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The Polish Crawling Peg System: A Cointegration Analysis

by

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Abstract

After a temporary period of a fixed exchange rate regime pegging the Polish zloty to the U.S. dollar, Poland established a preannounced crawling peg regime on October 15, 1991. In this system the zloty is tied to a currency basket and devalued with a preannounced monthly rate (rate of crawl). If the monetary authorities have been successful in defending the crawling peg stable long-run relationships between the Polish zloty on the one hand and the basket's value and the currencies comprising the basket on the other hand are expected to exist. I test for such long-run relationships within the cointegration framework. However, as the transition path of the Polish exchange rate was not smooth due to discrete step devaluations one has to apply cointegration tests taking such structural shifts into account. Using recently developed test procedures I find the postulated cointegration relations and conclude that the monetary authorities could defend the crawling peg for the sample period under study.

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1 Introduction

Like many other East European economies in transition Poland has faced the problem of choosing an exchange rate regime. The adopted regime aims to support the transition process from a centrally planned to a market economy. The main objectives underlying Poland's decision concerning the exchange rate system were to reduce the high inflation by cooling down inflation expectations and to restore and maintain external competitiveness.

One way to evaluate the implemented exchange rate systems is to analyze whether they have been successful in attaining their objectives. A second aspect is to judge if the exchange rate actually stayed in the range determined by the chosen regime. This question does not only refer to the overall credibility of the exchange rate policy but also to Poland's aim of joining the European Union and adopting the euro. To achieve these goals certain preconditions have to be fulfilled. A stable exchange rate development can be regarded as one of these prerequisites. I study this second aspect for the crawling peg system Poland opted for in October, 1991. In this system the zloty is pegged to a currency basket and devalued with a preannounced monthly rate (rate of crawl) against the basket. If the initial parities of the basket currencies against the zloty and their weights are known one can calculate the central rate of the zloty and determine whether the actual rate of the zloty lies within the introduced intervention band around the central rate. If this is the case, i.e. if the central bank could successfully defend the crawling peg, stable long-run relationships between the Polish zloty on the one hand and the basket's value and the currencies comprising the basket on the other hand are expected to exist. One can test for such long-run relationships within the cointegration framework. The advantage of this approach over a graphical or numerical comparison of the actual and theoretical zloty rate is that less information is needed for evaluating the crawling peg. Depending on the kind of model described in section 3 it is not necessary to know the initial parities of the currencies and the weights of the basket currencies.

However, the transition path of the Polish exchange rate was not smooth due to discrete step devaluations. That means the zloty rate exhibits shifts in its level. The use of standard cointegration tests that do not allow for such structural shifts may lead to an incorrect inference about the cointegration rank (compare e.g. Campos, Ericsson & Hendry 1996, Doornik, Hendry & Nielsen 1998). Thus, cointegration tests accommodating level shifts are applied. Such test procedures have been proposed by Johansen & Nielsen (1993) and Saikkonen & Lütkepohl (2000a). I analyze the sample period March 1, 1993 - February 28, 1994, thereby including the step devaluation on August 27, 1993.

The paper is organized as follows. In the next section I give a brief review of the main developments of the Polish exchange rate policy. In section 3 and 4 the theoretical models and the cointegration tests are introduced. Section 5 presents the empirical results. Summarizing remarks are given in Section 6.

2 Polish Exchange Rate Policy[1]

In a first step towards creating suitable conditions for a market economy Poland introduced a fixed exchange rate peg to the U.S. dollar on January 1, 1990. The fixed exchange rate was meant to be a nominal anchor that transmits world market prices into the domestic economy and thereby helps to set relative prices and to brake inflation expectations. The initial exchange rate was set at ZL 9,500 per U.S. dollar in order to bring the official rate into line with the black market rate and to ensure international competitiveness. Overall, the fixed exchange rate system was successful in reducing inflation. The monthly inflation rate fell from near hyperinflation levels reached in 1989 and early 1990 to less than ten percent during 1990. Due to tight monetary, fiscal and wage policies and a strong balance of payments the fixed rate could be maintained longer than expected. However, as the Polish inflation rate still exceeded the corresponding rates of its main trading partners the real effective exchange rate appreciated and the external competitiveness deteriorated. Therefore, the Polish authorities decided to devalue the zloty by 16.8 percent against the dollar and to shift to a fixed peg based on a currency basket on May 17, 1991. Finally, a preannounced crawling peg regime was established on October 15, 1991.

In this system the zloty is tied to a currency basket consisting of U.S. dollar (45% weight), German mark (35%), British pound (10%), French franc (5%) and Swiss franc (5%)[2] and devalued with a preannounced monthly rate (rate of crawl). The currency weights were chosen in rough accordance with the composition of Poland's foreign trade payments. If the

[1]For a more comprehensive description of the Polish exchange rate policy see Otker (1994). Chrabonszczewska (1994) gives an overview of the legal developments of the exchange rate regimes. Some further details are taken from Koptis (1995), Wojtowicz (1998) and the homepage of the National Bank of Poland (http://www.nbp.pl/home_en.html).

[2]Since January 1, 1999 the basket has been made up of the Euro (55% weight) and the U.S. dollar (45%).

crawling peg is consistently applied, it can give economic agents a high degree of certainty about the future path of the exchange rate. In general, the crawling peg system can be seen as a variant of a fixed exchange rate system that permits compensation for inflation differentials with trading partners. However, if the objective is to reduce inflation, the rate of crawl should be set below the projected inflation differentials and decreased progressively in order to dampen inflation expectations. Accordingly, the Polish authorities determined the depreciation rate of the zloty. The rate of crawl was initially set to 1.8 percent per month and lowered in several steps to 0.3 percent (in March 1999).[3] To support the credibility of the exchange rate system only a narrow intervention band[4] (+/- 0.5%) around the central rate was permitted at the introduction of the crawling peg. After the establisment of the crawling peg system several discrete step devaluations were required. On February 25, 1992 the zloty was devalued by 10.8 percent against the basket due to an acceleration in wage inflation. A premature cut in the domestic interest rates worsened Poland's balance of payments between mid-1992 and mid-1993. Therefore a further devaluation by 7.4 percent took place on August 27, 1993. The application of discrete devaluations should be rare as they undermine the credibility of the crawling peg system. Generally, discrete devaluations are the results of policy failures in other areas, e.g. monetary and fiscal policies. Hence, maintaining a credible crawling peg imposes certain constraints on other kinds of economic policies as well. If these constraints are not met and the exchange rate policy is not supported properly, the crawling peg regime cannot be sustained. However, the discrete devaluations in 1992 and 1993 remained exceptions and did not undermined the acceptance of Poland's exchange rate system. Generally, the Polish exchange rate policy in connection with monetary, fiscal and income policies has been able to reduce inflation and maintain external competitiveness. In 1999 the yearly inflation rate was below 6 percent and the share in western markets of Poland's export increased.

3 The Models

In order to test for cointegration we have to derive a model on which the tests can be based. Let us consider a currency basket consisting of N currencies. Taking currency N as

[3] A full floating system has been introduced on April 12, 2000.

[4] The intervention band was increased to +/- 1% in 1993, to +/- 2% in February 1995, to +/- 7% in May 1995 and to +/- 10% in February 1998.

numeraire we define the value of the basket at time t as

$$E_{CB,t}^{N} = w_N + \sum_{i=1}^{N-1} w_i E_{i,t}^{N}, \tag{3.1}$$

where E_{CB}^{N} is the value of the basket expressed in currency N, E_i^N is the exchange rate of currency i in terms of currency N and w_i are the weights attached to the different currencies comprising the basket. In this way we can denominate the Polish currency basket in U.S. dollar as $E_{CB,t}^{\$}$ using the given weights for the respective currencies. The actual value of the basket in zloty is then obtained as

$$E_{CB,t}^{ZL} = E_{\$,t}^{ZL} E_{CB,t}^{\$} \tag{3.2}$$

.

The theoretical value or the central rate of the Polish zloty at time t can be written as

$$E_{CB,t}^{ZL} = Q^t E_{CB,0}^{ZL}, \tag{3.3}$$

where Q is the preannounced rate of depreciation[5] and $E_{CB_0}^{Zl}$ is the initial parity of the Polish zloty to one unit of the currency basket. Assuming that the theoretical and actual value of the zloty are equal we can combine (3.2) and (3.3) and after taking the natural logarithm and rearranging we obtain the expression

$$e_{\$,t}^{ZL} = e_{CB,0}^{ZL} + qt - e_{CB,t}^{\$}, \tag{3.4}$$

where small letters denote the natural logarithm.

As mentioned in the foregoing sections the Polish zloty has undergone several discrete devaluations. Such devaluations can be modeled by the following shift dummy

$$d_t = \begin{cases} 0, & t < T_1 \\ 1, & t \geq T_1, \end{cases} \tag{3.5}$$

where T_1 is the time of the break point. Since I focus on just one devaluation in our empirical analysis I incorporate only one shift dummy into (3.4). Setting $q = \mu_1$ and regarding $e_{CB,0}^{ZL}$ as a mean term μ_0 we get the model

$$e_{\$,t}^{ZL} = \mu_0 + \mu_1 t + \gamma d_t - e_{CB,t}^{\$}. \tag{3.6}$$

[5] The value of Q should be set according to the data frequency chosen. Therefore, Q may differ from the monthly rate of crawl announced by the central bank.

As the equivalence of the theoretical and actual value of the zloty does not hold exactly in all periods an error term ε_t with $E(\varepsilon_t) = 0$ is added to (3.6) to capture the deviations of the actual from the theoretical rate:

$$e^{ZL}_{\$,t} = \mu_0 + \mu_1 t + \gamma d_t - e^{\$}_{CB,t} + \varepsilon_t. \tag{3.7}$$

We can assume that the error term is stationary if the actual rate of the zloty is only allowed to fluctuate within a narrow band around the central rate. In this case the error term process can be regarded as mean reverting.[6]

If the value of the basket expressed in U.S. dollar ($e^{\$}_{CB,t}$) is an $I(1)$ process, then, under stationarity of ε_t, the model implies that $e^{ZL}_{\$,t}$ and $e^{\$}_{CB,t}$ will be cointegrated with a cointegration vector $(1, -1)$.[7]

In equation (3.7) we have imposed the given weights determining the value of $E^{\$}_{CB,t}$. If we do not know the weights or do not want to impose them we can set the weights as free parameters. Then, we are testing for cointegration between the logarithm of the zloty-U.S. dollar rate and the other basket currencies denominated in U.S. dollar. Hence, we have[8]

$$e^{ZL}_{\$,t} = \mu_0 + \mu_1 t + \gamma d_t - \beta_1 e^{DM}_{\$,t} - \beta_2 e^{BP}_{\$,t} - \beta_3 e^{FF}_{\$,t} - \beta_4 e^{SF}_{\$,t} + \varepsilon_t. \tag{3.8}$$

Note, that (3.8) cannot be directly derived from (3.7) as $e^{\$}_{CB,t}$ is a logarithm of a sum (cf (3.1)). Nevertheless, we have ignored this fact here and used the logarithms of the exchange rates of the single currencies.[9]

To distinguish between the models (3.7) and (3.8) we refer to the former one as the basket model and to the latter one as the currency model.

Figure 1 shows the development of the actual and the theoretical value of the Polish zloty per basket unit on a daily basis between March 1, 1993 and February 28, 1994, the sample period under study (see Section 5). The actual and theoretical values have been calculated according to (3.2) and (3.3). It can be seen that the actual rate moves around the lower bound of the intervention band rather than around the central rate itself. This observation may be due to the fact that the exchange rates of the basket currencies the National Bank of

[6]See Christoffersen & Giorgianni (2000).

[7]The general form of the cointegration vector is (1, -β).

[8]With respect to the U.S. dollar only the term $\beta_0 = log(w_\$)$ would occur as the basket is expressed in U.S. dollar. This term is absorbed in the mean term μ_0 in (3.8).

[9]This should not cause any problems as $\beta_i, (i = 1, \dots, 4)$, are estimated freely.

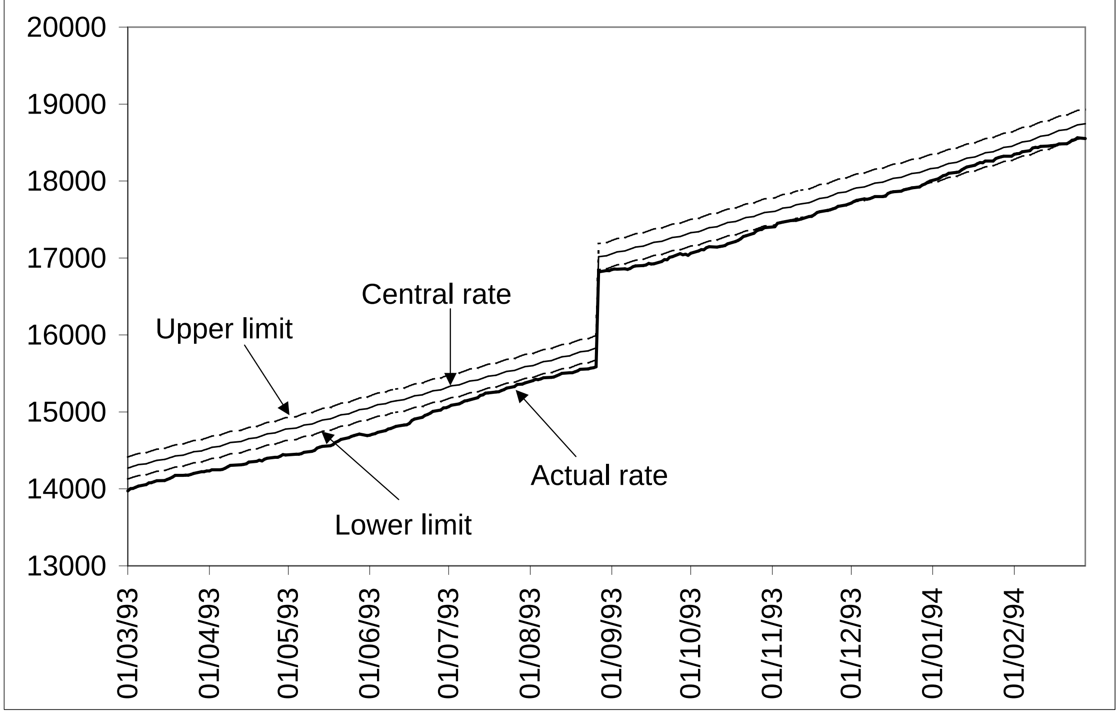

Figure 1. Exchange rate developments: zloty per unit of currency basket

Poland (NBP) used to calculate $E^{Zl}_{CB,0}$, i.e. the initial value of the basket in Polish zloty, are not available to me. Instead, I used data provided by the Federal Reserve Board of Governors (cf section 5) that may differ from those ones applied by the NBP. In contrast, to assess the observance of the crawling peg our models do not need the value of $E^{Zl}_{CB,0}$ or $e^{Zl}_{CB,0}$ as it is absorbed in the mean term μ_0. Using the currency model we can also do without the given weights since the model treats them as free parameters to be estimated.[10] Nevertheless, we can see in Figure 1 that the actual rate does not move away from the central rate and that its fluctuations are limited. Thus, we expect to find the postulated long-run relationships when testing for cointegration.

4 Cointegration Tests

To test for cointegration I have applied two systems cointegration tests that take structural shifts into consideration. The first test proposal has been made by Johansen & Nielsen (1993) (Johansen & Nielsen test) and the second one was suggested by Saikkonen & Lütkepohl (2000a) (Saikkonen & Lütkepohl test). Both test procedures are based on a multivariate

[10] As (3.8) is written in logarithm and μ_0 contains $e^{Zl}_{CB,0}$ and the weight of the U.S. dollar as well, it is not trivial to get estimators for the weights w_i in (3.1).

approach in which the variables of interest are modeled by a vector autoregressive (VAR) process.

The Johansen & Nielsen test can be regarded as a generalization of the standard Johansen procedure and is built on a n-dimensional vector error correction model (VECM) which is a reparameterization of a VAR(p) process:

$$\Delta y_t = \nu + \alpha(\beta' y_{t-1} - \tau(t-1) - \theta d_{t-1}) + \sum_{j=1}^{p-1} \Gamma_j \Delta y_{t-j} + \gamma \Delta d_t + \varepsilon_t, \qquad t = p+1, p+2, \dots, T, \tag{4.9}$$

where τ and θ are $n \times 1$ parameter vectors and $\varepsilon_t \sim N(0, \Omega)$. As $e^{ZL}_{\$,t}$ exhibits a linear trend a trend is included in the model and restricted it to the long-run relationship to rule out a quadratic trend. To model a level shift I introduce a restricted shift dummy (d_t) to capture the shift in the long-run relationship between the variables of interest and an impulse dummy (Δd_t) that enters the model unrestrictedly. The Johansen-Nielsen procedure tests for the rank r of the matrix $\Pi = \alpha\beta'$, where α $(n \times r)$ is the matrix of adjustment coefficients and the matrix β $(n \times r)$ contains the cointegration vectors. Hence, the rank r determines the number of cointegration relations. The test is performed by a maximum likelihood estimation of the model parameters leading to a generalized eigenvalue problem.[11] We have applied the trace variant testing the hypothesis $H_0(r_0) : \text{rk}(\Pi) = r_0 \quad vs. \quad H_1(r_0) : \text{rk}(\Pi) > r_0$. The resulting Likelihood Ratio (LR) test statistic is denoted as $LR_{J\&N}$. The limiting distribution of the test statistic depends on the relative timing of the break. The respective critical values can be calculated by using the simulation program DisCo (see Johansen & Nielsen 1993).

The Saikkonen & Lütkepohl test is based on the following data generating process:

$$y_t = \mu_0 + \mu_1 t + \delta d_t + x_t, \quad t = 1, 2, \dots, T. \tag{4.10}$$

The term x_t is an unobservable stochastic error which is assumed to be a VAR(p) process with a VECM representation:

$$\Delta x_t = \Pi x_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta x_{t-j} + \varepsilon_t, \quad t = 1, 2, \dots, T, \tag{4.11}$$

with $\varepsilon_t \sim N(0, \Omega)$. It is assumed that x_t is at most $I(1)$ and cointegrated with cointegrating rank r. Thus, we can again decompose the matrix Π into $\Pi = \alpha\beta'$, where α and β have the same interpretations as above.

[11] Details about the test procedure can be found e.g. in Johansen (1995) and Johansen & Nielsen (1993).

The idea of the test is to estimate the deterministic terms of (4.10) by a GLS procedure[12] and subtract them from y_t to obtain $\widehat{x}_t = y_t - \widehat{\mu}_0 - \widehat{\mu}_1 t - \widehat{\delta} d_t$. Thereby, we can also form an sample analog of (4.11) as

$$\Delta \widehat{x}_t = \Pi \widehat{x}_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta \widehat{x}_{t-j} + \varepsilon_t, \quad t = p+1, \dots, T. \tag{4.12}$$

Then, an LR type test as described above is performed on (4.12) and the resulting statistic for the trace test will be denoted by $LR_{S\&L}$. The test statistic does not depend on the time of the break point. Critical values can be found in Lütkepohl & Saikkonen (2000).

Lütkepohl, Saikkonen & Trenkler (2000) have pointed out that both test proposals have similar small sample properties when they are applied to small VAR systems. Hence, one should expect similar results for the basket model consisting of the zloty-U.S. dollar rate and the value of the currency basket denominated in U.S. dollar. However, in large systems the Johansen-Nielsen test suffers from an excessive size distortion especially if there exists just one cointegration relation between the variables. One should keep this fact in mind when interpreting and comparing the results for the currency model.

In contrast to Krauze (1998) I have applied systems cointegration tests to the exchange-rate models instead of single equation tests for two reasons. Firstly, I do not want to assume weak exogeneity of some of the regressors and secondly, it cannot be excluded a priori that there is more than one cointegration relation between the different exchange rates when testing within the currency model. It is possible that the exchange rates of the European basket currencies are cointegrated among themselves,[13] so that two or more long-run relationships may exist.

5 Empirical Results

5.1 The Data and Preliminary Analysis

The empirical analysis is based on daily data covering the period March 1, 1993 - February 28, 1994 and thereby including the discrete devaluation of the zloty by 7.4% on August 27, 1993. The starting year is determined by data availability. The additional restrictions of

[12] The GLS procedure is described in Saikkonen & Lütkepohl (2000a).

[13] One could at least expect a cointegration relation between the ERM members Germany and France as exchange rate bands have existed for their currencies (cf Kanas (1998) for the univariate case). Great Britain was not a member of the ERM during our sample period.

the sample period have been made to exclude the effects caused by the extension of the intervention band at the beginning of 1993 and the several reductions in the crawling rate starting in mid-1994.

The Polish zloty - U.S. dollar rate ($E^{ZL}_{\$,t}$) is the official exchange rate announced by the National Bank of Poland (NBP). The other exchange rates, i.e. the rates of German mark ($E^{DM}_{\$,t}$), British pound ($E^{BP}_{\$,t}$), French franc ($E^{FF}_{\$,t}$) and Swiss franc ($E^{SF}_{\$,t}$) against the U.S. dollar are noon buying rates in New York for cable transfers certified by the Federal Reserve Bank (FRB) of New York.[14] In case of holidays at just one exchange market the respective data of the other market are deleted. Therefore, we have 249 observations and the level shift in $E^{ZL}_{\$,t}$ caused by the devaluation on August 27, 1993 occurs at the 125th observation. Hence, the shift dummy d_{125} used in (4.9) and (4.10) is zero until the 124th observation (August 26, 93) and one thereafter according to (3.5). The value of the currency basket ($E^{CB}_{\$,t}$) denominated in U.S. dollar is calculated by using the rates for the basket currencies from the Federal Reserve Board according to (3.1). The natural logarithms of the time series are denoted as $e^{ZL}_{\$,t}, e^{DM}_{\$,t}, e^{BP}_{\$,t}, e^{FF}_{\$,t}, e^{SF}_{\$,t}$ and $e^{CB}_{\$,t}$ as in section 3.

PcGive 9.10 and PcFiml 9.10 by Doornik & Hendry (1996, 1997) have been used for the computations of the Dickey-Fuller unit root and the misspecification test statistics. The statistics for the cointegration tests and the unit root tests suggested by Lanne, Lütkepohl & Saikkonen (1999) have been calculated by using programs written in GAUSS.

Table 1 displays the results of the unit root tests for the levels and the first differences of the series. For all time series except $e^{ZL}_{\$,t}$ I have applied the Dickey-Fuller (DF) test including a mean term, as the Akaike information criterion (AIC) and the Schwartz criterion (SC)[15] suggested to include no lagged differences in the test regression for any of the variables. I have followed this suggestion, as misspecification tests[16] do not show significant autocorrelation in the residuals of the respective ADF regression.

As the $e^{ZL}_{\$,t}$ series exhibit a level shift I have used two unit root tests suggested by Lanne et al. (1999) that take such structural breaks into consideration. The idea of these tests is to estimate the deterministic parts and other nuisance parameter in a first step. Then the series

[14] The $E^{ZL}_{\$,t}$ rate is provided by the NBP via http://www.nbp.pl/asps/Arch_en.asp. The other rates can be obtained via http://www.federalreserve.gov/releases/H10/hist/ from the Federal Reserve Board of Governors.

[15] The criteria are described in Lütkepohl (1991).

[16] I have applied an LM test for autocorrelated residuals (Doornik & Hendry 1997).

Table 1. Unit Root Tests

Time Series (Levels)	t-statistic	Time Series (1st differences)	t-statistic
$e^{ZL}_{\$,t}$	-2.04 (τ^{+}_{int}) -1.78 ($\mathbf{t}_{int}$)	$\Delta e^{ZL}_{\$,t}$	-16.67^{**} (τ^{+0}_{int}) -11.04^{**}($\mathbf{t}^{0}_{int}$)
$e^{BP}_{\$,t}$	-2.92^{*}	$\Delta e^{BP}_{\$,t}$	-16.17^{**}
$e^{FF}_{\$,t}$	-1.46	$\Delta e^{FF}_{\$,t}$	-15.85^{**}
$e^{SF}_{\$,t}$	-2.39	$\Delta e^{SF}_{\$,t}$	-16.17^{**}
$e^{CB}_{\$,t}$	-2.02	$\Delta e^{CB}_{\$,t}$	-16.17^{**}

Note: ** and * denote significance at the 1% and 5% level respectively. Critical values for τ^{+}_{int} and $\mathbf{t}_{int}$ are -3.03 (5%) and -3.55 (1%) and for τ^{+0}_{int} and $\mathbf{t}^{0}_{int}$ are -2.88 (5%) and -3.48 (1%). They can be all found in Lanne et al. (1999). The critical values for the other t-statistics are taken from MacKinnon (1991): -2.87 (5%) and -3.46 (1%).

are adjusted for these terms and unit root tests of the Dickey-Fuller type are applied allowing for different modifications to take estimation errors in the nuisance parameter into account. For $e^{ZL}_{\$,t}$ I used the test versions allowing for a linear trend and a level shift denoted as τ^{+}_{int} and $\mathbf{t}_{int}$ in Lanne et al. (1999), for the first differences of the series the versions including a mean term only and an impulse dummy are applied (τ^{+0}_{int}, $\mathbf{t}^{0}_{int}$). The number of lags in the regression is set to one.

As it can be seen the null hypothesis of nonstationarity is not rejected for all level series except for $e^{BP}_{\$,t}$ at the 5% level. For $e^{BP}_{\$,t}$, nonstationarity is not rejected only at the 1% level. This seems to be somehow surprising, as nominal exchange rates are usually expected to be nonstationary. This is confirmed by the DF test for the full period of 1993 and 1994. Therefore, we treat $e^{BP}_{\$,t}$ as nonstationary. The first differences of all variables are clearly stationary, hence we can conclude that all variables are $I(1)$, i.e. integrated of order one.

5.2 Results for the Basket Model

I now present the results of the cointegration tests for the basket model consisting of $e^{ZL}_{\$,t}$ and $e^{CB}_{\$,t}$ according to (3.7). First, the order p of the VAR on which the cointegration tests are based has to be determined.[17] Again, I have used the AIC and the SC criteria. The

[17]The order p results in $p-1$ lags for the VECM models (4.9) and (4.11).

Table 2. Misspecification Tests (VAR(3))

Test	AR 1-4	Normality	ARCH 4	Hetero-scedasticity
$e_{\$,t}^{ZL}$	15.258** [0.000]	5.339 [0.069]	2.610* [0.036]	3.644** [0.000]
$e_{\$,t}^{CB}$	0.238 [0.917]	2.158 [0.333]	1.618 [0.171]	1.611 [0.072]
Vector statistic	5.170** [0.000]	7.053 [0.133]	—	1.855** [0.001]

Note: p-values are in parentheses. ** and * denote significance at a 1% and 5% level respectively.

AIC and the SC criteria suggest an order of $p = 6$ and $p = 3$ respectively. To decide which number of lags to choose I have applied several single and vector misspecification tests. The single equation tests used are an LM test for autocorrelated residuals (Doornik & Hendry 1997), a test for normality (Doornik & Hendry 1997), an LM test for autocorrelated squared residuals (Engle 1982) and a test for heteroscedasticity (White 1980). The vector autocorrelation test, normality test and the heteroscedasticity test used are described in Doornik & Hendry (1997). The single equation tests for the VAR(3) model in Table 2 show that the Zloty - U.S. dollar ($e_{\$,t}^{ZL}$) rate exhibit strong autocorrelation. This is also reflected in the respective vector test. Increasing the order to 6 or any higher number does not improve the model performance in any substantial way. One possibility to deal with this leftover autocorrelation is to include moving average terms into the model leading to the class of Vector Autoregressive Moving Average (VARMA) models.[18] However, I remain in the VAR model class referring to results stated in Lütkepohl & Saikkonen (1999). They have shown that the LR tests remain valid even if the data generating process is a VARMA or an infinite VAR process so far as the lag order is chosen by a consistent model selection criteria.[19]

Table 3 reveals that there exists a cointegration relation between $e_{\$,t}^{ZL}$ and $e_{\$,t}^{CB}$ as pos-

[18] The reason why a VARMA model may be more suited for our system could be due to the construction of the currency basket. The currency basket can be interpreted as a linear combination of variables that may be well characterized by a VAR process. However, a linear combination or transformation of a VAR model may not admit a VAR but just a VARMA representation (see Lütkepohl (1991), Chapter 6).

[19] Actually, this was proved only for processes without level shifts. It is assumed that these findings also hold in our context.

Table 3. Cointegration Tests for Basket Model ($e^{ZL}_{\$,t}$, $e^{CB}_{\$,t}$)

H_0	$LR_{J\&N}$	critical value (5%)	LR_+	critical value(5%)	$LR_{S\&L}$	LR_{GLS}	critical value (5%)
$r_0 = 0$	68.26**	30.49	14.65	25.47	23.46**	6.45	15.92
$r_0 = 1$	10.46	15.26	3.33	12.39	2.81	2.06	6.83

Note: ** denotes significance at a 1% level. Critical values for $LR_{S\&L}$ and LR_{GLS} are the same and taken from Lütkepohl & Saikkonen (2000). The critical values for $LR_{J\&N}$ are simulated with the program DisCo (Johansen & Nielsen 1993). Those ones for LR^+ are taken from Johansen (1995).

tulated. Both the Johansen & Nielsen test ($LR_{J\&N}$) and the Saikkonen & Lütkepohl test ($LR_{S\&L}$) reject the null hypothesis of a cointegration rank of zero at a 1% level, whereas they cannot reject the null hypothesis of $r_0 = 1$. If one ignores the structural shift in the $e^{ZL}_{\$,t}$ series, i.e. one does not incorporate the appropriate shift dummy into the model and apply the respective standard cointegration tests denoted by LR_+ (Johansen 1995) and LR_{GLS} (Saikkonen & Lütkepohl 2000b), I am not able to find cointegration as can be seen in Table 3. Hence, one may conclude that neglecting a structural shift makes it more difficult to detect cointegration. This fact corresponds to the univariate case when testing for a unit root. If a structural break is present and not accounted for, a wrong null hypothesis of a unit root may not be rejected (cf Perron 1989).

The Johansen-Nielsen procedure allows us to test for restrictions on the cointegration vector β by the use of likelihood ratio (LR) tests (see Johansen 1995). We are interested in whether the cointegration vector is $\beta = (1, -1)'$ as the theory predicts. Imposing the restriction of a cointegration rank of one we obtain the estimator $\widehat{\beta} = (1, -0.80)'$. The restriction $\beta = (1, -1)'$ is clearly rejected at a 1% level by the respective LR test statistic which has a value of 46.99 and is $\chi^2(1)$ distributed.

5.3 Results for the Currency Model

Now, we turn to the currency model comprising the individual currencies $e^{ZL}_{\$,t}, e^{DM}_{\$,t}, e^{BP}_{\$,t}, e^{FF}_{\$,t}$ and $e^{SF}_{\$,t}$ according to equation (3.8). Again, it is emphasized that the respective weights are estimated freely within the model because of the logarithm used in equation (3.8). The information criteria AIC and SC recommend a VAR order of two and one respectively. The misspecification tests indicate strong autocorrelation for the VAR(1) and still significant

Table 4. Misspecification Tests (VAR(3))

Test	AR 1-4	Normality	ARCH 4	Hetero-scedasticity
$e^{ZL}_{\$,t}$	1.832 [0.070]	4.235 [0.120]	3.428* [0.011]	1.248 [0.180]
$e^{DM}_{\$,t}$	0.281 [0.890]	1.119 [0.571]	1.576 [0.187]	0.881 [0.657]
$e^{BP}_{\$,t}$	1.018 [0.395]	1.616 [0.446]	0.454 [0.770]	1.211 [0.214]
$e^{FF}_{\$,t}$	0.759 [0.553]	3.863 [0.145]	2.495* [0.044]	1.217 [0.207]
$e^{SF}_{\$,t}$	0.373 [0.828]	0.482 [0.786]	0.487 [0.863]	1.248 [0.180]
Vector statistic	1.231 [0.070]	111.460** [0.000]	—	0.881 [0.657]

Note: p-values are in parentheses. ** and * denote significance at a 1% and 5% level respectively.

autocorrelation in the $e^{ZL}_{\$,t}$ equation for the VAR(2) model. Therefore, we increase the order to $p = 3$. The misspecification tests for VAR(3) show some ARCH effects for $e^{ZL}_{\$,t}$ and $e^{FF}_{\$,t}$ (Table 4). Additionally, vector normality is rejected at the 1% level. As the Johansen-Nielsen and the Saikkonen-Lütkepohl tests do not strictly depend on the normality assumption (Lütkepohl 1991, Saikkonen & Lütkepohl 2000a) we proceed with the VAR(3) model.

As shown in Table 5 the $LR_{J\&N}$ and $LR_{S\&L}$ tests find one cointegration relation between the single currencies. As in the basket model, applying standard cointegration tests (LR_{+}, LR_{GLS}) and ignoring the structural shift in the zloty-U.S. dollar rate, no cointegration between the variables has been found.

To check whether the cointegration relation emerges from cointegration between the basket currencies, I have built a VAR model just for $e^{DM}_{\$,t}, e^{BP}_{\$,t}, e^{FF}_{\$,t}$ and $e^{SF}_{\$,t}$. As these time series do not exhibit a linear trend or structural shifts only a mean term is included in the model and restricted to the long-run relationship in the VECM representation to rule out a linear trend. Therefore, I used the respective test variants taking this restriction into account.

Table 5. Cointegration Tests for Currency Model ($e^{ZL}_{\$,t}$, $e^{DM}_{\$,t}$, $e^{BP}_{\$,t}$, $e^{FF}_{\$,t}$, $e^{SF}_{\$,t}$)

H_0	$LR_{J\&N}$	critical value (5%)	LR_+	critical value(5%)	$LR_{S\&L}$	LR_{GLS}	critical value (5%)
$r_0 = 0$	233.69**	98.53	64.01	86.96	125.15**	39.72	65.69
$r_0 = 1$	49.45	72.15	42.00	62.61	28.74	27.76	45.12
$r_0 = 2$	32.23	49.38	26.24	42.20	10.63	11.26	28.47
$r_0 = 3$	17.29	30.49	11.94	25.47	5.67	5.50	15.92
$r_0 = 4$	4.39	15.26	4.27	12.39	1.65	2.44	6.83

Note: ** and * denote significance at a 1% and 5% level respectively. Critical values for $LR_{S\&L}$ and LR_{GLS} are the same and taken from Lütkepohl & Saikkonen (2000). The critical values for $LR_{J\&N}$ are simulated with the program DisCo (Johansen & Nielsen 1993). Those ones for LR^+ can be found in Johansen (1995).

They are denoted by LR_0 (Johansen 1995) and LR_{SL} (Saikkonen & Lütkepohl 2000b). According to the information criteria and the misspecification tests a VAR order $p = 2$ seems to be appropriate. The tests are not able to find cointegration between the basket currencies (Table 6). Hence, I conclude that the cointegration relation found for the currency model is due to fact that the Polish zloty is successfully pegged to a currency basket and therefore forms a stable long-run relationship with the currencies composing the basket.

Table 6. Cointegration Tests for Basket Currencies ($e^{DM}_{\$,t}$, $e^{BP}_{\$,t}$, $e^{FF}_{\$,t}$, $e^{SF}_{\$,t}$)

H_0	LR_0	critical value (5%)	LR_{SL}	critical value(5%)
$r_0 = 0$	39.91	53.42	23.57	39.71
$r_0 = 1$	20.61	34.80	11.03	24.08
$r_0 = 2$	6.45	19.99	2.90	12.21
$r_0 = 3$	1.89	9.13	0.55	4.14

Note: Critical values for LR_{SL} and LR^0 are taken from Johansen (1995). The Critical values for LR_{SL} are identical with those for the Johansen-Test without any deterministic terms (Saikkonen & Lütkepohl 2000b).

6 Summary

In this study I have evaluated whether the Polish monetary authorities were successful in defending the crawling peg regime Poland had opted for in October, 1991 by applying cointegration tests. Assuming a successful crawling peg I have derived two models. The basket model implies a stable long-run relationship between the logarithms of the zloty - U.S. dollar rate and the value of the basket denominated in U.S. dollar. The currency model predicts a long-run relationship between the logarithms of the zloty - U.S. dollar rate and the basket currencies expressed in U.S. dollar.

The advantage of testing for such long-run relationships within the cointegration framework over a direct comparison of the actual and theoretical zloty rate is that one needs less information to assess the observance of the crawling peg. Both models abstract from the initial parities between the zloty and the basket currencies, an information we are, in fact, lacking. Moreover, the currency model does not impose specific weights for the basket currencies as it regards them as free parameters.

As the zloty - U.S. dollar rate exhibits a structural shift due to a step devaluation during the sample period from March 1, 1993 - February 28, 1994, I have applied systems cointegration tests suggested by Johansen & Nielsen (1993) and Saikkonen & Lütkepohl (2000a) that take such structural breaks into account. Both test procedures have found one cointegration relation for both the basket model and the currency model. Ignoring the level shift cointegration could not be detected. Cointegration was not found either among the basket currencies. Therefore, I conclude that correcting for the level shift due to discrete step devaluation the Polish central bank could successfully defend the crawling peg during the sample period under study. This indicates a stable exchange rate development versus the basket currencies including the former ERM currencies German mark and French franc.

A longer record of a stable relationship to the ERM currencies and the euro itself is a necessary precondition for joining the European Monetary Union. Poland seems to have established a basis for this record in the first half of the 1990-ies. Thereby, the credibility of the exchange rate policy and the general process of joining the European Union is also supported. Further analysis has to show whether this stability continues to the present. Working within the framework presented in this paper, one has to deal with the numerous reductions of the rate of crawl and the extensions of the intervention band in the second half of the 1990-ies causing several trend breaks and possible heterogeneity in the error terms of the models.

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