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The timeless perspective vs. discretion: theory and monetary policy implications for an open economy

Alfred V. Guender
(University of Canterbury, Christchurch, New Zealand)

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Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-1
Telex within Germany 41227, telex from abroad 414431

Please address all orders in writing to: Deutsche Bundesbank,
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Abstract:

This paper proposes an open-economy Phillips Curve that features a real exchange rate channel. The resulting target rule under optimal policy from a timeless perspective (TP) involves additional history dependence in the form of lagged inflation. The target rule also depends on the discount factor as well as IS and Phillips Curve parameters. This is in sharp contrast to a closed economy where the target rule depends only on the change in the output gap, the current rate of inflation and the structural parameter in the Phillips Curve. Because of the additional history dependence in an open economy, price level targeting is no longer consistent with optimal policy. If a real exchange rate channel does not exist in the Phillips Curve, monetary policy eases in the wake of a positive cost-push disturbance under policy from a TP and is thus diametrically opposed to same under discretion. Maximum gains accrue from commitment relative to discretion in an open economy where the real exchange rate is absent from the Phillips Curve and the policymaker places strong emphasis on maintaining price stability.

Keywords: Timeless Perspective, Discretion, Price Level Targeting, Exchange Rate Channel.

JEL-Classification: E52, F41

Non-technical summary

The objective of the current paper is to address the conduct of optimal policy in an open-economy framework. A series of issues are considered. They are:

- What is the appropriate objective function of the policymaker in an open economy?
- The Phillips Curve: is it the same for both closed and open economies?
- Is the conduct of optimal monetary policy in a small open economy different from that in a closed economy?
- What are the gains from policy under commitment relative to pure discretion in an open economy?
- Is price-level targeting in an open economy consistent with policy from a timeless perspective?

One of several important findings of this paper is that the conduct of optimal monetary policy in an open economy differs markedly from same in a closed economy even if the objectives of society are the same. In an open economy, under both optimal policy from a timeless perspective and pure discretion, demand side and supply side parameters affect the weight the policymaker accords to the output gap in setting policy. This result stands in marked contrast to a closed economy setting where only one supply-side parameter is involved in determining the weight on the output gap in the target rule. The existence of a real exchange rate channel in the open-economy Phillips Curve accounts for the different specification of the target rule in the open-economy framework under both the timeless perspective and pure discretion. An important implication for monetary policy is that the effects on the target variables of demand side disturbances or disturbances that arise in the foreign exchange market can no longer be offset by manipulating the nominal interest rate. Adjusting the nominal rate of interest rate in response to such shocks, the central bank causes the real exchange rate to change, which in turn displaces the output gap and the rate of inflation from their target levels. Because of the importance of the real exchange rate channel in the Phillips

Curve, the current rate of inflation takes on a more prominent role vis-à-vis the current output gap in the policy-setting process in an open economy compared to a closed economy.

Another significant finding concerns the specification of the target rule in an open economy under policy from a timeless perspective. This form of policy under commitment exhibits additional *history dependence* provided that a real exchange rate channel is operational in the Phillips Curve. The target rule depends also on the lagged rate of inflation next to the current rate of inflation and the change in the output gap.

Evaluating the performance of policy from a timeless perspective versus discretion, the paper establishes that the impact effects of all disturbances on the target variables are smaller under the timeless perspective than discretion. While unambiguously superior to pure discretion from the standpoint of society's welfare, policy under the timeless perspective leads to greater variability of the output gap and the real exchange rate than discretionary policy.

The paper concludes with an assessment of the attractiveness of price level targeting in an open economy. As shown by Woodford (1999a), this policy strategy is consistent with policy from a timeless perspective in a closed economy. This result does not carry over to the open economy framework employed in this paper.

Nicht-technische Zusammenfassung

Das Ziel dieses Papiers ist es, die optimale Politik in einer offenen Volkswirtschaft zu analysieren. Dabei werden eine Reihe von Fragen angegangen:

- Was ist die angemessene Zielfunktion der Notenbank in einer offenen Volkswirtschaft?
- Ist die Phillipskurve in offenen und geschlossenen Volkswirtschaften identisch?
- Ist die optimale Geldpolitik in einer geschlossenen Volkswirtschaft verschieden von der in einer kleinen offenen Volkswirtschaft?
- Was gewinnt man, wenn man in einer offenen Volkswirtschaft eine sogenannte Politik der Selbstbindung verfolgt gegenüber einer diskretionären Politik?
- Besteht in einer offenen Volkswirtschaft zwischen einer Politik, die ein Preisniveauziel verfolgt, und einer sogenannten „Politik ohne Zeitabhängigkeit“, wie sie von Woodford (1999 a) definiert wurde, Übereinstimmung?

Ein wichtiges Ergebnis dieses Papiers ist, dass die optimale Politik in einer geschlossenen Volkswirtschaft merklich anders ist als in einer offenen Volkswirtschaft, selbst wenn die Ziele die Gleichen sind. In einer offenen Volkswirtschaft beeinflussen Nachfrage- und Angebotsparameter das Gewicht, das die Notenbank dem Output-Gap beimisst. Dies gilt sowohl für eine diskretionäre Politik als auch für eine sogenannte „Politik ohne Zeitabhängigkeit“. Dies ist deutlich anders als in der geschlossenen Volkswirtschaft, in der nur ein Angebotsparameter wichtig ist. Entscheidend für dieses Ergebnis ist ein Wechselkurskanal in der Phillipskurve der offenen Volkswirtschaft. Er impliziert, dass Störungen von der Nachfrageseite her oder vom Devisenmarkt nicht mit der Zinspolitik neutralisiert werden können. Wenn die Notebank dies versuchen würde, würde sie den realen Wechselkurs beeinflussen, was wiederum dazu führt, dass Output und Inflation von ihrem Zielwert abweichen. Diese Zusammenhänge haben auch zur Folge, dass in der offenen Volkswirtschaft - verglichen mit einer geschlossenen Volkswirtschaft - die Inflationsrate im Verhältnis zum Output eine wichtigere Rolle spielt, wenn es um die Bestimmung der Politik geht. Ein anderes wichtiges Ergebnis betrifft die Spezifikation der Zielregel in einer offenen Volkswirtschaft, wenn man eine

„Politik ohne Zeitabhängigkeit“ verfolgt. Wenn ein Wechselkurskanal existiert, dann führt diese Politik dazu, dass neben der aktuellen auch vergangene Inflationsraten in der geldpolitischen Regel eine Rolle spielen (history dependence).

Im Vergleich mit einer diskretionären Politik sind die Effekte von Störungen auf die Zielwerte (Inflation und Output) bei einer „Politik ohne Zeitabhängigkeit“ geringer. Aus wohlfahrtstheoretischer Sicht ist eine „Politik ohne Zeitabhängigkeit“ einer diskretionären Politik eindeutig überlegen. Sie führt allerdings zu größerer Variabilität des Output-Gaps und des realen Wechselkurses.

Das Papier schließt mit einer Betrachtung, wie attraktiv in einer offenen Volkswirtschaft eine Politik ist, die ein Ziel für das Preisniveau verfolgt. Woodford hat gezeigt, dass in einer geschlossenen Volkswirtschaft eine solche Strategie mit einer „Politik ohne Zeitabhängigkeit“ übereinstimmt. Dies gilt nicht in einem Modell der offenen Volkswirtschaft, wie es hier verwendet wird.

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The Timeless Perspective vs. Discretion: Theory and Monetary Policy Implications for an Open Economy*

1 Introduction

For some time now central banks and academics have been preoccupied with the way monetary policy ought to be conducted in an era of relative price stability. Woodford (1999a) proposes that the course of monetary policy in a forward-looking New Keynesian framework be set from a timeless perspective (commitment). This form of policy has a number of desirable features. To begin with, policy from a timeless perspective introduces history-dependence into the conduct of monetary policy because it is based on an optimal policy rule that depends on the *change* in the output gap. The policy instrument responds to a cost-push shock in the current and subsequent periods until the target variables return to their original targets. The gradual adjustment process gives rise to persistence in the behavior of the output gap and the rate of inflation. Because the conduct of policy is history-dependent under policy from the timeless perspective, this strategy dominates pure discretion under which the response of the target variables to the cost-push shock is confined to the current period. Moreover, since policy from a timeless perspective is a time-consistent form of optimal policy under commitment it serves as a standard of comparison for other forms of discretionary policy that also inject an element of history-dependence into policymaking such as price-level targeting, a speed limit policy, nominal income growth targeting, average inflation targeting or money growth targeting. Jensen (2002), Néssen and Vestin (2005), Soederstroem (2005), Vestin (2006), and Walsh (2003) evaluate the aforementioned discretionary strategies in a closed economy setting and verify to what extent these policies achieve the optimal stabilization results under policy from a timeless perspective.

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* Department of Economics, University of Canterbury, Private Bag 4800, Christchurch, New Zealand. E-mail: alfred.guender@canterbury.ac.nz Phone: (64)-3-364-2519. Fax: (64)-3-364-2635.

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This paper discusses several aspects of policymaking that arise in an open economy framework. The paper begins with analyzing the conduct of optimal monetary policy from a timeless perspective and under pure discretion in a simple forward-looking open economy framework. Central to our discussion of optimal policy in an open economy is a Phillips Curve that features a real exchange rate channel. This exchange rate channel appears in the Phillips Curve because domestic firms are concerned about their competitiveness at home and in world markets where their products compete with those produced by foreign firms. An important objective of a typical domestic firm is to avoid fluctuations in its firm-specific terms of trade. Hence an incipient rise in the foreign price of the competing foreign good or a rise in the nominal exchange rate leads the typical domestic firm to raise the price of its output. This response pattern at the firm level leads to the appearance of the (negative) expected change of the real exchange in the aggregate Phillips Curve.

The existence of a real exchange rate channel in the Phillips Curve has an important consequence for the conduct of optimal policy in an open economy.[1,2] This paper shows that the optimal target rule in an open economy under both policy from a timeless perspective and pure discretion, respectively, is distinctly different from the target rule in a closed economy if a real exchange rate channel is operative in the Phillips Curve. Under pure discretion the target rule locks the contemporaneous rate of inflation and the output gap into a systematic relationship. In stark contrast to its closed economy counterpart, the coefficient on the output gap in the open economy target rule depends on demand-side parameters in addition to the two parameters that appear in the Phillips Curve. The coefficient on the output gap is also smaller in the open economy

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[1] This exchange rate channel is not the only factor that alters the design of optimal monetary policy. Monacelli (2005) argues that incomplete exchange rate pass-through drives a wedge between policymaking in open versus closed economies. He derives an open economy Phillips Curve where the deviation of the world price from the domestic currency price of imports affects domestic and CPI inflation.

[2] Other contributions where an exchange rate channel has major implications for the conduct of monetary policy are Ball (1999), Walsh (1999) and Svensson (2000). Drawing on empirical evidence that shows only weak correlations between changes in the nominal exchange rates and inflation rates for a number of countries, McCallum and Nelson (2000, p. 89) are sceptical about the existence of a direct exchange rate channel and its relevance in policymaking. Moreover, in their theoretical set-up of an open economy the effect of the real exchange rate on the output gap is neutralized as it affects both the level of real output and the potential level of output in the same way. As a consequence, their Phillips Curve is the same as in a closed economy. Clarida, Gali, and Gertler (2001, 2002) and Gali and Monacelli (2005) derive essentially a closed-economy Phillips Curve too except that the coefficient on marginal cost is sensitive to the degree of openness of the economy.

rule than in the closed economy rule, suggesting that policymaker attaches less weight to the output gap in the conduct of optimal discretionary policy in an open economy.

The target rule in an open economy under policy from a timeless perspective is more complex than the target rule under pure discretion. This rule depends not only on parameters that appear in the IS relation and the Phillips Curve but also on the discount factor. The open economy target rule is history-dependent too but differs from its closed economy counterpart in a critical way: the open economy target rule under policy from a timeless perspective also features the lagged rate of inflation in addition to the lagged output gap. However, unlike the output gap, the rate of inflation does not enter the target rule in first-difference form.

The examination of optimal policy in a forward-looking open economy framework brings out a number of additional results that in turn have important implications for policymaking in an open economy. Comparing policy under a timeless perspective to discretion, we find that the former dominates the latter unambiguously. Policy under the timeless perspective also shields the target variables – the output gap and the domestic rate of inflation - better than discretion from the impact effects of all disturbances. Yet the overall variability of the output gap and the real exchange rate is larger under the timeless perspective than under discretion. Under policy from a timeless perspective, an adverse cost-push shock prompts the policymaker to "lean with the wind", i.e. lower the nominal interest rate provided that a real exchange rate channel in the Phillips Curve does not exist. If this channel exists, then the policymaker raises the interest rate. Such an ambiguous response cannot occur under discretion irrespective of whether a real exchange channel exists or not.

A final noteworthy finding concerns price level targeting in an open economy framework. Woodford (1999a) and Vestin (2006) argue that in a simple closed economy forward-looking model, price level targeting is consistent with optimal policy from a timeless perspective. This result does not carry over to the open economy framework proposed in this paper. There is a simple explanation for this result. The target rule under policy from a timeless perspective depends on the lagged rate of inflation. This has the effect of augmenting the history-dependence of optimal policy and rules out expressing the target rule governing price level targeting in such a way so as to be consistent with the target rule underpinning optimal policy from a timeless perspective. With the targeting rules being incongruous, the delegation of a price level target to a central banker with the requisite aversion to price level variability does not conform to optimal policy from a timeless perspective in an open economy even if the shocks follow a white noise process.

The organization of the remaining parts of the paper is as follows. Section 2 introduces the model. Section 3 analyzes the optimal conduct of monetary policy from a timeless perspective. To highlight the importance of an exchange rate channel in the Phillips Curve for the conduct of optimal policy, we begin our analysis with a standard version, i.e. closed-economy version of the Phillips Curve. We then re-examine the conduct of optimal policy from a timeless perspective under the assumption that the exchange rate channel is operative in the Phillips Curve. Section 4 examines the case of pure discretion. Section 5 compares and contrasts the two forms of optimal policy. Section 6 takes up the discussion of the compatibility of price level targeting with optimal policy from a timeless perspective in an open economy framework. Section 7 offers a brief conclusion.

2 The Model

The model that will serve as the foundation for the analysis of the monetary policy issues is laid out in the appendix and consists of three equations:

$$y_t = E_t y_{t+1} - a_1(R_t - E_t \pi_{t+1}^{CPI}) + a_2(q_t - E_t q_{t+1}) + a_3(y_t^f - E_t y_{t+1}^f) + v_t \quad (1)$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t + b(q_t - E_t q_{t+1}) + u_t \quad (2)$$

$$R_t - E_t \pi_{t+1} = R_t^f - E_t \pi_{t+1}^f + E_t q_{t+1} - q_t + \varepsilon_t \quad (3)$$

$\pi_t =$ the rate of domestic inflation

$E_t \pi_{t+1}^{CPI} =$ the expected rate of CPI inflation

q_t = the real exchange rate[3]

y_t = the output gap

R_t = the nominal rate of interest (policy instrument)

R_t^f = the foreign nominal rate of interest

$E_t \pi_{t+1}^f$ = expected foreign rate of inflation

y_t^f = the foreign output gap

Lower case variables represent logarithms. All parameters are positive. The discount factor β is less than or equal to one.

Equation (1) is the forward-looking open economy IS relation that features a real interest rate and real exchange rate channel. A foreign output shock and an idiosyncratic shock also affect the demand for domestic output. Equation (2) represents the open-economy Phillips Curve. The current rate of inflation moves not only in response to positive or negative realizations of the output gap but also in response to deviations of the current real exchange rate from its expectation next period. Equation (3) represents the uncovered interest rate parity (UIP) condition. Stochastic disturbances have been added to the three relations to reflect the existence of uncertainty in the economy.[4] More formally,

$$u_t \sim N(0,\sigma_u^2) \qquad v_t \sim N(0,\sigma_v^2) \qquad \varepsilon_t \sim N(0,\sigma_\varepsilon^2)$$

$$R_t^f \sim N(0,\sigma_{R^f}^2) \qquad \pi_t^f \sim N(0,\sigma_{\pi^f}^2) \qquad y_t^f \sim N(0,\sigma_{y^f}^2) \tag{4}$$

To simplify the analysis, we treat all foreign variables as white-noise random variables that are independent of each other.

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[3] The real exchange rate is defined as the difference between the domestic currency price of the foreign good and the price of the domestic good: $q_t = s_t + p_t^f - p_t$. s_t = the nominal exchange rate, expressed in terms of domestic currency per unit of foreign currency.

[4] The appendix shows how the domestic IS disturbance and the cost-push shock can be motivated. The shock in the UIP condition can be thought of as a risk-premium. The property that all shocks are white noise follows Woodford (1999). Its purpose is to show that gradual adjustment of the output gap, the rate of inflation, etc. and the policy instrument is not exclusively tied to the presence of autocorrelated disturbances in the model.

3 Optimal Monetary Policy from a Timeless Perspective

The policymaker has a standard objective function consisting of squared deviations of the real output gap and the rate of inflation, respectively. The rate of inflation is defined in terms of changes in the level of domestic prices. The explicit objective function that he attempts to minimize is given by

$$E_t[\sum_{i=0}^{\infty}\beta^i[y_{t+i}^2+\mu\pi_{t+i}^2]]\,. \tag{5}$$

All variables are as previously defined. β is the discount rate and μ represents the relative weight the policymaker attaches to the squared deviations of the rate of domestic inflation. Equation (5) implies that the policymaker's sole concern rests with real output and domestic inflation. Fluctuations in the real exchange rate do not enter explicitly the loss function.[5] [6]

To set the stage for illustrating how optimal policy in the open economy is carried out, it is helpful at the outset to reduce the dimension of the optimization problem to one involving only one constraint. A few simple steps need to be taken. First, we substitute for the rate of CPI inflation in Equation (1).[7] Next, we solve the UIP condition for the difference between the real exchange rate and the expected real exchange rate and substitute this expression into both the IS equation and the Phillips curve relation. We then solve the IS relation for the expected real rate of interest ($R_t - E_t\pi_{t+1}$). Following this, we insert the expression for the expected real rate of interest into the Phillips curve relation. The following expression results:

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[5] Adopting (5) as the welfare criterion ignores the effects on welfare of shifts in the real exchange rate on the potential level of real output. Including only the output gap and the rate of domestic inflation in the loss function is rather typical in the literature and thus facilitates comparing the results of this article to earlier contributions (e.g. Aoki (2001), Clarida, Gali, and Gertler (1999, 2001, 2002) or Svensson (2000)). Kirsanova, Leith, and Wren-Lewis (2006) also include domestic inflation in the objective function, arguing that the production of output requires only domestic labor. For a contrasting view the reader is referred to Allsopp, Kara, and Nelson (2006) who argue that CPI inflation is the relevant inflation target variable if production is based on a foreign intermediate input.

[6] The target for the output gap and the rate of inflation is zero, respectively.

[7] Under perfect exchange rate pass-through $E_t\pi_{t+1}^{CPI} = E_t\pi_{t+1} + \gamma E_t\Delta q_{t+1}$ where γ denotes the weight on the price of the imported good in the CPI.

$$\begin{aligned}\pi_t &= (\kappa + \frac{b}{a_1(1-\gamma)+a_2})y_t + \beta E_t\pi_{t+1} \\ &+ \frac{b}{a_1(1-\gamma)+a_2}\left[a_1(R_t^f - E_t\pi_{t+1}^f + \varepsilon_t) - (E_t y_{t+1} + v_t) - a_3(y_t^f - E_t y_{t+1}^f)\right] + u_t\end{aligned} \tag{6}$$

The minimization exercise thus reduces to the following:

$$\underset{y_t,\pi_t}{Min} \quad E_t[\sum_{i=0}^{\infty}\beta^i[y_{t+i}^2 + \mu\pi_{t+i}^2]] \text{ subject to} \tag{7}$$

$$\begin{aligned}\pi_t &= (\kappa + \frac{b}{a_1(1-\gamma)+a_2})y_t + \beta E_t\pi_{t+1} \\ &+ \frac{b}{a_1(1-\gamma)+a_2}\left[a_1(R_t^f - E_t\pi_{t+1}^f + \varepsilon_t) - (E_t y_{t+1} + v_t) - a_3(y_t^f - E_t y_{t+1}^f)\right] + u_t\end{aligned}$$

Let the time period in which the policy problem is formulated be denoted by *t=0*. Then the Lagrangean can be written in the following form:

$$\begin{aligned}\mathrm{M}_0 = E_0[&y_0^2 + \mu\pi_0^2 + \beta(y_1^2 + \mu\pi_1^2) + \beta^2(y_2^2 + \mu\pi_2^2) + \ldots.. \\ &+ \lambda_0((\kappa+c)y_0 + \beta\pi_1 + c(-y_1 - a_3(y_0^f - y_1^f) - v_0 + a_1\Omega_0) + u_0 - \pi_0) \\ &+ \beta\lambda_1((\kappa+c)y_1 + \beta\pi_2 + c(-y_2 - a_3(y_1^f - y_2^f) - v_1 + a_1\Omega_1) + u_1 - \pi_1) \\ &+ \beta^2\lambda_2((\kappa+c)y_2 + \beta\pi_3 + c(-y_3 - a_3(y_2^f - y_3^f) - v_2 + a_1\Omega_2) + u_2 - \pi_2) + \ldots..]\end{aligned} \tag{8}$$

where $\Omega_t = R_t^f - E_t\pi_{t+1}^f + \varepsilon_t$ $\qquad c = \frac{b}{a_1(1-\gamma)+a_2}$

$t = 0,1,2,...$

Taking the first-order conditions with respect to the two endogenous variables in each time period yields the following set of equations:

$$\frac{\partial \mathrm{M}_0}{\partial y_0} = 2y_0 + \lambda_0(\kappa + c) = 0 \tag{9}$$

$$\frac{\partial \mathrm{M}_0}{\partial y_1} = 2\beta y_1 - \lambda_0 c + \lambda_1\beta(\kappa + c) = 0 \tag{10}$$

$$\frac{\partial \mathrm{M}_0}{\partial y_2} = 2\beta^2 y_2 - \lambda_1\beta c + \lambda_2\beta^2(\kappa + c) = 0 \tag{11}$$

…

…

$$\frac{\partial \mathrm{M}_0}{\partial \pi_0} = 2\mu\pi_0 - \lambda_0 = 0 \tag{12}$$

$$\frac{\partial \mathrm{M}_0}{\partial \pi_1} = 2\mu\pi_1 + \lambda_0 - \lambda_1 = 0 \tag{13}$$

$$\frac{\partial \mathrm{M}_0}{\partial \pi_2} = 2\mu\pi_2 + \lambda_1 - \lambda_2 = 0 \tag{14}$$

…

…

In the remainder of this section we draw attention to the importance of a real exchange rate channel in the Phillips Curve and discuss its implication for optimal policymaking in an open economy framework. Part A takes up the case where the real exchange rate channel is suppressed while Part B considers the case where the real exchange rate channel is operative. Part C analyzes the behavior of the endogenous variables of the model and the policy instrument with the help of impulse response functions.

3.1 No Real Exchange Rate Channel in the Phillips Curve: *b=0*

Setting $b=0$ implies $c=0$. Closer inspection of equations (9)-(11) then reveals that the first-order condition for the output gap in each period establishes the same systematic relationship between the output gap and the Lagrange multiplier:

$$2y_t + \lambda_t \kappa = 0 \qquad t = 0, 1, 2, 3, \ldots \tag{15}$$

The invariant optimizing condition for the output gap is used below to substitute for the Lagrange multipliers to derive the optimal policy setting from a timeless perspective. Under this policy the policymaker ignores the start-up condition for the rate of inflation. Only the systematic relationship between the Lagrange multipliers and the rate of inflation from time $t=1$ onward is relevant:[8]

$$2\mu\pi_t + \lambda_{t-1} - \lambda_t = 0 \qquad t = 1, 2, 3, \ldots \tag{16}$$

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[8] Woodford (1999a,b) and McCallum and Nelson (2004) provide a detailed analysis of optimal policy from a timeless perspective in a closed economy framework.

After using equation (15) to substitute for the Lagrange multipliers, we can express the target rule under optimal policy from the timeless perspective as:

$$\pi_t + \frac{y_t - y_{t-1}}{\mu\kappa} = 0 \tag{17}$$

Thus in an open economy optimal policy from a timeless perspective is identical to optimal policy in a closed economy framework provided that there is no direct exchange rate channel in the Phillips Curve. This result is consistent with the observation by Clarida, Gali, and Gertler (2001), according to whom the conduct of optimal policy in an open economy is isomorphic to policy in a closed economy.

3.2 A Real Exchange Rate Channel in the Phillips Curve: *b>0*

With the direct exchange rate channel being operative, the structure of the first-order condition that applies to the output gap is no longer the same for all periods. More specifically, the condition in the initial period is different from the one that obtains in succeeding periods. In this respect the pattern followed by the output gap in the current context mirrors the pattern set by the rate of inflation in the previous section. In the start-up period the first-order condition that applies to the output gap is given by

$$2y_0 + \lambda_0(\kappa + c) = 0 \tag{18}$$

while for subsequent periods the first-order condition is given by

$$2\beta y_1 - \lambda_0 c + \lambda_1 \beta(\kappa + c) = 0\,. \tag{19}$$

Notice that the Lagrange multiplier of the initial period (λ_0) appears in both first-order conditions. It appears in the first-order condition for the output gap in period *1* because the output gap in period *1* appears as an element in the constraint that the policymaker faces. Thus forward-looking behavior on the demand side of the economy is now instrumental in determining the optimizing condition that applies to the output gap.

The first-order conditions for the rate of inflation in the initial period and period 1 are unaffected by the existence of a direct exchange rate channel in the Phillips Curve:

$$2\mu\pi_0 - \lambda_0 = 0 \tag{20}$$

$$2\mu\pi_1 + \lambda_0 - \lambda_1 = 0 \tag{21}$$

Due to the existence of an exchange rate channel in the Phillips Curve, optimal monetary from a timeless perspective cannot be conducted along the lines described in the previous section. The optimal behavior of real output in period *1* differs from that in the initial period. This being the case, the Lagrange multipliers λ_0 and λ_1 in equation (21) can no longer be substituted by drawing on the invariant initial optimizing condition for output for the initial period and the subsequent period.

To design a time-consistent policy rule in an open-economy framework, the policymaker must disregard the optimizing condition for *both* target variables in the initial period, i.e. period *0*. Thus, the policymaker must also ignore the initial optimizing condition for real output. The derivation of the target rule then requires the optimizing conditions from period *1* onward and proceeds as follows. Solve equation (14) for λ_2, substitute the resulting expression into equation (11), and solve for λ_1. Then substitute for λ_1 in equation (13) and solve for λ_0. Next replace both Lagrange multipliers in equation (10) with the expressions for λ_0 and λ_1 to obtain the optimal target rule:

$$\frac{y_2 - y_1}{\mu(\kappa + c)} + (\pi_2 - \frac{c}{\beta(\kappa + c)}\pi_1) = 0\,. \tag{22}$$

More generally,

$$\frac{y_t - y_{t-1}}{\mu(\kappa + c)} + (\pi_t - \frac{c}{\beta(\kappa + c)}\pi_{t-1}) = 0 \qquad c = \frac{b}{a_1(1-\gamma) + a_2} \tag{23}$$

for all periods except the initial period.

Just like its counterpart in Section 3, the target rule embodied by equation (23) is history-dependent as it is based on the change in the output gap. Notice, however, that the weight on the change in the output gap is smaller in case the Phillips Curve features a real exchange rate channel as $c > 0$. Moreover there is an additional source of history dependence as the target rule for an open economy is based on not only on the lagged output gap but also on lagged inflation. Interestingly, it is not the *change* in inflation that matters in the open-economy target rule. The lagged rate of inflation bears a coefficient different from unity.

Unlike the standard target rule (equation (17)), which depends only on κ apart from the policymaker's preference parameter, the optimal policy rule for the open economy depends also on parameters that appear in the Phillips Curve and the IS relation. The interest and exchange rate (semi) elasticities a_1 and a_2 as well as b determine the coefficients on the change in the output gap and on the lagged rate of inflation. The discount factor also plays an explicit role in the determination of the target rule.

It is instructive to examine how the relative size of the parameters of the model affects the weight on the change in the output gap and the weight on lagged inflation in the target rule. Both coefficients can be thought of as relative weights since they reflect the importance in the conduct of policy of the change in the output gap and lagged inflation relative to current inflation. If both κ and b are large relative to a_1 and a_2 then the rate of inflation responds sensitively to the output gap and the expected change in the real exchange rate while the output gap's response through the expected real interest rate and exchange rate channel, respectively is rather muted. As a consequence, the policymaker attaches a low relative weight to the change in the output gap when setting policy. Conversely, if a_1 and a_2 are large relative to κ and b then the relative weight on the output gap in the target rule increases as the output gap reacts sensitively to the expected real interest rate and an expected change in the real exchange rate. In this event, only a small increase in the policy instrument is required to engineer a desired reduction in inflation through a contraction of real output. The relative weight on lagged inflation decreases as well given the increased emphasis on the output gap in setting policy.

The coefficient $\frac{c}{\beta(\kappa+c)}$ measures the importance of lagged inflation in the target rule. Lagged inflation enters the target rule because of the existence of an exchange rate channel in the Phillips Curve. The greater the sensitivity of the rate of inflation to expected changes in the real exchange rate in the Phillips Curve, i.e. the greater the size of b for given values of a_1, a_2 and κ, the more important the lagged rate of inflation becomes in setting policy today. Conversely, the greater the sensitivity of the rate of inflation to the output gap in the Phillips Curve, i.e. the greater the size of κ for given values of a_1, a_2, and *b*, the less significant the role of past inflation in the target rule.

3.3 Why a Real Exchange Rate Channel in the Phillips Curve Makes a Difference: A Look at Impulse Response Functions.

The importance of the real exchange rate channel for the behavior of the endogenous variables of the model and the policy instrument is brought out in Figures *1 – 4*.[9] These figures show how the output gap, domestic inflation, the real exchange rate, and the nominal interest rate respond to a cost-push shock, an IS shock, and a UIP shock.[10] Figure *1* depicts the response of the four variables to a positive cost-push shock when the real exchange rate channel in the Phillips Curve exists (*b=0.05)* while Figure *2* repeats the exercise for the case when the real exchange rate does not exist (*b=0)*.[11] A comparison of the impulse response function of the two figures reveals that in the wake of a positive cost-push shock, the optimal behavior of the output gap, the real exchange rate, the policy instrument but not the rate of inflation depends critically on whether $b = 0.05$ or $b = 0$. A positive cost-push shock has a much greater impact effect on the output gap and the real exchange rate if the real exchange rate channel exists in the Phillips Curve than when it does not exist. Because of the stronger impact effect, both the output gap and the real exchange rate initially adjust more slowly towards their respective long-run level if the exchange rate channel is operative in the Phillips Curve. After about eight periods, the adjustment path of the output gap and the real exchange rate are virtually identical for both cases, i.e. for *b=0.05* and *b=0*.[12]

The reaction of the policy instrument to a positive cost-push shock in Figure *1* is as expected if *b>0*. As in the standard closed-economy model (Woodford (1999)), policy tightens in response to a positive cost-push shock. Notice the stark difference in Figure *2*: choosing the optimal response to a cost-push shock, the policymaker lowers

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[9] All four figures are based on $\mu = 10$. Table *1* lists the values of the parameters upon which the impulse response analysis in this section is based. The table also lists the size of the variances of the shocks that figure in the comparisons of policy under discretion and from a timeless perspective carried out in the next section.

[10] The remaining shocks are only of minor interest as their effects are the same as or similar to a UIP or IS shock. For instance, a foreign interest rate shock causes the same effect on the variables of interest as a UIP shock while a shock to the foreign output gap behaves essentially like an IS shock.

[11] Here we choose *b* to be of the same size as κ.

[12] At the tick marking period 8 the broken lines traced up to the impulse response functions and then across to the vertical axis record nearly identical values.

the nominal interest rate if no real exchange rate channel exists in the Phillips Curve. The intriguing behavior of the nominal interest rate can be traced to the UIP condition. The positive cost- push shock leads to a fall in the expected change of the real exchange rate, i.e. the right-hand side of the UIP condition increases. At the same time, the positive cost-push shock lowers expected inflation next period because of the decrease in the current output gap, thus also increasing the left-hand side of the UIP condition.[13] However, the reduction in the current output gap is sufficiently large to require a fall in the nominal interest rate so that the UIP condition is restored in the aftermath of the cost-push shock.[14] Thus, we observe a striking pattern: in an open-economy framework where the Phillips Curve is of the same structural form as in the closed economy, i.e. $b=0$, the optimal response of the policymaker to a positive cost-push shock is diametrically opposed to the optimal response in a closed economy.

Figure *3* depicts the optimal responses of the four variables in the wake of a positive IS disturbance for the case $b=0.05$. The two top panels show that both the output gap and the domestic rate of inflation deviate from their target variables in case an IS disturbance hits the economy if a real exchange rate channel is operative in the Phillips Curve. More specifically, the policymaker is unable to prevent a demand-side disturbance from affecting both target variables temporarily. The responses of the policy instrument and the real exchange rate, which are shown in the bottom panels help explain why this is the case. In his effort to provide the optimal stabilization response, the policymaker raises the nominal interest rate. The positive change in the setting of the policy instrument causes the real exchange rate to appreciate which in turn has flow-on effects on the target variables:[15] the domestic rate of inflation decreases and the output gap increases. A closer look at the target rule also explains why the behavior of the two target variables is clearly different if the real exchange rate channel in the

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[13] As shocks are white noise, expected inflation next period is given by: $E_t\pi_{t+1} = c_{20}y_t$ with $c_{20} > 0$

[14] Inspection of the reduced form equation for the output gap and the reaction function of the policymaker yields the same insight. For $b=0, \mu = 10$ and values for the other parameters in accordance with Table *1*, the two equations are:

$$y_t = 0.853893y_{t-1} - 0.426946u_t$$

$$R_t = 1.82519y_t - 1.50094y_{t-1} + 0.750496u_t$$

Substituting the former into the latter results in a negative coefficient on the cost-push shock. The nominal interest rate decreases in the wake of a positive cost-push shock.

[15] Strictly speaking, the increase in the nominal rate of interest leads to, ceteris paribus, a decrease in the difference between the real exchange rate and the expected real exchange rate next period.

Phillips Curve does not exist. If $b = 0$, the target rule is the same as in the standard closed economy model where demand-side disturbances do not affect the target variables because the policymaker simply adjusts the interest rate to offset the effect of the demand-side disturbance on the output gap. This keeps the output gap fixed at its target level. Because the output gap does not change and because of the absence of a direct exchange rate channel there is no spillover effect onto the Phillips Curve. Thus domestic inflation does not deviate from its target level.[16]

The responses of the two target variables, the real exchange, rate and the policy instrument to a positive UIP disturbance appear in Figure *4*. The reaction of the four variables to a positive UIP shock is very similar to that of a positive IS disturbance, albeit in the opposite direction. The critical parameter that determines how close the responses of the four variables to an UIP shock mirror those of an IS disturbance is a_1. The closer this parameter is to one, the more similar the shape of the impulse response functions to an IS disturbance become to those associated with an UIP disturbance.

4 Optimal Policy under Pure Discretion

Under pure discretion, the policymaker sets policy anew in every period. In carrying out the minimization exercise at the beginning of a given period, the policymaker treats the expectations of the endogenous variables that appear in the constraint as constants. Because the policymaker re-optimizes every period, the start-up optimizing conditions of the target variables form the basis for the optimal target rule under discretion. These optimizing conditions are given by equations (9) and (12):

$$2y_0 + \lambda_0(\kappa + c) = 0 \qquad (9) \qquad\qquad 2\mu\pi_0 - \lambda_0 = 0 \qquad (12)$$

Combining equation (9) with equation (12) yields the optimal target rule under discretion:

$$\frac{1}{\mu(\kappa + c)} y_0 + \pi_0 = 0 \qquad\qquad c = \frac{b}{a_1(1-\gamma) + a_2}.$$

More generally,

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[16] If $b=0$, the response of the policy instrument to an IS disturbance is identical to that of the real exchange rate, albeit in the opposite direction. For the sake of brevity, both impulse response functions have been omitted from the paper.

$$\frac{1}{\mu(\kappa+c)}y_t+\pi_t=0 \qquad\qquad t=0,1,2... \qquad (24)$$

Thus the optimal target rule under pure discretion does not introduce history dependence into the conduct monetary policy.[17] Compared to a closed economy framework, the weight on the output gap is smaller provided that there is a real exchange rate channel in the Phillips Curve, i.e. $c > 0$.

5 An Evaluation of the Two Policy Regimes

In this section we compare and contrast the performance of optimal policy from a timeless perspective relative to pure discretion in an open economy. Initially, we isolate the impact effect of three disturbances on the rate of inflation, the output gap, the real exchange rate, and the nominal rate of interest. Subsequently, our attention turns to measuring the overall size of fluctuations in the four aforementioned variables. To underscore the importance for policymaking of the existence of a real exchange rate channel in the Phillips Curve, we again distinguish between two cases: $b=0.05$ and $b=0$. In addition, we employ two different values of the policymaker's relative aversion to inflation variability: $\mu=1$ and $\mu=10$.

Table *2* reports the coefficients on the three disturbances in the reduced form equations for the three endogenous variables and the policy instrument. The coefficients in the top panel capture the contemporaneous response of the four variables to an IS shock, a cost-push shock, and a UIP shock for the case where a real exchange rate channel is operative in the Phillips Curve: $b=0.05$. Inspection of these coefficients yields a number of noteworthy insights. First, the impact effect of all three disturbances on the two target variables y_t and π_t are smaller under policy from a timeless perspective than under discretion. This is a direct consequence of the fact that commitment requires that the two target variables return gradually to their target levels in the wake of a shock while discretion requires adjustment of the variables to a shock within the period. Second, the impact effect (in absolute terms) of a cost-push disturbance on all four variables is smaller under policy from a timeless perspective

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[17] Examining the impulse response functions under discretion is not as revealing as under policy from the timeless perspective. Because of the absence of history dependence under discretion, the effect of the shock is felt only in the current period.

than discretion. Third, the picture is less clear for the remaining shocks. Inspecting the coefficients on the IS disturbance, we find that the contemporaneous reaction of the real exchange rate and the nominal rate, respectively, under policy from a timeless perspective exceeds that under discretion. For a UIP shock, only the real exchange rate prompts a larger contemporaneous response under policy from a timeless perspective compared to discretion.

The lower panel reports results for the case where a real exchange rate channel in the Phillips Curve does not exist. Here policy matters for the reaction of the policy instrument in the face of a cost-push shock. While discretionary policy will see to it that the policy instrument rises in response to a positive cost-push shock, policy from a timeless perspective results in a lowering of the policy instrument as explained in the previous section. In the absence of a real exchange rate channel in the Phillips Curve, IS and UIP shocks have no effect on the target variables under both forms of policy. Notice further that both policy from a timeless perspective and discretionary policy lead to the same contemporaneous response of the real exchange rate and the nominal rate of interest, respectively, to IS and UIP disturbances. This happens because the responses of both variables are purely mechanical in the sense that they depend neither on whether policy is conducted along discretionary lines or from a timeless perspective nor on the preference parameter μ.[18]

Table *3* summarizes the overall performance of the two targeting strategies and reports the variances of the three endogenous variables and the policy instrument for $\mu = 1$ and $\mu = 10$. The top panel considers the case where a real exchange rate channel is operative in the Phillips Curve while the bottom panel considers the case where it is absent. The dominance of policy under a timeless perspective over discretion is evident. In all four cases expected losses under policy from a timeless perspective are lower than under discretion. Notice though that the percentage gain from commitment relative to discretion depends very much on whether a real exchange rate channel exists in the

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[18] It is also worth pointing out that under discretion, the coefficient on the UIP shock in the reduced form equation for the real exchange equals one minus the coefficient on the UIP shock in the equation for the nominal exchange rate. This result holds also under policy from a timeless perspective provided the real exchange rate channel in the Phillips Curve is not operative. The real exchange rate and the nominal rate of interest respond alike to an IS shock albeit in opposite directions under discretion. This result also holds under commitment if $b=0$.

Phillips Curve. Substantial gains are realized in an open economy where the Phillips Curve is the closed-economy variant. Specifically, the gain from commitment rises from *4.63*% to *12.47*% as the relative weight on the variance of inflation in the expected loss function rises from $\mu = 1$ to $\mu = 10$. In stark contrast, the gain from commitment actually decreases slightly from *4.25*% to *4.21%* as μ increases from *1* to *10* and a real exchange rate channel is operative in the Phillips Curve.

While discretion is unambiguously an inferior policy choice relative to commitment from the standpoint of expected loss minimization, the discretionary conduct of monetary policy results in smaller fluctuations of the output gap and the real exchange rate irrespective of the size of the policymaker's preference parameter μ. Indeed, if $\mu = 1$ discretionary policymaking yields smaller fluctuations in the policy instrument as well as the output gap and the real exchange rate.

6 Is Price Level Targeting Consistent with Optimal Monetary Policy from a Timeless Perspective in an Open Economy?

Woodford (1999a) argues that price level targeting is consistent with optimal policy from a timeless perspective in the forward-looking model of a closed economy. This is a direct consequence of the fact that price level targeting produces the same optimal response to disturbances as policy under the timeless perspective. The literature on the delegation issue in the conduct of monetary policy has recognized the attractiveness of price level targeting in the forward-looking model.[19] That price level targeting under discretion is compatible with optimal monetary policy from a timeless perspective can be seen by comparing the target rules that underlie both strategies of monetary policy.

The target rule under optimal policy from the timeless perspective relates the rate of inflation to the change in the output gap:

$$\frac{1}{\mu\kappa}(y_t - y_{t-1}) + \pi_t = 0 \qquad (25)$$

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[19] See Vestin (2006) for an analysis of price-level targeting and the delegation issue in the context of a closed economy.

This target rule can be rewritten in terms of the output gap and the price level:[20]

$$\frac{1}{\mu\kappa}(1-L)y_t+(1-L)p_t=0 \text{ or}$$

$$\frac{1}{\mu\kappa}y_t+p_t=0 \tag{26}$$

The target rule under discretionary price level targeting is given by:

$$p_t+\frac{y_t(\beta(1-\phi_{22})+1)}{\kappa\hat{\mu}}-\frac{E_ty_{t+1}}{\kappa\hat{\mu}}=0 \tag{27}$$

The parameter $\hat{\mu}$ denotes the weight the policymaker assigns to the squared deviations of price level from its target value in his intertemporal loss function. After replacing the expectation of the output gap with $\phi_{12}p_t$ and some algebraic manipulation, we can restate equation (27) as:[21]

$$\frac{(\beta(1-\phi_{22})+1)y_t}{\kappa\hat{\mu}-\beta\phi_{12}}+p_t=0 \tag{28}$$

Comparing (26) with (28), we find that the two target rules differ only to the extent of the relative weight on the output gap. This in turn implies that in a closed-economy framework a suitably chosen central banker who engages in discretionary price level targeting can replicate the behavior of the rate of inflation and the output gap that occur under optimal policy from a timeless perspective.

To examine whether society can achieve the same outcome in the open-economy framework proposed in this paper, we return to the target rule of Section 2 that guides optimal policy from a timeless perspective:

$$\frac{y_t-y_{t-1}}{\mu(\kappa+c)}+(\pi_t-\frac{c}{\beta(\kappa+c)}\pi_{t-1})=0 \qquad c=\frac{b}{a_1(1-\gamma)+a_2} \tag{29}$$

If we can show that the target rule under discretionary price level targeting is compatible with equation (23), then the delegation of monetary policy to a suitably chosen central banker also works to society's benefit in the open economy framework.

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[20] In what follows we assume that the target for the price level (p^*) is zero.

[21] ϕ_{12} = the coefficient on the lagged price level in the putative solution for the current price level. ϕ_{22} = the coefficient on the lagged price level in the putative solution for the current output gap.

The target rule that applies to discretionary price level targeting in the open economy is given by:[22]

$$\frac{[\beta(1-\phi_{22})+c\phi_{12}+1]y_t}{(\kappa+c)\hat{\mu}-\beta\phi_{12}}+p_t=0 \tag{30}$$

Inspection of (23) and (29) reveals that the two target rules are incongruous. That is to say that the target rule under optimal policy from the timeless perspective cannot be manipulated so as to be expressed solely in terms of the output gap and the price level, the two variables that appear in the target rule under discretionary price level targeting. The direct implication of this result is that discretionary price level targeting in the open economy cannot replicate the behavior of the rate of inflation and the output gap that eventuate under optimal policy from a timeless perspective. The delegation of a price level target to a central banker, who acts with discretion, does not achieve the gains that accrue from commitment in the open economy.

The breakdown of the delegation process in the open economy is due to the lack of history dependence of policy under price level targeting. At the very least, policy would have to respond to the lag of the price level to make the target rule under discretionary price level targeting compatible with the target rule under optimal policy from the timeless perspective.[23] Stated differently, optimal policy under the timeless perspective makes the conduct of monetary policy depend on the lagged output gap and the lagged rate of inflation. Thus there are two sources that account for the history dependence and produce the optimal degree of inertia in the conduct of optimal policy under commitment.

Further inspection of the target rules under optimal policy from a timeless perspective and discretionary price level targeting shows that the breakdown of the delegation process in an open economy framework is due to the existence of an exchange rate channel in the Phillips Curve. Setting $b=0$ yields $c=0$. Most important, the lagged rate of inflation drops out of the target rule under optimal policy from a

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[22] The derivation of this equation is laid out in Appendix C.

[23] This can best be seen by setting $\beta=1$ and rewriting equation (23) in terms of the output gap and the price level:

$$\frac{1}{\mu(\kappa+c)}y_t+p_t-\frac{c}{\kappa+c}p_{t-1}=0$$

timeless perspective. This in turn restores the compatibility of discretionary price level targeting with optimal policy from a timeless perspective.

7 Conclusion

This paper has examined the design of optimal monetary policy in an open economy version of the forward-looking model. One major finding is that the target rules under policy from a timeless perspective and pure discretion are more complex in an open economy if an exchange rate channel exists in the Phillips Curve. The existence of such a channel introduces the lags of both target variables into the target rule that governs optimal policy from a timeless perspective. In addition, the discount factor as well as parameters that appear in the IS relation and the Phillips Curve help determine the weights attached to the change in the output gap and the lagged rate of inflation. Under pure discretion, the target rule depends only on the current output gap and the current rate of inflation.

Optimal policy from a timeless perspective in an open economy differs thus from same in a closed economy in several critical respects. First, there is an additional source of history dependence of policy as the target rule in an open economy includes the lagged rate of inflation. Second, the target rule features weights on the change in the output gap and the lagged rate of inflation that are sensitive to demand-side elasticities. Finally, the discount factor enters the target rule.

As in a closed economy, commitment dominates discretion in an open-economy framework, too. However, the gains from commitment are smaller for an open-economy specification of the Phillips Curve. Indeed, the gains from commitment actually decrease if a real exchange rate channel exists and the policymaker puts strong emphasis on controlling the variance of inflation. Under policy from a timeless perspective, the variance of the output gap and the real exchange rate are greater than under discretion. An interesting finding emerges in the open-economy framework if the real exchange rate channel is not operative in the Phillips Curve and the policymaker uses commitment. In this case, a positive cost-push shock evokes a decrease in the nominal interest rate as the adverse effect of the shock on the output gap lowers expected inflation. Under discretion, the same shock prompts the policymaker to raise the nominal interest rate irrespective of whether a real exchange rate channel exists or not in the Phillips Curve.

The paper has also uncovered one important implication for policy that a real exchange rate channel in the Phillips Curve generates. Discretionary price level targeting is consistent with optimal policy from a timeless perspective in a closed economy because the target rules that govern both strategies are compatible in the sense that they can be expressed in terms of the same target variables. This result does not carry over to the open economy framework of this paper because the timeless perspective introduces additional history dependence through inflation into the conduct of monetary policy. This additional history dependence cannot be matched by conventional price level targeting. However, this does not rule out the possibility that a suitably redefined price level targeting strategy achieves the outcomes associated with policy from a timeless perspective. Price level targeting in an open economy may have to take account of real exchange rate effects on the domestic price level to be as effective as in a closed economy. Current research is exploring this issue further.

Taken altogether, the findings reported in this paper warrant the conclusion that optimal policy in an open economy framework may be substantially different from optimal policy in its closed economy counterpart. The mere existence of an exchange rate channel in the Phillips Curve suffices for the conduct of optimal monetary policy from a timeless perspective to be more complex and information-intensive. The realistic assumption that in a small open economy firms take account of the prevailing world market price in setting the domestic price of the consumption good ensures a prominent role for the real exchange rate in the design of optimal monetary policy.

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Appendix A:

This appendix provides a step-by-step derivation of the open economy IS relation and the open economy Phillips Curve.[24]

The IS Relation

Consumers maximize expected utility over their lifetime. Their utility function depends on the consumption level of the domestically produced final good and an imported final good.

The period utility function takes the following form:

$$U(C_t^h, C_t^f) = \frac{C(C_t^h, C_t^f)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} exp^{\omega_t} \tag{1}$$

where $\sigma > 0$ is the intertemporal elasticity of substitution and C measures aggregate consumption while C_t^h and C_t^f measure the quantity of the domestic and foreign consumption good, respectively. ω_t is a shock to consumer preferences. It follows an autoregressive process with persistence parameter $0 \leq \tau < 1$.[25]

From the standard *intertemporal* utility maximization problem, the following first-order condition obtains (lower case letter denotes deviation from steady state value):

$$c_t = E_t c_{t+1} - \sigma(R_t - E_t \pi_{t+1}^{CPI}) + (1-\tau)\sigma\omega_t \tag{2}$$

where c_t denotes aggregate consumption and $R_t - E_t \pi_{t+1}^{CPI}$ denotes the real rate of interest, defined as the difference between the nominal rate of interest and the CPI rate of inflation.

The *intratemporal* first-order condition yields the following relationship: the demand for the domestic consumption good is proportional to aggregate consumption and depends inversely on its relative price:

$$c_t^h = -\eta(p_t^h - p_t^{CPI}) + c_t \tag{3}$$

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[24] The derivation of the IS curve is largely based on Guender (2006).

[25] For the sake of simplicity, the IS shock used in Section 2 of the paper follows a white noise process. See McCallum and Nelson (1999) for a detailed analysis of optimizing behavior in both a stochastic and deterministic setting.

η measures the elasticity of substitution between the domestic and the foreign consumption good. p_t^{CPI} and p_t^h are defined as the consumer price index and the price of the domestic consumption good, respectively.

With η taken to equal unity, the consumer price index can be written as a weighted average of the price of the domestic and the imported foreign consumption good, respectively:

$$p_t^{CPI} = (1-\gamma)p_t^h + \gamma(p_t^f + s_t). \tag{4}$$

p_t^f represents the price of the foreign consumption good, s_t is the spot exchange rate at time *t*, defined as the units of domestic currency required to buy one unit of foreign currency, and γ denotes the weight of the price of the foreign good in the CPI.

Substituting (4) into (3) yields the following expression:

$$c_t^h = \eta\gamma q_t + c_t \tag{5}$$

where q_t represents the real exchange rate and is defined as $q_t = p_t^f + s_t - p_t^h$.

The next step consists of substituting (5) into (2):

$$c_t^h - \eta\gamma q_t = E_t c_{t+1}^h - \eta\gamma E_t q_{t+1} - \sigma(R_t - E_t \pi_{t+1}^{CPI}) + (1-\tau)\sigma\omega_t \tag{6}$$

Expressing the resource constraint as a log-linearized equation around the steady state levels yields:

$$y_t = (1-\gamma)c_t^h + \gamma c_t^{hf} \tag{7}$$

where y_t is the real output gap and c_t^{hf} is foreign consumption of domestic goods, i.e. domestic exports.

Foreign demand for the domestic consumption good evolves in accordance with equation (8):

$$c_t^{hf} = c_t^f + \eta^f \gamma^f q_t \tag{8}$$

Foreign consumption is proportional to foreign real output, i.e. $c_t^f = \beta^f y_t^f$. Hence (8) can be written as:

$$c_t^{hf} = \beta^f y_t^f + \eta^f \gamma^f q_t \tag{9}$$

Updating and taking expectations of the resource constraint (Equation (7)) yields:

$$E_t y_{t+1} = (1-\gamma) E_t c_{t+1}^h + \gamma E_t c_{t+1}^{hf} \tag{10}$$

After solving for $E_t c_{t+1}^h$, we can restate the above equation as follows:

$$\frac{E_t y_{t+1} - \gamma E_t c_{t+1}^{hf}}{1-\gamma} = E_t c_{t+1}^h \tag{10'}$$

Next, substitute (10') into (6):

$$c_t^h = \frac{E_t y_{t+1} - \gamma E_t c_{t+1}^{hf}}{1-\gamma} + \gamma\eta(q_t - E_t q_{t+1}) - \sigma(R_t - E_t \pi_{t+1}^{CPI}) + (1-\tau)\sigma\omega_t \tag{11}$$

Expression (11) can then be substituted back into expression (7):

$$y_t = E_t y_{t+1} + (1-\gamma)\left[\gamma\eta(q_t - E_t q_{t+1}) - \sigma(R_t - E_t \pi_{t+1}^{CPI}) + (1-\tau)\sigma\omega_t\right] + \gamma(c_t^{hf} - E_t c_{t+1}^{hf}) \tag{12}$$

Making use of equation (9), we can restate equation (12) as:

$$\begin{aligned} y_t = {} & E_t y_{t+1} - (1-\gamma)\sigma(R_t - E_t \pi_{t+1}^{CPI}) + \gamma[(1-\gamma)\eta + \eta^f \gamma^f](q_t - E_t q_{t+1}) + \\ & \gamma\beta^f (y_t^f - E_t y_{t+1}^f) + (1-\gamma)(1-\tau)\sigma\omega_t \end{aligned} \tag{13}$$

or

$$y_t = E_t y_{t+1} - a_1(R_t - E_t \pi_{t+1}^{CPI}) + a_2(q_t - E_t q_{t+1}) + a_3(y_t^f - E_t y_{t+1}^f) + v_t \tag{14}$$

where $a_1 = (1-\gamma)\sigma > 0$

$a_2 = \gamma[(1-\gamma)\eta + \eta^f \gamma^f] > 0$

$a_3 = \gamma\beta^f > 0$

$v_t = (1-\gamma)(1-\tau)\sigma\omega_t$

Equation (14) represents the open economy IS relation. It is common to interpret γ as reflecting the degree of openness of the economy. All structural coefficients of the IS equation are thus very sensitive to the degree of openness of the economy. v_t is referred to as a domestic IS disturbance.

Phillips Curve

The starting point is Rotemberg (1982). Monopolistically competitive firms aim to minimize menu costs weighed against the cost of being away from the optimal price they would charge in the absence of those menu costs. This optimal price is denoted p^{OPT}. In an open economy, an additional factor influences pricing decisions. The price at which output produced is set affects the real exchange rate (terms of trade).[26] Being concerned about changes in their competitiveness vis-à-vis foreign firms, domestic firms wish to avoid fluctuations in their terms of trade by engaging in terms-of-trade smoothing. Specifically, at time *t* they attempt to minimize the squared difference between the current and next period's terms of trade.[27] The objective function faced by the typical firm *j* is:

$$\min_{p(j)_t} \Omega(j)_t = E_t \sum_{i=0}^{\infty} \beta^i \left[\left(p(j)_{t+i} - p(j)_{t+i}^{OPT} \right)^2 + c\left(p(j)_{t+i} - p(j)_{t+i-1} \right)^2 + d(q(j)_{t+1+i} - q(j)_{t+i})^2 \right] \quad (15)$$

where:[1]

$\Omega(j)_t$ = the total cost of firm *j* at time *t*

$p(j)_t$ = the price of the good produced by firm *j* at time *t*

$p(j)_t^{OPT}$ = the optimal price firm *j* charges

$q(j)_t = p_t^f + s_t - p(j)_t$ = firm-specific terms of trade

β = the constant discount factor

c = the parameter that measures the costs of changing prices relative to the costs of deviating from the optimal price

d = the parameter that measures the costs of changes in the firm's terms of trade relative to the costs of deviating from the optimal price

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[26] Here the assumption is that domestic firms cannot price-discriminate in world markets. Pricing to market is ruled out. Firms treat the nominal exchange rate and the price of foreign goods as exogenous factors.

[27] Alternatively, the firm could be concerned about minimizing the deviation between q_{t+i} and q_{t+i-1} in which case the first-order condition would contain the change in the current firm-specific terms of trade next to the change in the expected terms of trade. The resulting Phillips Curve would then also feature the change in the real exchange rate ($q_t - q_{t-1}$).

E_t = the expectations operator conditional on information available at time t.

After taking and rearranging the first-order condition for the above cost-minimization problem, we can characterize the relationship between past, current, and future price levels as well as the current and expected terms of trade as:

$$p_t(j) - p(j)_{t-1} = \beta E_t\left(p(j)_{t+1} - p(j)_t\right) - \frac{1}{c}\left(p(j)_t - p(j)_t^{OPT}\right) - \frac{d}{c}\left(E_t q(j)_{t+1} - q(j)_t\right) \quad (16)$$

The optimal price p^{OPT} is:

$$p(j)_t^{OPT} = \hat{p}_t + \vartheta y(j)_t + \varsigma(j)_t \qquad \vartheta > 0 \qquad (17)$$

where all variables are as previously defined. In addition:

$\hat{p}_t$ = the price charged by competing firms at time *t*

$y(j)_t$ = output produced (relative to potential) by firm *j*

$\varsigma(j)_t$ = a stochastic disturbance.

Under imperfect competition, a firm sets its optimal price as a mark-up over marginal cost. But marginal cost and real output are positively related.[28] Hence it is innocuous to replace marginal cost with the output gap in (17). Typically, the mark-up factor is determined by the constant price elasticity of demand which would call for the addition of a constant to Equation (17). However, there is substantial empirical evidence that suggests that the mark-up factor varies considerably over the business cycle.[29] To capture the idea of a time-varying mark-up factor, we treat it as a random element that enters into the process of setting the optimal price. Hence ς_t appears in Equation (17).

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[28] Within a general equilibrium framework, the comovement between marginal cost and economic activity can be established by combining the labor supply and demand relations with the market clearing condition in the goods market. On this point see Clarida, Gali, and Gertler (2001, 2002) or Gali and Monacelli (2005) who derive a similar relation that stresses the positive relation between real marginal cost and domestic consumption. The positive link between output and marginal cost is also characteristic of earlier models of monopolistic competition such as Blanchard and Kiyotaki (1987). The link features also prominently in Mankiw and Reis (2002) who propose an alternative Phillips curve that is based on slow dissemination of information. In sharp contrast to the New Keynesian Phillips Curve this alternative Phillips Curve satisfies the Natural Rate Hypothesis.

[29] For a recent investigation of the time-varying mark-up factor, see Ball and Romer (2003).

The other important factor that influences the firm's optimal price is the benchmark price set by competing firms. This price, denoted by, $\hat{p}_t$ equals the aggregate domestic price level p_t.

Substituting Equation (17) into (16) and aggregating over all firms yields Equation (18), a Phillips Curve relation for an open economy:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t + b(q_t - E_t q_{t+1}) + u_t \qquad (18)$$

where

$$\pi_t = p_t - p_{t-1}$$

$$E_t \pi_{t+1} = E_t p_{t+1} - p_t$$

$$\kappa = \frac{\vartheta}{c}$$

$$b = \frac{d}{c}$$

$$u_t = \frac{1}{c} \varsigma_t .$$

Appendix B:

The solutions for the endogenous variables and the policy instrument of the model under policy from the *Timeless Perspective* are:

Output Gap:

$y_t = c_{10} y_{t-1} + c_{11} \pi_{t-1} + c_{12} u_t + c_{13} v_t + c_{14} \varepsilon_t$ where

$$c_{10} = \frac{1}{X + \theta Y}(\theta(Y + \Lambda)) \qquad c_{11} = \frac{c}{\beta} c_{10}$$

$$c_{12} = \frac{-\Lambda}{X + \theta Y} \qquad c_{13} = \frac{1}{X + \theta Y}(1 - \Lambda(\theta + \kappa))$$

$$c_{14} = \frac{1}{X + \theta Y}(a_2 - a_1 \gamma - \Lambda B)$$

Inflation:

$\pi_t = c_{20}y_{t-1} + c_{21}\pi_{t-1} + c_{22}u_t + c_{23}v_t + c_{24}\varepsilon_t$ where

$$c_{20} = \frac{\theta}{X+\theta Y}(X - \theta\Lambda) \quad c_{21} = \frac{c}{\beta}c_{20}$$

$$c_{22} = \frac{\theta\Lambda}{X+\theta Y} \qquad\qquad c_{23} = -\frac{\theta}{X+\theta Y}(1-\Lambda(\theta+\kappa))$$

$$c_{24} = -\frac{\theta}{X+\theta Y}(a_2 - a_1\gamma - \Lambda B)$$

Real Exchange Rate:

$q_t = c_{30}y_{t-1} + c_{31}\pi_{t-1} + c_{32}u_t + c_{33}v_t + c_{34}\varepsilon_t$ where

$$c_{30} = \frac{(-c_{46}+c_{20})c_{10} + Vc_{20} - c_{40}}{1-c_{10}} \qquad\qquad c_{31} = \frac{(-c_{47}+c_{21})c_{21} + Wc_{11} - c_{41}}{1-c_{21}}$$

$$c_{32} = Wc_{12} + Vc_{22} - c_{42} \qquad\qquad c_{33} = Wc_{13} + Vc_{23} - c_{43}$$

$$c_{34} = Wc_{14} + Vc_{24} - (1 + c_{44})$$

Nominal Interest Rate:

$R_t = c_{40}y_{t-1} + c_{41}\pi_{t-1} + c_{42}u_t + c_{43}v_t + c_{44}\varepsilon_t$ where

$$c_{40} = c_{46}c_{10} + c_{47}c_{20} - \frac{\Lambda\theta}{A} \qquad\qquad c_{41} = c_{46}c_{11} + c_{47}c_{21} - \frac{c\Lambda\theta}{\beta A}$$

$$c_{42} = c_{46}c_{12} + c_{47}c_{22} + \frac{\Lambda}{A} \qquad\qquad c_{43} = c_{46}c_{13} + c_{47}c_{23} + \frac{\Lambda(\theta+\kappa)}{A}$$

$$c_{44} = c_{46}c_{14} + c_{47}c_{24} + \frac{\Lambda B}{A} \qquad\qquad c_{46} = \frac{\Lambda}{A}(\theta+\kappa)c_{10} + (\frac{\Lambda\beta}{A}+1)c_{20}$$

$$c_{47} = \frac{\Lambda}{A}(\theta+\kappa)c_{11} + (\frac{\Lambda\beta}{A}+1)c_{21}$$

$$A = (1-\gamma)a_1 + a_2 \qquad\qquad B = b + (\theta+\kappa)(a_2 - a_1\gamma)$$

$$\Lambda = \frac{A}{(\theta+\kappa)A + b} \qquad\qquad \theta = \frac{1}{\mu(\kappa+c)} \qquad\qquad c = \frac{b}{A}$$

$$Y = c_{11} - \Lambda((\theta+\kappa)c_{11} + \beta c_{21}) \qquad X = 1 - (c_{10} - \Lambda((\theta+\kappa)c_{10} + \beta c_{20}))$$

$$W = c_{30} - c_{46} + c_{20} \qquad V = c_{31} - c_{47} + c_{21}$$

The solutions for the endogenous variables and the policy instrument of the model under *Discretion* are:

Output Gap:

$$y_t = \frac{1}{D}(-Au_t + bv_t - a_1 b\varepsilon_t)$$

Inflation:

$$\pi_t = -\frac{\theta}{D}(-Au_t + bv_t - a_1 b\varepsilon_t)$$

Real Exchange Rate:

$$q_t = \frac{1}{A}((a_1 - \frac{a_1 b}{D})\varepsilon_t - \frac{A}{D}((\theta+\kappa)v_t + u_t))$$

Nominal Interest Rate:

$$R_t = \frac{1}{A}((\frac{a_1 b}{D} + a_2 - a_1\gamma)\varepsilon_t + \frac{A}{D}((\theta+\kappa)v_t + u_t))$$

where $D = b + A(\theta+\kappa)$

Appendix C:

Under discretionary price-level targeting, the policymaker minimizes the current and expected future deviations of the price level and the output gap from its respective target value. The minimization exercise is repeated every period and the process of expectations formation is taken as given. The constraint for the policy problem is obtained by combining the UIP condition and the IS relation with the Phillips Curve.

$$\underset{y_t, p_t}{Min}\, E_t \sum_{j=0}^{\infty} \beta^j (y_{t+j}^2 + \hat{\mu}(p_{t+j} - p^*)^2)$$

$$\begin{aligned} s.t.\ p_t = \frac{1}{1+\beta}[\beta E_t p_{t+1} + (\kappa + c)y_t + u_t + p_{t-1} + \\ c(a_1(R_t^f - E_t\pi_{t+1}^f + \varepsilon_t) - (E_t y_{t+1} + v_t) - a_3(y_t^f - E_t y_{t+1}^f)) + u_t] \end{aligned} \tag{C1}$$

$\hat{\mu}$ = policymaker’s aversion to price level variability.

Taking the first-order conditions with respect to the choice variables y_t and p_t yields:

$$2y_t + \frac{\lambda_t(\kappa + c)}{1+\beta} = 0 \tag{C2}$$

$$2\hat{\mu}(p_t - p^*) + \lambda_t[\frac{1}{1+\beta}(\beta\phi_{22} - c\phi_{12}) - 1] + \frac{\beta E_t \lambda_{t+1}}{1+\beta} = 0 \tag{C3}$$

Notice that the conditional expectations of the price level and the output gap in period *t+1* have been replaced with the conditional expectation of the respective putative solution. The undetermined coefficients ϕ_{12} and ϕ_{22} appear in the putative solution for the output gap and the price level, respectively:

$$y_t = \phi_{11}u_t + \phi_{12}p_{t-1} + \phi_{13}v_t + \phi_{14}\varepsilon_t + \phi_{15}R_t^f + \phi_{16}y_t^f + \phi_{17}\pi_t^f \tag{C4}$$

$$p_t = \phi_{21}u_t + \phi_{22}p_{t-1} + \phi_{23}v_t + \phi_{24}\varepsilon_t + \phi_{25}R_t^f + \phi_{26}y_t^f + \phi_{27}\pi_t^f \tag{C5}$$

Combining the first-order conditions (and setting $p^* = 0$) results in the target rule that systematically relates the price level to the current and the expected output gap in period *t+1*.

$$p_t + \frac{y_t(\beta(1-\phi_{22}) + c\phi_{12} + 1)}{\hat{\mu}(\kappa + c)} - \frac{\beta E_t y_{t+1}}{\hat{\mu}(\kappa + c)} = 0 \tag{C6}$$

Letting $E_t y_{t+1} = \phi_{12}p_t$ and rearranging the above equation yields the target rule under price level targeting in the text (Equation (29)).

Figure 1: The Response of the Output Gap, Inflation, the Nominal Interest Rate, and the Real Exchange Rate to a Cost-Push Shock: b=0.05.

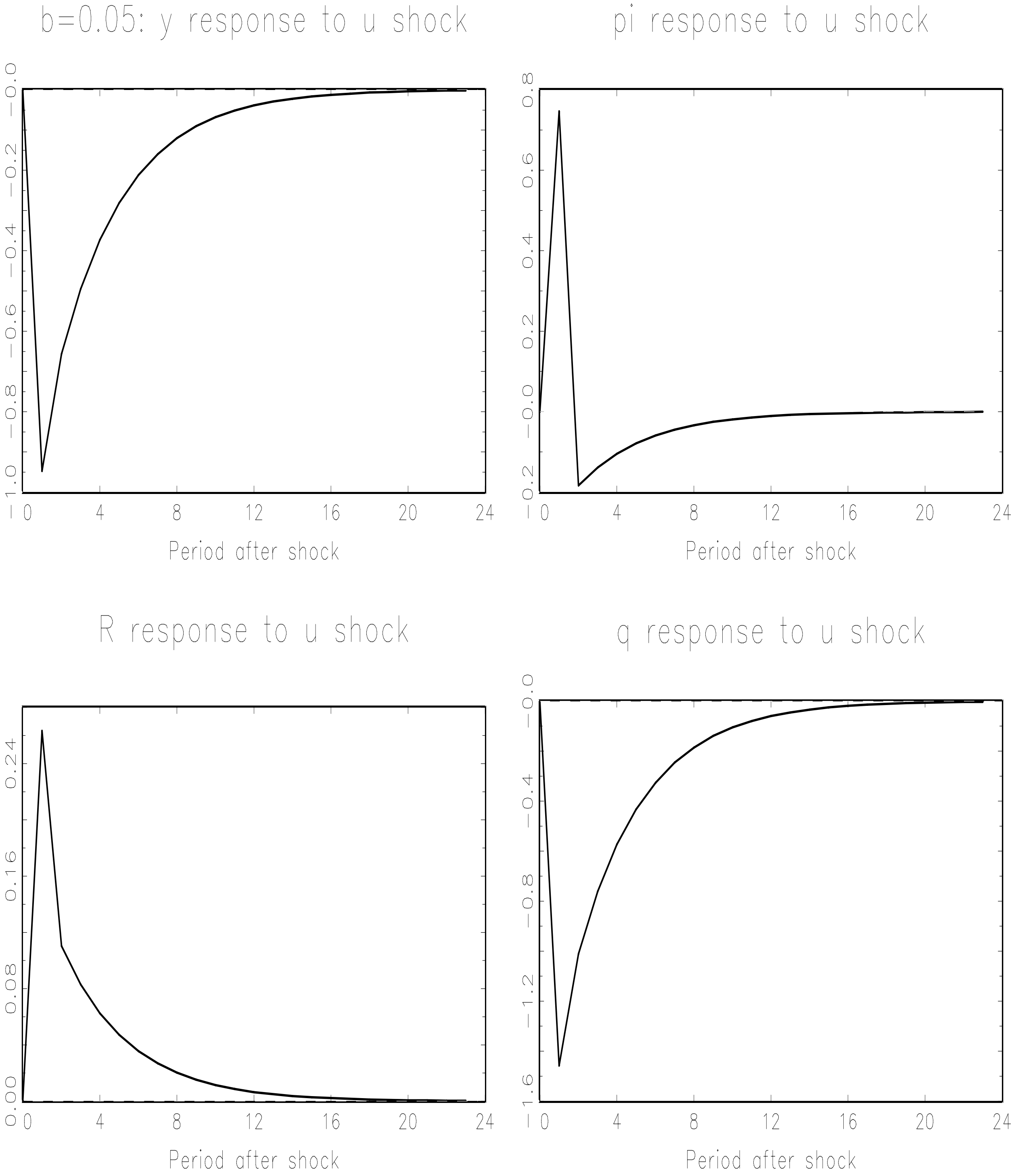


Figure 2: The Response of the Output Gap, Inflation, the Nominal Interest Rate, and the Real Exchange Rate to a Cost-Push Shock: b=0.

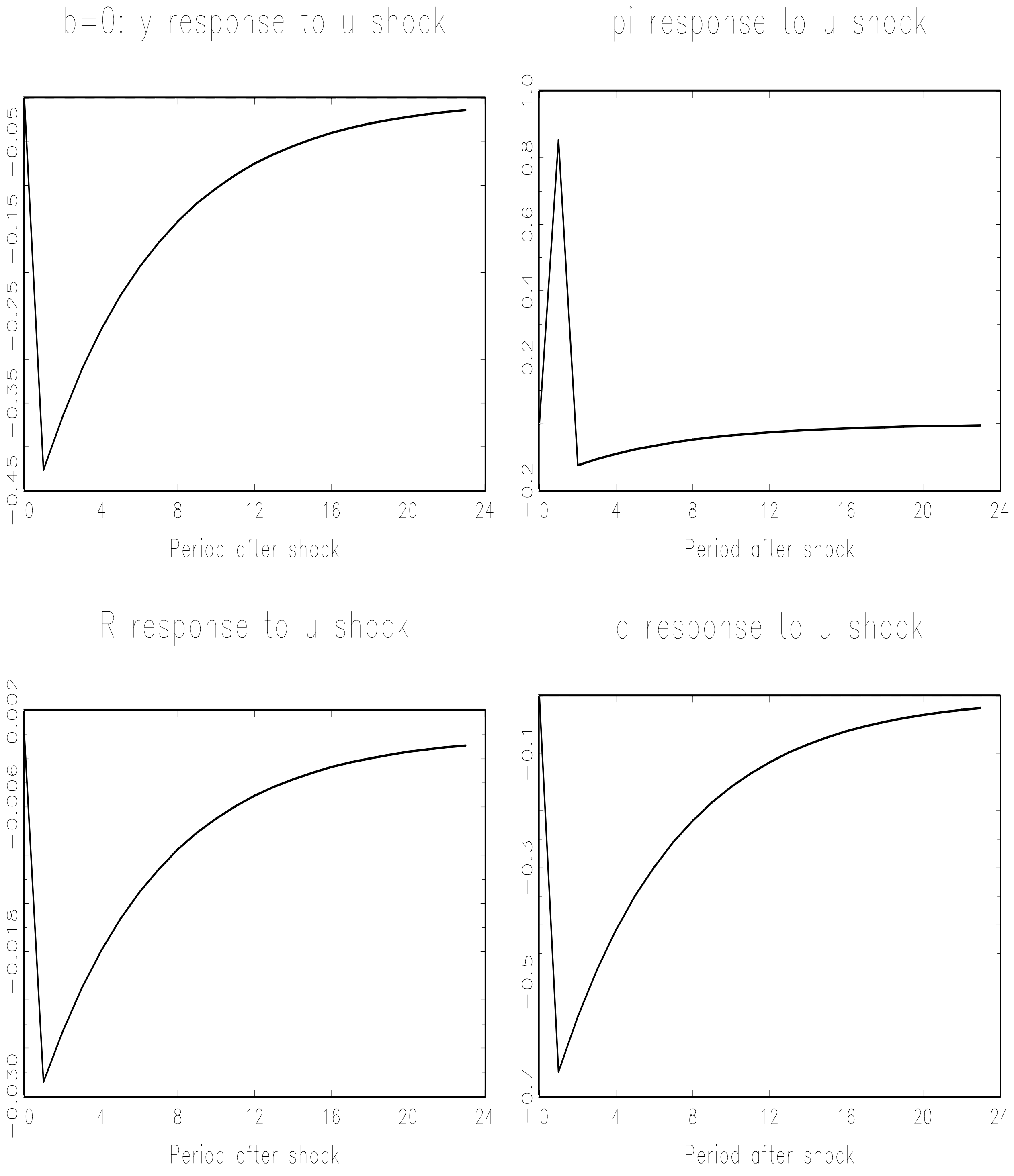
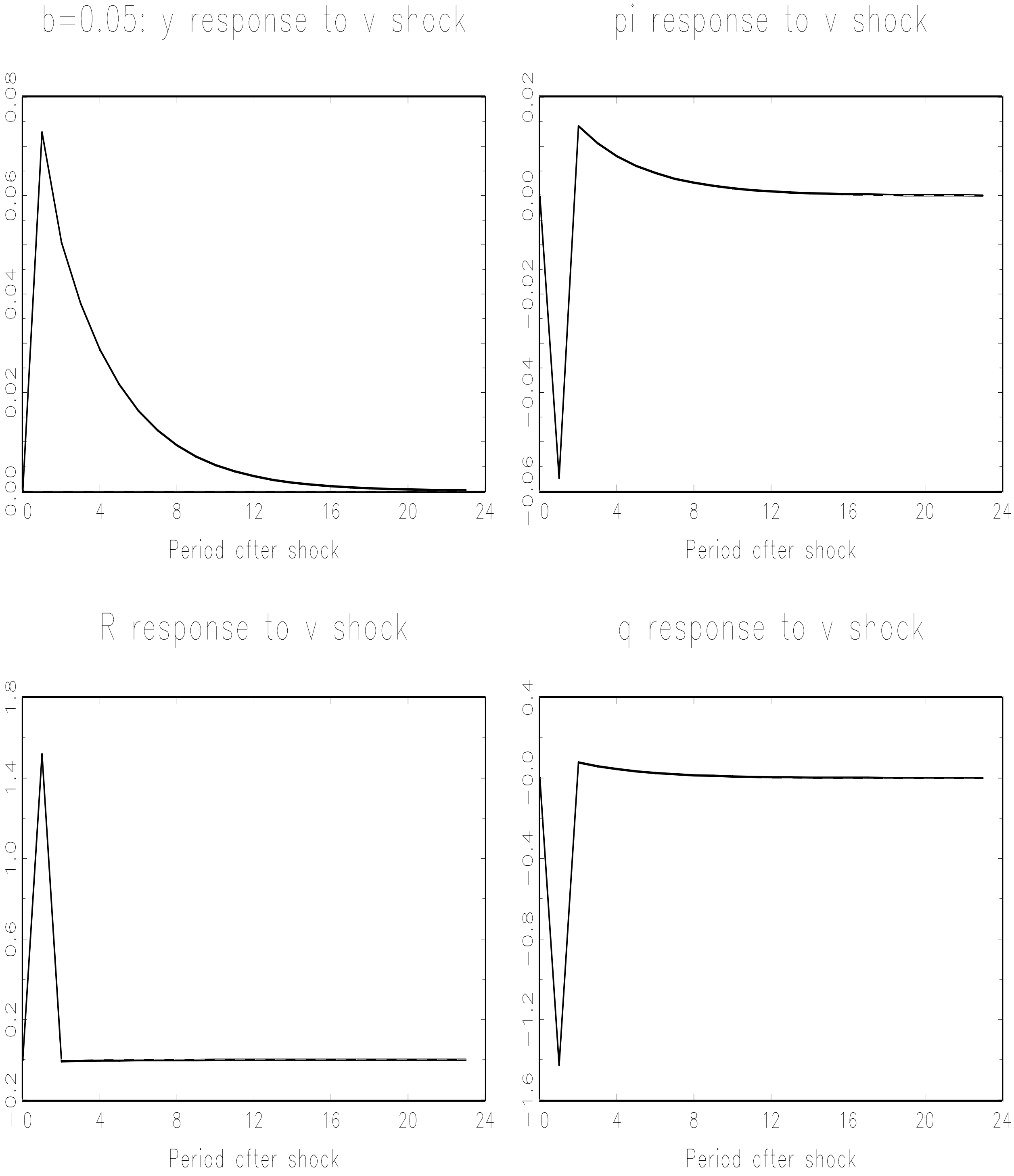


Figure 3: The Response of the Output Gap, Inflation, the Nominal Interest Rate, and the Real Exchange Rate to an IS Shock: b=0.05



b=0.05: y response to v shock

pi response to v shock

R response to v shock

q response to v shock

Figure 4: The Response of the Output Gap, Inflation, the Nominal Interest Rate, and the Real Exchange Rate to a UIP Shock: b=0.05

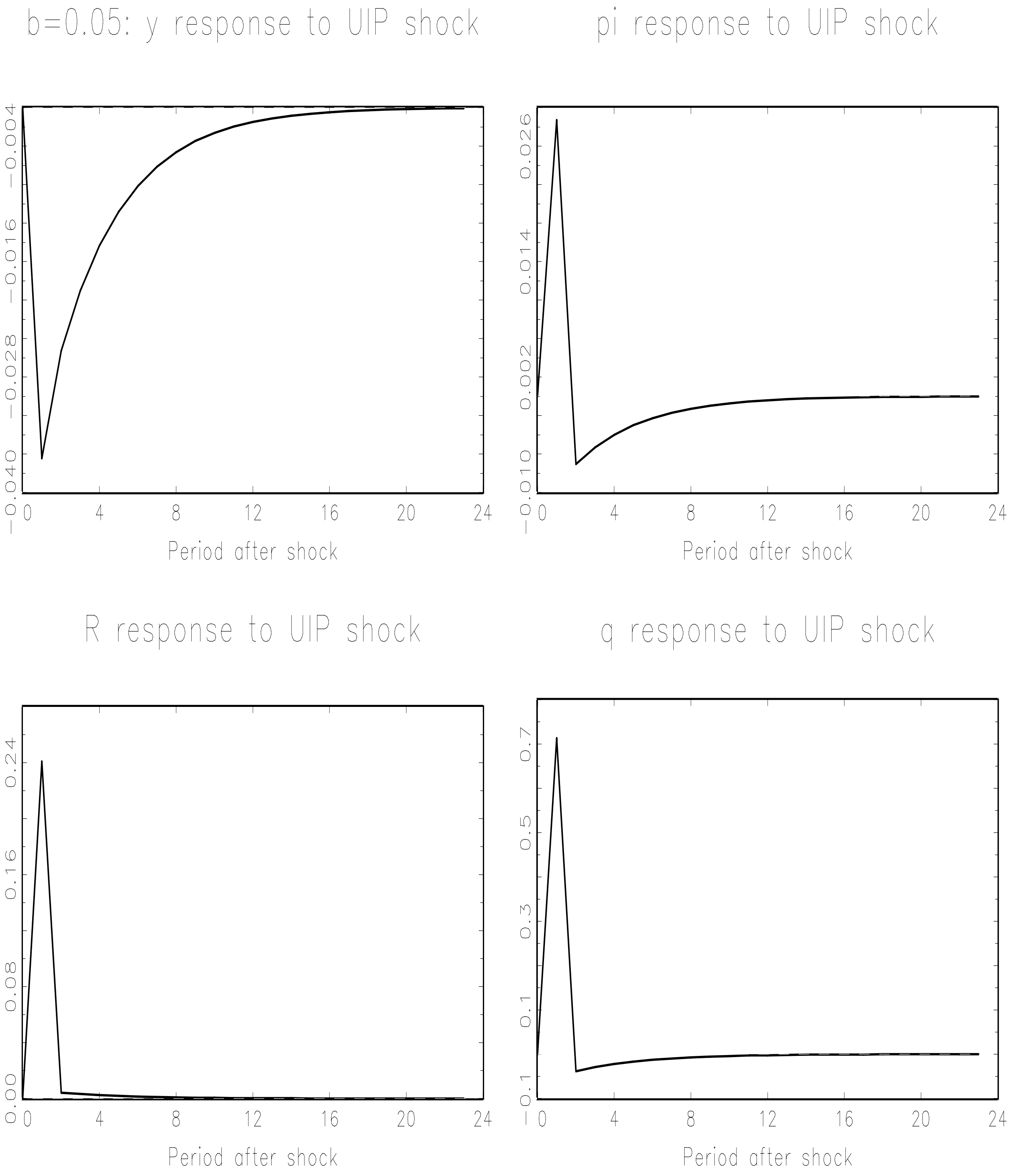


Table 1: The Parameters of the Model

σ	η	η^f	γ^f	γ	β^f	a_1	a_2	a_3	κ	b	μ
$5/7$	1	2	0.15	0.3	0.9	0.5	0.3	0.27	0.05	$(0, 0.05)$	$(1,10)$

The variances of all random disturbances are fixed at *0.9*

Table 2: The Impact Effect of the Disturbances on the Variables of the Model

	Timeless Perspective				**Discretion**			
	$\mu = 10;\ b = 0.05$							
	π_t	y_t	q_t	R_t	π_t	y_t	q_t	R_t
u_t	0.7464	-0.9473	-1.4575	0.2634	0.8612	-1.0931	-1.6817	1.6817
v_t	-0.0574	0.0728	-1.4263	1.5182	-0.0662	0.0840	-1.4091	1.4091
ε_t	0.0287	-0.0364	0.7131	0.2409	0.0331	-0.0420	0.7045	0.2955
	$\mu = 1;\ b = 0.05$							
	π_t	y_t	q_t	R_t	π_t	y_t	q_t	R_t
u_t	0.9422	-0.1195	-0.1839	0.0747	0.9841	-0.1249	-0.1921	0.1921
v_t	-0.0724	0.0091	-1.5243	1.5237	-0.0757	0.0096	-1.5236	1.5236
ε_t	0.0362	-0.0045	0.7621	0.2336	0.0378	-0.0048	0.7618	0.2382
	Timeless Perspective				**Discretion**			
	$\mu = 10;\ b = 0$							
	π_t	y_t	q_t	R_t	π_t	y_t	q_t	R_t
u_t	0.8538	-0.4269	-0.6568	-0.0287	0.9756	-0.4878	-0.7504	0.7504
v_t	0	0	-1.5384	1.5384	0	0	-1.5384	1.5384
ε_t	0	0	0.7692	0.2308	0	0	0.7692	0.2308
	$\mu = 1;\ b = 0$							
	π_t	y_t	q_t	R_t	π_t	y_t	q_t	R_t
u_t	0.9512	-0.0475	-0.0731	-0.0428	0.9975	-0.0498	-0.0767	0.0767
v_t	0	0	-1.5384	1.5384	0	0	-1.5384	1.5384
ε_t	0	0	0.7692	0.2308	0	0	0.7692	0.2308

Table 3: Summary Measures of the Performance of Commitment and Discretion

b=0.05	**Timeless Perspective**			**Discretion**			
$\mu = 10$							
$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$
0.5760	1.7189	6.3431	2.2146	0.6725	1.0834	4.7791	4.4109
$E[L^{TP}] = 7.4799$				$E[L^{D}] = 7.8086$			
% Gain from Commitment: 4.21							
$\mu = 1$							
$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$
0.8250	0.0293	2.6830	2.1840	0.8781	0.0141	2.6450	2.1737
$E[L^{TP}] = 0.8543$				$E[L^{D}] = 0.8922$			
% Gain from Commitment: 4.25							
b=0	**Timeless Perspective**			**Discretion**			
$\mu = 10$							
$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$
0.7079	0.6056	4.0962	2.1808	0.8566	0.2141	3.1696	2.6849
$E[L^{TP}] = 7.6850$				$E[L^{D}] = 8.7804$			
% Gain from Commitment: 12.47							
$\mu = 1$							
$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(R_t)$
0.8347	0.2139	2.7133	2.1954	0.8955	0.0022	2.6680	2.1834
$E[L^{TP}] = 0.8561$				$E[L^{D}] = 0.8977$			
% Gain from Commitment: 4.63							

Notes: Expected Loss = $E(L_t^S) = V(y_t^S) + \mu V(\pi_t^S)$ *S*=*TP* or *D* Gain from Commitment: $\dfrac{E(L_t^D) - E(L_t^{TP})}{E(L_t^D)} x100$

1. The above loss function obtains after premultiplying the intertemporal loss function by $(1-\beta)$ and letting $\beta \rightarrow 1$.
2. Only the variances of the cost-push shock, IS shock, and the UIP shock enter into the calculation of the variances of inflation, the output gap, the real exchange rate, and the policy instrument.

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