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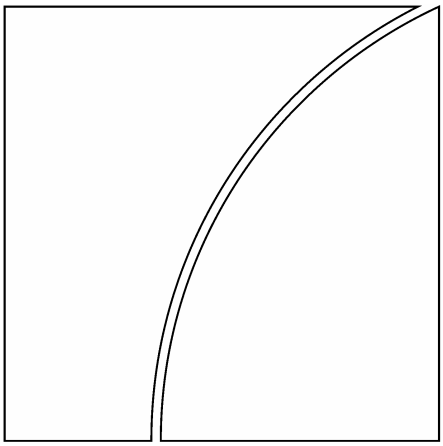

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The effectiveness of foreign exchange intervention in emerging market countries: evidence from the Czech koruna

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Abstract

We survey the literature on the efficacy of foreign exchange market intervention in emerging market countries, emphasising the differences with the literature on industrial countries. We then use official statistics on central bank intervention by the Czech National Bank in conjunction with options market data, to study the impact of intervention during 2001–02. We find that central bank intervention had some (weakly) statistically significant impact on the spot rate and the risk reversal but that this impact was small. We do not find evidence that intervention had an influence on short-term exchange rate volatility. We also find that, in our sample period, Czech authorities appeared to intervene mainly in response to an acceleration of the speed of koruna appreciation.

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1. Introduction[1]

This paper attempts to provide a comprehensive overview of what is known about the effectiveness of foreign exchange intervention in emerging market countries. This is done in two steps. First, an extensive review of the literature on the effectiveness of foreign exchange intervention in emerging market countries is conducted. Second, new evidence from a systematic study in the context of the Czech Republic using actual intervention data is presented.

A major stumbling block in assessing the effectiveness of intervention in emerging markets has been a lack of data. In constructing an overview of the results, it is therefore useful to combine the evidence that is available with the sizeable literature from advanced economies and taking into account specific institutional differences that may lead to considerable divergence in the effectiveness of intervention. Indeed, differences in the exchange rate regime pursued, the history of policy actions, the depth and sophistication of the foreign exchange market, as well as regulatory controls on various aspects of foreign exchange transactions, can significantly influence the impact of intervention.

That foreign exchange intervention appears to be more common in emerging market countries is partly a reflection of structural characteristics of such economies that often contribute not only to greater exchange rate volatility, but also to larger effects of such fluctuations on the real economy. Indeed, when the foreign exchange market is thin and dominated by a relatively small number of agents, it is likely that the exchange rate will be volatile if the authorities do not provide some guidance and support. This problem is compounded if there is no track record of stable macroeconomic policies that can firmly anchor market expectations about future monetary and exchange rate policy. Underdeveloped and incomplete financial markets also imply that hedging against exchange rate risk is costly and sometimes impossible, so that the costs of exchange rate volatility can be substantial for individual agents and for the economy as a whole.

Not surprisingly, the attitude of policymakers towards the exchange rate in emerging markets generally differs from that in industrial economies.[2] These differences, to some extent, also reflect alternative development strategies. For example, the reliance on export-led growth in East Asia during much of the 1980s and early 1990s meant that exchange rate policies in the region were geared towards maintaining export competitiveness, especially in the face of strong capital inflows. The heavy weight accorded to stabilising the exchange rate often occurred at the expense of greater volatility in other macroeconomic variables. Indeed, that developing countries tend to tolerate greater volatility in international reserves, domestic interest rates, and commodity prices than in exchange rates has been documented by Calvo and Reinhart (2002).[3] It is important to keep in mind this background in reviewing the literature on emerging market countries.

The empirical contribution of the paper is an analysis the impact of intervention by the Czech National Bank (CNB) on the koruna/euro exchange rate during 2001–02. The focus is on the level of the exchange rate, the implied volatility and risk reversals (ie market participants' bias between a much stronger and a much weaker koruna/euro rate). A comprehensive data set of news about macroeconomic variables and policy decisions is used to help distinguish the effect of intervention from that of the arrival of other relevant information. The simultaneous determination of intervention and market expectations is taken into account through instrumental variables estimation where estimates of CNB's reaction function are used as instruments.

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[1] This paper was written for the Meeting of Deputy Governors on "Forex intervention: motives, techniques and implications in Emerging Markets", held at the BIS on 2–3 December 2004. The collection of papers for this meeting will be published in a forthcoming BIS Paper. It was written while Piti Disyatat was visiting the BIS. We would like to thank Marian Micu for excellent research assistance, Claudio Borio, Martin Perina, Camilo Tovar and Philip Turner for helpful comments on an earlier version, and John Cairns for kindly providing us the IDEA data on intervention by Asian central banks that is perceived by market participants. All remaining errors are our sole responsibility. The views expressed are our own and do not necessarily reflect those of the Bank of Thailand or the Bank for International Settlements.

[2] A discussion of intervention objectives in the emerging market context can be found in Canales-Kriljenko et al(2003), while King (2003) offers a more general discussion based on experiences of advanced countries. A survey of empirical studies on the determinants of intervention can be found in Almekinders (1995) and Sarno and Taylor (2001).

[3] See also Ho and McCauley (2003).

The results suggest that during the period 2001–02, Czech authorities appeared to intervene mainly in response to an acceleration of the speed of koruna appreciation. These interventions had some weakly statistically significant impact on the spot rate. Consistent with the results for the spot rate, intervention had, on average, a weakly statistically significant effect on the risk reversal. Hence, following sales of korunas against euros, market participants tended to put more weight on a weaker rather than a stronger koruna. However, in economic terms, the impact on the spot rate and the risk reversal is small. Finally, intervention had no significant influence on implied volatility indicating that, on average, central bank intervention was not followed by an increase in uncertainty in the market about future exchange rate movements.

The outline of the paper is as follows. Section 2 discusses some of the reasons why foreign exchange intervention may be more effective in emerging market countries while Section 3 provides a comprehensive review of existing studies on the effectiveness of intervention in this context. The empirical results using Czech data is presented in Section 4 and Section 5 concludes.

2. Why might intervention be more effective in emerging market countries?

In thinking about how intervention may be effective, it is useful to conceptualise the exchange rate as an asset price. From this perspective, the current exchange rate depends on present and expected future fundamentals. A strand of research has also highlighted the susceptibility of exchange rate movements, at least in the short-run, to non-fundamental factors such as herd behaviour, information cascades, and speculation (Frankel and Froot (1990); Allen and Taylor (1992)). In this context, intervention might affect the spot exchange rate either through its impact on current fundamentals, expectations about future fundamentals, or expectations not based on fundamentals. The literature has focused discussion of these effects through four broad mechanisms: the monetary channel, the portfolio balance channel, the signalling channel and the microstructure or order flow channel.

In the context of managed floating regimes, the usefulness of intervention depends on whether or not exchange rates can be influenced independently of the monetary policy stance since only in this case will intervention constitute a truly separate policy instrument. As such, much of the focus in the literature has been on whether interventions that are sterilised (ie not backed by changes in monetary policy) have any significant effect. While the standard textbook distinction between sterilised and unsterilised intervention is based on a quantity criterion (the impact on base money), in practice the relevant condition is whether or not interest rates are affected. Since both the demand for and supply of base money changes significantly day to day due to autonomous factors, maintaining short-term interest rates does not always require that the entire amount of intervention be offset in the domestic money market.

With respect to the portfolio balance channel, one would not expect the effect to be very strong in advanced countries because typical intervention transactions are miniscule relative to the stock of outstanding assets. In addition, the degree of substitutability between domestic and foreign currency bonds tends to be quite high (Dominguez and Frankel (1993)). Galati and Melick (2002) argue that the portfolio channel may be more relevant for emerging markets because they are more likely to have large reserve portfolios relative to local foreign exchange market turnover or the stock of domestic bonds outstanding. Moreover, given that the degree of substitutability between emerging market currency debt and foreign currency debt is generally smaller – as reflected in higher risk premia on the former – the portfolio balance effect may also be stronger in these countries.

By contrast, it has been argued that the signalling channel is likely to be weaker in emerging market countries since central banks there have a shorter history of institutional and policy credibility than their counterparts in industrial economies. As such, they may have to make up for this by undertaking larger interventions (Canales-Krijenko et al (2003)). Indeed, in their analysis of intervention in Mexico and Turkey, Domaç and Mendoza (2002) found that monetary policy signals to the market do not seem to affect either the level or volatility of the exchange rate. Tapia and Tokman (2004), on the other hand, found public announcements of imminent intervention by the Banco Central de Chile to be effective in influencing both the level and trend of the exchange rate, which may reflect the high credibility of the Banco Central de Chile. It is therefore unclear whether the ability of central banks to convey policy signals is more or less effective in emerging market countries.

It is possible, however, that central banks in emerging market countries may have a better grasp of aggregate market conditions than domestic market participants if local markets are not very developed and remain highly segmented. This advantage may also arise from reporting requirements that give central banks in these countries a better picture of aggregate order flows and dealers with large net open positions. In this setting, and in line with the microstructure/order flow channel, intervention can be timed and conducted in a manner that potentially increases its market impact.[4] Under this channel, the size of intervention relative to market turnover is an important determinant of its effectiveness, which suggests that this channel may be more effective in emerging market countries where markets are less liquid. As documented by Ho and McCauley (2003), foreign exchange markets in most emerging economies do tend to be relatively small with bid-ask spreads that appear to be less uniform (both across currencies and across time) and wider than those among industrial country currencies, indicating less liquidity.[5]

Finally, in the current East Asian context, intervention may be more effective simply because they have tended to be undertaken in the same direction at roughly similar times. Interestingly, data on intervention that is perceived by traders suggest a link between intervention by the Bank of Japan and that of other central banks in the region which has increased in significance over 2003–04.[6] Probit estimates presented in Table 1 highlight this. The interventions appear to be more coincidental rather than coordinated, reflecting a concern for each country's respective effective exchange rates in the face of US dollar weakness and a resurgence of capital inflows into the region. While a lack of intervention data makes it difficult to test directly whether such common intervention are more effective, there is a perception that these interventions, which have been associated with large foreign reserve accumulation, have had at least some success in making the US dollar depreciation more gradual than it otherwise may have been.[7]

3. Existing empirical evidence

3.1 Advanced countries

Despite greater availability of high frequency intervention data, the empirical evidence on the effectiveness of intervention for advanced countries remains mixed.[8] Where foreign exchange intervention has been found to be effective, the magnitudes differ substantially across studies. The problem stems not only from differences in the data and methodology employed, but also from difficulties in defining a 'successful' intervention. In particular, much disagreement exists about the size and persistence of measured effects on the level and volatility of the exchange rate that constitutes success. This is partly a reflection of the absence of a reliable model of exchange rate determination that can be used to proxy the exchange rate path that would have obtained in the absence of intervention. Moreover, the objective of central bank intervention can change between intervention episodes so that the true success criteria may be time-varying. Indeed, one weakness of the literature on effectiveness of intervention is the implicit assumption that central banks' objective functions are

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[4] Scalia (2004) studied the effectiveness of intervention on Czech data from a microstructure perspective and found significant impact of order flow on the exchange rate. For industrial countries, the literature on the microstructure of exchange rate intervention is substantial with the broad conclusion being that central banks' intervention has significant impact on the first two moments of the exchange rate (eg Evans and Lyons (2001), Dominguez (2003), and Payne and Vitale (2003)).

[5] Canales-Krijlenko (2003) provides some survey evidence about the relative size of typical intervention in developing countries relative to market turnover.

[6] Data on foreign exchange intervention conducted by central banks in emerging market countries in Asia that is perceived by market participants were provided by IDEA. The data are daily and include information on the currencies that were traded as well as estimated amounts.

[7] For an analysis of reserve accumulation in the Asian region see, for example, BIS (2004).

[8] For extensive literature reviews, see Edison (1993), Almekinders (1995), Schwartz (2000), Sarno and Taylor (2001) and Humpage (2003).

stable across episodes of intervention.[9] Given the absence of direct data on why central banks intervene, a certain degree of judgement is needed in interpreting empirical evidence on the effectiveness of these operations.

Table 1

Relative frequency of intervention: coincidence with Bank of Japan intervention

Probit analysis

	2003–04
Hong Kong SAR	0.076 (1.19)
Korea	0.39 (6.19)
Philippines	0.02 (0.33)
Singapore	0.05 (0.78)
Thailand	0.11 (1.78)
Taiwan, China	0.33 (5.28)

Note: The table shows the probability of the joint perceived intervention in an emerging market country and actual Japanese Ministry of Finance intervention obtained from a Probit regression. The dependent variable is a dummy which takes the value of one for days with perceived emerging market interventions and zero otherwise. The independent variables are a constant and a dummy for the Japanese Ministry of Finance intervention. T-statistics are presented in parentheses.

Source: IDEA; Japanese Ministry of Finance; BIS calculations.

Overall, the evidence on advanced countries suggests that the bulk of the impact of intervention on the level of the exchange rate occurs during the day in which it is conducted, with only a smaller impact on subsequent days. With respect to volatility, the impact on implied volatility is found to be sample-dependent (Bonser-Neal and Tanner (1996), Dominguez (1998)) or strategy-dependent (Murray et al (1997)). Findings that intervention increases exchange rate volatility (Bonser-Neal and Tanner (1996) and Cheung and Chinn (1999)) suggest perhaps that the simultaneity problem has not been entirely corrected for (that is, intervention takes place at times when volatility is high). Or these findings could be a reflection of new information being transmitted into the market by the central bank. If the goal of intervention has primarily to do with the level of the exchange rate, however, then such volatility spikes do not necessarily indicate ineffectiveness of intervention.

Finally, a more recent focus has been on utilising information from options to infer the effects of intervention on higher moments of the exchange rate. An attractive feature of this approach is that it yields direct evidence on intervention's impact on market participants' beliefs and expectations. Not withstanding slight differences across sample, most of the results suggest that central bank intervention had no statistically significant systematic impact on the mean or higher moments of the exchange rate (Galati et al (2005)).

[9] Some exceptions include Hung (1997) and Fatum and Hutchison (2003). The former divided intervention data into two sub periods based on different perceived objectives of the Federal Reserve, while the latter examined several definitions of success and concluded that intervention appears to be effective according to different objectives. Galati and Melick (2002) also studied the effectiveness of intervention with respect to G3 currencies where the sample was conditioned on periods where the objectives were believed to be broadly consistent.

3.2 Emerging market countries

Although the empirical literature on emerging market countries where data limitations are much more severe is still relatively scant, some recent work does help to at least provide a broad sense of intervention's effectiveness in these countries. Most prominently, and not altogether surprising, the effectiveness of intervention is highly sample-dependent with conclusions varying significantly across countries. That said, the evidence also highlights some broad similarities. In particular, the effectiveness of intervention appeared to be dependent on the monetary policy framework pursued and whether the intervention was publicly announced or not. Tapia and Tokman (2004), for example, studied the effectiveness of intervention in Chile using both daily and intraday data. Their analysis indicated that the effectiveness of intervention operations varied throughout the sample in line with the changing policy framework of the central bank, with public announcements playing a bigger role after 2001. Similarly, Guimarães and Karacadag (2004) and Holub (2004) emphasized the role of public announcements in the case of Turkey and the Czech Republic, respectively. Another general observation is the asymmetry associated with intervention's effectiveness. Barabás (2003), for example, provides an account of how intervention by the Hungarian central bank successfully defended the strong edge of the exchange rate band arguing that it may be more feasible to resist appreciation than depreciation. Likewise, Domaç and Mendoza (2002) also found asymmetric effects in the case of Mexico and Turkey. Finally, there appears to be a link between the depth and sophistication of the capital market and the effectiveness of intervention as discussed, for example, by Rhee and Song (1999) in the context of Korea where it was found that as the capital market became more open, intervention policies appeared to become less effective.

In terms of the impact of intervention, the evidence is more clear-cut with respect to the volatility than the level of the exchange rate. Among those that found a significant effect on the level, Domaç and Mendoza (2002) concluded in the context of Mexico and Turkey that central bank foreign exchange sales (but not purchases) were generally effective in influencing the exchange rate in both countries. In particular, a net sale of US$100 million appreciated the exchange rate by 0.08% on average in Mexico and 0.2% in Turkey. In their study of the Chilean experience, Tapia and Tokman (2004) found that although actual intervention appeared to have a small and generally insignificant effect on contemporaneous exchange rate movements, public announcements of potential interventions had significant effects on the level and trend of the exchange rate. Similarly, Rhee and Song's (1999) study of Korean exchange rate policy during the pre-1997 crisis period found that sterilised intervention had a significant short-run effect on the exchange rate level that lasted for about one week. Ryu (2003), also found that intervention transactions – but not public announcements – by the Bank of Korea were effective in pushing the exchange rate in the desired direction.

In contrast, Guimarães and Karacadag (2004) find only weak supportive evidence for the effectiveness of intervention on the level of the exchange rate in these Mexico and Turkey. Given policy objectives, however, such findings do not necessarily indicate a failure of intervention. For example, the bulk of intervention undertaken in Mexico during the sample period was aimed at accumulating reserves rather than influencing the underlying exchange rate trend. In Turkey's case, the apparent ineffectiveness of intervention in influencing the level of the exchange rate may reflect the nature of intervention policies there. In particular, the vast majority of official interventions were conducted in the context of pre-announced foreign exchange auctions, where the timing and amounts were largely predetermined and known by market participants. Hence, the potential impact of interventions may have operated through the signalling channel well in advance of actual interventions themselves. Based on the analysis of monthly data, Pattanaik and Sahoo (2002) concluded that intervention operations of the Reserve Bank of India had very little perceptible influence on exchange rate levels. Similarly, using Granger causality tests, Sahadevan (2001) concluded that interventions by the Reserve Bank of India did not have any significant causal relationship with monetary variables and the exchange rate. In an interesting study, Sangmanee (2003) utilized option-implied probability density functions to examine whether intervention instantaneously influenced market expectations regarding the sustainability of Thailand's fixed exchange rate regime prior to the 1997 crisis. The results indicated that spot intervention did not have a statistically significant contemporaneous impact in this regard, although they were associated with a decrease in the kurtosis (ie likelihood of a very large change in either direction) of expected exchange rate returns. Finally, a number of studies found mixed results with respect to intervention's impact on the level of the exchange rate including Holub (2004), Barabás (2003), and Abenoja (2003) for the Czech Republic, Hungary, and the Philippines, respectively.

With respect to the impact of intervention on exchange rate volatility, the evidence is generally more positive. Domaç and Mendoza (2002) found in the context of Mexico and Turkey that intervention reduced exchange rate volatility in both countries. Pattanaik and Sahoo (2002) also concluded that intervention operations of the Reserve Bank of India had been effective in containing volatility of the rupee, although the degree of influence did not appear to be very strong. For the Philippines, Abenoja's (2003) study using daily intervention data from 1992 to 2003 indicated that although intervention reduced volatility contemporaneously, persistent operations actually increased volatility. This might suggest that successive interventions lead to greater market uncertainty. Less encouragingly, Mandeng (2003) analysed the experience of option-based foreign exchange intervention in Colombia through an event study method and an analysis of variance model and found that these have only been moderately successful in reducing exchange rate volatility. Moreover, the effects were not persistent and, after a 10-day lag, intervention did not appear to significantly affect volatility. The relative ineffectiveness was attributed to sub-optimal contract specifications. For Mexico and Turkey, and in contrast to Domaç and Mendoza (2002), Guimarães and Karacadag (2004) also did not find a significant impact of intervention on exchange rate volatility.

4. Empirical study

This section outlines some of the challenges posed by empirical studies of intervention's effectiveness and presents new estimation results using actual daily intervention data from the CNB. Overall, the results indicate that intervention can have a statistically significant impact on both the level but not the volatility of the exchange rate, as well as influence market expectations about its future direction, although the effect can be quite small and not very long-lasting.

4.1 Estimation strategies

A wide array of techniques has been employed to assess the effectiveness of intervention. Relatively recent surveys of these methodologies can be found in Humpage (2003) and Sarno and Taylor (2001). In general, it is not possible to disentangle precisely the channels through which intervention works. The focus has rather been on the overall impact of such operations. The single most important problem that confronts all empirical research on intervention is the simultaneous determination of official intervention and exchange-rate changes. The central hypothesis is that intervention affects the exchange rate, but the decision to intervene is not independent of the movements in the exchange rate. Also, once a central bank has decided to intervene, the magnitude and timing will typically depend on the response of the exchange rate to its trades. Time-series analysis or regression based event studies typically set up the timing of the data so that intervention occurs before the exchange rate (for example, lagging the intervention term by one period). Given that intervention often affects exchange rates within minutes, extremely high frequency data are needed.[10]

An alternative way of dealing with the simultaneity problem is to define a success criterion and analyse the frequency of success over a particular time period. This is in the spirit of traditional event studies. Studies based on this method have generally yielded stronger results about the effectiveness of intervention compared to those based on time-series techniques (Fatum and Hutchison (2003)). Since this methodology does not control for the effect of changes in other variables, however, studies where the event window is longer than a few days are more susceptible to the simultaneity problem since the likelihood that other factors affecting the exchange rate may enter the window is higher. Another approach would be to adopt an assumption on the central bank's reaction function, although estimates of such reaction functions are hampered by the discrete nature of intervention data. Unless the estimation is done over different sub-periods, such an approach also involves a presumption that the objective of intervention is constant through time, which may not always be appropriate.

[10] Forward obligations of the Bank of Thailand at the end of June 1997 were estimated at around US$ 26 billion (IMF 1998). Forward transactions have also been undertaken by the Reserve Bank of South Africa, though for the most part, these have been motivated by a desire to provide forward cover for export firms rather than to influence the exchange rate (Neely 2001).

A number of studies have tried to circumvent the simultaneity problem by using an indirect gauge of effectiveness suggested by Friedman (1953). The idea is that successful intervention should reverse market trends so that intervention operations are effective on average if the central bank makes a profit on their trades. Given that central banks sometimes care more about volatility than the level of exchange rates, and that such analyses do not in any way deal with the simultaneity problem, the conclusions from this approach are at best tenuous. Indeed, that central banks are profitable could simply reflect the fact that they have better timing than the market. Moreover, the horizons over which profitability is measured, as well as the measurement of profit itself, can also influence results substantially.[11]

An alternative approach consists in estimating effectiveness by using an instrumental variables approach. Dominguez and Frankel (1993), for example, use an instrumental variable method, with news that appeared in the financial press about changes in central banks' exchange rate policy as instruments. Galati and Melick (1999) and Galati et al (2005) first estimate a reaction function and then use the fitted values as instruments in regressions that estimate the effect of intervention. Kearns and Rigobon (2002) develop a similar technique for dealing with the simultaneity problem, which is based on a General Method of Moments, and apply it to Australian data. A similar method is used by Tapia and Tokman (2004).

Finally, a different but related methodology focuses on the link between profits associated with trading rules and intervention. A substantial number of studies have found that fairly simple technical trading rules generate profits that are difficult to explain in terms of standard risk measures. LeBaron (1999) and Szakmary and Mathur (1997) found that these excess returns generally occurred during periods of central bank intervention, suggesting that the latter introduces noticeable trends in the evolution of exchange rates that, in turn, create profit opportunities. Neely (2002), however, casts doubt about the direction of causality arguing that interventions tend to arise during periods when exchange rates are trending in a manner that would likely lead to technical trading rule profits.

4.2 An empirical assessment of the effectiveness of intervention in emerging market economies: the Czech case

This section presents an empirical approach to estimating the impact of foreign exchange market intervention on the spot rate and exchange rate expectations in emerging market economies. The case of intervention in the Czech koruna market is used to illustrate the approach. This is an interesting test case because the CNB has followed an explicit inflation targeting regime and at the same time intervened in the foreign exchange market on a number of occasions.[12]

The CNB recently published a detailed analysis of objectives, strategies and the efficacy of intervention (Holub (2004)). It has provided information on timing and magnitude of intervention operations to the public.[13] The CNB's interventions were typically aimed at slowing down the rate of appreciation of the koruna against the Deutsche mark and, since 1999, the euro. Sales of korunas were generally concentrated in periods lasting several weeks, followed by long periods in which the CNB did not intervene. The most active periods were February to July 1998, October 1999 to March 2000 and October 2001 to September 2002. The first and third periods were characterised by a sharp appreciation and high short-term volatility of the koruna both against the Deutsche mark/euro and in nominal effective terms. In the second period, the koruna appreciated against the euro but weakened in nominal effective terms.

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[11] Neely (1998), for example, shows that central banks often make losses in the short-run and profits only if the horizon is long enough.

[12] The inflation targeting regime was introduced in the autumn of 1997, following a speculative attack on the koruna in May. Holub (2004) notes that the important role of the exchange rate is underpinned by the openness of the Czech economy, with exports of goods and services amounting to 65% of GDP and imported goods accounting for 25% of the consumer basket. Holub (2004) also discusses the performance of the CNB in keeping inflation on target and the role of the exchange rate in deviations from the target.

[13] The information can be found on the CNB's website (www.cnb.cz). Starting in July 1998, monthly data on the volume of intervention have been published with a lag of two months. The intervention volume can be also estimated from the CNB's balance sheet, which is published every 10 days.

With respect to the transparency of interventions, the CNB announced immediately on a number of occasions that it had entered the market.[14] In other cases, intervention was carried out in a discreet fashion.[15] While a discussion of issues related to the exchange rate is regularly included in the minutes of both regular and extraordinary monetary policy meetings, only in a few cases did these contain explicit information on foreign exchange market intervention.[16]

The data

The empirical exercise focuses on daily movements of the koruna against the euro between September 2001 and October 2002, a period in which the CNB intervened frequently. The choice of the sample is also dictated by the availability of data on implied volatility and risk reversals needed to describe market expectations. The exchange rate data are taken at noon in London, quoted in koruna per euro. Data on intervention in the koruna market were provided by the CNB.

Control variables used in the estimation included those that capture the effect of news about macroeconomic or policy developments that may arrive on the same day on which intervention is carried out. The unexpected component of macroeconomic news was measured by the difference between official data announcements and the results of opinion surveys conducted during the days preceding the announcements by Bloomberg. News variables for the Czech Republic included news about CPI, PPI, GDP, industrial production, retail sales, the unemployment rate, construction output and the trade balance. We also used news variables for the euro area, including surprises about the policy rate, as well as surprises on German data for the IFO index, CPI, PPI, GDP and the unemployment rate.[17] Since survey data on expectations of monetary policy decisions by the CNB are not available, we captured the effect of news about changes in Czech policy rates by the percentage change in rates between policy meetings.

In recent years, data from foreign exchange option markets have been used to extract information on exchange rate expectations and to match them with intervention activity.[18] Given the liquidity of derivatives markets in the Czech koruna, there was not sufficient data to estimate the entire risk-neutral probability density function of the underlying exchange rate as in those studies.[19] However, data on spot and forward exchange rates, one-month implied volatility and one-month risk reversals can be used to provide a sufficiently broad characterisation of market expectations. Implied volatility can be interpreted as providing a measure of how uncertain the market is on a given day about the exchange rate that will prevail over the near future. The risk reversal – the price difference between two equally out-of-the money options – can be interpreted as the weight that market participants put on a much higher and a much lower koruna/euro exchange rate in the near future with respect to the forward rate. It therefore provides a measure of the skewness of market expectations.[20]

Intervention and exchange rate expectations

The panels of Graph 1 provide some information on the average movements of the spot rate, the implied volatility and the risk reversal of the koruna/euro exchange rate around intervention episodes by the CNB during the period 3 September 2001 to 1 October 2002. The CNB intervened on 41 days

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[14] Episodes that were made public in real time include 31 March 1998, 4 October 1999, 21 January 2002 and 10 April 2002.

[15] For example, in December 2001 or in July-September 2002.

[16] Examples are the extraordinary meetings on 21 January 2002 and 11 July 2002, and the regular meetings held on 4 October 1999, 30 March 2000 and 25 October 2001.

[17] We also added macroeconomic news for France, but these were generally found not to be significant.

[18] See, for example, Bonser-Neal and Tanner (1996), Murray et al (1997), Dominguez (1998), Galati and Melick (1999) and Galati et al (2005).

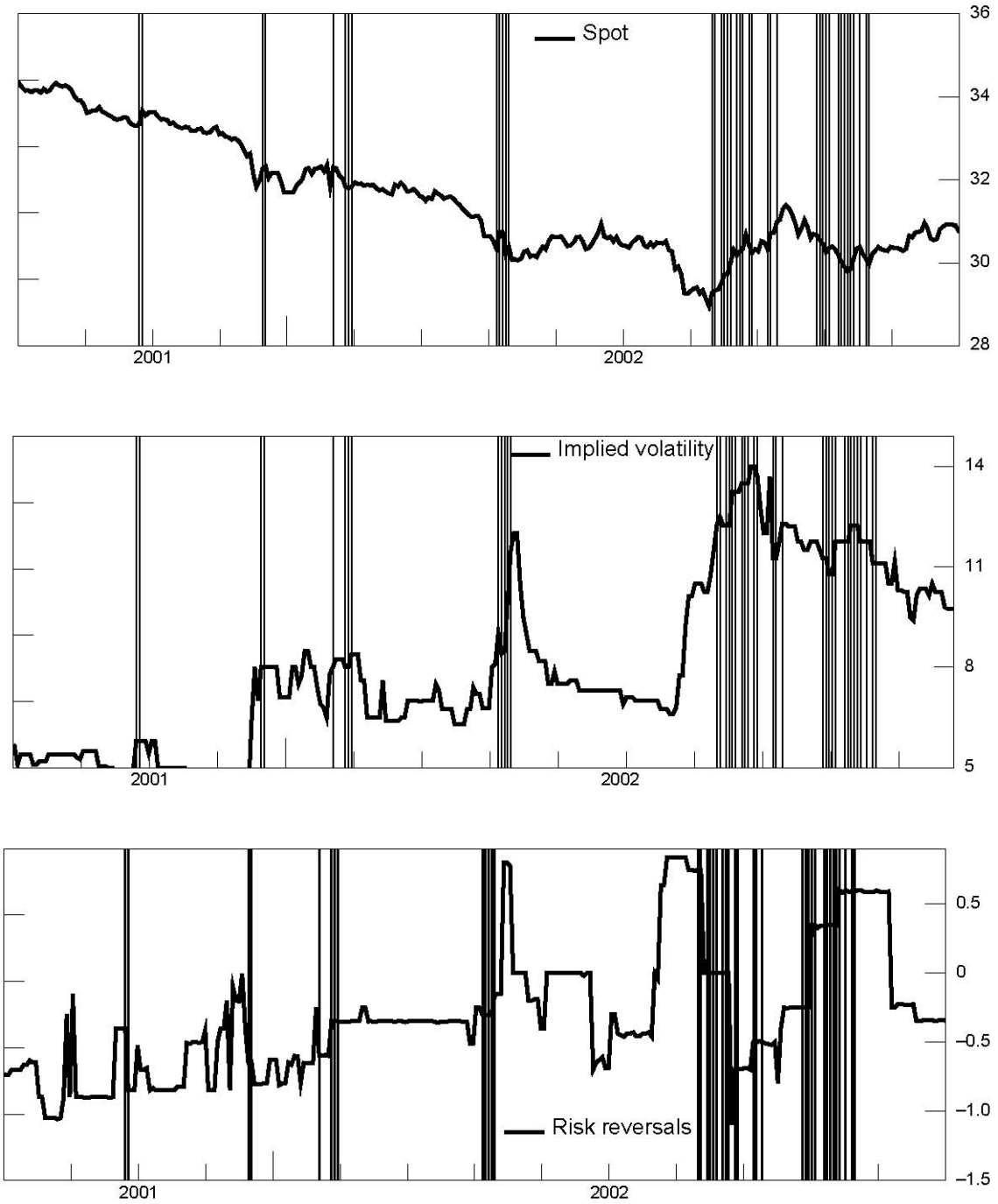
[19] In particular, in the absence of sufficiently liquid market for strangles, risk-neutral PDFs cannot be estimated. A strangle is a financial instrument that consists of a purchase or sale of an out-of-the-money put option and call option on the same underlying instrument, with the same expiration date. A strangle leads to profits if there is a drastic move in either direction of the price of the underlying asset, ie here in the koruna/euro rate.

[20] In interpreting the results, it should be emphasised that the interpretation of the option prices is complicated by the fact that they reflect both market views as to the likelihood of particular exchange rate outcomes as well as market preferences towards risk (see Galati et al (2005)).

during this period, buying a total of close to €3 billions. On average, it tended to enter the market for a period of about eight days. While the graph gives a broad sense of the effects of intervention over a particular period, it also indicates that the objectives of intervention and context under which they were carried out varied through time.

Graph 1

Movements of the koruna/euro spot rate, the implied volatility and the risk reversal around CNB intervention episodes, September 2001 - October 2002



Regression analysis

While the above panels are certainly interesting, one should be careful in using them to draw inferences about the impact of intervention for two main reasons. First, the CNB has at times carried out intervention on several successive days, with the length of the intervention episodes varying quite substantially. The graph does not allow disentangling the effect of repeated interventions. Second, on the days that the CNB intervened, other important macroeconomic or policy news might have arrived that could have led market participants to react. The behaviour of the variables would then reflect the combined effect of the CNB's intervention activity and the arrival of macroeconomic or policy news.

In order to assess the effect of intervention and control for these two issues, daily regression analysis is conducted that explains the spot rate, the implied volatility and the risk reversal in terms of current and lagged CNB intervention and other explanatory variables. To distinguish the effect of intervention from the effect of news about relevant macroeconomic variables or monetary policy decisions that may arrive on the same day, a set of variables measuring the unanticipated component of announcements of major macroeconomic variables is included.

It is also important to correct for potential simultaneity problems. For example, in a regression of the variance of the expected exchange rate on intervention, a positive coefficient on intervention can mean either that intervention increases expected volatility, or that the CNB intervened to smooth rising exchange rate volatility, but was not successful. This problem is addressed by estimating the regression equation using instrumental variables (IV). Estimates of a reaction function for the CNB was used as the instrument.[21]

In particular, the following two equations were estimated:

$$\Delta Y_t^j = a + \sum_{i=1}^{5} b_i \Delta Y_{t-i}^j + \sum_{i=0}^{5} c_i I_{t-i} + \sum_{i=0}^{5} d_i X_i + \varepsilon_t \qquad (1)$$

and

$$I_t = a + \sum_{j=1}^{3} \sum_{i=1}^{5} b_i^j \hat{Y}_{t-i}^j + \eta_t \qquad (2)$$

where ΔY_t^j is the change in the spot rate, implied volatility or risk reversal at time t, $\hat{Y}_{t-i}^j$ is the target value (explained below) for the variable lagged by i periods. I_t is the amount of intervention on day t, X_t is a vector of macroeconomic variables and ε_t and η_t are error terms. Instrumental variables estimation essentially involves replacing the intervention variable in (1) with its predicted value from the reaction function (2). The latter includes only lagged explanatory variables, and can therefore be estimated with OLS.

For the purpose of this empirical exercise, it was assumed that the CNB intervened when the spot rate, the implied volatility or the risk reversal deviated from implicit target ranges, with the likelihood of intervention depending on the distance from these targets.[22] As a first approximation, targets for the implied volatility and the risk reversal were set equal to their historic average. The implicit assumption, therefore, is that during the sample period the CNB tended to intervene whenever the variance or skewness of market expectations was abnormally high or low with respect to its historical average.[23]

The explanatory variables include the distance at time *t-i* of the koruna/euro spot rate from the bottom of the target range when the exchange rate is below that limit and a variable for the case in which the

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[21] As discussed in Galati et al (2005), the biggest drawback to this approach is the possibility of omitted variables bias in the OLS estimation of the reaction function, since only lagged values of the exchange rate moments are included and the contemporaneous values of the exchange rate moments via an instrument are omitted. However, this bias is likely to be trivial, since the changes in the spot rate, implied volatility and risk reversal show little if any persistence and thus there is not much correlation between the included lagged moments and the omitted instrument for the contemporaneous moments.

[22] An alternative approach used in the literature consists of setting the implicit target equal to the PPP value of the koruna/euro exchange rate, as in Dominguez and Frankel (1993). This approach appears less useful for the Czech case, since reliable estimates of PPP are very difficult to obtain. Almekinder and Eijffinger (1991) set the target rate equal to past levels of the exchange rate. However, this would amount to assuming that the CNB systematically leaned against the wind.

[23] The target bounds are taken here as the historical mean ± 1.5 standard deviations.

exchange rate breaks through the top of the target range. In addition, the distance of the variance from its historical average when the euro is, respectively, appreciating or depreciating was included. A variable to measure the distance of the risk reversal from its historical average when the koruna is depreciating and the market is skewed towards a much weaker koruna was also included. Finally, a measure of the distance from the average of skewness when the koruna is strengthening and the market is biased towards a much stronger koruna was used.

The reaction function was estimated over the period September 2001 to October 2002, during which time the CNB intervened on several occasions.[24] Table 2 reports the coefficients, t-statistics and significance levels for the reaction functions. The model seems to capture the intervention decisions taken by the CNB during September 2001 to October 2002 reasonably well, as suggested by an R^2 value of 0.18. The results suggest that during the sample period, the CNB tended to intervene mainly when the speed at which the koruna appreciated against the euro tended to accelerate.

To investigate the effect of CNB intervention on market expectations, equation (1) was estimated for the spot rate, the implied volatility and the risk reversal using daily data from 1 September 2001 to 30 September 2002 using instrumental variables. The instruments include the predicted values of intervention by the CNB taken from the estimated reaction functions, equation (2), as instruments.[25]

Table 2

Estimates of the reaction function for the CNB intervention in the koruna/euro foreign exchange market

Variable	Coefficient	t-statistic	Significance level
$Spot^{(H)}$	0.00	0.00	1.00
$Spot^{(L)}$	45.85	0.35	0.73
$Variance^{(H)}$	42.87	1.01	0.31
$Variance^{(L)}$	125.15	2.78	0.01
$Risk\ reversal^{(H)}$	151.13	0.99	0.32
$Risk\ reversal^{(L)}$	–200.35	–1.24	0.22
R^2	0.18		
Number of observations	276		

Note: The table reports coefficients of a model estimated for the CNB intervention. It is estimated with OLS using daily data over the period 1 September 2001 to 30 September 2002. Explanatory variables are five lags of the distances of the spot rate, implied volatility and risk reversals from their targets when the euro is appreciating (H) or depreciating (L) with respect to the koruna, as defined in the text. The coefficients on the lags two to five of the distances of the moments from their target values are generally not significant and are consequently not reported here.

The specification follows closely that used in Galati et al (2005). The dependent variables of the regression equations are expressed as first differences, while intervention enters in levels on the right-hand side. The explanatory variables include also five lags of intervention in order to capture the dynamics of the short-term effect of intervention, as well as lagged values of the change in the dependent variable. In addition, variables capturing the impact of news about macroeconomic or policy developments were introduced, as described above. In the regression equations for the implied volatility, all explanatory variables are expressed in absolute values, as it is assumed that their impact depends only on their size but not their sign. The results are summarised in Table 3, which reports the

[24] The sample period is dictated by the combination of a sufficiently high number of intervention days and the availability of reliable data on option prices.

[25] An alternative instrument for intervention, which has been commonly used in the literature, is lagged intervention.

coefficient on contemporaneous intervention and the cumulative sum of coefficients on contemporaneous and lagged intervention.[26]

Table 3 shows that in the regression equation for the spot rate, the coefficient on current intervention is not statistically significant, indicating that, on average during the period 2001–02, CNB intervention in the koruna/euro market had no statistically significant contemporaneous effect on the exchange rate level. However, the cumulative sum of current and lagged intervention is statistically significant at the 9% level, indicating that a cumulative effect of intervention over one week is present but hard to detect empirically. While the cumulative effect of intervention is (weakly) statistically significant, it is very small in economic terms: the combined impact of the contemporaneous level and five lags of intervention on the koruna/euro spot rate is in the order of 25 basis points. This result is consistent with the literature that looks at industrial countries during periods that include the Plaza and Louvre Accords and find evidence of statistically significant but economically very small impact (Galati and Melick (2002)). It is also consistent with recent research on intervention aimed at G3 exchange rates that is based on event studies (Fatum and Hutchison (2003)). However, it is in contrast with the existing literature that also controls for simultaneity and does not include the Plaza and Louvre periods.

Table 3

Estimates of the effect of intervention on the spot, implied volatility and the risk reversals of the Czech koruna/euro exchange

	Spot			**Implied volatility**			**Risk reversals**		
	Coeff.	**t-stat.**	**Sign. level**	**Coeff.**	**t-stat**	**Sign. level**	**Coeff.**	**t-stat**	**Sign. level**
Intervention									
Contemporaneous	0.00	1.24	0.22	0.00	–0.93	0.35	0.00	1.49	0.14
Cumulative	0.01	1.68	0.09	0.00	–0.61	0.54	0.01	1.81	0.07
Macroeconomic announcements in the Czech Republic									
CPI	–1.40	–1.83	0.07	–30.34	–0.31	0.76	–17.33	–0.48	0.63
Retail sales	–0.15	–2.26	0.02	11.88	1.42	0.16	0.01	0.00	1.00
Macroeconomic announcements in the Euro area (Germany)									
Industrial production	0.29	1.81	0.07	–21.15	–1.03	0.30	3.72	0.48	0.63
Number of observations	271			271			271		

Note: The table reports the estimation results for equation (1). The equation is estimated using daily data. Lags of the dependent variable, all not statistically significant, are not reported here. The sample period is from 1 September 2001 to 30 September 2002.

Interestingly, inflation surprises and news about retail sales have a statistically significant impact on the koruna/euro rate. High inflation or retail sales data are on average associated with an appreciation of the koruna, although the effect is very short-lived. Among the euro area news, a positive surprise on industrial production is associated with an appreciation of the euro with respect to the koruna.

The results in Table 3 also show that, on average between September 2001 and October 2002, intervention by the CNB did not lead to higher implied volatility. The coefficient on (both

[26] Table 3 reports the regression results for an equation that includes only those macroeconomic news variables that were found to be statistically significant.

contemporaneous and cumulative) intervention is actually negative, suggesting that intervention is associated with lower volatility. However, this effect is not statistically significant. This result indicates that, on average, intervention was not followed by a significant rise in market uncertainty. This finding is consistent with several studies on G3 exchange rates based on both GARCH measures of volatility (Connolly and Taylor (1994) and Baillie and Humpage (1992)) and implied volatility (Bonser-Neal and Tanner (1996), Dominguez (1998), Murray et al (1997) and Galati et al (2005)).[27] Finally, intervention, on average, had a statistically significant cumulative effect on market participants' balance of weights between a stronger and a weaker koruna, as measured by the risk reversal. Taken together with the results for the spot rate, this finding suggests the CNB managed to influence the spot exchange rate since it influenced market participants' balance of weights.

In summary, the empirical analysis highlights several important results. First, consistent with the general consensus that exchange rates are difficult to explain, changes in the spot rate, implied volatility and risk reversals in the Czech Republic are not easily explainable by either macroeconomic variables or central bank intervention activity. There was some, albeit weak, evidence that over the period September 2001 to October 2002, intervention on its own had statistically significant effects that lasted for at least one week. However, the small size of the regression coefficients suggests that this effect was rather limited in economic terms. These results are consistent with Holub's (2004) informal assessment of the Czech case. In line with Barabás (2003), the impact of intervention appears to be asymmetric with efforts to resist an appreciation rather than a depreciation of the domestic currency being more likely to have an impact. Finally, given that much of the intervention conducted by the CNB were openly announced, the results are also in line with the findings, more broadly, of Dominguez and Frankel (1993) and other studies that intervention in industrial countries, particularly when officially announced, had a statistically significant impact on exchange rates during the 1980s.

One interpretation is that intervention conducted by the CNB was large relative to the size of the koruna/euro market, and hence the portfolio channel is more likely to have been effective. The findings are also consistent with the view that the microstructure channel might be stronger in emerging market countries. Another interpretation is that the empirical studies that found a significant impact of intervention on the exchange rate typically looked at periods over which monetary authorities made credible statements about undertaking decisive policy action to influence exchange rate. In industrial countries, the Plaza and Louvre agreements are examples of such statements, which tended to reinforce the effect of intervention. By contrast, there is less evidence of a significant impact of intervention in studies that focus on periods in which monetary authorities refrained from making such statements.

5. Conclusion

Empirical studies on the effectiveness of intervention in emerging market countries are plagued by severe data limitations and frequent structural breaks. As such, much of the assessment must be complemented by evidence from advanced countries. In making this assessment, one would expect a priori that foreign exchange intervention in emerging market countries may be more effective because (i) the size of intervention relative to market turnover tends to be larger, (ii) the existence of some form of capital controls limiting access to international capital markets gives central banks in these countries greater leverage in the market, and (iii) the lower level of sophistication of the domestic market along with stringent reporting requirements may endow central banks with a greater informational advantage not only with respect to fundamentals but also aggregate order flows and net open positions of major traders.

Overall, combining the available evidence for emerging market countries with that from advanced economies, the tentative conclusion points towards the existence of a high-frequency – ranging from intradaily to a few days – connection between foreign exchange market intervention and both the level and volatility of exchange rates. There does not appear to be a reliable connection between official

[27] As noted in the literature review, the impact on implied volatility is found to be sample-dependent (Bonser-Neal and Tanner (1996) and Dominguez (1998)) or strategy-dependent (Murray et al (1997)).

transactions and fundamental determinants of exchange rates that would allow central banks to determine exchange rates independently of monetary policy for sustained periods. Instead, studies suggest that intervention can sometimes affect exchange rates temporarily in a manner that depends on market conditions and the firmness of agents' expectations.

This conclusion may appear somewhat contradictory to the perception that emerging market countries in Asia have been quite successful during the last few years in their intervention operations to resist, or at least make more gradual, the trend appreciation of their currencies with respect to the US dollar. However, if one views the literature reviewed in this paper as indicating effectiveness of sterilised intervention that lasts at most only a few days, then the only way for monetary authorities to impart an influence on the exchange rate for longer periods would be through repeated intervention activity and/or through intervention that is not entirely sterilised. The fact that central banks in these Asian countries have accumulated large foreign reserves as a by-product of their intervention efforts can be viewed as consistent with this interpretation.

From a policy perspective, the empirical results suggest that intervention may be useful in addressing undesired short run exchange rate fluctuations stemming from temporary shocks but cannot substitute for monetary policy in dealing with underlying fundamental inconsistencies in macro policy that may arise from time to time. Indeed, protracted one-sided interventions are often a reflection of an inconsistency between the desired path of exchange rates and underlying fundamentals, including the monetary policy stance. That said, in times of uncertainty when fundamentals do not point towards a clear direction for the exchange rate, monetary authorities may have an influential role in swaying market participants one way or the other. The extent to which intervention can serve a useful purpose in this regard depends on the institutional and policy credibility of the central bank. In addition, the method and strategy by which intervention is conducted can also sometimes make a difference at the margin, and these should be formulated based on the particular objective of intervention to maximise the impact.

The empirical exercise conducted in this paper using official data on intervention carried out by the Czech National during 2001–02 and options market data indicate that intervention had some (weakly) statistically significant impact on the spot rate and the risk reversal. However, this impact was small. There was no evidence that intervention had an influence on short-term exchange rate volatility.

The results are consistent with the view that the portfolio and microstructure channels are more likely to have been effective in emerging market economies than in industrial countries, and also that efforts to resist an appreciation rather than a depreciation of the domestic currency are more likely to have an impact. Finally, the findings are consistent with the literature that concludes that intervention is more likely to be effective in periods over which monetary authorities make credible statements about undertaking decisive policy action to influence exchange rate.

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