Review of Finance Advance Access published April 30, 2009

Review of Finance (2009), 1–17
doi: 10.1093/rof/rfp004
Advance Access publication: 28 November 2008

Inflation Targeting and Exchange Rate Regimes: Evidence from the Financial Markets*

MENACHEM BRENNER[1] and MEIR SOKOLER[2]
[1]*Stern School of Business, New York University;* [2]*IMF*

Abstract. Inflation targeting is gaining popularity as a framework for conducting monetary policy. At the same time many countries employ some sort of foreign exchange intervention policy assuming that these two policies can coexist. This paper attempts to show that both policies are not sustainable. Israel is a classic test case. We test our hypothesis using information from the financial markets. The results support the hypothesis that both policies cannot be sustained in the long run. The conclusion is that a credible monetary policy aimed at inflation targets should be conducted in a free floating exchange rate regime.

JEL Classification: E52, E58, F31, G13

1. Introduction

In recent years inflation targeting (IT) has gained popularity in both developed and emerging market countries as a framework for conducting monetary policy (see, for example, Financial Times, 2009). The success of inflation targeting depends critically on the credibility of monetary policy to achieve the inflation targets over the relevant horizon.[1]

It is generally agreed that a credible IT regime requires a considerable degree of exchange rate flexibility (see, for example, Masson, Savastano and Sharma, 1997 and Fischer, 2001). Indeed, almost all the countries that adopted inflation targeting

* The views expressed in this paper are the authors' only. We would like to thank Nissan Liviatan, Paul Wachtel, José Campa, Yoav Friedman, Sigal Ribbon, Oved Yosha for their helpful comments and suggestions. Special thanks to an anonymous referee and to the editor, Franklin Allen, for their excellent comments and suggestions that greatly improved the paper. We would also like to thank Rik Sen for his valuable assistance and remarks, to Roy Stein and Limor Baruch for their assistance in the early stages of research, to Lorenzo Naranjo for his editorial assistance and to Rachel Towse for patient typing.

[1] Inflation targets differ from country to country. The specification involves target horizons, the price index used, target range or points, escape clauses and who sets the target (the government or the central banks). Though the U.S. does not have an explicit inflation target, Ben Bernanke, the current Fed chairman is a long time proponent of explicit inflation targets.

have floated their currency or have moved to more flexible exchange rate regimes. However, as pointed out in an article in the Economist (2000) and in a study by Calvo and Reinhart (2002) “labels mean little”. Many countries, including those who use explicit inflation targets, use interest rates or currency intervention to influence their exchange rates.

Central banks in inflation targeting countries face the following questions: How strong is the conflict between active exchange rate management and inflation targeting? How is the conflict exacerbated by a change in stance of fiscal policy? What are the consequences of maintaining an exchange rate band in an IT regime? Is there a conflict between credibility of the inflation target and the sustainability of the foreign exchange policy (e.g. a foreign exchange band)?

The purpose of this paper is to try and answer these questions and in particular to test the extent to which an IT framework is sustainable along with an exchange rate band regime using the Israeli experience. Israel is an interesting case study for two reasons: One, it has adopted inflation targeting since 1992 and at the same time had an official exchange rate band whose lower limit (the appreciating one) had to be defended several times. Two, policy makers have at their disposal a set of unique forward-looking data which is useful in assessing the effectiveness of monetary policy and the sustainability of the nominal regime. The data includes: professional inflation forecasts, nominal and real yields obtained from nominal bonds and from bonds linked to the Consumer Price Index (CPI) as well as option premiums obtained from currency options.

The plan of the paper is as follows: Section 2 provides a brief background of the Israeli institutional setup and the data. Section 3 uses inflation forecasts, the real yield on the CPI linked bonds and the yields on nominal bonds to show that: a) monetary policy is effective and credible since June 1997 when the Bank of Israel (BOI) stopped intervening in the foreign exchange (FX) market. b) Monetary policy was ineffective and not credible prior to June 1997 when the BOI had to engage in FX sterilized intervention to defend the band’s lower official limit. Section 4 provides additional evidence, using two sets of FX options data, to show that inflation targeting is not sustainable in an FX band regime. Section 5 offers some general lessons based on the Israeli experience.

2. The Institutional Setup and Data

2.1 BACKGROUND

In 1992 Israel adopted an inflation targeting policy together with a crawling exchange rate band regime.[2] At first, monetary policy was aimed at the inflation

[2] The FX band is vis-à-vis a currency basket which is based on the currencies of Israel’s main trading partners where the dollar has about 60 percent of the weight and the Euro’s weight is about 25 percent.

target while the BOI was intervening directly in the FX market in an attempt to keep the exchange rate near the midpoint of the FX band. This joint effort failed and in February 1996 the BOI changed its FX policy and declared a policy of non-intervention within the official limits of the band. In addition, the problem was exacerbated by a change in the stance of fiscal policy from a tight one to a loose one. Following a number of years of a prudent fiscal policy, there was a substantial fiscal expansion in 1996, that was only contained in mid 1997 when a new fiscal package was introduced (the domestic deficit was 4.7% of GDP compared to a target of 2.5%). The monetary policy reaction to this expansion put more upward pressures on interest rates which in turn exerted more appreciating pressures on the exchange rate.

Thechange in the intervention policy did not stop the ongoing appreciation of the Israeli currency (Shekel) and eventually the exchange rate reached the lower edge of the band and got stuck there for more than six months. The massive FX purchases during the period Feb. 1996 to June 1997 were sterilized by the BOI. When it was realized that the policy is not sustainable, the width of the band was increased considerably. Consequently, on June 17 1997 the purchases have stopped.[3] The BOI has not intervened in the FX market since June 1997.[4]

This short history, which is divided into two periods, the heavy FX intervention period (Feb. 1996 to June 1997) and the non-intervention period (June 1997 to June 2001), provides an opportunity to examine empirically the extent of the conflict between inflation targeting and FX direct intervention.

2.2 DATA[5]

Monetary authorities nowadays use various types of forward looking data such as inflation forecasts by professionals, forecasts derived from the bond markets, risk premiums derived from currency options and other market derived forecasts.[6]

Such data add valuable information to monetary policy makers because it contains forward looking information which is useful in assessing the credibility of the commitment of monetary policy to inflation targeting, with and without FX intervention.

[3] On that day, an asymmetric change in the slopes of the band was introduced; six percent for the upper limit and four percent for the lower limit. An additional decrease to a slope of two percent of the lower limit was introduced in June 1998. The band was finally eliminated in May 2005.

[4] Since March 2008, after a long period of appreciation of the Shekel, the BOI intervenes daily in the FX market with the stated purpose of increasing the FX reserves.

[5] The sources and frequencies of the data are provided in the Appendix. The data is available from the authors upon request.

[6] For example, the Bank of England is routinely engaged in extracting data from financial markets to assess its monetary stance. Information from FX currency options has been used to assess the credibility of official exchange rate target zones (e.g. Campa and Chang, 1996) and to assess inflation risk premia (e.g. Azoulay et al.).

In Israel such data play an important role in the monthly monetary decision process. Due to Israel's long experience with high inflation, government bonds linked to the CPI with maturities up to 20 years are now traded regularly on the Tel-Aviv Stock Exchange (TASE). Non-linked nominal bonds are now also available, for up to 20 years. The difference between the nominal rates and real rates, also called 'breakeven' inflation, is used as an estimate of inflation expectations for various horizons.[7] The one-year-ahead market derived inflation expectations measure[8] is among the most important gauges of the credibility of the BOI monetary policy.

There are also inflation forecasts by professional forecasters which include banks as well as other firms and in the past few years have become another source used by policy makers. These forecasts are highly correlated with the market derived expectations.

In this study we also use two types of FX currency options. The first type is traded daily on the TASE and includes European call and put options with maturities up to six months. The second type is FX options offered in weekly auctions by the BOI.

Since 1993, the BOI has offered At-The-Money-Forward (*ATMF*) options for three and six months respectively. Since these options have no intrinsic value their price reflects only the uncertainty regarding the FX rate. Table I provides summary statistics of inflation forecasts π^e, actual inflation π, the BOI key policy rate KR, and FX implied volatility IV. These variables will be used in the forthcoming tests. Summary statistics of the variables used in the tests are given in Tables II and IV. We have not used options before 1996 since their values must have been affected by the active intervention of the central bank in the FX spot market before 1996. It is interesting to note that the expected inflation is on average higher than actual inflation but its standard deviation is lower.

Table I. Summary Statistics of Annualised Rates of Inflation and Exchange Rate Volatility

The table reports statistics computed using monthly observations for the period from February 1996 to June 2001. The variables are defined as follows: π is the rate of inflation in the previous 12 months, π^e is the one-year-ahead expected rate of inflation based on consensus forecasts, IV is the implied volatility from the 6-months FX option auctioned by the BOI, and KR is the key rate set by the BOI.

	Mean	SD	Min	Max
π	5.85	4.01	−0.12	12.93
π^e	6.40	3.54	0.76	13.72
IV	6.79	–	4.70	11.00
KR	12.54	2.83	7.04	18.53

[7] This estimate may be biased upwards since it may include a premium for inflation uncertainty. For this reason we have not used it in the equation (1) tests.

[8] For the details on the derivation of inflation expectations in Israel see Yariv (1993).

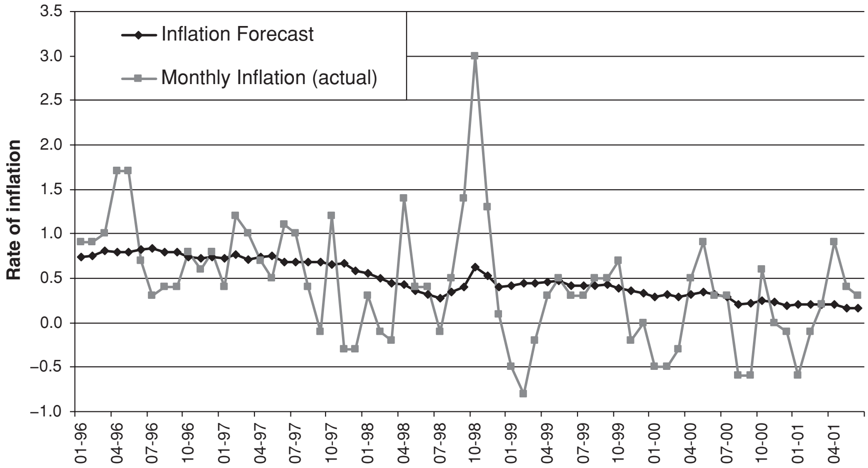

Figure 1. Inflation forecasts and actual inflation (Jan 96–June 01).
Monthly actual inflation is measured by the consumer price index (CPI). The inflation forecasts are the consensus forecasts provided by the private sector analysts.

The data is used in three ways. First, the information derived from the real and nominal bonds is used to assess their influence on inflation forecasts with and without FX intervention. Second, the traded FX currency options are used to construct an effective exchange rate band, which turns out to be much narrower than the official one and is more relevant to the participants in the FX market. Third, the effective band is then used to demonstrate the conflict between an IT regime and a crawling FX band regime.

We have used two sets of data mainly due to data availability. In the first test we used inflation expectations and realized inflation which is only available on a monthly basis. Figure 1 depicts expected inflation vs. realized inflation. In the second test, where FX options data is used we obtained weekly data, from the BOI weekly auctions. Since the period of interest was the 17 months, during which the BOI was forced to defend the FX band, it was very helpful to have weekly observations so that we have sufficient degrees of freedom when we are testing our hypotheses.

3. Credibility of Monetary Policy and FX intervention

In countries with inflation targeting the central bank steers the short-term interest rate (the *key* rate) under its control to achieve its goal. Changes in the *key* rate affect, to a large extent, future inflation through their effect on inflation expectations and as stated in Svensson (2001), and stressed by Woodford (1999, p. 277), "...the need to take account of the effects of the central bank's conduct upon private-sector expectations." More recently chairman Bernanke (2007) pointed out the possible direct influence of the key rate on inflation expectations. Since a key feature of the IT regime is its forward-looking nature,[9] expected inflation should, assuming rational expectations, embody all the relevant information regarding the future path of inflation. This depends on the current and future levels of the *key* interest rate, the current and expected states of economic activity and the exchange rate.

The way that inflation expectations respond to changes in the *key* rate depends on the credibility of the IT regime. The more credible the regime, the stronger is the direct response of inflation expectations to an expected change in the *key* rate. In reality, however, there never is full credibility and inflation expectations are never fully and permanently anchored at the desired inflation target. Rather, inflation expectations are affected by various shocks and are conditional, among other factors, on the way monetary policy responds to shocks.

Credibility may be adversely affected by various constraints placed on the transmission process of monetary policy. One such impeding constraint may be the FX regime. Specifically, the existence of an official exchange rate band in a small-open inflation targeting economy is a case in point. In such an economy, the exchange rate is an important channel through which monetary policy affects inflation (see Svensson, 2000 and Haldane and Batini, 1998). This channel is shut-off when the exchange rate is not allowed to appreciate beyond a certain arbitrary rate determined by the lower limit of an exchange rate band. When the limit is reached the central bank is forced to engage in sterilization operations which are problematic for well known reasons such as the "quasi-fiscal" costs of sterilization (see, for example, Calvo, 1991 and Kletzer and Spiegel, 2004) and the accumulation of national debt which sterilization generates. Moreover, by shutting off the exchange rate channel which is the fastest transmission channel, the other main channel which affects inflation, the real interest rate–the aggregate demand channel, must "work harder" (e.g. a higher rate of unemployment than in a full floating regime). In other words, the effectiveness of monetary policy is impaired when the central bank is forced to defend the limits of an exchange rate band. The issue is, how sustainable is an IT regime when exchange rate movements are restricted by an effective band.

Another threat to the effectiveness of monetary policy and to the sustainability of the IT regime, independent of the FX regime, is a change in the fiscal regime. If the short term discretionary fiscal expansion of 1996 were perceived to be permanent, it would have rendered monetary policy ineffective because of fears of fiscal dominance. Although we can not exclude entirely this possibility, it seems unlikely given the experience in 1992, 1993, 1994 in which the actual deficit was lower than the limits on the deficit as stipulated by the "declining deficit law" (see Flug, 2006).

[9] See for example, the survey by Clarida, Gali and Gertler (1999).

The effect of an FX band in an inflation targeting regime is tested next. As stated above, inflation expectations are affected by the monetary policy and also by economic activity.[10] The hypothesis which we test is that the FX band severely hampers the effectiveness of monetary policy. When the exchange rate is at the lower limit of the exchange rate band, inflation expectations react differently to the expected changes in the key rate than when the exchange rate is freely floating inside the band.

To minimize the effect of autocorrelation, present in our time-series data, we test the hypothesis using first differences in the following equation[11]

$$\Delta E_t \pi_{t+1} = b_0 + b_1 \Delta i_t + b_2 \Delta RS_t + e_t \quad (1)$$

Where $\Delta E_t \pi_{t+1}$ is the change in the 12-month ahead inflation forecast, Δi is the change in the difference between the daily key interest rate and the one year nominal rate on a zero coupon Treasury Note. A fall in the one year rate relative to the key rate, according to the pure expectations hypothesis, means that future key rates are expected to fall. Such a change means that the current tight monetary stance is expected to loosen. If the commitment to inflation targeting is credible and inflation expectations take into account the conduct of monetary policy then $b_1 < 0$.

The variable ΔRS is the change in the difference between the real yields to maturity on CPI linked bonds for 1 and 15 years respectively. A rise in the one year real yield relative to the 15 year yield is a signal of an expected slow down in economic activity which tends to decelerate inflation forecasts. The inclusion of a variable representing the expected state of economic activity is important because an expected slow down lowers, *ceteris paribus*, both inflationary pressures

[10] In a small open economy, with no or little intervention such as Israel, movements in the exchange rate should contain valuable information about its effect on the public's inflation expectations and should be included in the test. We ran a test with the rate of change of the exchange rate as an additional explanatory variable and the results were basically unchanged. The reason is that movements in the exchange rate, both downward and upward, were largely restricted by an effective FX band which was much narrower than the official one (more on this later). Thus, its value as an information variable which influences the formation of inflation expectations is severely curtailed and it may just add noise to the regression. So we decided not to include it in our tests.

[11] Aside from the issue of autocorrelation, there is a compelling reason why equation (1) was specified as a first difference rather than a level equation. During the period under consideration, there was a world-wide downtrend of inflation, inflation expectations, and interest rates. This was also true for many previously high inflation countries such as Israel. Thus, if (1) were specified as a level equation, a valid criticism might have been that any result pointing to the expected negative effect of the expected key rate on expected inflation does not reflect credibility but rather is a spurious result hiding the true global pressures which were the driving force behind the decline in both. The same argument cannot be made for a first difference specification. There are additional reasons for specifying (1) as a first difference equation: a) to reduce the effects that persistent shocks might have on inflation expectations and b) to reduce the effects that gradual policy responses to shocks (interest rate smoothing) might have on inflation expectations. Finally, we also ran equation (1) with lagged inflation and the results were not significantly different.

and inflation expectations for any given key rate. There are numerous empirical studies[12] which use the slope of the nominal yield curve as a predictor of economic activity. Here we use the slope of the *real* yield curve which should be even a better proxy of economic activity. Thus, b_2 should also be negative.[13]

Table II. Summary Statistics and Correlations of Variables in Equation 1

$\Delta E_t \pi_{t+1}$ is the change in the 12-month ahead inflation forecast, Δi is the change in the difference between the key rate and the 1 year nominal rate, and ΔRS is the first difference of the proxy for the output gap.

	Summary Statistics				Correlations		
	Mean	St Dev	Min	Max		Δi	ΔRS
$\Delta E_t \pi_{t+1}$	−0.105	0.566	−1.543	2.650	$\Delta E_t \pi_{t+1}$	−53.8%	−51.9%
Δi	**0.006**	**0.512**	**−1.087**	**1.803**	Δi		**63.6%**
ΔRS	0.015	0.490	−1.233	0.936			

We now test the hypothesis stated above that the reaction of inflation expectations to monetary policy depends crucially on how restrictive the FX band is; how does the band affect the exchange rate movements.[14] The test focuses on the difference between two periods. The first is from February 1996 to June 1997. During this period the exchange rate was stuck at the lower edge of the band for forty percent of the time. During the rest of the time it was very close to the lower limit (never more than 5.7 percent from the lower limit). The central bank was forced to buy dollars to defend the lower limit. Since the BOI was committed to the inflation target, it had no choice but to engage in sterilizing the effects of its intervention. In the first six months of 1997 alone the BOI purchased and sterilized more than 7 billion dollars. The second period is from June 1997 to June 2001. During this period the BOI did not intervene directly in the FX market, including the Russian default crisis and the

[12] Among related studies are Estrella and Mishkin (1997) and Smets and Tsatsaronis (1997) where the test is for more than one country. A recent study by Neiss and Nelson (2001) argues that the interest rate gap (the difference between the current and the natural real rate of interest) might be a better predictor of future inflation than the output gap.

[13] We are fully aware that equation 1 is an incomplete model of inflation expectations. Its only purpose is to test the impediment that an FX regime imposes on the monetary transmission mechanism, the link between the key rate and inflation expectations. See, for example, Gurkaynak, Levin and Swanson (2006) or Ball and Sheridan (2005) who use OECD forecasts.

[14] To capture the possible independent effect of the discretionary fiscal expansion, discussed before, we would have liked to control for it in our tests. However, we do not have a reasonable proxy for discretionary fiscal stance on a monthly basis. Even quarterly data would not resolve the problem since this would give us too few observations, given the relatively short period of about 15–16 months, to make it meaningful; the noise would overwhelm the signal. Another possibility is to use a dummy variable for the period when the discretionary fiscal expansion took place but that overlaps, almost entirely, the period of FX intervention.

Table III. Regression of Equation 1

The dependent variable of the regression is the change in the 12-month ahead inflation forecast ($\Delta E_t \pi_{t+1}$). Δi is the change in the difference between the key rate and the 1 year nominal rate, ΔRS is the first difference of the proxy for the output gap, the Intervention Dummy (*INTV*) is a variable equal to 1 from February 1996 to June 1997 (and 0 otherwise), and the *LTCM* Dummy is a variable equal to 1 in October and November 1998 (and 0 otherwise). Standard errors are heteroskedasticity-consistent, being estimated with the White method. The Breusch-Godfrey Serial Correlation LM Test fails to reject the null hypothesis of zero serial correlation for 1, 2, 3 and 4 lags. Test for heteroskedasticity are irrelevant since all standard errors and covariances are hereteroskedasticity consistent. The Wald test for the hypothesis $[\Delta i + (\text{FX Dummy} \times \Delta i)] = 0$ yields a Chi-square statistic of 0.161756 (P-value = 0.6875). The value of the sum of the two coefficients is 0.087353 with a standard error of 0.217195. The Wald test for the hypothesis $[\Delta RS + (\text{FX Dummy} \times \Delta RS)] = 0$ yields a Chi-square statistic of 0.060685 (P-value = 0.8054). The value of the sum of the two coefficients is 0.082540 with a standard error of 0.335060. The Wald test for the hypothesis that the coefficients on the FX Dummy and interaction terms involving the FX Dummy are jointly zero is rejected: the Chi-square statistic is 10.03017, with a P-value of 0.0183.

Variable	Coefficient	Std Error*	T-Statistic	P-value
Constant	−0.181303	0.055998	−3.237677	0.0020
Δi	−0.825965	0.148315	−5.568985	0.0000
ΔRS	−0.146795	0.140702	−1.043306	0.3011
INTV Dummy	0.141898	0.107714	1.317362	0.1929
INTV Dummy × Δi	0.913318	0.263004	3.472644	0.0010
INTV Dummy × ΔRS	0.229334	0.363404	0.631074	0.5305
LTCM Dummy	1.163644	0.284477	4.090472	0.0001
R-squared	0.601922	F-statistic		14.61667
Adjusted R-squared	0.560741	Prob(F-statistic)		0.000000
No. of observations	65	Durbin-Watson Stat		1.935166

Long Term Capital Management (LTCM) debacle (fall of 1998), during which the exchange rate rose about 15 percent above the lower limit. We tested the difference in the two periods using dummy variables for the intercept and the slopes of the two independent variables where the dummy variable is 1 for the intervention period (Feb. 1996 to June 1997) and 0 for the non intervention period. The test statistics should tells us whether the variables in equation (1) have a significantly different effect on inflation expectations in the non intervention period vs. the intervention period. We also introduce a dummy variable for the period October and November of 1998, to test the sensitivity of the results to the Russian/LTCM crises. The results are presented in Table III.

First, the results are consistent with our expectations, $b_1 < 0$ and $b_2 < 0$, though the proxy for the output gap is not significant (which may be due to the high correlation, 0.64, between Δi and ΔRS). Tighter monetary policy, increasing the key rate, reduces inflation expectations and an increase in the slack in the economy, as proxied by the real interest rate gap, also reduces expected inflation. Second, there is a significant difference between the two periods. During the Feb. 1996 to June 1997 period, when the exchange rate was at, or very close to, the lower limit of the band and the BOI intervened heavily in the FX market, changes in inflation expectations were not related either to Δi or to ΔRS. That is, they responded neither to changes in the monetary stance nor to changes in the variable representing the output gap. As the Wald tests show (bottom of Table III), the variables in the first period, the intervention period, have no significant effect on the formation of inflation expectations (the P-values for the *key* rate and the output gap are 0.6875 and 0.8054 respectively).

The R^2 of the regression is another indication that overall our simple model is a good representation of the relationship between inflation expectations and the policies of the BOI. The difference between the two periods can be explained by the difference in the credibility of the commitment to inflation targeting. This commitment was not very credible in the first period when the BOI had to defend the exchange rate and had to sterilize its purchases of foreign currency. Monetary policy at that time was in effect facing the situation described by Sargent and Wallace (1981) as "unpleasant monetarist arithmetic." In the second period, however, there was no FX intervention and the commitment to inflation targeting was much more credible. To test the robustness of the results, given the special circumstances in the fall of 1998, we also introduced a dummy variable for this period. The results in Table III (*LTCM*) show that indeed it was important to control for that period, the dummy variable is positive and significant. Finally, to support our claim that the chosen periods are indeed different we conduct a Wald test (bottom of Table III) with the null hypothesis that the Intervention dummy (*INTV*) and all coefficients involving interactions with *INTV* are jointly zero. This hypothesis is rejected (P-value = 0.0183).[15]

The above results show that in circumstances like the ones described here, when there is intervention in the foreign exchange market, monetary policy is ineffective and the transmission mechanism is hampered by the exchange rate policy.

4. Sustainability of Inflation Targeting and an Exchange Rate Band

This section provides evidence on the sustainability of the FX band regime in an IT framework. Many countries, in the past, have followed such policies in an attempt to strike a balance between the exchange rate and inflation.[16] Maintaining such a

[15] In our previous set of tests, not presented here, we ran separate regressions on the two periods to support our claim that there was a structural change from period one to period two. We also conducted a Chow test and obtained an F value of 6.54 which is statistically significant at the 1 percent level. This test is consistent with the results obtained here.

[16] This possible trade-off is pointed out by Fischer (2001) who considers it to be analogues to the Phillips curve tradeoff.

balance is rather problematic in countries with a long history of high inflation and a high pass-through from the exchange rate to consumer prices. In such countries, the efforts to reduce inflation through a tight monetary policy requires a consistent fiscal policy framework.

Pursuing a policy of sterilized FX intervention, with its "quasi fiscal costs," whose burden is not internalized in a transparent[17] way by the fiscal authorities, is clearly inconsistent with a tight monetary policy stance. The *key* rate deemed appropriate for achieving the inflation target may also affect the equilibrium FX rate, causing the domestic currency to appreciate. Since, however, the exchange rate is not allowed to appreciate below the lower limit of the FX band, maintaining the band simultaneously with the IT regime may prove to be unsustainable. Simply put, the commitment to fight inflation may result in the abandonment of the FX regime.

One way to detect in advance the conflict between the two policies is to examine the relationship between a tight monetary policy and expected FX volatility. If there is no conflict between IT and the FX band, raising the key rate (as, say, a response to a shock) should not affect FX volatility. If, however, raising the key rate is associated with large costly sterilization operations, which mean a greater danger of fiscal dominance, then it may result in greater exchange rate volatility. With higher volatility the inflation target may be violated because of the pass through from the exchange rates to consumer prices.[18]

To test the relationship between the *key* rate and expected FX volatility we need to control for the width of the FX band. Presumably, a wider band, as long as it is credible, should be associated with greater FX volatility. For the purpose at hand, the lower limit of the band is the official one, but the upper limit is **effectively** determined by the credibility of the policy to achieve the inflation target and the existing pass-through from the exchange rate to consumer prices. The upper effective limit, which is much lower than the official upper limit, reflects the public's perception regarding the ability of BOI to attain the inflation targets specified by the government. This perception takes into account high pass-through, from the exchange rate to consumer prices, which could interfere with the attainment of the inflation target. Thus, given this pass through, and as long as the exchange rate is inside the band, the more credible monetary policy becomes in reducing inflation the lower is the probability of a depreciation of the currency, i.e. the lower is the effective upper limit of the band.

---

[17] The cost of sterilization is internalized by the fiscal authorities in a transparent way if there are explicit arrangements where the Treasury covers Central Bank's losses stemming from sterilization operations. Such an arrangement is provided in the New Zealand Reserve Bank Act of 1984. This is not the case in Israel and in many other countries.

[18] Bufman and Leiderman (2001) estimated an average pass-through coefficient of 40 percent over the first 10 quarters after the shock while Elkayam (2001) reports an immediate pass through of 25 percent.

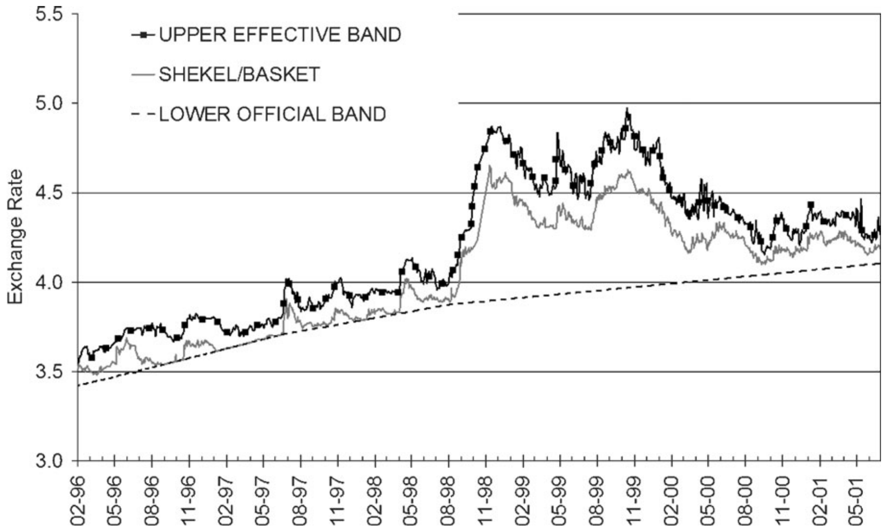

Figure 2. The effective upper exchange rate band, the official lower band and the actual exchange rate (2/1/96–6/30/01).
The lower official band is determined by the difference between the Israeli rate of inflation and the rate of inflation of Israel's main trading partners where the U.S. has a weight of about 60 percent and the Eurozone's weight is about 25 percent. The actual exchange rate between the Israeli Shekel and the FX basket, where the dollar's weight is about 60 percent, has been supported by the government several times during the period February 1996 and June of 1997. The upper Effective band was generated using information from the market for Dollar/Shekel options.

We next construct the upper effective limit which we need as a basis for our extended test of the sustainability of the twin policies. To construct the "effective" upper limit we used FX currency options with varying strike prices traded on the TASE. On any given trading day we searched for an **out-of-the-money** call option with the highest available strike price for which some minimal positive premium has been paid.[19] We mark the exchange rate corresponding to the strike price of this option as a point on the effective upper limit. This procedure is repeated for each trading day starting in February 1996 to June 2001. The result is an effective upper edge, which is depicted in Figure 2. We need to emphasize that we have no concern that the results may be spurious due to the use of option derived values on both sides of the equation since there is no correlation between the out-of-the-money options that determine the effective band and the premium paid for the *ATMF* options.

The effective FX band provides interesting information. First, from February 1996 to November 1998, just after the Russian/LTCM crises the effective band was

[19] To control for the changing time to maturity of the option we decided to use a constant 75 days to maturity. Since only on few occasions the maturity is of 75 days we have used options which originally had 60 days and 90 days to maturity and constructed a weighted average price of these two options.

only 4.4 percent wide with a standard deviation of 1.6 percent. As was mentioned earlier, during this period the parameters of the official band changed twice. These changes had little effect on the **width** of the effective band, which we use in our next test and is represented by *VK*.

The relationship between the *key* rate and FX uncertainty is now tested using the **width** of the FX band, *VK*, as an explanatory variable in the following equation.

$$PRM = a_0 + a_1 KR + a_2 VK + a_3 LRV + a_4 FXV + e \quad (2)$$

Expected exchange rate volatility is represented by the dependent variable *PRM*, which is the option premium[20] of the six months at-the-money-forward (*ATMF*) calls offered in weakly tenders by the BOI. The variable *KR* stands for the *key* rate and *e* is an error term. The data, *PRM* and *KR*, consists of weekly observations, which corresponds to the day (normally a Tuesday) on which the option is auctioned off by the BOI. To control for world wide factors on the proxy for exchange rate volatility (*PRM*) we have introduced two variables that could potentially have an effect on *PRM*, the volatility of the LIBOR rate (*LRV*) and the volatility of the Euro/Dollar exchange rate (*FXV*).

Table IV. Summary Statistics and Correlation of Variables in Equation 2

PRM is the proxy for exchange rate volatility, *KR* is the key rate, *VK* is the width of the FX band, FX Vol is the standard deviation of returns on USD/GBP exchange rate calculated over a 10-day window, and LIBOR Vol is the standard deviation of USD LIBOR rates calculated over a 10-day window.

Summary Statistics

	Mean	St Dev	Min	Max
PRM	1.950	0.387	1.373	3.774
KR	12.542	2.834	7.036	18.526
VK	9.00%	6.24%	1.60%	24.97%
FX Vol	0.44%	0.16%	0.13%	1.12%
LIBOR Vol	3.49%	3.50%	0.00%	33.30%

Correlations

	KR	*VK*	FX Vol	LIBOR Vol
PRM	21.6%	61.0%	−18.7%	−5.5%
KR		7.6%	−26.8%	−22.0%
VK			−24.6%	−9.1%
FX Vol				6.3%

[20] For *ATMF* options the premium is mainly determined by volatility. In the Black-Scholes model there is a one to one correspondence between option premiums and implied volatility.

Table V. Regression of Equation 2

The dependent variable of the regression is the proxy for exchange rate volatility (*PRM*). *KR* is the key rate, *VK* is the width of the FX band, *INTV* is an intervention dummy set equal to 1 from February 1996 to June 1997 (and 0 otherwise), the *LTCM* Dummy is a variable equal to 1 in October and November 1998 (and 0 otherwise), LIBOR volatility is the standard deviation of USD LIBOR rates calculated over a 10-day window, FX Volatility is the standard deviation of returns on USD/GBP exchange rate calculated over a 10-day window, and AR(1) and AR(2) are the first and second-order autoregressive terms, respectively. Standard errors are heteroskedasticity-consistent, being estimated by the White method. The Breusch-Godfrey Serial Correlation LM Test fails to reject the null hypothesis of zero serial correlation for 2, 3 and 4 lags. Tests for heteroskedasticity are irrelevant since all standard errors and covariances are hereteroskedasticity consistent. The Wald test for the hypothesis $[KR + (INTV \text{ Dummy} \times KR)] = 0$ yields a Chi-square statistic of 5.7802 (P-value = 0.0162). The value of the sum of the two coefficients is 0.145 with a standard error of 0.0606. The Wald test for the hypothesis $[VK + (INTV \text{ Dummy} \times VK)] = 0$ yields a Chi-square statistic of 1.510396 (P-value = 0.2191). The value of the sum of the two coefficients is −2.523465 with a standard error of 2.053298. The Wald test for the hypothesis that the coefficients on the *INTV* Dummy and interaction terms involving the *INTV* Dummy are jointly zero is rejected: the Chi-square statistic is 25.74204, with a P-value of 0.

Variable	Coefficient	Std Error*	T-Statistic	P-value
Constant	1.370018	0.208822	6.560692	0.0000
KR	0.019819	0.018520	1.070144	0.2857
VK	3.338832	1.307443	2.553711	0.0113
INTV Dummy	−1.805850	0.979756	−1.843162	0.0666
INTV Dummy × *KR*	0.125893	0.065265	1.928954	0.0550
INTV Dummy × *VK*	−5.862297	2.426778	−2.415671	0.0165
LTCM Dummy	−0.066029	0.087230	−0.756948	0.4498
LIBOR Volatility	−0.064834	0.348638	−0.185965	0.8526
FX Volatility	5.607791	10.99645	0.509964	0.6106
AR(1)	0.468138	0.095490	4.902461	0.0000
AR(2)	0.252669	0.092104	2.743315	0.0066
R-squared	0.687337	F-statistic		51.22105
Adjusted *R*-squared	0.673918	Prob(F-statistic)		0.000000
No. Of observations	244	Durbin-Watson stat		2.014909
Inverted AR Roots	.79	−.32		

As in our tests of Equation (1) we applied the test of equation (2) to the whole period Feb. 1996 to June 2001 and separated the two periods[21] using dummy variables for the intercept and the slopes of the two main variables, *KR* and *VK*.

The results in Table V confirm our hypothesis that tighter monetary policy is associated with greater FX volatility when the exchange rate is restricted by a band, $a_1 > 0$. It is particularly strong during the BOI intervention period, Feb. 1996–June 1997, when the exchange rate was stuck at the lower edge of the band. This can be inferred from the Wald test (bottom of table V) which shows that during the

[21] As in the 1st equation, here too the Wald test supports the choice of the two periods.

intervention period, $a_1 = 0.1457$, is highly significant while it is not significant during the non-intervention period (the P-value is 0.2857). During that period, a one percentage point rise in the *key* rate (*KR*) resulted in about 0.15 percentage point increase in FX volatility as measured by the volatility proxy (*PRM*). Not surprisingly the conflict between inflation targeting and the FX band regime was particularly strong in the intervention period.

Second, when the exchange rate is inside the band, a wider effective band (*VK*) is associated, as expected, with larger FX volatility. During the non intervention period, July 1997–June 2001, the coefficient of *VK*, a_2 is positive (3.33) and highly significant. However, when the exchange rate is stuck at the band's lower limit, during the intervention period, the width of the effective band does not seem to affect exchange rate volatility as can be seen from the Wald test (see Table V, the Wald test for the *VK* slope dummy). As in equation 1 we have also introduced the two control variables to account for world wide factors and excluded the Russian crisis period. They have not affected our results. Unlike the first regression where the serial correlation issue was handled by using first differences, in this regression we have dealt with serial correlation using the AR procedure, as can be observed by the Durbin-Watson test. The standard errors and covariances are White-heteroskedastic-consistent (White 1980) and the independent variables have low correlations with each other as can be seen in the Table IV.

Third, the overall fit of the regression as measured by the R^2 provides additional support to our main hypothesis as tested by the specification given in equation 2 including the use of dummy variables to distinguish the intervention period from the non-intervention period. That is, when the exchange rate is stuck at the lower limit of the band, not only is an increase in the *key* rate ineffective in reducing inflation expectations but it also points to an increase in exchange rate volatility. That is, a tighter monetary policy leads in this case to a higher volatility of the exchange rate.

5. Conclusions

The main question addressed here is the following, could a country simultaneously commit itself to an inflation target and an exchange rate band. The inherent conflict between the two exists even when the band is very wide.

Is the Israeli experience relevant for inflation targeting countries with no official band but with direct currency intervention. Could the case be made, for inflation targeting countries, that intervention could be useful "so long as they are not perceived as trying to defend a particular rate" as stated by Fischer (2001). We doubt that it is possible to maintain an intervention policy in an inflation targeting regime. The fact that very few central banks disclose information regarding their FX intervention means, in our judgment, that they themselves cannot clearly distinguish between intervention to keep "orderly markets" and intervention aimed to affect the exchange rate because it is "clearly away from fundamentals." Even an implicit exchange rate band might lead to conflicts such as in Israel.

The results of this study suggest that maintaining a credible inflation targeting regime is sustainable only if we view the exchange rate as a financial asset whose value is determined by market forces.

Appendix: Sources and Frequencies of Data

Variable	Frequency	Source
BOI key policy rate ($\underline{KR}$)	Daily	BOI
Inflation (π)	Monthly	Israel's Central Bureau of Statistics
Inflation expectations (π^{ε})	Monthly	BOI (responses by Banks & Forecasters to a Fixed Survey)
Premium on BOI *ATMF* call Options (*PRM*)	Weekly	BOI (Results from Weekly Options)
Prices of options traded on the TASE (to construct *VK*)	Daily	Tel Aviv Stock Exchange (TASE)
Makam-12 Months T-Bill to construct the variable (Δi)	Daily	TASE
Galil-1 & 15 years CPI linked Gov. Bonds to construct the variable (ΔRS)	Daily	TASE
$ LIBOR rates to construct LIBOR volatility (*LRV*)	Daily	British Bankers Association www.bba.org.uk
USD/EURO exchange rates to construct FX volatility (*FXV*)	Daily	US Federal Reserve website www.federalreserve.gov

References

Azoulay, E., Brenner, M. and Landskroner, Y. (2007) *Inflation Risk premium Implied by Foreign Exchange Options*, Stern School of Business Working Paper, FIN-07-01.

Ball, L. and Sheridan, N. (2005) Does inflation targeting matter? In Bernanke B. and Woodford M. (eds.), *The Inflation-Targeting Debate*, NBER.

Bernanke, B. (2007) Inflation expectations and inflation forecasting, Presentation at the Monetary Economics Workshop of the NBER Summer Institute.

Bufman, G. and Liederman, L. (2001) Surprises on Israel's road to exchange rate flexibility, IMF conference on Exchange Rate Regimes: Hard peg or Free Floating, IMF, March 19–20.

Calvo, G. A. (1991) The Perils of Sterilization, *International Monetary Fund Staff Papers* **38**, 921–926.

Calvo, G. A. and Reinhart C. M. (2002) Fear of Floating, *Quarterly Journal of Economics* **117**, 379–408.

Campa, J. M. and Chang, P. H. K. (1996) Arbitrage–Based Tests of Target Zone Credibility: Evidence from ERM Cross-Rate Options, *American Economic Review* **86**, 726–740.

Clarida, R., Gali, J. and Gertler, M. (1999) The Science of Monetary Policy: A New Keynesian Perspective, *Journal of Economic Literature* **37**, 1661–1707.

The Economist (2000) Currency Dilemmas, November 18.

Elkayam, D. (2001) A Model for Monetary Policy Under Inflation Targeting: The Case of Israel, Working Paper, Bank of Israel.

Estrella, A. and Mishkin F. S. (1997) The Predictive Power of the Term Structure of Interest Rates in Europe and the United States: Implications for the European Central Bank, *European Economic Review* **41**, 1375–1401.

Financial Times (2009) The US Federal Reserve yesterday adopted a de facto inflation target of 2 per cent or slightly less - closely mirroring the formal target at the European Central Bank, February 19.

Fischer, S. (2001) Exchange Rate Regimes: Is the Bipolar View Correct? Distinguished Lecture on Economics in Government, Jointly Sponsored by the American Economic Association and the Society of Government Economists, New Orleans, January 2001.

Flug, K. (2006) Fiscal rules? Fiscal policy in Israel since the 90's, Paper Presented at the Euro-Mediterranean Conference at the ECB on 27.11.06.

Gurkaynak, R. S., Levin, A. and Swanson, E. T. (2006) Does Inflation Targeting Anchor Long-Run Inflation Expectations? Evidence from Long-Term Bond Yields in the U.S., U.K. and Sweden, Working Paper, Federal Reserve Bank of San Francisco.

Haldane, A. and Batini, N. (1998) Forward-Looking Rules for Monetary Policy, Working Paper no. 6543, National Bureau of Economic Research.

Kletzer, K. and Spiegel, M. (2004) Sterilization Costs and Exchange Rate Targeting, *Journal of International Money and Finance* **23**, 897–915.

Masson, P. R., Savastano, M. A. and Sharma, S. (1997) The Scope for Inflation Targeting in Developing Countries, Working Paper, *International Monetary Fund*.

Neiss, S. K. and Nelson, E. (2001) The Real Interest Rate Gap as an Inflation Indicator, *Macroeconomic Dynamics* **7**, 239–262.

Sargent, T. J. and Wallace, N. (1981) Some Unpleasant Monetary Arithmetic, *Federal Reserve of Minneapolis Review*, 1–17.

Smets, F. and Tsatsaronis, K. (1997) Why Does the Yield Curve Predict Economic Activity? Dissecting the Evidence for Germany and the United States, Working Paper no. 49, BIS.

Svensson, L. E. O. (2000) Open-Economy Inflation Targeting, *Journal of International Economics* **50**, 155–183.

Svensson, L. E. O. (2001) Independent Review of the Operation of Monetary Policy in New Zealand: Report to the Minister of Finance, 1–78.

White, H. (1980) A heteroskedasticity-consistent covariance matrix and a direct test for heteroskedasticity, *Econometrica* **48**, 817–38.

Woodford, M. (1999) Commentary: How Should Monetary Policy be Conducted in an Era of Price Stability? In: *New Challenges for Monetary Policy: A Symposium Sponsored by the Federal Reserve Bank of Kansas City*, Federal Reserve Bank of Kansas City, 277–316.

Yariv, D. (1993) Efficiency of the Israeli Securities Market, *Bank of Israel Economic Review* **65**, 1–15.