The Unsettling Behavior of Exchange Rates under Inflation Targeting[1]

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Abstract

Over the last few decades, many central banks have adopted an inflation targeting framework and this has generally been associated with reduced inflation variability. In this paper we examine how inflation targeting has changed the behavior of exchange rates and we uncover a rather curious pattern. Using a large set of countries, we find that as countries switched to inflation targeting their currencies became tied to the price of oil, that is, under inflation targeting currencies tend to appreciate with rising oil prices while prior to inflation targeting regime they did not exhibit such a relationship. Importantly, this data pattern is observed independent of whether the country is a net oil exporter or importer. We argue that such a pattern may reflect that, under inflation targeting, the equilibrium dynamics for the nominal exchange rate becomes indeterminate when uncovered interest parity (UIP) *does not hold*. In such situations, oil prices may well act as a focal point for currency pricing decisions.

JEL Classification: E4, F4

Keywords: Inflation targeting, exchange rate, commodity currency, indeterminacy

1 Introduction

Inflation targeting has become an increasingly popular monetary policy operating regime over the past three decades. Starting from New Zealand's initial adoption in 1989, the list of inflation targeting countries has now grown to over thirty. The baseline versions of inflation targeting regimes essentially stipulate an inflation target for the central bank, the index to be used for measurement, some communication and review protocols, and a few exceptional conditions in which the central bank may deviate from its basic goal (such as maintaining financial stability). The proponents of inflation targeting regimes laud the clarity of the regime as well as its positive effect on anchoring private sector expectations.

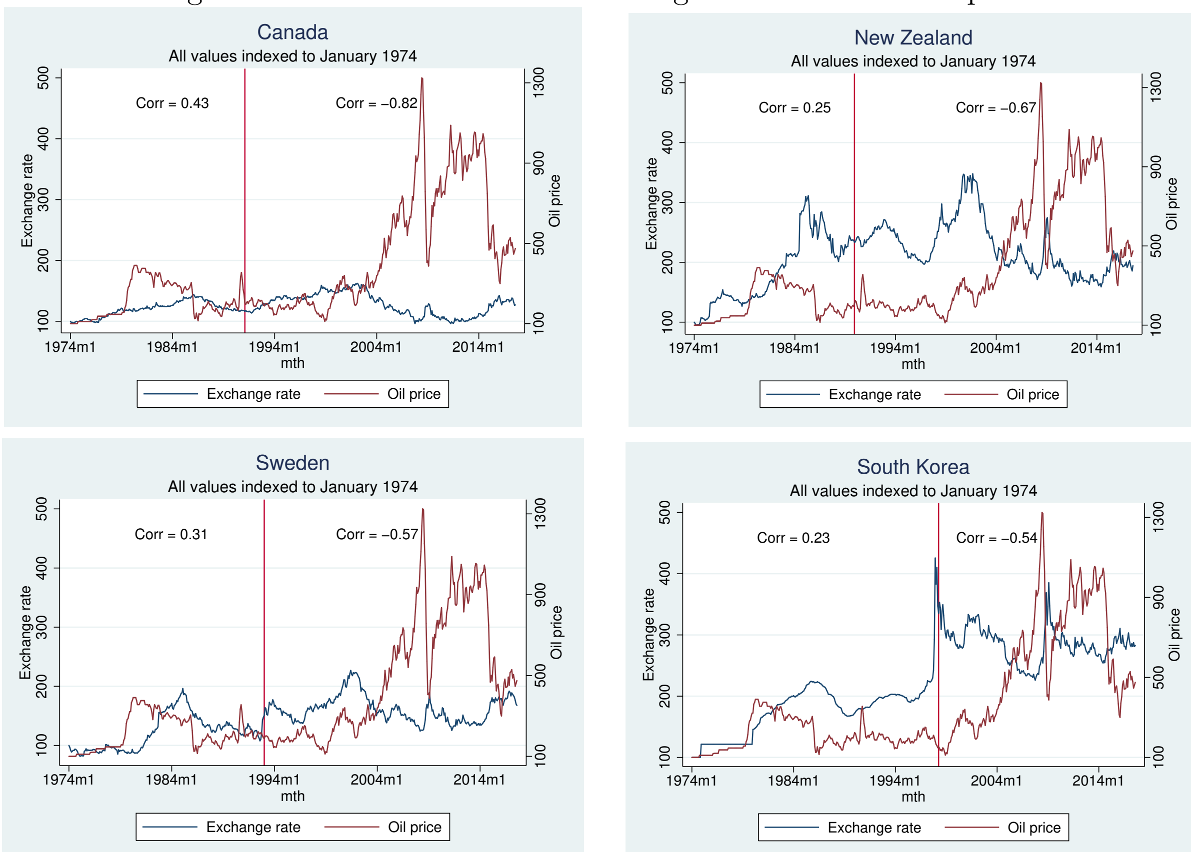
Inflation targeting has proved to be remarkably successful in maintaining low and stable inflation in countries that adopted it. This partly explains its rising popularity over time. However, it also has some interesting ancillary policies. One of them is the fact that central banks that target inflation typically allow their exchange rates to float freely. The idea underneath is that in an environment with inflation targeting, fluctuating exchange rates would allow the system to accommodate shocks to the goods market that require a change in the real exchange rate. While being good in theory, it remains an open question of how inflation targeting actually affects exchange rate behavior. The object of this paper is to (1) document how exchange rate behavior within a country changed between pre and post inflation targeting and (2) offer an explanation to the observed pattern.

In the first part of the paper we uncover a startling data pattern: countries that adopted inflation targeting as their monetary policy framework have seen their currencies becoming systematically linked to the world oil price. Specifically, the currencies of inflation targeting countries tend to appreciate when the world oil price rises and depreciate when the oil price falls. Crucially, this relationship between the exchange rate and world oil prices emerged only after these countries switched to inflation targeting. We find that this empirical relationship is independent of whether or not the country is an oil exporter or importer, and is not driven by time or decade specific affects. This result was quite unexpected, at least to us, and calls for an explanation. In the second part of the paper we propose the elements of one potential answer. Our explanation builds on the observation that in open economies, inflation targeting when combined with the failure of interest parity tends to render the equilibrium dynamics indeterminate. We provide a two dynamic small open economy examples to demonstrate this point. Since in such a situation the exchange rate is no longer pinned down by fundamentals, there is room for exchange rate behavior to become tied to arbitrary forces. Given that many of the early adopter of inflation targeting where commodity exporters, having exchanges rate expectations under inflation targeting become tied to oil prices may have emerged as a natural focal point.

Some of the bizarre or potentially excessive fluctuations of exchanges rates under inflation targeting have recently attracted attention. For example, Canada witnessed a dramatic appreciation of its currency between 2005 and 2013 as world oil prices rose and then an even sharper depreciation since 2015 as oil prices declined. This may not be too surprising as Canada is a oil exporter. Such exchange rate movements may provide implicit exchange rate risk hedging to resource based industries whose prices and revenues are in US dollars but costs are in local currency. Canada, however, was by no means unique in witnessing this oil linked currency cycle. Thus, the Swedish Krona, for example, had a similar cycle. It appreciated from over 9 to 6.4 kronas per US dollar between March 2009 and March 2014 but then began a sharp secular depreciation that left the currency at just over 9 kronas per US dollar by March 2017. Figure 1 shows the exchange rates of four inflation targeting countries from four different continents who adopted inflation targeting at different times. The outcomes are quite similar. While the exchange rates used to typically depreciate during periods of oil price increases, the relationship flipped after they adopted inflation targeting with the correlation becoming negative, i.e., the exchange rate tended to appreciate when oil prices rose. It seems that inflation targeting converted previously non-commodity currencies into commodity currencies.

In general, one would expect the relationship between exchange rates and oil prices to be dependent on country specific factors such as whether the country imports or exports oil (or

Figure 1: Correlation between exchange rate and world oil prices

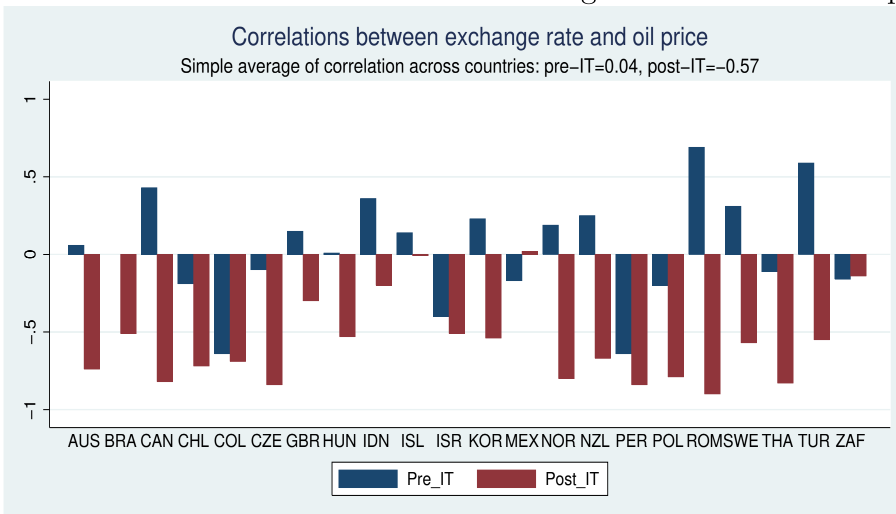


Note: The figure plots the world oil price and the nominal exchange rates of Canada, New Zealand, Sweden and South Korea over time. Exchange rates are local currency units per US dollar which are then indexed to their January 1974 value. The vertical line indicates the date when the country switched to inflation targeting. Corr indicates the correlation coefficient between the exchange rate and the world oil price. The numbers to the left of the vertical lines are the correlations before inflation targeting and the numbr to the right of the line is the correlation post inflation targeting.

energy more generally), amongst other possible factors. Indeed, in a broader sample of twenty two inflation targeting countries, Figure 2 shows that the exchange rate and the world oil price exhibited a mix of positive and negative correlations across the sample before these countries adopted inflation targeting. The average of the country correlations during the pre-inflation targeting phase was 0.04. Intriguingly, the correlation turns negative for most of the countries after they adopted inflation targeting with the average of the country correlations becoming -0.57.

The evidence presented above raises a number of questions. First, does the puzzling

Figure 2: Correlation between nominal exchange rates and world oil price



effect of inflation targeting on the relationship between exchange rates and the world oil price generalize to the full sample of inflation targeting countries? We find that it indeed does generalize. Moreover, it also generalizes beyond oil prices to world energy prices as well. Second, given that it does generalize, is the identified effect of inflation targeting actually representing the effect of a country's reliance on oil exports or some time specific effects related to when most countries adopted inflation targeting? We find that the result is robust to controlling for the country's dependence on oil exports, as well as to country and time effects. Third, if the relationship is not being driven by factors such as oil exports or time effects, how does one explain it? Our explanation is based on the fact that the joint impact of inflation targeting and the failure of uncovered interest parity renders indeterminate the equilibrium dynamics of an open economy. Intuitively, allowing the exchange to fluctuate freely in an environment with inflation targeting with no aggregate nominal anchor makes any given nominal interest rate consistent with a continuum of different levels of the domestic price level and the nominal exchange rate. In such environments, markets could focus on oil or commodity prices more generally to price such an asset. It is important to clarify here that our proposed explanation for the data fact unearthed here is by no means intended to be the only possible explanation. There may well be other complementary explanation as well.

Our work is focused on the interaction between monetary policy, commodity prices (generally) and its effect on the nominal exchange rate. As such it is related to at least three different bodies of research. The first is the long and distinguished work on forecasting exchange rates going back to Meese and Rogoff (1983). The bulk of this literature finds that it is hard to forecast exchange rates using structural models any better than the random walk model. A recent paper that is particularly relevant for our message is by Devereux and Smith (2017) who show that the observed contemporaneous correlation between commodity prices and exchange rates can be rationalized by incorporating the fact that changes in commodity prices impact future monetary policy which in turn, affects the current exchange rate. The second related literature is the work on uncovered interest parity. This work tends to find that uncovered interest is often violated in simple data tests, a feature that we build on in our theoretical model. A recent updated overview of this literature along with the implications for monetary policy can be found in Engel, Lee, Liu, Liu, and Wu (2017). The third strand of work that relates to us is the research on the macroeconomic effects of monetary policy rules, particularly the Taylor rule. An overview of this body of work can be found in Woodford (2003).

In the next section we present the basic data fact. Section 3 presents the model which we use to illustrate our explanation for the data fact. Section 4 presents some evidence of the failure of uncovered inteest parity in our sample of inflation targeting countries while the last section concludes.

2 The Empirical Relationship

Our interest is in systematically teasing out the relationship between oil prices and the exchange rates of countries that have chosen inflation targeting as their preferred monetary policy regime. In order to uncover this relationship we examine monthly data for sample of twenty seven countries which chose to adopt inflation targeting at some point. We examine this relationship using monthly data between January 1974 and August 2017.

2.1 Data

The list of countries along with the date on which these countries switched to inflation targeting is taken from Hammond (2012). Table 1 gives the names of the countries along with the year and month in which they adopted the inflation targeting regime. The oil price series we use is the spot rate of WTI crude taken from the FRED database of FRB St. Louis. In some of our specifications, we control for the economic dependence on oil of the countries in our sample. For this we use net exports of oil as a share of GDP. Our oil trade data comes from the United Nations COMTRADE database.

Since the primary aspect of our exercise is to determine the behavior of exchange rates, we need to select countries that actually allow their exchange rates to fluctuate in response to market pressures. We use the updated version of Reinhart and Rogoff (2004) to classify countries into flexible exchange rate regimes. Specifically, we use their fine classifications 11-14 as indicators of flexible exchange rate regimes. Clearly, countries could have periods where they are classified as flexible and other periods where they are not. For our empirical analysis we only consider years for which a country had a flexible exchange rate. Our monthly exchange rate data comes from International Financial Statistics of the IMF. Details regarding the data are provided in the Appendix.

2.2 Empirical results

We examine the empirical relationship between exchange rates and oil prices in two different ways. We first study the individual country level impulse responses of exchange rates to oil price shocks identified from a three variable vector autoregression model. We then study the relationship between exchange rates and oil prices using panel regressions that control for various possible confounding factors including oil exporter status, country fixed effects and time effects.

Table 1: Inflation Targeting Countries: Early and Late Adopters

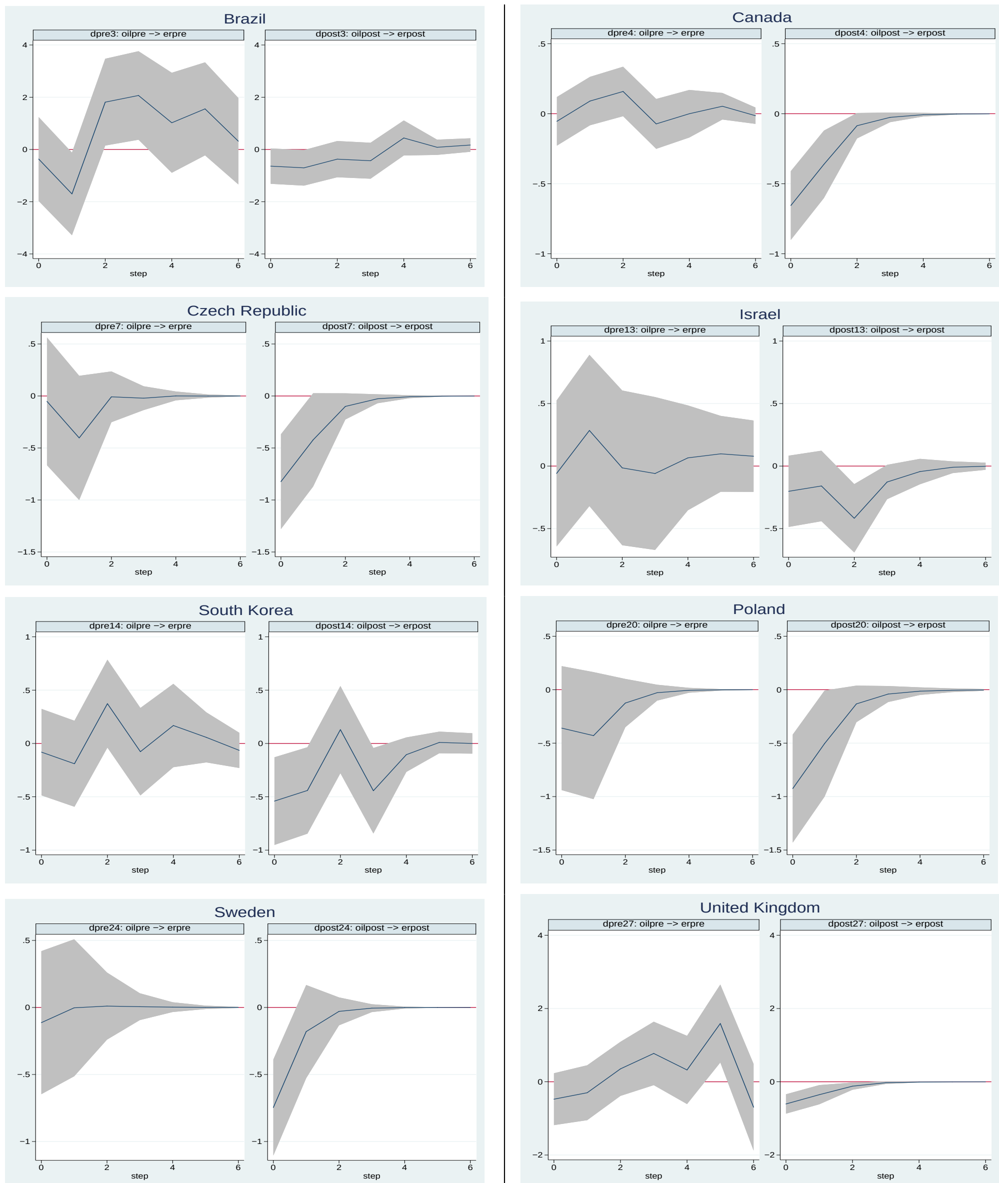
Early adopters		Late adopters	
Country	*Date of adoption*	*Country*	*Date of adoption*
New Zealand	December 1989	South Africa	February 2000
Canada	February 1991	Thailand	May 2000
United Kingdom	October 1992	Mexico*	January 2001
Sweden	January 1993	Norway	March 2001
Australia	June 1993	Hungary	June 2001
Israel	June 1997	Peru	January 2002
Czech Republic	December 1997	Philippines	January 2002
Poland*	January 1998	Guatemala*	January 2005
South Korea	April 1998	Iceland	March 2005
Brazil	June 1999	Indonesia	July 2005
Chile	September 1999	Romania	August 2005
Colombia	October 1999	Armenia	January 2006
		Turkey	January 2006
		Serbia	September 2006
		Ghana	May 2007

Notes: 1. The table reports the list of countries that have adopted inflation targeting. The countries have been collected in two groups – early adopter who adopted prior to 2000 and late adopters who adopted from 2000 onwards. 2. * indicates that the precise date of adoption is not avaialble. For our econometric analysis below we assume the adoption month to be January for these countries.

2.2.1 Vector AutoRegressions (VAR)

We start by estimating a three-equation VAR model for each country in our sample. Specifically, the model includes the exchange rate, the consumer price index and the world oil price. We estimate the model in growth rates rather than levels since the levels of prices are often non-stationary. For each country we estimate the VARs separately for the pre-inflation targeting and post-inflation targeting periods. Our identification scheme involves assuming that the exchange rate is most endogenous while world oil prices are most exogenous. There were insufficient observations to estimate the pre and post inflation targeting priods separately for Armenia, Australia, Chile, Colombia, Ghana, Guatemala, Indonesia, New Zealand, Peru, Philippines, Romania and Serbia. This left us with estimated models for fifteen countries. The impulse responses of the exchange rate to world oil price shocks from the estimated VAR models are shown in the figures below.

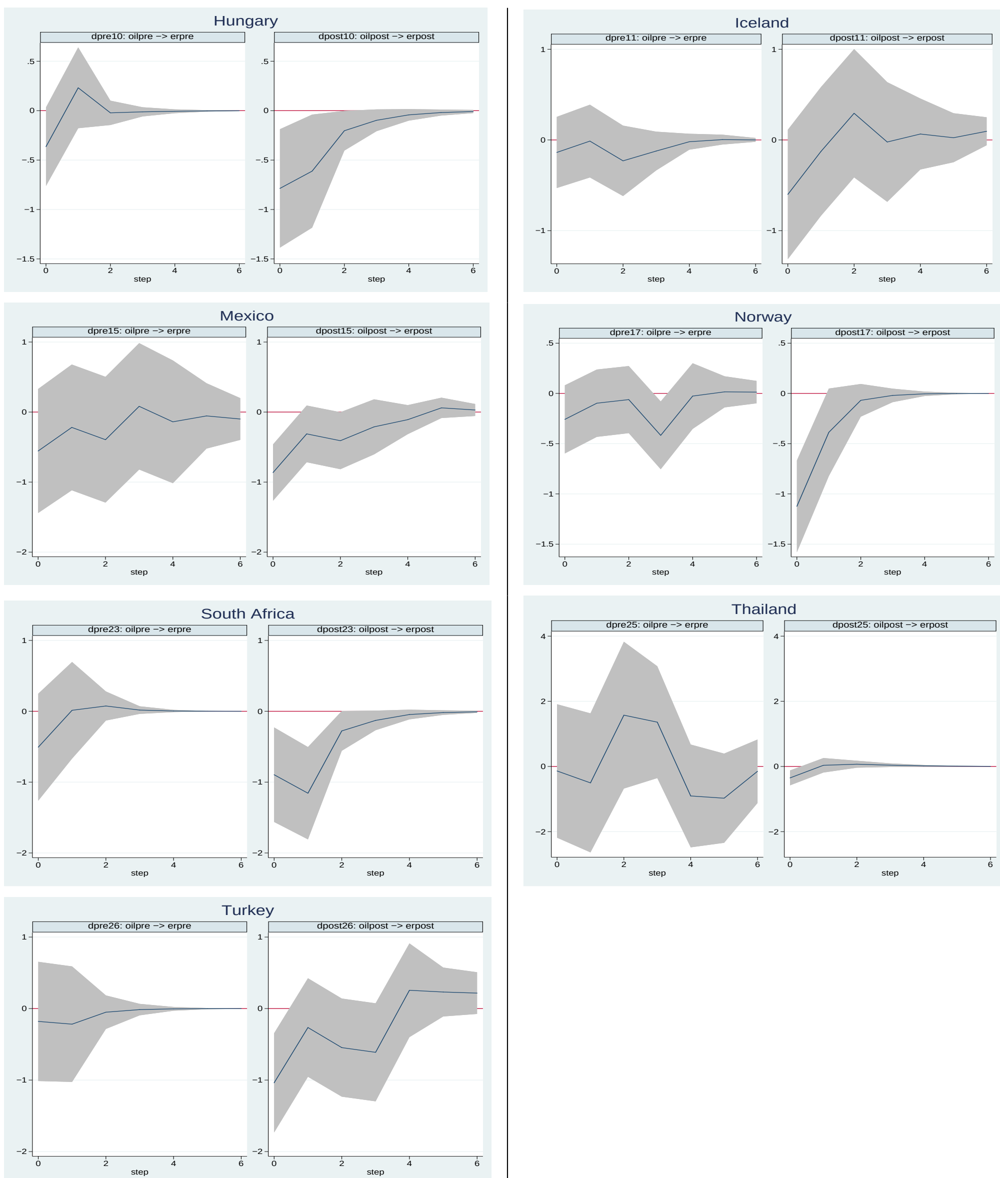
Figure 3: Exchange rate response to oil price shock in early IT adopters



Notes: The figure plots the impulse response of the growth rate of the nominal exchange rate to a one unit shock to the growth rate of the world oil price from a three variable VAR model including the exchange rate, consumer price index and the world oil price (all in growth rates). The Choleski ordering for identification is oil price, CPI, exchange rate. The shaded regions depict 95 percent confidence intervals around the impulse response functions.

Figure 3 shows the impulse response of the exchange rate to a one unit shock to the world oil price. The shaded areas depict the 95 percent confidence intervals. The striking feature of the Figure is the sharp contrast between the pre and post IT periods n the impact effect of an oil shock on exchange rates. While in the pre-IT period the effect of an oil shock on the exchange rate is insignificantly different from zero, in the post-IT period the impact effect is significantly negative in seven out of the eight countries.

Figure 4: Exchange rate response to oil price shock in late IT adopters



Notes: The figure plots the impulse response of the growth rate of the nominal exchange rate to a one unit shock to the growth rate of the world oil price from a three variable VAR model including the exchange rate, consumer price index and the world oil price (all in growth rates). The Choleski ordering for identification is oil price, CPI, exchange rate. The shaded regions depict 95 percent confidence intervals around the impulse response functions.

Figure 4 shows the corresponding impulse responses of exchange rates to oil price shocks in the countries that were late adopters of inflation targeting. Just as in the early adopters, in this group too the impulse responses are strikingly different in the pre and post inflation targeting periods. In six out of the seven countries, the exchange rate appreciates significantly on impact of an oil price shock during the post inflation targeting period whereas during the pre inflation targeting phase the exchange rate response was statistically insignifcantly different from zero.

We find these results quite striking both in terms of the contrast between the pre and post inflation targeting periods but also for their similarity across dissferent groups of countries that adopted inflation targeting at very different times and which have very different country characteristics.

2.2.2 Panel Regressions

The VAR results, while instructive and interesting, leave open some important issues. Thus, the results could be driven by the dependence of these countries on oil. Specifically, oil price shocks could impact countries differently depending on whether they are oil importers or exporters.One might also wonder if time effects related to when these countries adopted inflation targeting may be driving some of the results.

To test the general effect of inflation targeting on the relationship between the exchange rate and world oil prices while controlling for different confounding factors, we estimate the following baseline panel regression:

$$E_{it} = \alpha + \beta_1 Oil\_price_t + \beta_2 Oil\_price_t * IT_{it} + \varepsilon_{it}$$

where Oil_price_t is the world oil price (in dollars) at date t and IT_{it} is a dummy variable that takes value one if country i at date t is an inflation targeter, and zero otherwise. In running the regressions we also add in country fixed effects as well as quinquennial dummies to control for time effects that might also be important in driving the relationship between oil prices and exchange rates. The coefficient of interest for us is β_2 in this regression.

The column labeled (1) in Table 2 presents our baseline results. The coefficient on the interaction term is negative and significant at the 1 percent level indicating that relative to non-inflation targeting countries, exchange rates of inflation targeting countries tend to appreciate when the world oil price rises. Indeed, this appreciation of the currency in inflation targeting countries is not just relative to non-inflation targeting countries but also in absolute terms (the sum of the coefficients on the oil price and the oil price and inflation targeting dummy interaction term is negative). Importantly, the effect of oil prices on the exchange rates of non-inflation countries is insignificant. Clearly, the simple correlations and visual impressions conveyed by Figures 1 and 2 generalize to more formal econometric methods where one includes controls for other variables as well as country and time effects.

An immediate concern regarding our baseline results is that they may just be picking up the fact that a number of inflation targeting countries may be oil exporters and the estimates may just be indicating that the exchange rate tends to appreciate in oil exporting countries when the world oil price rises. Since oil prices are denominated in dollars, higher dollar earnings of oil exporting countries likely increase the demand for their own currency and cause an appreciation. Column (2) of the Table adds four additional regressors: an oil exporter dummy which takes the value one in every period in which the country is a net exporter of oil and zero otherwise; an interaction between the oil net exporter dummy and the inflation targeting dummy; an interaction between the oil exporter dummy and oil prices; and a triple interaction between the oil exporter dummy, the inflation targeting dummy and the oil price. The regression coefficient on the triple interaction gives the differential effect of oil prices on the exchange rate in inflation targeting regimes that are net oil exporters (relative to oil importers).

The results in Column (2) of the table show that the baseline results are robust to controlling for the net oil exporter status of the country. While higher oil prices do tend to appreciate the currency more in inflation targeting countries that are net oil exporters (relative

Table 2: Exchange rate and oil prices

VARIABLES	(1) E_{it}	(2) E_{it}	(3) E_{it}	(4) E_{it}
Oil_price_t	1.372	4.642***		
	(0.869)	(1.279)		
IT_{it}	9.079	-42.67	8.465	-16.29
	(27.41)	(39.30)	(27.97)	(32.92)
$Oil\_price_t * IT_{it}$	-2.333***	-5.278***		
	(0.892)	(1.317)		
Oil_NX_{it}		-111.4***		
		(28.75)		
$Oil\_NX_{it} * IT_{it}$		150.6***		
		(37.43)		
$Oil\_NX_{it} * IT_{it} * Oil\_price_t$		-1.137**		
		(0.476)		
$Energy\_price_t$			1.023	1.304
			(0.692)	(0.767)
$Energy\_price_t * IT_{it}$			-1.767**	-1.831**
			(0.708)	(0.791)
$Energy\_NX_{it}$				162.4***
				(23.98)
$Energy\_NX_{it} * IT_{it}$				-2.493
				(30.6)
$Energy\_NX_{it} * IT_{it} * Energy\_price_t$				-0.500
				(0.316)
Observations	7023	5096	7023	6450
R-squared	0.034	0.043	0.033	0.043
Countries	25	24	25	24
Country fixed effects	YES	YES	YES	YES
Quinquennial time dummies	YES	YES	YES	YES

Notes: 1. The table reports the results of regressions of the nominal exchange rate on various country, time and world characteristics. IT_{it} is a dummy for an inflation targeting country i at date t. Oil_NX_{it} denotes a dummy variable for that takes value 1 when net exports of oil by country i at date t are positive. Oil_price_t denotes the world oil price at date t (measured in US dollars). 2. All exchange rates are measured in local currency units per US dollar. 3. Standard errors of the estimates are in parenthesis. *** indicates significance at the 1 percent level, ** at the 5 percent level and * indicates significance at the 10 percent level.

to oil importing inflation targeters), the exchange rate appreciating effect of higher oil prices in inflation targeting countries becomes even stronger after controlling for the oil exporter status of the countries in the sample.

Oil prices tend to be very correlated with commodity prices and energy price indices in general. An immediate check for the robustness of our results is to examine if the results carry over to broader measures of world energy prices. Columns (3) and (4) of Table 2 re-run the regressions in Columns (1) and (2) but with the world energy price index instead. The results are very similar to those obtained from the oil price regressions. Higher energy prices cause significant exchange rate appreciations in inflation targeting countries both relative to non-inflation targeting countries and in absolute terms. Contrarily, the exchange rates of non-inflation targeting countries are statistically unaffected by changes in world energy prices. Column (4) of the Table shows that these results are robust to controlling for the energy net exporter status of the countries in our sample. Interestingly, there are no statistically differential effects of energy prices on the exchangge rate of energy exporting inflation targeters relative energy importing inflation targeting countries.

A potentially confounding issue with running regressions of nominal exchange rates on other prices such as world oil prices is the possible non-stationarity of the two series. To alleviate concerns regarding spurious inference from regressions of levels on levels of non-stationary time series, we also ran the specification with both exchange rates and oil prices in growth rates rather than levels. The results are reported in Table 3. The main result to note is that the coefficients on the interaction term between oil prices and the inflation targeting dummy remain negative and highly significant as do the coefficients on the interaction term between the growth rate of energy prices and the inflation targeting dummy. We conclude from these regression that our inference regarding inflation targeting converting currencies into commodity currencies is not spuriously driven by the non-stationarity of exchange rates and oil prices. The relationship emerges even in stationary specifications where these variables enter in growth rates rather than levels.

The set of countries that have adopted inflation targeting can be broadly broken into to groups – the early adopters who adopted before 2000 and the later adopters who waited till after 2000. Table 1 gives the list of the countries along with the date on which they adopted the regime. The early adopters tended to be more developed than the later adopters. One

Table 3: Growth Rates of Exchange Rates and Oil Price

	(1)	(2)	(3)	(4)
VARIABLES	E_{it}	E_{it}	E_{it}	E_{it}
Oil_price_t	-0.0290**	-0.0397***		
	(0.0123)	(0.0125)		
IT_{it}	-0.0023	-0.0010	-0.0021	-0.0070***
	(0.0025)	(0.0028)	(0.0025)	(0.0025)
$Oil\_price_t * IT_{it}$	-0.0550***	-0.0423***		
	(0.0151)	(0.0157)		
Oil_NX_{it}		-0.0020		
		(0.0030)		
$Oil\_NX_{it} * IT_{it}$		-0.0005		
		(0.0028)		
$Oil\_NX_{it} * IT_{it} * Oil\_price_t$		-0.0116		
		(0.0167)		
$Energy\_price_t$			-0.0261**	0.0200
			(0.0140)	(0.0135)
$Energy\_price_t * IT_{it}$			-0.0766***	-0.0823***
			(0.0175)	(0.0178)
$Energy\_NX_{it}$				-0.0031
				(0.0030)
$Energy\_NX_{it} * IT_{it}$				0.0066***
				(0.0025)
$Energy\_NX_{it} * IT_{it} * Oil\_price_t$				-0.0042
				(0.0199)
Observations	6981	5072	6981	6411
R-squared	0.037	0.041	0.038	0.044
Countries	24	23	24	23
Country fixed effects	YES	YES	YES	YES
Quinquennial time dummies	YES	YES	YES	YES

Notes: 1. The table reports the results of regressions of the growth rate of the nominal exchange rate on various country, time and world characteristics. IT_{it} is a dummy for an inflation targeting country i at date t. Oil_NX_{it} denotes a dummy variable for that takes value 1 when net exports of oil by country i at date t are positive. Oil_price_t denotes the growth rate of the world oil price at date t (measured in US dollars). 2. All exchange rates are measured in local currency units per US dollar. 3. Standard errors of the estimates are in parenthesis. *** indicates significance at the 1 percent level, ** at the 5 percent level and * indicates significance at the 10 percent level.

might wonder whether our results are being driven by specific characteristics of countries that belong to one of these two groups rather than revealing anything about inflation targeting itself. To check this we ran the baseline regressions on the early and late adopters separately. Table 4 reports the results for regressions both in levels of exchange rates and oil prices as well as in growth rates of the two variables. Our baseline results for the entire sample clearly hold within each sub-sample of early and late adopters. In both sets of countries, the coefficient on the interaction term between oil prices and the inflation targeting dummy in the level regression is negative and significant at the 1 percent level. The corresponding coefficient in the growth rate regressions are also negative for both groups. The only specification in which the oil price and IT dummy interaction term is insignificant is for the late adopter sub-sample. This is due to the greater imprecision of the estimate due to the somewhat smaller sample size of the late-adopter group.[1]

In summary, the regression results in Tables 2 and 3 confirm the simple negative correlations that summarized the relationship between oil prices and exchange rates in inflation targeting countries. This relationship is robust to including controls for net oil exporter status, country effects, time effects, split samples as well broader measures of energy prices. The fact is puzzling. Why does inflation targeting tend to convert currencies into commodity currencies?

3 An Explanation

Consider a small open economy with two goods – a traded and a non-traded good. The economy has access to international capital markets where they can trade in riskless international bonds. However, we will allow for deviation from uncovered interest parity. Specifically, we will assume that

$$\psi (i_t - r) = \varepsilon_t \tag{3.1}$$

where i is the domestic nominal interest and ε is the rate of depreciation of the domestic currency. $\psi = 1$ corresponds to the standard interest parity case. $\psi < 0$ is the case where interest parity not only fails but we have the forward premium anomaly, which is a feature of

[1]We have also run the regressions of exchange rates on energy prices using the same specifications as reported 4. The coefficient on the interaction term between energy prices and the inflation targeting dummy is negative and significant at the 5 percent level for both levels and growht rates for both the early and late IT adopters.

Table 4: Exchange rate and oil prices in early and late adopters

	Early IT adopters		Late IT adopters	
VARIABLES	E_{it}		E_{it}	
	Level	*Growth rate*	*Level*	*Growth rate*
Oil_price_t	0.566	-0.0237	5.776**	-0.0505**
	(0.468)	(0.0145)	(2.924)	(0.0228)
IT_{it}	0.298	-0.0040*	19.87	0.0039
	(13.38)	(0.0032)	(127.6)	(0.0076)
$Oil\_price_t * IT_{it}$	-1.423***	-0.0649***	-5.262*	-0.0110
	(0.4820)	(0.0170)	(3.072)	(0.0338)
Oil_NX_{it}	13.07	0.0006	9.228	-0.0077
	(8.486)	(0.0029)	(253.7)	(0.0218)
$Oil\_NX_{it} * IT_{it}$	94.95***	-0.0006	-3.251	0.0114
	(11.09)	(0.0031)	(127.63)	(0.0071)
$Oil\_NX_{it} * IT_{it} * Oil\_price_t$	-2.383***	0.0076	0.0014	-0.0564
	(0.143)	(0.0166)	(1.490)	(0.0385)
Observations	3417	3408	1679	1664
R-squared	0.153	0.048	0.201	0.056
Countries	11	11	13	12
Country fixed effects	YES	YES	YES	YES
Quinquennial time dummies	YES	YES	YES	YES

Notes: 1. The table reports the results of regressions of the nominal exchange rate on various country, time and world characteristics, separately for early late adopters of inflation targeting. IT_{it} is a dummy for an inflation targeting country i at date t. Oil_NX_{it} denotes a dummy variable for that takes value 1 when net exports of oil by country i at date t are positive. Oil_price_t denotes the world oil price at date t (measured in US dollars). 2. All exchange rates are measured in local currency units per US dollar. 3. Standard errors of the estimates are in parenthesis. *** indicates significance at the 1 percent level, ** at the 5 percent level and * indicates significance at the 10 percent level.

the data.

The economy also has frictionless access to international goods markets so that the law of one price will hold on traded goods. Given the small open economy structure, the law of one price makes it impossible to accommodate nominal price stickiness in a one traded good environment. To talk about sticky prices we need to introduce a non-traded good into the model whose prices will be assumed to be sticky.

The economy is inhabited by a representative agent who maximizes lifetime welfare given by

$$V = \int_{t=0}^{\infty} e^{-\rho t} \left[\gamma \ln \left(c_t^T \right) + (1-\gamma) \ln \left(c_t^N \right) + \ln \left(z_t \right) \right] dt \tag{3.2}$$

where c^T is consumption of the traded good, c^N is consumption of the non-traded good, and $z = M/P$ denotes real money balances in terms of the price index. $P = E^{\gamma} \left(P^N\right)^{1-\gamma}$ denotes the price index for this economy. Note that we are assuming that utility is derived from holding nominal balances deflated by the price index since the consumer consumes two goods. Moreover, throughout we are normalizing the world dollar price of the traded good to unity.

The agent receives a constant endowment y^T of the traded good. The foreign currency price of the traded good is constant and normalized to unity. Hence, the domestic currency price of the traded good is just the nominal exchange rate E_t. It is assumed that the domestic currency price of the non-traded good is sticky. Production of the non-traded good is demand determined — producers supply the output that is demanded at the previously posted price. In the following we shall use the traded good as the numeraire.

The agent's flow budget constraint is

$$\dot{b} = rb + y^T + \frac{y_t^N}{e_t} + g_t - c_t^T - \frac{c_t^N}{e_t} - \dot{m}_t - \varepsilon_t m_t \tag{3.3}$$

where b are international risk free bonds denoted in terms of the traded good, r is the world risk-free rate of interest, $e = E/P^N$, $m = M/E$ and $\varepsilon = \frac{\dot{E}}{E}$. Rewriting this constraint by using $a = b + m$ and using equation 3.1 gives

$$\dot{a} = ra + y^T + \frac{y_t^N}{e_t} + g_t - c_t^T - \frac{c_t^N}{e_t} - (r + \varepsilon_t) \frac{z_t}{e_t^{1-\gamma}}$$

Note that the price index implies that $m = z/e^{1-\gamma}$.

The first-order conditions for this problem are

$$\begin{aligned} \frac{\gamma}{c_t^T} &= \lambda_t \\ \frac{1-\gamma}{c_t^N} &= \frac{\lambda_t}{e_t} \\ \frac{1}{z_t} &= \frac{\lambda_t (r + \varepsilon_t)}{e_t^{1-\gamma}} \end{aligned}$$

$$\dot{\lambda}_t = (\rho - r)\,\lambda_t$$

Combining the first two conditions gives

$$\frac{\gamma}{1-\gamma}\frac{c_t^N}{c_t^T} = e_t$$

This conditions says that the marginal rate of substitution between traded and non-traded goods should equal the relative price e. Note that e is the real exchange rate in this model.

It is useful to solve for money demand in a couple of different ways. Money demand in terms of the price index is given by

$$z_t = \frac{c_t^N}{(1-\gamma)\,e_t^{\gamma}\,(r+\varepsilon_t)} \tag{3.4}$$

Since $m = \frac{z}{e^{1-\gamma}}$, money demand in terms of the traded good is given by

$$m_t = \frac{c^T}{\gamma\,(r+\varepsilon_t)} \tag{3.5}$$

On the supply side of the non-tradable sector, the key feature is price stickiness. We make the standard assumption under nominal stickiness that non-tradable producers supply goods to meet demand at the predetermined price. Hence, non-tradable output is demand determined. In order to formalize the price setting process we need additional notation. In particular, let $\pi_t \equiv \frac{\dot{P}^N}{P^N}$. We assume that P^N is a predetermined variable. We assume that non-tradable producers set prices according to a staggered prices formulation due to Calvo (1983). This formulation implies that inflation is fully flexible since producers who change their prices at date t are free to set it at any level they choose. Since producers set their prices in a forward looking way, inflation is a jump variable. Calvo showed that the model implied that

$$\dot{\pi}_t = \theta\left(\bar{y}^N - y_t^N\right), \qquad \theta > 0 \tag{3.6}$$

where $\bar{y}^N$ is the full employment level of output. Hence, the rate of change of inflation is a negative function of excess demand.

The consolidated government (the fiscal and the monetary authority combined) in this economy holds interest bearing international reserves R, prints money and makes lump-sum payments g to the private sector. The government's flow constraint is

$$\dot{R}_t = rR_t + \dot{m} + \varepsilon_t m_t - g_t \tag{3.7}$$

Combining the government's and private sector's flow constraint gives the aggregate resource constraint for the economy:

$$\dot{f}_t = rf_t + \bar{y}^T - c_t^T$$

In deriving this resource constraint we have used the market clearing condition for non-traded goods:

$$y_t^N = c_t^N$$

3.1 Equilibrium

To describe the equilibrium of this economy, we start with the policy variables. The exchange rate is freely flexible. Hence, $\dot{R} = 0$ at all times. The central bank is assumed to follow a Taylor rule in choosing the domestic interest rate i. The interest rate at any point in time is predetermined but the monetary authority varies it to target two variables: inflation and the level of excess demand in the economy. Specifically,

$$\dot{i}_t = \mu_1 \pi_t + \mu_2 \left(c_t^N - \bar{y}^N \right), \qquad \mu_1 > 0, \mu_2 > 0 \tag{3.8}$$

where, with no loss of generality, we have assumed that the monetary authority targets a long run inflation rate of zero.

The constant level of tradable consumption is

$$\bar{c}^T = rf_0 + \bar{y}^T$$

Moreover, consumption of the non-tradable is

$$c_t^N = \left(\frac{1-\gamma}{\gamma}\right)\left(rf_0 + \bar{y}^T\right)e_t$$

Recall that the full-employment level of non-tradable production is $\bar{y}^N$. Hence, when the economy is at full employment we must have

$$\bar{y}^N = \left(\frac{1-\gamma}{\gamma}\right)\left(rf_0 + \bar{y}^T\right)\bar{e}$$

where $\bar{e}$ is the real exchange rate consistent with full-employment.

$$\bar{e} = \left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\bar{y}^N}{rf_0 + \bar{y}^T}\right)$$

Combining these expressions gives

$$c_t^N - \bar{y}^N = \left(\frac{1-\gamma}{\gamma}\right)\left(rf_0 + \bar{y}^T\right)(e_t - \bar{e})$$

Hence, the Taylor rule given in equation 3.8 can be rewritten as

$$\dot{i}_t = \mu_1 \pi_t + \mu_3 (e_t - \bar{e}), \qquad \mu_3 \equiv \mu_2 \left(\frac{1-\gamma}{\gamma}\right)\left(rf_0 + \bar{y}^T\right) > 0$$

The real exchange rate dynamics, by definition, are governed by the differential equations

$$\dot{e}_t = (\varepsilon_t - \pi_t)\, e_t$$

where ε is the rate of depreciation of the local currency. Substituting equation 3.1 into this and rewriting it gives

$$\dot{e}_t = [\psi (i_t - r) - \pi_t] e_t$$

The dynamic system for this economy can be characterized by the system

$$\dot{\pi}_t = \theta \left[\bar{y}^N - \left(\frac{1-\gamma}{\gamma} \right) \left(r f_0 + \bar{y}^T \right) e_t \right] \tag{3.9}$$

$$\dot{e} = [\psi (i_t - r) - \pi_t] e_t \tag{3.10}$$

$$\dot{i}_t = \mu_1 \pi_t + \mu_3 (e_t - \bar{e}) \tag{3.11}$$

This is a system with two jump variables (π and e) (note that $e = E/P^N$ which is a jump variable because E can jump) and one predetermined variable i. Hence, saddle dynamics requires one stable root while indeterminacy would be indicated by two or more stable roots.

The steady state of this system is $\dot{\pi} = \dot{e} = \dot{i} = 0$. Using stars to denote steady state values, in steady state we must have $c^{N*} = \bar{y}^N, e^* = \bar{e}, \pi^* = 0$ and $i^* = \frac{r}{\psi}$. The determinant of the Jacobian matrix of this system is

$$|J| = -\psi \mu_1 \theta \left(\frac{1-\gamma}{\gamma} \right) \left(r f_0 + y^T \right) \bar{e} = -\psi \mu_1 \theta \bar{y}^N$$

Hence, the product of the roots is positive or negative as ψ is negative or positive, respectively. Moreover, the sum of the diagonal elements of the Jacobian matrix is zero.[2]

Case 1: $\psi > 0$: In this case the product of the roots is negative. Hence, we have either one or three negative roots. Since the sum of the roots is zero, the only possibility is one negative root. Hence, the system is saddle path stable.

Case 2: $\psi < 0$: In this case the product of the roots is positive while their sum is still zero. The only consistent possibility is two negative roots. Hence, we have an indeterminacy since this system has only one predetermined variable i.

[2] In terms of stability properties of the system, recall that the system is a saddle if there are as many stable roots as the number of predetermined variables, a sink if the number of stable roots exceeds the number of predetermined variables and a source if the number of stable roots is less than the number of predetermined variables of the system.

We collect these results in the following proposition:

Proposition 1 *The small open economy described by equations 3.1,3.2,3.3,3.6,3.7 and 3.8 is characterized by a unique steady state. The perfect foresight dynamic equilibrium path to this unique steady state is unique if $\psi > 0$ and indeterminate if $\psi < 0$.*

Proposition 1 essentially says that when uncovered interest parity fails, so that $\psi < 0$, the equilibrium dynamics of the economy around its unique steady state is locally indeterminate. Hence, one cannot uniquely pin down the transition path starting any given initial condition for the state variables of the economy. As is well known, indeterminacy of equilibria lead to multiple possibilities including possible sunspot equilibria where variables extrinsic to the economy can serve as focal points for the economy to pick one amongst a multitude of equilibria.

In the context of our focus on exchange rates, these results suggest that one rationalization of our empirical findings is that inflation targeting along with the failure of interest parity renders the equilibrium dynamics of open economies indeterminate. To understand the result better it is instructive to recall from equation (3.5) that the demand for money in terms of the traded good is given by

$$m_t = \frac{c^T}{\gamma \psi i_t}$$

Since c^T is invariant over time due to consumption smoothing, every nominal interest rate i_t is uniquely associated with a unique real money demand m_t. However, since neither the nominal stock of money nor the nominal exchange rate at date t are predetermined, one needs one of these two variables to be uniquely pinned down in order for the other variable to become determinate. The indeterminacy implies that the path of the exchange rate cannot be pinned down uniquely by the initial conditions. Hence, the path of the nominal money stock is also indeterminate. Put differently, the system has no nominal anchor. In these conditions, oil prices may well serve as a way for markets to price the currencies of these countries.

To complete the argument, we need to demonstrate one more result, namely, that when countries choose not to be inflation targeters, the system becomes saddle path stable and the dynamic equilibrium path is uniquely pinned down by initial conditions. In terms of our model economy, no inflation targeting corresponds to $\mu_1 = 0$ while inflation targeting implies $\mu_1 > 0$. It is straightforward to check that with $\mu_1 = 0$ the system has a zero root and the other two roots are of opposing signs of equal magnitude. That indicates saddle path stability. Hence, under no inflation targeting the equilibrium dynamics are unique independent of whether or not interest parity holds, i.e., it is independent of whether ψ is positive or negative.

3.2 Reduced form specification

The model outlined above has a couple of features that are debatable. The first is the specification of the Philips curve. The Calvo time-dependent price setting environment that we have used gives rise to a Philips curve given in equation (3.6) as $\dot{\pi}_t = \theta \left(\bar{y}^N - y_t^N\right)$. This implies that inflation is rising during recessions (when y^N is below full employment) and falling during booms (when y^N is above full employment). This implication does not find support in the data. Consequently, the Calvo specification for price setting has been criticised as failing a basic data test (see, for example, Mankiw (2001)).

A second distinctive feature of the model outlined above was the specification of the Taylor rule in equation (3.8). We specified the rule as $\dot{i}_t = \mu_1 \pi_t + \mu_2 \left(c_t^N - \bar{y}^N\right)$. This is a specification that makes the policy interest rate a state variable at any point in time with the monetary authority choosing the *change* in the rate at date t based on the inflation rate and the level of excess demand. An alternative, and possibly more common, specification for the Taylor rule is in terms of the level of the policy rate rather than in the change in the level of the rate.

How sensitive are our results to the specifications for the Philips curve and the Taylor rule? We examine this question by respecifying the model with an empirically motivated Philips curve and a more conventional Taylor rule. In particular, suppose

$$\pi_t = \theta \left(c_t^N - \bar{y}^N\right) \tag{3.12}$$

$$i_t = \mu_1 \pi_t + \mu_2 \left(c_t^N - \bar{y}^N\right) \tag{3.13}$$

The last equation that describes this economy is the evolution equation for the real exchange rate. The definition of the real exchange rate as $e = E/P^N$ gives

$$\dot{e} = (\varepsilon - \pi) e \tag{3.14}$$

Note that since P^N is sticky under our assumptions. Hence, the real exchange rate e can jump at any date only if the nominal exchange rate jumps.

Two features of this modified Taylor rule specification in equation (3.13) are noteworthy. First, this policy rule reduces to that of a strict inflation targeter when $\mu_2 = 0$. In the following we shall assume that $\mu_2 = 0$ since our interest is in understanding the effect of inflation targeting on the dynamics of the economy. Second, under the Taylor principle $\mu_1 > 1$. We shall maintain this assumption below.

Combining equations (3.14) with equations (3.12), (3.13) and the modified interest parity condition $\varepsilon_t = \psi (i_t - r)$ (from equation (3.1) above) gives

$$\dot{e} = \psi \mu_1 \theta_1 (e - \bar{e}) e - \theta_1 (e - \bar{e}) e$$

where we have assumed that $\mu_2 = 0$ and where $\theta_1 \equiv \theta \left(\frac{1-\gamma}{\gamma}\right) \left(r f_0 + \bar{y}^T\right) > 0$. In deriving the above we have used the fact that $c_t^N - \bar{y}^N = \left(\frac{1-\gamma}{\gamma}\right) \left(r f_0 + \bar{y}^T\right) (e_t - \bar{e})$. Differentiating this with respect to time and evaluating around the steady state where $e = \bar{e}$ gives

$$\left.\frac{d\dot{e}}{de}\right|_{e=\bar{e}} = \theta_1 \bar{e} (\psi \mu_1 - 1) \tag{3.15}$$

Clearly, the equilibrium dynamics in a local neighborhood of the steady state will indeterminate if $\psi \mu_1 < 1$. On the other hand, if $\psi \mu_1 > 1$ then the system is unstable around the steady state. Hence, e must jump to its steady state value $\bar{e}$ immediately at $t = 0$.

There are two cases of interest:

1. *Uncovered interest parity holds* so that $\psi = 1$. In this event we must have $\psi \mu_1 > 1$ since $\mu_1 > 1$ by the Taylor principle. Hence, under uncovered interest parity the economy

must jump to its unique steady state at the initial date and there cannot be any transition dynamics.

2. *Uncovered interest parity fails* so that $\psi < 1$. In this case $\frac{d\dot{e}}{de}\Big|_{e=\bar{e}} \gtreqless 0$ as $\psi\mu_1 \gtreqless 1$. Put differently, when uncovered interest parity fails, the system exhibits equilibrium indeterminacy if and only if $\psi < \frac{1}{\mu_1} < 1$. This condition for indeterminacy is weaker than the condition we derived in the microfounded version of the model where one needed $\psi < 0$ for indeterminacy. Note that since P^N is predetermined, real exchange rate indeterminacy at $t = 0$ also implies nominal exchange rate indeterminacy.

To summarize, under inflation targeting regimes, results for the empirically relevant but reduced form specifications for the Philips curve and the traditional Taylor rule yield the same basic insight as the more microfounded structure: equilibrium dynamics are uniquely determined when uncovered interest parity holds but can become indeterminate when it fails. Equilibrium indeterminacy of the real exchange rate implies that the path of nominal exchange rate is also indeterminate which opens the door to non-fundamental equilibria such as sunspots and focal points for exchange rate pricing such as oil price movements.

4 Uncovered Interest Parity?

The key condition that determines whether or not the model outlined above exhibits equilibrium indeterminacy under inflation targeting regimes is whether or not uncovered interest parity. While there is a lot of work on testing uncovered interest parity and voluminous evidence that it often fails in the data, for our proposed explanation to pass a preliminary data test, we need to show that uncovered interest parity also fails in the sample of inflation targeting countries that we have studied. To check this we run the following panel regression for our sample of countries:

$$\ln E^i_{t+1} - \ln E^i_t = \alpha_i + \beta\left(R^i_t - R^{US}_t\right) + \eta^i_{t+1}$$

where E^i is the nominal exchange rate in country i (local currency units per unit of the US dollar) while R^i is the nominal interest rate in country i. We run this regression for the flexible exchange rate periods for each inflation targeting country in our sample during the period January 1974 to August 2016. We use both one month and three month interest rate spreads to check for robustness of the results. Table 5 below reports the results.

Table 5: Uncovered interest parity tests

	One-month	Three-month
Interest rate spread	0.463***	-1.102*
	(0.0185)	(0.616)
Observations	7114	683
R-squared	0.081	0.005
Number of countries	22	16
Country fixed effects	Yes	Yes

Notes: 1. The table reports the coefficient on the interest rate differential in a regression of the nominal exchange rate depreciation on interest rate differential with the USA. Standard errors are reported in parenthesis. 2. The one month spread is between money market rates while the three month spreads are between T-bill rates. 2. ***p<0.01, **p<0.05, *p<0.1

The coefficient on the one-month interest rate spread is significantly different from both zero and one, the latter indicating that interest parity fails to hold in the panel. Correspondingly, the coefficient on the three-month interest differential is significantly less than zero indicating a more extreme version of failure of uncovered interest parity.[3]

We view this evidence as supportive of the key condition underlying equilibrium indeterminacy result highlighted by our model.

5 Conclusions

Over the past three decades inflation targeting as a monetary policy paradigm has gained increasing popularity and central banking acceptance. In this paper we have documented

[3]We also ran these interest parity regressions individually for each country for both the one-month and three-month horizons. The average of the one-month interest spread coefficient was 0.60 while the average for the three-month interest rate spread was -1.16.

a previously little known consequence of inflation targeting: the currencies of countries that adopt this regime tend to get systematically linked to the world oil prices specifically, and world energy prices more generally. Somewhat startlingly, this link is very systematic: higher world oil prices tend to appreciate the currency of an inflation targeting country. This systematic relationship in inflation targeting countries emerges independent of whether or not they are oil exporters or importers and other country characteristics.

We have proposed one rationalization of this data pattern based on equilibrium indeterminacy under inflation targeting. We have shown that a small open economy characterized by sticky prices but where uncovered interest parity does not hold will exhibit equilibrium indeterminacy if it pursues inflation targeting. The equilibrium indeterminacy disappears if the country ceases to target inflation. In the presence of equilibrium indeterminacy, one rationale for the link of the exchange rate to oil prices is that markets use oil prices as a focal point to select an equilibrium.

The main contribution of the paper is documenting the data fact. Our explanation for the oil price linkage of currencies of inflation targeting countries is not intended as the only possible explanation of the phenomenon. There may doubtless be other possibile explanations as well. We hope to explore such other possibilities in future work.

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