THE FEDERAL RESERVE BANK *of* KANSAS CITY

RESEARCH WORKING PAPERS

Phillips Curve Instability and Optimal Monetary Policy

Troy Davig

July 2007; Revised November 2015

RWP 07-04

RESEARCH WORKING PAPERS

Phillips Curve Instability and Optimal Monetary Policy

Troy Davig[*]

November 25, 2015

Abstract

Evidence suggests a flattening of the Phillips curve in recent decades, indicating inflation has become less responsive to movements in measures of aggregate economic activity, such as the output gap. To capture this feature of the data, I develop a framework where firms face a changing cost of price adjustment, which produces a Phillips curve with a slope coefficient that varies over time. For example, periods when firm's face large costs of price adjustment produce a relatively 'flat' Phillips curve, though can be followed by periods of low costs of adjustment and a 'steep' curve. The Phillips curve derives from the firm's optimal pricing problem. To evaluate the implications for monetary policy, I construct a utility-based welfare criterion, which has the novel feature that the relative weight on output gap deviations in the central bank's loss function changes synchronously with changes in the cost of price adjustment and therefore, also with the slope of the Phillips curve. For optimal policy under both discretion and commitment from a timeless perspective, the systematic component of the targeting rule that implements the optimal policy is constant. In contrast, the systematic component of the targeting rule under an ad-hoc criteria that holds the relative weight on output gap deviations constant shifts along with changes in the slope of the Phillips curve.

1. Introduction

The slope of the Phillips curve is an important parameter in the minds of policymakers. Empirical evidence suggests a flattening of the Phillips curve in recent decades across several countries, indicating inflation has become less responsive to movements in measures of aggregate economic activity, such as the output gap.[1] Although this phenomenon appears using reduced-form estimation procedures, as in Atkeson and Ohanian (2001), it also appears using structural approaches to estimation, as in Smets and Wouters (2007). In the New Keynesian framework, the slope of the Phillips curve appears in targeting rules describing optimal monetary policy. Given these observations, this paper addresses two issues: (1) the derivation of a Phillips curve with a changing slope, driven by changes in the cost of price adjustment and (2) the implications for optimal monetary policy confronting this type of structural change.

The channel generating the change in the slope of the Phillips curve is a shift in the price setting friction for monopolistically competitive firms.[2] The microfoundations of the firm's price-setting problem are similar to Rotemberg (1982), except the term governing the cost of price adjustment is subject to change over time. The equation describing the optimal price-setting behavior of the firm is similar to a standard forward-looking New Keynesian Phillips curve, except the coefficients on expected inflation and the output gap are subject to change.

In the presence of markup shocks, a central bank trying to stabilize inflation and output faces the Phillips curve as the constraint on achieving these objectives. Under discretion, for example, the optimal targeting rule balances policy objectives by prescribing adjustments to the output gap in response to movements in inflation. The central bank adjusts the output

---

[1]For example, Atkeson and Ohanian (2001), Roberts (2006), Williams (2006), Kleibergen and Mavroeidis (2008), Stock and Mark A. Watson (2010), Matheson and Stavrev (2013), Ball and Mazumder (2011), Coibion, Gorodnichenko, and Koustas (2013) and IMF (2013) document the flattening of the Phillips curve for the U.S., whereas Iakova (2007) does so for the U.K., Musso, Stracca, and van Dijk (2009) for the euro area and De Veirman (2007) for Japan. Kuttner and Robinson (2010) provide evidence of flatting in the U.S. and Australia.

[2]Several competing explanations for the change in the slope of the Phillips exist. For example, improvements in the conduct of monetary policy and globalization present additional rationale for a decline in the slope of the Phillips curve. However, this paper does not address these potential causes and focuses only on changes arising from the price setting friction. See Mishkin (2007) for an overview.

gap aggressively if the relative weight on output gap fluctuations in its objective function is small or the slope coefficient on the output gap in the Phillips curve is large. If the slope of the Phillips curve changes, then the optimal targeting rule will also change under a loss function that has a constant relative weight on output gap deviations, such as a common ad-hoc loss function in squared deviations of inflation and the output gap.

A benefit of deriving the Phillips curve under the potential for structural change is that it makes possible the derivation of a utility-based welfare criterion. In contrast to an ad-hoc loss function with a constant relative weight on output gap deviations, a central feature of the utility-based measure is that this weight depends on the slope of the Phillips curve, so changes when the slope of the Phillips curve shifts. The changing weight reflects that higher losses arise due to inflation in states with relatively high costs of price adjustment. Since inflation imposes higher costs on firms in states with relatively sticky prices, it is precisely in these states that monetary policy increases the relative weight on inflation stabilization. In contrast to the ad-hoc rule, the optimal targeting rule under the utility-based welfare criterion directs the central bank to have a constant systematic response to inflation. That is, the optimal targeting rule under discretion advocates a policy that consistently adjusts the output gap to the same extent in response to inflation, regardless of the slope of the Phillips curve. The case of commitment from a timeless perspective produces similar results, as the optimal rule under the utility-based metric directs policy to consistently adjust changes in the output gap to movements in inflation.

From a policy standpoint, the slope of the Phillips curve can be an important parameter governing policy decisions. For example, as Mishkin (2007) discusses, there are positives and negatives to a flatter Phillips curve from a policymaker's perspective. From the positive standpoint, a flatter Phillips curve indicates than an overheating economy poses less of a threat in terms of generating inflationary pressure. In response, policymakers may be tempted to adjust policy gradually, since the threat of higher inflation may be perceived to be low. On the other hand, a rise in inflation will require a larger movement in either spare capacity or marginal costs to bring about a decline in inflation. In this case, policymakers may be tempted to adjust policy aggressively to bring down inflation. In contrast, a steeper Phillips curve reverses these channels. For example, a steeper Phillips curve indicates that

a positive output gap poses a risk of higher inflation, but may require a more modest policy response to bring inflation back towards target. The central point is that policymakers may be tempted to adjust the force of their policy response depending on the slope of the Phillips curve.

To calibrate an appropriate policy response to various shocks, however, policymakers need to consider the underlying cause of a change in the slope of the Phillips curve. For example, an economy with stable inflation may eventually lead to greater price setting frictions, since customers may become accustom to stable prices and in response, be more resistent to price changes. As a consequence, the Phillips curve will flatten, reflecting a higher cost of price adjustment for firms that change the price of their good. This paper presents a model that explicitly incorporates this changing cost of price adjustment into the monetary authority's optimal response and illustrates that a monetary authority should not necessarily alter its targeting rule in response to changes in the slope of the Phillips curve. Instead, adjusting policy in a constant systematic manner will generate improved outcomes if the Phillips curve is shifting due to changes in price setting frictions.

Related work in this area includes Moessner (2006), Zampolli (2006), Svensson and Williams (2007) and Blake and Zampolli (2011). These papers also demonstrate how shifts in parameters governing private sector relations generate shifts in the central bank's targeting rule. This paper, however, differs from this previous work in two respects. First, the Phillips curve relation with changing coefficients arises from a representative firm's optimal pricing problem. Moessner (2006), Zampolli (2006) and Svensson and Williams (2007) study macroeconomic relations with changing parameters, but do not incorporate the potential for parameter change into the original optimization problems of households and firms. In this paper, the potential for structural change is built into the primitive optimization problem of the firm. The different approaches, however, stems partially from the different focus. For example, Svensson and Williams (2007) are specifically interested in model uncertainty and not with the mechanics generating shifts in the private sector relations. Second, this paper constructs a utility-based welfare criterion, instead of using an ad-hoc loss, to evaluate different monetary policies confronting shifts in the slope of the Phillips curve. Deriving the utility-based metric is possible because the microfoundations of the firm's pricing problem

are made explicit. Debortoli and Ricardo (2014) also model changes in the relative weight attached to output gap deviations in the central bank's loss function. In this paper, the relative weight is given a structural interpretation, as it is a function of the cost of price adjustment that also affects the slope of the Phillips curve. Similar to the mechanism in this paper, Kuttner and Robinson (2010) and Coibion and Gorodnichenko (2015) also posit a changing cost of price adjustment as a factor driving the declining slope in the Phillips curve. Given the extent of the decline, however, Coibion and Gorodnichenko (2015) conclude other factors, such as the declining labor share and higher markups, were also important in the flattening of the Phillips curve.

In terms of empirical evidence documenting changes in the slope of the Phillips curve, Kleibergen and Mavroeidis (2008) find that the New Keynesian Phillips curve has flattened considerably after 1984. Using nonparametric methods, Stock and Mark A. Watson (2010) estimate the slope of the Phillips curve, allowing it to vary with the level of inflation, and find a tendency for it to be flatter at low levels of inflation. Other flexible estimation techniques, such as the time-varying parameter approach in Matheson and Stavrev (2013), also find the slope coefficient has drifted lower over time. Kuttner and Robinson (2010), Ball and Mazumder (2011), Coibion, Gorodnichenko, and Koustas (2013) and IMF (2013) also provide evidence that the Phillips curve has flattened. Fitzgerald and Nicolini (2014) also report finding instability in the Phillips curve when using national data, though highlight the relationship is more stable when using regional data in the estimation.

2. Modeling Change in the Slope of the Phillips Curve

This section presents a framework that embeds state-dependent parameters into the optimal pricing problem of a monopolistically competitive firm. As in Rotemberg (1982), the firm faces quadratic costs of price adjustment, except the term governing the magnitude of the cost is subject to change. Introducing these changing costs into the pricing problem results in a Phillips curve relation with coefficients on the output gap and expected inflation that change over time.

2.1 Changing Costs of Price Adjustment

The Rotemberg (1982) formulation imposes a cost on monopolistic intermediate-goods producing firms for adjusting their price, given by

$$ac_{jt} = \frac{\varphi}{2} \left(\frac{P_t(j)}{\Pi P_{t-1}(j)} - 1 \right)^2 Y_t, \tag{1}$$

where $\varphi \geq 0$ governs the magnitude of the price adjustment cost, Π denotes the gross steady-state rate of inflation and $P_t(j)$ denotes the nominal price set by firm $j \in [0,1]$.[3] The cost is measured in terms of the final good Y_t. The assumption of quadratic adjustment costs implies that firms change their price every period in the presence of shocks, but will adjust only partially towards the optimal price the firm would set in the absence of such costs. As with any type of quadratic adjustment cost, a firm prefers a sequence of small adjustments to very large adjustments in a given period. Alternatively, these costs may vary according to a state, s_t, such as

$$ac_{jt}(s_t) = \frac{\varphi(s_t)}{2} \left(\frac{P_t(j)}{\Pi P_{t-1}(j)} - 1 \right)^2 Y_t, \tag{2}$$

where firms face a state-dependent cost of price adjustment.[4] For $s_t \in \{1,2\}$, the state evolves according to a two-state Markov chain with transition probabilities given by $p_{mn} = \Pr[s_t = n | s_{t-1} = m]$ for $m, n = 1, 2$.[5] Both private agents and the central bank observe s_t.[6]

Changes in the price setting friction reflect shifts in the myriad of costs facing firms when they adjust their price.[7] At the macroeconomic level, these various factors are summarized by φ and evidence suggests price setting frictions have changed over time. For example, estimation of DSGE models suggest a change in the parameters governing price setting frictions in the early 1980s. For example, Boivin and Giannoni (2006) and Smets and Wouters (2007) split samples and estimate a lower slope coefficient on the output gap in the New Keynesian Phillips curve after about 1980. They discuss the change in slope

---

[3]See Ireland (2004) for a detailed treatment of quadratic costs of price adjustment in a DSGE model.

[4]Note that changes in φ do not have any steady state effects, so linearization of the model, which is done in the next section, occurs around a single steady state.

[5]The assumption of two states is made for convenience and tractability, it can be replaced with an assumption concerning any finite number of states.

[6]See Ellison (2006) for an example of a model where the central bank and private agents are unable to observe the slope of the Phillips curve, but formulate beliefs as to whether it is 'high' or 'low.'

[7]The review of Blinder, Canetti, Lebow, and Rudd (1998) and Zbaracki, Ritson, Levy, Dutta, and Bergen (2004) emphasize the complexity of the price adjustment process

as potentially arising from less frequent price adjustment under the low and stable inflation rates of the past few decades.[8] Using the Rotemberg (1982) framework, this interpretation implies firms face higher costs of price adjustment in the post-Volcker period. Under the specification of adjustment costs in (2), the exogenously evolving cost of price adjustment captures these shifts in price setting frictions, but does not incorporate the possible linkages between aggregate conditions and firm-level pricing behavior.

As a final point on the price adjustment friction, I use the Rotemberg (1982) approach of costly price adjustment instead of a Calvo (1983) mechanism that allows the average frequency of price adjustment to evolve stochastically. Under the Calvo-style mechanism, the distribution of prices at time t is no longer a simple convex combination of the lagged aggregate price level and optimal relative price set at time t when the frequency of adjustment may change. Instead, the firm's first-order condition is an infinite sum embedding the changing coefficients and is not as easily mapped into a recursive form. These complications make the Calvo-style formulation considerably less amenable to analytic analysis, whereas the firm's first-order condition under the Rotemberg mechanism lends itself naturally to a recursive formulation under a changing cost of price adjustment.

2.2   The Optimal Pricing Problem

Each of the monopolistically competitive intermediate-goods producing firms seek to maximize the expected present-value of profits,

$$E_t \sum_{s=0}^{\infty} \beta^s \Delta_{t+s} \frac{D_{t+s}(j)}{P_{t+s}}, \tag{3}$$

where Δ_{t+s} is the representative household's stochastic discount factor, $D_t(j)$ are nominal profits of firm j, and P_t is the nominal aggregate price level. Also, firm j produces good j. For given s_t, real profits are

$$\frac{D_t(j)}{P_t} = \frac{P_t(j)}{P_t} y_t(j) - \Psi_t y_t(j) - \frac{\varphi(s_t)}{2} \left(\frac{P_t(j)}{\Pi P_{t-1}(j)} - 1 \right)^2 Y_t, \tag{4}$$

---

[8]Nakamura and Steinsson (2008) support this finding that the frequency of price adjustment has been drifting lower, though Klenow and Kryvtsov (2008) report little variation from 1988-2004 in the frequency of price adjustments.

where Ψ_t denotes real marginal cost and $y_t(j) = n_t(j)$ is the production of intermediate goods by firm j using labor input $n_t(j)$.

There exists a final-goods producing firm that purchases the intermediate inputs at nominal prices $P_t(j)$ and combines them into a final good using the following constant-returns-to-scale technology

$$Y_t = \left[\int_0^1 y_t(j)^{\frac{\theta_t - 1}{\theta_t}} \, dj \right]^{\frac{\theta_t}{\theta_t - 1}}, \tag{5}$$

where $\theta_t > 1 \; \forall \; t$ is the elasticity of substitution between goods. Variations in θ_t translate into markup shocks of the monopolistic firm's price over its marginal cost. The profit-maximization problem for the final-goods producing firm yields a demand for each intermediate good given by

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta_t} Y_t. \tag{6}$$

For a given s_t, substituting (4) and (6) into (3) then differentiating with respect to $P_t(j)$ yields the first-order condition

$$
\begin{aligned}
0 = & \; (1 - \theta_t) \Delta_t \left(\frac{P_t(j)}{P_t} \right)^{-\theta_t} \left(\frac{Y_t}{P_t} \right) + \theta_t \Delta_t \Psi_t \left(\frac{P_t(j)}{P_t} \right)^{-\theta_t - 1} \left(\frac{Y_t}{P_t} \right) - \\
& \; \varphi(s_t) \Delta_t \left(\frac{P_t(j)}{\Pi P_{t-1}(j)} - 1 \right) \left(\frac{Y_t}{\Pi P_{t-1}(j)} \right) + \\
& \; \beta E_t \left[\varphi(s_{t+1}) \Delta_{t+1} \left(\frac{P_{t+1}(j)}{\Pi P_t(j)} - 1 \right) \left(\frac{P_{t+1}(j) Y_{t+1}}{\Pi P_t(j)^2} \right) \right],
\end{aligned} \tag{7}
$$

where an analogous condition exists for each s_t.

In a symmetric equilibrium, every firm faces the same Ψ_t and Y_t, so the pricing decision is the same for all firms, implying $P_t(j) = P_t$. Also, steady-state inflation and output are constant across states. Steady-state marginal costs are given by

$$\Psi = \frac{\theta - 1}{\theta}, \tag{8}$$

and $\Psi^{-1} = \mu$, where μ is the steady-state markup of price over marginal cost. In the flexible-price case, where $\varphi(1) = \varphi(2) = 0$, marginal cost is $\Psi_t = \theta_t^{-1}(\theta_t - 1)$ and the markup is $\mu_t = \Psi_t^{-1}$.

To obtain a linear system that captures the firm's pricing decision, (7) is log-linearized conditional on s_t. Imposing symmetry and (8), the linear approximation to the firm's optimal

price-setting equation is

$$\pi_t = \varphi_i^{-1} \beta E_t \left[\varphi \left(s_{t+1} \right) \pi_{t+1} \right] + \frac{\theta - 1}{\varphi_i} \left(\psi_t + u_t \right), \tag{9}$$

where $\varphi_i = \varphi(i)$ for $i = 1, 2$, $\psi_t = \log \left(\Psi_t / \Psi \right)$, $\pi_t = \log \left(\Pi_t / \Pi \right)$ and $u_t = \log \left(\mu_t / \mu \right) = -\left(\theta - 1 \right)^{-1} \widehat{\theta}_t$ is the markup shock, where $\widehat{\theta}_t = \log(\theta_t/\theta)$. Equation (9) illustrates how changing costs of price adjustment affect the coefficients on marginal cost and expected inflation. High costs of price adjustment result in a 'flat' Phillips curve, whereas lower costs results in a 'steep' Phillips curve. Thus, movements in real marginal cost in states with a flat Phillips curve have a relatively small effect on inflation, so equilibrium adjustments to shocks occur relatively more through quantities than prices.

3.   Households

To analyze the implications of instability in the Phillips curve in a dynamic stochastic general equilibrium setting, this section gives the representative household's problem and optimality conditions. In a subsequent section, the households period-utility function forms the basis of the central bank's loss function.

The representative household chooses $\{C_t, N_t, B_t\}_{t=0}^{\infty}$ to maximize lifetime utility

$$E_t \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1 - \sigma} - \frac{H_t^{1+\eta}}{1 + \eta} \right) \tag{10}$$

where C_t is the composite good, $H_t = \int_0^1 h_t(j)dj$ is time spent working, $\beta \in (0,1)$ is the discount factor and $\sigma > 0$ is the coefficient of relative risk aversion. Utility maximization is subject to the intertemporal budget constraint

$$P_t C_t + Q_t B_t = B_{t-1} + \left(1 + \nu \right) W_t H_t + P_t X_t - P_t T_t, \tag{11}$$

where B_t are nominal bond holdings, X_t are real profits from ownership of firms, T_t are lump-sum taxes, P_t is the aggregate price level, W_t is the nominal wage and Q_t is the inverse of the gross nominal interest rate. Lump-sum taxes finance a constant employment subsidy, ν, which offsets the inefficiently low level of production in the steady-state arising from the

monopolistic distortion. The subsidy is set equal to $(1 + \nu) = \mu$, which sets the flexible-price steady-state level of output equal to the level that would prevail in the absence of the monopolistic distortion (i.e. the efficient level).

The household's first-order conditions are

$$(1 + \nu) \frac{W_t}{P_t} = \frac{H_t^\eta}{C_t^{-\sigma}}, \tag{12}$$

$$\beta E_t \left[(Q_t \Pi_{t+1})^{-1} \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \right] = 1. \tag{13}$$

In the previous section, the household discount factor is $\Delta_{t+s} = (C_{t+s}/C_t)^{-\sigma}$. In equilibrium, $H_t = N_t$ must also hold, where $N_t = \int_0^1 n_t(j) dj$. Also, there is no price dispersion in a symmetric equilibrium with quadratic costs of price adjustment, so aggregate output equals aggregate labor effort, so $Y_t = N_t$.[9]

The aggregate resource constraint is

$$Y_t = C_t + \frac{\varphi(s_t)}{2} (\Pi_t - 1)^2, \tag{14}$$

where steady-state inflation is set to zero (i.e. $\Pi = 1$).

4. Optimal Discretionary Policy

Optimal policy under discretion in a standard New Keynesian framework, such as in Clarida, Gali, and Gertler (1999), instructs policy to contract aggregate demand when inflation rises. The extent of the response depends on two factors: the slope of the Phillips curve and the weight policymakers assign to output gap deviations in their loss function. A Phillips curve with a steep slope allows the central bank to exert considerable influence over inflation by adjusting aggregate demand.

The same intuition guides optimal policy in the current setting, except the slope of the Phillips curve changes. To illustrate, the following utility-based loss function is from an approximation to the period utility function of the representative household

$$L_t^{ub} = \Omega_i \left[\pi_t^2 + \lambda_i x_t^2 \right], \tag{15}$$

---

[9]That is, $\int_0^1 n_t(j) dj = \int_0^1 y_t(j) dj$ is equivalent to $N_t = Y_t \int_0^1 \left(\frac{P_t(j)}{P_t} \right)^{-\theta_t} dj$, where $\int_0^1 \left(\frac{P_t(j)}{P_t} \right)^{-\theta_t} dj = 1$.

where $\Omega_i = .5\varphi_i$ scales the loss according to the cost of price adjustment and

$$\lambda_i = \frac{\eta + \sigma}{\varphi_i}, \tag{16}$$

indicating that the weight on output gap deviations depends on the state governing the cost of price adjustment.[10] Assuming the utility function has log consumption and is linear in labor, so $\sigma = 1$ and $\eta = 0$, then (16) is simply $\lambda_i = \varphi_i^{-1}$.

In a state with a relatively low cost of price adjustment, deviations in inflation create a small loss, so the weight on the output gap is relatively high. Conversely, in a state with a high cost of price adjustment, deviations in inflation are costly, so the central bank should place less emphasis on output stabilization. This intuition is similar to that from the utility-based welfare criteria derived under the Calvo mechanism of price adjustment, as in Woodford (2003). When price adjustment is infrequent, losses arise from price dispersion, so the central bank should place low weight on output stabilization relative to the case when price adjustment occurs more frequently.

The optimal discretionary policy takes private sector expectations as given and minimizes (15) subject to

$$\pi_t = \varphi_i^{-1}\beta E_t\left[\varphi\left(s_{t+1}\right)\pi_{t+1}\right] + \kappa_i x_t + e_t, \tag{17}$$

where $\kappa_i = \varphi_i^{-1}\left(\sigma + \eta\right)\left(\theta - 1\right)$, $x_t = \log(Y_t/Y)$ and $e_t = \varphi_i^{-1}\widehat{\theta}_t$.[11] The disturbance e_t represents a scaled markup shock. Under discretion, the optimization problem is static, so the central bank only needs to be concerned with setting policy based on the current state and can disregard how the slope of the Phillips curve may change in the future. The optimal targeting rule is then given by

$$x_t = -\frac{\kappa_i}{\lambda_i}\pi_t, \tag{18}$$

or after substituting for λ_i and κ_i,

$$x_t = \left(1 - \theta\right)\pi_t, \tag{19}$$

indicating the central bank should not optimally vary how aggressively it acts to offset aggregate supply disturbances. The optimal targeting rule is a constant relation between

---

[10]See the appendix for details. See also Eusepi (2005), who derives the utility-based welfare function for price adjustment subject to quadratic costs, as in Rotemberg (1982), and shows how the weight on the output gap term depends on the parameter governing the cost of price adjustment.

[11]The relationship between the output gap and marginal cost term is given by $\psi_t = (\sigma + \eta)x_t$.

output and inflation, independent of the state, and depends only upon the elasticity of substitution between goods.

In contrast, if the central bank uses the following period ad-hoc loss function

$$L_t = \pi_t^2 + \lambda x_t^2, \tag{20}$$

where λ is the relative weight on output deviations, then the optimal targeting rule is

$$x_t = -\frac{\kappa_i}{\lambda} \pi_t, \tag{21}$$

for $i = 1, 2$. The central bank has a separate rule for each state, which indicates that policy should vary how aggressively it acts to offset aggregate supply disturbances depending on the slope of the Phillips curve. In states with relatively low costs of price adjustment, say in $s_t = 1$, the Phillips curve is steep and implies that inflation is relatively responsive to changes in the output gap. In this case, the optimal targeting rule instructs policy to use this leverage and adjust the output gap more aggressively in response to inflation. So with $\kappa_1 > \kappa_2$, the central bank adjusts aggregate demand more aggressively when $s_t = 1$ than when $s_t = 2$.

In the state with relatively high costs of price adjustment, both the weight attached to output gap stabilization in the utility-based criteria and the slope coefficient in the Phillips curve are relatively small. Under an ad-hoc loss, a high cost of price adjustment (i.e. flat Phillips curve) directs policy to reduce the systematic output gap response to inflation deviations precisely because such movements are less effective at stabilizing inflation. However, inflation volatility is more costly to firms in states with high costs of price adjustment, an aspect that the ad-hoc loss function neglects. The utility-based welfare criterion captures this higher cost of inflation volatility by reducing the weight on output gap stabilization in the states with a high cost of price adjustment.

Thus, in the high-cost state, two opposing forces exactly offset to bring about the invariant policy response under the utility-based criteria : 1) a lower slope of the Phillips curve, which directs policy to reduce output gap movements to stabilize inflation and 2) a lower weight on the output gap, which directs policy to increase output gap movements to stabilize inflation.[12]

---

[12]Analogous reasoning applies to the low-cost state.

The difference in comparison to the optimal policy under the ad-hoc loss function is that it only accounts for the first factor, the change in the slope of the Phillips curve, and ignores the welfare implications of inflation in the different states.

5.   Commitment under a Timeless Perspective

While optimal discretionary policy is time consistent, the central bank can further improve outcomes by precommiting to future actions that can affect inflation and output today in a way that improves welfare. Under commitment, the objective is to choose sequences for inflation and output that minimizes the following

$$L_t = .5 E_t \sum_{j=0}^{\infty} \beta^i [\varphi(s_{t+j}) \left(\pi_{t+j}^2 + \lambda_i x_{t+j}^2 \right)$$
$$+ \gamma_{t+j} \left(\pi_{t+j} - \beta \varphi \left(s_{t+j} \right)^{-1} \varphi \left(s_{t+j+1} \right) \pi_{t+j+1} - \kappa \left(s_{t+j} \right) x_{t+j} + e_{t+j} \right)].$$

The first-order conditions are

$$\pi_t \quad : \quad \varphi_i \pi_t + \gamma_t = 0, \tag{22}$$

$$\pi_{t+j \ (j \geq 1)} \quad : \quad E_t \left[\varphi \left(s_{t+j} \right) \pi_{t+j} + \gamma_{t+j} - \varphi \left(s_{t+j-1} \right)^{-1} \varphi \left(s_{t+j} \right) \gamma_{t+j-1} \right] = 0, \tag{23}$$

$$x_t \quad : \quad \varphi_i \lambda_i x_t - \gamma_t \kappa_i = 0. \tag{24}$$

For $j = 0$, the central bank sets the inflation rate according to (22), which is the optimal rule under discretion, though differs from how inflation should optimally be set in future periods and highlights the dynamic inconsistency inherent in constructing optimal policies under committment. The optimal commitment policy uses the assumption that the policy was chosen in the distant past, referred to as the timeless perspective, so policy is set to ensure (23) and (24) hold in every period.

To solve for how the central bank should implement optimal policy, rewrite equation (24) as

$$\gamma_t = \frac{\varphi_i \lambda_i}{\kappa \left(s_t \right)} x_t$$

or

$$\gamma_t = \frac{\varphi_i}{(\theta - 1)} x_t,$$

13

and substitute into (23), which yields

$$x_t - x_{t-1} = (1 - \theta) \pi_t, \tag{25}$$

showing that the central bank now adjusts the change in the output gap in response to inflation. As in the case of discretion, variations in the cost of adjustment that affect the Phillips curve also affect the weight on output gap deviations in the welfare criterion. The two effects offset, generating a rule that directs the central bank to adjust changes in the output gap in a consistent manner that is independent of the price setting friction and slope of the Phillips curve. The targeting rule is history dependent, but the only lagged state variable influencing policy is the output gap. Also, the optimal commitment policy, as in the standard case when the slope of the Phillips curve is constant, induces inertia into the response of inflation and the output gap following a markup shock. Even when the markup shock is *i.i.d.*, the central bank responds to the past level of the output gap as a device to affect current and expected inflation that reduce losses from output gap and inflation fluctuations relative to the case under discretion.

Alternatively, consider the case when the central bank assumes an ad-hoc loss function, so equation (24) becomes

$$\gamma_t = \frac{(\varphi_i)^2 \lambda}{(\theta - 1)} x_t.$$

Then substituting this expression into (23) yields

$$\pi_t + \frac{\varphi(s_t) \lambda}{(\theta - 1)} x_t - \frac{\varphi(s_{t-1}) \lambda}{(\theta - 1)} x_{t-1} = 0$$

or rearranging

$$x_t = -\frac{\kappa(s_t)}{\lambda} \pi_t + \frac{\kappa(s_t)}{\kappa(s_{t-1})} x_{t-1},$$

revealing a more complex targeting rule. Not only would the central bank adjust policy in response to the current price setting regime, but also to the one in the previous period. The history dependence on past regimes would substantially complicate monetary policy, as there are four different rules with two price setting regimes, since the past and current regime enter into the rule.

The takeaway of the results under both discretion and commitment is that monetary policy may be misguided if attempts are made to alter policy responses to apparent shifts in

the slope of the Phillips curve. If the Phillips curve flattens due to changes in price setting behavior, then policy needs to evaluate how this would affect the relevant weight on output gap deviations in the central bank's utility-based welfare metric. Even if policy pursues time invariant targeting rules due to changes in price behavior, as the results above suggest, this does not imply the equilibrium dynamics of the economy will be the same across different price setting regimes. Changes in the slope of the Phillips curve will affect equilibrium dynamics, though monetary policy will improve welfare-based outcomes if the targeting rule remains consistent across regimes.

6. Conclusion

This paper shows that a change in the cost of price adjustment can generate instability in a forward-looking Phillips curve relation. In particular, the coefficients on both expected inflation and marginal cost, or the output gap, change when the parameter governing the cost of adjusting prices changes.

In addition, Phillips curve instability has implications for optimal monetary policy. Under an ad-hoc welfare criterion, the coefficient in the optimal targeting rule changes when the slope of the Phillips curve changes. However, since the microfoundations of the firm's optimization problem are made explicit, it is possible to derive a utility-based welfare metric. A novel feature of this metric is that it has a state-dependent weight on the output gap term. The weight depends inversely on the cost of price adjustment, so in the low cost state, relatively more weight is placed on output stabilization. The implication for optimal monetary policy, under either discretion or commitment, is that the optimal targeting rule should not vary the systematic component of policy, standing in contrast to the prescription coming from the ad-hoc criterion.

References

ATKESON, A., AND L. E. OHANIAN (2001): "Are Phillips Curves Useful for Forecasting Inflation?," *Federal Reserve Bank of Minneapolis Quarterly Review*, 25(6), 2–11.

BALL, L., AND S. MAZUMDER (2011): "Inflation Dynamics and the Great Recession," *Brookings Papers on Economic Activity*, 1, 337–381.

BLAKE, A. P., AND F. ZAMPOLLI (2011): "Optimal Policy in Markov-Switching Rational Expectations Models," *Journal of Economic Dynamics and Control*, 35(10).

BLINDER, A. S., E. R. CANETTI, D. E. LEBOW, AND J. B. RUDD (1998): *Asking About Prices: A New Approach to Understanding Price Stickiness*. Russell Sage Foundation, New York.

BOIVIN, J., AND M. P. GIANNONI (2006): "Has Monetary Policy Become More Effective?," *The Review of Economics and Statistics*, 88(3), 445–462.

CALVO, G. A. (1983): "Staggered Prices in a Utility Maxmimizing Model," *Journal of Monetary Economics*, 12(3), 383–398.

CLARIDA, R., J. GALI, AND M. GERTLER (1999): "The Science of Monetary Policy : A New Keynesian Perspective," *Journal of Economic Literature*, 37, 1661–1707.

COIBION, O., AND Y. GORODNICHENKO (2015): "Is the Phillips Curve Alive and Well After All? Inflation Expectations and the Missing Deflation," *American Economic Journal: Macroeconomics*, 7, 197–232.

COIBION, O., Y. GORODNICHENKO, AND D. KOUSTAS (2013): "Amerisclerosis? The Puzzle of Rising U.S. Unemployment Persistence," *Brookings Papers on Economic Activity*, pp. 193–241.

DE VEIRMAN, E. (2007): "Which Nonlinearity in the Phillips Curve? The Absence of Accelerating Deflation in Japan," Reserve Bank of New Zealand Discussion Paper 2007/14.

DEBORTOLI, D., AND N. RICARDO (2014): "Monetary Regime-Switches and Central Bank Preferences," *Journal of Money, Credit and Banking*, forthcoming.

ELLISON, M. (2006): "The Learning Cost of Interest Rate Reversals," *Journal of Monetary Economics*, 53, 1895–1907.

EUSEPI, S. (2005): "Central Bank Transparency and Model Uncertainty," Federal Reserve Bank of New York, Staff Report no. 199.

FITZGERALD, T., AND J. P. NICOLINI (2014): "Is There a Stable Relationship between Unemployment and Future Inflation? Evidence from U.S. Cities," Federal Reserve Bank of Minneapolis, Working Paper 713.

IAKOVA, D. (2007): "Flattening of the Phillips Curve : Implications for Monetary Policy," IMF Working Paper, WP/07/76.

IMF (2013): "The Dog That Didn't Bark: Has Inflation Been Muzzled or Was it Just Sleeping?," World Economic Outlook.

IRELAND, P. N. (2004): "Technology Shocks in the New Keynesian Model," *Review of Economics and Statistics*, 86(4), 923–936.

KLEIBERGEN, F., AND S. MAVROEIDIS (2008): "Weak Instrument Robust Tests in GMM and the New Keynesian Phillips Curve," *Journal of Business and Economic Statistics*, 27(3).

KLENOW, P. J., AND O. KRYVTSOV (2008): "State-Dependent or Time-Dependent Pricing: Does It Matter for Recent U.S. Inflation," *Quarterly Journal of Economics*, 123(4), 863–904.

KUTTNER, K., AND T. ROBINSON (2010): "Understanding the Flattening of the Phillips Curve," *North American Journal of Economics and Finance*, 21, 110–125.

MATHESON, T., AND E. STAVREV (2013): "The Great Recession and the Inflation Puzzle," IMF Working Paper, WP/13/124.

MISHKIN, F. S. (2007): "Inflation Dynamics," NBER Working Paper No. 13147.

MOESSNER, R. (2006): "Optimal Discretionary Policy in Rational Expectations Models with Regime Switching," Bank of England Working Paper No. 299.

MUSSO, A., L. STRACCA, AND D. VAN DIJK (2009): "Instability and Nonlinearity in the Euro-Area Phillips Curve," *International Journal of Central Banking*, 5, 181–212.

NAKAMURA, E., AND J. STEINSSON (2008): "Five Facts About Prices: A Proposal To Replace the New Keynesian Phillips Curve," *Quarterly Journal of Economics*, 123(4), 1415–1464.

ROBERTS, J. M. (2006): "Monetary Policy and Inflation Dynamics," *International Journal of Central Banking*, 2, 193–230.

ROTEMBERG, J. J. (1982): "Monopolistic Price Adjustment and Aggregate Output," *The Review of Economic Studies*, 49(4), 517–531.

SMETS, F., AND R. WOUTERS (2007): "Shocks and Frictions in US Business Cycles : A Bayesian DSGE Approach," *American Economic Review*, 97(3), 586–606.

STOCK, J. H., AND M. A. MARK A. WATSON (2010): "Modeling Inflation After the Crisis," Federal Reserve Bank of Kansas City, Proceedings of the Economic Policy Symposium; Jackson Hole, Wyoming.

SVENSSON, L. E., AND N. WILLIAMS (2007): "Monetary Policy with Model Uncertainty : Distributional Forecast Targeting," Princeton University, mimeo.

WILLIAMS, J. C. (2006): "The Phillips Curve in an Era of Will-Anchored Inflation Expectations," Working Paper, Federal Reserve Bank of San Francisco.

ZAMPOLLI, F. (2006): "Optimal Monetary Policy in a Regime-Switching Economy : The Response to Abrupt Shifts in Exchange Rate Dynamics," *Journal of Economic Dynamics and Control*, (30), 1527–1567.

ZBARACKI, M. J., M. RITSON, D. LEVY, S. DUTTA, AND M. BERGEN (2004): "Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets," *Review of Economics and Statistics*, 86(2), 514–533.

Appendix

A. Deriving the Phillips Curve Under Changing Costs of Price Adjustment

For $s_t = 1$, the conditional first-order condition after distributing the $\varphi(s_{t+1})$ term is

$$
\begin{aligned}
0 = {} & (1 - \theta_t)\, \Delta_t \left(\frac{P_t(j)}{P_t} \right)^{-\theta_t} \left(\frac{Y_t}{P_t} \right) + \theta_t \Delta_t \Psi_t \left(\frac{P_t(j)}{P_t} \right)^{-\theta_t - 1} \left(\frac{Y_t}{P_t} \right) - \qquad \text{(A-1)} \\
& \varphi(1)\, \Delta_t \left(\frac{P_t(j)}{\Pi P_{t-1}(j)} - 1 \right) \left(\frac{Y_t}{\Pi P_{t-1}(j)} \right) + \\
& \beta p_{11} \varphi(1)\, E_t \left[\Delta_{t+1} \left(\frac{P_{t+1}(1, j)}{\Pi P_t(j)} - 1 \right) \left(\frac{P_{t+1}(1, j) Y_{t+1}(1)}{\Pi P_t(j)^2} \right) \right] + \\
& \beta(1 - p_{11})\, \varphi(2)\, E_t \left[\Delta_{t+1} \left(\frac{P_{t+1}(2, j)}{\Pi P_t(j)} - 1 \right) \left(\frac{P_{t+1}(2, j) Y_{t+1}(2)}{\Pi P_t(j)^2} \right) \right],
\end{aligned}
$$

where $P_{t+1}(i, j)$ represents the nominal price for firm j when $s_{t+1} = i$ and $Y_{t+1}(i)$ represents final output when $s_{t+1} = i$. An analogous first-order condition exists for $s_t = 2$, except p_{11} is replaced with $(1 - p_{22})$ and $(1 - p_{11})$ is replaced with p_{22}. Using $(A - 1)$, the firm's optimal pricing condition for $s_t = 1$, after imposing $P_t(j) = P_t$, is given by

$$
\begin{aligned}
0 = {} & (1 - \theta)\, \Delta_t \left(\frac{Y_t}{P_t} \right) + \theta \Delta_t \Psi_t \left(\frac{Y_t}{P_t} \right) - \varphi(1)\, \Delta_t \left(\frac{P_t}{\Pi P_{t-1}} - 1 \right) \left(\frac{Y_t}{\Pi P_{t-1}} \right) + \quad \text{(A-2)} \\
& \beta p_{11} \varphi(1)\, E_t \left[\Delta_{t+1}(1) \left(\frac{P_{t+1}(1)}{\Pi P_t} - 1 \right) \left(\frac{P_{t+1}(1) Y_{t+1}(1)}{\Pi P_t^2} \right) \right] + \\
& \beta(1 - p_{11})\, \varphi(2)\, E_t \left[\Delta_{t+1}(2) \left(\frac{P_{t+1}(2)}{\Pi P_t} - 1 \right) \left(\frac{P_{t+1}(2) Y_{t+1}(2)}{\Pi P_t^2} \right) \right],
\end{aligned}
$$

where substituting in $P_t / P_{t-1} = \Pi_t$ yields

$$
\begin{aligned}
0 = {} & (1 - \theta_t)\, \Delta_t + \theta_t \Delta_t \Psi_t - \varphi(1)\, \Delta_t \left(\frac{\Pi_t}{\Pi} - 1 \right) \left(\frac{\Pi_t}{\Pi} \right) + \qquad \text{(A-3)} \\
& \beta p_{11} \varphi(1)\, E_t \left[\Delta_{t+1}(1) \left(\frac{\Pi_{t+1}(1)}{\Pi} - 1 \right) \left(\frac{\Pi_{t+1}(1) Y_{t+1}(1)}{\Pi Y_t} \right) \right] + \\
& \beta(1 - p_{11})\, \varphi(2)\, E_t \left[\Delta_{t+1}(2) \left(\frac{\Pi_{t+1}(2)}{\Pi} - 1 \right) \left(\frac{\Pi_{t+1}(2) Y_{t+1}(2)}{\Pi Y_t} \right) \right].
\end{aligned}
$$

Log-linearizing around the constant steady state yields

$$
\begin{aligned}
0 = \ & \left(1 - \theta\left(1 + \widehat{\theta}_t\right)\right) \Delta\left(1 + \widehat{\Delta}_t\right) + \theta\left(1 + \widehat{\theta}_t\right) \Delta\left(1 + \widehat{\Delta}_t\right) \Psi\left(1 + \psi_t\right) - \quad\quad\text{(A-4)} \\
& \varphi\left(1\right) \Delta\left(1 + \widehat{\Delta}_t\right) \pi_t\left(1 + \pi_t\right) + \\
& \beta p_{11} \varphi\left(1\right) E_t\left[\Delta\left(1 + \widehat{\Delta}_{t+1}\left(1\right)\right) \pi_{t+1}\left(1\right)\left(1 + \pi_{t+1}\left(1\right)\right)\left(1 + Y_{t+1}\left(1\right)\right)\left(1 - Y_t\right)\right] + \\
& \beta\left(1 - p_{11}\right) \varphi\left(2\right) E_t\left[\Delta\left(1 + \widehat{\Delta}_{t+1}\left(2\right)\right) \pi_{t+1}\left(2\right)\left(1 + \pi_{t+1}\left(2\right)\right)\left(1 + Y_{t+1}\left(2\right)\right)\left(1 - Y_t\right)\right],
\end{aligned}
$$

where $\pi_t = \log\left(\Pi_t/\Pi\right)$, $\psi_t = \log\left(\Psi_t/\Psi\right)$, $\widehat{\Delta}_t = \log\left(\Delta_t/\Delta\right)$, and $\widehat{\theta}_t = \log\left(\theta_t/\theta\right)$. Values without a time subscript are steady-state values. Eliminating higher-order terms and using $\Psi = \theta^{-1}\left(\theta - 1\right)$ yields

$$
\pi_t = \beta p_{11} E_t\left[\pi_{1,t+1}\right] + \left(1 - p_{11}\right)\beta\frac{\varphi_2}{\varphi_1} E_t\left[\pi_{2,t+2}\right] + \frac{\left(\theta - 1\right)}{\varphi_1}\left(\psi_{1t} + u_t\right), \quad\quad\text{(A-5)}
$$

where $u_t = -\left(\theta - 1\right)^{-1}\widehat{\theta}_t$. The same approach is taken for $s_t = 2$, where the general representation can be rewritten as (9).

B. Deriving the Utility-Based Welfare Criterion

If prices are fully flexible, then monopolistic firms set prices using

$$
\left(\frac{P_t\left(j\right)}{P_t}\right) = \frac{\theta_t}{\left(\theta_t - 1\right)}\frac{W_t}{P_t},
$$

where in a symmetric equilibrium

$$
\left(W_t/P_t\right) = \mu_t^{-1}.
$$

Substituting this expression into (12) and using $Y_t = C_t = H_t$ gives

$$
\left(1 + \nu\right)\frac{1}{\mu_t} = \frac{Y_t^{\eta}}{Y_t^{-\sigma}},
$$

where $(1 + \nu)\, \mu^{-1} = 1$ by construction, where then solving for the steady-state yields the efficient steady-state level for production of $Y^* = 1$. Under the labor subsidy, monetary policy focuses on stabilization policies, versus policies to undo the monopolistic distortion. Also, in the steady state, the monopolistic firm is not adjusting its price, so the changing parameter governing the costs of price adjustment does not create any distortions.

Substituting (14) into (10) yields

$$U\left(Y_t, \Pi_t, s_t\right) = \frac{\left(Y_t - \frac{\varphi(s_t)}{2}\left(\Pi_t - 1\right)^2\right)^{1-\sigma}}{1 - \sigma} - \frac{Y_t^{1+\eta}}{1 + \eta}. \tag{A-6}$$

The second-order approximation to the first term of the representative agent's period utility function is given by

$$\frac{\left(Y_t - \frac{\varphi(s_t)}{2}\left(\Pi_t - 1\right)^2\right)^{1-\sigma}}{1 - \sigma} \approx \frac{Y^{1-\sigma}}{1 - \sigma} + Y^{1-\sigma}\left(\frac{Y_t - Y}{Y}\right) - \frac{1}{2}\sigma Y^{1-\sigma}\left(\frac{Y_t - Y}{Y}\right)^2 \tag{A-7}$$

$$- \frac{\varphi\left(s_t\right)}{2} Y^{-\sigma}\left(\Pi_t - 1\right)^2. \tag{A-8}$$

Second-order approximations of the relative deviations in terms of the log deviations are

$$\frac{Y_t - Y}{Y} \approx \widehat{y}_t + \frac{1}{2}\widehat{y}_t^2 \tag{A-9}$$

$$\Pi_t - 1 \approx \widehat{\pi}_t + \frac{1}{2}\widehat{\pi}_t^2 \tag{A-10}$$

which yields

$$\frac{\left(Y_t - \frac{\varphi(s_t)}{2}\left(\Pi_t - 1\right)^2\right)^{1-\sigma}}{1 - \sigma} \approx \frac{Y^{1-\sigma}}{1 - \sigma} + Y^{1-\sigma}\left(\widehat{y}_t + \frac{1}{2}\widehat{y}_t^2\right) -$$

$$\frac{1}{2}\sigma Y^{1-\sigma}\left(\widehat{y}_t + \frac{1}{2}\widehat{y}_t^2\right)^2 - \frac{\varphi\left(s_t\right)}{2} Y^{-\sigma}\left(\pi_t + \frac{1}{2}\pi_t^2\right)^2.$$

Removing terms higher than second order and denoting terms independent of policy as *t.i.p.*

yields

$$\frac{\left(Y_t - \frac{\varphi(s_t)}{2}\left(\pi_t - 1\right)^2\right)^{1-\sigma}}{1-\sigma} \approx Y^{1-\sigma}Y_t + \frac{1}{2}Y^{1-\sigma}\widehat{y}_t^2 - \frac{1}{2}\sigma Y^{1-\sigma}\widehat{y}_t^2 \tag{A-11}$$

$$-\frac{\varphi(s_t)}{2}Y^{-\sigma}\pi_t^2 + t.i.p. \tag{A-12}$$

The second-order approximation to the second term of the utility function is

$$\frac{Y_t^{1+\eta}}{1+\eta} \approx Y^{1+\eta}\left(\frac{Y_t - Y}{Y}\right) + \frac{1}{2}\eta Y^{1+\eta}\left(\frac{Y_t - Y}{Y}\right)^2 + t.i.p. \tag{A-13}$$

Using second-order approximations in terms of log deviations yields

$$\frac{Y_t^{1+\eta}}{1+\eta} \approx Y^{1+\eta}\left(\widehat{y}_t + \frac{1}{2}\widehat{y}_t^2\right) + \frac{1}{2}\eta Y^{1+\eta}\left(\widehat{y}_t + \frac{1}{2}\widehat{y}_t^2\right)^2 + t.i.p. \tag{A-14}$$

$$= Y^{1+\eta}\widehat{y}_t + \frac{1}{2}Y^{1+\eta}\widehat{y}_t^2 + \frac{1}{2}\eta Y^{1+\eta}\widehat{y}_t^2 + t.i.p. \tag{A-15}$$

Combining both components of the utility function and removing $t.i.p.$ yields

$$U\left(Y_t, \pi_t, s_t\right) \approx Y^{1-\sigma}\widehat{y}_t + \frac{1}{2}Y^{1-\sigma}\widehat{y}_t^2 - \frac{1}{2}\sigma Y^{1-\sigma}\widehat{y}_t^2 - \frac{1}{2}\varphi(s_t)Y^{-\sigma}\pi_t^2 - Y^{1+\eta}\left(\widehat{y}_t + \frac{1}{2}\left(1+\eta\right)\widehat{y}_t^2\right).$$

Rearranging terms and setting $Y = 1$ yields

$$U\left(Y_t, \pi_t, s_t\right) \approx Y^{1-\sigma}\widehat{y}_t + \frac{1}{2}Y^{1-\sigma}\widehat{y}_t^2 - \frac{1}{2}\sigma Y^{1-\sigma}\widehat{y}_t^2 - \frac{1}{2}\varphi(s_t)Y^{-\sigma}\pi_t^2 - Y^{1+\eta}\left(\widehat{y}_t + \frac{1}{2}\left(1+\eta\right)\widehat{y}_t^2\right),$$

$$= -\frac{1}{2}\varphi(s_t)\left(\pi_t^2 + \frac{(\sigma+\eta)}{\varphi(s_t)}\widehat{y}_t^2\right).$$