Real wages and monetary policy: A DSGE approach

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Abstract

Economists have long investigated the cyclical behavior of real wages in order to draw inferences regarding the relative stickiness of prices and wages. Recent studies have adopted techniques intended to identify monetary shocks and examined the response of real wages and output or employment to such shocks. A finding that real wages are procyclical in response to a positive monetary policy shock, for example, is taken as evidence that prices are stickier than wages. In this paper, we show that factors other than wage and price stickiness affect the response of real wages to a monetary policy shock. Accordingly, examining the response of real wages is not enough to sort out the relative stickiness of prices and wages.

We use two prominent DSGE models to help us address this issue. These models incorporate both sticky wages and prices but in different ways. The first model (Huang, Liu, and Phaneuf, *American Economic Review*, 2004) is relatively simple and is not intended for policy analysis. Its relative simplicity allows us to approach the issues both analytically and through simulations. The second model (Smets and Wouters, *American Economic Review*, 2007) is a relatively complex model of the U.S. economy with many frictions and intended to be useful for policy analysis. Because of its complexity, we must rely principally on simulation exercises.

Using these models we offer robust evidence that the real wage response to monetary policy is affected in important ways by properties of the economy other than stickiness of wages and prices, such as the importance of intermediate goods in the production process and the size of key elasticities. Consequently, we cannot appropriately infer the relative stickiness of wages and prices from examining only the response of real wages to a monetary policy shock.

Real Wages and Monetary Policy: A DSGE Approach

Since the publication of Keynes's *General Theory*, economists have been interested in the cyclical behavior of real wages. A principal motivation for this interest has been to provide evidence that allows us to discriminate among alternative explanations of cyclical fluctuations, especially those that rely on either sticky prices or sticky wages. The early Keynesian sticky-wage explanation of the business cycle fluctuations predicted countercyclical real wages. In that model, nominal wages are fixed and employment is determined by a stable, negatively-sloped labor demand curve. Consequently, an aggregate demand (nominal) shock will cause real wages and employment (output) to move in opposite directions. John Dunlop's (1938) early evidence of procyclical real wages was widely seen as an important challenge to this view. For many years the cyclical behavior of real wages was examined in numerous studies by, in one way or another, exploring the correlation between real wages and either output or employment. Conclusions varied widely depending on the variables chosen, the sample period, or other factors. In a survey paper, Stanley Fischer (1988) concluded that "the weight of the evidence by now is that the real wage is slightly procyclical." This was taken by many to support the conclusion that prices have been stickier than wages.[1]

It was eventually pointed out that the correlation between real wages and output (employment) cannot be interpreted as simply reflecting the short-run real effects of nominal shocks if the economy is, in fact, affected by other shocks as well since empirical correlations reflect the effects of all shocks. The issue has therefore become, how do real wages respond to nominal (aggregate demand) shocks setting all other shocks to zero? This question cannot be answered by looking at simple correlations between the real wage rate and output or employment.

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[1] For example, such conclusions were drawn by Bennett McCallum (1986), N. Gregory Mankiw (1987), and Laurence Ball, Mankiw, and David Romer (1988).

Accordingly, more recent studies[2] have attempted to empirically identify monetary shocks and then investigate the response of real wages and output or employment to such shocks. A finding that real wages are procyclical in response to a positive (expansionary) monetary policy shock, for example, is taken as evidence that prices are stickier than wages. For such inferences to be justified, the cyclical response of real wages must principally reflect the relative stickiness of wages and prices, not other factors.

The purpose of this paper is to argue that there are many characteristics of the economy beyond wage and price stickiness that affect the cyclical response of real wages to monetary policy shocks. Consequently, even evidence regarding the cyclical behavior of real wages in response to a monetary shock will not allow us to draw unambiguous conclusions. Our specific objective is to investigate the broad array of factors that affect the cyclicality of real wages including not only the relative stickiness of wages and prices but other factors as well. Indeed, we see that the relative stickiness of wages and prices represents only a part of the picture.

To address this issue, we take an approach that is different from earlier studies. Rather than taking the estimates from empirical models to infer something about relative stickiness, we consider dynamic stochastic general equilibrium (DSGE) models in which we parameterize the relative stickiness of prices and wages and then observe the response of real wages to a monetary policy shock. Using this approach we can more carefully explore other factors beyond wage and price stickiness that affect the cyclical response of real wages to monetary shocks.

We use two prominent DSGE models to help us address this question. These models incorporate both sticky wages and prices but in different ways. The first model is relatively simple and is not intended for policy analysis. Kevin Huang, Zheng Liu, and Louis Phaneuf (2004), HLP, develop a model to investigate the impact of the changing importance of the intermediate goods sector on the cyclicality of real wages. Accordingly, their model is characterized by a production

[2] See, for example, Sumner and Silver (1989), Gamber and Joutz (1993), Spencer (1998), and Fleischman (1999).

function that requires intermediate goods as inputs as well as capital and labor. Households provide differentiated labor skills to firms which produce differentiated goods. Wage and price stickiness is modeled using the staggered price and staggered wage contracts model of John Taylor (1980, 1999) and Fischer (1977). Given the narrow focus of their paper, HLP include a monetary policy shock as the only shock in the model. Calibrating the model, they show that, given the relative stickiness of prices and wages, the real wage switches from being countercyclical to procyclical as the share of intermediate goods in the production process increases.

The second model, due to Frank Smets and Rafael Wouters (2007), SW, is a relatively complex model of the U.S. economy with many frictions and is intended for policy analysis. It includes seven shocks, one of which is a monetary policy (interest rate) shock. It also incorporates differentiated labor and goods, habit persistence in consumption, investment adjustment costs, and sticky prices and wages with partial backward indexation to past inflation. Price and wage stickiness is modeled using the Calvo (1983) setup. The SW model's primary parameters are estimated using a Bayesian likelihood approach.

The next two sections of the paper use the HLP and SW models, respectively, to investigate how key factors in those models affect the cyclicality of the response of real wages to monetary policy shocks. In each case, we examine how the response is affected as we vary these key factors over an array of values for wage and price stickiness. The third section attempts a preliminary synthesis of what we have learned from these exercises and the final section provides a conclusion.

I. The Huang, Liu, and Phaneuf Model

The central issue of the Huang, Liu, and Phaneuf (2004), HLP, paper is to investigate how the response of real wages to a monetary policy shock is affected by changes in the input-output structure of the economy in the face of wage and price stickiness. Their focus on real wages and monetary policy makes their model particularly well suited to our purposes. They construct a dynamic stochastic general equilibrium, DSGE, model that is relatively simple and, thus, allows us to approach the issues analytically as well as through simulations.

Their model has differentiated intermediate goods and differentiated labor. Each intermediate goods producer supplies a unique good and enjoys some degree of monopoly power. The same is true of households which supply unique forms of labor. Final goods producers combine intermediate goods into a final good which can be used for consumption, investment, or as an input in the production of intermediate goods. Similarly, the various unique forms of labor are aggregated into a labor composite which is also used in the production of intermediate goods.

Any particular intermediate good is produced using three inputs: capital, labor and an aggregation of all intermediate goods. The importance of final goods is summarized by the key parameter φ, which is the Cobb-Douglas share of intermediate goods (as opposed to capital and labor) in the goods production function.

Suppliers of intermediate goods and labor set prices using a staggered Taylor-style price setting arrangement. That is, contracts are set for *N* periods and one-*N*th of the firms (or households) are allowed to set prices each period. Intermediate goods producers and labor suppliers solve two types of problems. First, given their fixed price or wage set previously, they choose the optimal amount to supply each period. Second, every *N* periods they choose what the fixed price or wage will be for the next *N* periods.

Households are allowed to insure their consumption each period via a set of complete financial markets. Hence, every household consumes the same amount, but it will supply differing amounts of labor based on their previously chosen fixed wage.

There is a monetary authority that creates new money each period and transfers it lump-sum to the households. The growth rate of the money supply is assumed to follow an AR(1) process.

HLP focus on the parameter $\varphi \in (0,1)$, the importance of intermediate goods in the production function (with a value of zero reflecting a zero share of intermediate goods in production). They look at this in the context of three specific models: the first with staggered price-setting and flexible wages, the second with staggered wage-setting and flexible prices, and the third with both staggered price- and wage-setting. They show that, given a calibrated parameterization of the model, when prices are sticky and wages flexible, real wages respond *procyclically* to a monetary policy shock regardless of the value of φ. In the reverse situation with sticky wages and flexible prices, their model implies that real wages respond *countercyclically* to a monetary policy shock regardless of the value of φ.[3]

In the model with *both* price and wage stickiness, however, the response of real wages to a monetary policy shock depends critically on φ. When φ is small so intermediate goods are not so important in the production process, real wages tend to be countercyclical in response to monetary policy shocks and, when φ is large, real wages are procyclical. Since, by assumption, wages and prices are equally sticky in the third model, we see that the cyclical behavior of real wages does not have unambiguous implications for the relative stickiness of wages and prices. Thus, HLP show that other factors, in particular the importance of intermediate goods in production, will also affect the cyclicality of real wages. This is an important finding.

We use the HLP model to consider how the cyclicality of the response of real wages to a monetary shock is affected by other properties of the model. For example, how is the cyclicality of the real wage affected by changing the relative stickiness of prices and wages for various values of φ? Several other parameters play potentially important roles in the model: $\sigma \in (1, \infty)$, the elasticity of substitution between differentiated labor skills, $\theta \in (1, \infty)$, the elasticity of substitution between differentiated goods, $\alpha \in (0,1)$, the elasticity of value added with respect to capital, $\xi \in (1, \infty)$, the inverse of the elasticity of intertemporal substitution of labor hours, and $\psi > 0$, the capital adjustment cost parameter. Accordingly, we also examine how the cyclical response of real wages changes as these parameters are varied.

[3] These results are reminiscent of the underlying motivation behind the empirical debate regarding the relative stickiness of prices and wages discussed in the opening section of this paper.

A. Varying Price and Wage Stickiness

As indicated above, the HLP model incorporates price and/or wage stickiness using the staggered price- and wage-setting models of Taylor (1980, 1999) and Fischer (1977). In this setup, each firm (worker) faces a price (wage) contract of length N_p (N_w). During each period, fraction $1/N_p$ ($1/N_w$) of the firms (workers) choose a new price (wage) optimally that will last for N_p (N_w) periods. Since they focus on the role of changes in φ, in their reported results, HLP choose to set $N_p = N_w = 4$. What happens to the cyclical behavior of real wages when, for various values of φ, we consider an array of other values for N_p and N_w? Selected impulse response function (IRF) results are reported in Table 1. Retaining the HLP postwar calibrated parameter values for σ, θ, and α,[4] we vary the integer values of N_p and N_w between 1 and 8 for each of HLP's interwar and postwar calibrated values of φ, 0.4 and 0.7. The results reported in Table 1 are the first period (one quarter) responses of the real wage rate to a one percent positive shock to the money growth rate with each matrix corresponding to a different value of φ.[5] For example, when $\varphi = 0.7$ and $N_p = N_w = 4$, a one percent increase in the money growth rate causes a 0.30 percent increase in the real wage rate after one quarter.[6]

[Insert Table 1 about here.]

The bold line in each matrix indicates the dividing line between countercyclical and procyclical real wages. There are three things to notice. First, if prices are sticky ($N_p > 1$) but wages

[4] The HLP parameter values are $\sigma = 3$, $\theta = 11$, and $\alpha = 0.4$.
[5] To obtain the results reported in Table 1, we simulate the model for each of the 630 specified parametric configurations. In each case, we compute the impulse response function (IRF) for the real wage with respect to a one percent money growth shock and report the first (one quarter horizon) value. Since it would be impractical to report the full IRF for each case, we take the magnitude and especially the sign of this first IRF coefficient to be an indicator of the cyclical response of the real wage to a monetary policy shock. Since a positive shock to money growth will result in an increase in employment, a negative effect on the real wage indicates a countercyclical response of real wages.
[6] This matches the result obtained by HLP and reported in their Figure 3.B.: see their IRF for $\varphi = 0.7$ at the first quarter horizon.

are flexible (N_w = 1), real wages are strongly procyclical and changing the value of φ makes little difference. Similarly, if wages are sticky ($N_w > 1$) but prices are flexible (N_p = 1), real wages are strongly countercyclical and changing the value of φ makes no difference whatsoever. This, of course, simply confirms and extends the original HLP results.[7] Second, for any given values of φ and N_p, real wages are more countercyclical for larger values of N_w. These results are intuitive given that, other things equal, stickier nominal wages imply more procyclical real wages. Third, as φ increases, the range of values of N_p and N_w for which real wages are countercyclical decreases. This generalizes the principal result reported by HLP for $N_p = N_w = 4$:[8] For any combination of N_p and N_w, real wages become more procyclical as the importance of intermediate goods in production increases. HLP explain that this happens because an increase in φ increases the sluggishness of movements in marginal cost. This, in turn, increases the sluggishness of nominal prices and allows the procyclicality of nominal wages to dominate the real wage.

B. Varying Other Parameters

We also investigate what happens to the cyclicality of real wages as we vary the elasticity parameters, σ, θ, α, and ξ as well as the capital adjustment cost parameter ψ.

Table 2 reports the results for variations of σ, the elasticity of substitution between differentiated labor skills. The separate grids assume the values of σ to be 1.5, 3.0, 11.0. Since the wage markup is $\frac{\sigma}{\sigma-1}$, these values imply wage markup coefficients of 3.0, 1.5, and 1.1 respectively. By reviewing the grids in sequence, we can see what happens as σ increases. First, if wages are sticky ($N_w > 1$), as σ increases, real wages become more countercyclical for any given pair of price and wage stickiness parameters. Second, if wages are flexible (N_w = 1), changes in σ have no influence on the cyclicality of the real wage whatsoever.

[7] See the real wage IRFs reported in their Figures 1 and 2.

[8] Of course, our results confirm theirs for the specific case examined by HLP. For $N_p = N_w = 4$, when $\varphi = 0.4$, the real wage is slightly countercyclical. For $N_p = N_w = 4$, when $\varphi = 0.7$, the real wage becomes procyclical. See the corresponding IRFs at the one-quarter horizon in their Figure 3.B.

The first phenomenon occurs because individuals, when able to re-contract their wage, face a tradeoff between a higher nominal wage and an increase in hours employed. This tradeoff is highlighted by varying the elasticity of substitution between differentiated labor. If the elasticity is high (markup is low), the labor aggregator will prefer an individual with a wage lower than the fixed wages of others. Alternatively, if the elasticity is low (markup is high), labor demand will be slow to decrease even if the individual increases her wage. Therefore, nominal wages are less procyclical (and even countercyclical) when σ is high and more procyclical when σ is low. Since prices are generally procyclical, as σ rises, the real wage becomes increasingly countercyclical.

The second phenomenon, that changing the elasticity has no effect when wages are flexible, is explained by noting that if every wage is re-contracted each period, there is no ability to undercut other laborers. Thus, the incentive to increase the nominal wage is unchallenged. This incentive is not affected by the elasticity of substitution without the countering incentive, so changing σ has no influence on the cyclicality of the real wage.

[Insert Table 2 about here.]

The HLP model implies that varying θ, the elasticity of substitution between differentiated goods, makes no difference in the response of real wages to a monetary shock. In general, because of staggered wage setting, the real wage is a weighted average of markups over past, present, and expected future values of the marginal rate of substitution between consumption and leisure, *MRS*. Since the *MRS* is not a function of θ, varying the value of θ will have no effect on the cyclicality of the real wage. We have confirmed this by computing the first IRF coefficients for various values of θ and obtain results identical to those reported in Table 1.[9]

[9] We include the relevant tables for θ = 1.5, 3.0, and 11.0 in an Appendix available from the authors.

We have conducted similar exercises with the following values of α, the elasticity of value added with respect to capital: 0.2, 0.4, and 0.6. We have held σ and θ constant at their HLP calibrated values. As α increases, the absolute value of the first IRF coefficient rises, but the locus of acyclicality over the range of price and wage contract length (the bold line) does not change. To save space, we do not report the results here.[10]

The intuition here is easier to follow if we again think of the limiting case where all prices and wages are flexible. In this case the share of labor in GDP is $1-\alpha$. Hence the percent change in the real wage is the percent change in GDP minus the percent change in the labor input. The aggregate production function for the HLP model with perfect flexibility is a modified Cobb-Douglas. Combining these gives the following breakdown of the percentage change in the real wage.

$$\hat{W} = \alpha(\hat{K} - \hat{L})$$

where a carat ($\hat{}$) indicates percent change. That is, the percent change in the real wage is α times the percent change in the capital-labor ratio. The latter could be either positive or negative, but is largely unaffected by α. Hence as α rises the responsiveness of the real wage will become larger in absolute value, but will not change sign.

The parameter ξ measures the elasticity of intertemporal labor substitution. We examine four values between 1.0 and 10.0. The results reported in Table 3 indicate that changing ξ makes very little difference when wages are very sticky relative to prices (the lower left corner area of each grid), but that the real wage becomes much more procyclical when wages are close to flexible and prices are very sticky (corresponding to the upper right corner area of each grid) as ξ increases. As a person becomes more willing to substitute labor tomorrow for leisure today, they become more likely to increase their wage if the incentive to undercut other labor is low (wage contracts are short), especially if inflation is low in the short run (price contracts are long).

[10] All results not reported here are in an Appendix available from the authors.

[Insert Table 3 about here.]

As noted by HLP (see their footnote 13), the behavior of real wages is not sensitive to the capital adjustment cost parameter, ψ. This is not a feature of the underlying model but, rather, is a consequence of log-linearization. After linearization, the quadratic adjustment costs become linear.

To summarize, we have discovered that, in the HLP model, real wages become more procyclical in response to a monetary policy shock 1) the more important intermediate goods are in the production process (the larger φ), 2) the stickier prices are relative to wages (the larger N_p is relative to N_w), and 3) the smaller the elasticity of substitution between labor skills (the smaller σ). On the other hand, variation in either the elasticity of substitution between goods (θ) or in the elasticity of value added with respect to capital (α) has little or no effect on (at least the direction of) the cyclical response of real wages.

II. The Smets and Wouters (SW) Model

The Smets and Wouters (2007), SW, model is a popular model for analyzing monetary policy in the U.S. However, being considerably more complex than the HLP model, it is much more difficult to analytically evaluate the factors that influence the cyclical behavior of real wages. We rely principally on simulation experiments to draw our conclusions.

The SW DSGE model employs several real and nominal rigidities in a differentiated goods market and a differentiated labor market. Households maximize utility by choosing infinite-horizon consumption and labor paths assuming habit formation in consumption. Households also accumulate capital subject to capital adjustment costs and rent a variable amount of that capital to firms. Firms produce unique goods by choosing capital and labor inputs.

Rather than assuming staggered prices and wages as HLP, SW model stickiness for prices and wages using a Calvo (1983) mechanism where only a randomly selected fraction of firms and households are permitted to renegotiate contracts each period. The parameters governing these fractions are denoted ξ_p and ξ_w where $(1-\xi_p)$ is the proportion of firms allowed to re-optimize prices each period and where $(1-\xi_w)$ is the corresponding value for households and their wage contracts. The SW model assumes that those firms and households not selected to update their contracts have their prices and wages partially indexed to past inflation.

Were prices and wages fully flexible (i.e. $\xi_p = \xi_w = 0$), they would be equal to a constant markup over the marginal product of labor and marginal rate of substitution between consumption and leisure, respectively. Analogous to the HLP parameters σ and θ, the SW parameters ϕ_p and ϕ_W capture these markup coefficients with $\frac{\phi_p}{\phi_p - 1}$ and $\frac{\phi_W}{\phi_W - 1}$ being the price and wage markups, respectively.

The model is closed by assuming the monetary authority sets the interest rate according to a generalized Taylor rule.

Seven components of the model are influenced by stochastic processes: total factor productivity, investment-specific technology, the risk premium, exogenous (government) spending, the price mark-up, the wage mark-up, and monetary policy.

SW use a Bayesian likelihood approach to estimate their model for the U.S. over 1966:1 – 2004:4. Because the Calvo price- and wage-stickiness parameters are so important for the cyclical behavior of the real wage, we have investigated the sensitivity of these estimates to alternative priors. Though we find that the posterior means for ξ_p vary between 0.47 and 0.76 and the posterior means for ξ_w vary between 0.66 and 0.88, we always find strong support for significant price and wage stickiness.

Once again, our principal interest is in discovering how changing key parameters of the model affects the cyclical response of real wages to monetary policy shocks where, in contrast to the HLP model, monetary policy follows a generalized Taylor rule so monetary policy shocks are interest rate shocks rather than money supply shocks. Given its complexity, the SW model has many parameters and other properties that could potentially be examined. In order to maintain a manageable project, we must be selective.

A. Varying Price and Wage Stickiness

As in the HLP model, we begin by investigating the impact of changes in the relative stickiness of prices and wages. Whereas the HLP model assumed staggered prices and wages with a fixed deterministic contract length, price and wage stickiness in the SW model is captured by assuming separate stochastic Calvo mechanisms for prices and wages. We vary the Calvo price and wage parameters, ξ_p and ξ_w, and, as above, examine the consequences for the effect of a one standard deviation monetary policy shock on the real wage after one quarter as given by the value of the corresponding IRF at a horizon of one quarter. We allow ξ_p and ξ_w to each vary between 0.0 and 1.0 in increments of 0.1.[11] In this exercise, for each pair of selected values, we retain all other parameters at their original estimated values. The results are reported in Table 4. Each cell entry reports the first quarter response of the real wage to a one-standard deviation expansionary shock to monetary policy; i.e., a one-standard-deviation decline in the interest rate.

[Insert Table 4 about here.]

Once again, the bold line in the grid indicates the dividing line between countercyclical and procyclical real wages. The results are broadly similar to those reported for the HLP model. We confirm that if prices are sticky ($\xi_p > 0.0$) but wages are flexible ($\xi_w = 0.0$), real wages are strongly procyclical. Similarly, if wages are sticky ($\xi_w > 0.0$) but prices are flexible ($\xi_p = 0.0$), real wages are

[11] Since, under the usual Calvo assumptions, firms reset their prices (households reset their wages) with probability 1 - ξ_p (1 - ξ_w), when $\xi_p = 0.0$ ($\xi_w = 0.0$) all prices (wages) are flexible. Though the model cannot be solved numerically in the case that both prices and wages are perfectly flexible ($\xi_p = \xi_w = 0.0$), theory suggests the real wage would be acyclical in response to a monetary shock. The model is similarly numerically intractable when both prices and wages are perfectly fixed ($\xi_p = \xi_w = 1.0$).

strongly countercyclical. Furthermore, we see that the stickier are wages (the larger is ξ_w), the more likely real wages are to be countercyclical even with some degree of price stickiness.

In order to draw comparisons between the results of Table 4 and the related results from the HLP model reported in Table 1, it is first necessary to have a mapping between the stickiness parameters of the staggered contract and Calvo models. We note that $1/(1-\xi_p)$ is often interpreted as the average *duration (length)* of price contracts.[12] Dixon and Kara (2005) show, however, that this ratio is correctly interpreted as the average *age* of price contracts. This confusion has led some to an incorrect mapping between ξ_p and N_p. As shown by Dixon and Kara, the correct mapping is $\xi_p = \frac{N_p - 1}{N_p + 1}$, or, equivalently, $N_p = \frac{2}{1-\xi_p} - 1$. So, for $N_p = 4$, the contract length assumed by HLP in their model, the corresponding value for the Calvo parameter, ξ_p, is 0.6. A similar mapping holds for wage stickiness parameters.

To consider a single comparison, let $N_p = N_w = 4$ and, thus, $\xi_p = \xi_w = 0.6$. We note that for the HLP model, when $\varphi = 0.7$,[13] it's calibrated value for the postwar U.S. economy, real wages are procyclical. The SW model also produces procyclical real wages. A broader comparison suggests that real wages tend to respond more procyclically in the SW model than the HLP model for comparable degrees of price and wage stickiness.[14]

B. Varying the Steady State Markup Parameters

[12] For example, Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007) refer to this ratio as giving the average duration of price contracts. Christiano, Eichenbaum, and Evans further suggest a mapping consistent with $N_p = 1/(1-\xi_p)$.

[13] As HLP emphasize in their model, the cyclical response of real wages to monetary policy shocks depends critically on the value of this parameter which summarizes the relative importance of intermediate goods in production. This parameter, however, does not have a counterpart in the SW model. Thus, to compare the results of the two models, we must choose a value of φ for the HLP model that "fits the data" since the SW model is estimated using U.S. data. HLP suggest that a value of 0.7 is appropriate for the post-war U.S. economy.

[14] For example, when $N_p = 2$ ($\xi_p = 0.33$) and $Nw = 3$ ($\xi_p = 0.5$), the HLP model produces countercyclical real wages in response to a monetary shock while the SW model produces procyclical real wages.

We also investigate the effects of varying the steady state markup parameters in both the labor and goods markets, $\frac{\phi_w}{\phi_w - 1}$ and $\frac{\phi_p}{\phi_p - 1}$ respectively. These exactly correspond to the markups related to σ and θ in the HLP model, $\frac{\sigma}{\sigma - 1}$ and $\frac{\theta}{\theta - 1}$ respectively. SW calibrate ϕ_w to be 1.5 and estimate ϕ_p to be 1.6. As in our experiment for σ and θ in HLP, we let ϕ_w and ϕ_p each take on values of 1.5, 3.0, and 11.0 corresponding to steady state markups of 3.0, 1.5, and 1.1, respectively. The results are reported in Tables 5 and 6. From Table 5, we see that for any given value of ϕ_p, real wages become more countercyclical as ϕ_w increases, which is analogous to the results for the HLP model (recall Table 2). On the other hand, for a fixed value of ϕ_w, as we see in Table 6, real wages become slightly more countercyclical as the price markup increases. Recall that in HLP, varying the θ, the corresponding parameter, had no influence on the real wage cyclicality. As the SW model has a less transparent monetary transmission mechanism, we hypothesize that, unlike in the HLP model, the price markup does indirectly influence the MRS (marginal rate of substitution between consumption and leisure) in such a way as to incentivize early earnings over undercutting other laborers' wages.

[Insert Tables 5-6 about here.]

C. Varying the Elasticity of Intertemporal Labor Substitution

Now we investigate the effect of changing the labor supply elasticity in the SW model. We examine the cyclical response of real wages for four alternative values of the labor supply elasticity, σ_l: 1.0, 1.5, 3.0, and 10.0. The SW estimated value is 1.53. Our results are reported in Table 7. Note that the other parameter values are not reestimated, but taken at the values estimated by SW.

[Insert Table 7 about here.]

We note that, when prices are completely flexible and wages fully sticky (ξ_p = 0.0 and ξ_w = 1.0), changes in labor supply elasticity make essentially no difference. This must reflect the fact that when prices are fully flexible and wages are fixed by contract, the effective labor supply curve becomes perfectly elastic (horizontal) and the elasticity of the utility-maximizing labor supply curve is irrelevant.[15] On the other hand, when prices are fully sticky and wages flexible (ξ_p = 1.0 and ξ_w = 0.0), changes in labor supply elasticity make a much larger difference in the cyclical response of real wages.

Overall, however, even though the range of values for the labor supply elasticity is quite wide, changes don't make a substantial difference in the cyclical response of real wages to monetary shocks. In particular, the reference line dividing the range of countercyclical and procyclical real wages does not change markedly as we increase the labor supply elasticity from 1.0 to 10.0. This result is similar to the HLP results for ξ where we also observed very little change in the magnitude or direction of cyclicality. While we do observe some movement in the procyclical direction as σ_l increases when wages are flexible and prices sticky, the magnitude of change is far smaller than in the HLP results.

D. Varying the Kimball Aggregator Parameter

Traditional DSGE models have typically used the Dixit-Stiglitz (CES) aggregator in the labor and intermediate goods markets. SW use the more general Kimball aggregator; see Kimball (1995). The Kimball aggregator is more flexible in that it allows the elasticity of demand to increase as relative price increases depending on the value of the Kimball parameter, ε. The Dixit-Stiglitz model is a special case with $\varepsilon = 0$. The Kimball aggregator is applied in both the goods and labor markets with parameters denoted ε_p and ε_w respectively. SW calibrated the values of both ε_p and ε_w

[15] Note that this explanation would indicate that there would be no change in the cyclicality of the real wage as the elasticity varies. As our results are asymptotic approximations of the perfectly sticky and fully flexible cases, we only observe approximate invariance to the elasticity.

to be 10.0; these are the values assumed for all previous tables reporting results for the SW model. Here we consider two additional values: $\varepsilon_p = \varepsilon_w = 0.0$ which collapses to the Dixit-Stiglitz special case and $\varepsilon_p = \varepsilon_w = 33.0$ which is the value suggested by Kimball in his original paper. A higher value of ε_p means that the demand for differentiated goods becomes more elastic as the relative price increases. Similarly, a higher value of ε_w means that the demand for differentiated labor becomes more elastic as the relative wage increases.

While we have investigated the consequences of varying the value of ε_p for each of the three choices of values of ε_w, to save space, we report only a subset of these results in Table 8.[16] There, we see evidence that, given ε_p, increasing ε_w implies greater real wage countercyclicality and, given ε_w, increasing ε_p implies less real wage countercyclicality. From the full results, we find that, as we increase ε_p and ε_w together, there is only a negligible effect on the countercyclical response of real wages.

[Insert Table 8 about here.]

To understand the phenomenon observed in Table 8, consider the market for labor. As the curvature of labor demand (ε_w) increases, the labor demand curve bows away from the origin. For points on the curve with higher wages than at the inflection point (where our market likely will be in equilibrium given the monopoly power of the households), this implies a less steep curve. Thus, when the labor supply curve shifts up in response to a monetary policy shock, the corresponding change in nominal wage will be smaller for higher levels of curvature. Thus our real wages will be more countercyclical.

[16] The full results are contained in an Appendix available from the authors on request.

The result for changes in ε_p is explained by similar reference to the intermediate goods market. Changes in price will be less drastic for higher curvature, leading to a more procyclical real wage in response to a monetary policy shock.

III. Summary

Our investigation has confirmed that, as expected, relative wage and price stickiness plays a very important role in the cyclical response of real wages to monetary policy shocks. Furthermore, we obtain qualitatively similar results for two models. For both the HLP and SW DSGE models, as wages become stickier relative to prices, real wages become more countercyclical in response to changes in monetary policy. However, it is important to note that a procyclical real wage response does not necessarily mean that prices are stickier than wages as measured by the stickiness parameters of these models. Indeed, in both models, other things equal, when wages and prices are equally sticky, real wages tend to be procyclical. Thus, merely from the observation that real wages seem to respond procyclically to monetary shocks, it is misguided to conclude, as some have done,[17] that prices are stickier than wages. This reflects the fact that there are other important factors that are relevant to the behavior of real wages. The major purpose of our investigation has been to examine these other factors. We have discovered that some of them have significant effects.

Both models have revealed that the elasticity of substitution between differentiated labor and the implied wage markup coefficients are important. When wages are sticky, real wages become more countercyclical in response to a monetary shock as this elasticity increases regardless of the stickiness of prices. The models offer slightly different (but not opposite) implications when wages are flexible: In the HLP model, increases in this elasticity have no effect while in the SW model we see slightly more countercyclical wages in this case. We ascribe this difference to the higher complexity of the SW model which allows more complicated effects.

[17] See the discussion in the introduction to this paper and the references cited there.

The models are in broad agreement regarding the effects of changes in the elasticity of intertemporal labor substitution. Both models suggest that when wages are sticky relative to prices, increases in this elasticity have a rather small effect. On the other hand, when prices are sticky relative to wages, increases in this elasticity cause the real wage to respond more procyclically to a monetary policy shock.

Each model also has parameters that seem to play an important role for which there is no counterpart in the other. For example, a key parameter in the HLP model, φ, reflects the relative importance of intermediate goods in production. We confirm and extend the HLP finding that increases in φ cause real wages to be more procyclical for all pairs of wage and price stickiness parameter values. As indicated by HLP, this is consistent with the conventional wisdom regarding the changing cyclicality of real wages during the postwar period in which intermediate goods have become increasingly important.

The SW model also includes a more flexible aggregator function, the Kimball aggregator. This aggregator generalizes the usual Dixit-Stiglitz aggregator by including an additional parameter which allows the elasticity of demand to increase as relative price increases. We find that if the Kimball parameter increases symmetrically in both the intermediate goods and labor markets, it has little effect on the cyclical response of real wages. However, if the value of the Kimball parameter is larger in goods markets than labor markets, this will produce more procyclical real wages.

IV. Conclusion

Many business cycle theories posit that monetary shocks have real effects as a consequence of the existence of sticky prices and/or sticky wages. Since alternative theories have distinct implications for the cyclical response of real wages to a monetary policy shock, many previous studies have examined the behavior of real wages in order to draw inferences about the relative stickiness of prices and wages. Early studies essentially looked, in one way or another, at the correlation between the real wage and either output or employment. Such correlations will tell us little or nothing about the response to monetary shocks if the data are generated in a world in which there are nonmonetary shocks as well.

More recent studies have improved on this state of affairs by using structural VAR (SVAR) models to isolate the effects of monetary policy shocks on real wages. However, the validity of this approach depends on the assumption that the response of real wages to a monetary policy shock reflects only the relative stickiness of wages and prices, not other characteristics of the economy.

The purpose of this paper has been to examine this implicit assumption. Using two different DSGE models, we have examined the role of other factors in explaining the cyclical response of real wages to monetary policy changes and have found that several of these appear to play important roles. As a consequence, to draw inferences about the relative stickiness of wages and prices, it is not enough to look at how real wages respond to monetary policy. It seems that it is necessary to find direct measures of the stickiness of wages and prices. SW have done this in their model since they estimate the Calvo stickiness parameters using historical data.

Though we only look at how characteristics of a model economy affect the influence of monetary policy on real wages, the response of other variables to monetary shocks will also be affected in important ways by characteristics of the model. Just how is a topic for future research. All of this reminds us that while the transmission mechanism for monetary policy may not seem complicated in these and related models, it in fact depends on many parameters in complex ways.

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Table 1: Variation in the real wage IRF at the one-quarter horizon in response to a one percent increase in the money growth rate across pairs of values of N_p and N_w and for selected values of φ in the HLP model.

$\varphi = 0.4$ (Interwar calibrated value)

Wage Stickiness (N_w) \ Price Stickiness (N_p)	1	2	3	4	5	6	7	8
1		9.29	15.33	19.99	23.81	27.06	29.90	32.43
2	-1.32	0.02	1.28	2.33	3.21	3.97	4.63	5.23
3	-1.75	-0.57	0.00	0.56	1.02	1.42	1.77	2.09
4	-1.97	-0.84	-0.33	-0.01	0.31	0.58	0.81	1.02
5	-2.13	-1.00	-0.51	-0.22	0.00	0.20	0.37	0.52
6	-2.25	-1.10	-0.62	-0.34	-0.15	0.00	0.14	0.26
7	-2.35	-1.18	-0.70	-0.42	-0.24	-0.10	0.00	0.11
8	-2.44	-1.24	-0.75	-0.48	-0.30	-0.17	-0.07	0.01

$\varphi = 0.7$ (Postwar calibrated value)

Wage Stickiness (N_w) \ Price Stickiness (N_p)	1	2	3	4	5	6	7	8
1		12.01	19.12	24.30	28.44	31.94	34.99	37.73
2	-1.32	0.46	1.94	3.13	4.11	4.94	5.67	6.32
3	-1.75	-0.30	0.37	0.98	1.48	1.92	2.30	2.65
4	-1.97	-0.60	-0.06	0.30	0.63	0.91	1.15	1.37
5	-2.13	-0.76	-0.27	0.02	0.25	0.45	0.63	0.79
6	-2.25	-0.87	-0.39	-0.12	0.06	0.21	0.35	0.47
7	-2.35	-0.95	-0.47	-0.21	-0.05	0.08	0.18	0.28
8	-2.44	-1.01	-0.53	-0.28	-0.12	0.00	0.09	0.16

Table 2: Variation in the real wage IRF at the one-quarter horizon in response to a one percent increase in the money growth rate across pairs of values of N_p and N_w and for selected values of σ in the HLP model.

σ = 1.5 (Wage markup = 3.0)

Wage Stickiness (N_w) \ Price Stickiness (N_p)	1	2	3	4	5	6	7	8
1		12.01	19.12	24.30	28.44	31.94	34.99	37.73
2	-1.09	0.96	2.95	4.52	5.78	6.84	7.77	8.59
3	-1.51	0.03	0.85	1.69	2.38	2.97	3.49	3.95
4	-1.74	-0.33	0.27	0.72	1.18	1.57	1.91	2.22
5	-1.89	-0.54	0.00	0.34	0.62	0.90	1.15	1.37
6	-2.01	-0.67	-0.17	0.13	0.34	0.53	0.73	0.90
7	-2.11	-0.76	-0.28	0.00	0.19	0.34	0.47	0.61
8	-2.20	-0.83	-0.36	-0.10	0.08	0.21	0.32	0.42

σ = 3.0 (Wage markup = 1.5)

Wage Stickiness (N_w) \ Price Stickiness (N_p)	1	2	3	4	5	6	7	8
1		12.01	19.12	24.30	28.44	31.94	34.99	37.73
2	-1.32	0.46	1.94	3.13	4.11	4.94	5.67	6.32
3	-1.75	-0.30	0.37	0.98	1.48	1.92	2.30	2.65
4	-1.97	-0.60	-0.06	0.30	0.63	0.91	1.15	1.37
5	-2.13	-0.76	-0.27	0.02	0.25	0.45	0.63	0.79
6	-2.25	-0.87	-0.39	-0.12	0.06	0.21	0.35	0.47
7	-2.35	-0.95	-0.47	-0.21	-0.05	0.08	0.18	0.28
8	-2.44	-1.01	-0.53	-0.28	-0.12	0.00	0.09	0.16

σ = 11.0 (Wage markup = 1.1)

Wage Stickiness (N_w) \ Price Stickiness (N_p)	1	2	3	4	5	6	7	8
1		12.01	19.12	24.30	28.44	31.94	34.99	37.73
2	-1.91	-0.42	0.42	1.05	1.56	2.00	2.39	2.74
3	-2.31	-0.90	-0.38	-0.02	0.25	0.47	0.66	0.82
4	-2.53	-1.09	-0.59	-0.32	-0.12	0.04	0.16	0.26
5	-2.56	-1.19	-0.69	-0.43	-0.27	-0.14	-0.04	0.04
6	-2.55	-1.25	-0.75	-0.49	-0.34	-0.23	-0.14	-0.07
7	-2.54	-1.29	-0.79	-0.53	-0.37	-0.27	-0.19	-0.13
8	-2.53	-1.32	-0.81	-0.55	-0.39	-0.29	-0.22	-0.17

Table 3: Variation in the real wage IRF at the one-quarter horizon in response to a one percent increase in the money growth rate across pairs of values of N_p and N_w and for selected values of ξ in the HLP model.

$\xi = 1.00$

Price Stickiness (N_p)

Wage Stickiness (N_w)	1	2	3	4	5	6	7	8
1		7.67	11.71	14.50	16.67	18.50	20.10	21.54
2	-1.27	0.41	1.68	2.62	3.36	3.97	4.49	4.95
3	-1.68	-0.29	0.33	0.87	1.30	1.65	1.96	2.23
4	-1.90	-0.57	-0.06	0.27	0.57	0.81	1.02	1.21
5	-2.05	-0.73	-0.25	0.03	0.23	0.42	0.57	0.71
6	-2.17	-0.83	-0.37	-0.11	0.06	0.20	0.33	0.43
7	-2.26	-0.91	-0.44	-0.20	-0.04	0.08	0.18	0.27
8	-2.35	-0.97	-0.50	-0.26	-0.10	0.00	0.09	0.16

$\xi = 1.50$

Price Stickiness (N_p)

Wage Stickiness (N_w)	1	2	3	4	5	6	7	8
1		9.97	15.59	19.59	22.77	25.44	27.77	29.87
2	-1.30	0.44	1.84	2.93	3.81	4.55	5.19	5.76
3	-1.72	-0.30	0.36	0.94	1.41	1.82	2.17	2.48
4	-1.95	-0.59	-0.06	0.29	0.61	0.87	1.10	1.31
5	-2.10	-0.75	-0.26	0.03	0.24	0.44	0.61	0.76
6	-2.22	-0.85	-0.38	-0.12	0.06	0.21	0.34	0.46
7	-2.31	-0.93	-0.46	-0.21	-0.04	0.08	0.18	0.28
8	-2.40	-0.99	-0.52	-0.27	-0.11	0.00	0.09	0.16

Table 3 (cont.)

ξ = 3.00

Price Stickiness (N_p)

Wage Stickiness (N_w)	1	2	3	4	5	6	7	8
1		15.56	25.42	32.85	38.86	43.95	48.40	52.36
2	-1.34	0.48	2.06	3.37	4.48	5.45	6.31	7.07
3	-1.77	-0.31	0.38	1.03	1.56	2.04	2.46	2.85
4	-2.00	-0.61	-0.06	0.30	0.65	0.95	1.21	1.45
5	-2.16	-0.78	-0.27	0.02	0.25	0.47	0.65	0.82
6	-2.28	-0.89	-0.40	-0.13	0.06	0.21	0.36	0.49
7	-2.39	-0.96	-0.48	-0.22	-0.05	0.08	0.19	0.29
8	-2.44	-1.02	-0.54	-0.28	-0.12	0.00	0.09	0.16

ξ = 10.0

Price Stickiness (N_p)

Wage Stickiness (N_w)	1	2	3	4	5	6	7	8
1		32.52	55.70	75.08	91.79	106.41	119.39	131.03
2	-1.38	0.51	2.27	3.81	5.20	6.46	7.62	8.69
3	-1.82	-0.32	0.41	1.11	1.71	2.26	2.76	3.23
4	-2.06	-0.63	-0.07	0.32	0.70	1.02	1.32	1.59
5	-2.22	-0.80	-0.28	0.02	0.26	0.50	0.70	0.88
6	-2.35	-0.91	-0.41	-0.13	0.06	0.22	0.38	0.51
7	-2.44	-0.99	-0.50	-0.23	-0.05	0.08	0.19	0.30
8	-2.45	-1.05	-0.56	-0.29	-0.13	-0.01	0.09	0.17

Table 4: Variation in the real wage IRF at the one-quarter horizon in response to a one-standard-deviation decline in the interest rate across pairs of values of ξ_p and ξ_w in the SW model.

	Price Stickiness (ξ_p)										
Wage Stickiness (ξ_w)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.20	0.32	0.43	0.54	0.65	0.77	0.91	1.09	1.43	2.43
0.1	-0.01	0.15	0.26	0.35	0.44	0.53	0.63	0.75	0.91	1.22	2.13
0.2	-0.01	0.12	0.20	0.28	0.35	0.43	0.51	0.61	0.75	1.03	1.85
0.3	-0.01	0.09	0.15	0.21	0.27	0.34	0.41	0.49	0.60	0.85	1.59
0.4	-0.02	0.06	0.11	0.16	0.20	0.25	0.31	0.38	0.47	0.68	1.35
0.5	-0.02	0.03	0.07	0.11	0.14	0.18	0.22	0.27	0.35	0.53	1.11
0.6	-0.03	0.01	0.04	0.06	0.09	0.11	0.15	0.18	0.24	0.39	0.88
0.7	-0.03	-0.01	0.01	0.03	0.04	0.06	0.08	0.11	0.15	0.26	0.66
0.8	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.03	0.04	0.07	0.15	0.44
0.9	-0.05	-0.04	-0.04	-0.03	-0.02	-0.02	-0.01	0.00	0.01	0.06	0.22
1.0	-0.08	-0.07	-0.06	-0.05	-0.05	-0.04	-0.03	-0.02	-0.01	0.01	

Table 5: Variation in the real wage IRF at the one-quarter horizon in response to a one-standard-deviation decline in the interest rate across pairs of values of ξ_p and ξ_w and for selected values of ϕ_w, given ϕ_p = 1.6, in the SW model.

ϕ_w = 1.5 (Wage markup = 3.0)

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.20	0.33	0.44	0.54	0.65	0.77	0.91	1.09	1.42	1.96
0.1	-0.01	0.14	0.24	0.33	0.41	0.50	0.60	0.71	0.86	1.15	1.63
0.2	-0.01	0.10	0.18	0.25	0.31	0.38	0.46	0.55	0.68	0.94	1.36
0.3	-0.02	0.07	0.13	0.18	0.23	0.29	0.35	0.42	0.53	0.75	1.13
0.4	-0.02	0.04	0.09	0.13	0.17	0.21	0.26	0.31	0.40	0.59	0.93
0.5	-0.02	0.02	0.05	0.08	0.11	0.14	0.18	0.22	0.29	0.45	0.74
0.6	-0.03	0.00	0.02	0.04	0.06	0.08	0.11	0.14	0.19	0.33	0.57
0.7	-0.04	-0.02	0.00	0.01	0.02	0.04	0.06	0.08	0.11	0.22	0.41
0.8	-0.04	-0.03	-0.02	-0.01	-0.01	0.00	0.01	0.03	0.05	0.12	0.26
0.9	-0.06	-0.05	-0.04	-0.03	-0.03	-0.02	-0.02	-0.01	0.01	0.05	0.12
1.0	-0.07	-0.06	-0.05	-0.05	-0.04	-0.04	-0.03	-0.02	-0.01	0.02	

ϕ_w = 3.0 (Wage markup = 1.5)

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.20	0.33	0.44	0.55	0.66	0.78	0.92	1.09	1.39	2.18
0.1	-0.01	0.09	0.16	0.23	0.29	0.36	0.43	0.52	0.64	0.87	1.52
0.2	-0.02	0.05	0.10	0.14	0.18	0.23	0.28	0.34	0.43	0.62	1.19
0.3	-0.02	0.02	0.05	0.08	0.11	0.15	0.18	0.23	0.30	0.46	0.95
0.4	-0.03	0.00	0.03	0.05	0.07	0.09	0.12	0.15	0.21	0.34	0.77
0.5	-0.03	-0.01	0.00	0.02	0.03	0.05	0.07	0.10	0.14	0.25	0.61
0.6	-0.04	-0.02	-0.01	0.00	0.01	0.02	0.03	0.05	0.08	0.17	0.47
0.7	-0.04	-0.03	-0.03	-0.02	-0.01	0.00	0.01	0.02	0.04	0.11	0.35
0.8	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	-0.01	0.00	0.01	0.06	0.22
0.9	-0.06	-0.06	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	-0.01	0.02	0.10
1.0	-0.09	-0.08	-0.08	-0.07	-0.06	-0.05	-0.04	-0.03	-0.01	0.00	

Table 5 (cont.)

ϕ_w = 11.0 (Wage markup = 1.1)

Price Stickiness (ξ_p)

Wage Stickiness (ξ_w)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.20	0.33	0.44	0.55	0.67	0.79	0.93	1.09	1.37	1.74
0.1	-0.02	0.02	0.06	0.09	0.12	0.16	0.20	0.25	0.32	0.48	0.75
0.2	-0.03	0.00	0.02	0.03	0.05	0.07	0.10	0.13	0.18	0.30	0.52
0.3	-0.04	-0.02	-0.01	0.01	0.02	0.03	0.05	0.07	0.11	0.21	0.39
0.4	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.02	0.04	0.07	0.14	0.29
0.5	-0.04	-0.04	-0.03	-0.02	-0.01	-0.01	0.00	0.01	0.04	0.10	0.22
0.6	-0.05	-0.04	-0.04	-0.03	-0.02	-0.02	-0.01	0.00	0.02	0.07	0.16
0.7	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	-0.01	0.00	0.04	0.11
0.8	-0.06	-0.05	-0.05	-0.04	-0.04	-0.04	-0.03	-0.02	-0.01	0.02	0.06
0.9	-0.08	-0.07	-0.06	-0.06	-0.05	-0.05	-0.04	-0.03	-0.02	0.00	0.02
1.0	-0.09	-0.08	-0.08	-0.07	-0.06	-0.05	-0.04	-0.03	-0.02	0.00	

Table 6: Variation in the real wage IRF at the one-quarter horizon in response to a one-standard-deviation decline in the interest rate across pairs of values of ξ_p and ξ_w and for selected values of ϕ_p, given ϕ_w = 1.5, in the SW model.

ϕ_p = 1.5 (Price markup = 3.0)

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.62	0.78	0.90	1.00	1.10	1.24	1.46	1.84	2.39	2.62
0.1	0.00	0.51	0.64	0.74	0.83	0.93	1.05	1.25	1.59	2.09	2.30
0.2	0.00	0.41	0.52	0.61	0.68	0.77	0.88	1.05	1.36	1.81	2.00
0.3	0.00	0.32	0.41	0.48	0.55	0.62	0.72	0.88	1.15	1.55	1.72
0.4	0.00	0.24	0.32	0.37	0.42	0.49	0.57	0.71	0.95	1.30	1.45
0.5	0.00	0.17	0.23	0.27	0.31	0.36	0.44	0.55	0.76	1.07	1.20
0.6	0.00	0.11	0.15	0.18	0.22	0.26	0.31	0.41	0.58	0.84	0.95
0.7	0.00	0.06	0.09	0.11	0.13	0.16	0.21	0.28	0.42	0.62	0.70
0.8	-0.01	0.02	0.04	0.05	0.06	0.08	0.11	0.17	0.26	0.41	0.47
0.9	-0.01	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.12	0.20	0.23
1.0	-0.01	-0.01	-0.01	0.00	0.00	0.01	0.01	0.03	0.05	0.09	

ϕ_p = 3.0 (Price markup = 1.5)

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.35	0.51	0.63	0.74	0.84	0.95	1.08	1.29	1.81	2.63
0.1	0.00	0.28	0.41	0.51	0.61	0.70	0.79	0.91	1.09	1.57	2.31
0.2	-0.01	0.22	0.33	0.41	0.49	0.57	0.65	0.75	0.91	1.34	2.01
0.3	-0.01	0.17	0.26	0.32	0.39	0.45	0.52	0.60	0.75	1.13	1.73
0.4	-0.01	0.13	0.19	0.24	0.29	0.34	0.40	0.47	0.60	0.94	1.47
0.5	-0.01	0.09	0.13	0.17	0.21	0.25	0.29	0.35	0.46	0.75	1.21
0.6	-0.01	0.05	0.08	0.11	0.14	0.17	0.20	0.25	0.33	0.58	0.97
0.7	-0.02	0.02	0.04	0.06	0.08	0.10	0.12	0.15	0.22	0.41	0.72
0.8	-0.02	0.00	0.01	0.02	0.03	0.04	0.05	0.07	0.12	0.26	0.48
0.9	-0.03	-0.02	-0.02	-0.01	-0.01	0.00	0.01	0.02	0.04	0.12	0.24
1.0	-0.04	-0.04	-0.03	-0.02	-0.02	-0.01	-0.01	0.00	0.01	0.03	

Table 6 (cont.)

ϕ_p = 11.0 (Price markup = 1.1)

	Price Stickiness (ξ_p)										
Wage Stickiness (ξ_w)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.18	0.30	0.41	0.51	0.62	0.74	0.88	1.06	1.39	1.93
0.1	-0.01	0.14	0.24	0.33	0.42	0.51	0.61	0.73	0.89	1.18	1.67
0.2	-0.01	0.11	0.19	0.26	0.33	0.41	0.49	0.60	0.73	0.99	1.44
0.3	-0.02	0.08	0.14	0.20	0.26	0.32	0.39	0.47	0.59	0.82	1.22
0.4	-0.02	0.05	0.10	0.15	0.19	0.24	0.29	0.36	0.46	0.66	1.01
0.5	-0.02	0.03	0.06	0.10	0.13	0.17	0.21	0.26	0.34	0.51	0.82
0.6	-0.03	0.01	0.03	0.06	0.08	0.11	0.14	0.18	0.23	0.37	0.63
0.7	-0.04	-0.01	0.01	0.02	0.04	0.05	0.07	0.10	0.14	0.25	0.46
0.8	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.02	0.04	0.07	0.14	0.29
0.9	-0.06	-0.05	-0.04	-0.03	-0.03	-0.02	-0.01	-0.01	0.01	0.05	0.14
1.0	-0.07	-0.06	-0.05	-0.05	-0.04	-0.04	-0.03	-0.02	-0.01	0.02	

Table 7: Variation in the real wage IRF at the one-quarter horizon in response to a one-standard-deviation decline in the interest rate across pairs of values of ξ_p and ξ_w and for selected values of σ_l in the SW model.

σ_l = 1.00

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.19	0.32	0.42	0.53	0.63	0.75	0.87	1.04	1.39	2.41
0.1	-0.01	0.15	0.25	0.34	0.42	0.51	0.61	0.72	0.86	1.17	2.08
0.2	-0.01	0.11	0.20	0.27	0.34	0.41	0.49	0.58	0.70	0.97	1.78
0.3	-0.02	0.08	0.15	0.20	0.26	0.32	0.38	0.45	0.55	0.79	1.51
0.4	-0.02	0.06	0.10	0.15	0.19	0.23	0.28	0.34	0.43	0.63	1.25
0.5	-0.02	0.03	0.07	0.10	0.13	0.16	0.20	0.25	0.31	0.48	1.01
0.6	-0.03	0.01	0.03	0.06	0.08	0.10	0.13	0.16	0.21	0.35	0.78
0.7	-0.04	-0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.12	0.23	0.57
0.8	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.02	0.03	0.06	0.13	0.37
0.9	-0.06	-0.05	-0.04	-0.03	-0.03	-0.02	-0.01	-0.01	0.01	0.05	0.18
1.0	-0.08	-0.07	-0.06	-0.06	-0.05	-0.04	-0.03	-0.02	-0.01	0.01	

σ_l = 1.50

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.19	0.32	0.43	0.54	0.65	0.77	0.90	1.07	1.42	2.42
0.1	-0.01	0.15	0.26	0.35	0.44	0.53	0.63	0.75	0.90	1.21	2.12
0.2	-0.01	0.12	0.20	0.28	0.35	0.42	0.51	0.61	0.74	1.01	1.84
0.3	-0.02	0.09	0.15	0.21	0.27	0.33	0.40	0.48	0.59	0.84	1.57
0.4	-0.02	0.06	0.11	0.15	0.20	0.25	0.30	0.37	0.46	0.67	1.33
0.5	-0.02	0.03	0.07	0.11	0.14	0.18	0.22	0.27	0.34	0.52	1.09
0.6	-0.03	0.01	0.04	0.06	0.09	0.11	0.14	0.18	0.24	0.38	0.86
0.7	-0.03	-0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.14	0.26	0.64
0.8	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.03	0.04	0.07	0.15	0.42
0.9	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	-0.01	0.00	0.01	0.06	0.21
1.0	-0.08	-0.07	-0.06	-0.06	-0.05	-0.04	-0.03	-0.02	-0.01	0.01	

Table 7 (cont.)

σ_l = 3.00

Wage Stickiness (ξ_w)	Price Stickiness (ξ_p): 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.20	0.34	0.46	0.57	0.69	0.82	0.98	1.17	1.52	2.47
0.1	-0.01	0.16	0.27	0.37	0.47	0.57	0.69	0.82	1.00	1.32	2.22
0.2	-0.01	0.13	0.22	0.30	0.38	0.47	0.57	0.68	0.84	1.13	1.98
0.3	-0.01	0.10	0.17	0.23	0.30	0.37	0.45	0.55	0.69	0.96	1.74
0.4	-0.02	0.07	0.12	0.18	0.23	0.29	0.35	0.43	0.55	0.79	1.51
0.5	-0.02	0.04	0.08	0.12	0.16	0.21	0.26	0.33	0.42	0.63	1.28
0.6	-0.02	0.02	0.05	0.08	0.11	0.14	0.18	0.23	0.30	0.47	1.05
0.7	-0.03	0.00	0.02	0.04	0.06	0.08	0.10	0.14	0.19	0.33	0.81
0.8	-0.04	-0.02	-0.01	0.00	0.01	0.03	0.04	0.06	0.10	0.19	0.56
0.9	-0.05	-0.04	-0.03	-0.03	-0.02	-0.01	-0.01	0.00	0.02	0.08	0.29
1.0	-0.07	-0.06	-0.06	-0.05	-0.05	-0.04	-0.03	-0.02	-0.01	0.02	

σ_l = 10.0

Wage Stickiness (ξ_w)	Price Stickiness (ξ_p): 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.24	0.40	0.54	0.69	0.84	1.01	1.22	1.48	1.87	2.70
0.1	-0.01	0.20	0.34	0.46	0.59	0.73	0.88	1.07	1.32	1.70	2.55
0.2	-0.01	0.16	0.28	0.39	0.50	0.62	0.76	0.93	1.16	1.52	2.38
0.3	-0.01	0.13	0.23	0.32	0.41	0.51	0.63	0.79	0.99	1.34	2.21
0.4	-0.01	0.10	0.17	0.25	0.32	0.41	0.51	0.65	0.83	1.15	2.02
0.5	-0.01	0.07	0.13	0.19	0.25	0.32	0.40	0.51	0.67	0.96	1.82
0.6	-0.02	0.04	0.08	0.13	0.17	0.23	0.29	0.38	0.50	0.76	1.58
0.7	-0.02	0.02	0.04	0.07	0.11	0.14	0.19	0.25	0.34	0.55	1.30
0.8	-0.03	-0.01	0.01	0.03	0.04	0.07	0.09	0.13	0.19	0.34	0.97
0.9	-0.04	-0.03	-0.02	-0.01	-0.01	0.00	0.02	0.03	0.06	0.15	0.53
1.0	-0.06	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	0.00	0.03	

Table 8: Variation in the real wage IRF at the one-quarter horizon in response to a one-standard-deviation decline in the interest rate across pairs of values of ξ_p and ξ_w and for selected values of ε_w, given $\varepsilon_p = 0$, in the SW model.

$\varepsilon_w = 0$, $\varepsilon_p = 0$ *(Dixit-Stiglitz case)*

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.04	0.10	0.16	0.23	0.31	0.41	0.54	0.72	1.00	1.62
0.1	-0.01	0.04	0.09	0.14	0.21	0.28	0.38	0.50	0.66	0.93	1.51
0.2	-0.01	0.03	0.07	0.13	0.18	0.25	0.34	0.45	0.60	0.84	1.40
0.3	-0.01	0.02	0.06	0.11	0.16	0.22	0.29	0.39	0.53	0.75	1.27
0.4	-0.01	0.02	0.05	0.09	0.13	0.18	0.25	0.33	0.45	0.65	1.13
0.5	-0.02	0.01	0.04	0.07	0.10	0.14	0.20	0.27	0.37	0.54	0.97
0.6	-0.02	0.00	0.02	0.04	0.07	0.10	0.14	0.20	0.28	0.42	0.80
0.7	-0.02	-0.01	0.00	0.02	0.04	0.06	0.09	0.13	0.19	0.29	0.61
0.8	-0.03	-0.02	-0.01	-0.01	0.01	0.02	0.04	0.06	0.10	0.16	0.40
0.9	-0.04	-0.04	-0.04	-0.03	-0.03	-0.02	-0.01	0.00	0.02	0.05	0.19
1.0	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.04	-0.04	-0.03	-0.01	

$\varepsilon_w = 33$, $\varepsilon_p = 0$

Wage Stickiness (ξ_w) \ Price Stickiness (ξ_p)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0		0.04	0.10	0.16	0.23	0.31	0.41	0.54	0.72	1.00	1.61
0.1	-0.01	0.02	0.05	0.09	0.14	0.20	0.26	0.35	0.48	0.69	1.19
0.2	-0.02	0.01	0.03	0.06	0.09	0.13	0.18	0.24	0.34	0.50	0.91
0.3	-0.02	-0.01	0.01	0.03	0.06	0.08	0.12	0.17	0.24	0.36	0.71
0.4	-0.02	-0.01	0.00	0.01	0.03	0.05	0.07	0.11	0.16	0.25	0.54
0.5	-0.03	-0.02	-0.01	0.00	0.01	0.02	0.04	0.07	0.10	0.17	0.41
0.6	-0.04	-0.03	-0.02	-0.02	-0.01	0.00	0.01	0.03	0.06	0.11	0.30
0.7	-0.04	-0.04	-0.03	-0.03	-0.02	-0.02	-0.01	0.00	0.02	0.05	0.20
0.8	-0.05	-0.05	-0.04	-0.04	-0.04	-0.03	-0.03	-0.02	-0.01	0.02	0.12
0.9	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.04	-0.03	-0.03	-0.01	0.05
1.0	-0.10	-0.09	-0.09	-0.09	-0.08	-0.08	-0.07	-0.06	-0.04	-0.02	