When both wages and prices are sticky

Previously, in the basic models, only product prices were allowed to be sticky. In practice, it is possible that other prices are sticky as well. In addition, some prices might be more or less sticky than others and this could be important for the dynamics in the economy as a whole. For instance, producer prices, consumer prices, product prices, prices on services, wages, prices on tradeables, asset prices, etc. may differ substantially with respect to stickiness. In this section we therefore extend the basic model to include sticky wages. It is well-known that wages, particularly for labor with non-standard jobs, are sticky and that labor contracts may have a long duration. In Sweden, for instance, it is presently common with 3-year contracts. The model presented here was originally developed by (Erceg, C. J., D. W. Henderson and A. T. Levin 2000) and a somewhat simplified version of their model is described in (Gali, J. 2008), who is followed here. The sticky wages follow the same model from (Calvo, G. A. 1983) that was applied for producer prices in the basic model.

This means that there is monopolistic competition in the labor market and that the households supply differentiated labor to the firms, analogous to the firms supplying differentiated products to the consumers. Each period a constant fraction of the households are allowed to change their nominal wage. Consequently, the aggregate nominal wage responds sluggishly to shocks, implying inefficient markups on wages. Also, analogously with the product markets, relative wages change in response to nominal shocks and create an inefficient allocation of labor. For the central bank, there is now the additional problem of how to best counteract these inefficiencies.

The model with sticky wages and prices

Firms

A continuum of firms is assumed, similar to the basic model:

$$Y_t(i) = A_t N_t(i) \tag{1}$$

where $N_t(i)$ is an index of labor input used by firm i and defined by

$$N_t(i) \equiv \left[\int_0^1 N_t(i,j)^{1-\frac{1}{\varepsilon_w}} dj \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}} \tag{2}$$

where $N_t(i,j)$ denotes the quantity of the type j labor employed by firm i in period t. The parameter ε_w is the substitution elasticity among labor varieties. Let $W_t(j)$ be the nominal wage for type j labor in period t. Wages are set by workers, or by unions that represent them, of each type and these wages are taken as given by firms. Firms minimize cost and choose the demand of labor of each type, given the firms' total employment (output) and is obtained as the partial derivative of the cost function with respect to wage of the jth type of labor as

$$N_t(i,j) = \left(\frac{W_t(j)}{W_t} \right)^{-\varepsilon_w} N_t(i) \tag{3}$$

where

$$W_t = \left[\int_0^1 W_t(i,j)^{1-\varepsilon_w} dj \right]^{\frac{1}{1-\varepsilon}} \tag{4}$$

is an aggregate wage index. Substituting (3) into (2) yields the wage bill

$$\int_0^1 W_t(j) N_t(i,j) dj = W_t N_t(i)$$

as the product of the wage index and the employment index. The firms then solve the same problem as in the basic model, i.e.

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta_p^k E_t \left\{ Q_{t,t+k} \left(P_t^* Y_{t+k|t} - \psi_{t+k} \left(Y_{t+k|t} \right) \right) \right\}$$

subject to the sequence of demand constraints

$$Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon_p} C_{t+k}$$

where $Q_{t,t+k} \equiv \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+k}} \right)$ is the stochastic discount factor for nominal payoffs, $\psi_{t+k}(.)$ is the cost function and $Y_{t+k|t}$ denotes the output in period t+k for a firm that last reset its price in period t. As in the basic model a Phillips curve can be derived as

$$\pi_t^p = \beta E_t \left\{ \pi_{t+1}^p \right\} - \lambda_p \hat{\mu}_t^p \tag{5}$$

where $\hat{\mu}_t^p \equiv \mu_t^p - \mu^p = -(mc_t - mc)$ and $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p} \frac{1-\alpha}{1-\alpha+\alpha\varepsilon_p}$.

Households

As in the basic model the typical household maximizes

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U \left(C_t(j), N_t(j) \right) \right\}$$

subject to a sequence of budget constraints where $N_t(j)$ is the quantity of labor supplied and

$$C_t(j) \equiv \left(\int_0^1 C_t(i,j)^{1-\frac{1}{\varepsilon_p}} di \right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}} \tag{6}$$

where i refer to the type of good and j refer to the type of labor that the household is specialized to supply.

In each period a fraction θ_p reset their wage, while a fraction $1-\theta_p$ keep their wage fixed.

Optimal wage setting

Consider the household that optimize and chooses the wage W_t^* in order to maximize

$$E_t\left\{\sum_{k=0}^{\infty}(\beta\theta_w)^k U\left(C_{t+k|t}, N_{t+k|t}\right)\right\} \tag{7}$$

the expected discounted utility from consumption and leisure (disutility from working) during the period during which the wage is expected to be fixed at the level W_t^* set in the current period. (7) is maximized subject to the constraints given by the demand functions (3) and the flow budget constraints that are effective while W_t^* is. The optimality condition can be written

$$\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{N_{t+k|t}U_c\left(C_{t+k|t}, N_{t+k|t}\right)\frac{W_t^*}{P_{t+k}} + \mathrm{M}_w U_n\left(C_{t+k|t}, N_{t+k|t}\right)\right\}$$

where $\mathrm{M}_w = \dfrac{\varepsilon_w}{\varepsilon_w - 1}$ is the wage markup and be rewritten as

$$\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{N_{t+k|t}U_c\left(C_{t+k|t}, N_{t+k|t}\right)\left(\frac{W_t^*}{P_{t+k}} - \mathrm{M}_w MRS_{t+k|t}\right)\right\} \tag{8}$$

where $MRS_{t+k|t} \equiv -\dfrac{U_n\left(C_{t+k|t}, N_{t+k|t}\right)}{U_c\left(C_{t+k|t}, N_{t+k|t}\right)}$ is the marginal rate of substitution between consumption and hours worked in period t+k for the household that resets its wage in period t. In the special case of full wage flexibility, $\theta_w = 0$, we have $\dfrac{W_t^*}{P_t} = \dfrac{W_t}{P_t} = \mathrm{M}_w MRS_{t|t}$. That means that the wage markup is the wedge between the real wage and the marginal rate of substitution in the absence of wage rigidities. Log-linearising around the steady state yields the following approximate wage setting rule

$$w_t^* = \mu^w + (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{mrs_{t+k|t} + p_{t+k}\right\} \tag{9}$$

where $\mu^w = \log \mathrm{M}_w$. The wage equation is increasing in expected future prices, which reflects that households are concerned about their purchasing power. The wage is also increasing in the marginal rate of substitution of labor (disutility of work) in terms of goods over the life of the set wage, because households adjust their expected real wage, given expected future prices. It can also be seen as depending on the value of the marginal disutility of working hours in terms of goods. As in the basic model the specification

$$U(C,N) = \frac{C^{1-\sigma}}{1-\sigma} - \frac{N^{1+\varphi}}{1+\varphi}$$

which applied to (9) gives

$$w_t^* = \beta\theta_w E_t\left\{w_{t+1}^*\right\} + (1-\beta\theta_w)\left(w_t - \left(1+\varepsilon_w\varphi\right)^{-1}\hat{\mu}_t^w\right) \tag{10}$$

where $\hat{\mu}_t^w \equiv \mu_t^w - \mu^w$ denotes the deviation of the average wage markup from its steady state value μ^w and $\mu_t^w = (w_t - p_t) - mrs_t$. The log-linearised aggregate wage equation can then be derived as

$$w_t = \theta_w w_{t-1} + (1-\theta_w)w_t^* \tag{11}$$

By combining (10) and (11) and using $\pi_t^w = w_t - w_{t-1}$ one obtains the wage inflation equation

$$\pi_t^w = \beta E_t\left\{\pi_{t+1}^w\right\} - \lambda_w\hat{\mu}_t^w \tag{12}$$

where $\lambda_w = \dfrac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\varepsilon_w\varphi)}$. The wage inflation equation is analogous to the price inflation equation (NKPC) in (5) and the interpretation of it is similar. When the desired markup is below the steady state level the wage inflation increases in order to catch up. In this extended model the wage inflation equation (12) replaces the condition $w_t - p_t = mrs_t$ in the basic model. As in the basic model there is an Euler equation for the consumers

$$c_t = E_t\left\{c_{t+1}\right\} - \frac{1}{\sigma}\left(i_t - E_t\left\{\pi_{t+1}^p\right\} - \rho\right) \tag{13}$$

where as before in the basic model $i_t = -\log Q_t$ is the yield on the one period bond.

Equilibrium

The analysis of equilibrium makes use of output gaps $\tilde{y}_t = y_t - y_t^n$ where the natural rate of output is the output that materializes in the absence of both sticky prices and sticky wages. The wage gap is defined as

$$\tilde{\varpi}_t = \varpi_t - \varpi_t^n$$

where $\varpi_t = w_t - p_t$ is the real wage rate and ϖ_t^n is the real wage in absence of sticky prices and wages, given by

$$\varpi_t^n = \log(1-\alpha) + \psi_{wa}^n a_t - \mu^p$$

where $\psi_{wa}^n \equiv \dfrac{1-\alpha\psi_{ya}^n}{1-\alpha}$ and $\psi_{ya}^n \equiv \dfrac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$, the latter already derived in the basic model.

We can now use $\mu_t^p = mpn_t - \varpi_t$ to get the price markup gap

$$\begin{aligned}\hat{\mu}_t^p &= (mpn_t - \varpi_t) - \mu^p \\ &= (\tilde{y}_t - \tilde{n}_t) - \tilde{\varpi}_t \\ &= -\frac{\alpha}{1-\alpha}\tilde{y}_t - \tilde{\varpi}_t\end{aligned} \tag{14}$$

Combining the previous price inflation equation with (14) gives

$$\pi_t^p = \beta E_t\left\{\pi_{t+1}^p\right\} + \kappa_p \tilde{y}_t + \lambda_p \tilde{\varpi}_t \tag{15}$$

where $\kappa_p \equiv \frac{\alpha\lambda_p}{1-\alpha}$. Similarly, we can calculate

$$\begin{aligned}\hat{\mu}_t^w &= \varpi_t - mrs_t - \mu^w \\ &= \tilde{\varpi}_t - \left(\sigma\tilde{y}_t + \varphi\tilde{n}_t\right) \\ &= \tilde{\varpi}_t - \left(\sigma + \frac{\varphi}{1-\alpha}\right)\tilde{y}_t\end{aligned} \tag{16}$$

for the wage markup and by combining (12) and (16) get

$$\pi_t^w = \beta E_t\left\{\pi_{t+1}^w\right\} + \kappa_w \tilde{y}_t - \lambda_w \tilde{\varpi}_t \tag{17}$$

where $\kappa_w = \lambda_w\left(\sigma + \frac{\varphi}{1-\alpha}\right)$. In addition there is an identity relating the changes in the wage gap to price and wage inflation and the natural real wage given by

$$\tilde{\varpi}_t \equiv \tilde{\varpi}_{t-1} + \pi_t^w - \pi_t^p - \Delta\varpi_t^n \tag{18}$$

The dynamic IS equation is now derived as

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - E_t\left\{\pi_{t+1}^p\right\} - r_t^n\right) + E_t\left\{\tilde{y}_{t+1}\right\} \tag{19}$$

where the natural rate of interest rate $r_t^n \equiv \rho + \sigma E_t\left\{\Delta y_t^n\right\}$ is the rate in an equilibrium with flexible prices and wages. Finally, the model is closed by formulating an interest rule

$$i_t = \rho + \phi_p \pi_t^p + \phi_w \pi_t^w + \phi_y \tilde{y}_t + v_t \tag{20}$$

where v_t is an disturbance term. (15) – (20) forms a dynamic system which may or may not have a unique solution. (Gali, J. 2008) shows that this system in general has no unique solution. However, restrictions can be imposed on the interest rate rule (20) that guarantees a unique solution. Provided $\phi_y = 0$ the condition $\phi_p + \phi_w > 1$ guarantees a unique solution $\tilde{y}_t = \pi_t^p = \pi_t^w = 0$ for all t. Diagram 1 shows the determinacy regions in that case.

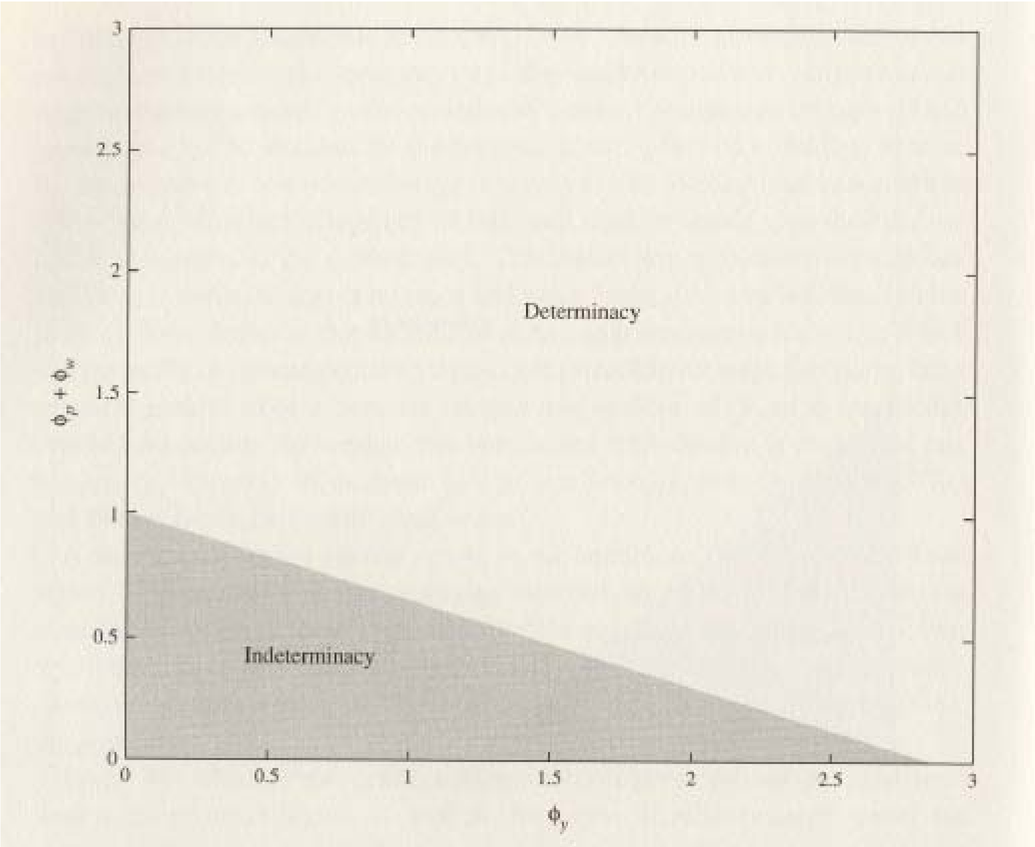

Diagram 1. Regions of determinacy and indeterminacy when $\phi_y = 0$. Source: (Gali, J. 2008).

(Gali, J. 2008) also studies the effects of monetary policy shocks, i.e. shocks to the interest rate rule in (20). Gali assumes $\phi_p = 1.5$ but $\phi_w = \phi_y = 0$ so that only the effects of the sticky wages are studied. He also assumes $\theta_p = 2/3$ and $\theta_w = 3/4$. In diagram 2 the effects of the shock, which is an 0.25 percentage points increase in the exogenous component of the interest rate rule, v_t, which in the absence of endogenous components in the rule would correspond to a one percentage point increase in the annualized nominal interest rate. The solid line shows the response when both wage and prices are sticky and the dashed and dotted lines when prices or wages are sticky, respectively. Obviously then, wage inflation shows a large impact when wages are flexible and price inflation when prices are flexible. However, the most realistic response seems to be realized when both prices and wages are flexible.

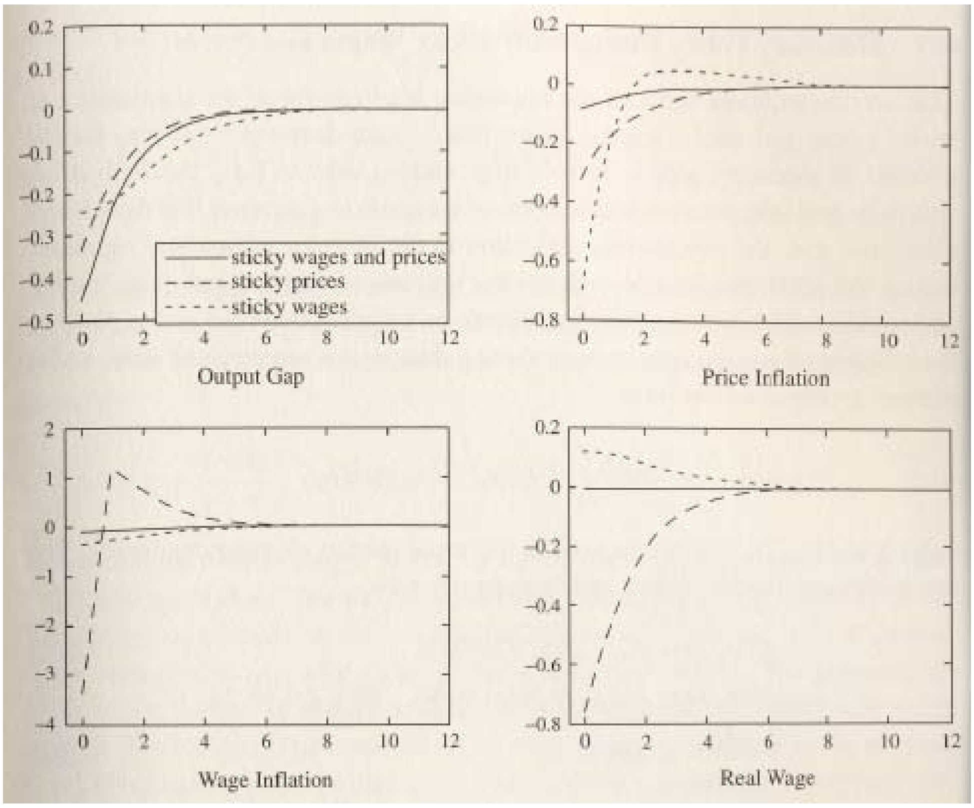

Diagram 2. Sticky prices and/or wages and the effects of monetary policy shocks. Source: (Gali, J. 2008).

Monetary policy with sticky prices and wages

How to design monetary policy in the presence of sticky wages and prices

We now turn to the question of how to design monetary policy when both wages and prices are sticky. In the first place there is the question about the distortion of the steady state, i.e. whether the flex-price, natural rate equilibrium is efficient or not. For the social planner the objective is to maximize the period utility function

$$\max \int_0^1 U\left(C_t(j), N_t(j)\right) dj$$

subject to the three constraints

$$Y_t(i) = A_t N_t(i)^{1-\alpha}$$

$$N_t(i) = \left[\int_0^1 N_t(i,j)^{1-\frac{1}{\varepsilon_w}} dj\right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}}$$

$$C_t(j) = \left(\int_0^1 C_t(i,j)^{1-\frac{1}{\varepsilon_p}} di\right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$

which has the solutions given by the first order conditions

$$C_t(i,j) = C_t \quad \forall i,j \in [0,1]$$
$$N_t(i,j) = N_t(j) = N_t(i) = N_t \quad \forall i,j \in [0,1]$$
$$-\frac{U_{n,t}}{U_{c,t}} = MPN_t$$

where $MPN_t = (1-\alpha)A_t N_t^{1-\alpha}$. If all firms and households would optimize their prices and wages each period, then they would choose the same prices and wages and hence the two first FOCs would be satisfied. However, optimal price and wage setting implies

$$\frac{W_t}{P_t} = -\frac{U_{n,t}}{U_{c,t}} \mathrm{M}_w$$
$$P_t = \mathrm{M}_p \frac{(1-\tau)W_t}{MPN_t}$$

where τ is the employment subsidy, financed with lump-sum taxes, that would guarantee that the flex-price equilibrium is efficient. By choosing $\tau = 1 - \frac{1}{\mathrm{M}_p \mathrm{M}_w}$ that is attained and the third FOC above is satisfied. As is usual in the literature, see (Erceg, C. J., D. W. Henderson and A. T. Levin 2000), this is assumed here.

It can then be shown that there exists a second-order approximation (see (Erceg, C. J., D. W. Henderson and A. T. Levin 2000) to the average welfare losses experienced by households in this economy through the variations across the flex-price equilibrium due to sticky prices and wages, which can be written

$$L = \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left(\left(\sigma + \frac{\varphi + \alpha}{1-\alpha} \right) \tilde{y}_t^2 + \frac{\varepsilon_p}{\lambda_p} (\pi_t^p)^2 + \frac{\varepsilon_w (1-\sigma)}{\lambda_w} (\pi_t^w)^2 \right) \tag{21}$$

where the weights are functions of the model's deep parameters. The additional term due to wage stickiness $\frac{\varepsilon_w (1-\sigma)}{\lambda_w}$ shows that the welfare costs increase with

a) the elasticity of substitution between different labor types, ε_w,
b) the elasticity of output with respect to labor input, $1-\sigma$, and
c) the degree of wage stickiness, θ_w, which is inversely related to λ_w.

a) and b) amplify the negative effect on aggregate productivity of any given dispersion of wages across labor types while c) increases the degree of wage dispersion for any given rate of wage inflation.

In general, as described above, a policy with zero welfare loss in general is not attainable. Therefore, the optimal policy will face a tradeoff in stabilizing the three variables in the loss function. As shown in the basic new Keynesian model in the limiting case of no sticky wages, the optimal policy could be obtained with a policy aiming at stabilizing price inflation. In the limiting case of no sticky prices the optimal policy could similarly concentrate on wage inflation. However, in the case where both prices and wages are sticky, a policy aiming at stabilizing price inflation only, would clearly be suboptimal.

Optimal monetary policy

In this case (Gali, J. 2008) considers the case in which the central bank fully commits to its policy. In the case with sticky prices and wages this means minimizing

$$L=\frac{1}{2}E_0\sum_{t=0}^{\infty}\beta^t\left(\left(\sigma+\frac{\varphi+\alpha}{1-\alpha}\right)\tilde{y}_t^2+\frac{\varepsilon_p}{\lambda_p}(\pi_t^p)^2+\frac{\varepsilon_w(1-\sigma)}{\lambda_w}(\pi_t^w)^2\right)$$

subject to the three constraints

$$\pi_t^p=\beta E_t\left\{\pi_{t+1}^p\right\}+\kappa_p\tilde{y}_t+\lambda_p\tilde{\varpi}_t$$

and

$$\pi_t^w=\beta E_t\left\{\pi_{t+1}^w\right\}+\kappa_w\tilde{y}_t-\lambda_w\tilde{\varpi}_t$$

and

$$\tilde{\varpi}_t\equiv\tilde{\varpi}_{t-1}+\pi_t^w-\pi_t^p-\Delta\varpi_t^n$$

(Gali, J. 2008) shows the response in the output gap, price and wage inflation and the real wage in the diagram below and under the previous three assumptions about parameter values and the optimal policy under commitment just assumed.

When only prices are sticky (dashed lines) the outcome coincides with the outcome from the basic model, i.e. stabilization of the price level and no effect on inflation and the output gap. The flexible nominal wage increases rapidly and the real wage then decrease gradually with the decrease in inflation. Since the policy mirrors the allocation implied by flexible prices and wages the responses of both output and the real wage follows their natural rate counterparts which is accompanied by large changes in wage inflation, which causes no distortions since wages are assumed to be flexible.

When only wages are sticky (dotted lines) the optimal policy stabilizes wage inflation in a manner similar to the previous case with sticky prices and obtains zero wage inflation. The necessary increase of the real wage now comes about through deflation, which is efficient since prices now are perfectly flexible.

When both prices and wages are sticky the efficient natural rate allocation is no longer attainable. Using the previously calibrated parameters as inputs for the weights in the loss function, the central bank weighs the three variables in the loss function accordingly. The response to the technology shock then applies as in Diagram 1 below as a rise in the real wage, but now the central bank adjusts the interest rate such that there is a gradual adjustment of the real wage through a decline in price and increase in wage inflation. The initial increase in the real wage then is smaller than in the natural rate real wage and hence there is an increase in the output gap compared to the previous two cases.

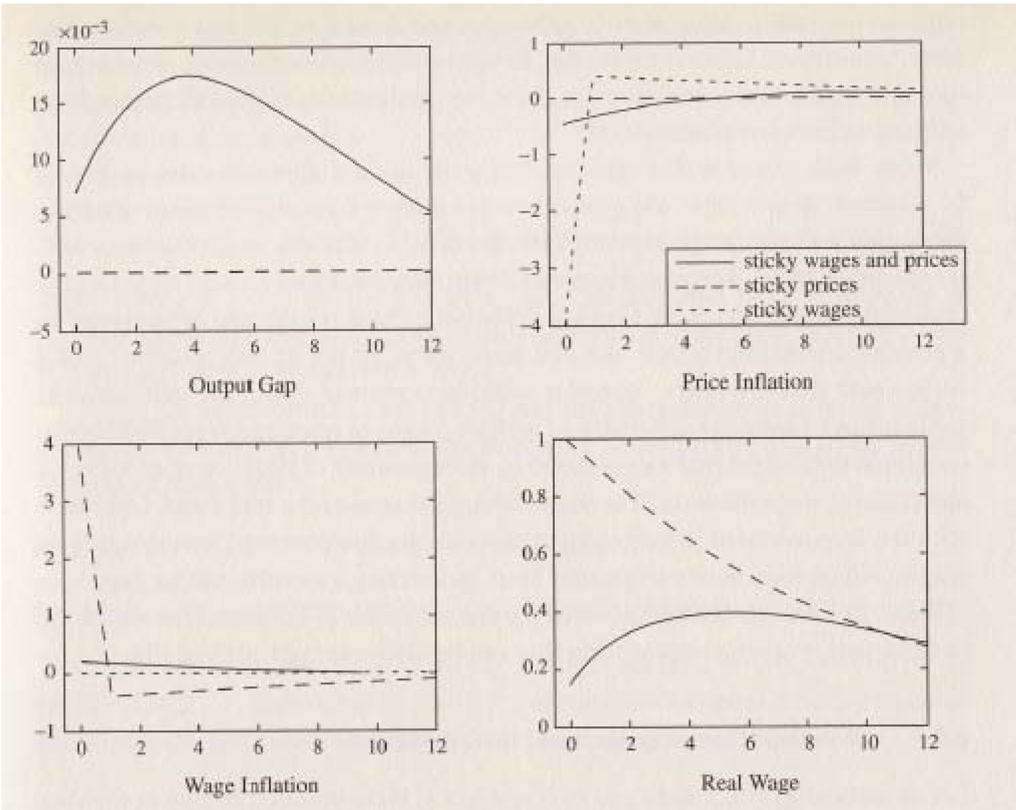

Diagram 1. The effects of a technology shock under the optimal policy.

The optimal rules require the knowledge of the model's structural parameters, the output gap and the inflation rate in wages and prices, which is a strong requirement in practice. (Gali, J. 2008) also considers the special case in which

$\kappa_p = \kappa_w$ and $\varepsilon_p = \varepsilon_w(1-\alpha) \equiv \varepsilon$

Defining $\pi_t = (1-\vartheta)\pi_t^p + \vartheta\pi_t^w$ where $\vartheta = \dfrac{\lambda_p}{\lambda_p + \lambda_w}$ as the *composite inflation index* Gali shows that the Phillips curve for this index can be written $\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa\tilde{y}_t$ where now $\kappa = \dfrac{\lambda_p\lambda_w}{\lambda_p + \lambda_w}\left(\sigma + \dfrac{\varphi+\alpha}{1-\alpha}\right)$ which implies that there is no tradeoff between stabilizing the output gap and this measure of inflation. This would be advantageous in the sense that only knowledge of inflation and not the troublesome output gap is required.

Simulations with simple rules

However, this policy in general is not optimal. Therefore, it is interesting to see which simple rules that generate welfare losses close to the outcome of the optimal rules. Table 1 from (Gali, J. 2008) shows some such simulation results.

It is then assumed that variations in productivity are the only source of fluctuations. Productivity is assumed to follow a persistent AR(1) time series process as before ($a_t = 0.9a_{t-1} + v_t$) with a standard deviation of one percent in the error term. The deep structural parameters are set as before and the stickiness parameters θ_p and θ_w as in the table below. Six different simple rules are analyzed:

- ✓ strict price inflation targeting
- ✓ strict wage inflation targeting
- ✓ strict composite inflation targeting

and their flexible inflation targeting counterparts implied by using the simple rule

$$i_t = \rho + 1.5\pi_t^k$$

where *k* refer to price, wage and composite inflation measures respectively.

		Optimal Policy	Strict Rules			Flexible Rules		
			Price	Wage	Composite	Price	Wage	Composite
$\theta_p = \frac{2}{3}$	$\theta_w = \frac{3}{4}$							
	$\sigma(\pi^p)$	0.64	0	0.82	0.66	1.50	1.08	1.12
	$\sigma(\pi^w)$	0.22	0.98	0	0.19	1.05	0.30	0.42
	$\sigma(\widetilde{y})$	0.04	2.38	0.52	0	0.75	1.16	0.01
	$\mathbb{L}$	0.023	0.184	0.034	0.023	0.221	0.081	0.089
$\theta_p = \frac{2}{3}$	$\theta_w = \frac{1}{4}$							
	$\sigma(\pi^p)$	0.29	0	0.82	0.21	1.40	1.45	1.30
	$\sigma(\pi^w)$	1.24	2.91	0	1.63	1.49	0.98	1.25
	$\sigma(\widetilde{y})$	0.19	0.61	0.52	0	0.29	0.68	0.32
	$\mathbb{L}$	0.010	0.038	0.034	0.012	0.097	0.104	0.083
$\theta_p = \frac{1}{3}$	$\theta_w = \frac{3}{4}$							
	$\sigma(\pi^p)$	1.64	0	1.91	1.75	2.58	2.10	2.10
	$\sigma(\pi^w)$	0.11	0.98	0	0.06	1.47	0.07	0.10
	$\sigma(\widetilde{y})$	0.17	2.38	0.27	0	0.87	0.60	0.58
	$\mathbb{L}$	0.016	0.184	0.021	0.017	0.271	0.030	0.031

Table 1. Evalutation of simple monetary policy rules when both prices and wages are sticky. Source: (Gali, J. 2008).

Results are given in the table above along with results for the optimal policy. The table shows the standard deviation of price and wage inflation as well as the output gap and the resulting welfare loss as given by the loss function. The first part of the table shows the most likely parameter values in terms of price and wage stickiness, $\theta_p = 2/3$ and $\theta_w = 3/4$ while the second part of the table shows a lower degree of wage stickiness and the third part a lower degree of price stickiness.

For the base case the loss with the optimal policy is the very low standard deviation 0.023. However, this result may also be obtained by following the rule based on strict composite inflation targeting, i.e. paying attention to both price and wage inflation. An acceptable outcome can also be generated through strict wage inflation targeting, while the other rules give considerably higher welfare losses.

Interestingly, even in the case when a lower price stickiness is assumed in the second part of the table shows that the strict inflation targeting rule generates an inferior outcome. Another interesting result is that the flexible rules in general are inferior compared to the strict rules.

To summarize, it is noteworthy that in practice central banks use strict or flexible price inflation targeting rules, seemingly ignoring wage inflation. This generates considerably higher welfare losses compared to both wage inflation and composite inflation targeting rules in this model.

References

CALVO, G. A. (1983): "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 12, 383-398.

ERCEG, C. J., D. W. HENDERSON, and A. T. LEVIN (2000): "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*, 46, 281-313.

GALI, J. (2008): *Monetary Policy, Inflation, and the Business Cycle*. Princeton: Princeton University Press.