Which Price Level to Target? Strategic Delegation in a Sticky Price and Wage Economy

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Abstract

This paper assesses the value of delegating price level targets to a discretionary central bank in an economy with nominal frictions in both labor and product markets. In contrast to recent studies that demonstrate the benefits of targeting the price of output, model simulations provide evidence that favors targeting the price of labor, or the nominal wage, instead. While both policies impart inertia (a salient feature of commitment), wage targeting dominates output-price targeting because the former delivers more favorable tradeoffs between the stabilization goals appearing in the social welfare function. Delegating joint price and wage targets, however, nearly replicates the commitment policy from a timeless perspective.

Keywords: Price Targeting, Wage Targeting, Delegation, Timeless Perspective

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1 Introduction

Recent analyses of monetary policy in forward-looking models reveals that discretionary policy suffers from a stabilization bias (e.g., Woodford (1999), Clarida, Galí, and Gertler (1999), and Woodford (2003a)). The bias emerges in the form of suboptimal responses to shocks that create tension between the objectives of the central bank, normally taken to be inflation and output gap stability. This dynamic inefficiency can be traced to the fact that optimal policies under commitment introduce considerable history dependence or inertia into the monetary rule. By making current actions depend on past behavior, a policymaker can influence private sector expectations in a way that improves the volatility tradeoffs that it faces. As demonstrated by Woodford (1999), however, "optimal monetary policy inertia" is generally absent under discretion, resulting in less efficient stabilization outcomes.

Recognizing the benefits of policy inertia has led some researchers to question whether it is not more preferable to direct policy towards stabilizing the price level instead of the inflation rate. Svensson (1999b), Dittmar and Gavin (2000), and Vestin (2006) show that when the central bank operates under discretion, targeting the price level can deliver a more efficient combination of inflation and output gap volatility than inflation targeting.[1] Their argument rests on the notion that the price level is intrinsically persistent in forward-looking models but the inflation rate is not. Thus, a discretionary central bank assigned the task of stabilizing the price level has to adjust policy for several periods after shocks that would otherwise have only a temporary effect on inflation. This kind of response mimics the inertial behavior observed under inflation targeting with commitment. If such commitments are not possible, a central bank can "engineer" inertia by managing a price level target instead.

In this paper I reexamine the effects of delegating price level targets to a central bank that conducts policy under discretion. The analysis departs from the current literature along two

[1]Yetman (2005) demonstrates that the benefits of price level targeting are sensitive to alternative assumptions about the formation of expectations and the credibility of the central bank's inflation target.

critical dimensions. First, previous studies regularly employ small-scale models in which the only nominal frictions present are sticky product prices. Price level targeting in such models implicitly means stabilizing the price of output. In light of recent contributions that call into question the ability of sticky prices alone to generate plausible business cycle dynamics (e.g., Chari, Kehoe, and McGratten (2000) and Christiano, Eichenbaum, and Evans (2005)), I use a version of the model developed by Erceg, Henderson, and Levin (2000) (henceforth, EHL) that emphasizes sticky nominal wages in addition to sticky product prices. A log-linearization of the price-setting equations produces a pair of Phillips curves, one for goods-price inflation and the other for nominal wage inflation, that together form the constraints for the policymaker's control problem. As a means of imparting inertia, the prominence of a "dual" Phillips curve calls attention to the possibility of targeting the price of labor or the nominal wage as an alternative to the price of output.

The second point of departure concerns the preferences of the central bank. In most single-friction models, policy objectives are usually represented with a social loss function defined over an arbitrary weighted sum of the variances of goods-price inflation and the output gap. By contrast, I assume that policies are ranked on a welfare basis according to a "true" social loss function that is derived by taking a quadratic approximation to the representative consumer's expected utility. As illustrated by Rotemberg and Woodford (1997) and EHL (2000), a utility-based measure of social loss reveals the stabilization goals and corresponding policy weights that are consistent with household optimization. The sticky price and wage model implies three objectives, namely, goods-price inflation, nominal wage inflation, and the output gap. The policy weights are functions of the underlying structural parameters that govern, among other things, the duration of price and wage stickiness.

The assumption that policy maximizes expected utility is significant because it alters the stabilization problem in a way that has previously been unaddressed in the price targeting literature. In the absence of sticky wages, the policymaker confronts a singular tradeoff between the variances of goods-price inflation and the output gap, and only so-called "cost-push" shocks create tension between these objectives. As demonstrated by Vestin (2006) and others, an assessment of price level targeting in such a framework amounts to determining whether or not the policy delivers a more efficient combination of price inflation and output gap variability than inflation targeting. Incorporating sticky nominal wages expands the number of tradeoffs in the model by two. The policymaker now confronts a similar exchange between the variances of wage inflation and the output gap as well as the variances of price and wage inflation. Evaluating the merits of price level targeting in this expanded framework requires a more careful review of how well policies manage all three tradeoffs collectively.

The aim of this paper is to assess the potential gains from delegating price level targets to a discretionary central bank that would otherwise pursue inflation targeting. Three price targeting strategies are considered: goods-price targeting, nominal wage targeting, and a combination policy that jointly targets the price of output and the nominal wage. I find that goods-price targeting along the lines of Vestin (2006) is often dominated by inflation targeting policies despite the ability of the former to impart the kind of inertia that has been shown to generate improved outcomes in previous studies. Conversely, an optimally designed nominal wage target has more desirable stabilization properties that reduce the cost of achieving a given degree of price and wage inflation volatility. For numerous parameter configurations, nominal wage targeting strictly dominates goods-price and inflation targeting. I trace this finding to the realization that the central bank usually has a greater incentive to offset shocks when managing a nominal wage target. As a result, the private sector lowers its expectations of future price and wage inflation, thereby improving the volatility tradeoffs discussed above. Finally, I show that the combination policy nearly replicates the optimal commitment equilibrium from the timeless perspective (e.g., Woodford (2003a)) and is robust to variation in the structural parameters.

2 A Sticky Price and Wage Model

The model is a modified version of EHL (2000) driven by productivity shocks and time-varying markups. Monopolistically competitive firms set prices in a staggered fashion and manufacture products using labor and a fixed quantity of capital. Households choose optimal sequences of consumption and supply labor in monopolistically competitive factor markets. They set wages according to the same staggering mechanism that firms use to set prices.

2.1 The Economy

Aggregate demand is derived by taking a log-linear approximation of the consumption Euler equation. Denote x_t the output gap, the log deviation of output from a "natural" level, and let π_t be the rate of goods-price inflation between dates $t-1$ and t. The output gap follows

$$x_t = E_t x_{t+1} - \sigma^{-1}(i_t - E_t \pi_{t+1} - r_t^n), \tag{1}$$

where i_t is the nominal interest rate, and E_t is a conditional expectations operator. The parameter $\sigma > 0$ measures the inverse of the intertemporal elasticity of substitution, and r_t^n is a stochastic disturbance summarizing exogenous variation in the natural real interest rate.

The aggregate supply equations are log-linear approximations of the price-setting conditions of firms and households who stagger contracts in the spirit of Calvo (1983). Denote π_t^w the rate of nominal wage inflation between dates $t-1$ and t, and w_t the log of the real wage. Goods-price inflation, nominal wage inflation, and the real wage are determined by

$$\begin{aligned}
\pi_t &= \beta E_t \pi_{t+1} + \xi_p \left(\frac{\alpha}{1-\alpha}\right) x_t + \xi_p (w_t - w_t^n) + e_{\pi,t}, && (2)\\
\pi_t^w &= \beta E_t \pi_{t+1}^w + \xi_w \left(\frac{\chi}{1-\alpha} + \sigma\right) x_t - \xi_w (w_t - w_t^n) + e_{w,t}, && (3)\\
\pi_t^w &= w_t - w_{t-1} + \pi_t, && (4)
\end{aligned}$$

where w_t^n is the natural real wage and $\beta \in (0,1)$ is the subjective discount factor.[2]

The coefficient ξ_p measures the impact of variations in average real marginal cost on goods-price inflation, and ξ_w determines the sensitivity of wage inflation to departures of the real wage from the households' average marginal rate of substitution between labor and consumption. Both parameters are functions of the primitive coefficients governing preferences and technologies. Specifically, $\xi_p = (1-\varepsilon_p)(1-\beta\varepsilon_p)/(\varepsilon_p(1+\frac{\alpha}{1-\alpha}\theta))$ and $\xi_w = (1-\varepsilon_w)(1-\beta\varepsilon_w)/(\varepsilon_w(1+\chi\eta))$, where $\varepsilon_p \in [0,1]$ and $\varepsilon_w \in [0,1]$ carry information about the frequency of price and wage adjustments, and $\theta > 1$ and $\eta > 1$ are the mean elasticities of demand for varieties of goods and labor.[3] The parameter $\chi > 0$ measures the inverse of the Frisch elasticity of labor supply, and $\alpha \in (0,1)$ is the capital elasticity of output.

Woodford (2003a) shows that (2) is a generalization of the conventional New Keynesian Phillips curve linking inflation to the output gap and expected future inflation. Profit maximization ensures that firms select prices as a markup over a stream of real marginal cost. When wages are flexible ($\varepsilon_w = 0$), average real marginal cost is positively related to the output gap alone. Wage stickiness, however, implies that real marginal cost co-moves with deviations of both output and the real wage from their respective natural rates.

The Phillips curve equations contain a disturbance term that summarizes all exogenous variation in price and wage inflation not attributed to fluctuations in real marginal cost or the marginal rate of substitution. Both shocks are governed by autoregressive processes

$$\begin{aligned} e_{\pi,t} &= \rho_\pi e_{\pi,t-1} + u_{\pi,t}, \\ e_{w,t} &= \rho_w e_{w,t-1} + u_{w,t}, \end{aligned}$$

[2]The natural levels of output, the real wage, and the real interest rate are defined as hypothetical levels that would prevail in a distortionless economy marked by flexible prices and wages and the absence of market power. For a more detailed discussion, refer to EHL (2000) or Woodford (2003a, Chapter 4).

[3]Using "Calvo" terminology, ε_p (ε_w) corresponds to the fixed probability that a randomly selected firm (household) will be unable to optimally reset its price (wage) in any given period.

where $\rho_\pi, \rho_w \in [0,1)$ and $u_{\pi,t}$ and $u_{w,t}$ are independent, mean-zero innovations with standard deviations σ_π and σ_w. Following Steinsson (2003), I assume that these shocks are the result of time-varying markups in product and factor markets. Stochastic markups drive a wedge between the level of output prevailing under flexible prices and wages and the efficient level consistent with zero market power. Including markup shocks is also a convenient way of generating an inflation-output gap variance tradeoff common to models of monetary policy.

Finally, equilibrium is determined in part by the dynamics of w_t^n and r_t^n. In the absence of market distortions, real allocations depend entirely on shocks to preferences and technologies. To simplify the exposition, I assume that productivity shocks account for all variation in the efficient equilibrium. Denote a_t the productivity shock governed by an autoregressive process

$$a_t = \rho_a a_{t-1} + u_{a,t},$$

where $\rho_a \in [0,1)$ and $u_{a,t} \sim i.i.d.(0, \sigma_a^2)$. It turns out that w_t^n and r_t^n can be expressed as $w_t^n = \left(\frac{\chi+\sigma}{1-\alpha}\right) a_t / \left(\frac{\alpha+\chi}{1-\alpha} + \sigma\right)$ and $r_t^n = -\sigma(\frac{1+\chi}{1-\alpha})(1-\rho_a)a_t / \left(\frac{\alpha+\chi}{1-\alpha} + \sigma\right)$.

2.2 The Social Loss Function

The goal of monetary policy is to minimize the distortions that result from the inability of firms and households to adjust prices and wages. The proper metric for evaluating the magnitude of these distortions is the household's utility function given by

$$\mathbb{W}_t \equiv U(C_t) - \int_0^1 \nu(H_t(i))di,$$

where $\mathbb{W}_t$ is an equally weighted average of household welfare comprised of positive utility flows from consumption $U(C_t)$ and negative utility flows from supplying labor $\nu(H_t(i))$.

I assume that policies are ranked by the following criterion that measures the expected deadweight loss ($\mathbb{L}$) associated with a chosen equilibrium relative to the efficient one:

$$\mathbb{L} \equiv -E\left(\frac{\mathbb{W}_t - \mathbb{W}_t^n}{U_c(\bar{C})\bar{C}}\right). \tag{5}$$

$\mathbb{W}_t^n = U(C_t^n) - \nu(H_t^n)$ represents the natural welfare function consistent with perfectly flexible prices and wages and zero market power. The welfare deviations $\mathbb{W}_t - \mathbb{W}_t^n$ are scaled by $U_c(\bar{C})\bar{C}$ in order to express deadweight loss as a fraction of steady state consumption.

To calculate loss using (1) – (4), I follow EHL (2000) in constructing a quadratic approximation of (5) around a zero-inflation steady state. The approximation takes the form

$$\mathbb{L} \approx \tilde{\lambda}_\pi Var(\pi_t) + \tilde{\lambda}_w Var(\pi_t^w) + \tilde{\lambda}_x Var(x_t), \tag{6}$$

indicating that deadweight loss equals a particular weighted sum of the variances of goods-price inflation, nominal wage inflation, and the output gap. Equation (6) is equivalent to an infinite discounted sum of period loss functions

$$\mathbb{L} \approx E_0(1-\delta)\sum_{t=0}^{\infty}\delta^t\{\tilde{\lambda}_\pi \pi_t^2 + \tilde{\lambda}_w \pi_t^{w^2} + \tilde{\lambda}_x x_t^2\} \tag{7}$$

when the central bank's discount factor $\delta \to 1$.[4] Thus, the approximate welfare criterion can be expressed as a more familiar intertemporal loss function defined over squared deviations of price and wage inflation and the output gap from their respective target levels.[5]

The nonnegative coefficients $\{\tilde{\lambda}_\pi, \tilde{\lambda}_w, \tilde{\lambda}_x\}$ are weights that measure the policymaker's relative preference for stabilizing each variable. The utility-based welfare function places the

[4]Refer to Rudebusch and Svensson (1999) for details.

[5]The assumption of monopoly power causes output to be inefficiently low in the steady state, implying that (7) should include a positive target value for the output gap. I assume that fiscal policy offsets these steady-state distortions in order to avoid issues concerning an average inflation bias under discretion (e.g., Kydland and Prescott (1977) and Barro and Gordon (1983)).

following cross-parameter restrictions on the size of the policy weights:

$$\tilde{\lambda}_\pi = \frac{\theta}{2\xi_p}, \quad \tilde{\lambda}_w = \frac{\eta(1-\alpha)}{2\xi_w}, \quad \tilde{\lambda}_x = \frac{1}{2}\left(\frac{\chi+\alpha}{1-\alpha} + \sigma\right).$$

A reduction in the frequency of price changes (a rise in ε_p), for example, increases $\tilde{\lambda}_\pi$ while leaving $\tilde{\lambda}_w$ and $\tilde{\lambda}_x$ unchanged. A symmetric relationship exists between the ε_w and $\tilde{\lambda}_w$.

3 The Delegation Problem

To achieve the goals embodied by the social loss function (7), I adopt the concept of strategic delegation pioneered by Rogoff (1985). Specifically, the policymaker delegates to the central bank the conduct of monetary policy through control of the nominal interest rate. The central bank then adjusts the interest rate to stabilize a set of target variables designated by the policymaker.[6] The chosen variables are represented by an assigned loss function that may be very different from the true social loss function. Nevertheless, the policy weights attached to each target variable are preselected to ensure minimum social loss.[7]

The family of price targeting and inflation targeting regimes considered here are nested using a general loss function of the form

$$L = E_0(1-\delta)\tilde{\lambda}_\pi \sum_{t=0}^{\infty} \delta^t \{(1+f_\pi)\pi_t^2 + (\lambda_w + f_w)\pi_t^{w^2} + \lambda_x x_t^2 + g_p p_t^2 + g_n n_t^2\}, \qquad (8)$$

where p_t denotes the price of output, n_t is the nominal wage, and the normalized loss function weights are given by $\lambda_w = \tilde{\lambda}_w/\tilde{\lambda}_\pi$ and $\lambda_x = \tilde{\lambda}_x/\tilde{\lambda}_\pi$. The auxiliary weights $\{f_\pi, f_w, g_p, g_n\}$ are chosen optimally at the delegation stage to minimize social loss $\mathbb{L}$. Each regime is demarcated by certain constraints placed on the values of the chosen weights.

[6] In this paper the central bank is *instrument* independent but not *goal* independent.

[7] Strategic delegation is closely related to what Svensson (1999a) calls a *targeting rule*, the selection of a particular loss function that specifies a set of target variables and corresponding policy weights.

As a benchmark, I first compute the optimal commitment policy from the "timeless perspective" (TP) described by Woodford (2003a). In this case the policymaker sets $f_\pi = f_w = g_p = g_n = 0$ and minimizes (8) subject to (2) – (4). Unlike discretion, the central bank internalizes private sector expectations in its formulation of policy which enables it to impart considerable inertia into the monetary rule.[8] The result is an improved tradeoff between price inflation, wage inflation, and output gap variability.

Shifting to discretionary rules, I start by considering two different inflation targeting policies. The first regime is *pure discretion* (PD), obtained by setting $f_\pi = f_w = g_p = g_n = 0$. PD amounts to discretionary optimization of the true social loss function and provides a natural reference point for quantifying the gains or losses from assigning different targets. I call the second regime *inflation targeting* (IT), in which case the policymaker sets $g_p = g_n = 0$, but finds optimal values for $f_\pi \in [-1, \infty)$ and $f_w \in [-\lambda_w, \infty)$. Although the target variables coincide with the ones in (7), the weights assigned to these objectives may differ. Values of $f_\pi > 0$ or $f_w > 0$, for instance, correspond to the appointment of a "conservative central banker" in the sense of Rogoff (1985) because the policymaker places additional emphasis on attaining inflation stability relative to output gap stability.

I next consider three different price targeting strategies. The first regime, *price level targeting* (PT), instructs the central bank to jointly stabilize goods prices and the output gap by optimizing over $g_p \in [0, \infty)$ while setting $f_\pi = -1$, $f_w = -\lambda_w$, and $g_n = 0$. It is equivalent to the class of policies examined by Vestin (2006). Instead of targeting the price of output, the second regime, *nominal wage targeting* (WT), directs policy towards stabilizing the price of labor. In this case the policymaker optimizes over $g_n \in [0, \infty)$ and sets $f_\pi = -1$, $f_w = -\lambda_w$, and $g_p = 0$. The third regime is called *price and wage targeting* (PWT), a combination policy obtained by setting $f_\pi = -1$ and $f_w = -\lambda_w$ while optimizing

[8] Refer to appendix A for a derivation of the optimal timeless perspective policy. Svensson and Woodford (2005) provide further analysis of the timeless perspective.

over $g_p \in [0, \infty)$ and $g_n \in [0, \infty)$. PWT seeks a balance between goods-price, nominal wage, and output gap stability. It serves primarily as an illustration of the gains from implementing joint price and wage targets.

I use the methods described by Söderlind (1999) to solve for the equilibrium dynamics of the model. First, rewrite the supply equations using the identities $\pi_t = p_t - p_{t-1}$, $\pi_t^w = n_t - n_{t-1}$, and $w_t = n_t - p_t$. Denote $X_{1,t} = [a_t \; e_{\pi,t} \; e_{w,t} \; p_{t-1} \; n_{t-1}]'$ the vector of exogenous and endogenous predetermined variables and $X_{2,t} = [p_t \; n_t]'$ the vector of forward-looking variables. Denote $u_t = [u_{a,t} \; u_{\pi,t} \; u_{w,t}]'$ the vector of innovations to the structural shocks contained in $X_{1,t}$. Next, stack the policy constraints in the following way:

$$\begin{bmatrix} X_{1,t+1} \\ \Omega E_t X_{2,t+1} \end{bmatrix} = A \begin{bmatrix} X_{1,t} \\ X_{2,t} \end{bmatrix} + Bx_t + \begin{bmatrix} Nu_{t+1} \\ 0 \end{bmatrix}, \tag{9}$$

where Ω, A, and B are matrices of structural parameters, and N is a 5×3 selector matrix.[9]

Similarly, denote $T_t = [\pi_t \; \pi_t^w \; x_t \; p_t \; n_t]'$ the vector of target variables. T_t is related to the state vector and the policy instrument by

$$T_t = C \begin{bmatrix} X_{1,t} \\ X_{2,t} \end{bmatrix} + Dx_t,$$

where

$$C = \begin{bmatrix} 0 & 0 & 0 & -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{and} \quad D = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{bmatrix}.$$

[9]In solving the model I treat the output gap as the policy instrument. Equation (1) can then be used to back out the implied path of the nominal interest rate.

Reformulating (8) in terms of T_t, the central bank's loss function can be written as

$$L = E_0(1-\delta)\tilde{\lambda}_\pi \sum_{t=0}^{\infty} \delta^t T_t' Q T_t \qquad Q = \begin{bmatrix} 1+f_\pi & 0 & 0 & 0 & 0 \\ 0 & \lambda_w + f_w & 0 & 0 & 0 \\ 0 & 0 & \lambda_x & 0 & 0 \\ 0 & 0 & 0 & g_p & 0 \\ 0 & 0 & 0 & 0 & g_n \end{bmatrix},$$

where Q is a diagonal matrix whose nonzero elements are the policy weights. The outcome corresponds to a Markov-perfect equilibrium in which the central bank reoptimizes (8) subject to (9) every period taking the expectations of households and firms as given.

To determine the weights characterizing a particular regime, I perform a numerical search over acceptable values of $\{f_\pi, f_w, g_p, g_n\}$. For a given set of weights, I use the reduced-form solution to the model under discretion to calculate the asymptotic value of (7). The policy weights are then inserted into a gradient-based hill climbing algorithm that quickly identifies the particular combinations that minimizes social loss.[10,11]

4 Welfare Analysis

In this section I conduct simulations of the model to assess the welfare properties of the targeting regimes defined above. I first discuss the calibration procedure, taking values that

[10]The MATLAB function fmincon.m was used to locate optimal policies. The unconstrained function fminsearch.m produced identical results. Because hill climbing algorithms can converge to local extremum in some situations, I restarted the optimization routine for many different initial values. In each case the algorithm converged to the same point in the parameter space, ensuring that a global minimum was found.

[11]Blake and Kirsanova (2008) show that discretionary policy in a linear quadratic framework can generate multiple equilibria when the model contains predetermined endogenous state variables. To ensure that the sticky price and wage model has a unique equilibrium, I randomize the initialization of the Söderlind (1999) programs for each targeting regime considered. The discretionary solution is characterized by a matrix triplet that determines the quadratic form of the loss function and how the forward-looking variables and policy instruments depend on the state vector. I reoptimize the assigned loss function 10,000 times using a random draw for the initial matrix triplet in each trial. This procedure was unable to detect multiple equilibria.

Table 1: BASELINE PARAMETER VALUES

Parameter	Description	Calibration
β	subjective discount factor	0.99264
α	capital elasticity of output	1/3
σ	inverse of the intertemporal elasticity of substitution	2
χ	inverse of the Frish elasticity of labor supply	1
θ	mean elasticity of demand for goods	11
η	mean elasticity of demand for labor	11
ε_p	fraction of firms unable to reset prices	0.6
ε_w	fraction of households unable to reset wages	0.6
σ_a	standard deviation of technology shock	0.007
σ_π	standard deviation of goods markup shock	0.005
σ_w	standard deviation of labor markup shock	0.005
ρ_a	serial correlation of the technology shock	0.95
ρ_π	serial correlation of goods markup shock	0
ρ_w	serial correlation of labor markup shock	0
λ_w	optimal relative weight on wage inflation	1.2308
λ_x	optimal relative weight on the output gap	0.0151

are broadly consistent with recent empirical estimates whenever possible. That said, the analysis contains no strict data fitting component, so I do not claim that the model matches every detail of the business cycle. The absence of formal parameter estimates also makes it difficult to quantify the uncertainty surrounding key results. Thus, I repeat the simulations for a wide range of values to demonstrate robustness.

4.1 Calibration

The unit of time equals one quarter. The discount factor β is set equal to $1.03^{-1/4}$ so that the model delivers a steady state annualized mean real interest rate of 3 percent. I set $\alpha = 1/3$, implying a steady state labor income share of about 67 percent. Regarding preferences, I fix $\sigma = 2$ and $\chi = 1$, implying an intertemporal elasticity of substitution of 0.5 and a unitary Frish elasticity of labor supply, respectively.[12] Concerning productivity

[12] The values for σ and χ are within the range of estimates provided by Smets and Wouters (2005) and Levin, Onatski, Williams, and Williams (2005).

shocks, I set $\sigma_a = 0.007$ and $\rho_a = 0.95$, identical to the values chosen by Cooley and Prescott (1995). As for markup shocks, Smets and Wouters (2005) and Levin *et al.* (2005) report that labor market shocks are slightly larger than the product market variety. They also find that markup shocks are somewhat less volatile than productivity shocks and, hence, I set $\sigma_\pi = \sigma_w = 0.005$. I initially fix $\rho_\pi = \rho_w = 0$, but later relax this assumption to examine whether serial correlation alters the main findings.

Concerning the price and wage-setting parameters, I fix $\theta = \eta = 11$, implying a 10 percent steady state markup in product and factor markets and close to the estimates reported by Rotemberg and Woodford (1997), Amato and Laubach (2003), and Christiano *et al.* (2005). Numerous studies, however, report conflicting estimates of the frequency of price and wage adjustments. Smets and Wouters (2005) and Levin *et al.* (2005) conclude that ε_p and ε_w range from 0.75 to 0.9, meaning that the average lifespan of a contract lasts anywhere from four to ten quarters. Christiano *et al.* (2005) report values of $\varepsilon_p = 0.6$ and $\varepsilon_w = 0.64$, suggesting that neither exceeds three quarters. In light of these opposing views, I initially set $\varepsilon_p = \varepsilon_w = 0.6$ and then subsequently vary both along the unit interval.

4.2 Policy Evaluation

Table 2 reports the welfare cost $\mathbb{L}$ in terms of steady state consumption, the corresponding optimal loss function weights, and the standard deviations of $\{\pi_t, \pi_t^w, x_t\}$. The table also reports decompositions of deadweight loss into orthogonal components attributed to the three exogenous shocks. These statistics reveal the contribution that individual shocks make to the overall welfare cost of each policy.

Figure 1 plots the impulse response functions for price inflation, wage inflation, and the output gap implied by PD, PT, WT, and TP.[13] Because TP delivers the highest level of

[13] I do not display the response functions associated with IT or PWT because they are virtually identical to the ones for PD and TP, respectively.

Table 2: SIMULATION RESULTS FOR THE BASELINE PARAMETER VALUES

Regime	$\mathbb{L}$	Optimal Weights	$\sigma(\pi)$	$\sigma(\pi^w)$	$\sigma(x)$	$\phi(u_a)$	$\phi(u_\pi)$	$\phi(u_w)$
TP	0.468	–	0.435	0.303	1.831	7.8	49.8	42.4
PD	0.534	–	0.452	0.328	2.095	7.0	46.3	46.7
IT	0.534	$f_\pi = 0.101,\ f_w = -0.022$	0.450	0.331	2.087	7.0	46.5	46.5
PT	0.608	$g_p = 0.122$	0.424	0.472	0.559	11.3	38.5	50.2
WT	0.492	$g_n = 1.170$	0.470	0.289	1.768	10.4	49.2	40.4
PWT	0.470	$g_p = 1.022,\ g_n = 1.226$	0.438	0.303	1.823	8.1	49.7	42.2

Notes: **TP** - timeless perspective, **PD** - pure discretion, **IT** - inflation targeting, **PT** - price targeting, **WT** - wage targeting, **PWT** - price and wage targeting; $\mathbb{L}$ - expected deadweight loss in terms of steady state consumption, $\sigma(z)$ - unconditional standard deviation of z, $\phi(\varepsilon)$ - fraction of social loss attributed to ε. The welfare costs, standard deviations, and loss decompositions are multiplied by 100 to express these statistics in percentage points.

welfare, the proximity of a response profile for a given regime to the one implied by TP indicates how well that policy deals with the variance tradeoffs present in the model.

The first result is that IT and PD dominate PT for a plausible calibration of the model. The welfare cost of PT is equivalent to 0.608 percent of steady state consumption. The standard deviations indicate that while PT achieves a lower volatility of goods-price inflation, it permits excess wage inflation volatility and over-stabilizes the output gap (considering the small relative weight on the output gap in the social loss function). This finding contrasts with Vestin (2006) who shows that the advantage of price targeting comes from the ability to impart inertia in response to cost-push shocks. Figure 1 illustrates that the same feature emerges in the sticky price and wage model. Following a shock to $e_{\pi,t}$, PT calls for a persistent output gap contraction, generating an inflation response that is nearly identical to TP.

Why then does PT lead to poor outcomes? The reason is that policies are assessed according to how well they manage all three of the tradeoffs described earlier, not just the price inflation-output gap variance tradeoff common to most sticky price models. Clearly, the weakness of PT stems from a failure to efficiently manage the volatility of wage inflation. Figure 1 shows that the impact of a technology shock on wage inflation is much larger under

PT than under TP. This inefficiency is reflected in the fact that technology shocks account for 11.3 percent of deadweight loss under PT but only 7.8 percent under TP. The tension between wage and price inflation is even more apparent in the face of markup shocks in the labor market. The output gap adjustment following a shock to $e_{w,t}$ is small under PT, and the result is a much larger impact on π_t^w. Compared to the TP benchmark, labor markup shocks make a larger contribution to deadweight loss under PT (50.2 percent compared with 42.4 percent). Taken together, the results suggest that the benefits of price targeting identified by Vestin (2006) in a single-friction model is not sufficient to guarantee good performance in a model with nominal rigidities and markup shocks in two sectors, the combination of which produces additional tradeoffs that output-price targeting alone is ill-equipped to handle.

The second result is that WT delivers a more favorable outcome than either PT or IT. The welfare cost of WT is equivalent to 0.492 percent of steady state consumption.[14] The standard deviations indicate that WT generates a mildly inefficient volatility of price inflation, but the variances of wage inflation and the output gap are nearly optimal. Compared to PT, markup shocks in product markets make a larger contribution to deadweight loss under WT and shocks to productivity and labor markups to make a smaller contribution. This breakdown is closer to the optimal decomposition observed under TP.

I attribute the welfare gains from WT to the stabilizing effect of expectations. It turns out that the central bank has a greater incentive to offset shocks when presiding over a wage target than it does under a price level mandate. Combined with the fact that wage targeting also entails significant policy inertia, a more conservative stance by the central bank reduces expectations of future wage and price inflation by signaling stronger contractive behavior in later periods. Harnessing expectations in this manner enables WT to impart a more collective restraining effect on π_t and π_t^w (since $E_t\pi_{t+1}$ and $E_t\pi_{t+1}^w$ affect π_t and π_t^w in (2) -

[14]This finding is similar to the one reported by Levin *et al.* (2005). They maximize welfare by searching over the coefficients of a simple feedback rule for the nominal interest rate and conclude that a parsimonious rule responding to wage inflation alone nearly replicates the outcome under the optimal commitment policy.

(3)), thereby improving the key price inflation-wage inflation variance tradeoff that is absent in the models of Vestin (2006) and others. Stated differently, WT is more efficient because it makes better use of expectations to shoulder part of the task of stabilization.

Figure 1 illustrates that WT calls for a sharp and persistent decline in the output gap following a shock to $e_{w,t}$. The ensuing path of wage inflation is practically equivalent to the efficient dynamics under TP. After an $e_{\pi,t}$ shock, WT recommends a small but persistent reduction in the output gap. Although the adjustment is modest, the mere understanding that policy will largely offset wage shocks lowers expected future price inflation (since w_t affects π_t in (2)), helping to stabilize price inflation. In fact, the response of π_t following a shock to $e_{\pi,t}$ under WT is nearly identical to the paths implied by PT and TP.

There are two aspects of the model that elicit greater activism for a wage targeting central bank. The first one concerns the weights in the social loss function. Under the baseline calibration, $\lambda_w = 1.2308$, indicating a larger preference for wage stability than price stability. It follows that a wage targeter will offset shocks to π_t^w more aggressively than a price targeter will counter shocks to π_t.

The second aspect concerns the part of the Phillips curve that governs how difficult the stabilization task assigned to the central bank will be. In the event of price or wage shocks, a discretionary central bank stabilizing p_t or n_t on the one hand and x_t on the other will pursue a "lean against the wind" policy. How forcefully it should adjust x_t depends positively on the benefit from an incremental reduction of prices or wages per unit of output loss, or equivalently, on the magnitude of the output gap elasticity of inflation (i.e., the slope of the Phillips curve).[15] The elasticity of π_t^w (0.079) is higher than the corresponding elasticity of π_t (0.021), implying that WT will feature more activism than PT. Through its impact on expected inflation, the stabilization problem becomes less costly in terms of output gap

[15]The coefficient $\xi_p \left(\frac{\alpha}{1-\alpha}\right)$ measures the output gap elasticity of price inflation while $\xi_w \left(\frac{\chi}{1-\alpha} + \sigma\right)$ represents the output gap elasticity of wage inflation.

variability under wage targeting. This property together with a greater societal preference for wage stability is what elevates the degree of activism under wage targeting. Both features are reflected in the fact that the optimal value of g_n is larger than that of g_p ($\frac{g_n}{g_p} = 9.59$).

The final result is that the combination policy outperforms all other delegation schemes considered. The welfare cost of PWT amounts to only 0.465 percent of steady state consumption and is virtually identical to TP. The optimal weights also indicate a strong preference for both nominal wage and price level stability, a fact that is perhaps surprising given the small weight on p_t observed under PT. For a policymaker who wants to strike a balance between price and wage inflation volatility, however, a policy of targeting only output prices must be cautious so that output gap adjustments themselves do not become a source of wage instability. Under a combination regime, the private sector understands that policy will offset shocks to both prices and wages. This lowers expected future wage inflation, which helps to stabilize current wage inflation via the Phillips curve. The central bank can, therefore, risk being more aggressive in the face of price shocks without greatly destabilizing nominal wages. Such an expectations effect on wage inflation is largely absent under PT.

Before proceeding, I repeat the analysis under different assumptions about the distributional properties of the markup shocks. The results are displayed in Table 3. In the first experiment (Panel A), I allow both markup shocks to be serially correlated by setting $\rho_\pi = \rho_w = 0.7$.[16] In the second experiment (Panel B), I allow the variance of the markup shocks in product markets to be larger by setting $\sigma_\pi = 0.02$.

With persistent markup shocks, deadweight loss is higher for all regimes because serial correlation increases the variances of $e_{\pi,t}$ and $e_{w,t}$. Yet, persistence has little impact on their comparative ranking for the reasons discussed earlier. Alternatively, policies appear sensitive to changes in the relative volatility of markup shocks. PT dominates IT and

[16] There is ample evidence of inflation persistence in the data (e.g., Fuhrer (1997)), and incorporating serially correlated markup shocks is one way to generate such persistence.

Table 3: SIMULATION RESULTS FOR DIFFERENT MARKUP SHOCK ASSUMPTIONS

A. *Serially Correlated Markup Shocks* ($\rho_\pi = \rho_w = 0.7$)

Regime	$\mathbb{L}$	Optimal Weights	$\sigma(\pi)$	$\sigma(\pi^w)$	$\sigma(x)$	$\phi(u_a)$	$\phi(u_\pi)$	$\phi(u_w)$
TP	2.448	–	1.017	0.524	5.614	1.5	62.7	35.8
PD	3.388	–	1.175	0.771	5.420	1.1	54.5	44.3
IT	2.887	$f_\pi = 2.021,\ f_w = 3.175$	1.067	0.419	7.391	1.3	58.1	40.6
PT	3.647	$g_p = 0.187$	0.925	1.158	4.040	2.1	46.0	52.0
WT	2.681	$g_n = 0.607$	1.164	0.423	5.446	1.9	65.2	32.9
PWT	2.476	$g_p = 0.516,\ g_n = 0.612$	1.028	0.518	5.639	1.5	62.9	35.5

B. *Large Markup Shocks in Product Markets* ($\sigma_\pi = 0.02$)

Regime	$\mathbb{L}$	Optimal Weights	$\sigma(\pi)$	$\sigma(\pi^w)$	$\sigma(x)$	$\phi(u_a)$	$\phi(u_\pi)$	$\phi(u_w)$
TP	3.965	–	1.650	0.353	2.754	0.9	94.1	5.0
PD	4.238	–	1.690	0.383	3.247	0.9	93.2	5.9
IT	4.175	$f_\pi = -0.418,\ f_w = 0.752$	1.701	0.297	3.127	1.0	92.5	6.5
PT	4.112	$g_p = 0.173$	1.650	0.510	1.963	1.8	90.8	7.3
WT	4.115	$g_n = 1.545$	1.716	0.273	2.083	1.3	93.9	4.9
PWT	3.973	$g_p = 0.818,\ g_n = 1.023$	1.653	0.353	2.735	1.0	94.0	5.0

Notes: **TP** - timeless perspective, **PD** - pure discretion, **IT** - inflation targeting, **PT** - price targeting, **WT** - wage targeting, **PWT** - price and wage targeting; $\mathbb{L}$ - expected deadweight loss in terms of steady state consumption, $\sigma(z)$ - unconditional standard deviation of z, $\phi(\varepsilon)$ - fraction of social loss attributed to ε. The welfare costs, standard deviations, and loss decompositions are multiplied by 100 to express these statistics in percentage points.

WT when product market shocks are large. Surprisingly, the gains over WT are marginal (moving from WT to PT is equivalent to an increase in steady state consumption of only 0.003 percentage points), indicating that product market shocks would have to be very large relative to labor market shocks for PT to measurably outperform WT.

4.3 Sensitivity Analysis

To ensure that the main findings are not overly sensitive to the chosen calibration, I repeat the simulations for alternative values of the structural parameters. Figure 2 plots the deviation of social loss from the timeless perspective policy for values of $\{\varepsilon_p, \varepsilon_w, \sigma, \chi, \alpha\}$ that encompass the baseline configuration. The spread between policies is expressed as a fraction of deadweight loss under the timeless perspective. For regime i, I plot the function

$$F^i(\varepsilon_p, \varepsilon_w, \sigma, \chi, \alpha) = \frac{\mathbb{L}^i - \mathbb{L}^{\text{TP}}}{\mathbb{L}^{\text{TP}}} \times 100,$$

where $i \in \Psi = \{\text{PD}, \text{IT}, \text{PT}, \text{WT}, \text{PWT}\}$. For any $i, j \in \Psi$, regime i dominates regime j for a given set of parameter values if and only if $F^i < F^j$.

The first panel of Figure 2 depicts the welfare deviations for values of ε_p ranging from zero (flexible prices) to unity (fixed prices). Despite the ability to impart inertia, PT performs worse than IT and PD for a wide range of plausible values but becomes relatively more efficient as price stickiness increases. The main results concerning wage targeting are also robust to changes in the frequency of price adjustment. For $\varepsilon_p < 0.89$, WT strictly dominates PT. As price rigidity rises, the importance of stabilizing π_t in the social loss function increases ($\tilde{\lambda}'_\pi(\varepsilon_p) > 0$), leading to a reversal in their relative performance. At this end of the parameter space, however, the difference between the two is minimal. The reason is due to the opposing effect increases in ε_p have on the slope of the Phillips curve given by $\xi_p \left(\frac{\alpha}{1-\alpha}\right)$. Because $\xi'_p(\varepsilon_p) < 0$, that is the Phillips curve gets flatter with increases in ε_p, stabilizing output prices becomes more costly in terms of output gap variability. This partially offsets the benefit of targeting output prices when π_t becomes the primary goal of monetary policy.

The second panel illustrates how much the welfare departures vary in response to changes in ε_w from zero (flexible wages) to unity (fixed wages). For numerous levels of wage stickiness, WT dominates IT which, in turn, dominates PT. Only with very little wage stickiness ($\varepsilon_w < 0.35$), signaling a diminished weight on π_t^w in the social loss function ($\tilde{\lambda}'_w(\varepsilon_w) > 0$), does PT deliver a better outcome than WT.

To highlight the regularity with which WT outperforms PT, I compare the welfare cost under both policies for all combinations of ε_p and ε_w. Figure 3 plots level sets of the function

$$G(\varepsilon_w, \varepsilon_p) = \frac{\mathbb{L}^{\mathrm{PT}} - \mathbb{L}^{\mathrm{WT}}}{\mathbb{L}^{\mathrm{WT}}} \times 100,$$

which records the deviations of WT from PT, expressed as a percentage of the loss accrued under WT. Positive entries on the map represent $(\varepsilon_w, \varepsilon_p)$ combinations where WT dominates PT. A number of conclusions can be drawn. First, for every point below the 45 degree line, WT unambiguously dominates PT. Thus, wage targeting always leads to higher welfare when the duration of wage contracts are no shorter than price contracts. Second, in regions where wage adjustments are somewhat more frequent than price adjustments (points just north of the 45 degree line), WT continues to perform as well or better than PT. A survey of recent empirical studies reveals that formal estimates of ε_w and ε_p tend to bisect the 45 degree line. Interestingly, using any of those estimates in the present model delivers a welfare cost under PT that exceeds WT by as little as five percent but as much as twenty-five percent. Third, the gains under PT are significant only in the event that wages are almost fully flexible.

Returning to Figure 2, the third panel graphs welfare spreads for values of σ ranging from one to five. A number of key results still hold. In particular, WT outperforms PT and IT, generating a welfare cost that exceeds TP by about five percent for all values of σ considered. The reason why wage targeting is robust to variations in σ is because of the way in which this parameter enters the model. While σ is positively related to the output gap elasticity of wage inflation, it has no impact on the corresponding elasticity of price inflation. Increasing σ, therefore, makes stabilizing the nominal wage less costly in terms of output gap variability. Galí, Gertler, and López-Salido (2007) argue that formal estimates of the inverse intertemporal elasticity of substitution typically vary between three and ten. The results indicate that expanding the set of values for σ along these dimensions would amplify the already sizable advantages of WT.

The fourth panel plots welfare departures for values of χ along $[0.5, 5.5]$. Increases in the labor supply elasticity parameter weaken the performance of PT but strengthen that of WT. This finding is an artifact of the positive relationship between χ and $\tilde{\lambda}_w$ since increases in χ actually diminish the size of the output gap elasticity of wage inflation, making the stabilization problem under WT more difficult. Evidently, the former effect outweighs the latter so much so that for large values of χ the difference between WT and TP is trivial. Micro-level estimates of χ often range from three to twenty, so the baseline value perhaps understates the salutary effects of wage targeting.[17]

The fifth panel examines the impact of adjusting α along the interval $[0.15, 0.50]$. Although the ranking of policies is generally robust to variations in α, the performance of WT relative to PT diminishes rapidly at the upper end of the parameter space. The relative improvement in PT originates from the impact of α on the policy weights in the social loss function. Because $\tilde{\lambda}'_\pi(\alpha) > 0$, $\tilde{\lambda}'_w(\alpha) < 0$, and $\tilde{\lambda}'_x(\alpha) > 0$, increases in the capital elasticity of output elevate the importance of price inflation and output gap stability while lowering the importance of wage stability. For large values of α, PT will result in lower deadweight loss than WT, but this occurs only when $\alpha > 0.5$, implying a steady-state capital share of income in excess of fifty percent.

5 Alternative Delegation Schemes

Recognizing the benefits of policy inertia has led other researchers to devise alternative institutional arrangements capable of delivering such persistence. In this section I compare the stabilization properties of price level targeting to a number of delegation schemes that have received attention in the literature.

Walsh (2003) argues that a "speed limit" policy designed to balance the stability of

[17] See Galí *et al.* (2007) for a discussion.

inflation and the one-period change in the output gap imparts a substantial degree of inertia. A *speed limit* policy (SL) will be defined by the loss function $\pi_t^2 + \lambda_w \pi_t^{w^2} + \lambda_{\Delta x}(x_t - x_{t-1})^2$, where $\lambda_{\Delta x}$ is chosen optimally to minimize social loss. Woodford (2003b) generates policy inertia by mandating a preference for *interest rate smoothing* (IS). Such a regime can be constructed using the loss function $\pi_t^2 + \lambda_w \pi_t^{w^2} + \lambda_{\Delta i}(i_t - i_{t-1})^2$ with $\lambda_{\Delta i}$ chosen optimally. Jensen (2002) and Guender (2002) explore the possibility of targeting the growth rate of nominal income. I consider two versions of *nominal income growth* targeting. In the first (NIG1), income growth accompanies the price and wage inflation objectives within the loss function $\pi_t^2 + \lambda_w \pi_t^{w^2} + \lambda_{NI}(y_t - y_{t-1} + \pi_t)^2$. In the second (NIG2), it appears alongside the output gap objective as $\lambda_x x_t^2 + \lambda_{NI}(y_t - y_{t-1} + \pi_t)^2$, where λ_{NI} measures the optimized weight attached to nominal income growth.[18] Finally, I consider an *encompassing policy* (EP) in which y_t^2 and i_t^2 are added to (8) with weights λ_y and λ_i, respectively. A broadly defined regime that contains all of the model's endogenous variables in the loss function allows one to determine which stabilization objectives are most important for maximizing welfare.

Table 4 records the welfare cost of each policy, the optimized weights, and the standard deviations of $\{\pi_t, \pi_t^w, x_t\}$. After the encompassing policy, PWT generates the smallest welfare cost among all regimes considered. The outcomes under SL, IS, and NIG1, however, are quite competitive, each garnering a loss of around 0.48 percent of steady state consumption. The cost of moving from PWT to SL, for example, is only 0.012 percent. The weights assigned under EP clarify two points about optimal delegation. First, the price level and the nominal wage are the most important stabilization goals for minimizing social loss. Second, there remains a small role for stabilizing nominal wage inflation, an even smaller role for stabilizing output and the interest rate, and no role for stabilizing goods-price inflation.

Despite the absence of an explicit goal for price stability, WT performs nearly as well as

[18] Real output and the output gap are related according to $x_t = y_t - y_t^n$, where y_t denotes actual real output and y_t^n represents the natural rate of real output.

Table 4: Simulation Results for Alternative Delegation Schemes

Regime	$\mathbb{L}$	Optimal Weights	$\sigma(\pi)$	$\sigma(\pi^w)$	$\sigma(x)$	Rank
TP	0.468	–	0.435	0.303	1.831	–
PD	0.534	–	0.452	0.328	2.095	8
IT	0.534	$f_\pi = 0.101,\ f_w = -0.022$	0.450	0.331	2.087	7
PT	0.608	$g_p = 0.122$	0.424	0.472	0.559	10
WT	0.492	$g_n = 1.170$	0.470	0.289	1.768	6
PWT	0.470	$g_p = 1.022,\ g_n = 1.226$	0.438	0.303	1.823	2
SL	0.482	$\lambda_{\Delta x} = 0.014$	0.441	0.307	1.886	3
IS	0.482	$\lambda_{\Delta i} = 0.008$	0.441	0.307	1.890	4
NIG1	0.484	$\lambda_{NI} = 0.014$	0.438	0.308	1.923	5
NIG2	0.602	$\lambda_{NI} = 0.555$	0.450	0.445	0.753	9
EP	0.470	$f_\pi = -1,\ g_p = 1.565,\ \lambda_y = 1.150\text{e}-5$ $f_w = -0.814,\ g_n = 1.772,\ \lambda_i = 0.004$	0.437	0.303	1.825	1

Notes: **TP** - timeless perspective, **PD** - pure discretion, **IT** - inflation targeting, **PT** - price targeting, **WT** - wage targeting, **PWT** - price and wage targeting, **SL** - speed limit policy, **IS** - interest rate smoothing, **NIG1** - nominal income growth targeting (no output gap), **NIG2** - nominal income growth targeting (no inflation), **EP** - encompassing policy; $\mathbb{L}$ - expected deadweight loss in terms of steady state consumption, $\sigma(z)$ - unconditional standard deviation of z. The welfare costs and standard deviations are multiplied by 100 to express these statistics in percentage points. The right-most column provided an ordinal ranking for each targeting regime.

SL, IS, and NIG1. The cost of switching from SL to WT amounts to a decline in steady state consumption of only 0.01 percentage points. Comparing standard deviations, the shortcoming of WT relative to superior policies is a slightly larger volatility of π_t (0.470 under WT and 0.441 under SL). The quantitative impact on welfare, however, is minimal. By contrast, PT engenders the largest welfare cost. Moving from SL to PT is equivalent to a consumption loss of 0.126 percentage points.[19]

[19] The finding that speed limit policies are more robust than output-price targeting to the presence of wage stickiness parallels the one reported in Yetman (2006) who shows that such policies are also less sensitive to deviations from rational expectations or perfect credibility.

6 Concluding Remarks

A number of recent studies have concluded that delegating a price level target along the lines of Vestin (2006) to a discretionary central bank delivers a more efficient stabilization outcome than inflation targeting. The evidence presented here suggests that such gains do not necessarily extend to an equilibrium model that emphasizes sticky nominal wages in addition to sticky product prices. For numerous parameter configurations, I find that goods-price targeting generates greater deadweight loss than inflation targeting. This occurs despite the ability of the former to impart the kind of inertial response to shocks that is characteristic of an optimal commitment policy. Conversely, assigning a nominal wage target yields outcomes that are superior to goods-price targeting and inflation targeting for empirically relevant parameter values. The gains from targeting the price of labor can be traced to the importance of nominal wage inflation in the utility-based social loss function as well as the sensitivity of wages to output gap fluctuations via the Phillips curve.

I conclude by briefly discussing the feasibility of targeting the nominal wage in practice. Conventional wisdom holds that U.S. monetary policy is consistent with the goal of keeping so-called "core" price inflation within an acceptable range. The measure of core inflation often referenced in published Federal Reserve transcripts is the annual percentage change in the deflator for Personal Consumption Expenditures less volatile food and energy prices. Something closer to nominal wage targeting could in principle be implemented by shifting the focus of policy away from core inflation to alternative indicators that reflect growth in wages or compensation. Likely candidates include the wage and salary component of the Employment Cost Index (a product of the National Compensation Survey), Average Weekly Earnings (a product of the Establishment Survey), or Nonfarm Hourly Compensation. Policy could be eased or tightened in a straightforward manner with the goal of preventing these quantities from escaping a targeted range that is deemed consistent with wage stability.

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Appendix A. The Timeless Perspective Policy

I compute the equilibrium process $\{\pi_t, \pi_t^w, x_t, w_t\}_{t=0}^{\infty}$ that minimizes (7) under commitment from a timeless perspective. Following Woodford (2003a), the Lagrangian is

$$\begin{aligned}\mathcal{L} = \min \ E_0(1-\delta)\sum_{t=0}^{\infty}\delta^t\{&\tilde{\lambda}_\pi \pi_t^2 + \tilde{\lambda}_w \pi_t^{w^2} + \tilde{\lambda}_x x_t^2 + 2\upsilon_t[w_t - w_{t-1} + \pi_t - \pi_t^w] \\ &+ 2\varphi_{\pi,t}[\pi_t - \beta\pi_{t+1} - \xi_p\left(\frac{\alpha}{1-\alpha}\right)x_t - \xi_p(w_t - w_t^n) - e_{\pi,t}] \\ &+ 2\varphi_{w,t}[\pi_t^w - \beta\pi_{t+1}^w - \xi_w\left(\frac{\chi}{1-\alpha}+\sigma\right)x_t + \xi_w(w_t - w_t^n) - e_{w,t}]\}\end{aligned}$$

where $\varphi_{\pi,t}$, $\varphi_{w,t}$, and υ_t are the multipliers associated with (2), (3), and (4), respectively.[20]

Differentiating the Lagrangian delivers a system of first-order conditions

$$\begin{aligned}\tilde{\lambda}_\pi \pi_t + \varphi_{\pi,t} - \delta^{-1}\beta\varphi_{\pi,t-1} + \upsilon_t &= 0, & \text{(A.1)}\\ \tilde{\lambda}_w \pi_t^w + \varphi_{w,t} - \delta^{-1}\beta\varphi_{w,t-1} - \upsilon_t &= 0, & \text{(A.2)}\\ \tilde{\lambda}_x x_t - \xi_p\left(\frac{\alpha}{1-\alpha}\right)\varphi_{\pi,t} - \xi_w\left(\frac{\chi}{1-\alpha}+\sigma\right)\varphi_{w,t} &= 0, & \text{(A.3)}\\ \upsilon_t - \xi_p\varphi_{\pi,t} + \xi_w\varphi_{w,t} - \delta E_t\upsilon_{t+1} &= 0. & \text{(A.4)}\end{aligned}$$

Instead of imposing initial conditions $\varphi_{\pi,(-1)} = \varphi_{w,(-1)} = 0$, the timeless perspective policy requires that (A.1) – (A.4) hold for any $-\infty < t < \infty$. The first order conditions and (2) – (4) characterize the optimal state-contingent solution $\{\pi_t, \pi_t^w, x_t, w_t, \varphi_{\pi,t}, \varphi_{w,t}, \upsilon_t\}_{t=-\infty}^{\infty}$.

To find a targeting rule that implements the desired equilibrium, eliminate the Lagrange multipliers from (A.1) – (A.4). All of the information collapses to the following time-invariant criterion that involves only leads and lags of the variables in the loss function:

$$\kappa(\tilde{\lambda}_\pi\xi_p\pi_t - \tilde{\lambda}_w\xi_w\pi_t^w) + (\xi_p+\xi_w)q_t + [q_t - \delta^{-1}\beta q_{t-1} - \delta E_t q_{t+1} + \beta E_{t-1}q_t] = 0, \qquad \text{(A.5)}$$

[20] I treat the output gap as the policy instrument, and then subsequently use (1) to find the interest rate plan that is consistent with the optimal path of the output gap.

where the variable q_t satisfies

$$q_t = \tilde{\lambda}_\pi \xi_p \left(\frac{\alpha}{1-\alpha} \right) \pi_t + \tilde{\lambda}_w \xi_w \left(\frac{\chi}{1-\alpha} + \sigma \right) \pi_t^w + \tilde{\lambda}_x (x_t - \delta^{-1} \beta x_{t-1}), \tag{A.6}$$

and $\kappa = \xi_w \left(\frac{\chi}{1-\alpha} + \sigma \right) - \xi_p \left(\frac{\alpha}{1-\alpha} \right)$. The joint equilibrium process $\{\pi_t, \pi_t^w, x_t, w_t, q_t\}_{t=-\infty}^{\infty}$ implied by (2) – (4) and (A.5) – (A.6) generates the desired state-contingent evolution characterized by the timeless perspective policy.

Denote $Z_{1,t} = [a_t \; e_{\pi,t} \; e_{w,t} \; E_{t-1} q_t \; q_{t-1} \; w_{t-1} \; x_{t-1}]'$ the vector of predetermined state variables, $Z_{2,t} = [\pi_t \; \pi_t^w \; w_t \; x_t \; q_t]'$ the vector of forward-looking variables, and $u_t = [u_{a,t} \; u_{\pi,t} \; u_{w,t}]'$ the vector of innovations to the shocks contained in $Z_{1,t}$ with covariance matrix Σ_u. In compact notation, the system of expectational difference equations can be written as

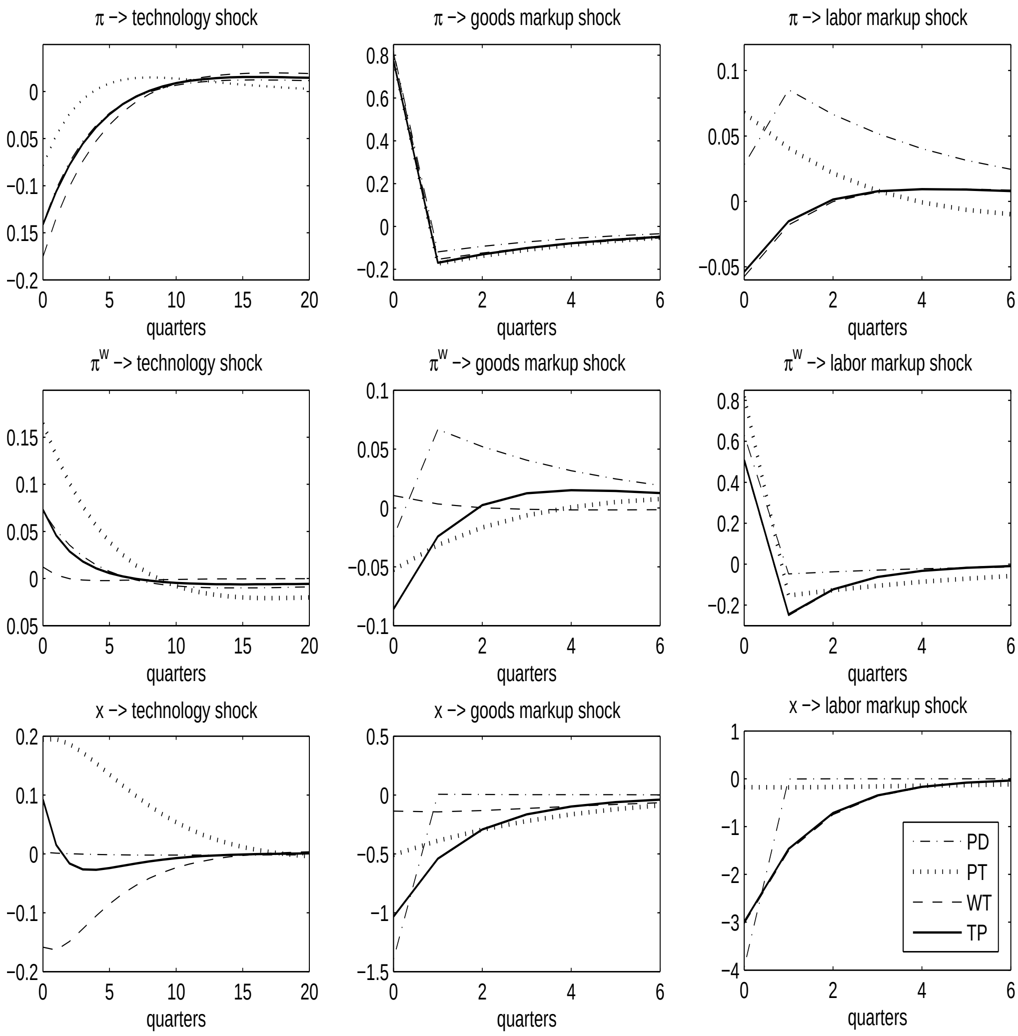
$$\Gamma \begin{bmatrix} Z_{1,t+1} \\ E_t Z_{2,t+1} \end{bmatrix} = \Lambda \begin{bmatrix} Z_{1,t} \\ Z_{2,t} \end{bmatrix} + \begin{bmatrix} \Upsilon u_{t+1} \\ 0 \end{bmatrix}, \tag{A.7}$$

where Γ and Λ are matrices containing the structural parameters and policy weights, and Υ is a 7×3 selector matrix. I seek a unique bounded solution to (A.7) of the form

$$Z_{2,t} = \Phi Z_{1,t}, \tag{A.8}$$

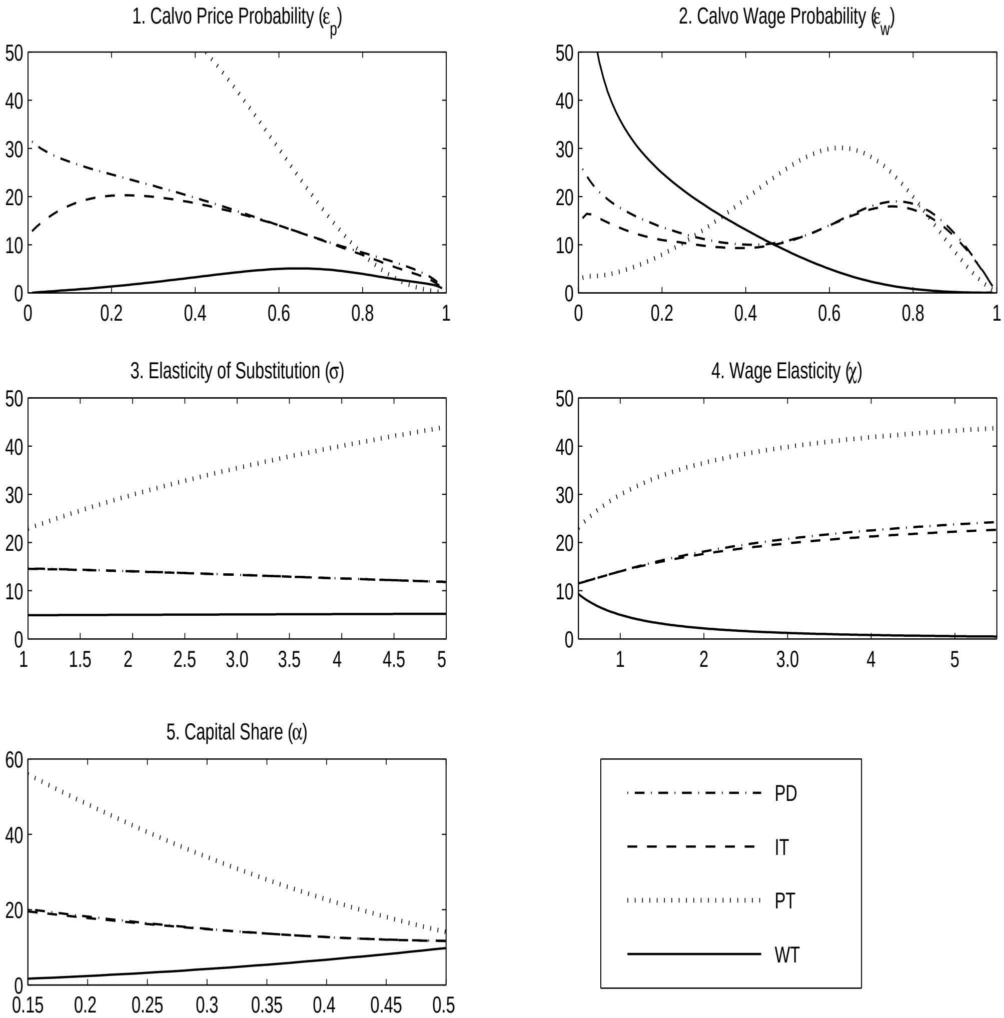
where Φ is a matrix characterizing the linear mapping of the forward-looking variables into the space spanned by the predetermined variables. Because Γ is singular by construction, I follow the technique expounded in Klein (2000) which uses the generalized Schur form to separate (A.7) into stable and unstable blocks of equations. A unique bounded solution exists if the number of stable eigenvalues equals the number of predetermined variables. I verify numerically that the determinacy condition is satisfied for the various parameter configurations used in this paper.

Figure 1: Impulse Response Functions



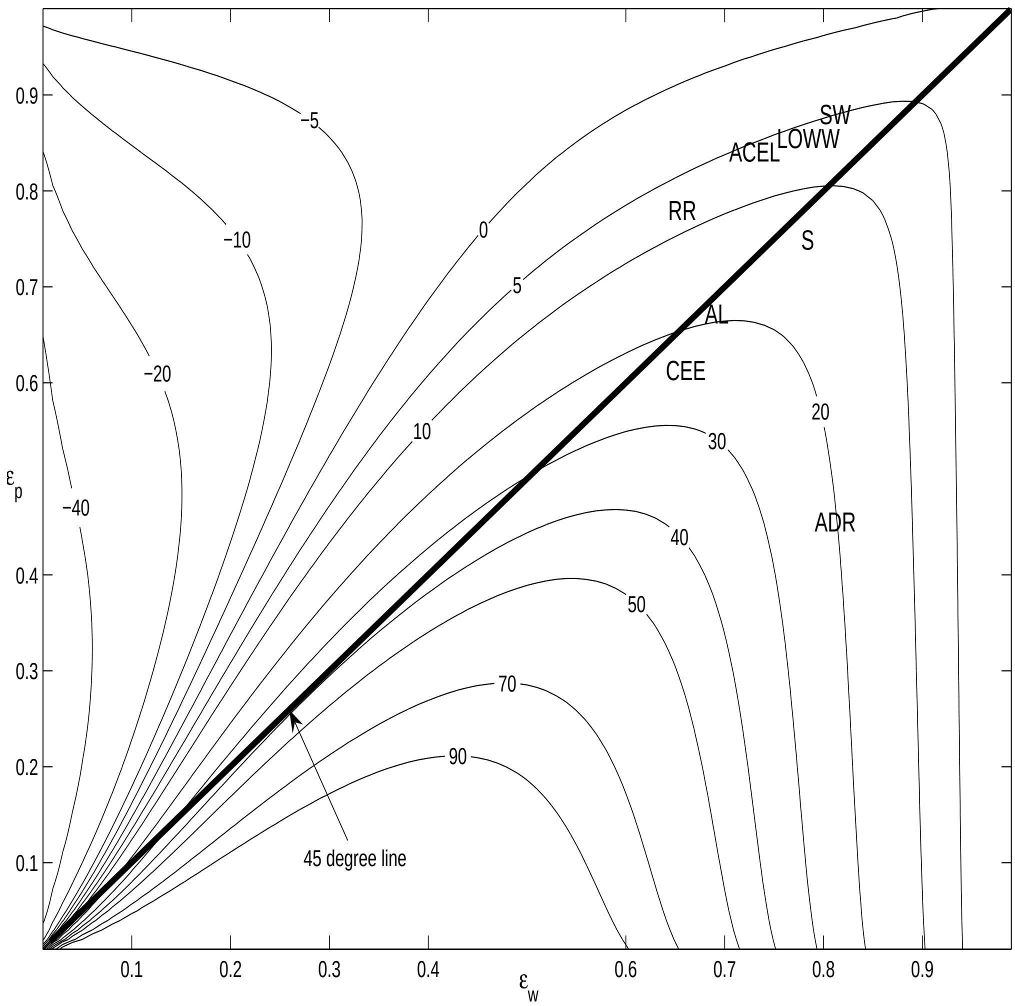
Notes: The three columns graph consecutively the impulse response function to a unit increase in the technology shock (a), the goods markup shock (e_π), and the labor markup shock (e_w). Price inflation (π), wage inflation (π^w), and the output gap (x) are measured in percent deviations from a steady state. Each panel contains the response profile implied by pure discretion (dash-dotted line), price targeting (dotted line), wage targeting (dashed line), and the timeless perspective (solid line).

Figure 2: Welfare Deviations from the Timeless Perspective



Notes: The figure graphs deviations of deadweight loss from the timeless perspective policy for the following regimes: pure discretion (dash-dotted line), inflation targeting (dashed line), price targeting (dotted line), and wage targeting (solid line). The deviations are multiplied by 100 to express them in percentage points. Each panel corresponds to variations in one parameter of the set $\{\varepsilon_p, \varepsilon_w, \sigma, \chi, \alpha\}$. As that parameter is varied, all others are held fixed at their baseline values. Optimal policy weights are recomputed for each regime and for all values of the parameter under examination. Welfare deviations for the joint price and wage targeting regime are not shown because they are very close to zero for all parameter variations considered.

Figure 3: Welfare Deviations for the Calvo Parameters



Notes: The figure graphs welfare deviations between price targeting and wage targeting for all possible values of ε_p and ε_w. Each axis is divided into 99 equally spaced grid points ranging from 0.01 to 0.99. For every (ε_w,ε_p) pair, the optimal weights are computed under both policies. The letters on the contour map locate (ε_w,ε_p) combinations that have been formally estimated by the following authors: **CEE** - Christiano *et al.* (2005), **AL** - Amato and Laubach (2003), **ACEL** - Altig, Christiano, Eichenbaum, and Linde (2005), **S** - Sbordone (2006), **RR** - Rabanal and Rubio-Ramírez (2005), **LOWW** - Levin *et al.* (2005), **SW** - Smets and Wouters (2005), and **ADR** - Ambler, Dib, and Rebei (2004).