Altered Band and Exchange Volatility

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Abstract:

This paper examines the behavior of the Czech crown's exchange rate when pegged to a currency basket. The peg is supposed to limit the overall instability of the currency. The GARCH(1,1) model with a dummy variable for the volatility response is used to account for a change in the width of the fluctuation band. The results of this paper show that volatility of the exchange rate decreased after a much wider fluctuation band was introduced to limit movements of the currency basket index.

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1. Introduction

This paper examines the behavior of the exchange rate of the Czech crown when pegged to a currency basket under different fluctuation bands. The peg is supposed to limit the overall instability of the currency. Such limiting means stabilizing the exchange rate and lowering its volatility. This is conditional on the central bank keeping the index of the currency basket within a narrow band and not subjectively tampering with it. The goal of the paper is to show how the volatility of the exchange rate was affected by allowing for a wider fluctuation band.

The GARCH(1,1) model with a dummy variable for the volatility response to the crown's appreciation in a variance equation is applied in order to model conditional variance in exchange rates. This is done to account for a change in the width of the fluctuation band. Estimates of the models are presented for the mean and variance equations.

The results of this paper show that contrary to conventional wisdom, volatility of the various exchange rates decreased after a much wider fluctuation band was introduced to limit movements of the currency basket index. The rest of the paper is organized as follows. Sections 2 and 3 describe the data and the currency basket. Section 4 presents the methodology used and all empirical results. A brief conclusion follows.

2. The Data

The data consists of daily midpoint exchange rates of the Czech crown (CZK) to six major currencies from January 4, 1993 to December 31, 1996. The data was supplied by the Czech National Bank (CNB), Prague. The rates of foreign currencies in terms of the Czech crown are: Deutsche Mark (DEM), U.S. Dollar (USD), British pound (GBP), Canadian dollar (CAD), Japanese yen (JPY), and Swedish crown (SEK). The six major currencies were selected for this study because the majority of them are quite important in international trade (USD, GBP, JPY), and some of them are included in the currency basket to which the Czech crown is currently pegged (USD, DEM). Another reason is that they represent a set of currencies that are governed by different exchange rate regimes: from a real free float (USD, CAD, JPY) to a more limited float or interlinked peg (DEM, SEK, GBP). A significant reason for analyzing

CAD, JPY, GBP, and SEK is the fact that these currencies are not in any formal way associated with the composition of the basket during the researched period.

There are a total of 1016 daily observations for each currency. The data is not stationary but is a first order integrated process. A further analysis is performed on the rate of change of respective exchange rates calculated as a percentual change between two consecutive business days. Such a transformed time series exhibits the usual mean close to zero and skewness and kurtosis far from normality, as one would expect in the case of high frequency financial data.

3. Currency Basket as a Tool to Stabilize Exchange Rate

In 1991, former Czechoslovakia officially started its economic transformation. From this time the role of the exchange rate could no longer be downplayed as in the former centrally planned economy. However, a certain reduction in the relative volatility of exchange rates was desirable in order to promote export, direct foreign investments and generally favorable economic development during the transition to a free market economy.[1] The shock of the transition needed to be buffered, and therefore, to introduce a floating exchange rate system would have been premature. A floating exchange rate regime requires that no restrictions on financial capital movement be imposed. This necessitates a strong mature economy with sufficient reserves of convertible currencies. During the early stages of economic reform, the country did not meet these conditions and an eventual bank run could have caused vast damage. The situation called for a temporary anchor of the currency basket peg.

In the beginning of 1993 Czechoslovakia was split into two independent nations. Monetary separation of the Czech and Slovak republics followed shortly after the formal division of the state.[2] From this point on the Czech crown has remained more or less stable, unlike its Slovak counterpart, which has devalued to a certain extent over time. Full convertibility of the crown was implemented on October 1, 1995, and meant that the crown could be traded for foreign exchange without restrictions by both companies and citizens. However, this step was not paired with

[1] With the absence of fully functioning financial markets, the newly emerged private sector was extremely vulnerable to exchange rate fluctuations. The fixed exchange rate provided a less volatile environment according to policy makers at that time.

[2] A detailed conditional variance analysis of the crown's evolution covering periods before and after the monetary separation can be found in Kočenda (1996).

any change in the exchange rate regime and thus the crown remained pegged to the currency basket.

The currency basket was primarily meant to be a nominal anchor that allows, under a prudent policy, to keep a relatively stable nominal exchange rate. Currency is pegged to a currency basket when it is bound to several currencies via exchange rates in certain proportions. The currency basket is, according to the International Monetary Fund, categorized as a type of fixed exchange rate arrangement. The CNB introduced the basket system at its current general level at the beginning of 1991 and constructed the basket as a weighted average of nominal exchange rates.[3] The change in the value of the currency basket is measured by its index I(t,w), which the CNB defines as

$$I(t,w) = \sum_{j=1}^{N} w_j \left[R_j(t) / R_j(0) \right] \qquad (1)$$

where w_j is a weight ($\sum w_j = 1$), $R_j(t)$ is the domestic exchange rate at time t, and $R_j(0)$ is the domestic exchange rate at time 0, i.e. the base exchange rate. Both rates are at nominal levels. In order to peg the home currency to a currency basket, the index must be fixed. In this case it means that the index is set to be equal to one (I(t,w) = 1). It should be stressed that the index is calculated from daily midpoint exchange rates and, for the purpose of this paper, serves only as an illustration of how the index evolved over time.

During the researched period two changes took place. First, the CNB changed the composition of the basket on May 2, 1993. Table 1 illustrates a change in weights and base rates that took place during the four-year period. The weights represent the relative importance of the particular foreign currency in the turnover of the Czech balance of payments (excluding banking operations).

Table 1

Basket Composition, Currency Weights, and Base Rates across Periods

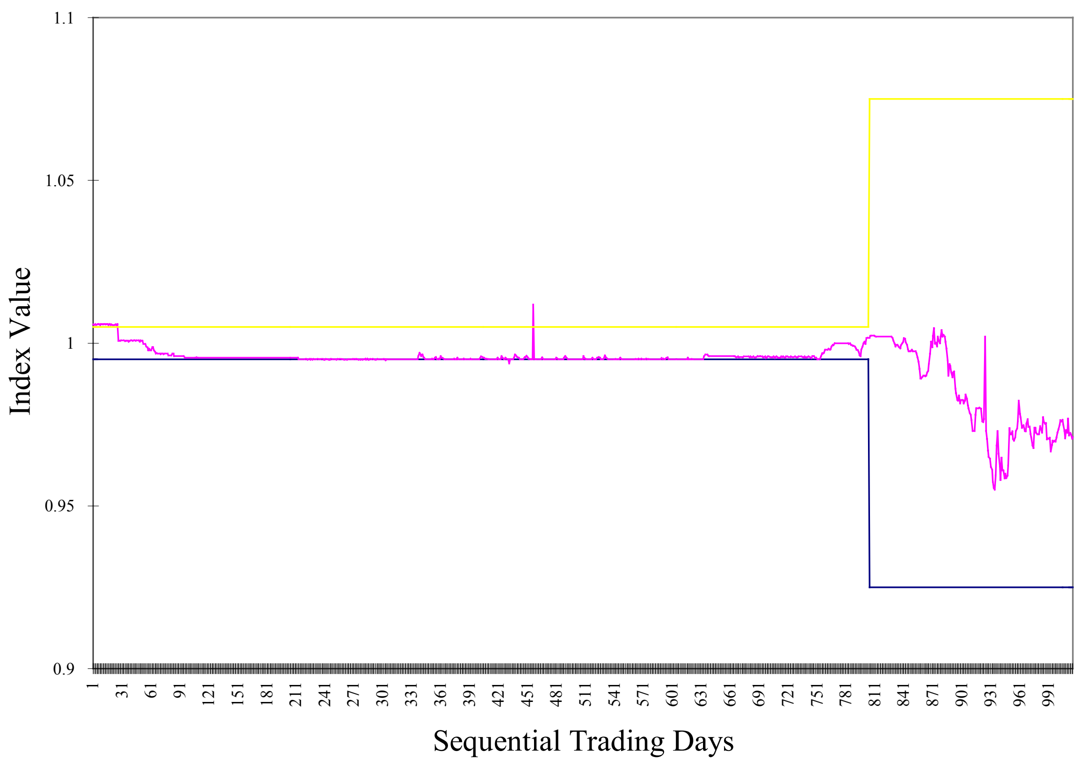
Period		ATS	DEM	USD	CHF	FRF
Jan. 2, 1992 - May 2, 1993	Weight	0.0807	0.3615	0.4907	0.0379	0.0292
	Base Rate	2.61	18.35	27.84	20.57	5.37
May 3, 1993 - Sep. 30, 1994	Weight	-	0.6500	0.3500	-	-
	Base Rate	-	17.995	28.443	-	-

Weights sum up to 1 and represent the relative importance of a particular currency in the balance of payments. Base rates are constant over each respective period.

[3] Using weighted average mathematically creates a slight discrepancy by not fully using the importance of the respective currencies, which are represented by their weights. This would be eliminated by using a geometric average instead.

The second, and most important, change concerns the fluctuation band. The band imposed on the basket was originally set at ± 0.5%. It was widened on February 28, 1996 to allow the index to fluctuate by ± 7.5%. The CNB managed to keep the index of the basket within the band during both periods. However, minor incidents of mismanagement occurred, as can be seen in Figure 1, which shows the evolution of the currency basket index over the entire period. The change in the fluctuation band allows us to divide the whole span of data into two periods. The first one covers the period from January 4, 1993 to February 27, 1996, and has 804 observations. The latter one, with 212 observations, covers the rest of the data until the end of 1996.

Figure 1. Evolution of the Currency Basket Index



By allowing for a wider fluctuation band, the CNB let the exchange rate fluctuate more freely, thus reducing its potential nominal stability. Because of the fact that the currency basket was introduced to keep a relatively stable nominal exchange rate, a further implication is that allowing for a wider fluctuation band should lead to more pronounced movements and increased volatility of the crown. Whether this is true is addressed in the following analysis.

4. Analysis of Volatility

4.1 Leverage Effect

One effective approach to modeling volatility is the autoregressive conditional heteroskedasticity (ARCH) model specified by Engle (1982), which suggests that current volatility depends on past squared innovations in order to explain the tendency of large residuals to cluster together.[4] Bollerslev (1986) extended the original framework to a generalized autoregressive conditional heteroskedasticity model (GARCH) where current volatility depends not only on past squared residuals but also on a lagged autoregressive component, e.g. lagged own variances. By deriving residuals ε_t from an underlying process, which are conditioned by the information set Ω_t , a GARCH(p,q) process is given by $\varepsilon_t|\Omega_{t-1} \sim N(0,\sigma_t^2)$ with conditional autoregressive variance specified as $\sigma_t^2 = \omega + \sum_{j=1}^{p} \alpha_j \varepsilon_{t-j}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2$. By far the most popular ARCH model that has been used to describe financial data volatility is the generalized specification GARCH(1,1).

The prevalent view in literature is that exchange rates follow a random walk. However, no strong statistical evidence has emerged to confirm or refute this view so far. Research done with exchange rates and security prices uses random walk as well as different univariate processes. When taking into account the basket pegged character of the exchange rates in the data set, one cannot overlook the possibility of a specific underlying process. Therefore, an autoregressive process was chosen as a proxy to model the underlying process in the data and the number of lags was determined to be 1, 1, 3, 1, 1, and 2 for DEM, USD, GBP, CAD, JPY and SEK respectively. The mean equation was specified as

$$\mathrm{r}_t = \mathrm{a}_0 + \sum_{i=1}^{k} \mathrm{a}_i r_{t-i} + \varepsilon_t \qquad (2)$$

[4] Many economic and especially financial variables reflect the stylized facts attributed to Mandelbrot (1963). These are: (1) unconditional distributions have thick tails, (2) variances change over time, and (3) large (small) changes tend to be followed by large (small) changes of either sign. These stylized facts are especially appealing in the context of high frequency financial data such as exchange rates and stock prices.

where, $\varepsilon_t | \Omega_{t-1} \sim D(0, \sigma_t^2)$.

In order to analyze volatility of the crown the following change is introduced. A change in volatility is analyzed with the use of a phenomenon known as a "leverage effect," which is the negative correlation between volatility and past returns. Following the parametrization of Glosten, Jagannathan, and Runkle (1993) and its application by Engle and Ng (1991) and Hamilton and Susmel (1994), the variance equation was specified as

$$\sigma_t^2 = \omega + \alpha \cdot \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 + \xi \cdot d_{t-1} \cdot \varepsilon_{t-1}^2 \qquad (3)$$

where d_{t-1} is a dummy variable that is equal to zero if $\varepsilon_{t-1} > 0$, and equal to unity if $\varepsilon_{t-1} \leq 0$. The leverage effect predicts that $\xi > 0$. The restrictions on the parameters in the variance equation require that $\omega > 0$, $\alpha \geq 0$, and $\beta \geq 0$. Further, when $\alpha + \beta < 1$, then the unconditional variance is finite and stationarity is ensured by not having unit root, as shown by Bollerslev (1986). The above specification yields the GARCH-L(1,1) model that will be estimated later.

The leverage effect was analyzed in stock price movements. For example, in the case of equities, Black (1976) and Nelson (1991), among others, argued that a stock price decrease tends to increase subsequent volatility by more than would a stock price increase of the same magnitude. In the case of the exchange rate, the leverage effect represents the fact that a decrease in the price of a foreign currency in terms of the crown, or the crown's appreciation, would tend to increase the subsequent volatility of the crown more than would a depreciation of an equal magnitude. Despite the fact that holding foreign exchange is similar, in terms of risk, to holding equities, literature dealing with the "leverage effect" in the context of exchange rate fluctuation is still lacking.

The value of the statistically significant leverage coefficient ξ then indicates the magnitude of the leverage effect, and the sign its direction. A positive value of the coefficient ξ indicates an increase, and a negative coefficient indicates a decrease in subsequent volatility of the exchange rate. By comparing values and signs of statistically significant leverage coefficients for a particular exchange rate in the two separate periods of narrow and wide fluctuation bands, it is possible to comment on the effect of the fluctuation band change on the crown's volatility as well.

4.2 Empirical Results

An estimation of the model is performed by using a log-likelihood function of the form $L = \left(-\tfrac{1}{2}\ln\sigma_t^2 - \tfrac{1}{2}\varepsilon_t^2/\sigma_t^2\right)$. The maximum likelihood estimates are obtained by using a numerical optimization algorithm described by Berndt, Hall, Hall, and Hausman (1974). The results from the estimation are presented in Tables 2 and 3 for narrow and wide fluctuation band periods respectively.

Coefficients of the mean equation reveal a small and mostly insignificant intercept for both periods. Lagged rates are mostly insignificant in the first period but highly significant in the later one. The second period dominates the whole process and the number of lags in the AR model is kept the same for the sake of consistency.

Table 2 Estimating GARCH-L (1,1): First (Narrow Band) Period

Estimates and statistics	DEM	USD	GBP	CAD	JPY	SEK
a_0	0.00006 (0.00009)	-0.00009 (0.00015)	0.00059 (0.00091)	-0.00018 (0.00020)	0.00014 (0.00021)	0.00001 (0.0021)
a_1	-0.135[a] (0.035)	-0.039 (0.035)	-0.553[a] (0.035)	-0.018 (0.035)	0.028 (0.035)	0.004 (0.035)
a_2	-	-	-0.292[a] (0.039)	-	-	-0.113[a] (0.035)
a_3	-	-	-0.122[a] (0.035)	-	-	-
ω	$2.01\cdot10^{-6}$[a] ($0.51\cdot10^{-6}$)	$7.29\cdot10^{-7}$[a] ($1.50\cdot10^{-7}$)	0.00059 (0.00052)	0.00011[a] (0.00003)	0.00001[a] (0.000003)	0.00012[a] (0.000017)
α	0.059[a] (0.019)	0.004 (0.009)	0.165 (0.174)	0.005 (0.012)	0.103[a] (0.018)	0.024 (0.033)
β	0.886[a] (0.030)	0.922[a] (0.016)	0.822[a] (0.159)	0.933[a] (0.017)	0.893[a] (0.017)	0.554[a] (0.061)
ξ	-0.167[a] (0.023)	0.079[a] (0.017)	-0.567 (0.503)	0.062[a] (0.018)	-0.054[a] (0.021)	0.217[a] (0.055)

Standard errors are in parentheses. Significantly different from zero at 1% ([a]) , 5% ([b]) and, 10%([c]) level.

In the case of the variance equation, coefficients of constant ω are small and mostly insignificant. Estimates of lagged squared residuals α and lagged variance β are generally large and comparable with those found in the literature. Nearly all of them are significantly different from zero at 5 or 10% level; however, 1% level significance predominates. The magnitude of the lagged variance in most of the currencies provides irrefutable evidence of the importance of including this lagged term in the equation of the conditional variance.

The focal results of this paper are provided by comparing the leverage effect coefficients. The focus is naturally on the DEM and USD. In both periods the

Deutsche mark shows quite a large negative coefficient which increased roughly by one third from one period to another. The volatility of this exchange rate tends to decrease during the wide band period. The dollar starts with a relatively small positive coefficient for the first period and ends up with an almost equal coefficient of the negative sign in the second one. This represents a significant change in the behavior of this exchange rate as well as the tendency for the volatility to decrease during the wide band period as in the case of the Deutsche mark.

Table 3 Estimating GARCH-L (1,1): Second (Wide Band) Period

Estimates and statistics	DEM	USD	GBP	CAD	JPY	SEK
a_0	-0.00030 (0.00026)	-0.00009 (0.00029)	0.00052 (0.00034)	0.00013 (0.00037)	-0.00047 (0.00041)	-0.00006 (0.00031)
a_1	-0.199[a] (0.067)	-0.148[a] (0.068)	-0.041 (0.070)	-0.218[a] (0.067)	-0.118[c] (0.069)	-0.054 (0.069)
a_2	-	-	0.042 (0.071)	-	-	0.041[a] (0.069)
a_3	-	-	-0.012 (0.070)	-	-	-
ω	$0.87 \cdot 10^{-6}$[a] ($0.27 \cdot 10^{-6}$)	$2.66 \cdot 10^{-5}$[a] ($1.69 \cdot 10^{-6}$)	$0.41 \cdot 10^{-6}$[a] ($0.04 \cdot 10^{-6}$)	0.00042[a] (0.00002)	0.00001[a] (0.000003)	0.00001[c] (0.000078)
α	0.140[a] (0.045)	0.182[a] (0.044)	0.023[a] (0.007)	0.148[a] (0.073)	0.031[b] (0.016)	0.217[b] (0.101)
β	0.807[a] (0.022)	0.750[a] (0.102)	0.940[a] (0.004)	0.812[a] (0.073)	0.941[a] (0.061)	0.756[a] (0.061)
ξ	-0.221[a] (0.066)	-0.082[c] (0.049)	-0.059[a] (0.015)	-0.054 (0.624)	-0.430[a] (0.244)	-0.242[b] (0.125)

Standard errors are in parentheses. Significantly different from zero at 1% ([a]) , 5% ([b]) and, 10%([c]) level.

What happened in the case of the other currencies? The exchange rate of the Japanese yen records an increase of the negative leverage coefficient. The British pound, on the other hand, exhibits a decrease of the negative leverage coefficient. The coefficient is however, statistically insignificant in the first period, so any strong statement concerning intertemporal comparison is precluded. A similar situation regards the Canadian dollar, which starts with a positive coefficient and ends with a negative one in the wide band period. The latter one is statistically insignificant, though. The Swedish crown shows a change in the behavior of the exchange rate since it starts with a positive leverage coefficient but records a negative one later. This indicates a considerable decrease in volatility for this exchange rate.

The results of the analysis clearly indicate that allowing for the wider fluctuation band resulted in a decrease in volatility of the key currencies (DEM and USD), as well as of two other ones (JPY and SEK). An analysis of the other two currencies (GBP and CAD) is unfortunately precluded by the lack of statistical significance associated with the leverage effect coefficient in the broad or wide band periods respectively. One possible explanation might be the fact that the key currencies (DEM and USD), being a part of the currency basket, affect themselves directly. Their movements actually counteract each other because their influences represented by weights in the basket must be strictly balanced in order to keep the basket index constant. However, the wide fluctuation band allows relatively far deviations from this target. This is empirically documented by the evolution of the index which stayed almost entirely within the appreciation part of the fluctuation band during the wide band period (see Figure 1).

The currencies that are not part of the basket are affected indirectly by a simple mechanical calculation of their exchange rate for each respective day. Their diminished volatility associated with a wider fluctuation band then goes against conventional wisdom, which is documented in some previously published work. Flood and Rose (1995) claim that "fixed exchange rates are less volatile than floating rates, but the volatility of macroeconomic variables such as money and output does not change very much across exchange rate regimes." Hasan and Wallace (1996) argue that using long-term data "real exchange rate volatility is greater for flexible exchange rate periods than for fixed-rate periods."

5. Conclusions

The exchange rate of the Czech crown pegged to a currency basket is analyzed. The change of the value of the basket is measured by its index. The central point of the analysis is how the change in the fluctuation band of the index affected volatility of the exchange rate.

By allowing for a wider fluctuation band, the CNB let the exchange rate fluctuate more freely, thus reducing its potential nominal stability. Because of the fact that the currency basket was introduced to keep a relatively stable nominal exchange rate and limit its volatility, a further implication is that allowing for a wider fluctuation band should lead to more pronounced movements and increased volatility of the crown.

The analysis showed that, against conventional wisdom, the volatility of the exchange rate diminished after a much wider fluctuation band was introduced. Particularly, the results of the analysis clearly indicate that allowing for a wider fluctuation band resulted in a decrease in volatility of the key currencies (DEM and USD). Two other currencies (JPY and SEK) exhibited decreased volatility, after the narrow fluctuation band was abolished, as well.

References

Berndt, E. K., Hall, B. H., Hall, R. E., and Hausman, J. A., 1974, Estimation of Inference in Nonlinear Structural Models, *Annals of Economic and Social Measurement 4*, 653-665.

Black, F., 1976, Studies of Stock market Volatility Changes, *1976 Proceedings of the American Statistical Association, Business and Economic Statistics Section*, 177-181

Bollerslev, T., 1986, Generalized Autoregressive Conditional Heteroskedasticity, *Journal of Econometrics 31*, 307-327.

Flood, R. P., and Rose, A. K., 1995, Fixing Exchange Rates: A Virtual Quest for Fundamentals, *Journal of Monetary Economics* 36(1), 3-37

Engle, R. F., 1982, Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation, *Econometrica 50*, 987-1007.

Engle, R. F. and Ng, V. K., 1993, Measuring and Testing the Impact of News on Volatility, *Journal of Finance 48(5)*, 1749-78

Glosten, L., Jagannathan, R., and Runkle, D., 1993, Relationship Between the Expected Value and the Volatility of the Nominal Excess Returns on Stocks, *Federal Reserve Bank of Minneapolis Staff Report # 157*

Hamilton, J. D., and Susmel, R., 1994, Autoregressive Conditional Heteroskedasticity and Changes in Regime, *Journal of Econometrics 64*, 307-333

Hasan, S., and Wallace, M., 1996, Real Exchange Rate Volatility and Exchange Rate Regimes: Evidence from Long-term Data, *Economics Letters* 52, 67-73

Kočenda, E., 1996, Volatility of a Seemingly Fixed Exchange Rate, *Eastern European Economics*, 6(34), 37-67

Mandelbrot, B., 1963, The Variation of Certain Speculative Prices, *Journal of Business 36*, 394-419.

Nelson, D., 1991, Conditional Heteroskedasticity in Asset Returns: A New Approach, *Econometrica 59*, 347-370