elasticities for the effort versus workweek margins.

[18] In particular, if prices are sticky then increased effort might create sharper reductions in hiring, since price cuts cannot maintain output sold and produced. For this reason, wage stickiness may better complement price stickiness as a force for employment volatility in our model than in standard Keynesian models with fixed effort, where wage and pricing frictions act somewhat as substitutes.

replacement rate (in terms of utility), $b \Big/ \left(w_{ss} + \psi \frac{(1-e)^{1-1/\gamma}-1}{1-1/\gamma} \right)$, equals 75 percent, which is the benchmark value in Costain and Reiter (2008).

Our parameter choices are summarized in Table 1.

4 Characterizing the Model's Wage Dynamics

Since analytical solutions are not available, we largely rely on numerical solutions that approximate the log-linearized equilibrium dynamics around steady state to describe business cycles in our model. Before performing the full quantitative analysis, we first focus on the model's wage dynamics in order to gain intuition for what drives the differences between our model and a standard fixed-effort, sticky-wage model. Implications for the model's other key variables such as effort and labor-market tightness follow from these dynamics in wages. (Detailed derivations of the steady state and the entire log-linearized dynamics around the steady state are provided in Appendix A.)

Let $\widetilde{x}$ denote the steady state of variable x, while $\widehat{x}$ denotes the percentage deviation of x from $\widetilde{x}$.[19] The first-order condition for the wage at steady state is $\eta\widetilde{J} = (1-\eta)\widetilde{H}$. This yields the well-known condition for the Nash-bargained wage:

$$\widetilde{w} = (1-\eta)\left(b - \psi \frac{(1-\widetilde{e})^{1-1/\gamma}-1}{1-1/\gamma} \right) + \eta(\alpha\widetilde{y} + \kappa\widetilde{\theta}). \tag{13}$$

$\widetilde{y} = \widetilde{z}\widetilde{k}^{1-\alpha}\widetilde{e}$ is output in the steady state, where $\widetilde{k} = \bar{K}/(\widetilde{n}\cdot\widetilde{e})$ denotes steady-state capital per efficiency unit of labor. The wage is a weighted average of the loss from working (unemployment benefits and foregone utility from leisure) and the sum of the firm's output and the vacancy posting costs per unemployed worker.

The steady-state effort choice, $\widetilde{e}$, for both bargaining protocols, equates the marginal rate of substitution between effort and consumption to effort's marginal productivity: $\psi(1-\widetilde{e})^{-1/\gamma} = \alpha\widetilde{z}\widetilde{k}^{1-\alpha}$. The steady-state Frisch elasticity equals $\gamma\frac{1-\widetilde{e}}{\widetilde{e}}$, which we denote for convenience by $\widetilde{\gamma}$.

For a "standard" sticky-wage version of our model with effort fixed, the deviation in the

[19]The steady state values are derived assuming no aggregate uncertainty, i.e., $z_t = \widetilde{z}$ for all t. Hence all variables are constant and, especially, the distribution of wages is degenerate at $\widetilde{w}$.

Nash-bargained wage can be expressed as:

$$\widehat{w}_t^* = (1-\tau)\sum_{j=0}^{\infty}\tau^j E\widehat{w}_{F,t+j}^*, \tag{14}$$

where $\tau = \beta(1-\delta)\lambda$. $\widehat{w}_{F,t}^*$ is the wage that would occur under flexible wage setting, often called the target or spot wage.[20] Equation (14) is the familiar time-dependent wage setting rule, e.g. Calvo (1983). The bargained wage reflects anticipated target flexible wage rates, with weights declining geometrically into the future. For our calibration $\tau = 0.713$.

The aggregate wage reflects $\widehat{w}_t^*$; but it also reflects the previous aggregate wage for the share, $\lambda(1-\delta)$, of workers who continue at their previous wage. For comparing wage dynamics across models, we express the aggregate wage $\widehat{\overline{w}}_t$ as a weighted average of its lagged value ($\widehat{\overline{w}}_{t-1}$), its expected value one period ahead ($E\widehat{\overline{w}}_{t+1}$), and the target flexible wage ($\widehat{w}_{F,t}^*$):

$$\widehat{\overline{w}}_t = \pi_1\widehat{\overline{w}}_{t-1} + \pi_2 E\widehat{\overline{w}}_{t+1} + (1-\pi_1-\pi_2)\widehat{w}_{F,t}^*, \tag{15}$$

where $\pi_1 = \frac{\lambda(1-\delta)}{1+\beta\lambda^2(1-\delta)^2}$ and $\pi_2 = \frac{\beta\lambda(1-\delta)}{1+\beta\lambda^2(1-\delta)^2}$.

We can contrast these dynamics for $\widehat{w}_t^*$ and $\widehat{\overline{w}}_t$ with those under our model with variable effort. For exposition, we focus first on our preferred specification with common effort. At the end of the section we consider wage dynamics under individual effort choice.

The choice for $\widehat{w}_t^*$ under common effort can be written to parallel (14) as:

$$\widehat{w}_t^* = (1-\varphi)\sum_{j=0}^{\infty}\varphi^j E\widehat{w}_{F,t+j}^* + \left(1-\frac{\varphi}{\tau}\right)\sum_{j=0}^{\infty}\varphi^j E\left(\widehat{\overline{w}}_{t+j} - \widehat{w}_{F,t+j}^*\right), \tag{16}$$

where $\varphi = \tau\frac{(1+\widetilde{\gamma}(1-\alpha))\eta\widetilde{J}}{(1-\eta(1-\alpha))\widetilde{\gamma}\alpha\widetilde{y}+(1+\widetilde{\gamma}(1-\alpha))\eta\widetilde{J}}$, and $\widetilde{\gamma} = \gamma\frac{1-\widetilde{e}}{\widetilde{e}}$ is the Frisch elasticity of effort. As $\widetilde{\gamma}$ goes to zero, φ converges to τ, and the model becomes identical to the fixed effort case. That is, our model nests the standard model of fixed effort as the Frisch elasticity goes to zero.

[20] $\widehat{w}_{F,t}^*$ is the Nash bargained wage under wage flexibility derived in Appendix A. For fixed effort

$$\widehat{w}_{F,t}^* = \eta\alpha\left(\frac{\widetilde{y}}{\widetilde{w}}\right)(\widehat{z}_t - (1-\alpha)\widehat{n}_t) + \eta\kappa\left(\frac{\widetilde{\theta}}{\widetilde{w}}\right)\widehat{\theta}_t,$$

which is a special case, with $\widetilde{\gamma} = 0$, of the flexible wage under variable effort, (A.29):

$$\widehat{w}_{F,t}^* = \alpha\left(\frac{\widetilde{y}}{\widetilde{w}}\right)\left(\frac{\eta+\widetilde{\gamma}}{1+\widetilde{\gamma}(1-\alpha)}\right)(\widehat{z}_t - (1-\alpha)\widehat{n}_t) + \eta\kappa\left(\frac{\widetilde{\theta}}{\widetilde{w}}\right)\widehat{\theta}_t.$$

More generally, φ is less than τ. For instance, for the benchmark calibration $\frac{\varphi}{\tau}$ equals only 0.277. (φ equals 0.198.) This implies that the newly set wage reflects, not just the anticipated target flexible wages, but also any expected deviation of the aggregate wage from that target. In fact, for the calibrated model the coefficient, $1 - \frac{\varphi}{\tau}$, is large, equaling 0.723. Any expected deviation in the aggregate wage from its flexible counterpart means that the worker's effort will be pushed in that same direction; for this reason, the Nash bargain also pushes $\widehat{w}_t^*$ upward—a high wage is associated with high effort.

But the choice for $\widehat{w}_t^*$ differs from that under fixed effort in (14), even if the aggregate wage is not expected to deviate from the target flexible wage. For $\widetilde{\gamma} > 0$, because φ is less than τ, wage setting puts more weight on target wages in the near term than implied by discounting at factor τ. This reflects that the wage choice here influences the path for effort, as well as dividing the rents. It is optimal to align the wage with the current spot wage to achieve a more efficient effort choice today. Of course, this implies, in expectation, a less efficient choice later in the contract. But, due to separations or the Calvo probability of re-contracting, that impact on future effort choice may never arise. The larger is the Frisch elasticity, $\widetilde{\gamma}$, the more wage setting focuses on the current target wage relative to future values. Thus, because effort can respond in the future, the wage setting acts "as if" wages will be much more flexible in the future than implied simply by the Calvo parameter.

The aggregate wage under common effort can be written to parallel (15) as:

$$\widehat{\overline{w}}_t = \pi_1^c \widehat{\overline{w}}_{t-1} + \pi_2^c E \widehat{\overline{w}}_{t+1} + (1 - \pi_1^c - \pi_2^c) \widehat{w}_{F,t}^*, \tag{17}$$

where $\pi_1^c = \frac{\phi}{1+\varphi\phi-(1-\phi)(1-\varphi/\tau)}$, $\pi_2^c = \frac{\varphi}{1+\varphi\phi-(1-\phi)(1-\varphi/\tau)}$ and $\phi = (1-\delta)\lambda$.

We show in the Appendix that $\pi_1^c > \pi_1$. For our benchmark calibration it is much higher, with $\pi_1^c = 0.871$ versus $\pi_1 = 0.475$ under fixed effort. Thus, the aggregate wage exhibits much more inertia if effort responds. This inertia is anticipated from (16) by the impact on the negotiated wage of expected departures of future aggregate wages from target wages. These deviations project heavily on $\widehat{\overline{w}}_{t-1}$ in a sticky-wage setting. We also show in the Appendix that $\pi_2^c < \pi_2$. For our calibration $\pi_2^c = 0.115$, versus $\pi_2 = 0.471$ under fixed effort. Again, this is anticipated from (16) by the severe down-weighting of future target wage rates when effort responds. Finally, we can show that the coefficient on the current target flexible wage, $(1 - \pi_1^c - \pi_2^c)$, is pushed very low under the common effort model. For our calibration it is only 0.013, compared to 0.053 under fixed effort.

Effort will deviate from its flexible-wage counterpart so as to mirror the deviations of the aggregate wage from the flexible, target wage. So factors, such as a larger Frisch elasticity ($\widetilde{\gamma}$) or stickier wage rate (larger λ), that generate greater wage inertia will, in turn, generate greater effects on effort. The model implications for labor market tightness and employment are more difficult to analyze, except numerically. But, to the extent wages are pushed above the target wage, thereby driving up effort, this reduces labor's marginal product given $\alpha < 1$. Thus the importance of wage stickiness on cyclicality of new hires follows from the inertia in aggregate wages, in combination with the size of capital's share, $1 - \alpha$.

Under individual effort choice the Nash bargained wage, $\widehat{w}_t^*$, and aggregate wage, $\widehat{\overline{w}}_t$, can be written respectively as:

$$\widehat{w}_t^* = (1-\varphi)\sum_{j=0}^{\infty}\varphi^j E\widehat{w}_{F,t+j}^* + \left(1 - \frac{\varphi}{\tau_i}\right)\sum_{j=0}^{\infty}\varphi^j E\left(\widehat{\overline{w}}_{t+j} - \widehat{w}_{F,t+j}^*\right), \tag{18}$$

$$\widehat{\overline{w}}_t = \pi_1^i \widehat{\overline{w}}_{t-1} + \pi_2^i E\widehat{\overline{w}}_{t+1} + (1 - \pi_1^i - \pi_2^i)\widehat{w}_{F,t}^*, \tag{19}$$

where $\tau_i = \tau\frac{\eta\widetilde{J}}{\widetilde{\gamma}\alpha\widetilde{y}+\eta\widetilde{J}}$, $\pi_1^i = \frac{\phi}{1+\varphi\phi-(1-\phi)(1-\varphi/\tau_i)}$, and $\pi_2^i = \frac{\varphi}{1+\varphi\phi-(1-\phi)(1-\varphi/\tau_i)}$.

Although (18) and (19) take the same forms under individual effort choice as under common effort, the equations' parameters differ dramatically. For our calibration, $\frac{\tau_i}{\tau}$ equals only 0.283. (τ_i equals 0.202.) In turn, $\frac{\varphi}{\tau_i} = 0.979$; and $\left(1 - \frac{\varphi}{\tau_i}\right)$ equals only 0.021. So, under individual effort, anticipated aggregate wage rates, given the target flexible wages, have essentially no impact on current wage setting.[21] By contrast, under common effort the calibrated value for $\left(1 - \frac{\varphi}{\tau}\right)$ is 0.723. Note that $\widehat{w}_t^*$ still differs importantly from it choice under fixed effort; because $\varphi < \tau$, wage setting puts much more weight on the target wage in the near term than implied by discounting at factor τ, as would be done under fixed effort. For our calibration, repeating from above, φ is only 0.198, whereas $\tau = 0.713$. As under common effort, the wage influences the path for effort, as well as dividing rents. For this reason, bargaining aligns the wage closer to the current target wage, since the burden this creates in the future is discounted relative to its benefit today.

[21] The only impact of the sticky aggregate wage on current wage setting in (18) is through general equilibrium: Other workers' wages influence their effort levels, thereby affecting the marginal product of labor. If we set capital's share to zero ($\alpha = 0$), making labor's marginal product perfectly elastic, then the coefficient $(1 - \frac{\varphi}{\tau_i})$ in (18) becomes exactly zero.

Turning to (19), we show in the Appendix that $\pi_1^c > \pi_1^i > \pi_1$; that is, inertia in the individual effort model is intermediate to the cases of fixed effort and common-effort choice. For our calibration π_1^c, π_1^i, and π_1 equal 0.871, 0.704, and 0.475 respectively. π_1^i exceeds π_1 because so much less weight is placed on future target wages with endogenous effort. The complement of this is that π_2^i is much less than its corresponding value under fixed effort. Because the coefficient π_2^i is so scaled down, the coefficient on the current target wage in (19), $1 - \pi_1^c - \pi_2^c$, is actually much higher than under fixed effort. For our calibration it equals 0.20, compared to 0.053 with effort fixed, and only 0.013 under common-effort choice. As a result, wages and, in turn, effort show far less persistence under individual than under common effort. We highlight these differences in the full model results to follow.

5 Results

We illustrate how our model with endogenous effort responds to contractionary aggregate shocks. We first consider a recession driven by a negative productivity shock that reduces labor demand. Below (section 5.4) we examine robustness of these predictions to a recession driven by a preference shock reducing labor supply.

5.1 Impact of Sticky Wages with Fixed Effort

First consider the impact of wage stickiness under fixed effort. Figure 1 shows model responses to a one percent decrease in aggregate productivity, with autocorrelation 0.95,[22] under both flexible and sticky wages. Sticky wages have expected duration of four quarters–Calvo parameter of 0.75.

Panels 2 and 3 show wage responses, first for new matches or those re-bargaining, then for all workers. New-bargain wages respond similarly under flexible (denoted by "$--$") and sticky wages (denoted by "$-$"). It responds slightly less under sticky wages, however, reflecting that the bargained wage will be stuck below its expected value under fully flexible wages. But the expected present value of wages for new hires is the same under flexible and sticky wages. The aggregate wage responds much less on impact under sticky wages. But

[22] An autocorrelation of 0.95 for productivity shocks is standard in the literature. It is also extremely close to the autocorrelation of 0.957 we see for U.S. TFP, after removing a quadratic trend, for 1960 to 2013. (We correct TFP for modestly procyclical capital utilization, as discussed in the data appendix.)

after six, or so, quarters most wages will reflect the shock to productivity–so the aggregate wage coincides under flexible or sticky wages. The last panel of Figure 1 illustrates how employment responds to the productivity shock. As anticipated by the literature (Shimer, 2004, among others), these responses are identical under flexible and sticky wages–wage stickiness has no impact on the real economy under fixed effort.

5.2 Introducing Bargaining over Worker Output (Effort)

Figure 2 presents impulse responses allowing for bargaining over effort. We consider three scenarios: (1) fully flexible wages, (2) sticky wages with an individual effort choice, (3) sticky wages with a common effort choice across workers. Figure 2 illustrates the responses of key variables, such as wage rates and effort, again to a one percent decrease in productivity.

Focus first on the case of completely flexible wage rates (denoted by "−.−"). The top three panels depict the impulse responses in the newly-bargained wage, the average wage, and average effort. Under flexible wages, of course, wages of new bargains and the average wage decrease by the same amount. The decrease in wage reflects both the negative shock to productivity as well as the negative effort response. With Frisch elasticity of one-half, effort responds -0.4 percent for the 1 percent drop in productivity. As a result, the wage decreases by nearly 1.2 percent, even more than the underlying shock to productivity. Output and measured TFP (panels 4-5) show decreases of about this same magnitude, as each also reflects effort as well as the productivity shock. The last panel in Figure 2 shows that employment responds with a lag, bottoming in the third period. This reflects not only the search friction, but also the decrease in worker effort, which lessens the response in employment.

Next consider sticky wages with effort chosen separately across workers (denoted by "−−"). The first two panels of Figure 2 show that, while the average wage responds less initially than under flexible wages, the newly-bargained wage actually drops nearly 40 percent more. The reason is apparent from Figure 3, which depicts the varied responses in effort across workers. The initial response for workers under sticky wages (i.e., old contracts) is an effort increase of 0.8 percent. But that effort increase drives the marginal product of labor lower (along the downward-sloping marginal product of labor schedule) than under flexible wages. For this reason, workers under new bargains decrease effort even more than if all wages were flexible. As a result, the wage decreases more for new bargains.

Overall, as depicted in Figure 2's third panel, average effort initially increases. This reduces the impact on output and TFP (panels 3 and 4). But, by reducing the capital-labor ratio, it pushes the marginal product of new hires even lower. For this reason, it magnifies the initial impact on employment. But, looking at panel 6 of the figure, this effect is small and short lived. After six quarters the relative responses in effort under flexible versus sticky wages actually reverse, with average effort, output, and measured TFP all lower under sticky than flexible wages. The reasoning is as follows. On impact the negative shock induces a sharp rise in effort for workers who are under sticky wages. But this effect is essentially gone by the sixth quarter, as nearly all wages have been renegotiated. At the same time, effort and wages are reduced in wage bargains occurring the first several quarters after the shock. Because these lower wage rates are locked in by wage stickiness, it also locks in reduced effort by these workers. The total impact is a humped shaped response in average effort, output, and measured TFP, despite no such shape for the underlying productivity shock.

Returning to Figure 3, we see that the model yields dramatically different effort responses across workers. While the workers under sticky bargains increase effort by nearly enough to keep their productivity constant, the newly negotiating workers adjust their effort sharply in the opposite direction. If we view these workers operating within an organization, it seems unreasonable to have such varying work rules across employees. It is presumably difficult for any employer engaging workers in team production to assign expectations of effort and performance that differ so dramatically across coworkers. For this reason, we now move to our preferred model with bargaining over a common effort level (denoted by solid line "$-$").

Looking at the first panel of Figure 2, under common effort we see that the wage in new bargains, though flexible, decreases far less than the magnitude of the productivity shock. As a result, as anticipated by Section 4, the model generates a great deal of inertia in wages. Even after two years, at which point 90 percent of wages have adjusted, the average wage is decreased by about 0.25 percent, which is only half the size of the decline in output.

The intuition is as follows. In bargaining over effort, firms face a trade-off between what is efficient for new bargains and what is most profitable for workers under sticky wages. After a negative shock the efficient new bargain asks for lower effort, combined with deeper wage cuts. But, because workers with dated wage bargains are overly paid, the firm can demand more effort from these workers. The effort bargain trades off these objectives, but is heavily driven by the desire to obtain the possible effort level from the sticky-wage workers (which is the majority of the workforce). Why does wage inertia persist well after all wages are renegotiated? Consider wage bargains in the first period after the shock. Because effort is increased for these workers, their wage is cut less. But that wage is then stuck higher going forward, acting to generate higher effort choices. In turn, this pushes future bargains to adopt higher effort and higher wages. Thus the wage rigidity pushes up effort, which pushes up subsequent wages, pushing up subsequent effort, and so forth.

Turning to panel 3 of Figure 2, we see that common effort increases to offset much of the negative shock to productivity. Output (panel 4) and measured TFP (panel 5) decline by less than half as much as the underlying shock to productivity during the first few quarters, and by about one-third less even after two years.

The strong response in effort reduces new hires' marginal product, and the benefit of hiring, beyond the direct impact of the drop in productivity. As a result, employment (panel 6) drops by 50 percent more than under flexible wages. (And by nearly 40 percent more than under fixed effort.) In fact, there is complementarity between the cyclical responses in effort and employment. The increase in effort amplifies the shock's impact on employment. But, by lowering labor market tightness, this in turn drives up match surplus for workers, thereby further increasing the choice for effort. The upshot is that sticky wages in existing contracts magnifies cyclicality of new hires, even though wages are flexible for these new hires.[23]

In Table 2 we report key business cycle moments from our simulated models with fixed versus variable effort. The model economies are subjected to persistent productivity shocks (autocorrelation of 0.95), with standard deviation chosen so that each model exhibits a standard deviation of HP-filtered TFP equal to that for the data of 1.10 percent.[24] The table reports the standard deviation for output. For the other variables it reports the standard deviation relative to that in output as well as its correlation with output. The table includes

[23]We explored robustness of results to the frequency of wage change and the Frisch elasticity for effort. Predictably, a lower frequency of wage change magnifies the effects. For instance, if wage duration is increased from one to two years, the common-effort response magnifies the impact on employment by nearly 70 percent, compared to the 50 percent impact in our benchmark calibration. If we increase the Frisch elasticity from 0.5 to 1.0, effort's response magnifies the impact on employment by 80 percent, rather than by 50 percent.

[24]Because TPF reflects effort responses, this implies that the volatility of the shocks differ across models. For the models with fixed effort the standard deviation of the innovation to technology is 0.86%. For the models with effort fluctuations this standard deviation is respectively 0.69%, 1.06%, and 2.83% under flexible wages, sticky wages with individual effort, and sticky wages with common effort.

results under flexible and sticky wages; for brevity we focus on those under sticky wages.

The first column reports corresponding quarterly statistics for the U.S. economy for 1960 to 2013. In addition to output (real GDP), the table reports employment, average hourly earnings, and TFP. The series for output, employment, and average earnings are for the U.S. business sector as reported by the BLS program on Labor Productivity and Costs (http://www.bls.gov/lpc/). TFP is constructed from output, hours, from the same source, and business-sector capital stock from the U.S. Department of Commerce.[25]

The standard deviation of employment in the data is 0.79 that for output.[26] But under fixed effort, or with individually chosen effort, model-predicted employment is much less volatile, with standard deviations one-sixth to one-eighth that in output. By contrast, the standard deviation of employment under our preferred model with common effort is 0.57 that in output. Directly related, the model with a common effort response matches much better the relative standard deviation of TFP (0.66 versus 0.56 in the data). Finally, while none of the models match the low correlation of wages with output in the data, 0.17, the common-effort model does much better, 0.54, than all other models.

In Table 2 we report the newly bargained wage, w^*, for the model, but not the data, as there is no aggregate data series corresponding to w^*. All sticky wage models predict, not surprisingly, more volatility in w^* than in $\overline{w}$. Although there is no data series for w^*, a number of studies estimate cyclicality of new-hire wages. New hires are one component of workers that newly bargain on wages. Basu and House (2016) estimate an annual series for new-hire wages based on the NLS Youth (NLSY) panel data for 1978 to 2013. They then construct a quarterly time series based on imputing these patterns in the NLSY to quarterly data and to time periods before the NLSY time frame. Much of the volatility of such a series reflects sampling error in the estimates. So the moments in Table 2, standard deviations and correlations with output, will be biased upwards and downwards respectively by these errors. For this reason, we turn in Table 3 to reporting elasticities of key variables, including w^*, with respect to real GDP. Sampling error in the new-hire wage series should

[25] The capital series is annual; we interpolate to create a quarterly series. It also reflects a correction for procyclical capital utilization, as discussed in the data appendix.

[26] All hours fluctuations in the models reflect employment. For the data we also examined statistics on total hours (employment times workweek). Its standard deviation relative to that in output is 0.93; its correlation with output is 0.86.

not in principle bias its projection on fluctuations in real GDP.

The elasticity of the Basu-House new-hire real wage with respect to real GDP is 0.29. The elasticity of the average aggregate wage with respect to real GDP is only 0.08. So the new-hire wage series is more cyclical, though neither series displays much cyclicality. All the models generate greater wage cyclicality than in the data. But our model with a common effort response displays wage cyclicality much closer to the data, with elasticities of 0.35 and 0.16 respectively for w^* and $\overline{w}$. All other models, with sticky or flexible wages, generate w^* series with output elasticities 2.5 to 3.5 that in the data; they generate $\overline{w}$ series with output elasticities 4 to 10 times the data's.

Table reports cyclical elasticities in hours and TFP as well. Again, the model with common effort is closest to the data. Most notably, its elasticity of hours with respect to output, at 0.55, is nearly 70 percent that seen in the data. All the other models display elasticities that are less than one-fourth that seen in the data.

5.3 Volatility of Employment Versus Productivity

Shimer (2005) pointed out that the volatility of unemployment (or employment) relative to labor productivity is at odds with calibrated responses of the Mortensen-Pissarides model. Sticky wages for existing workers, provided that of new hires is flexible, does not alter these calculations under fixed effort. We show here that our preferred model, with bargaining over common effort, has a relatively small Shimer (2005) puzzle, despite the replacement flow value of unemployment being calibrated to only 75 percent. There are two reasons for this: (1) The effort response in the model exacerbates employment's response to productivity, as outlined above. (2) Effort's response masks part of the cyclicality of the underlying shock, so that employment fluctuations look larger relative to those in productivity.

To illustrate, we first feed in a series of productivity shocks matched to our series for U.S. TFP for 1960:1 to 2013:4. The upper panel of Figure 4 displays this data series in the upper left, after HP filtering. The upper and middle right panels display the predicted time series for employment, also HP-filtered, for a model with fixed effort and for our common-effort model under sticky wages. The model with fixed effort displays the standard volatility problem–employment exhibits a standard deviation only one-seventh that in the data (also displayed in the panel). Employment moves more in the model with effort response, with employment volatility one-fifth that in the data. The middle, left panel shows, however, that measured TFP in our model moves much less than that in the data. Bigger shocks are required in order to obtain the same volatility of TFP in the model as seen in the data.

For this reason, we modify the series of shocks to productivity that we feed to the model, increasing their volatility, so that the model generates a series for TFP that corresponds to the time series actually observed in the data. More exactly, we iterate on the shocks, period by period, until they converge to those observed for the data. The resulting shocks (HP-filtered) together with the predicted series for employment are given in the bottom two panels of Figure 4. The model accounts for nearly two-thirds of employment volatility (1.00 percent in the model versus 1.56 percent in the data).[27]

Since effort partially masks the impact of productivity shocks on TFP, larger productivity shocks are required to map to the same cyclicality in TFP. The series we feed in for productivity exhibits a standard deviation 2.0 times that for TFP. Given the literature does not have especially compelling explanations for productivity shocks, this doubling in size could be viewed as a deficiency of our model. But in our model productivity shocks are not the only source of volatility in TFP. We next entertain shocks to preferences. These produce business cycles in our model that closely resemble those from productivity shocks–in particular, TFP is modestly procyclical. So we could entertain a mixture of productivity and preference shocks, with much smaller productivity shocks, and achieve a similar level of success in terms of relative volatility in employment and productivity as in Figure 4. Of course, it is typically possible in models with fixed effort to match the Shimer puzzle with the right mixture of productivity and non-productivity shocks. So our model differs in that it matches the data reasonably well regardless of the realized mix of shocks.[28]

[27]Notice that our model with flexible wages and effort response generates an even greater volatility of TFP relative to employment than if effort is fixed. So wage stickiness is key. Barnichon (2012) considers a model with endogenous effort under flexible wages. He reports a smaller Shimer puzzle *conditional on both productivity and non-productivity shocks*. A positive productivity shock is actually *contractionary* for employment in his model. Prices are so sticky that output does not go up with technology; so employment declines, with the shock's impact on measured productivity masked by a decline in effort. If wages, as well as prices, were sticky in Barnichon's model, we conjecture that effort would not decline in response to a positive productivity shock that reduces labor market tightness.

[28]Efficiency wage models, like our sticky-wage model, can produce effort that moves opposite underlying shocks to productivity. Uhlig and Xu (1996) show that for some parameter values that model can produce fluctuations in employment relative to wages comparable to the data. But they stress that this requires productivity shocks be far more volatile, by a factor of 7 in terms of standard deviation, than is TFP.

5.4 Responses to Preference Shock

The shocks to productivity generate procyclical labor demand. But employment fluctuations can reflect shocks that generate movements along a labor demand schedule. We entertain shocks to the preference parameter ψ. Antecedents for such shocks, but under fixed effort, include Sveen and Weinke, 2008. An increase in ψ is a contractionary shock to labor supply, employment, and output. We illustrate responses to a one percent increase in ψ, giving the shock an autocorrelation of 0.95 to mimic that for productivity shocks.

First consider responses if effort is fixed, illustrated in Figure 5 under both flexible and sticky wages. Newly-bargained wages increase under either flexible or sticky ongoing wages, reflecting the negative shock to labor supply. But the increase is less under sticky wages because the wage is stuck higher in expectation going forward. The aggregate wage (third panel) responds much less initially under sticky wages; but after about six quarters its response largely converges to its flexible-wage counterpart. The last panel illustrates employment's negative response of about 0.1 percent; this is half the employment response to a 1 percent shock to productivity. This response is the same under flexible and sticky wages as, under fixed effort, wage stickiness for ongoing contracts is irrelevant for quantities.

Figure 6 turns to models allowing effort to respond. Under all three models, opposite the fixed-effort case, wage rates decline in response to the negative labor supply shock because it drives down worker effort. But the magnitudes differ considerably across the models. Under flexible wages effort declines by just over 0.4 percent. The decline in wage (same for w^* and $\overline{w}$) is only about half as large as in effort because the negative labor supply shock increases the effective price of labor. Output and measured TFP (panels 4-5) both show decreases of similar magnitude as in the wage. The last panel shows employment's response. Employment responds even less than under fixed effort, as the bulk of the response in effective labor is through effort, not employment.

Under sticky wages, but with effort a separate choice across workers, the new-bargain wage actually falls more than under flexible wages because effort in new bargains falls more. These responses parallel those to a negative productivity shock. Across all workers, however, wages and effort fall less than under flexible wages; therefore output and TFP decline less for the first several quarters.

Finally we turn to our preferred model with common effort. Effort and wages decline in response to the negative labor supply shock; but these effects are much more muted under common effort. As with the productivity shock, the model generates a great deal of inertia in wages rates with the newly-bargained and aggregate wage both still declining 4 years after the shock. Reflecting effort's response, both output and TFP display hump-shaped declines. Employment (panel 6) drops by about 30 percent more than under flexible wages.

Comparing the model responses for the preference shock, Figure 6, to those for the productivity shock, Figure 2, they are remarkably similar, except with respect to effort. Effort declines in response to the contractionary preference shock, whereas it increases in response to the contractionary shock to productivity. But the relative patterns in wages, output, TFP, and employment are qualitatively similar across all three models for the two shocks. (The magnitudes differ, in that it would take about a 3 percent shock to ψ to have the same impact as a 1 percent shock to productivity.)

In Table 4 we report key business cycle moments from our simulated models. The model economies are subjected to persistent preference shocks (autocorrelation 0.95). We set the standard deviation of its innovations to 2.83 percent to be the same size as the productivity shocks to our preferred model with common effort. The table reports the standard deviation for output; for other variables it reports its standard deviation relative to that for output and correlation with output. We focus discussion on the models with sticky wages.

The fixed effort model generates very different fluctuations under preference versus productivity shocks. The volatility of employment now exceeds that in output. Wages are extremely countercyclical, exhibiting correlations with respect to output of -0.88 to -0.98. The moments for models with variable effort closely resemble those generated by productivity shocks (Table 2). In particular, for the model with common effort the volatility of employment versus output is 0.63, compared to 0.57 under productivity shocks. These each fall a little short of the corresponding value in the data of 0.79. But the match to the data is much closer than for the other models.

Returning to Table 3, the bottom panel reports elasticities of the key variables with respect to output when the models are subjected to preference shocks. As with productivity shocks, these elasticities are much closer to the data for the model with a common effort response. That model does extremely well matching the wage elasticities. The model produces elasticities of about 0.6 for both TFP and employment; in the data these are, respectively, 0.4 and 0.8. The other models with variable effort predict wages and productivity that are far too cyclical and employment that is far too acyclical. Notice this also holds for these models under productivity shocks. Therefore, there is no mix of the shocks for which the variable-effort model under flexible wages, or under individual effort, can reasonably match the data. The models with fixed effort generate extremely procyclical TFP for productivity shocks, but acyclical for preference. So, under the right mix of shocks, they could potentially be in the ballpark of the data. The model with common effort will fit the data reasonably well regardless of the relative mix of the two shocks.

6 Cross-Industry Tests of the Model

The model provides a channel for wage stickiness to affect productivity, and thereby affect the number of workers hired. From data on the aggregate economy it is difficult to test those predictions without knowing the underlying shocks to the economy. For instance, our model predicts that productivity responds less to disturbances to productivity than under flexible wages. But, without knowing the true shocks to productivity, it is hard to evaluate the model based on the cyclicality of measured productivity. Instead, we examine cross-industry patterns in the cyclicality of wages, hours, and productivity. One key to the quantitative importance of our model is the extent that effort levels are common across workers at a firm. A second key is the degree of stickiness in wages. Here we construct empirical proxies across 50 U.S. industries for both flexibility in work rules and flexibility in wage rates. The next subsection describes these constructions, after first describing our cross-industry data panel. We then report how cyclicality of wages, hours, and productivity relate to industry differences in flexibility in work rules and wages. We relate these empirical results to statistics above from models that differ in work rules and wage stickiness.

6.1 Constructing Industry Data Measures

6.1.1 KLEMS Data for Cyclicality of Industry Wage, Hours, and Productivity

The U.S. KLEMS provides data on output and inputs annually from 1987 to 2012 for detailed sectors (excluding government, nonprofit, and private household sectors). From these data, we construct series for average hourly earnings, total hours worked, and value added TFP. This construction is described in the data appendix, including how we calculate value-added TFP and adjust that TFP for the impact of procyclical utilization of capital. The data reflect 50 industries, with 22 producing goods, including 18 manufacturing, while 28 provide services. Industries are listed, with value-added shares, in Table 5.

6.1.2 Measuring Workplace Flexibility

Our model results are stronger if effort levels are tied across workers. We do not have direct measures of dependence of effort choices across workers. We do, however, have data on dependence of other work-place choices, specifically hours, based on supplemental questions in the May 1997, 2001, and 2004 Current Population Surveys (CPS). These supplements ask workers, with respect to their main job, "Do you have flexible hours that allow you to vary or make changes in the time you begin/end work?" Thus we can construct a measure of work rules being tied across workers, by industry, from the fraction answering no on this question. We view the fraction with tied hours choices as a useful proxy for connected effort choices. For one, it may suggest importance of team production. Team production is a rationale to coordinate workers' hours choices; it is also presumably a reason to coordinate their effort or output choices. Secondly, firms may remove workers' option to set individual hours because they cannot monitor these choices if they depart from a workplace norm. In that setting, we presume it would also be impractical to monitor a wide diversity in effort choices. Finally, for an important segment of the workforce, those paid by salary, hours worked is an important dimension of effort choice. So tying hours of work across workers to an important extent ties effort choices across these workers.

We can match 106,624 workers from the CPS supplement to our 50 industries. Of these, 29 percent state they *can* independently affect their work schedule. Results by industry appear in Table 5.[29] The table reports the fraction answering *no* to the question, so it reflects the share of industry workers with firm-dictated hours. This varies from a low of 49 percent in the sector encompassing information processing and miscellaneous professional, scientific, and technical services to a high of 92 percent in rail transportation.

[29] The sample is restricted to workers aged 20 to 60 that neither work for the government, are self-employed, or in the armed forces.

6.1.3 Measuring Wage Flexibility

We construct measures of wage flexibility–frequency of wage change–for each of our 50 industries based on the Survey of Income and Program Participation (SIPP). The data appendix describes our SIPP sample and variable constructions. We calculate frequency of wage changes over the 4-month intervals between interviews for workers who remain with the same employer. Employed respondents report monthly earnings. We also calculate a weekly wage, dividing monthly earnings by weeks worked. A little over half of workers additionally report an hourly rate of pay. We define a worker's wage as not changing if any of these three measures remains the same across surveys.

A concern with micro data on wage changes is that some changes reflect measurement errors. Barattieri, Basu, and Gottschalk (2014), for instance, count only wage changes in the SIPP that can be viewed as a structural shift for the worker's wage series. We also allow for measurement error in wages, but adopt a simpler treatment. We assume an industry-specific Calvo probability of wage change over four months of α, while also allowing an industry-specific probability that the wage is measured with error. By comparing frequencies of wage changes over 4 versus 8 months, we can identify the 4-month probability of a change as:

$$\alpha = \frac{\Delta_8 - \Delta_4}{1 - \Delta_4}, \tag{20}$$

where Δ_4 and Δ_8, are probabilities of observing a wage change over 4 and 8-month intervals.[30]

Table 6 presents the frequencies of wage changes, over 4 and 8 months, the implied Calvo true 4-month frequency, and the probability of measurement error. We present results separately for the 1990-1993, 1996, and 2001 SIPP panels.[31] To illustrate, consider results for

[30] α is identified because, while the true probability of wage change over 8 months should equal $(2 - \alpha)$ times the 4-month probability, because measurement error contaminates measured wages, Δ_4 and Δ_8 are given by:

- $\Delta_4 = \alpha + (1 - \alpha)(2\phi - \phi^2)$
- $\Delta_8 = (2\alpha - \alpha^2) + (1 - 2\alpha - \alpha^2) * (2\phi - \phi^2)$,

where ϕ is the probability of the wage is measured with error. These yield α as in (20); and ϕ solves the equation, $0 = \phi^2 - 2\phi + \frac{2\Delta_8 - \Delta_4^2 - \Delta_4}{1 - \Delta_4}$. This identification assumes: (i) zero probability of a true wage change, followed by an exactly offsetting true wage change; (ii) zero probability that change in measurement error exactly offsets a true wage change.

[31] Beginning with the 2004 panel, the SIPP carries employment information forward from the prior survey, conditional on a respondent stating that their employment and earnings are basically unchanged. This raises concern that true wage changes, especially small ones, are missed. For this reason, we restrict attention to the 1990 through 2001 SIPP panels.

the 1990-93 panels. These show very high rates of wage changes, 69 percent over 4 months and 78 percent over eight. Under Calvo, a *true* 69 percent 4-month frequency would imply a 90 percent frequency over 8 months, rather than 78 percent. Our approach rationalizes observed rates if the true 4-month frequency is 0.30 and the probability of measurement error equals 0.33. The 1996 and 2001 panels show higher frequencies. Our estimates interpret this as reflecting slightly higher measurement error for these panels and modestly more flexible wages (Calvo parameters of 0.38 and 0.33 for the 1996 and 2001 panels.)

The bottom of the table aggregates the panels. The calculated Calvo parameter is 0.33. Inverting this frequency, and multiplying by the period of 4 months, implies an average duration of wages of 12 months. Papers in the literature often calibrate wage stickiness to a duration of 12 months; so our results support that choice.[32]

Table 5 reports the Calvo duration of wages (in months) for each KLEMS industry. That duration varies from a low of 10.1 months for wood products and for petroleum and coal products to a high of 20.7 months for water transportation.

6.2 Industry Patterns in Cyclicality of Wages, Hours, and TFP

6.2.1 Industry Results by Restricted Hours Choice

We ask how an industry's cyclical behavior depends on the flexibility of its work rules. We measure the cycle by the behavior of HP-filtered annual U.S. real GDP. We regress fluctuations in an industry's relative wage, TFP (corrected for capital utilization), and total hours (employment times workweek) on real GDP interacted with the fraction of industry workers with common work rules.[33] All regressions include a full set of year dummies– so movements in all variables are interpreted as relative to aggregates. (Each industry is weighted by its relative value added in that year.) Recall that we treat our CPS measure of group-chosen work hours as the proxy for group-chosen effort levels.

The top panel of Table 7 gives results. As anticipated by the model, industries with common work rules display significantly less cyclical wages and significantly more cyclical

[32] These results combine hourly and salaried workers. But we find similar frequencies across the groups– Calvo parameter 0.35 for hourly versus 0.31 for salaried. While the frequency of wage change is higher for salaried workers, our approach interprets this as reflecting their greater frequency of measurement errors.

[33] Although the model focuses on employment, ignoring movements in the paid workweek, the index for labor input in the diaggregated KLEMS data is for total hours.

hours. The point estimate also implies that industries with common rules, as anticipated by the model, display less procyclical TFP. But this estimated effect is very poorly tied down. The estimated impact on cyclicality of wages and hours is large. The range across industries in the share of workers with common work rules is 49 percent (high of 92 percent versus low of 43 percent). The point estimates suggests that an industry at the top of this range would display, for each 1 percent drop in GDP, a 1.2 percent *smaller* reduction in the wage, a 0.3 percent *smaller* reduction in TFP, and a 2.0 percent *larger* decline in hours than the industry with the least tied rules. These estimates align qualitatively with the model's predictions–i.e., compare model results with common versus individual effort choice, Columns 5 versus 4, in Table 3. But the estimated effects for wages and hours in Table 7 are actually much larger than suggested by the model.[34]

Real output, and therefore TFP, is presumably better measured for goods industries than for services, as it is particularly difficult to measure output quality for services. For this reason, the second panel of the table restricts attention to the 22 industries that produce goods (agriculture, mining, construction, and manufacturing industries). The results are qualitatively similar to those for the full set of industries. But the predicted impact of tied work rules on cyclicality of wages and hours is now even larger. The point estimates now suggest that, for each 1 percent drop in GDP, an industry at the top of the range for common work rules would display a 2.1 percent smaller reduction in the wage and a 2.9 percent larger decline in hours than an industry with least tied rules.

The bottom panel of Table 7 restricts the sample to 14 industries that produce durable goods. We anticipate much more procyclical labor demand for these industries, given the cyclical shift in expenditures toward these goods. When we restrict to durables, we again see qualitatively similar results, with the industries with common work rules showing much less cyclical wages and much more cyclical hours.

[34] Our model does not have distinct industries. To treat our cross-industry results as literally comparable to model predictions under individual versus commonly chosen effort requires some nontrivial assumptions. For instance, we would need to assume that our empirical industries have industry-specific capital and labor markets. If we do compare to the model results in Table 3, the impact on wages and hours is at least several times that suggested by the model.

6.2.2 Industry Results by Wage Stickiness

We next ask how an industry's cyclical behavior depends on its wage flexibility. We regress fluctuations in an industry's relative wage, TFP, and hours on the aggregate cycle (HP-filtered real GDP) interacted with stickiness of that industry's wage. Stickiness is measured by expected wage duration in months, calculated under the Calvo assumption.

The top panel of Table 8 gives results for all 50 industries. As predicted by the model, industries with stickier wages display less cyclical TFP and more cyclical hours. But these effects are not estimated very precisely. Furthermore, we do not see less cyclical wages for the stickier wage industries; so this makes the data harder to interpret in light of the model.

The second panel of the table restricts attention to the 22 good industries, in light of concerns that output and TFP may be poorly measured in services. The impact of wage stickiness on cyclicality of TFP and hours is stronger for these industries. As predicted by the model, industries with stickier wages display less cyclical TFP and more cyclical hours, with these effects statistically different from zero. Greater industry wage stickiness is now also associated with less procyclical wages; but this estimated effect is not statistically significant. The range across goods industries in wage duration is 5.3 months, reflecting a high of 15.4 months versus a low of 10.1. The point estimates for goods industries suggests that, for each 1 percent drop in GDP, an industry with the most sticky wages would display a 0.6 percent *smaller* reduction in the wage, a 2.2 percent *smaller* reduction in TFP, and a 1.3 percent *larger* decline in hours than an industry with the most flexible wages. The estimates align qualitatively with the model predictions, though they appear larger in magnitude than we would anticipate from our model.[35]

The bottom panel of the table restricts the sample to the 14 durable goods industries. The results are qualitatively similar to that for all goods industries, but with a modestly larger impact on TFP cyclicality and modestly smaller impact on hours cyclicality.

[35] We compared our benchmark economy with wage duration of 12 months to one calibrated with 6 months duration. That comparison suggests an impact of wage stickiness on hours cyclicality that is only one-third as large as we see empirically across goods industries. For TFP cyclicality, it suggests an impact that is an order of magnitude smaller.

7 Conclusion

We start from what we view as a reasonable depiction of wage setting with wages sticky for many current workers, but flexible for new hires. We depart from standard treatments of sticky wages by allowing worker effort to respond to the wage being too high or low. We see this as consistent with firms making fairly frequent choices for production and work assignments, more frequent than wages are re-bargained.

The model has several implications for cyclicality of wages and employment. One is that wage stickiness in existing matches does matter for employment in our matching model, even though it does not under fixed effort. A higher wage in existing contracts, by driving up worker effort, crowds out hiring. We also find that wage setting in our model places much less weight on future desired wage rates because deviations from future target wages will be partially undone by effort's response. Thus it weakens the forward-looking element of wage setting, even though expectations are fully rational. If we constrain choices for effort to be common across workers then the model generates a great deal of wage inertia–for our benchmark calibration, only after six quarters does the aggregate wages achieve the same decline that is achieved in one quarter under sticky wages with fixed effort. Finally, under common effort, volatility in employment is increased relative to that in labor productivity because effort magnifies the impact of a labor demand shock on employment, while partially masking its impact on labor productivity. Thus it generates a much smaller Shimer puzzle than under flexible wages or under fixed effort.

We construct measures of tied work rules and wage stickiness across 50 industries to test the prediction that wage stickiness matters most when effort choice is coordinated across workers. We do find that industries with tied work rules display less cyclical wages and more cyclical total hours. Also consistent with the model, industries with stickier wages show less procyclical TFP and more procyclical hours; but these industries do not show less procyclical wage rates, which the model would suggest.

We end with a speculative discussion on whether our model can help understand why productivity has been less procyclical in recent recessions. U.S. labor productivity has been modestly procyclical for the last 50 years. Our model is fairly consistent with this pattern for both shocks considered (Table 3). For the last 25, or so, years labor productivity is acyclical, or perhaps even slightly countercyclical.[36] The most common explanations put forward for this change is that the underlying shocks have shifted or structural changes have occurred in the labor market. (See Gali and Gambetti, 2009, Van Zandweghe, 2010, and Fernald and Wong, 2015, for discussions.) Our model suggests that effort variations can be important. There are a couple of reasons why it may have become possible for firms to ask more of workers during recessions.

Match rents may have especially fallen for firms in recent recession. Firms that faced borrowing problems during the Great Recession cut back dramatically on investment, advertising, and research as well as on hiring (e.g., Campello, et al., 2010). Facing tight resource constraints, the firm's ability to bargain for greater effort may have been stronger than in past recessions. In terms of our model, a match facing a sharper drop in $J - H$ generates a stronger effort increase.

Secondly, there have been structural changes in the workplace that have arguably made it easier for firms to ask more of workers in downturns. For one, a much greater share of workers are now paid by salary, rather than hourly. This means the real pay of workers can be reduced by asking for more hours, at a given pay, without expanding exertion per hour. Anger (2011) shows that extra unpaid hours are highly countercyclical for salaried workers. Also, the share of union workers has sharply declined, possibly providing greater flexibility for firms to adjust demands on workers in response to economic conditions. Schmitz (2005) presents an example from ore mining where relaxing terms in union contracts led to a dramatic change in work rules and productivity.[37]

[36] For 1960 to 2013 the elasticity of labor productivity with respect to output equals 0.20 (standard error 0.05). Data are quarterly from the BLS program on Labor Productivity and Costs. For the first and second halves of the sample (1960-1986, 1987-2013) the elasticities are respectively 0.31 (0.04) and -0.08 (0.07).

[37] Gali and van Rens (2014) argue that greater flexibility of employment has caused firms to exhibit less cyclical labor hoarding. They associate labor hoarding in a recession as a rationale to ask less of workers. But we stress that this does not follow under sticky wages–so it implicitly assume flexible wages. Wong (2014) points out that the a natural implication of the Gali hypothesis is that the paid workweek would have become less cyclical; but Wong and Fernald and Wong (2015) argue that effort and capital utilization have move toward countercyclical, while the paid workweek remains just as procyclical.

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Appendices

A Log-Linearized Dynamics of the Models

In this appendix, we describe how to derive the log-linearized dynamics of key variables around the steady state for all 5 model specifications. Production is subject to technology shocks (z) and the utility from leisure is subject to preference shocks (ξ). We assume that z and ξ follows AR(1) process in logs. For variable x, $\hat{x}$ denotes the percentage deviation from its steady state $\tilde{x}$.

A.1 Log-Linearized Equations for All Model Specifications

Sticky Wage Individual Effort Model Given the first-order Taylor approximation of worker's match surplus, $H(w, \mathbf{s}) - H(w^{*\prime}, \mathbf{s}) = \frac{\partial H(w^*, \mathbf{s})}{\partial w}\big(w - w^{*\prime}\big)$. The value of match surplus of a worker (3) is expressed as:

$$
\begin{aligned}
H(w, \mathbf{s}) = w - b + \xi\psi\frac{(1-e)^{1-1/\gamma} - 1}{1 - 1/\gamma} &+ \beta(1-\delta)\lambda\mathbb{E}\big[\epsilon(w^{*\prime}, \mathbf{s}')(w - w^{*\prime})|\mathbf{s}\big] \\
+ \beta\big(1 - \delta - p(\theta)\big)\mathbb{E}\big[H(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big]&
\end{aligned}
\tag{A.1}
$$

where $\epsilon(w^*, \mathbf{s})$ denotes the increase in worker surplus (for a newly-negotiated match) from a marginal wage increase:

$$
\epsilon(w^*, \mathbf{s}) = \frac{\partial H(w^*, \mathbf{s})}{\partial w} = 1 - \xi\psi(1-e)^{-1/\gamma}\Lambda(w^*, \mathbf{s}) + \beta(1-\delta)\lambda\mathbb{E}\big[\epsilon(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big], \tag{A.2}
$$

where $\Lambda(w^*, \mathbf{s}) = \partial e(w^*, \mathbf{s})/\partial w$ denotes the effort change induced by a wage increase. Analogously, the value of match surplus for the firm (4) is:

$$
J(w, \mathbf{s}) = \alpha z k^{1-\alpha} e - w + \beta(1-\delta)\lambda\mathbb{E}\big[\mu(w^{*\prime}, \mathbf{s}')(w - w^{*\prime})|\mathbf{s}\big] + \beta(1-\delta)\mathbb{E}\big[J(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big], \tag{A.3}
$$

where $\mu(w^*, \mathbf{s})$ denotes decrease in firm surplus (for a newly-negotiated match) from a marginal wage increase:

$$
\mu(w^*, \mathbf{s}) = -\frac{\partial J(w^*, \mathbf{s})}{\partial w} = 1 - \alpha z k^{1-\alpha}\Lambda(w^*, \mathbf{s}) + \beta(1-\delta)\lambda\mathbb{E}\big[\mu(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big]. \tag{A.4}
$$

The log-linearized dynamics of $H(w,\mathbf{s})$, $J(w,\mathbf{s})$ and $\mu(w^*,\mathbf{s})/\epsilon(w^*,\mathbf{s})$ are:

$$\begin{aligned}\widehat{H} = \frac{1}{\widetilde{H}}\Bigg\{ &\widetilde{w}\widehat{w} + \widetilde{B}\widehat{\xi} - \psi(1-\widetilde{e})^{-1/\gamma}\widetilde{e}\widehat{e} + \beta(1-\delta)\lambda\widetilde{\epsilon}\widetilde{w}\big(\widehat{w} - E\widehat{w}^{*\prime}\big) \\ &+ \left(\frac{\eta}{1-\eta}\right)\left(\left[\frac{(1-\delta)\eta\kappa}{\widetilde{q}} - \kappa\widetilde{\theta}\right]\widehat{\theta} - \left[\frac{(1-\delta)\kappa}{\widetilde{q}} - \kappa\widetilde{\theta}\right]E\big[\widehat{\mu}' - \widehat{\epsilon}'\big]\right)\Bigg\},\end{aligned} \tag{A.5}$$

$$\widehat{J} = \frac{1}{\widetilde{J}}\left\{\alpha\widetilde{y}\big(\widehat{z} + (1-\alpha)\widehat{k} + \widehat{e}\big) - \widetilde{w}\widehat{w} - \beta(1-\delta)\lambda\widetilde{\mu}\widetilde{w}\big(\widehat{w} - E\widehat{w}^{*\prime}\big) + \frac{(1-\delta)\eta\kappa}{\widetilde{q}}\widehat{\theta}\right\}, \tag{A.6}$$

$$\widehat{\mu} - \widehat{\epsilon} = -\frac{\widetilde{\gamma}\alpha\widetilde{y}}{\eta\widetilde{J}}\left[\widehat{z} + (1-\alpha)\widehat{k} - \widehat{\xi} - \frac{1}{\widetilde{\gamma}}\widehat{e}\right] + \beta(1-\delta)\lambda E\big[\widehat{\mu}' - \widehat{\epsilon}'\big], \tag{A.7}$$

where $\widetilde{B} = \psi\dfrac{(1-\widetilde{e})^{1-1/\gamma} - 1}{1-1/\gamma}$ and $\widetilde{\epsilon} = \widetilde{\mu} = \dfrac{\eta\widetilde{J}}{\widetilde{\gamma}\alpha\widetilde{y} + \eta\widetilde{J}\big(1-\beta(1-\delta)\lambda\big)}$.

The F.O.C.'s of wage and effort bargaining, (7) and (9), yield:

$$\widehat{\mu} - \widehat{\epsilon} = \widehat{z} + (1-\alpha)\widehat{k} - \widehat{\xi} - \frac{1}{\widetilde{\gamma}}\widehat{e} = \left(\frac{\eta\widetilde{J}}{\widetilde{\gamma}\alpha\widetilde{y} + \eta\widetilde{J}}\right)\beta(1-\delta)\lambda E\big[\widehat{\mu}' - \widehat{\epsilon}'\big]. \tag{A.8}$$

This implies that $\widehat{\mu} = \widehat{\epsilon}$ for all $\mathbf{s}$. Given the generalized Nash bargaining for matches whose wage are re-negotiated, the increased surplus for the worker is proportional to the decreased surplus for the firm.[38] Therefore, when the wage is renegotiated, i.e., $\widehat{w} = \widehat{w}^*$, effort equals the Frisch elasticity multiplied by the marginal product of labor:

$$\widehat{e}(\widehat{w}^*) = \widetilde{\gamma}\Big(\widehat{z} + (1-\alpha)\widehat{k} - \widehat{\xi}\Big). \tag{A.9}$$

The F.O.C. for effort bargaining (9) yields:

$$\widehat{J} + \frac{1}{\widetilde{\gamma}}\widehat{e} = \widehat{H} + \widehat{z} + (1-\alpha)\widehat{k}. \tag{A.10}$$

Substituting (A.5) and (A.6) into (A.10) with $\widehat{\mu} = \widehat{\epsilon}$ yields the individual effort choice as:

$$\begin{aligned}\left(\frac{\widetilde{\gamma}\alpha\widetilde{y} + \eta\widetilde{J}}{\widetilde{\gamma}}\right)\widehat{e} = &\frac{\widetilde{w}}{1-\tau_i}\widehat{w} - \frac{\tau_i\widetilde{w}}{1-\tau_i}E\widehat{w}^{*\prime} - \eta\kappa\widetilde{\theta}\widehat{\theta} \\ &+ \Big((1-\eta)\widetilde{B} - \eta\widetilde{J}\Big)\widehat{\xi} + \eta\left(\widetilde{J} - \alpha\widetilde{y}\right)\left(\widehat{z} + (1-\alpha)\widehat{k}\right),\end{aligned} \tag{A.11}$$

[38]Note that the first-order condition for the wage bargaining, (7), does not necessarily implies $\mu(w^*,\mathbf{s}) = \epsilon(w^*,\mathbf{s})$ for all $\mathbf{s}$. Surplus for each party changes in proportion to a first-order approximation: $\widehat{\mu} = \widehat{\epsilon}$.

where $\tau_i = \dfrac{\beta(1-\delta)\lambda\widetilde{\mu}}{1+\beta(1-\delta)\lambda\widetilde{\mu}} = \left(\dfrac{\eta\widetilde{J}}{\widetilde{\gamma}\alpha\widetilde{y}+\eta\widetilde{J}}\right)\tau$.

Integrating (A.11) over the wage distribution $G(w)$ and applying the definitions for aggregate effort, $\overline{e} = \displaystyle\int e(w)dG(w)$, and aggregate wage, $\overline{w} = \displaystyle\int wdG(w)$, and $\widehat{k} = -\big(\widehat{n}+\widehat{\overline{e}}\big)$ yields the following expression for aggregate effort:

$$\begin{aligned}\Xi\widehat{\overline{e}} =& \frac{\widetilde{w}}{1-\tau_i}\widehat{\overline{w}} - \frac{\tau_i\widetilde{w}}{1-\tau_i}E\widehat{w}^{*\prime} - \eta\kappa\widetilde{\theta}\widehat{\theta} \\ &+ \left((1-\eta)\widetilde{B}-\eta\widetilde{J}\right)\widehat{\xi} + \eta\left(\widetilde{J}-\alpha\widetilde{y}\right)\left(\widehat{z}-(1-\alpha)\widehat{n}\right),\end{aligned} \tag{A.12}$$

where $\Xi = \big(1-\eta(1-\alpha)\big)\alpha\widetilde{y} + \left(\dfrac{1}{\widetilde{\gamma}}+1-\alpha\right)\eta\widetilde{J}$.

Log-linearizing the first-order condition for the wage bargaining, (7), and substituting (A.5) and (A.6) for $\widehat{J}$ and $\widehat{H}$, respectively, with $\widehat{\mu}-\widehat{\epsilon}=0$ yields the Nash-bargained wage:

$$\begin{aligned}\widehat{w}^* = (1-\tau_i)\Bigg\{&\alpha\left(\frac{\widetilde{y}}{\widetilde{w}}\right)(\eta+\widetilde{\gamma})\big(\widehat{z}+(1-\alpha)\widehat{k}\big) \\ &+\eta\kappa\left(\frac{\widetilde{\theta}}{\widetilde{w}}\right)\widehat{\theta} + \left(\frac{\widetilde{\gamma}\alpha\widetilde{y}+(1-\eta)\widetilde{B}}{\widetilde{w}}\right)\widehat{\xi}\Bigg\} + \tau_i E\widehat{w}^{*\prime}.\end{aligned} \tag{A.13}$$

Substituting (A.12) for $\widehat{\overline{e}}$ in $\widehat{k} = -(\widehat{n}+\widehat{\overline{e}})$ shows that the Nash-bargaining wage depends on its future expectation $E\widehat{w}^{*\prime}$, the aggregate wage $\widehat{\overline{w}}$, and the wage rate under the flexible wage $\widehat{w}^*_F$ (described below in the model with flexible wage):

$$\widehat{w}^* = \left(1-\frac{\varphi_1}{\widetilde{\gamma}\Xi}\right)\widehat{\overline{w}} + \frac{\varphi_1}{\widetilde{\gamma}\Xi}\Big\{(1-\tau_i)\widehat{w}^*_F + \tau_i E\widehat{w}^{*\prime}\Big\}, \tag{A.14}$$

where $\varphi_1 = \big(1+\widetilde{\gamma}(1-\alpha)\big)\big(\widetilde{\gamma}\alpha\widetilde{y}+\eta\widetilde{J}\big)$. The law of motion for total wage payment, $n'\overline{w}' + (1-\delta)\lambda n\overline{w} + mw^{*\prime}$, and that for employment, $\widehat{n}' = (1-\delta)\widehat{n}+\delta\widehat{m}$, yields the aggregate wage as a weighted average of newly-negotiated wage and its lagged value $\widehat{\overline{w}}_{-1}$:

$$\widehat{\overline{w}} = \big(1-\lambda(1-\delta)\big)\widehat{w}^* + \lambda(1-\delta)\widehat{\overline{w}}_{-1} = (1-\phi)\widehat{w}^* + \phi\widehat{\overline{w}}_{-1}.$$

Substituting (A.14) for $\widehat{w}^*$ expresses the aggregate wage in terms of its future expectation $E\widehat{w}^{*\prime}$, its lagged value, and the wage under the flexible wage $\widehat{w}^*_F$:

$$\widehat{\overline{w}} = \frac{\varphi_1}{\varphi_1-\varphi_2}(1-\phi)\Big\{(1-\tau_i)\widehat{w}^*_F + \tau_i E\widehat{w}^{*\prime}\Big\} + \frac{\widetilde{\gamma}\Xi}{\varphi_1-\varphi_2}\phi\widehat{\overline{w}}_{-1}, \tag{A.15}$$

where $\varphi_2 = \phi(1-\alpha)(\eta+\widetilde{\gamma})\widetilde{\gamma}\alpha\widetilde{y}$.

Finally, log-linearizing the free entry condition (5) using (A.6) yields the forward-looking difference equation for $\widehat{\theta}$:

$$\frac{\eta\kappa}{\widetilde{q}}\widehat{\theta} = \beta E\left[\alpha\widetilde{y}\left(\widehat{z}' + (1-\alpha)\widehat{k}' + \widehat{e}'\right) - \frac{\widetilde{w}}{1-\tau_i}\widehat{w}^{*\prime} + \frac{\tau_i\widetilde{w}}{1-\tau_i}\widehat{w}^{*\prime\prime} + \frac{\eta\kappa}{\widetilde{q}}(1-\delta)\widehat{\theta}'\right]. \tag{A.16}$$

Substituting (A.13) and (A.9) into (A.16) yields the dynamics of v/u ratio as:

$$\frac{\eta\kappa}{\widetilde{q}}\widehat{\theta} = \beta E\left[(1-\eta)\alpha\widetilde{y}\left(\widehat{z}' + (1-\alpha)\widehat{k}'\right) + \frac{\eta\kappa}{\widetilde{q}}(1-\delta-\widetilde{p})\widehat{\theta}' + (1-\eta)\widetilde{B}\widehat{\xi}'\right]. \tag{A.17}$$

Sticky Wage Common Effort Model Match surpluses under sticky wages with common effort choice are identical to those in the individual effort model: (A.1) and (A.3). So are their log-linearized equations: (A.5) and (A.6). However, the effects of the wage bargaining on the match surpluses differ slightly from (A.2) and (A.4), reflecting the assumption that individual wage bargains do not influence the common effort choice, i.e. $\Lambda(w^*, \mathbf{s}) = \frac{\partial e(w^*,\mathbf{s})}{\partial w} = 0$. For this reason, the surplus gain to a worker and surplus loss to a firm, from a wage increase in the common effort model are simply:

$$\epsilon(w^*, \mathbf{s}) = \frac{\partial H(w^*, \mathbf{s})}{\partial w} = 1 + \beta(1-\delta)\lambda\mathbb{E}\left[\epsilon(w^{*\prime}, \mathbf{s}')|\mathbf{s}\right], \tag{A.18}$$

$$\mu(w^*, \mathbf{s}) = -\frac{\partial J(w^*, \mathbf{s})}{\partial w} = 1 + \beta(1-\delta)\lambda\mathbb{E}\left[\mu(w^{*\prime}, \mathbf{s}')|\mathbf{s}\right]. \tag{A.19}$$

It is clear that $\epsilon(w^*, \mathbf{s}) = \mu(w^*, \mathbf{s})$ for all $\mathbf{s}$, with $\widetilde{\epsilon} = \widetilde{\mu} = \dfrac{1}{1-\beta(1-\delta)\lambda}$; so $\widehat{\mu} - \widehat{\epsilon} = 0$ for all $\mathbf{s}$.[39]

The log-linearized first-order condition for common effort bargaining is given by:

$$\frac{1}{\widetilde{\gamma}}\widehat{e} = \widehat{z} + (1-\alpha)\widehat{k} + \int\left[\widehat{H} - \widehat{J}\right]dG, \tag{A.20}$$

and $\widehat{H} - \widehat{J}$ is obtained from (A.5) and (A.6) as:

$$\begin{aligned}\widehat{H} - \widehat{J} = \frac{1}{\eta\widetilde{J}}\Big\{&(1-\eta)(\widetilde{w}-b)\widehat{\xi} + \left(1+\beta(1-\delta)\lambda\widetilde{\mu}\right)\widetilde{w}\widehat{w} - \beta(1-\delta)\lambda\widetilde{\mu}E\widehat{w}^{*\prime} \\ &- \eta\kappa\widetilde{\theta}\widehat{\theta} - \alpha\widetilde{y}\widehat{e} - \eta\alpha\widetilde{y}\left(\widehat{z} + (1-\alpha)\widehat{k}\right) - \frac{\eta\kappa}{\widetilde{q}}(1-\delta-\widetilde{p})E\left[\widehat{\mu}' - \widehat{\epsilon}'\right]\Big\}.\end{aligned} \tag{A.21}$$

[39]Therefore, (8), the F.O.C. of wage bargaining, holds exactly (not to a first-order approximation) in the common effort model.

Integrating (A.21) over the wage distribution, substituting the resulting expression into (A.20), and applying the equilibrium condition, $\widehat{e} = \widehat{\overline{e}}$, yields the log-linearized expression for aggregate effort. That expression is identical to (A.12) except now $\tau = \beta(1-\delta)\lambda$.

The log-linearized first-order condition for the wage bargaining is given as $\widehat{H} = \widehat{J}$. Substituting (A.5), (A.6) and (A.12) for $\widehat{H}$, $\widehat{J}$ and $\widehat{\overline{e}}$, respectively, yields the log-linearized expression for the bargained wage:

$$\widehat{w}^* = \left(1 - \frac{\varphi_3}{\widetilde{\gamma}\Xi}\right)\widehat{\overline{w}} + \frac{\varphi_3}{\widetilde{\gamma}\Xi}\Big\{(1-\tau)\widehat{w}^*_{FV} + \tau E\widehat{w}^{*\prime}\Big\}, \tag{A.22}$$

where $\varphi_3 = \big(1 + \widetilde{\gamma}(1-\alpha)\big)\eta\widetilde{J}$.

Substituting (A.22) into $\widehat{\overline{w}} = (1-\phi)\widehat{w}^* + \phi\widehat{\overline{w}}_{-1}$ and rearranging terms yields the log-linearized expression for the aggregate wage:

$$\widehat{\overline{w}} = \frac{\varphi_3}{\varphi_3 + \varphi_4}(1-\phi)\Big\{(1-\tau)\widehat{w}^*_F + \tau E\widehat{w}^{*\prime}\Big\} + \frac{\widetilde{\gamma}\Xi}{\varphi_3 + \varphi_4}\phi\widehat{\overline{w}}_{-1}, \tag{A.23}$$

where $\varphi_4 = \phi\big(1 - \eta(1-\alpha)\big)\widetilde{\gamma}\alpha\widetilde{y}$.

The dynamics of v/u ratio in the common effort model is characterized by the same equation as (A.17). Moreover, the log-linearized expressions for v/u ratio are identical regardless of the specifications of wage and effort bargaining. Note that, despite the identical expressions for v/u ratio across models, its quantitative properties differ considerably because the models exhibit quite different behaviors in wages and effort.

Flexible Wage Variable Effort Model If wages are perfectly flexible, i.e., $w = w^*$, match surpluses and the derivative of match surpluses with respect to the wage are:

$$H(w^*, \mathbf{s}) = w^* - b + \xi\psi\frac{(1-e)^{1-1/\gamma} - 1}{1 - 1/\gamma} + \beta(1 - \delta - p(\theta))\mathbb{E}\big[H(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big], \tag{A.24}$$

$$J(w^*, \mathbf{s}) = \alpha z k^{1-\alpha} e - w^* + \beta(1-\delta)\mathbb{E}\big[J(w^{*\prime}, \mathbf{s}')|\mathbf{s}\big], \tag{A.25}$$

$$\epsilon(w^*, \mathbf{s}) = 1 - \xi\psi(1-e)^{-1/\gamma}\Lambda(w^*, \mathbf{s}), \tag{A.26}$$

$$\mu(w^*, \mathbf{s}) = 1 - \alpha z k^{1-\alpha}\Lambda(w^*, \mathbf{s}). \tag{A.27}$$

Note that these expressions are exactly identical to (A.1), (A.3), (A.2) and (A.4) with $\lambda = 0$.

The F.O.C. for the effort choice, combined with (A.26) and (A.27), is:

$$\widehat{\mu} - \widehat{\epsilon} = \widehat{z} + (1-\alpha)\widehat{k} - \widehat{\xi} - \frac{1}{\widetilde{\widetilde{\gamma}}}\widehat{e} = -\frac{\eta\widetilde{J}}{\widetilde{\gamma}\alpha\widetilde{y}}\Big(\widehat{\mu} - \widehat{\epsilon}\Big),$$

which implies $\widehat{\mu} = \widehat{\epsilon}$ for all $\mathbf{s}$, and $\widehat{e} = \widetilde{\gamma}\big(\widehat{z} + (1-\alpha)\widehat{k} - \widehat{\xi}\big)$. Substituting $\widehat{k} = -(\widehat{n} + \widehat{e})$ yields the effort choice:

$$\widehat{e} = \frac{\widetilde{\gamma}}{1+\widetilde{\gamma}(1-\alpha)}\Big(\widehat{z} - (1-\alpha)\widehat{n} - \widehat{\xi}\Big). \tag{A.28}$$

The (log-linearized) first-order condition for the bargained wage becomes:

$$\begin{aligned}\widehat{w}^*_F = \alpha\left(\frac{\widetilde{y}}{\widetilde{w}}\right)\left(\frac{\eta+\widetilde{\gamma}}{1+\widetilde{\gamma}(1-\alpha)}\right)\big(\widehat{z} - (1-\alpha)\widehat{n}\big) + \eta\kappa\left(\frac{\widetilde{\theta}}{\widetilde{w}}\right)\widehat{\theta} \\ - \left(\frac{\widetilde{\gamma}\alpha\widetilde{y}\big(1-\eta(1-\alpha)\big)}{\big(1+\widetilde{\gamma}(1-\alpha)\big)\widetilde{w}} + \frac{(1-\eta)\widetilde{B}}{\widetilde{w}}\right)\widehat{\xi}\end{aligned} \tag{A.29}$$

Flexible Wage Fixed Effort Model Under flexible wages and fixed effort, the worker and firm match surpluses are identical to (A.24) and (A.25) respectively, with $e = \widetilde{e}$ and $\epsilon(w^*, \mathbf{s}) = \mu(w^*, \mathbf{s}) = 1$ for all $\mathbf{s}$. Then, the Nash bargained wage is:

$$\widehat{w}^*_F = \eta\alpha\left(\frac{\widetilde{y}}{\widetilde{w}}\right)\big(\widehat{z} - (1-\alpha)\widehat{n}\big) + \eta\kappa\left(\frac{\widetilde{\theta}}{\widetilde{w}}\right)\widehat{\theta} - \left(\frac{(1-\eta)\widetilde{B}}{\widetilde{w}}\right)\widehat{\xi}, \tag{A.30}$$

which is identical to the expression for $\widehat{w}^*_F$ in (A.29) when $\widetilde{\gamma} = 0$. (The fixed effort case is nested in (A.29).)

Sticky Wage Fixed Effort Model Under the standard sticky-wage with effort fixed, match surpluses for worker and firm are identical to (A.1) and (A.3) respectively, with $e = \widetilde{e}$ fixed at its steady-state level. Because $\epsilon(w^*, \mathbf{s}) = 1 + \beta(1-\delta)\lambda\mathbb{E}[\epsilon(\mathbf{s}')|\mathbf{s}]$ and $\mu(w^*, \mathbf{s}) = 1 + \beta(1-\delta)\lambda\mathbb{E}[\mu(\mathbf{s}')|\mathbf{s}]$, we have $\epsilon(w^*, \mathbf{s}) = \mu(w^*, \mathbf{s})$ for all $\mathbf{s}$, where $\widetilde{\epsilon} = \widetilde{\mu} = \dfrac{1}{1-\beta(1-\delta)\lambda} = \dfrac{1}{1-\tau}$. This implies the increase (decrease) in value of match surplus for the worker (firm) of a wage increase is simply 1.

The log-linearized first-order condition for wage bargaining is:

$$\widehat{w}^* = (1-\tau)\widehat{w}^*_F + \tau E\widehat{w}^{*\prime}. \tag{A.31}$$

where $\widehat{w}^*_F$ is the bargained wage under flexible wage and fixed effort in (A.30). The aggregate wage becomes:

$$\widehat{\overline{w}} = (1-\phi)\Big\{(1-\tau)\widehat{w}^*_F + \tau E\widehat{w}^{*\prime}\Big\} + \phi\widehat{\overline{w}}_{-1}. \tag{A.32}$$

Other Aggregate Variables Given the aggregate wage, effort and the labor-market tightness, $\widehat{\overline{w}}$, $\widehat{\overline{e}}$ and $\widehat{\theta}$, dynamics of other aggregates are as follows:

$$\begin{aligned}
\widehat{z} &= \rho_z \widehat{z}_{-1} + \widehat{\varepsilon}_z \\
\widehat{\xi} &= \rho_\xi \widehat{\xi}_{-1} + \widehat{\varepsilon}_\xi \\
\widehat{y} &= \widehat{z} + \alpha\left(\widehat{n} + \widehat{\overline{e}}\right) \\
\widehat{v} &= \widehat{\theta} + \widehat{u}_{-1} \\
\widehat{u} &= -\frac{\widetilde{n}}{1-\widetilde{n}}\widehat{n} \\
\widehat{n} &= (1-\delta)\widehat{n}_{-1} + \delta\widehat{m} \\
\widehat{m} &= (1-\eta)\widehat{\theta} + \widehat{u}_{-1} \\
\widehat{TFP} &= \widehat{z} + \alpha\widehat{\overline{e}}
\end{aligned}$$

A.2 Aggregate Wage Dynamics in Sticky Wage Models

We now illustrate the aggregate wage dynamics across the models (which we described in Section 4). By iterating on (A.14), the Nash bargained wage in the individual effort model is can be written as follows, which is essentially identical to (18) in the main text:

$$\begin{aligned}
\widehat{w}^* =& \sum_{j=0}^{\infty}\left(\frac{\varphi_1\tau_i}{\widetilde{\gamma}\Xi}\right)^j\left\{\frac{\varphi_1}{\widetilde{\gamma}\Xi}(1-\tau_i)\widehat{w}^*_{F,t+j} + \left(1-\frac{\varphi_1}{\widetilde{\gamma}\Xi}\right)\widehat{\overline{w}}_{t+j}\right\} \\
=& \varphi\left(\frac{1}{\tau_i}-1\right)\frac{E\widehat{w}^*_{F,t}}{1-\varphi\mathbb{F}} + \left(1-\frac{\varphi}{\tau_i}\right)\frac{E\widehat{\overline{w}}_t}{1-\varphi\mathbb{F}},
\end{aligned} \tag{A.33}$$

where $\varphi = \dfrac{\varphi_1\tau_i}{\widetilde{\gamma}\Xi}$ and $\mathbb{F}$ is a forward operator, i.e., $\mathbb{F}x_t = Ex_{t+1}$. Analogously, by iterating on (A.22), the Nash bargained wage under common effort (where $\varphi_1\tau_i = \varphi_3\tau$) can be written as follows, which is essentially identical to (16) in the main text:

$$\begin{aligned}
\widehat{w}^* =& \sum_{j=0}^{\infty}\left(\frac{\varphi_3\tau}{\widetilde{\gamma}\Xi}\right)^j\left\{\frac{\varphi_3}{\widetilde{\gamma}\Xi}(1-\tau)\widehat{w}^*_{F,t+j} + \left(1-\frac{\varphi_3}{\widetilde{\gamma}\Xi}\right)\widehat{\overline{w}}_{t+j}\right\} \\
=& \varphi\left(\frac{1}{\tau}-1\right)\frac{E\widehat{w}^*_{F,t}}{1-\varphi\mathbb{F}} + \left(1-\frac{\varphi}{\tau}\right)\frac{E\widehat{\overline{w}}_t}{1-\varphi\mathbb{F}}.
\end{aligned} \tag{A.34}$$

While the two expressions appear nearly identical, τ_i in the individual effort model differs considerably from the τ in the common effort model. As a result, the aggregate wage dynamics of the two models differ significantly, with aggregate wages much more sluggish under common effort (as explained in Section 4).

The model with fixed effort is readily obtained by simply setting the Frisch elasticity of effort to zero, $\widetilde{\gamma} = 0$, which also implies $\varphi = \tau$. Hence, the Nash bargained wage is:

$$\widehat{w}^* = (1-\tau)\sum_{j=0}^{\infty} \tau^j E\widehat{w}^*_{F,t+j} = (1-\tau)\frac{E\widehat{w}^*_{F,t}}{1-\tau\mathbb{F}}. \tag{A.35}$$

Substituting (A.33) into $\widehat{\overline{w}}_t = (1-\phi)\widehat{w}^*_t + \phi\widehat{\overline{w}}_{t-1}$, and multiplying both sides by $1-\varphi\mathbb{F}$, yields the aggregate wage in the individual effort model (19) in Section 4:

$$\widehat{\overline{w}}_t = \pi_1^i \widehat{\overline{w}}_{t-1} + \pi_2^i E\widehat{\overline{w}}_{t+1} + (1-\pi_1^i - \pi_2^i)\widehat{w}^*_{F,t},$$

where $\pi_1^i = \dfrac{\phi}{1+\varphi\phi - (1-\phi)(1-\varphi/\tau_i)}$ and $\pi_2^i = \dfrac{\varphi}{1+\varphi\phi - (1-\phi)(1-\varphi/\tau_i)}$.

Analogous to (A.34) and (A.35), the aggregate wage under common effort (17) is:

$$\widehat{\overline{w}}_t = \pi_1^c \widehat{\overline{w}}_{t-1} + \pi_2^c E\widehat{\overline{w}}_{t+1} + (1-\pi_1^c - \pi_2^c)\widehat{w}^*_{F,t},$$

where $\pi_1^c = \dfrac{\phi}{1+\varphi\phi - (1-\phi)(1-\varphi/\tau)}$, $\pi_2^c = \dfrac{\varphi}{1+\varphi\phi - (1-\phi)(1-\varphi/\tau)}$.

Similarly, the aggregate wage in the standard sticky wage with fixed effort (15) is

$$\widehat{\overline{w}}_t = \pi_1 \widehat{\overline{w}}_{t-1} + \pi_2 E\widehat{\overline{w}}_{t+1} + (1-\pi_1 - \pi_2)\widehat{w}^*_{F,t},$$

where $\pi_1 = \dfrac{\phi}{1+\tau\phi}$ and $\pi_2 = \dfrac{\tau}{1+\tau\phi}$.

Since $\dfrac{\varphi}{\tau} = \dfrac{\varphi_3}{\widetilde{\gamma}\Xi} < 1$ and $\dfrac{\varphi}{\tau_i} = \dfrac{\varphi_1}{\widetilde{\gamma}\Xi} > 1$, $\tau_i < \varphi < \tau$. It follows that $\pi_1^c > \pi_1^i$ and $\pi_2^c > \pi_2^i$. It is also clear that $\pi_2 > \pi_2^c$, as $\tau[1+\varphi\phi - (1-\phi)(1-\varphi/\tau)] - \varphi[1+\tau\phi] = \phi(\tau-\varphi) > 0$. The relative sizes of π_1 and π_1^i depends on the sign of $\phi(\tau-\varphi) + (1-\phi)(1-\varphi/\tau_i)$, which cannot be determined analytically. However, under our benchmark calibration (as well as for a wide range of parameter values), this sign is positive, which implies that $\pi_1^i > \pi_1$. Combining all these results yields $\pi_1^c > \pi_1^i > \pi_1$ and $\pi_2 > \pi_2^c > \pi_2^i$.

B Data Description

B.1 KLEMS Industry Data

The U.S. KLEMS (http://www.bls.gov/mfp/) data provide nominal and real values for gross output, inputs of intermediates, labor, and capital annually from 1987 to 2012 for 60 industries. The KLEMS data exclude the government, nonprofit, and private household sectors, as production for these sectors is measured by inputs; so productivity is not measured. As a result, the shares of some sectors here, notably Education Services, are reduced compared to national income accounts. Some of the 60 KLEMS industries are quite small. For these industries the number of workers is insufficient to arrive at a reliable measure of work-rule flexibility from CPS supplements or wage flexibility from SIPP data. For this reason, we combined certain industries. For instance, three mining industries in the original KLEMS data are combined into a single mining sector for our industry classification. Our resulting data reflect 50 distinct industries. These are listed, with value-added shares, in Table 2.

The KLEMS data provide industry productivity, as measured by real gross output relative to real inputs (gross output TFP). We also construct measures of value added TFP measured by real value added relative to inputs of capital and labor. Industry real value added and its deflator are constructed using the Divisia method from values and prices for gross output and intermediate inputs, as described by Basu and Fernald (1997). (In this construction we equate intermediate inputs cost shares with their revenue shares; so, implicitly we assume a zero rate of profit.)

We adjust the KLEMS TFP measure for the impact of procyclical utilization of capital as done in Bils, Klenow, and Malin's (2012, BKM for short). BKM employ data on utilization rates of capital constructed by Gorodnichenko and Shapiro (2011) for two-digit manufacturing for 1974 to 2004. BKM find that a one-percent increase in the labor to capital stock ratio is associated with a one-third percent increase in the utilization rate of capital. So we adjust TFP by subtracting capital's share multiplied by one-third times movements in the labor-capital ratio. The adjustment for capital utilization makes TFP slightly less procyclical, but does not affect estimates of how industry flexibility in work rules or industry wage flexibility affects cyclicality of TFP.

B.2 SIPP Data for Measuring Wage Flexibility

The SIPP is a longitudinal survey of households designed to be representative of the U.S. population. It consists of a series of overlapping longitudinal panels. Each panel is three or more years in duration. Each is large, containing samples of about 20,000 households. Households are interviewed every four months. At each interview, information on work experience (employers, hours, earnings) are collected. Each year from 1984 through 1993 a new panel was begun. New, somewhat longer, panels were initiated in 1996, 2001, 2004, and 2008. In our analysis we employ the 6 panels from 1990 through 2001. (The 1984-1989 panels contain less reliable information on employer changes. The 2004 and 2008 panels carry forward employment information, including the wage rate, if the respondent deems changes to be small.) The SIPP interviews provide employment status and weeks worked for each of the prior four months. But earnings information is only collected for the interview month; so we restrict attention to the survey month observations.

For our purposes the SIPP has some distinct advantages. Compared to a matched CPS sample, we are able to calculate workers' wage changes across multiple surveys and at intervals of four months, rather than 12. It also provides better information for defining employer turnover. The SIPP has both a larger and more representative sample than the PSID or NLS panels and, most importantly, individuals are interviewed every four months.

We restrict our sample to persons of ages 20 to 60. Individuals must not be in the armed forces, not disabled, and not be attending school full-time. We only consider wage rates for workers who usually work more than 10 hours per week and report monthly earnings of at least $100 and no more than $25,000 in December 2004 CPI dollars. Any reported hourly wage rates that are imputed, top-coded, or below $4 in December 2004 dollars are set equal to missing. Although the SIPP panels draw representative samples, in constructing all reported statistics we employ SIPP sampling weights that account for sample attrition. We also weight individuals by their relative earnings in the sample period, as this is consistent with the influence of workers for aggregate labor statistics.

We calculate frequency of wage changes over the 4-month interval between surveys for workers who remain with the same employer for their main job. For the 1990 to 1993 panels we define workers as stayers if the SIPP employer ID remains the same across surveys. We employ the 1990-1993 SIPP revised employer ID's, which have been edited at the Census to be consistent with information available in the non-public Census version of the data. Such edits have not been undertaken for 1996 and later panels. For the later panels a number of changes in employer ID appear (based on wages, et cetera) to not represent an employer change. For the later panels we define stayers based on responses to when the reference job began. More exactly, we define the worker as a new hire if they report that their job began within the last four months, or if in the prior survey they report that the reference job had ended by the survey. (This latter case is relatively rare.) We additionally call the worker a new hire if the employer ID and the industry of employment both change across surveys. We similarly calculate frequency of wage changes across eight-month intervals for those workers we classify as stayers over that 8-month interval. In calculating the Calvo parameter we use 4-month frequencies calculated just for 8-month stayers, so that the 4 and 8-month changes are calculated for the same sample.

Employed respondents report monthly earnings. In addition, just over half report an hourly rate of pay. For each worker we also calculate a weekly wage by dividing monthly earnings by the number of weeks worked in the month. We define a worker's wage as not changing if any of these three measures remains the same across the surveys.

The SIPP provides the worker's 3-digit industry code, allowing us to map SIPP workers to KLEMS industries. The total sample, combining observations from the 1990 to 2001 panels is large. For calculating 4-month and 8-month frequencies of wage changes it equals 350,044 observations; of these, 294,678 map to one of our KLEMS industries.

Table 1: Benchmark Parameter Values

Parameter	Description
$\lambda = 3/4$	Prob. for wage not renegotiated
$\alpha = 0.64$	Labor share in production function
$\beta = 0.99$	Discount factor
$\widetilde{\gamma} = 0.5$	Frisch elasticity of labor supply
$\delta = 0.04$	Job separation rate
$\eta = 0.5$	Elasticity of matching w.r.t. vacancy
$\chi = 0.6$	Scale parameter in matching function
$R = 0.035$	User cost of capital
$\psi = 0.5936$	Scale parameter for utility from leisure
$b = 0.4367$	Unemployment insurance benefits
$\kappa = 0.1345$	Vacancy posting cost
$\rho_z = 0.95$	Persistence of aggregate productivity
$\rho_\xi = 0.95$	Persistence of preference shock

Table 2: Business Cycle Moments of Models in Response to Productivity Shock

	Data		Flexible Wages				Sticky Wages					
			Fixed Effort		Variable Effort		Fixed Effort		Individual Effort		Common Effort	
	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*
Output	1.99	1.00	1.25	1.00	1.20	1.00	1.25	1.00	1.28	1.00	1.69	1.00
Employment	0.79	0.79	0.17	0.97	0.12	0.97	0.17	0.97	0.16	0.98	0.57	0.97
Aggregate Wage	0.48	0.17	0.78	1.00	0.85	1.00	0.45	0.79	0.75	0.98	0.30	0.54
Newly Hired Wage	–	–	0.78	1.00	0.85	1.00	0.69	1.00	1.24	0.88	0.39	0.91
TFP	0.56	0.71	0.89	1.00	0.93	1.00	0.89	1.00	0.90	1.00	0.66	0.99

Notes: The standard deviations (S.D.) are relative to output except for output itself. The correlations with output are denoted by *cor*. All variables are logged and H-P filtered with smoothing parameter 1,600. In all simulations, the autocorrelations of aggregate productivity shock are 0.95 and the standard deviation for innovation is chosen for the model to match the volatility of measured TFP in the U.S. data (see footnote 22 in the text). The S.D. of total hours and its correlation with output are respectively, 0.93 and 0.86. The data statistics are based on 1960:I - 2013:IV. The auto-correlations in the data (H-P filtered) are 0.86, 0.92, 0.67, and 0.73 respectively for output, employment, aggregate wage, and TFP. Those in our preferred benchmark model are 0.8, 0.84, 0.96, and 0.79, respectively.

Table 3: Cyclicality Under Various Model Specifications

	Data	Model under Productivity Shocks (z)				
		Flexible Wage		Sticky Wage		
		Fixed Effort	Variable Effort	Fixed Effort	Individual Effort	Common Effort
Employment*	0.62 (0.05)	0.17	0.12	0.17	0.16	0.55
Aggregate Wage	0.08 (0.04)	0.78	0.85	0.35	0.73	0.16
Newly Hired Wage	0.29 (0.12)	0.78	0.85	0.69	1.09	0.35
TFP	0.39 (0.04)	0.89	0.92	0.89	0.90	0.65
	Data	Model under Preference Shocks (ξ)				
		Flexible Wage		Sticky Wage		
		Fixed Effort	Variable Effort	Fixed Effort	Individual Effort	Common Effort
Employment*	0.62 (0.05)	1.56	0.21	1.56	0.27	0.62
Aggregate Wage	0.08 (0.04)	-1.13	0.71	-0.61	0.59	0.09
Newly Hired Wage	0.29 (0.12)	-1.13	0.71	-1.03	0.90	0.22
TFP	0.39 (0.04)	0.00	0.86	0.00	0.83	0.60

Note: Coefficients are projection of ln(X) on ln(GDP), where X takes roles of employment, wages, and TFP. All logged variables are quarterly and HP-filtered with smoothing parameter 1,600. Data are based on 1960:I-2013:IV. *The projection coefficient of total hours on GDP is 0.80 (0.05).

Table 4: Business Cycle Moments of Models in Response to Preference Shock

	Data		Flexible Wages				Sticky Wages					
			Fixed Effort		Variable Effort		Fixed Effort		Individual Effort		Common Effort	
	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*	S.D.	*cor*
Output	1.99	1.00	0.40	1.00	1.99	1.00	0.40	1.00	1.67	1.00	0.89	1.00
Employment	0.79	0.79	1.56	1.00	0.22	0.97	1.56	1.00	0.27	0.99	0.63	0.99
Aggregate Wage	0.48	0.17	1.15	-0.98	0.71	1.00	0.69	-0.88	0.61	0.97	0.19	0.50
Newly Hired Wage	–	–	1.15	-0.98	0.71	1.00	1.06	-0.97	1.01	0.89	0.25	0.87
TFP	0.56	0.71	–	–	0.86	1.00	–	–	0.83	1.00	0.61	0.99

Notes: The standard deviations (S.D.) are relative to output except for output itself. The correlations with output are denoted by *cor*. All variables are logged and H-P filtered with smoothing parameter 1,600. In all simulations, the autocorrelations of aggregate preference shock are 0.95 (before H-P filtered) and the standard deviation for innovation is the same as that for the productivity shock in the common effort model, 2.83% (see footnote 14 in the text). The S.D. of total hours and its correlation with output are respectively, 0.93 and 0.86. The data statistics are based on 1960:I - 2013:IV. The auto-correlations in the data (H-P filtered) are 0.86, 0.92, 0.67, and 0.73, respectively for output, employment, aggregate wage, and TFP. Those in our preferred benchmark model are 0.8, 0.84, 0.96, and 0.77, respectively.

Table 5: KLEMS Industries

INDUSTRY	NAICS Code	VA Share	% Tied Schedule	Wage Duration (months)
Crop and Animal Production	111,112	1.6	69	14.6
Forestry and Fishing	113-115	0.3	70	13.0
Mining	211-213	1.9	76	15.4
Utilities, Pipeline Transportation, Waste Management	22,486,562	3.2	74	13.0
Construction	23	6.0	76	14.3
Food, Beverage, and Tobacco	311,312	2.1	80	10.8
Textile Mills and Textile Products	313,314	0.4	91	14.8
Apparel and Leather products	315,316	0.3	84	14.8
Wood products	321	0.4	86	10.1
Paper Products	322	0.9	81	10.4
Printing and Publishing	323,511,516	2.3	67	13.3
Petroleum and Coal products	324	1.0	66	10.1
Chemical products	325	2.8	66	11.4
Plastics and Rubber products	326	0.8	83	12.0
Nonmetallic Mineral Products	327	0.6	78	13.3
Primary Metals	331	0.7	85	14.4
Fabricated Metal products	332	1.6	83	11.1
Machinery	333	1.6	78	13.1
Computer and Electronic products	334	2.6	56	11.1
Electrical Equipment and Appliances	335	0.7	71	11.5
Transportation Equipment	336	2.8	77	12.0
Furniture and related products	337	0.4	82	10.4
Miscellaneous Manufacturing	339	0.8	72	11.0
Wholesale Trade	42	6.8	65	13.0
Retail Trade	44,45	7.8	66	12.4
Air Transportation	481	0.5	69	12.5
Rail Transportation	482	0.4	92	13.3
Water Transportation	483	0.1	77	20.7

Truck Transportation	484	1.2	71	13.6
Transit and Ground Passenger Transportation	485	0.2	75	14.1
Other Transportation, Warehousing and Storage	487,488,492, 493	1.3	82	11.3
Motion Picture and Recording Industries	512	0.9	56	15.8
Broadcasting and Telecommunications	515,517	2.7	66	11.4
Information Processing, Computer Systems, Misc. Professional, Scientific, Technical Services, Management of Enterprises	518,519,5412-5414,5415, 5416-5419,55	9.7	49	12.1
Credit Intermediation and Related Activities	521,522	3.6	69	12.8
Securities, Commodities, Investments, Funds, Trusts, and other Financial Vehicles	523,525	2.4	60	16.7
Insurance Carriers and Related Activities	524	2.6	54	12,9
Real Estate	531	4.7	55	12.7
Rental and Leasing Services	532,533	1.7	63	16.8
Legal Services	5411	1.9	61	13.8
Administrative and Support Services	561	3.3	71	12.6
Educational Services	61	0.3	71	10.5
Ambulatory Health Care Services	621	3.9	68	13.4
Hospitals, Nursing, Residential Care Facilities	622,623	1.3	75	10.8
Social Assistance	624	0.3	66	10.4
Performing Arts, Spectator Sports, Museums, and Related Activities	711,712	0.5	55	11.1
Amusements, Gambling, and Recreation	713	0.5	62	13.4
Accommodation	721	0.8	71	12.5
Food Services and Drinking Places	722	2.0	66	12.8
Other Services, except Government	81	2.6	57	13.8

Table 6: Frequency of Wage Changes SIPP, 1990-2004

	4-month Freq	8-month Freq	Error Rate (Calvo)	Calvo 4-mo Parameter	Taylor 4-mo Parameters
1990-1993 Panels (Approx. 1990-1995)	0.69	0.78	0.33	0.30	0.23
1996 Panel (Approx. 1996-1999)	0.74	0.83	0.34	0.38	0.28
2001 Panel (Approx. 2001-2004)	0.74	0.82	0.37	0.33	0.25
Average 1990 to 2001 Panels	0.71	0.81	0.35	0.33	0.25

Notes: Observation by panel (top to bottom) are 218,819, 86,086, 46,894, and 351,799. Observations are weighted both by the SIPP sampling weight and by the workers relative monthly earnings. In aggregating panels, the 1990-1993 panels, which span about 6 years, are given 1.5 times the weight of the others, each spanning about 4 years.

Table 7: Industry Cyclicality by Tied Work Rules

	Dependent Variable		
	Wage	TFP	Hours
		All 50 Industries	
GDP*Tied	−2.37 (0.86)	−0.60 (1.63)	4.08 (0.98)
		22 Goods Industries	
GDP*Tied	−4.28 (1.58)	−0.62 (3.11)	5.90 (1.73)
		14 Durable Goods Industries	
GDP*Tied	−3.97 (2.32)	−2.39 (3.38)	4.00 (2.00)

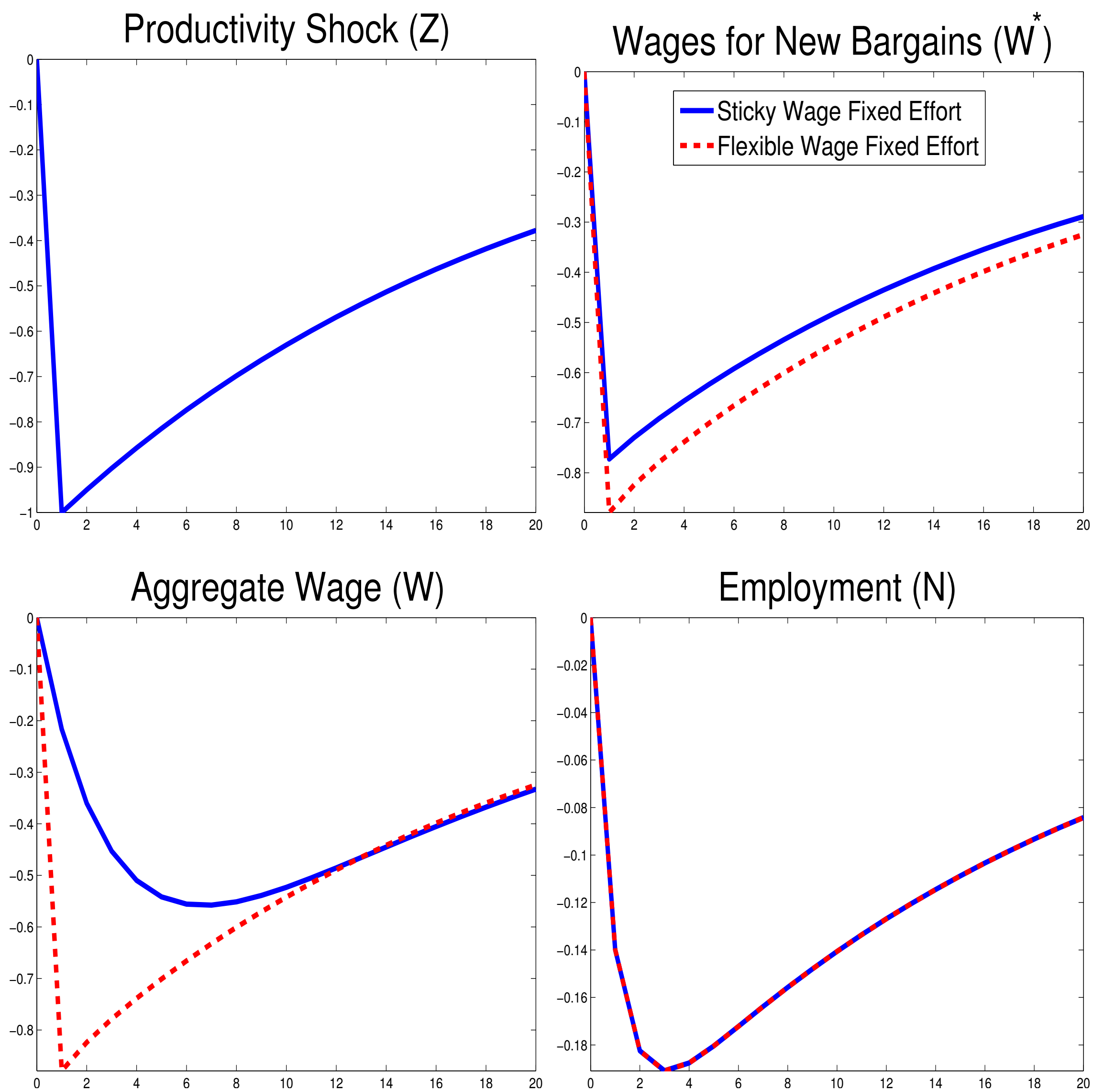
Notes: GDP is HP-filtered aggregate real GDP. Tied is fraction of workers who cannot vary start or ending times. TFP measures are adjusted for estimated capital utilization. Regressions include a full set of year dummies. Industry observations are weighted by its relative value added. Standard errors (in parentheses) are adjusted by Newey-West procedure by industry.

Table 8: Industry Cyclicality by Wage Stickiness

	Dependent Variable		
	Wage	TFP	Hours
	All 50 Industries		
GDP*Stickiness	0.13 (.09)	−0.22 (.12)	0.08 (.06)
	22 Goods Industries		
GDP*Stickiness	−0.12 (.07)	−0.42 (.16)	0.24 (.08)
	14 Durable Goods Industries		
GDP*Stickiness	−0.15 (.11)	−0.56 (.19)	0.17 (.09)

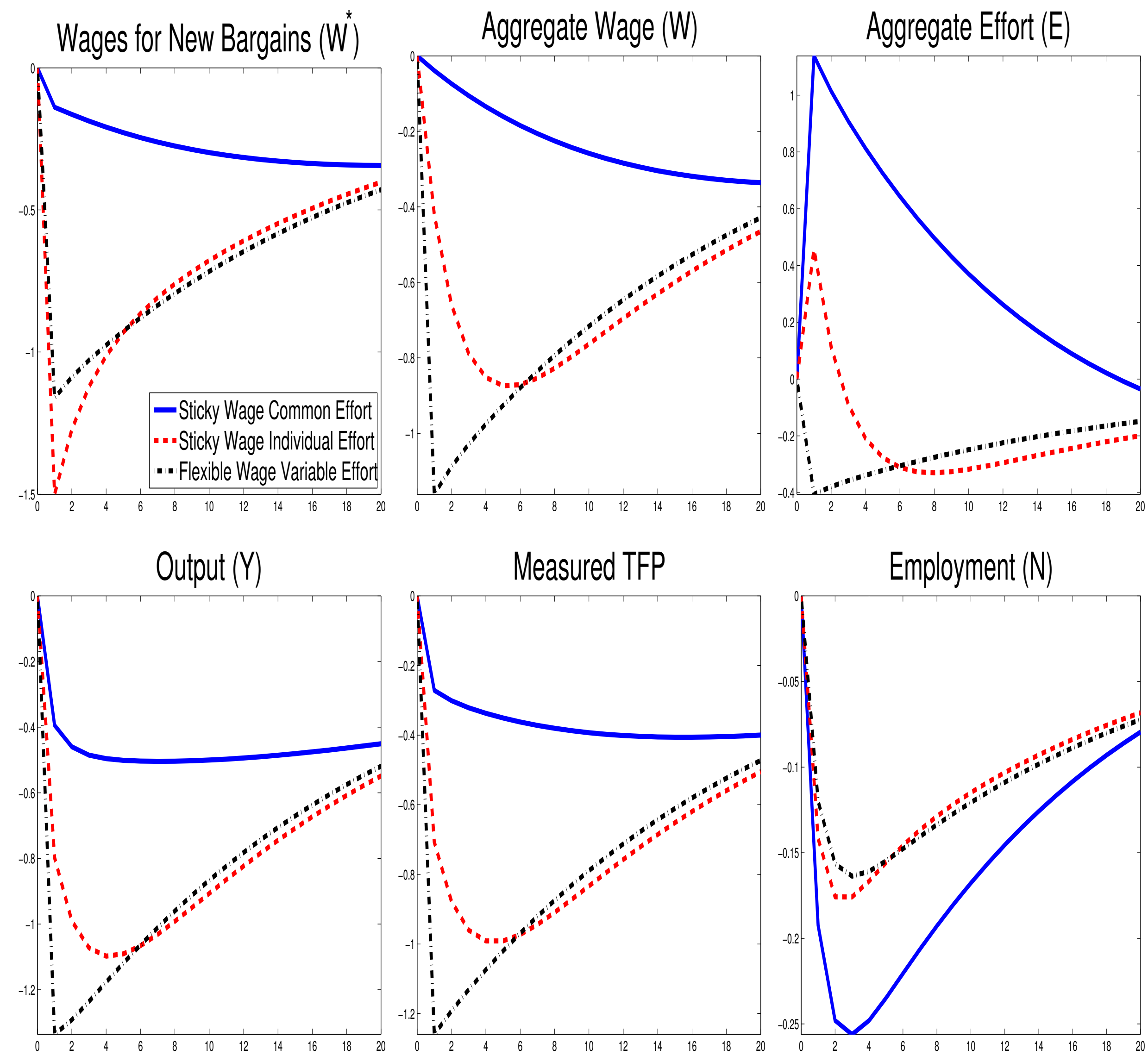
Notes: GDP is HP-filtered aggregate real GDP. Stickiness is the Calvo implied duration of wages in the industry (in months). TFP measures are adjusted for estimated capital utilization. Regressions include a full set of year dummies. Industry observations are weighted by its relative value added. Standard errors (in parentheses) are adjusted by Newey-West procedure by industry.

Figure 1: Model with Fixed Effort



Notes: Productivity decreases by 1% in period 1 with autocorrelation of 0.95. The dashed line (−−) represents the model with flexible wages. The solid line represents the model with sticky wages. The x axis represents periods (in quarters) and y axis represents percentage deviation from the steady state.

Figure 2: Model with Variable Effort



Notes: Productivity decreases by 1% in period 1 with autocorrelation of 0.95. The dash-dot line (−.) represents the model with flexible wages. The dashed line (−−) represents the sticky wage model with individual effort choice. The solid line represents the sticky wage model with common effort choice. All models feature $\alpha = 0.64$, $\widetilde{\gamma} = 0.5$, $\lambda = 3/4$, and $\widetilde{e} = 0.5$.

Figure 3: Efforts in Individual Effort Choice Model

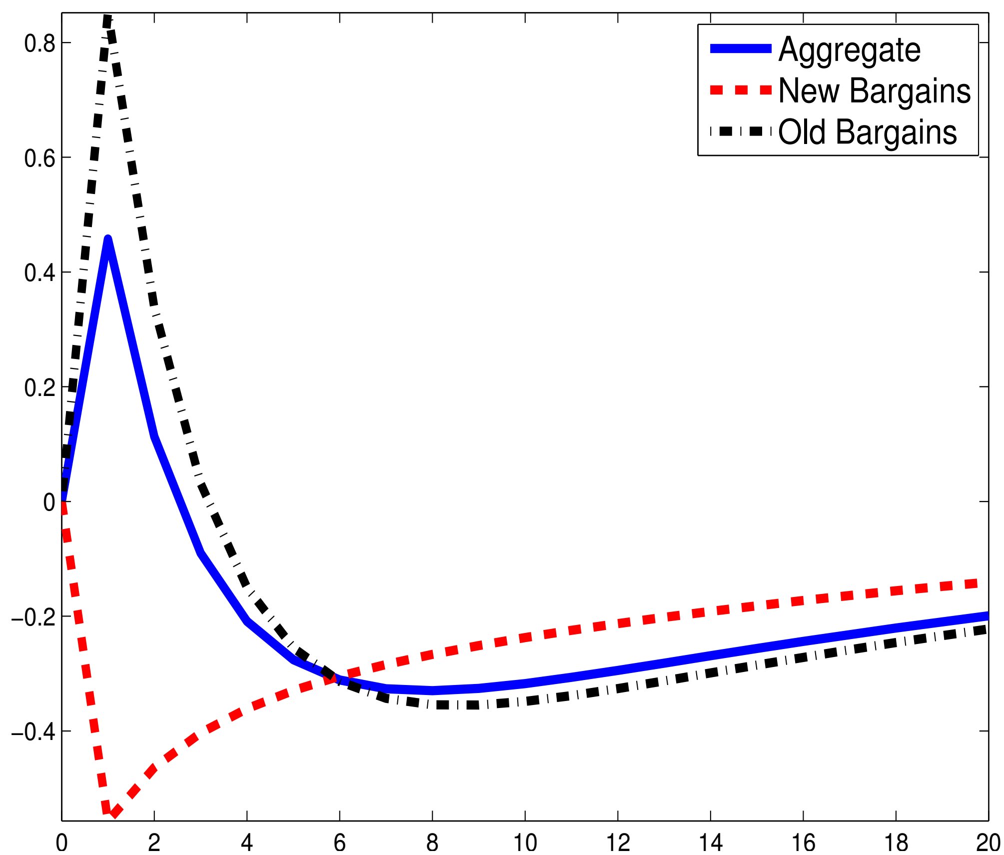


Figure 4: Measured TFP, Productivity Shock and Employment Rate

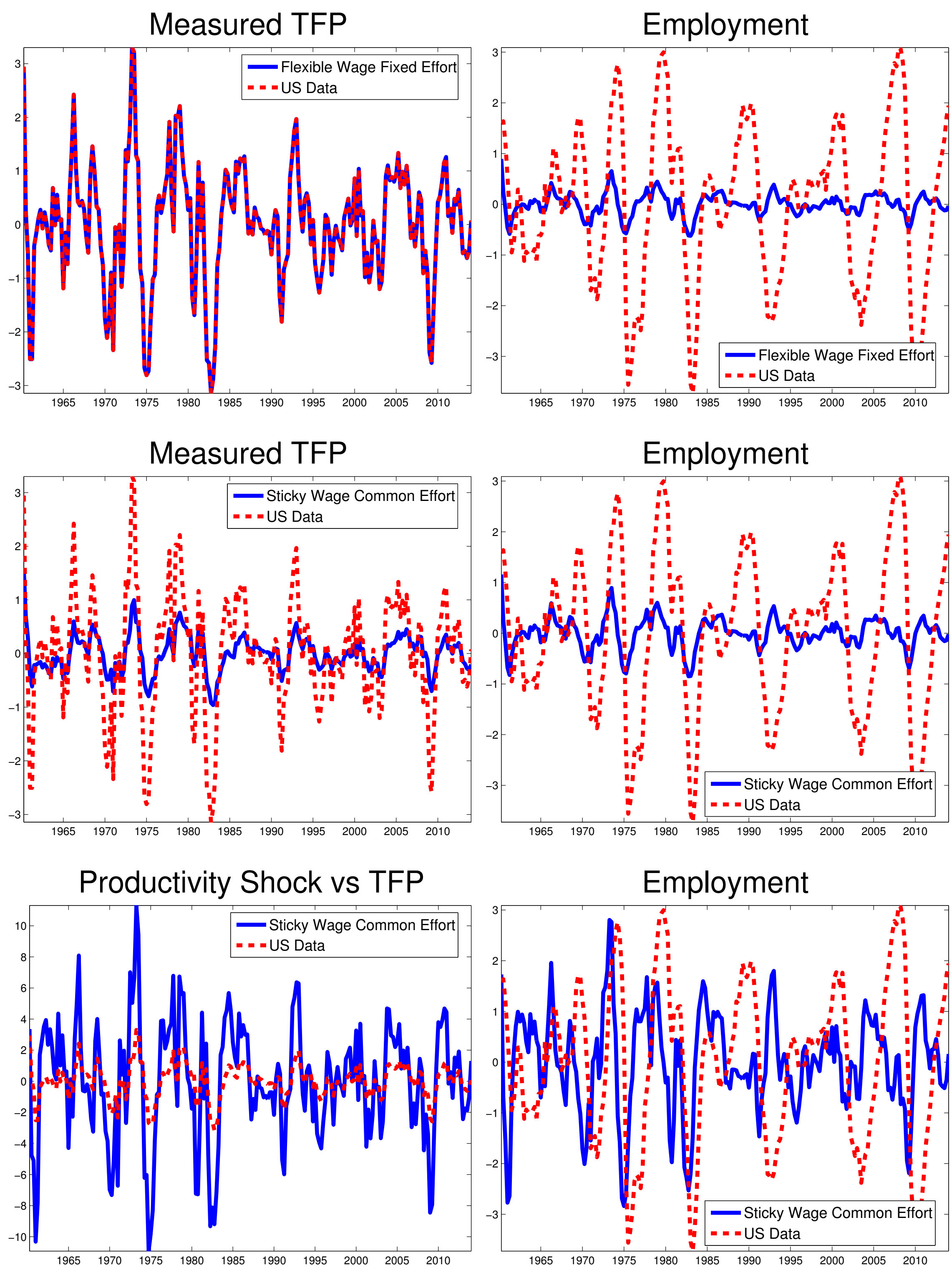
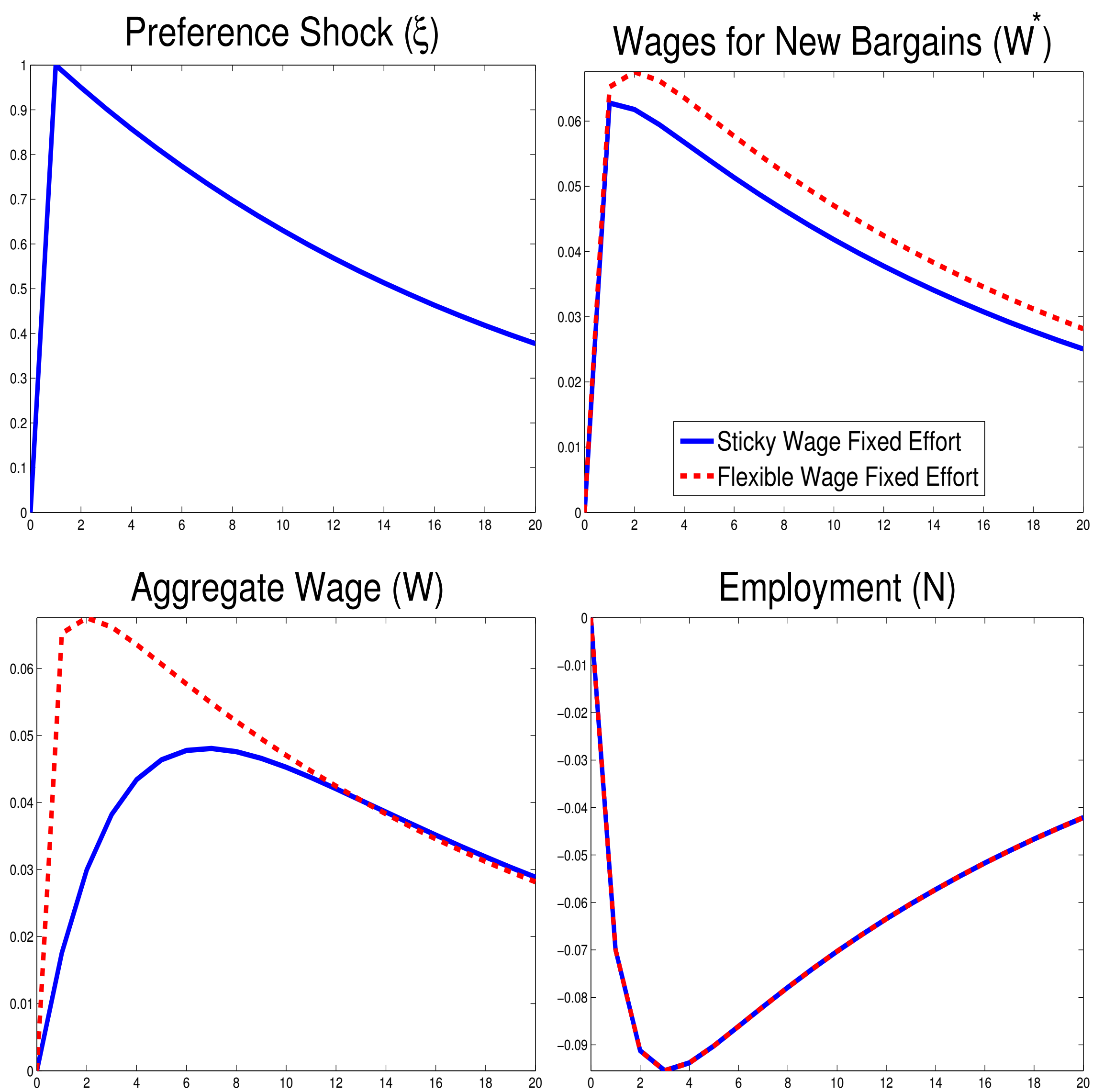
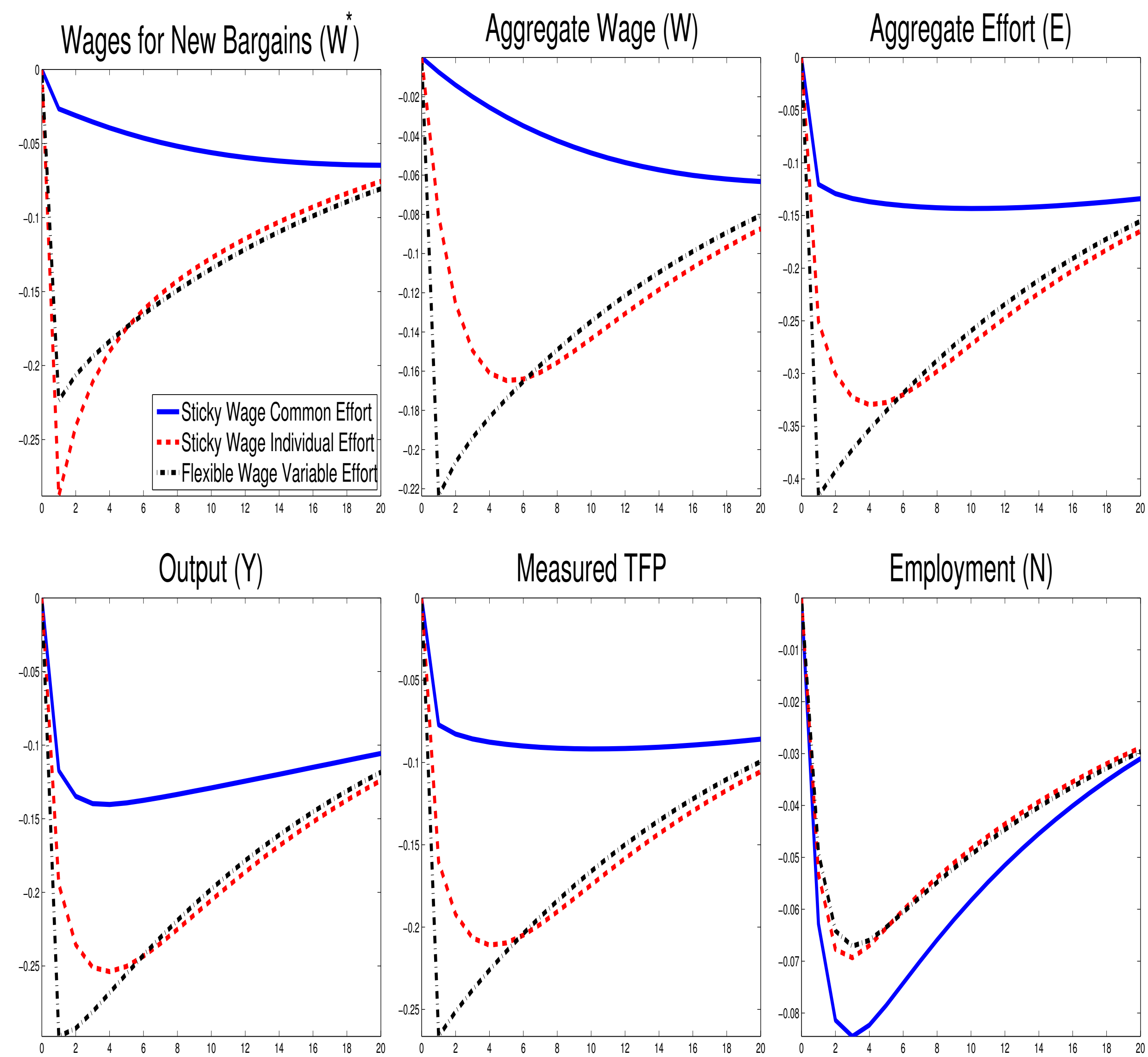


Figure 5: Model with Fixed Effort (Positive Preference Shock)



Notes: Preference shock decreases by 1% in period 1 with autocorrelation of 0.95. The dashed line (−−) represents the model with flexible wages. The solid line represents the model with sticky wages. The x axis represents periods (in quarters) and y axis represents percentage deviation from the steady state. All models feature $\alpha = 0.64$, $\widetilde{\gamma} = 0.5$, $\lambda = 3/4$, and $\widetilde{e} = 0.5$.

Figure 6: Model with Variable Effort (Positive Preference Shock)



Notes: Preference shock decreases by 1% in period 1 with autocorrelation 0.95. The dash-dot line (−.) represents the model with flexible wages. The dashed line (−−) represents the sticky wage model with individual effort choice. The solid line represents the sticky wage model with common effort choice. All models feature $\alpha = 0.64$, $\widetilde{\gamma} = 0.5$, $\lambda = 3/4$, and $\widetilde{e} = 0.5$.