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# Is Bad News about Inflation Good News for the Exchange Rate? And, If So, Can That Tell Us Anything about the Conduct of Monetary Policy?

Richard H. Clarida and Daniel Waldman

**Dollar Rises as U.S. Consumer Inflation Accelerates in February**

March 23, 2005 (Bloomberg)—The dollar rose against the euro after a measure of inflation accelerated last month, bolstering expectations the Federal Reserve will raise its benchmark interest rate at a faster pace.

## 9.1 Introduction

The interplay between monetary policy and asset prices is a subject of longstanding interest in financial economics. Often, but not always, the focus is directed at trying to understand how monetary policy, or shocks to policy, impacts asset prices—whether these be the prices of equities, bonds, property, or currencies. Less often, the focus is on how, or should, asset prices influence the conduct of monetary policy. This chapter takes a different approach. We ask whether the response of an asset price (in our case the exchange rate) to a nonpolicy shock (in our case a surprise in inflation) can tell us something about how monetary policy is conducted.

This chapter makes a theoretical point and provides some empirical support for this point. We show in a simple, but robust, theoretical monetary exchange rate model that the sign of the covariance between an inflation surprise and the nominal exchange rate can tell us something about how monetary policy is conducted. Specifically, we show that "bad news" about

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inflation—that it is higher than expected—can be "good news" for the nominal exchange rate—that it appreciates on this news—if the central bank has an inflation target that it implements with a Taylor Rule. This result at first seemed surprising to us because our model is one of inflation, not price level, targeting so that in the model, a shock to inflation has a permanent effect on the price level. Because purchasing power parity (PPP) holds in the long run of the model, the nominal exchange rate depreciates in the long run to an inflation shock, even though on impact it can appreciate in response to this shock. We show that in a traditional overshooting model in which the central bank sets a growth rate for the money stock, the exchange rate would be expected to depreciate in response to an inflation shock.

The empirical work in this chapter examines point-sampled data on inflation announcements and the reaction of nominal exchange rates in ten-minute windows around these announcements for ten countries and several different inflation measures for the period July 2001, through March 2005. Eight of the countries in our study are inflation targeters, and two are not. When we pool the data, we do in fact find that bad news about inflation is indeed good news for the nominal exchange rate, that the results are statistically significant, and that $R$-squared is substantial, in excess of 0.25 for core measures of inflation. We also find significant differences comparing the inflation targeting countries and the two noninflation targeting countries. For the noninflation targeting countries, there is no significant impact of inflation announcements on the nominal exchange rate, although the estimated sign is, indeed, in line with our story. For each of the IT countries, the sign is as predicted by the theory and quite significant. Finally, we study two countries, the United Kingdom and Norway, in which there was a clear regime change during a period when we can obtain data. We study the granting of independence to the Bank of England in 1997 and the shift to formal inflation targeting by Norway in 2001. For both countries, the correlation between the exchange rate and the inflation surprise before the regime change reveal that "bad news about inflation was bad news about the exchange rate." After the regime change, we find that, indeed, "bad news about inflation is good news about the exchange rate."

## 9.2 Optimal Monetary Policy in the Open Economy: Some Results

Before we proceed further, it will be useful to review some of the results from a model of optimal monetary policy and exchange rate determination in the open economy developed in Clarida, Gali, and Gertler (2002). There are two countries, each with staggered price setting and facing cost-push shocks that generate inflation inertia. Home and foreign countries produce differentiated traded goods—the terms of trade is a key relative price. International spillovers arise via a marginal cost/optimal labor supply channel, and these impact inflation dynamics via staggered optimal price setting as in Calvo. The chapter follows Woodford (2003) and derives the central bank welfare function and the optimal monetary policy reaction function in the open economy from taste, technology, and market clearing subject to the Calvo pricing constraint. Solving the model under discretion, there are several results that are relevant to the present discussion.

First, optimal monetary policy in each open economy can be formulated as a Taylor Rule:

$$i = rr + E\pi_{+1} + b(\pi - \pi^*), \tag{1}$$

where $i$ is the nominal interest rate, $rr$ is the time varying real interest rate, $\pi$ is inflation, $\pi^*$ is the inflation target, and $E$ is the expectations operator. Second, under optimal monetary policy, the Taylor Rule is a function of deep parameters:

$$b = [\sigma + (1 - \sigma)\gamma]\xi(1 - \rho) > 0, \tag{2}$$

where $\sigma$ is the intertemporal elasticity of substitution, $\gamma$ is the share of imports in the consumption basket, $\xi$ is the elasticity of substitution across varieties of intermediate inputs to the production of final output, and $\rho$ is the exogenous persistence in shocks to marginal cost. Third, optimal monetary policy features a flexible exchange rate, but the exchange rate itself does not enter the reaction function. Fourth, openness has its effects through the neutral real interest rate and the slope of the Taylor rule. Fifth, the nominal exchange rate under optimal policy has a unit root as does the domestic price level, and they are cointegrated so that PPP holds in the long run.

Clarida, Gali, and Gertler (2002) work out in some detail the symmetric, two-country Nash equilibrium under central bank discretion. They show that in the symmetric equilibrium, bad news about inflation is good news for the exchange rate. That is, a Phillips curve shock that pushes up actual (and expected) inflation triggers under optimal policy an aggressive rise in nominal and real interest rates that actually causes the nominal exchange rate to appreciate. This is so even though in the long run, the nominal exchange rate must depreciate in response to an inflation shock.

There is a tension. Using uncovered interest parity and long-run PPP we have (normalizing foreign interest rates and log price levels to zero):

$$e = -\Sigma_{j=0,\infty} Ei_j + \Sigma_{j=0,\infty} E\pi_j + p_{-1}. \tag{3}$$

In the long run, the level of the nominal exchange rate must depreciate in line with PPP in response to an inflation shock. Under an inflation targeting monetary policy of the sort derived by Clarida, Gali, and Gertler (2002), after its initial jump, the nominal exchange rate must be depreciating along the adjustment path (because the home nominal interest rate is above the world interest rate when inflation is above target). However, in response to an inflation shock, the domestic price level rises on impact, which will tend to make the exchange rate weaker. In the Clarida, Gali, and Gertler (2002) theoretical model, optimal monetary policy has the property that the rise in interest rates in response to the monetary policy shock is sufficiently large to deliver the association between an adverse inflation shock and a nominal currency appreciation.

## 9.3 Inflation Shocks in a Dornbusch Style Model

In a Dornbusch style model with a money growth target, a shock that pushes up inflation will, under plausible circumstances, result in a depreciation of the nominal exchange rate Intuitively, in a Dornbusch model with a money growth target—but one that accommodates to some extent an inflation shock so that the price level has a unit root—the long-run PPP anchor tends to make the nominal exchange rate and the price level move in the same direction whether the shock is to the money supply or to the Phillips curve. The analysis is straightforward.

We begin with a money demand equation:

$$m - p = -\lambda(e^e - e), \tag{4}$$

where $\lambda$ is the interest semielasticity of money demand. Next is a standard Phillips curve from this literature augmented with an inflation shock term $\varepsilon$.

$$p = p_{-1} + \mu + \eta(e - p) + \varepsilon \tag{5}$$

Next is a money growth equation, which features the empirically plausible feature that inflation shocks are at least partially accommodated.

$$m = m_{-1} + \mu + f\varepsilon_{-1} \tag{6}$$

Without this feature, the price level would be stationary in the model, at odds with the vast body of evidence that price levels have a unit root and that central banks tend to accommodate price level shocks. We could easily include a permanent shock to the money supply, in which case bad news about inflation would be bad news about the exchange rate as in the textbook model. Note that the trend rate of growth in the money supply $\mu$ anchors the trend depreciation in the exchange rate. Finally, we note for future reference that the ex ante real interest rate satisfies by uncovered interest parity $r = q^e - q$ with $q = e - p$.

We solve the model for the response of $e$ to an inflation shock. To illustrate our point as simply as possible, we assume that the accommodation parameter $f$ is such that policy accommodates the inflation shock with a one-period lag, and the model reaches new steady state in one period with $q^e = 0$. We will solve for the unique $f$ that satisfies this condition, which admits an intuitive interpretation. Interestingly, a more general version of this setup, which allows for gradual accommodation, can feature sunspot equilibriums. Because the subject of sunspot equilibriums with money growth targeting is not the subject of this chapter, we stick with the simple example here.

We can rewrite the model as

$$m - p = -\lambda(q^e - q) - \lambda(p^e - p) = \lambda q - \lambda\mu. \tag{7}$$

We have

$$dp = -\lambda dq. \tag{8}$$

Thus, if an inflation shock causes inflation, the real exchange rate must appreciate under this policy rule. Actual inflation must satisfy

$$dp = \eta dq + d\varepsilon. \tag{9}$$

Collecting terms, under full accommodation (with a lag of one period),

$$\left(1 + \frac{\eta}{\lambda}\right)dp = d\varepsilon. \tag{10}$$

Thus, indeed, an inflation shock causes inflation, so we know the real exchange rate appreciates. The appreciation dampens the impact of the inflation shock so that inflation rises less than one for one with the inflation shock. Even with ex ante full accommodation, in the period of the shock, the money supply is fixed which results in a contraction in demand. Now, what about the nominal exchange rate? Because PPP holds in the long run, and policy fully accommodates the shock with a lag, the price level will be permanently higher and, thus, the exchange rate will be permanently higher (weaker) too.

There is a presumption that the nominal exchange rate will depreciate on impact. And, in fact, it almost certainly will in this textbook model. To see this, note that

$$de = dq + dp = dp\frac{\lambda - 1}{\lambda}. \tag{11}$$

Now $\lambda$ is the interest semielasticity of money demand, which in empirical studies is usually estimated to be much larger than 1 and in calibration models is often assumed to exceed 5. For example, if the interest elasticity of money demand is 0.5, then starting from an interest rate of 4 percent, a 1 percentage point rise in the interest rate is a 25 percent increase in that rate and will reduce money demand by 12.5 percent for a semielasticity of 12.5 Thus, there is a presumption that that "bad news about inflation is bad news about the exchange rate" in a textbook model, both in the long run and on impact in the very short run. Finally, note that for the expectation of full accommodation to be rational, the central bank must set

$$f = 1 + \frac{\eta}{\lambda}. \tag{12}$$

Thus, while a policy to accommodate may be chosen freely by the central bank, there is a unique value of the feedback parameter $f$ that insures this is a rational expectation equilibrium. Note also that even though this central bank is a money targeter, an inflation shock will induce the ex ante real interest rate to rise since by uncovered interest parity (UIP), in the period of the shock:

$$dr = -dq = (\lambda + \eta)^{-1} d\varepsilon. \tag{13}$$

Thus, a rise in nominal and real interest rates in response to an inflation shock, which is a feature of a stable Taylor rule in a wide variety of models, is also true under money growth targeting with partial accommodation.

## 9.4 Exchange Rate Dynamics under Open Economy Taylor Rules

### 9.4.1 Overview

In Dornbusch (1976) and Mussa (1982), and in virtually all exchange rate papers written until quite recently—including the "new open economy" contributions of Obstfeld and Rogoff (1996, 2000) and the many other papers recently surveyed and reviewed in Sarno and Taylor (2001)—it is the (stochastic process for) the supply of money that is the key nominal forcing variable for understanding the dynamics of the nominal exchange rate. Although Mussa (1982), in particular, allows for a quite general specification of the stochastic process for the money supply, in practice, theoretical exchange rate models are almost always solved under quite simple—and counterfactual—restrictions on monetary policy, namely, that the instrument of monetary policy is the stock of money. However, for most of the world's major central banks, the empirical evidence in Clarida, Gali, and Gertler (1998) suggests that monetary policy is better described by an *interest* rate rule of the sort first proposed by Henderson and McKibbon (1990) and Taylor (1993). Recent papers by Engel and West (2005, 2006) and by Mark (2004) have begun to explore some of the empirical implications for exchange rates if central banks follow Taylor rules for setting interest rates.

The goal of the next two sections is to characterize exchange rate dynamics in a more or less standard open economy model in which the central bank follows an interest rate rule to implement an inflation targeting strategy. The key to solving the model in closed form is to recognize that—as shown in Campbell and Clarida (1987)—if the *equilibrium* ex ante real interest rate implied by the Taylor rule exhibits first order autoregressive dynamics, then the equilibrium level of the real exchange rate will, period by period, be proportional to the equilibrium ex ante real interest rate. However, the "constant" of proportionality that links the real exchange rate and the ex ante real interest rate is not a free parameter. Instead, it is a fixed point in the space of expectations for the Markov process, which describes the equilibrium inflation process. We show that in this model, conditional on the minimum set of state variables, this fixed point is unique and that the equilibrium is stationary (more precisely, the Blanchard and Kahn [1980] conditions for a unique rational expectations equilibrium are satisfied if the Taylor condition is satisfied).

Some interesting results are obtained. We find that in response to a temporary Phillips curve shock that pushes the inflation rate above target, the nominal exchange rate can either depreciate or appreciate on impact, depending upon how aggressively—as indexed by the Taylor rule slope coefficient on the expected inflation gap—the central bank raises real interest rates to bring inflation back to target. Because of inflation inertia, this adjustment does not happen immediately. We find that the equilibrium half-life of an inflation shock (on inflation, output, and the real interest rate) is inversely related to the Taylor rule coefficient on the inflation gap and is directly related to the Taylor rule coefficient on the output gap. Thus, the more aggressive is the central bank response to an inflation shock, the faster the economy returns to target. However, the more aggressive is the central bank response to the output gap, the slower the economy returns to target.

We also examine the dynamic effect of a once-and-for-all permanent reduction in the central bank inflation target. The announcement of a lower inflation target causes the exchange rate to appreciate on impact, inducing a real appreciation and a recession. Inflation falls on impact, but not all the way to target. Along the adjustment path to the new inflation target, the exchange rate is depreciating. Thus, the exchange rate overshoots in response to a "tightening" of monetary policy.

### 9.4.2 A Model

To illustrate the idea as clearly as possible, we will work with the simplest model required. It is a simplified version of the model studied in Svensson (2000). It is comprised of four equations: an aggregate demand equation, an aggregate supply equation, a Taylor rule equation, and an uncovered interest parity equation. The economy is small and takes the world interest rate and world inflation as given and equal to 0. The aggregate demand equation is given by

$$y = -r + (e - p), \tag{14}$$

where $y$ is log deviation of output from potential, $r = i - E\pi_{+1}$ is the ex ante real interest rate, $e$ is the log nominal exchange rate, and $p$ is the log of the domestic price level. The aggregate supply equation is given by

$$\pi = \pi_{-1} + y + \varepsilon, \tag{15}$$

where $\pi = p - p_{-1}$ and $\varepsilon$ is a white noise shock to the Phillips curve. Note that we assume a high degree of inflation inertia so that it is the change in inflation that is increasing in output gap. This actually will work against the Clarida, Gali, and Gertler (2002) prediction that under optimal policy "bad news is good news" because inflation inertia will tend to increase the long-run effect on the price level of any given inflation shock. I assume the central bank conducts monetary policy by according to the following Taylor rule:

$$i = E\pi_{+1} + b\{\pi - \pi^*\} + ay, \tag{16}$$

where $\pi^*$ is the central bank inflation target and $b$ and $a > 0$. Finally, uncovered interest parity implies, in real terms, that

$$e - p = E\{e_{+1} - p_{+1}\} - r. \tag{17}$$

We let $q = e - p$ denote the real exchange rate. Note that $e = \pi + p_{-1} + q$.

We solve equation (17) forward as in Campbell and Clarida (1987) and Svensson (2000) to obtain $q = E\lim_{i\to\infty} q_{+i} - E\Sigma_{k=0,\infty} r_{+k}$. Thus, the log level of the real exchange rate equals the expected long-run equilibrium real exchange rate minus the expected undiscounted sum of short-term real interest rates. In our model, the long-run log real exchange rate is constant and equal to 0, so the level of the real exchange rate is given by

$$q = -E\sum_{k=0,\infty} r_{+k}. \tag{18}$$

We will "guess"—and later verify—that in equilibrium, the ex ante real interest rate follows a zero mean AR(1) process so that $Er_{+j} = d^j r$ with $0 < d < 1$. As shown in Campbell and Clarida (1987), this implies that

$$q = \frac{-r}{(1-d)}. \tag{19}$$

It is sometimes just assumed in models like this (see Ball [1999], for example) that the real exchange rate is proportional to the short-term real interest rate. Although our model has this feature in equilibrium, $d$ is not a "free" parameter but is, in fact, a fixed point (and as well will see, a function of monetary policy) in the space of expectations for the stochastic process that describes equilibrium inflation.

By substituting equation (19) into the aggregate demand curve, we obtain $y = (2 - d)q$. Substituting the Taylor rule into the real exchange rate equation and using the Phillips curve equation, the system can be written as two equations in two unknowns, $q$ and $\pi$:

$$q = \frac{-b(\pi - \pi^*)}{(1-d)} - \frac{a(2-d)q}{(1-d)}, \tag{20}$$

$$\pi = \pi_{-1} + (2-d)q + \varepsilon. \tag{21}$$

From equation (20), we see that $-q[(1-d) + a(2-d)] = r[1 + a(2-d)/(1-d)] = b(\pi - \pi^*)$. Thus, in equilibrium, the ex ante real interest rate is proportional to the inflation gap, even though the central bank also seeks to stabilize output. The dynamics of the system are completely described by the following equation:

$$\pi = \pi_{-1} - \frac{(2-d)b(\pi - \pi^*)}{(1-d) + a(2-d)} + \varepsilon. \tag{22}$$

Before moving on, it is useful to pause and understand the logic. To obtain equation (22), we guessed that the equilibrium ex ante real interest rate follows an AR(1) process so that $Er_{+j} = d^j r$. Equation (22) shows that if this guess is correct, inflation follows an AR(1) process. But, from the Taylor rule, if inflation follows an AR(1) process, then so does the ex ante real interest rate. Thus, our guess is not logically inconsistent. However, this logic does not prove that there exists a unique fixed point in the space of expectations over the AR(1) process for $r$. Collecting terms, we can rewrite equation (22) as $(\pi - \pi^*)\{1 + (2-d)b/[(1-d) + a(2-d)]\} = (\pi_{-1} - \pi^*) + \varepsilon$. It follows that any fixed point in the space of expectations for $r$ must satisfy $\{1 + (2-d)b/[(1-d) + a(2-d)]\} = 1/d$. The solutions to this equation are just eigenvalues of the dynamic system when written out in Blanchard-Kahn form. It is easy to show that for any $a > 0$, $b > 0$ is necessary and sufficient for the existent of a unique rational expectations equilibrium. Figure 9.1 presents the determination of this unique equilibrium.

*Result 1:* A rational expectations equilibrium exists, is unique, and is stationary. The equilibrium persistence $d(b, a)$ in inflation and in deviations from PPP $0 < d(b, a) < 1$ depends upon the parameters of monetary policy. Persistence is strictly decreasing in $b$—the Taylor rule coefficient on the inflation gap—and strictly increasing in $a$—the Taylor rule coefficient on the output gap.

Thus, for any given Taylor rule coefficients $a \geq 0$ and $b > 0$, there is a unique, stationary rational expectations equilibrium. The more aggressively the central bank reacts to the inflation gap (as indexed by the parameter $b$), the faster the economy converges to the long-run equilibrium and the less persistent are deviations from PPP. However, the larger the weight placed on output stabilization (as indexed by the parameter $a$), the slower the economy converges to the long-run equilibrium. Indeed, it is easy to establish the following three limiting cases: first, for any given $a$, as $b \to 0$, $d(b, a) \to 1$. That is, as the weight placed on inflation stabilization goes to zero, inflation and the real exchange rate approach a random walk. Second, for any given $a$, as $b \to \infty$, $d(b, a) \to 0$. That is, as the weight placed on inflation stabilization goes to infinity, the inflation gap and the real exchange rate approach white noise. Third, for any given $b$, as $a \to \infty$,

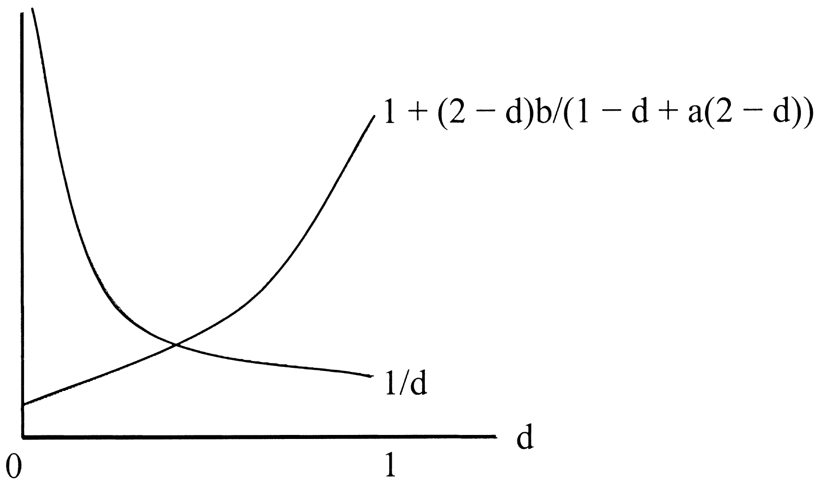


**Fig. 9.1 Equilibrium as a function of Taylor rule parameters *b* and *a***

$d(b, a) \rightarrow 1$. That is, as the weight placed on output stabilization goes to infinity, inflation and the real exchange rate approach a random walk.

*An Adverse Inflation Shock*

A temporary Phillips curve shock $\varepsilon > 0$ pushes up inflation, but by less than the shock. This is because the central bank reacts to the inflation shock by pushing up the nominal and the ex ante real interest rate. The real exchange rate appreciates on impact. Output contracts. The effect of a Phillips curve shock on the level of the nominal exchange rate depends upon $b$, the Taylor rule reaction parameter to the inflation gap. The following result is easily verified using equation (20) and the fact that $d$ is decreasing in $b$.

*Result 2:* For any given $a \geq 0$, there exists a $b(a)$ such that, for all $b > b(a)$, $\partial e_t/\partial\varepsilon_t < 0$. That is, if the central bank responds sufficiently aggressively to a rise in inflation, the nominal exchange rate *appreciates* on impact in response to an adverse inflation shock. For $b < b(a)$, $\partial e_t/\partial\varepsilon_t > 0$.

Thus, while the real exchange rate must appreciate in response to an adverse inflation shock, the effect on the nominal exchange rate depends upon the Taylor rule reaction function. Interestingly, the "inflation nutter" case $a = 0$ and $b > 0$ is not sufficient to guarantee $\partial e_t/\partial\varepsilon_t < 0$.

The impulse response dynamics to an adverse inflation shock are easy to characterize and are shown in figures 9.2 and 9.3. The nominal interest rate and inflation fall monotonically over time at rate $d$ to $\pi^*$, and the output gap and the real exchange rate rise monotonically over time at rate $d$ to 0. Along the adjustment path, the nominal exchange rate is depreciating at

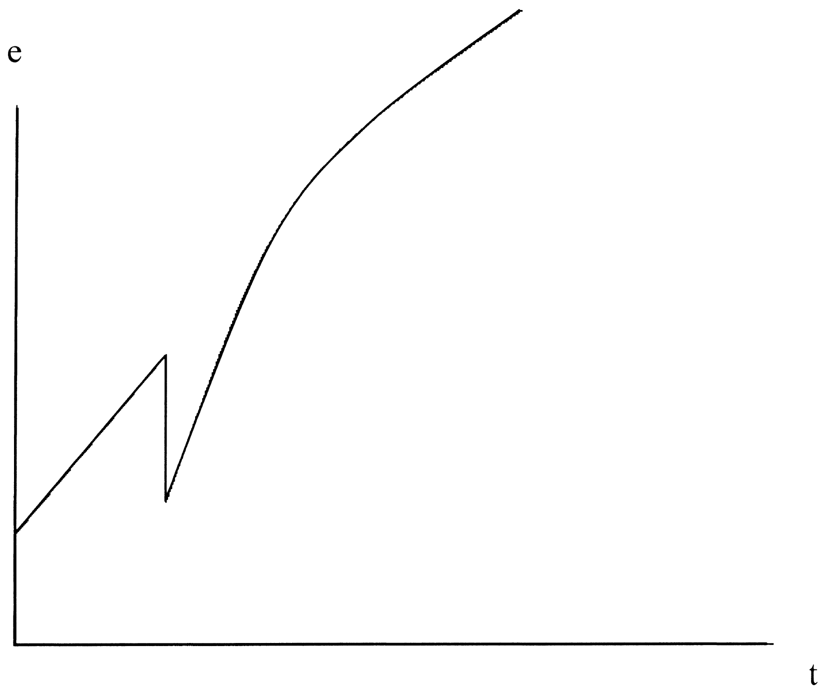


**Fig. 9.2 Impulse response to inflation shock: "good news" case $b > b(a)$**

the rate equal to the nominal interest rate, until in the steady state it depreciates at the rate $\pi^*$.

*A Cut in the Inflation Target*

We now consider a once-and-for-all cut in the inflation target to $\underline{\pi}^* < \pi^*$. In our model, this is assumed to be immediately credible and to shape expectations on impact. That is, following McCallum (1983), the minimum set of state variables for this model is $s = \{\underline{\pi}^*, \varepsilon, \pi_{-1}\}$. As shown in the preceding, there is a unique rational expectations equilibrium corresponding to this state vector and the parameters $a$ and $b$, which maps $s \rightarrow \{\pi, y, q, i, E\pi_{+1}\}$. Of course, in equilibrium the nominal exchange rate and the price level are non-stationary and are a function of $\{\pi^*, \varepsilon, \varepsilon_{-1}, \varepsilon_{-2}, \ldots\}$.

Assume for concreteness that $\pi_{-1} = \pi^*$ and $\varepsilon = 0$. In the period in which the inflation target is cut, the equation for inflation in the period of the regime change can be written

$$\pi = d\pi^* + \underline{\pi}^* (1 - d). \tag{23}$$

Thus, because of inflation inertia, $0 < \partial\pi/\partial\underline{\pi}^* < 1$ because $d(a, b) < 1$ for $b$. It follows that the derivative of the inflation gap with respect to the infla-

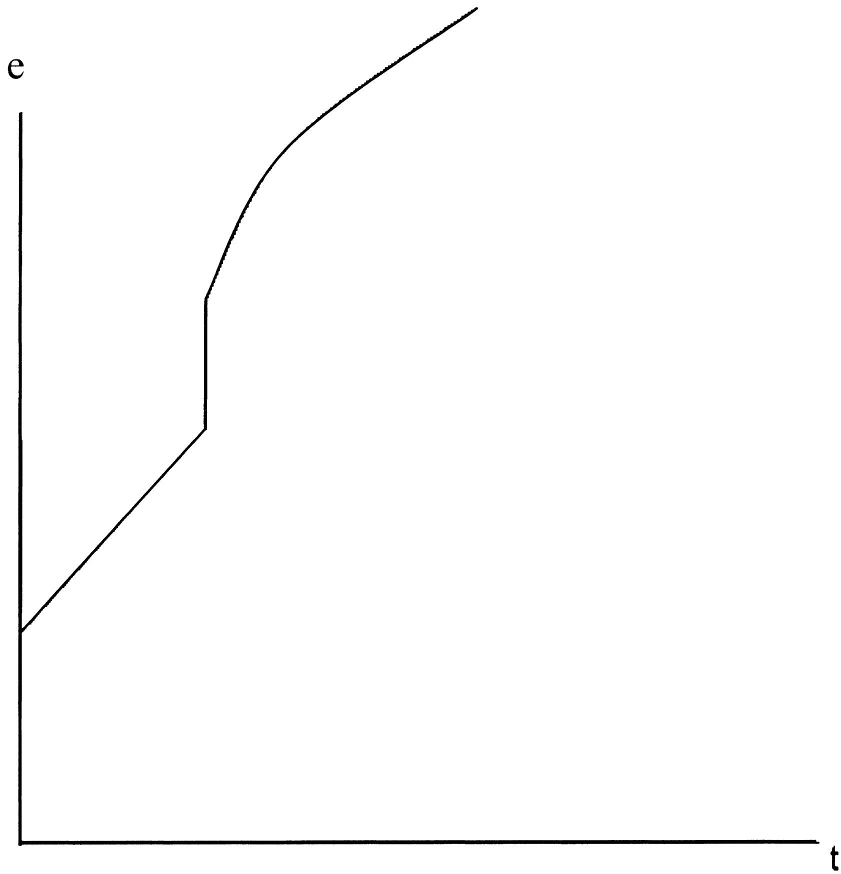


**Fig. 9.3 Impulse response to inflation shock: "bad news" case $b < b(a)$**

tion target is given by $\partial(\pi - \underline{\pi}^*)/\partial\underline{\pi}^* = -d$. Thus, a cut in the inflation target leads to a rise in the inflation gap. By the Taylor rule, the ex ante real interest rate must rise, and, thus, the real exchange rate must appreciate. As a result, output declines. Indeed, it is the induced decline in output that reduces inflation part of the way to $\underline{\pi}^*$. Because inflation falls and the real exchange rate appreciates, the nominal exchange rate must appreciate as well.

We now discuss the impulse response dynamics in periods subsequent to the cut in the inflation target. For concreteness, we focus on the case in which the new inflation target is zero, $\underline{\pi}^* = 0$. After the regime change, the nominal interest rate remains above its new steady state level of $i^{SS} = \underline{\pi}^* = 0$. This is because the inflation gap is positive. Thus, along the adjustment path, the nominal interest rate is everywhere above the world interest rate of $i^* = 0$ so that the nominal exchange rate must depreciate along the adjustment path.

*Result 3:* In response to a cut in the inflation target, the nominal exchange rate exhibits overshooting. That is, it appreciates on impact and depreciates over time to its new steady state level.

Thus, if the "surprise" fall in inflation is due to a cut in the inflation target (not a Phillips curve shock), good news for inflation (that it falls) is good news for the exchange rate (it appreciates on impact). Because the model is symmetric, it will also be the case that if a "surprise" rise in inflation is due to an increase in the inflation target (not a Phillips curve shock), bad news for inflation (that it rises) is bad news for the exchange rate (it depreciates on impact).

## 9.5 Empirical Results

In this section, we use data on inflation announcements and the response of nominal exchange rates around these announcements to empirically test our theoretical model. We focus on three questions: (1) What is the sign of the correlation between inflation surprises and nominal exchange rate changes? (2) Is it significant? (3) Is it different for inflation targeters and noninflation targeters?

Previewing our results, we find that when we pool the data, bad news about inflation is good news for the exchange rate. The sign of the correlation between inflation surprises and exchange rate changes is positive and statistically significant. When we separate the data into inflation targeters and noninflation targeters, we find that these results continue to hold for inflation targeting countries, but the coefficients become insignificant for noninflation targeters.

### 9.5.1 Data

Our data set consists of high frequency exchange rate and inflation expectation and announcement data. In the following, we describe the construction and properties of our data.

*Exchange Rate Data*

Our exchange rate data consists of continuously recorded five-minute nominal spot data for nine U.S. dollar crosses: USD-JPY, USD-CAD, USD-NOK, USD-SEK, USD-CHF, EUR-USD, GBP-USD, AUD-USD, and NZD-USD. The data, provided by Olsen Associates and Merrill Lynch, begins in July 2001, and ends in December 2005. For GBP-USD and USD-NOK, we also have high frequency exchange rate data covering the periods 1993 to 1996 and 1997 to 2000, respectively.

**Table 9.1** **10-minute exchange rate returns (%)**

| | AUD-USD | NZD-USD | EUR-USD |
|---|---|---|---|
| Mean | 0.00 | 0.00 | 0.00 |
| Standard deviation | 0.07 | 0.09 | 0.05 |
| | GBP-USD | USD-JPY | USD-CAD |
| Mean | 0.00 | 0.00 | 0.00 |
| Standard deviation | 0.05 | 0.05 | 0.05 |
| | USD-NOK | USD-SEK | USD-CHF |
| Mean | 0.00 | 0.00 | 0.00 |
| Standard deviation | 0.07 | 0.07 | 0.06 |

We convert the raw spot data to returns, taking ten-minute percentage changes. Although the spot data is recorded at five-minute intervals, we use ten-minute changes because we are interested in exchange rate behavior during the period beginning five minutes before an inflation announcement and ending five minutes after such an announcement.

Table 9.1 provides summary statistics for our ten-minute exchange rate return data. For all nine U.S. dollar crosses, the mean ten-minute return is 0.00 percent. Although the mean returns are similar across currency pairs, the standard deviations are not, ranging from 0.05 percent to 0.09 percent. The range of standard deviations may be related to the depth and liquidity of markets in different exchange rate crosses. The most liquid currency pairs—USD-JPY, EUR-USD, and USD-CAD—have the lowest standard deviations, and the least liquid crosses—NZD-USD, AUD-USD, USD-NOK, and USD-SEK—have the highest standard deviations.

*Inflation Data*

We define an *inflation surprise* as the difference between the market expectation for an announcement and the announced value of inflation. We arrange the data so that a positive surprise indicates that inflation was higher than expected, while a negative surprise indicates that inflation was announced lower than expected.

For the 2001 to 2005 period, our inflation expectations data is from the Bloomberg News Service. Bloomberg surveys commercial and investment banks on their expectations for a wide range of macroeconomic announcements, including inflation. We use the median of these expectations as the inflation expectation for a particular announcement.

Our inflation announcement data for 2001 to 2005 is from the Bloomberg News Service as well. Bloomberg records and preserves the announced value of macroeconomic variables, in addition to the revised values. This is an important distinction, as macroeconomic data is often revised in the months following its initial release. Because we are concerned only with the immediate response of the exchange rate to an inflation surprise, we need the actually announced data.

In addition to the 2001 to 2005 data, we have inflation expectation and announcement data for the United Kingdom and Norway for the periods 1993 to 1996 and 1997 to 2000, respectively. Data for both is provided by Money Market Services and is similar to the Bloomberg data.

For all countries except the United Kingdom, where we use retail prices, we use consumer prices as our inflation metric. For most countries in our sample, expectation and announcement data are available for both headline and core inflation, where core inflation is headline inflation minus some of the volatile components, such as food and energy. We have up to four different measures of inflation for each country in our sample: headline inflation measured as month-over-month and year-over-year changes, and core inflation measured as month-over-month and year-over-year changes.

In table 9.2, we present summary statistics for our inflation surprise variables. For most countries in the sample, the mean inflation surprise is slightly less than zero, indicating that forecasters have tended to underestimate inflation. However, across all countries and measures of inflation, the absolute value of mean inflation surprises is never greater than 0.1 percentage points, indicating that any potential bias is small. The standard deviations for the inflation surprises are larger than the means, ranging from 0.1 to 0.3 percentage points.

### 9.5.2 The Model

We follow the macroeconomic announcement surprise literature, estimating the following equation:

$$R_t = \alpha + \beta S_t + u_t. \tag{24}$$

Here $R_t$ is the ten-minute return around the inflation announcement, $S_t$ is the inflation surprise, and $u_t$ is the error term. The exchange rate return is calculated so that a positive value indicates an appreciation of the local currency, and a negative value represents a depreciation of the local currency. In all tables, the coefficient represents the percentage change in the local currency for a 1 percentage point surprise in inflation.

*All Countries*

Pooling data from all countries in our sample and running a stacked ordinary least squares (OLS) regression on equation (24), we find that bad news about inflation is indeed good news for the nominal exchange rate. For all four specifications (table 9.3), the sign on the inflation surprise variable is positive and statistically significant, indicating that higher than expected inflation results in an immediate currency appreciation and that

**Table 9.2** **Inflation surprises**

| | Canada | | | | United Kingdom | | | |
|---|---|---|---|---|---|---|---|---|
| | Headline | | Core | | Headline | | Core | |
| | MoM | YoY | MoM | YoY | MoM | YoY | MoM | YoY |
| Mean | –0.04 | –0.04 | –0.03 | –0.01 | 0.00 | –0.01 | –0.02 | –0.02 |
| Standard deviation | 0.21 | 0.23 | 0.15 | 0.17 | 0.13 | 0.15 | 0.15 | 0.14 |
| | **Norway** | | | | **Sweden** | | | |
| | Headline | | Core | | Headline | | Core | |
| | MoM | YoY | MoM | YoY | MoM | YoY | MoM | YoY |
| Mean | –0.07 | –0.09 | –0.09 | –0.10 | –0.03 | –0.05 | –0.03 | –0.03 |
| Standard deviation | 0.27 | 0.30 | 0.22 | 0.21 | 0.17 | 0.17 | 0.17 | 0.19 |
| | **Japan** | | | | **United States** | | | |
| | Headline | | Core | | Headline | | Core | |
| | MoM | YoY | MoM | YoY | MoM | YoY | MoM | YoY |
| Mean | 0.03 | 0.02 | 0.02 | 0.02 | –0.01 | 0.04 | 0.00 | 0.00 |
| Standard deviation | 0.13 | 0.12 | 0.10 | 0.08 | 0.14 | 0.18 | 0.10 | 0.12 |
| | **Australia** | | **Euro area** | | **New Zealand** | | **Switzerland** | |
| | Headline | | Headline | | Headline | | Headline | |
| | QoQ | YoY | MoM | YoY | QoQ | | MoM | YoY |
| Mean | –0.01 | 0.00 | 0.00 | 0.00 | –0.04 | | –0.03 | –0.07 |
| Standard deviation | 0.18 | 0.19 | 0.09 | 0.07 | 0.16 | | 0.20 | 0.23 |

**Table 9.3** **All countries**

| | Headline | | Core | |
|---|---|---|---|---|
| | MoM | YoY | MoM | YoY |
| Coefficient | 0.2 | 0.2 | 0.5 | 0.5 |
| *T*-statistic | 5.9 | 6.2 | 9.7 | 9.2 |
| *R*-squared | 0.08 | 0.09 | 0.27 | 0.25 |
| No. of observations | 394 | 387 | 257 | 259 |

*Notes:* Regression method: stacked OLS. Percentage change in exchange rate results from a 1 percentage point upward surprise in inflation. Positive coefficient indicates appreciation of domestic currency. Countries: Australia, Canada, euro area, Japan, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and United States. Data: July 2001–December 2005. Some countries missing observations.

lower than expected inflation results in an immediate currency depreciation. The $R$-squares from the regressions are substantial, particularly for the specifications using core inflation, where they exceed 0.25.

Although the signs are positive and significant for all specifications, the results are stronger for the core measures. The coefficients, $t$-statistics, and $R$-squares are all larger, with coefficients 2.5 times the size of those in the regressions using headline inflation and $R$-squares nearly three times greater. Given the tendency of central banks to focus on core inflation, it is not surprising that markets have reacted more strongly to surprises in this measure.

*Inflation Targeters versus Noninflation Targeters*

Our ten-country sample includes eight inflation targeters and two noninflation targeters—the United States and Japan. Our groupings are similar to those used by the International Monetary Fund (IMF), though the IMF does not include the European Central Bank (ECB) among inflation targeters, as the ECB gives weight to a "reference value" for growth of money supply in the euro area. Despite this dual mandate, we include the ECB in the inflation targeting group, as it has lessened its emphasis on the money supply reference value in recent years. Including the ECB among the noninflation targeters would not significantly alter our results.

For our study, the key question is whether the sign and significance of $\beta$ are different for inflation targeters and noninflation targeters. Separating and pooling the data into two categories—inflation targeters and noninflation targeters—we find significant differences between the two. For noninflation targeting countries, the impact of inflation surprises is not significant, though the estimated sign is generally positive (table 9.4). For in-

**Table 9.4 Inflation targeters versus noninflation targeters**

| | Inflation targeters | | | | Noninflation targeters | | | |
|---|---|---|---|---|---|---|---|---|
| | Headline | | Core | | Headline | | Core | |
| | MoM | YoY | MoM | YoY | MoM | YoY | MoM | YoY |
| Coefficient | 0.3 | 0.2 | 0.6 | 0.5 | 0.01 | –0.08 | 0.1 | 0.1 |
| $T$-statistic | 6.1 | 6.7 | 9.4 | 8.9 | 0.2 | –0.8 | 1.3 | 1.1 |
| $R$-squared | 0.11 | 0.13 | 0.37 | 0.31 | 0.00 | 0.01 | 0.02 | 0.02 |
| No. of observations | 286 | 310 | 152 | 182 | 108 | 77 | 105 | 77 |

*Notes:* Regression method: stacked OLS. Percentage change in exchange rate resulting from a 1 percentage point upward surprise in inflation. Positive coefficient indicates appreciation of domestic currency. Inflation targeters include: Australia, Canada, euro area, New Zealand, Norway, Sweden, Switzerland, and United Kingdom. Noninflation targeters include: Japan and United States. Noninflation targeters YoY includes only Japan. Data: July 2001–December 2005. Number of observations may be less than total months due to missing observations.

flation targeters, the estimated coefficients are positive and statistically significant in all four specifications. The $R$-squares are quite substantial for the inflation targeting regressions, exceeding 0.30 for both core specifications (table 9.4).

Estimating equation (24) separately for each country confirms these results (table 9.5). For the two noninflation targeters, the coefficients are not significant, and for headline inflation in the United States are actually of the opposite sign of what the theory predicts. For all eight inflation targeters, the estimated signs are positive and are statistically significant for six of the countries. These results are particularly strong for the core measures, with $R$-squares ranging from 0.18 for the United Kingdom to 0.65 for Norway.

*Regime Changes*

We can also test whether our results hold when there is a clear regime change over time. To test this, we study the granting of independence to the Bank of England in 1997 and the shift to formal inflation targeting in Norway in 2001. For both countries, we have nominal exchange rate and inflation expectation and announcement data prior to and following the regime shifts.

For both countries, the correlation between inflation surprises and nominal exchange rate changes is positive and significant for the 2001 to 2005 period, indicating that when central banks in both countries were inflation targeters, bad news about inflation was good news for the exchange rate. However, prior to the regime changes in both countries, the estimated coefficients were negative (though not statistically significant), implying that bad news about inflation was bad news for the exchange rate (table 9.6).

*Sign Effects*

Finally, we examine whether the reaction of the nominal exchange rate differs according to the sign of the surprise. We separate the data into three categories: higher than expected inflation, lower than expected inflation, and as expected inflation. We discard observations where inflation was as expected and pool the remaining data for all countries into two groups—positive inflation surprises (bad news) and negative inflation surprises (good news). We then estimate equation (24) for both (table 9.7), though we omit the constant in the regression.

Doing so, we find that although the coefficients are positive and statistically significant across all specifications, the effect is stronger for negative inflation surprises (good news) than it is for positive inflation surprises (bad news). The coefficients, $t$-statistics, and $R$-squares are substantially higher for the regressions that use negative inflation surprises. Thus, for equivalent inflation surprises, good news will have a larger impact than will bad news.

**Table 9.5** **Individual country results**

| | Canada | | | | United Kingdom | | | |
|---|---|---|---|---|---|---|---|---|
| | Headline | | Core | | Headline | | Core | |
| | MoM | YoY | MoM | YoY | MoM | YoY | MoM | YoY |
| Coefficient | 0.07 | 0.04 | 0.5 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 |
| *T*-statistic | | | | | | | | |
| OLS | 1.2 | 0.8 | 5.0 | 3.3 | 2.9 | 3.1 | 3.3 | 4.0 |
| White | 1.4 | 1.0 | 6.3 | 2.8 | 2.2 | 2.6 | 2.8 | 3.3 |
| Newey-West | 1.2 | 0.9 | 6.7 | 2.7 | 1.9 | 2.1 | 2.3 | 2.7 |
| *R*-squared | 0.02 | 0.01 | 0.47 | 0.19 | 0.14 | 0.16 | 0.18 | 0.23 |
| No. of observations | 54 | 54 | 30 | 50 | 53 | 54 | 50 | 54 |

| | Norway | | | | Sweden | | | |
|---|---|---|---|---|---|---|---|---|
| | Headline | | Core | | Headline | | Core | |
| | MoM | YoY | MoM | YoY | MoM | YoY | MoM | YoY |
| Coefficient | 0.5 | 0.6 | 1.3 | 1.3 | 0.3 | 0.2 | 0.2 | 0.2 |
| *T*-statistic | | | | | | | | |
| OLS | 2.8 | 3.5 | 7.5 | 7.7 | 3.4 | 3.3 | 3.1 | 3.1 |
| White | 2.3 | 2.4 | 5.7 | 5.4 | 3.6 | 3.0 | 3.3 | 3.2 |
| Newey-West | 2.0 | 2.1 | 6.6 | 5.7 | 3.4 | 3.1 | 2.9 | 2.9 |
| *R*-squared | 0.19 | 0.27 | 0.65 | 0.64 | 0.23 | 0.21 | 0.21 | 0.20 |
| No. of observations | 35 | 35 | 32 | 35 | 41 | 42 | 40 | 42 |

| | Australia | | Euro Area | | New Zealand | Switzerland | |
|---|---|---|---|---|---|---|---|
| | Headline | | Headline | | Headline | Headline | |
| | QoQ | YoY | MoM | YoY | QoQ | MoM | YoY |
| Coefficient | 0.1 | 0.1 | 0.1 | 0.1 | 0.7 | 0.1 | 0.1 |
| *T*-statistic | | | | | | | |
| OLS | 1.0 | 1.1 | 1.1 | 0.9 | 3.0 | 2.9 | 3.1 |
| White | 1.0 | 1.1 | 1.2 | 1.0 | 3.3 | 2.7 | 3.0 |
| Newey-West | 1.1 | 1.2 | 1.1 | 1.2 | 3.2 | 2.7 | 3.4 |
| *R*-squared | 0.06 | 0.08 | 0.02 | 0.02 | 0.38 | 0.16 | 0.16 |
| No. of observations | 18 | 17 | 54 | 54 | 17 | 48 | 53 |

| | Japan | | | | United States | | | |
|---|---|---|---|---|---|---|---|---|
| | Headline | | Core | | Headline | | Core | |
| | MoM | YoY | MoM | YoY | MoM | YoY | MoM | YoY |
| Coefficient | 0.07 | 0.1 | 0.07 | 0.07 | –0.1 | –0.2 | 0.1 | 0.2 |
| *T*-statistic | | | | | | | | |
| OLS | 1.4 | 1.8 | 1.0 | 0.7 | –0.4 | –1.1 | 0.9 | 0.7 |
| White | 1.2 | 1.9 | 0.8 | 0.7 | –0.4 | –1.1 | 0.9 | 0.7 |
| Newey-West | 1.3 | 1.6 | 0.7 | 0.7 | –0.4 | –1.2 | 0.9 | 0.8 |
| *R*-squared | 0.04 | 0.06 | 0.02 | 0.01 | 0.00 | 0.05 | 0.01 | 0.02 |
| No. of observations | 54 | 54 | 51 | 52 | 54 | 25 | 54 | 25 |

*Notes:* Percentage change in exchange rate results from a 1 percentage point upward surprise in inflation. Positive coefficient indicates appreciation of domestic currency. For U.S. results, currency appreciation/depreciation is measured against the euro. Data: July 2001–December 2005. Number of observations may be less than total months due to missing observations. White and Newey-West used to correct for potential heteroscedasticity.

**Table 9.6** **UK and Norway preinflation targeting**

| | UK | | | Norway |
|---|---|---|---|---|
| | Headline | | Core | Headline |
| | MoM | YoY | YoY | YoY |
| Coefficient | 0.006 | –0.05 | –0.06 | –0.08 |
| *T*-statistic | | | | |
| OLS | 0.1 | –0.5 | –0.7 | –1.0 |
| White | 0.1 | –0.7 | –0.8 | –1.6 |
| Newey-West | 0.1 | –1.1 | –1.4 | –1.6 |
| *R*-squared | 0.00 | 0.01 | 0.01 | 0.02 |
| No. of observations | 46 | 46 | 46 | 40 |

*Notes:* Percentage change in exchange rate results from a 1 percentage point upward surprise in inflation. Positive coefficient indicates appreciation of domestic currency. Dates: Norway (August 1997–December 2000); United Kingdom (March 1993–December 1996). Number of observations may be less than total months due to missing observations. White and Newey-West used to correct for potential heteroscedasticity.

**Table 9.7** **Good news versus bad news**

| | Headline | | | | Core | | | |
|---|---|---|---|---|---|---|---|---|
| | MoM | | YoY | | MoM | | YoY | |
| | Positive | Negative | Positive | Negative | Positive | Negative | Positive | Negative |
| Coefficient | 0.1 | 0.3 | 0.1 | 0.3 | 0.4 | 0.6 | 0.3 | 0.6 |
| *T*-statistic | 2.4 | 5.1 | 2.5 | 5.4 | 4.9 | 7.1 | 4.1 | 7.2 |
| No. of observations | 126 | 164 | 113 | 169 | 80 | 98 | 83 | 102 |

*Notes:* Regression method: stacked OLS. Percentage change in exchange rate results from a 1 percentage point upward surprise in inflation. Positive coefficient indicates appreciation of domestic currency. Countries: Australia, Canada, Euro area, Japan, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and United States. Data: July 2001–December 2005. Number of observations may be less than total months due to missing observations. Positive indicates inflation higher than expected—bad news. Negative indicates inflation lower than expected—good news.

## 9.6 Concluding Remarks

In this chapter, we have presented what is apparently a new empirical regularity—that for inflation targeting countries, bad news for inflation is good news for the exchange rate. There are two antecedents for this empirical finding of which we are aware. The paper by Anderson et al. (2003) who report in their tables but don't discuss, that for some dollar exchange rates during the 1990s, inflation surprises and exchange rates covaried in the way reported in this chapter, but the estimated effects were not significant. In Goldberg and Klein (2006), it is shown that for most of the sample 1999 to

2005, bad news about inflation was bad news for the euro but that bad news about inflation become good news for the euro starting in 2003. They interpret this as consistent with improved ECB credibility during the period. Faust et al. (forthcoming) look at fourteen years of data for the United States and find that bad news about inflation is bad news for the exchange rate. Our findings are also related to but distinct from those in the much cited paper by Engel and Frankel (1984) and the paper of Hardouvelis (1984). They looked at the effect of money supply surprises (not inflation surprises) on the exchange rate. They argued that if a money growth targeting regime were credible, then a surprise increase in the money supply—that pushed money growth above target—would be expected to be reversed and that this would cause the nominal exchange rate to appreciate, which is, in fact, what they found for the Fed and the dollar in the early 1980s. We have presented a simple theoretical model that delivers the prediction that under certain inflation targeting regimes, bad news about inflation can be good news for the exchange rate. This is a workhorse model that does not require the two-country dynamic stochastic general equilibrium framework with optimal monetary policy as featured in Clarida, Gali, and Gertler (2002), and yet it delivers a similar prediction. What can these results tell us about monetary policy? They suggest two conclusions. First, the inflation targeting regimes in the countries featured in our sample are sufficiently credible in that they anchor expectations of inflation and the monetary policy path required to achieve the inflation target to such an extent that the currency becomes *more valuable* upon receipt of news that inflation is surprising high. This credibility effect has to be strong enough to counterbalance the long-run PPP anchor, which would tend to depreciate the currency on the impact of bad inflation news. We note that this is exactly what we find for the Bank of England before independence and for Norway before the adoption of inflation targeting. A second conclusion is that a credible inflation target is not enough for the "bad news is good news" effect to prevail. In other words, we cannot conclude that if bad news about inflation is bad news for the exchange rate, that a central bank is not an inflation targeter. The central bank must raise interest rates sufficiently aggressively to an inflation shock, and not just greater than one for one as required by the Taylor principle. In particular, this observation is important for correctly interpreting the results for the United States and Japan, for which we did not find significant evidence of the "bad news is good news" effect. Especially in the case of the Fed, we do not interpret our results necessarily as evidence against Fed credibility in anchoring inflation expectations. They are also consistent with the Fed's anchoring those expectations in the context of its dual mandate.

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## Comment Charles Engel

This chapter is a very nice contribution, not only to our understanding about monetary policy, but also to our understanding about exchange rates. The key finding of the chapter is that in inflation targeting countries, an announcement of higher inflation leads to a stronger currency. At first this might seem puzzling—doesn't inflation weaken a currency? But clearly markets believe that the central bank in the inflation targeting country will react to news of higher inflation by raising real interest rates. Higher real interest rates strengthen the currency.

The evidence in the chapter is strong—only in inflation targeting countries do we consistently see a relation between announcements of higher inflation and a stronger currency. Indeed, in England and Norway, there is evidence that the effect changed as the countries changed monetary policy to inflation targeting.

The fact that news of higher inflation leads to a stronger currency is not a new result. This is precisely the point that Engel and West (2006) highlighted in their model of exchange rate behavior based on Taylor rules. It is easy to understand the effect using the present value formulation for the real exchange rate as in Engel and West. To see this, simply substitute equation (16) of Clarida and Waldman into their equation (18) to get:

$$q_t = -E_t \sum_{j=0}^{\infty} [b(\pi_{t+j} - \pi^*) + ay_{t+j}]. \tag{1}$$

Here, assuming symmetric Taylor rules in the home and foreign country, $\pi_t$ is the home inflation rate relative to the foreign inflation rate, and $y_t$ is the home output gap relative to the foreign output gap. The real exchange rate, $q_t$, is defined in such a way that a decline in the real exchange rate is a home real appreciation.

Denote the exchange rate immediately before the announcement as $q_{t-}$, and immediately after $q_{t+}$. Then we have:

$$q_{t+} - q_{t-} = -(E_{t+} - E_{t-}) \left[ \sum_{j=0}^{\infty} (b\pi_{t+j} + ay_{t+j}) \right]. \tag{2}$$

If the market learns current inflation is higher, and if there is some persistence to inflation, then $q_t$ must fall.

Engel and West (2006) measure inflation surprises (and output gap surprises) using a vector autoregression (VAR) in inflation, output gap, and interest rates. They construct a "model" real exchange rate by constructing the present value in equation (1) and compare its behavior to the actual real

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exchange rate.[1] One of the key findings is that, as predicted, positive inflation surprises (in the home relative to the foreign country) lead to a real appreciation.

I very much like the Clarida-Waldman approach. An obvious shortcoming of the Engel-West approach is that the measure of inflation surprise (and our output gap surprise) is inferred from the VAR. What we want to measure is the surprise to the market. Undoubtedly, the market uses much more information in constructing forecasts than is included in the Engel-West VAR. The "event study" approach of Clarida and Waldman gives us a very crisp measure of the surprise—the difference between the actual announced inflation and the expectation of that announcement as collected by Bloomberg News Service from professional forecasters.

Clarida and Waldman mention the relationship of their method to my study with Frankel many years ago (Engel and Frankel 1984.) We looked at the effects of announcements of the money supply in the United States in the early 1980s on the value of the dollar. Like Clarida and Waldman, we related the change in the exchange rate to the difference between the announced value of the money supply and the expected value of the announced money supply as calculated from a survey of forecasters. The flavor of the finding is similar—we found that an unexpectedly high money supply led to an appreciation of the currency. Why? Because it indicated that the central bank was likely to react to this announcement by contracting the money supply. Indeed, we also found that short-term interest rates reacted positively to the money surprise. In the early 1980s, the Fed (supposedly) had a money supply target, so the reaction of the real exchange rate reflected the credibility of Fed policy. Likewise, the exchange rate reaction to news about inflation in the Clarida and Waldman chapter reflects credibility of inflation targeting central banks.

Clarida and Waldman mention three recent studies that have explicitly looked at the exchange rate reaction to announcements about inflation, and the results in those studies tend to support the findings of this chapter. There actually have been many other papers over the years that have examined the reaction of exchange rates to macroeconomic announcements. I will not attempt a survey of them here, but I do want to mention one of the earlier ones, Hardouvelis (1988). Hardouvelis looks at the reaction of interest rates and exchange rates to announcements of a number of economic variables in the October 1979 to August 1984 period. His findings are consistent both with Engel-Frankel and Clarida-Waldman. That is, he finds that the dollar consistently and significantly appreciates in response to positive surprises in the money supply, as in Engel-Frankel, and as we would expect if the Fed were credibly targeting the money stock. But the

1. Engel and West (2006) actually construct a discounted present value because the Taylor rule in one country includes a term for the real exchange rate. Mark (2007) considers a model very much like that in equation (1).

reaction of the dollar to announcements of the Consumer Price Index (CPI) and purchasing power parity (PPI) inflation is mixed. Across seven exchange rates, the sign of the response varies and is never statistically significant. As in the Clarida-Waldman chapter, bad news about inflation is not good news for the currency if the central bank is not inflation-targeting.

Although Clarida and Waldman emphasize the usefulness of their findings for interpreting the credibility of inflation targeting central banks, I think another point worth emphasizing is that the chapter provides empirical support for a fairly standard macroeconomic model of exchange rates. The important difference between this and some other empirical models is that the endogeneity of monetary policy is explicit, but otherwise the building blocks are familiar. Elsewhere, Ken West and I (Engel and West 2005) have emphasized that the standard metric for assessing exchange rate models—can they produce a better out-of-sample forecast of the exchange rate than the random walk model?—is not appropriate. Under plausible conditions, the models actually imply that exchange rates should approximately follow a random walk and, therefore, may not be capable of outforecasting the random walk model.

How, then, should we assess exchange rate models? I think the practical problem is that exchange rate changes are primarily driven by changes in expectations. The models pin down which expectations matter—monetary and real fundamentals. But we have a very hard time measuring the market's expectations. Rational expectations imply that the sample distribution of realized ex post values of variables should be the same as the ex ante distribution of agents' expectations. But in practice, when economic fundamentals are very persistent and subject to regime changes, it is difficult to validate rational expectations models using ex post data.

What is needed, instead, is some more direct way to capture the effects of changes in expectations. I think the approach of Clarida and Waldman (and others that use high-frequency responses to announcements) is one excellent way to deal with the problem. The survey data used here are probably a pretty good measure of expectations. The surveys are taken very close to the time of the announcement and are asking about expectations of a very specific number. The "surprise" in inflation measured by Clarida and Waldman is probably very highly correlated with the surprise to the market.

The fact that exchange rates react to news about inflation precisely the way the models predict—bad inflation news is good news for the currency of countries with inflation targeting—is also confirmation of the exchange rate model.

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## Discussion Summary

*Jordi Galí* said that based on reduced-form regressions and structural vector autoregressions (VARs) uncovered interest parity was rejected in the data and that it must, therefore, be the case that the size of the exchange rate response did not match the size of the interest rate response in the way that would be implied by uncovered interest parity.

*John C. Williams* said that it would be interesting to look further into the uncovered interest parity issue—for example, to look at the movements of interest rates in the two countries and to see whether they also moved as predicted. He also argued that the particular value of the coefficient on surprise inflation in Clarida and Waldman's regressions did not necessarily relate to credibility or lack of credibility, but could reflect the particular loss function of the central bank in question. Clarida agreed that the most that could be inferred was the strength of the central bank's response to inflation.

*Marvin Goodfriend* recalled that in December 2002, the Fed mentioned deflation for the first time. The ten-year Treasury yield collapsed. He wondered whether this was due to expectations of deflation, or to expectations of a Fed response, and what other asset prices could tell us about this.

Regarding the U.K. evidence, *Peter Westaway* said that he considered that the main policy shift had taken place in 1992, when inflation targeting was adopted, rather than in 1997, when the Bank of England was made independent. Clarida replied that the authors used the 1997 reform because it was as close as possible to an unanticipated regime change. Westaway wondered what results would be obtained with other types of policy rule. Clarida said that in some sense, a Taylor rule could never be disentangled from a sufficiently complicated money rule. Westaway concluded by saying that over long periods, uncovered interest parity did not work well. On the other hand, at the time scale of individual days, it worked well, especially in response to classic monetary shocks.