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# SECTORAL DIFFERENCES IN PRICE-ADJUSTMENT FREQUENCIES AND OPTIMAL MONETARY POLICY: A NOTE

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This paper reconsiders the monetary policy implications of a model from which a distinction between CPI inflation and PPI inflation arises. More specifically, this paper addresses the policy conclusion by K. Huang and Z. Liu [2005, Inflation targeting: What inflation rate to target, *Journal of Monetary Economics* 52, 1435–1462], which states that central banks should use an optimal inflation index that gives substantial weight to stabilizing both CPI and PPI. This paper argues that these authors' findings rely on the assumption that producer prices are as sticky as consumer prices and shows that once empirically relevant frequencies of price adjustment are used to calibrate the model, CPI inflation receives substantial weight in the optimal inflation index. Moreover, this rule is remarkably robust to uncertainty regarding the model parameters.

**Keywords:** Inflation Targeting, Optimal Monetary Policy

## 1. INTRODUCTION

Over the past decade, many central banks have adopted inflation targeting as a framework for monetary policy making. Most, if not all, inflation-targeting central banks use the measure of consumer price inflation or one of its variants as a target. Consumer price inflation seems the most appropriate measure of inflation if one views the ultimate goal of monetary policy as household welfare, as this measure is the most relevant to calculating the cost of living.

This practice raises the question of whether central banks should ignore developments in other measures of inflation, such as the producer price index (PPI). The answer to this question depends mainly on whether higher prices for intermediate goods or raw materials imply a significant increase in inflation risk at the consumer

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level. If so, then an inflation-targeting central bank may also wish to target PPI inflation to minimize the disruptive effect of producer prices on consumer prices. However, this assumption is contested by Ben Bernanke (2004), who argues that the disruptive effect of producer prices is limited, because "raw materials costs are a small portion of total cost." Jean-Claude Trichet (2004) makes a similar claim. If we were to construct an "optimal inflation index" that was an appropriately weighted average of CPI and PPI inflation rates, Bernanke's argument would dictate that CPI receive substantial weight, with comparatively little weight attributed to PPI inflation.

However, recent work by K. Huang and Z. Liu (2005) calls this position into question. The authors provide an answer to the original question using a dynamic stochastic general equilibrium (DSGE) model, in which a distinction between the two indices arises endogenously. In this model, a composite of intermediate goods is required to produce the consumption goods. The price index of the intermediate goods is roughly equivalent to the PPI. The authors argue that a simple inflation-targeting rule under which the short-term interest rate responds to an "optimal inflation index" results in a welfare level close to the optimum only in cases where the "optimal inflation index" places substantial weight on both CPI inflation and PPI inflation. More specifically, they find that the target weight assigned to PPI inflation in such an index is far from negligible, at around 50%. Obviously, this finding stands in sharp contrast to the claims made by Bernanke and Trichet.

However, the conclusions reached by Huang and Liu rely substantially on the assumption that producer prices are as sticky as consumer prices. This assumption is inconsistent with recent microevidence, which suggests that producer price adjustment occurs at a higher frequency than consumer price adjustment. Table 1 presents estimates of the mean frequency of change in both consumer prices and producer prices in several EU countries, the Euro area, the United Kingdom, and the United States. The United States has no single PPI index. The PPI is represented in a tripartite format according to stage of process (finished goods, intermediate goods, and crude materials). The table presents statistics for both intermediate goods and finished goods. Although the difference in price stickiness between CPI and PPI is more pronounced in some countries than in others, consumer prices are stickier than producer prices in all of the regions listed. I will show that even a small difference in the frequency of price adjustment can significantly affect the policy conclusions that arise from the model.

This paper aims to determine which inflation index should be targeted by central banks by studying the options in the version of the Huang and Liu model that accounts for the differences between CPI and PPI in terms of nominal rigidity. The findings reported suggest that central banks should use an optimal inflation index that gives a lot of weight to CPI inflation, which is in line with the practice of many central banks. Moreover, a variety of experiments undertaken for this paper indicate that this practice leads to a more robust policy than one that places substantial weight on stabilizing both PPI inflation and CPI inflation.

**TABLE 1.** Monthly mean frequency of consumer prices and producer prices

| Country | Consumer prices (%) | Producer prices (%) |
|---|---|---|
| Euro area | 15 | 21 |
| Belgium | 14 | 24 |
| France | 19 | 25 |
| Germany | 11 | 22 |
| Italy | 11 | 15 |
| Portugal | 21 | 23 |
| Spain | 15 | 21 |
| U.K. | 15 | 26 |
| U.S. | 21.1 | 26.7 (intermediate goods)<br>24.7 (finished goods) |

*Sources:* Bunn and Ellis (2012a, 2012b), Dhyne et al. (2005), Nakamura and Steinsson (2008), and Vermeulen et al. (2007).

The remainder of the paper is organized as follows. Section 2 outlines the model and presents the welfare function of the central bank based on the utility function of the representative household. Section 3 describes monetary policy. Section 4 details calibration. Section 5 presents my results. Section 6 summarizes the conclusions.

## 2. THE MODEL

The model used in this paper is the same as that in Huang and Liu (2005). In this otherwise standard DSGE model with monopolistic competition and no capital accumulation, the production of consumption goods requires a composite of intermediate goods and labor as inputs, whereas the production of intermediate goods requires labor as the only input. The exposition here aims to outline the basic elements of the model.

There are three types of agents in the economy: firms, consumers, and the government. I will first describe the behavior of households and the government, which are standard. Then I will describe the behavior of firms. Huang and Liu (2005) provide a detailed discussion of the assumptions underlying this model and the derivation of its structural equations. The presentation here is kept brief. I focus solely on the log-linearized macroeconomic framework.

### 2.1. Structure of the Economy

The model assumes a continuum of identical and infinitely lived households. Households provide labor ($N_t$) in a common labor market and derive utility from consumption ($C_t$) and leisure $[-V(N_t)]$. The utility is separable in consumption and leisure and is given by $U_t = U(C_t) - V(N_t)$. Consumption is an aggregate

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of differentiated consumption goods produced by firms. When calibrating their model, Huang and Liu (2005) made the simplifying assumption that the utility function is linear in hours and log-linear in consumption. Specifically, they assume that the relative risk aversion is unity. My presentation is based on the simplified version of the model. The government conducts monetary policy and provides production subsidies to eliminate any distortions in the steady state. The production subsidies are financed by lump-sum taxes.

The production side of the economy can be thought of as having two sectors: sector $m$, in which intermediate goods are produced, and sector $f$, in which final consumption goods are produced. It is assumed that the sectors are hit by sector-specific productivity shocks. A fraction of households are employed in sector $m$ ($N_{mt}$) and the rest ($N_{ft}$) are employed in sector $f$. Within each sector, there is a continuum of firms. In each sector, firms have monopoly power over a specific product, for which the demand has a constant price elasticity $\theta_k$ for $k \in \{f, m\}$. In sector $f$, firms operate a technology $Y_{ft}(j) = (\bar{Y}_{mt})^{\phi}[A_{ft}N_{ft}(j)]^{1-\phi}$ that transforms labor and a composite of intermediate goods ($\bar{Y}_{mt}$)—namely a Dixit–Stiglitz aggregate of differentiated intermediate goods—into output ($Y_{ft}$), subject to productivity shocks in that sector($A_{ft}$). $\phi$ denotes the cost share of intermediate goods in the production of final goods. In sector $m$, firms produce the intermediate goods that are required to produce final consumption goods. Firms in this sector operate a technology $Y_{mt}(i) = A_{mt}N_{mt}(i)$ that transforms labor into output $[Y_{mt}(i)]$ subject to sector-specific productivity shocks ($A_{mt}$). Within each sector, prices are assumed to be sticky and are according to the Calvo process.

## 2.2. Log-Linearized Economy

The Euler condition for the representative household's consumption is given by

$$\tilde{c}_t = E_t\tilde{c}_{t+1} - (r_t - E_t\pi_{ft+1} - rr_t^*), \tag{1}$$

where $\tilde{c}_t = c_t - c_t^*$ is the gap between actual output $c_t$ and the flexible-price equilibrium output level $c_t^* = \phi a_{mt} + (1-\phi)a_{ft}$. $a_{kt}$ is the level of productivity in sector $k$. $\pi_{ft}$ is the inflation rate in the finished goods sector, $r_t$ is the nominal interest rate, and $rr_t^*$ denotes the real interest rate when prices are flexible. In each sector, the dynamics of inflation in terms of real marginal cost are described by an equation analogous to the one associated with a standard one-sector model. In each sector, inflation depends both on expected inflation in that sector and on real marginal cost,

$$\pi_{kt} = \beta E_t\pi_{kt+1} + \kappa_k\tilde{v}_{kt}, \tag{2}$$

with

$$\kappa_k = \frac{(1-\alpha_k)(1-\alpha_k\beta)}{\alpha_k} \text{ for } k \in \{f, m\},$$

where $\beta$ is the discount rate, $\phi$ is the cost share of intermediate input in final goods production, and $(1-\alpha_k)$ is the Calvo reset probability in sector $k$. $\tilde{v}_{ft}$ and $\tilde{v}_{mt}$ are the real marginal costs in the finished goods sector and in the intermediate goods sector, respectively, which are given by

$$\tilde{v}_{ft} = (1-\phi)\,\sigma\tilde{c}_t + \phi\tilde{q}_t, \tag{3}$$

$$\tilde{v}_{mt} = \sigma\tilde{c}_t - \tilde{q}_t, \tag{4}$$

where $\tilde{q}_t = q_t - q_t^*$ is the relative price gap. $q_t = p_{mt} - p_{ft}$ denotes the relative price of intermediate goods in units of consumption goods, and $q_t^*$ denotes the value of this relative price in the flexible-price-level equilibrium. Note that it is no longer possible to express the real marginal cost entirely as a function of the output gap, as in a one-sector economy. In this economy, the real marginal cost in each sector depends on the output gap as well as the relative price gap. Another important difference between this model and the standard one is that here both output and relative price fluctuate in flexible-price-level equilibrium according to productivity shocks. In the standard model, only output fluctuates in the flexible-price-level equilibrium. The presence of sector-specific productivity shocks is the reason for this difference. The relative price in the flexible equilibrium is given by

$$q_t^* = p_{mt}^* - p_{ft}^* = (1-\phi)\left(a_{ft} - a_{mt}\right). \tag{5}$$

Therefore, the relative price gap is given by

$$\tilde{q}_t = \tilde{q}_{t-1} + \pi_{mt} - \pi_{ft} - (1-\phi)\left(\Delta a_{ft} - \Delta a_{mt}\right), \tag{6}$$

where $\Delta a_{kt} = a_{kt} - a_{kt-1}$ is the productivity growth rate in sector $k \in \{f, m\}$. Finally, shocks to the productivity growth rate each follow an $AR(1)$ process,

$$\Delta a_{kt} = \rho_k \Delta a_{kt-1} + \varepsilon_{kt}\ , k \in \{f, m\}, \tag{7}$$

where $\varepsilon_{kt}$ is an idd$(0, \sigma_k^2)$.[1]

## 2.3. Welfare Function: Woodford's Approximation

Huang and Liu (2005) follow the procedure described in Woodford (2003) to derive a utility-based objective function for a central bank. This provides a benchmark for evaluating the performance of alternative inflation targeting monetary policy rules. In a model that leads to the equilibrium conditions (1)–(6), Huang and Liu show that the second-order approximation to the welfare of the representative household is given by

$$W_t = E\sum_{t=0}^{\infty}\beta^t U_t = -\frac{U_c(C)C}{2}E\sum_{t=0}^{\infty}\beta^t L_t + \text{t.i.p.} + O(\|a\|^3), \tag{8}$$

where $C$ is steady state consumption, $U_c(C)$ is the marginal utility of consumption, t.i.p. collects all the terms that are independent of policy, and $O(\|a\|^3)$ summarizes

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all terms of third or higher order. The quadratic loss function $L_t$, based on the assumption that utility is linear in consumption and in leisure, is given by

$$L_t = \tilde{c}_t^2 + \phi (1 - \phi) (\tilde{c}_t - \tilde{q}_t)^2 + \frac{\theta_f}{\kappa_f} \pi_{ft}^2 + \phi \frac{\theta_m}{\kappa_m} \pi_{mt}^2. \quad \textbf{(9)}$$

This loss function shows that the central bank cares about fluctuations in the output gap, CPI inflation, PPI inflation, and the marginal cost gap in the intermediate sector. When $\phi = 0$, the loss function reduces to the loss function in a standard one-sector model, as in Woodford (2003, p. 400). I use equation (9) for calculations. But it is instructive to note the outcome of normalizing the coefficient on the variance of CPI inflation. The normalized quadratic loss function $L_t^n$ is given by

$$L_t^n = \frac{\kappa_f}{\theta_f} \tilde{c}_t^2 + \frac{\kappa_f \phi (1 - \phi)}{\theta_f} (\tilde{c}_t - \tilde{q}_t)^2 + \pi_{ft}^2 + \phi \frac{\kappa^{\text{gap}}}{\theta^{\text{gap}}} \pi_{mt}^2, \quad \textbf{(10)}$$

where $\kappa^{\text{gap}} = \kappa_f / \kappa_m$ and $\theta^{\text{gap}} = \theta_f / \theta_m$. When discussing the weight that should be assigned to PPI inflation, Huang and Liu (2005) emphasize the role of the share of intermediate goods. However, it is important to note that the weight assigned to the PPI sector in the loss function depends not only on the share of intermediate goods, but also on the relative degree of nominal rigidity ($\kappa^{\text{gap}}$) and the relative elasticity of substitution ($\theta^{\text{gap}}$). All of these variables play a crucial role in shaping the objective of the central bank. Ignoring any of these factors may result in an objective function that is not an appropriate objective of policy, which in turn may lead to the design of welfare-maximizing inflation-targeting rules that are unsuitable for implementation.

## 3. MONETARY POLICY

A Pareto-optimal allocation of resources is not attainable in this model because of the assumption that the economy is hit by sector-specific productivity shocks. As noted earlier, under this assumption, both output and the relative price fluctuate in the flexible-price equilibrium. These fluctuations create a trade-off for the central bank. Given that the first-best allocation cannot be achieved, I employ Lagrangian methods to determine the optimal monetary policy. In particular, I compute the optimal policy that can be obtained by maximizing the welfare level defined in (8) subject to the equilibrium conditions (1)–(6). I obtain the first-order conditions of this problem by differentiating the Lagrangian with respect to each of the endogenous variables and setting these conditions to zero. The first-order conditions are given by

$$\left(\frac{\theta_f}{\kappa_f}\right)\pi_{ft} + \lambda_{ft} - \lambda_{ft-1} - \lambda_{qt} = 0, \tag{11}$$

$$\left(\frac{\theta_m}{\kappa_m}\right)\pi_{mt} + \lambda_{mt} - \lambda_{mt-1} + \lambda_{qt} = 0, \tag{12}$$

$$\sigma\tilde{c}_t + \phi(1-\phi)(\sigma\tilde{c}_t - \tilde{q}_t)\sigma - \lambda_{ft}(1-\phi)\kappa_f\sigma - \lambda_{mt}\kappa_m\sigma = 0, \tag{13}$$

$$-\phi(1-\phi)(\sigma\tilde{c}_t - \tilde{q}_t) - \lambda_{ft}\kappa_f\phi + \lambda_{mt}\kappa_m - \lambda_{qt} + E_t\lambda_{qt+1} = 0, \tag{14}$$

where $\lambda_{ft}$, $\lambda_{mt}$, and $\lambda_{qt}$ denote the Lagrange multipliers associated with the constraints. These first-order conditions hold for each date $t \geqslant 1$. They also hold at time zero, if one substitutes the values $\lambda_{q,-1} = \lambda_{f,-1} = \lambda_{m,-1} = 0$. These conditions at time zero simply reflect the fact that during period zero there are no previous policy commitments that the central bank needs to take into account. Given that each of these first-order conditions holds at each period $t$, they should also hold under commitment.[2] I use these first-order conditions along with the equilibrium conditions for the model to solve and calculate the level of welfare under optimal monetary policy. I then use this welfare level to evaluate the performance of alternative simple rules.

I examine the performance of a Taylor style rule under which the short-term interest rate reacts to the lagged interest rate and CPI inflation as well as to PPI inflation:

$$r_t = a_r r_{t-1} + a_{\pi_f}\pi_{ft} + a_{\pi_m}\pi_{mt}. \tag{15}$$

The coefficients in front of the targeting variables are chosen to maximize the welfare function in equation (8). This rule is different from the one proposed by Huang and Liu (2005), which includes the output gap as an additional targeting variable. Such a rule would be more difficult to implement than the inflation-targeting rule employed here. As is well known [see, e.g., McCallum (1999), Woodford (2003), Levin et al. (2005), and Erceg and Levin (2006)], a rule that involves the output gap as an additional targeting variable is not easy to implement because it requires an estimate of the economy's natural rate. The process of measuring the natural rate of output is both difficult and controversial. Therefore, in practice, central banks may still prefer to choose inflation as their target. Thus, I focus on an inflation-targeting rule. In any case, findings from tests that are not reported here indicate that adding the output gap to the rule in (15) does not significantly affect the results.

## 4. CHOICE OF PARAMETERS AND COMPUTATION

I begin with a calibration of the parameters indicating the degrees of nominal rigidity in the PPI sector, $\alpha_m$, and in the CPI sectors, $\alpha_f$. Huang and Liu (2005) assume that the level of nominal rigidity is the same in the two sectors. Specifically,

**TABLE 2.** The optimal weight of PPI inflation with empirically relevant frequencies for the United States

| | $\frac{1-\alpha_m}{1-\alpha_f}$ | $a_r$ | $a_{\pi f}$ | $a_{\pi m}$ | PPI weight |
|---|---|---|---|---|---|
| CPI–PPI (intermediate goods) | | | | | |
| Mean $(\alpha_f = 0.37, \alpha_m = 0.2)$ | 1.27 | 0.99 | 3.00 | 0.62 | 0.17 |
| Median $(\alpha_f = 0.74, \alpha_m = 0.6)$ | 1.54 | 0.97 | 3.00 | 0.65 | 0.18 |
| CPI–PPI (finished goods) | | | | | |
| Mean $(\alpha_f = 0.37, \alpha_m = 0.26)$ | 1.17 | 0.98 | 3.00 | 0.94 | 0.24 |
| Median $(\alpha_f = 0.74, \alpha_m = 0.68)$ | 1.23 | 1.10 | 3.00 | 1.10 | 0.27 |

they set $\alpha_m = \alpha_f = 0.75$. However, this assumption is inconsistent with recent microeconomic evidence provided by Nakamura and Steinsson (2008).

As detailed in Table 1, Nakamura and Steinsson (2008) find that the mean frequency of change in consumer prices is 21.1% per month, whereas the corresponding figure for intermediate goods prices is 26.7%. Nakamura and Steinsson (2008) note that there is considerable heterogeneity across the categories and therefore suggest that the median frequency of price changes would be a better statistical measure than the mean frequency. The median frequency of change in consumer prices is 8.7% per month, whereas the corresponding figure for intermediate goods prices is 13.3%.[3]

I have chosen to calibrate the model for both mean and median frequencies. Given the assumptions of the model, using the statistics for intermediate goods for the purpose of calibration is the natural way to proceed. However, a few may argue that the finished goods category of the PPI is a better measure of producer prices than the category of intermediate goods. Therefore I will also report the results obtained using the version of the model calibrated with reference to the finished goods category of the PPI. The mean frequency of price change for finished goods is 24.7% and the median frequency is 10.8%. Following Bils and Klenow (2004), I interpret the frequencies as Calvo reset probabilities. I convert these monthly figures to quarterly figures and use them to calibrate the model for the U.S. economy. The quarterly figures used for simulations are reported in Table 2.

The rest of the parameter values are taken from Huang and Liu (2005). Specifically, I set $\theta_m = \theta_f = 10$, $\phi = 0.6$, $\beta = 0.99$, $\rho_k = 0.95$, and $\sigma_k = 0.02$. Throughout the paper, welfare levels ($W$) are expressed in terms of the equivalent percentage decline in steady state consumption, which can be obtained by dividing $W$ by $U_c C$ (and multiplying by 100).

### 4.1. Computation

I use Dynare to solve the model [see Juillard (1996)]. To compute $a-$coefficients, I numerically minimize the welfare loss with respect to the parameters in the

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monetary policy rule, subject to the equilibrium conditions [(1)–(6)]. Following Schmitt-Grohe and Uribe (2006), the coefficients are restricted to taking values between 0 and 3, because large policy coefficients would make communications with the public difficult. This optimization is carried out using Matlab's "fminsearchbnd" routine.

Note that there is a slight error in Huang and Liu's Matlab code. In their code, the inverse of $\kappa_k$ is defined as $d_k^{\mathrm{HL}} = \frac{1}{\kappa_k} = \frac{\alpha_k(1-\alpha_k)}{(1-\beta\alpha_k)}$. The correct definition is $d_k = \frac{\alpha_k}{(1-\beta\alpha_k)(1-\alpha_k)}$. As discussed in Section 3, the price dispersion in each sector in sector $k \in \{f, m\}$ depends on $d_k$. Because $d_k^{\mathrm{HL}} < d_k$, Huang and Liu (2005) underestimate price dispersion.

## 5. THE IMPLICATIONS OF VARIATION IN NOMINAL RIGIDITY

To understand the effects of different degrees of nominal rigidity on monetary policy, I set the value of the Calvo CPI-sector parameter, $\alpha_f$, to 0.75, following Huang and Liu, and let the value of the Calvo PPI parameter, $\alpha_m$, vary from 0.75 to 0. All of the other parameters are held at their baseline values. For each case, I optimize the coefficients of the hybrid rule to maximize welfare in the model, and then use the optimized coefficients to construct an optimal inflation index and to calculate the weight assigned to PPI inflation. The optimal weight that the PPI sector receives is given by $a_{\pi_m}/(a_{\pi_f} + a_{\pi_m})$.

The welfare levels under the hybrid rule and the optimal policy are reported in Figure 1. Figure 1 shows that the hybrid rule performs very well, giving a welfare outcome close to the optimum. However, the net benefit of switching to the hybrid rule depends on the degree of nominal rigidity in the PPI sector. When sectors have the same degree of nominal rigidity, for example, the optimal CPI rule incurs a welfare loss of 4%, which is about 1.6 times greater than the loss under the optimal policy.[4] However, as the figure shows, the net gain from using the hybrid rule falls dramatically as the PPI sector becomes more flexible.

Figure 2 reports the weight assigned to the PPI sector in the optimal index. This figure raises two important points. First, the optimal weight of the PPI sector is highly sensitive to the Calvo parameter in that sector and decreases as the PPI adjustment occurs more frequently relative to consumer prices. This result is in line with the findings reported by Mankiw and Reis (2003), Woodford (2003), and Benigno (2004).[5] Second, if the PPI sector has fully flexible prices, then the weight assigned to the PPI sector in the optimal index is zero, which is in line with the findings of Aoki (2001).

The mechanism generating these results is similar to that at work in a two-sector model [see Aoki (2001) and Mankiw and Reis (2003)]. Firms that reset their prices less frequently tend to make larger changes to prices, taking into account that they will have to charge the same price for the whole duration of the contract. Because there is a trade-off between price stability and output gap stability, large price adjustments by firms require large changes in the output gap to control price

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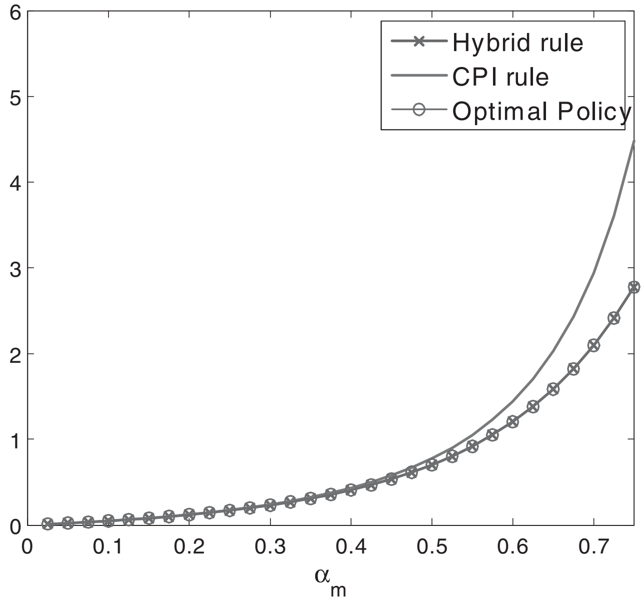


**FIGURE 1.** Welfare losses under alternative inflation targeting regimes: percentage of steady state consumption.

stability. An inflation-targeting central bank can minimize the disruptive effect of the stickier sector by putting more weight on this sector. Furthermore, in the model employed here, CPI inflation is influenced by price levels in the PPI sector. This is shown clearly by using equations (3) and (4). Marginal cost in the CPI sector is related to price levels in the PPI sector ($p_{mt}$) as follows:

$$v_{ft} = \sigma \tilde{c}_t + \phi p_{mt} + (1 - \phi) p_{ft} - \phi q_t^*. \tag{16}$$

Thus, there is a spillover effect from the PPI sector to the CPI sector via marginal cost. A policy rule that aimed to stabilize fluctuations in PPI inflation would also minimize the disruptive effect of producer prices on consumer prices.

It is important to note that the results are also related to the findings obtained using a model with sticky prices and sticky wages, such as Erceg et al. (2000), in which it is argued that optimal monetary policy can be closely approximated by targeting nominal wages. As noted by Huang and Liu, the main difference between the model used in this paper and that of the latter is that in the latter, the primary input is labor rather than intermediate goods. However, this difference has important implications for monetary policy design, because the nominal rigidity of labor contracts is different in essence from the nominal rigidity of intermediate goods. Nominal rigidity is likely to be much larger for labor than that for intermediate goods. As the previous findings suggest, if I had taken labor to be the primary input, the optimal weight of this sector would have been high.

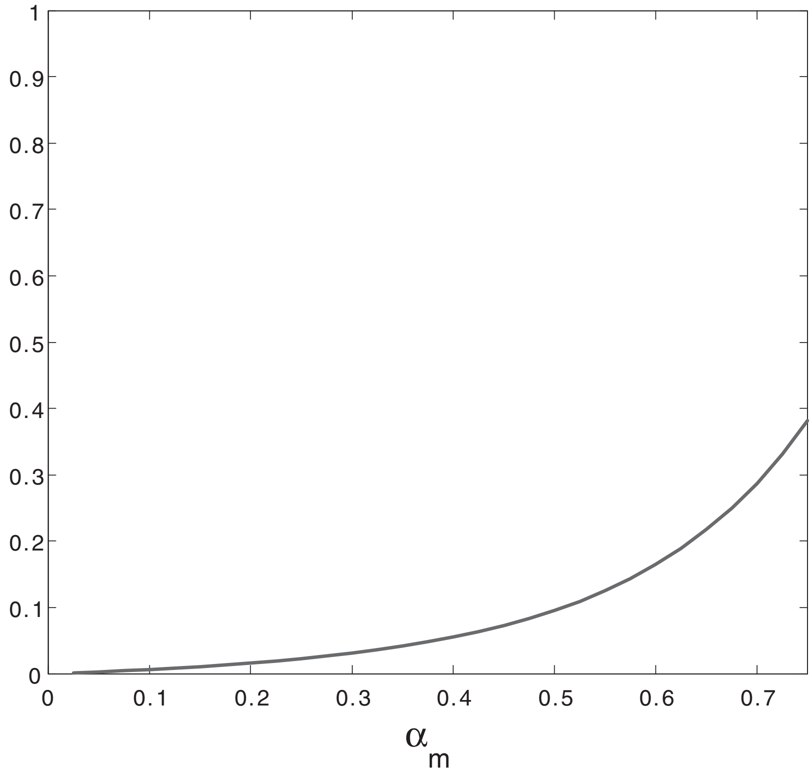


**FIGURE 2.** The weight on PPI inflation in the optimal inflation index.

## 5.1. An Application to U.S. Data

The findings outlined in the preceding section show explicitly that differences in nominal rigidity between the PPI sector and the CPI sector can have significant implications for optimal monetary policy. The question, then, is: How much weight should the central banks assign in reality to PPI and CPI? Table 2 provides an answer by applying the model to frequencies of price adjustment for the U.S. economy. Reported here are the relative degrees of stickiness, the coefficients on targeting variables, and the target weight of the PPI inflation in several scenarios, as discussed in the preceding.

My conclusion is evident: Once the empirically relevant contract lengths for each sector are used to calibrate the model, the model suggests that the central bank should react aggressively to CPI inflation. In all the cases reported in the table, the coefficient on CPI inflation hits the upper bound of 3,[6] whereas the coefficient on PPI inflation is around or less than 1. As a result, the weight received by PPI inflation in the optimal inflation index is low. Specifically, the target weight assigned to the PPI sector is around 25%, roughly half of the weight proposed by

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**TABLE 3.** Welfare losses when the central bank misperceives the relative degree of nominal rigidity between sectors

| | Perceived rigidity | |
|---|---|---|
| Actual rigidity | $(1-\alpha_f) < (1-\alpha_m)$ | $(1-\alpha_f) = (1-\alpha_m)$ |
| $(1-\alpha_f) < (1-\alpha_m)$ | 1.00 | 1.28 |
| $(1-\alpha_f) = (1-\alpha_m)$ | 1.18 | 1.00 |

Huang and Liu (2005). This is true even in the case in which the PPI sector is calibrated according to the frequency of price adjustment for finished goods. In this case, the difference between the sectors in terms of nominal rigidity is small.

It is worth pointing out that the determinacy conditions are satisfied in all of the cases I report in Table 2. This is true even when the coefficient on PPI inflation is less than 1. This finding is in line with the results reported by Carlstrom et al. (2006). These authors show analytically that in a two-sector model, reacting to either one of the two price indices is sufficient to satisfy local determinacy conditions.

## 5.2. Degree of Nominal Rigidity Uncertainty

How important are the findings in the preceding section? In order to determine their significance, I consider a case in which the central bank formulates its policy by assuming, incorrectly, that the sectors are identical in terms of nominal rigidity. The central bank places substantial weight on stabilizing both CPI and PPI. I then compute the welfare loss under such a policy rule in the "true" economy, where producer prices adjust more frequently than consumer prices.

Table 3 reports the welfare losses under misperceived degree of nominal rigidity relative to that under the correctly perceived case.[7] The table indicates that if the PPI sector is more flexible than the CPI sector in the true economy, formulating monetary policy based on the incorrect assumption that the sectors are the same in terms of their contract length will lead to substantial welfare losses.

Next I consider a case in which the policy maker optimizes the parameters of the policy rule, based on the assumptions that in the PPI sector the prices adjust more frequently than the prices in the CPI sector. Thus, the policy maker places substantial weight on CPI inflation. However, in the true economy, it turns out in this instance that the degree of nominal rigidity between the sectors is the same. I again compute the welfare loss incurred by such a policy rule in the true economy. As Table 3 shows, employing a rule that is optimized under the assumption that the prices in the PPI sector adjust more frequently within a model that assumes the same degree of nominal rigidity between the sectors results in a welfare loss. However, this results in considerably less welfare loss than when the monetary policy is formulated by assuming the identical degree of nominal rigidity. The loss incurred in the former case is roughly half of that under the previous rule.

**TABLE 4.** Standard deviations(%) when the central bank misperceives the relative degree of nominal rigidity between sectors

| | Perceived rigidity | | | | | |
|---|---|---|---|---|---|---|
| | $(1-\alpha_f) < (1-\alpha_m)$ | | | $(1-\alpha_f) = (1-\alpha_m)$ | | |
| Actual rigidity | $\tilde{c}_t$ | $\pi_{ft}$ | $\pi_{mt}$ | $\tilde{c}_t$ | $\pi_{ft}$ | $\pi_{mt}$ |
| $(1-\alpha_f) < (1-\alpha_m)$ | 0.03 | 0.65 | 2.95 | 0.65 | 1.36 | 2.21 |
| $(1-\alpha_f) = (1-\alpha_m)$ | 0.82 | 0.65 | 2.94 | 0.05 | 1.36 | 2.21 |

Table 4 explains why welfare losses are smaller in the second scenario than in the first. Reported in the table are the standard deviations of the output gap, CPI inflation, and PPI inflation arising from the central bank's misunderstanding of nominal rigidity. Consider first the case in which the central bank formulates its policy by assuming that prices in the PPI sector adjust more frequently than those in the CPI sector, whereas in the true economy the two sectors show the same degree of nominal rigidity. As noted earlier, the target weight assigned to PPI inflation in this case is around 18%, whereas the corresponding value in the true economy is around 38%. Not surprisingly, increasing the target weight of CPI inflation reduces the variability of CPI inflation, but at the cost of greater PPI inflation and increased output gap variability. On the other hand, if the central bank overestimates the nominal rigidity of the PPI sector when formulating its policy, its more aggressive response to PPI inflation will reduce PPI inflation variability. However, this in turn leads to greater CPI inflation and increased output gap variability. Increased volatility of CPI inflation volatility is more costly in the latter case, because the rise in CPI inflation volatility has more weight in the loss function. Thus, overestimating the degree of nominal rigidity in the PPI sector leads to a larger deterioration in social welfare.

## 6. SUMMARY AND CONCLUSIONS

Using a model that features input–output connections between sectors such that a distinction between CPI and PPI arises from the model, I have shown that a central bank seeking to maximize welfare should use an optimal inflation index that gives substantial weight to CPI inflation. This policy is in line with the practice of many central banks but contrasts with the findings of Huang and Liu (2005), who argue that the "optimal inflation index" should place substantial weight on both CPI inflation and PPI inflation.

The main reason for this difference lies in our assumptions regarding the degree of nominal rigidity between sectors. The conclusions reached by Huang and Liu (2005) are predicated on the assumption that the PPI sector and CPI sector have the same level of nominal rigidity, when in fact they do not. Rather, microevidence tends to suggest that producer prices adjust more frequently than consumer prices. The degree of nominal rigidity between sectors plays an important role in determining the optimal weight assigned to each sector. For example, the optimal weight assigned to PPI inflation is smaller if prices in this sector are more flexible, as the prices can adjust more frequently, reducing the disruptive effect of PPI inflation on the economy.

Therefore, a rule targeting inflation that focuses primarily on CPI inflation represents a sensible approach to policy.

## NOTES

1. Note that levels of productivity are not stationary. In calculating the steady state of the model, Huang and Liu (2005) assume that there is no trend growth in productivity. They further assume that the steady state values for productivity are $A_m = A_f = 1$.

2. However, as is well known [e.g., Wolman (2001, p. 41), Woodford (2003, p. 473)], this policy is not time-consistent. This is true because if the central bank were allowed to reoptimize in period $t > 0$ to determine the optimal policy commitment from that period onward, the policy chosen would be different from the policy selected in period $t = 0$.

3. Note that these numbers exclude sales. This is the approach taken by Golosov and Lucas (2007) and Nakamura and Steinsson (2010). As Golosov and Lucas (2007) note, when discussing whether sales should be excluded, "[to] obtain a good match between theory and data, then, sales must either be removed from the data or added to the model. . . . we took the first course."

4. The scale of welfare losses is in line with that reported by Canzoneri et al. (2007), but differs from that in Huang and Liu. For example, when the degree of nominal rigidity is the same across the sectors, the findings reported by Huang and Liu (2005) suggest that the CPI rule incurs a welfare loss of 0.25%. The difference in scale arises from the fact that, for the reasons discussed earlier, the price dispersion in each sector is underestimated by Huang and Liu (2005).

5. When the degree of nominal rigidity is the same in the sectors, as in the case studied by Huang and Liu, the target weight received by the PPI sector is 38%. This is lower than the value reported by Huang and Liu, namely 46%. Again, this difference arises from the error in Huang and Liu's calculations, as described previously.

6. Note that removing the upper bound does not affect the results significantly.

7. In this experiment, the frequency of price adjustment in the PPI sector is calibrated according to the frequency of price adjustment for intermediate goods. I use median frequencies to calibrate the model. Calibrating the model to the other cases reported in Table 2 does not change the conclusions reached.

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