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*Władysław Milo**, *Magdalena Rutkowska***

NOTES ON FORECASTING NOMINAL EQUILIBRIUM EXCHANGE RATES OF PLN AGAINST USD

Abstract. Exchange rate is one of the most important prices in an open economy. For theoretical and practical reasons it is useful to calculate an equilibrium level of exchange rate. There is a wide range of theories explaining exchange rate determinants. This article presents determinants of exchange rates derived from monetary theory and balance of payments theory. Upon these fundamental economic theories and defining different definitions of equilibrium we have calculated predictors of nominal exchange rate of PLN against USD. We have also computed equilibrium level of this exchange rate. Empirical results have shown that the theoretical equilibrium values do not statistically significantly differ on the method used in equilibrium computations and they are similar to the empirical trajectory of PLN/USD in the period 1995–2003.

Keywords: exchange rates, equilibrium, forecasting.
JEL Classification: C62, D58, F31, F37.

1. INTRODUCTION

One of the central prices in an open economy is exchange rate. It influences so many market members that "getting the currency right" has become a critical objective purpose of all decision makers and market players (Rosenberg 1996, p. 2). For theoretical and practical reasons it is useful to calculate an equilibrium level of exchange rate.

Around this equilibrium level will fluctuate the value of nominal exchange rate in the long run.[1] It is hard to define one theoretical concept of the

* Prof. dr. hab. (Full Professor), Department of Econometrics, University of Łódź.
** Mgr (M.A.), Department of Econometrics, University of Łódź.

[1] John Williamson (1985) – the pioneer in defining fundamental equilibrium exchange rate (FEER), recognized that PPP is not the satisfactory measure of equilibrium. He defined the FEER as the exchange rate, which is "expected to generate a current-account surplus or deficit equal to the underlying capital flow over the cycle, given that the country is pursuing internal balance as the best as it can and not restricting trade for balance-of-payment reasons" – Williamson (1985) after Rosenberg (1996), p. 56.

determinants of exchange rate. According to literature the theoretical equilibrium level can be obtained, e.g. either by the implementation of purchasing power parity PPP theory or balance of payments BOP theory. Existence of equilibrium trajectory of exchange rate means that exchange rate will not move randomly but it will gravitate toward its equilibrium path.

On the basis of fundamental economic theories and theories of equilibrium we will present some empirical examples of forecasting equilibrium exchange rate of PLN against USD in the period 1995–2003.

Our analysis will be based on two theoretical definitions of determinants of nominal exchange rate and two different approaches in defining equilibrium value of our variable – this means that we will have four definitions of nominal value of equilibrium level of exchange rate.

We will examine whether our theoretical trajectories of equilibrium level of exchange rate are similar to the empirical values of exchange rate of PLN against USD. We will also evaluate whether using equilibrium models to forecasting exchange rates is better than a traditional approach. We will try to answer the question, whether all obtained trajectories of equilibrium exchange rate of PLN against USD are comparable or do the results depend on the used method. We also compare the predicted values of exchange rate with its observed value.

2. EQUILIBRIUM PRICE

There is a wide range of methods of calculating long-run level (or trajectory) of equilibrium exchange rates. Every approach may give different results. In this paper we will focus on the methods of computing equilibrium values of currencies based on the fundamental theories (balance of payments theory, monetary extension of PPP theory) of exchange rate behavior in combination with the methods of finding an equilibrium.

Exchange rate of home currency is the price of foreign currency expressed in the value of domestic currency. Because exchange rate is a kind of price our concern will be focused on the methods of computing price equilibrium. There are several ways of computing equilibrium value of variable P (price). We will introduce two different definitions of equilibrium value of price P^*.

Definition 1. The equilibrium price P^* is the price under which demand (Y_t^d) equals supply (Y_t^s), both for the observable as well as for historical forecasts, i.e. $Y_t^d(P_t^*) = Y_t^s(P_t^*)$, and $\hat{Y}_t^d = \hat{Y}_t^s$ $t = 1, ..., n$. Thus if

$$\begin{aligned} Y_t^s &= \alpha_0 + \alpha_1 P_t + \mathbf{X}_t^T \boldsymbol{\alpha} + \xi_{st} \\ Y_t^d &= \beta_0 + \beta_1 P_t + Z_t^T \boldsymbol{\beta} + \xi_{dt} \end{aligned} \Rightarrow P_t^* \equiv \hat{P}_t^* = \frac{\hat{\beta}_0 - \hat{\alpha}_0}{\hat{\beta}_1 - \hat{\alpha}_1} + \frac{\mathbf{Z}_t^T \hat{\boldsymbol{\beta}} - \mathbf{X}_t^T \hat{\boldsymbol{\alpha}}}{\hat{\beta}_1 + \hat{\alpha}_1},$$

where $\mathbf{X}_t^T = (X_{1t}, X_{2t}, ..., X_{kt})$, $\mathbf{Z}_t^T = (Z_{1t}, Z_{2t}, ..., Z_{kt})$ are row vectors of values of exogenous variables that influence supply and demand respectively, $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ are the vectors of unknown parameters, ξ_{it} – represents the white noise type error of specification for the equation $i = s, d$.

Definition 2. The equilibrium price (P_t^*) is the price that corresponds to the situation when all forces ($\mathbf{X}$) that influence P_t keep balance and P_t stays stable ($\Delta P_t = 0$) or almost stays stable ($\Delta P_t \approx 0$).
Therefore, if

$$\Delta P_t = \alpha_0 + \alpha_t P_{t-\tau} + \mathbf{X}_t^T \boldsymbol{\alpha} + \xi_t \Rightarrow \Delta P_t = 0$$

then

$$P_{t-\tau} \equiv \hat{P}_{t-\tau}^* = -\frac{\alpha_0}{\alpha_1} - \frac{\mathbf{X}_t^T \boldsymbol{\alpha}}{\alpha_1} - \frac{\xi_t}{\alpha_1} \text{ or } \hat{P}_{t-\tau}^* = \hat{P}_t^* = -\hat{\alpha}_1^{-1}\left(\hat{\alpha}_0 + \hat{\mathbf{X}}_t^T \hat{\boldsymbol{\alpha}}\right),$$

where $\hat{\alpha}_0$, $\hat{\alpha}_1$, $\hat{\boldsymbol{\alpha}}$ are $lse(\alpha_0)$, $lse(\alpha_1)$, $lse(\boldsymbol{\alpha})$.

3. THE THEORY OF EXCHANGE RATES

3.1. Balance of Payments Theory

The first conventional way of analyzing changes in exchange rate is to study the changes in the current and capital account transactions (Rosenberg 1996, p. 68). Standard balance of payments equilibrium condition is given by equality of current (*curracc*) and capital accounts (*capacc*) of balance of payments (equation 1)

$$capacc_t = curracc_t. \tag{1}$$

We can define current account as a sum of net exports (*nex*) and net interest payments on net foreign assets (MacDonald 2000, p. 3) (*niponfa*) (equation 2).

$$curracc_t = nex_t + niponfa_t. \tag{2}$$

Further, we can write, as in the equation 3 below, that capital account is a function of home interests rates (*hir*), foreign interest rates (*fir*) and expected first difference of exchange rate (Δer_t^e).

$$capacc_t = \alpha_1(hir_t - fir_t + \Delta er_t^e). \tag{3}$$

Net export is a function of exchange rate, difference in foreign (fp) and home level (hp) of prices and incomes ($hgdp$, $fgdp$) (equation 4):

$$nex_t = \alpha_2(er_t + fp_t - hp_t) - \alpha_3 hgdp_t + \alpha_4 fgdp_t. \tag{4}$$

From equations (1) to (4) we can derive equilibrium exchange rates that satisfy balance of payments condition (equation 5):

$$er_t^* = (hp_t - fp_t) + \frac{\alpha_1}{\alpha_2}(hir_t - fir_t + \Delta er_t^e) + \frac{\alpha_3}{\alpha_2} hgdp_t - \frac{\alpha_4}{\alpha_2} fgdp_t - \frac{1}{\alpha_2} niponfa_t. \tag{5}$$

3.2. The Monetary Extension of PPP Theory

Purchasing power parity (PPP) theory stipulates that the long-term equilibrium value of currency is determined only by the ratio of domestic price level (HP) relative to the foreign price level (FP) (Rosenberg 1996, p. 8). The condition of purchasing power parity may be written by equation 6 (Williamson 1994, p. 245–247):

$$ER_t = \frac{HP_t}{FP_t}, \tag{6}$$

or[2]

$$er_t = hp_t - fp_t. \tag{6a}$$

PPP theory is adequate to the economies where deviations from equilibrium level are monetarily induced.[3] Demand for money (M) is a function of income and interest rate. Equation 7 and 8 describe a function of demand for money for home and foreign country respectively:

$$hm_t - hp_t = \beta_1 hgdp_t - \beta_2 hir_t, \tag{7}$$

$$fm_t - fp_t = \beta_1 fgdp_t - \beta_2 fir_t. \tag{8}$$

By substituting (7) and (8) into (6) we obtain nominal exchange rate, which is driven by relative excess money supplies (equation 9):

$$er_t^* = (hm_t - fm_t) + \beta_1(fgdp_t - hgdp_t) + \beta_2(hir_t - fir_t). \tag{9}$$

[2] To simplify the algebra, equations can be expressed in logarithms, lower case letters will represent the logs of the variable.

[3] PPP cannot be applied if disturbances are caused bz real factors (eg. productivity shocks) – Rosenberg (1996), p. 8.

4. EMPIRICAL RESULTS

The mentioned theories were applied in formulating empirical econometric models of exchange rate of PLN against USD. Estimations were made on data concerning Poland and USA from first quarter of 1995 till fourth quarter of 2003.

Equations (5) and (9) enable us to derive exchange rates under different theories of equilibrium. We have two different equations describing equilibrium exchange rates consistent with the first definition of equilibrium prices and two other equations consistent with the second definition of such prices.

Combining (5) with Definition 1 of equilibrium gave us 3 different trajectories of *ERF* (*ERF_BOP*, *ERF_BOPECM*, *ERF_BOPECMRES*), then using the same theoretical approach but according to the second definition of equilibrium we have computed *ERF_DBOP*. Forecasts based on monetary extension of PPP are all denoted with letters *MEPPP*. We have obtained 4 different paths of forecasts of *ER* based on the first definition of equilibrium (*ERF_MEPPP*, *ERF_MEPPP2*, *ERF_MEPPPECM*, *ERF_MEPPPER*) and two trajectories based on the second definition (ERF_DMEPPP1, ERF_DMEPPP2). All this predictions are presented in Figure A1 (cf. Appendix).

Table 1. Forecasts evaluation criteria

Forecast of *ER*	Mean	R^2 (%)	MAPE (%)	SC (%)	TPC (%)	Deviation of mean (*ER*) from mean (*ERF*)
ER	3.59					
ERF_BOP	3.65	93.47	2.26	48.57	70.59	0.07
ERF_BOPECM	3.73	97.10	2.21	51.43	52.94	0.14
ERF_BOPECMRES	3.59	96.27	2.34	68.57	58.82	0.00
ERF_DBOP	3.75	77.66	6.13	54.29	41.18	0.17
ERF_DMEPPP1	3.77	80.67	4.74	62.86	17.65	0.19
ERF_DMEPPP2	3.75	88.37	4.53	48.57	47.06	0.17
ERF_MEPPP	3.73	91.84	2.44	68.57	23.53	0.14
ERF_MEPPP2	3.73	94.13	1.66	71.43	52.94	0.14
ERF_MEPPPECM	3.77	94.78	2.34	57.14	41.18	0.18
ERF_MEPPPER	3.73	94.51	2.36	57.14	47.06	0.14

Note: SC – sign coincidence; TPC – turning point concordance.

Table 2. Descriptive statistics of forecasts of equilibrium exchange rates (*ERF_*) in comparison with descriptive statistics of *ER*

Forecast of *ER*	Mean	Median	Maximum	Minimum	Standard deviation	Skewness	Kurtosis	Jarque-Bera	Sum	Sum square dev.
ER	3.77	3.95	4.50	2.67	0.50	–0.77	2.68	3.08	112.99	7.15
ERF_BOP	3.76	3.95	4.39	2.65	0.48	–0.85	2.73	3.67	112.87	6.66
ERF_BOPECM	3.76	3.93	4.46	2.63	0.49	–0.89	2.89	3.94	112.72	7.01
ERF_BOPECMRES	3.76	3.92	4.44	2.64	0.49	–0.84	2.84	3.54	112.87	6.89
ERF_DBOP	3.86	3.96	4.43	2.83	0.37	–1.03	3.80	6.10	115.91	4.00
ERF_DMEPPP1	3.84	3.94	4.36	2.89	0.40	–0.95	2.94	4.50	115.29	4.58
ERF_DMEPPP2	3.82	3.92	4.48	2.76	0.43	–0.80	3.05	3.17	114.73	5.48
ERF_MEPPP	3.76	3.91	4.39	2.65	0.48	–0.90	2.86	4.03	112.66	6.60
ERF_MEPPP2	3.75	3.88	4.45	2.67	0.48	–0.81	2.80	3.32	112.62	6.80
ERF_MEPPPECM	3.76	3.93	4.40	2.67	0.48	–0.88	2.66	4.06	112.91	6.75
ERF_MEPPPER	3.76	3.92	4.37	2.65	0.48	–0.87	2.71	3.90	112.78	6.78

We may observe that the values of empirical nominal exchange rates and forecasts of monetary and balance of payments equilibrium rates are relatively close to each other in the period 1999–2002. In 1995–1997, some trajectories based on the BOP theory let us infer that PLN was in this period overvalued. In 2000 empirical nominal value of PLN was undervalued. In 2003, however, it starts a phenomenon of growing difference between empirical nominal *ER* and any equilibrium nominal *ER* taken from the bundle of equilibrium exchange rates, especially from MPPP theory. It means that USD is quite undervalued (PLN overvalued) in 2003. We can see that equilibrium values received from each equation have close trajectories to the observed values. It means that the observed values of exchange rates are most often corresponding to their theoretical equilibrium values.

We can now compare basic statistics of time series of predicted values of equilibrium and empirical exchange rates.

We have obtained 10 different paths of equilibrium values of exchange rate. It is easily seen that equilibrium values received from each equation have close trajectories to the observed values. It means that the observed values of exchange rates are most often corresponding to their theoretical equilibrium values. Descriptive statistics of all series of *ERF* are also comparable in values. Comparing forecasts based on the first definition of equilibrium with the forecasts based on the second definition we cannot say that one of this approach gave better historical forecasts. The same can be said about the predictors based on monetary extension of PPP and balance of payments theories. Therefore, we expect that our predictors are good for making predictions of equilibrium exchange rates of PLN/USD. We may say that the values of empirical exchange rates are close to equilibrium values forecasts under MEPPP and BOP conditions.

It is also interesting to find combined forecasts by the use of obtained equilibrium exchange rates forecasts (Figure 1).

The combined historical predictor is defined as the unweighted arithmetical mean of 10 predictors of equilibrium nominal exchange rates. It matches empirical values of *ER* of PLN/USD in 89%. It turns out that under the assumption that all our theoretical equations give some information about equilibrium exchange rates their combination gives the best possible trajectory of *ERF*. This trajectory is similar to the historical *ER*. Consequently, we can suppose that the exchange rate of PLN against USD during 1995–2003 was shaped in accordance with equilibrium conditions as well.

After putting a shock to home interest rate (i.e. we increased hir by 10% and 20%) in all equations, then, it turned out that all predictions came back to their previous values obtained without this disturbing shock.

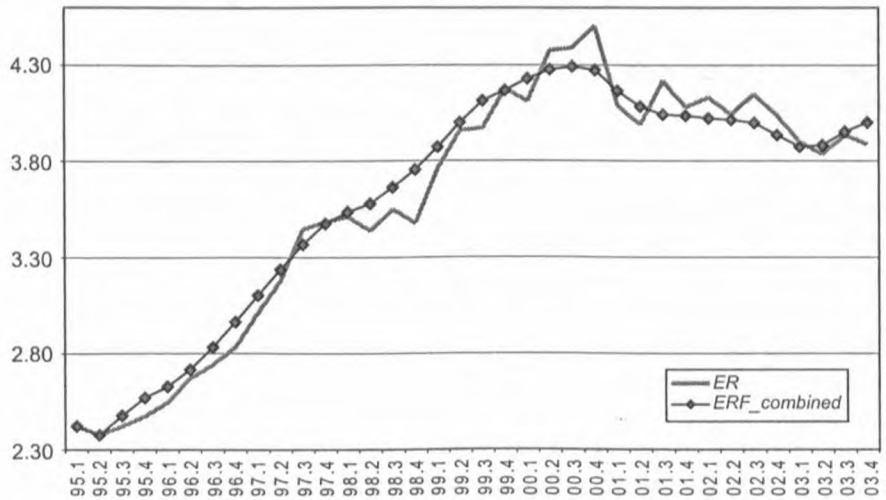

Fig. 1. Combined predictor (*ERF_combined*) of empirical values of nominal exchange rates of PLN/USD (*ER*)

5. CONCLUSIONS

Nominal exchange rate of PLN against USD was, in analyzed period, close to the equilibrium value of this rate. We have shown that the theoretical equilibrium values do not statistically significantly differ on the method used in equilibrium computations, i.e. neither the applied economic theories as the base for choosing determinants for exchange rates, nor the definition of equilibrium that was used for computations. Since both kinds of definitions of equilibrium gave similar results we can suppose that our results are interesting from the theoretical and empirical point of view.

Before PLN will be anchored into ERM2, it is very important to find whether the empirical value of exchange rate is close to its equilibrium counterpart (Lipiński and Słowiński 2003, p. 137). If it is not it will be necessary to answer the question how to achieve the equilibrium exchange rates and what are the implications for the choice of the euro conversion rates. Unfortunately, particular theoretical models do not give clear answers for these questions (Rawdanowicz 2003, p. 20). It is a very important issue in the aspect of entering Monetary Union and anchoring the zloty in the ERM2. If we could find appropriate exchange rate before anchoring, then we could expect that the introduction of Eurozone in Poland will be carried out "unobserved" and Polish currency will join euro very softly.

APPENDIX

1. BOP

$$\underset{t\text{-stat}}{\hat{er}} = 2.23 + \underset{(2.59)}{1.90}\,(hp_t - fp_t) - \underset{(-3.29)}{0.18} fgdp_{t-2} - \underset{(-2.25)}{0.005}(hir_{t-1} - fir_{t-1}) + \underset{(7.83)}{0.80} er_{t-1}$$

$R^2 = 0.97$ $D\text{-}W = 2.6$ $I(0)$ $n = 34$

2. BOPECM

$$\underset{t\text{-stat}}{\Delta \hat{er}_t} = -20.7 + \underset{(-2.46)}{2.5}\,(hp_{t-1} - fp_{t-1}) + \underset{(2.13)}{1.57} fgdp_{t-4} - \underset{(2.3)}{0.37} fgdp_{t-1} + \underset{(3.515)}{0.038}(hir_{t-4} - fir_{t-4}) - \underset{(-3.85)}{0.48} ECM_{t-1}$$

$R^2 = 0.52$ $D\text{-}W = 2.38$ $I(0)$ $n = 32$

3. BOPECMRES

$$\underset{t\text{-stat}}{\Delta \hat{er}_t} = 6.64 + 1(hp_{t-1} - fp_{t-1}) - \underset{(-2.27)}{0.96} hgdp_{t-2} + \underset{(2.16)}{0.39} fgdp_{t-2} + \underset{(2.36)}{0.0218}(hir_{t-4} - fir_{t-4}) - \underset{(-2.61)}{0.32} ECM_{t-1}$$

$R^2 = 0.36$ $D\text{-}W = 2.4$ $I(0)$ $n = 32$

4. DBOP

$$\underset{t\text{-stat}}{\Delta \hat{er}_t} = -12.74 + \underset{(1.62)}{1.12}(hp_{t-3} - fp_{t-3}) + \underset{(2.12)}{1.6} hgdp_{t-3} - \underset{(-3.19)}{0.41} fgdp_{t-2} - \underset{(-3.32)}{0.009}(hir_{t-3} - fir_{t-3}) - \underset{(-3.11)}{0.43}\, er_{t-1}$$

$R^2 = 0.47$ $D\text{-}W = 2.49$ $I(0)$ $n = 33$

5. DMEPPP1

$$\underset{t\text{-stat}}{\Delta \hat{er}_t} = -1.05 + \underset{(3.39)}{0.46}\,(hm_t - fm_t) + \underset{(2.72)}{0.16}(fgdp_t - hgdp_t) - \underset{(-3.64)}{0.52}\, er_{t-1}$$

$R^2 = 0.46$ $D\text{-}W = 1.92$ $I(0)$ $n = 32$

6. DMEPPP2

$$\underset{t\text{-stat}}{\Delta \hat{er}_t} = 24.14 + \underset{(5.46)}{1.11}\,(hm_t - fm_t) - \underset{(-3.39)}{3.33} hgdp_{t-1} + \underset{(4.14)}{0.87} fgdp_t + \underset{(3.74)}{0.01}\, hir_t - \underset{(-2.98)}{0.03} fir_{t-1} - \underset{(-4.59)}{0.68}\, er_{t-1}$$

$R^2 = 0.69$ $D\text{-}W = 1.87$ $I(0)$ $n = 32$

7. MEPPP

$$\underset{t\text{-stat}}{\hat{er}_t} = -1.98 + \underset{(13.03)}{0.81}(\, hm_t - fm_t) + \underset{(15.38)}{0.42}(fgdp_t - hgdp_t) + \underset{(2.91)}{0.0006}\,(hir_t - fir_t)$$

$R^2 = 0.96$ $D\text{-}W = 1.19$ $I(0)$ $n = 32$

8. MEPPP2

$$\underset{t\text{-stat}}{\hat{er}_t} = \underset{}{23.32} + \underset{(7.24)}{1.34\,(hm_t - fm_t)} - \underset{(-3.3)}{3.47 hgdp_{t-1}} + \underset{(4.90)}{1.03 fgdp_t} + \underset{(4.74)}{0.01\ hir_t} - \underset{(-2.93)}{0.03 fir_{t-1}}$$

$R^2 = 0.97$ $D\text{-}W = 1.46$ $I(0)$ $n = 32$

9. MEPPPECM

$$\underset{t\text{-stat}}{\Delta\hat{er}_t} = \underset{}{-3.19} + \underset{(-1.87)}{0.21(hm_{t-1} - fm_{t-1})} + \underset{(1.84)}{0.26(fgdp_t - hgdp_t)} + \underset{(2.171)}{0.04(hir_{t-1} - fir_{t-1})} + \underset{(-2.44)}{0.23 ECM_{t-1}}$$

$R^2 = 0.42$ $D\text{-}W = 2.15$ $I(0)$ $n = 31$

10. MEPPPER

$$\underset{t\text{-stat}}{\hat{er}_t} = \underset{}{-1.05} + \underset{(3.39)}{0.46(\,hm_t - fm_t)} + \underset{(2.72)}{0.16(fgdp_t - hgdp_t)} + \underset{(3.31)}{0.48 er_{t-1}}$$

$R^2 = 0.96$ $D\text{-}W = 1.92$ $I(0)$ $n = 32$

where:

er – log of the nominal exchange rate of PLN against USD;
hp – log of the Polish producer price index (1995q1 = 100);
fp – log of the USA producer price index (1995q1 = 100);
hgdp – log of the Polish gross domestic product (1995q1 = 100);
fgdp – log of the USA gross domestic product (1995q1 = 100);
hm – log of the money supply in Poland (M3) (1995q1 = 100);
fm – log of the money supply in USA (M3) (1995q1 = 100);
hir – WIBOR3M,
fir – LIBOR3M.

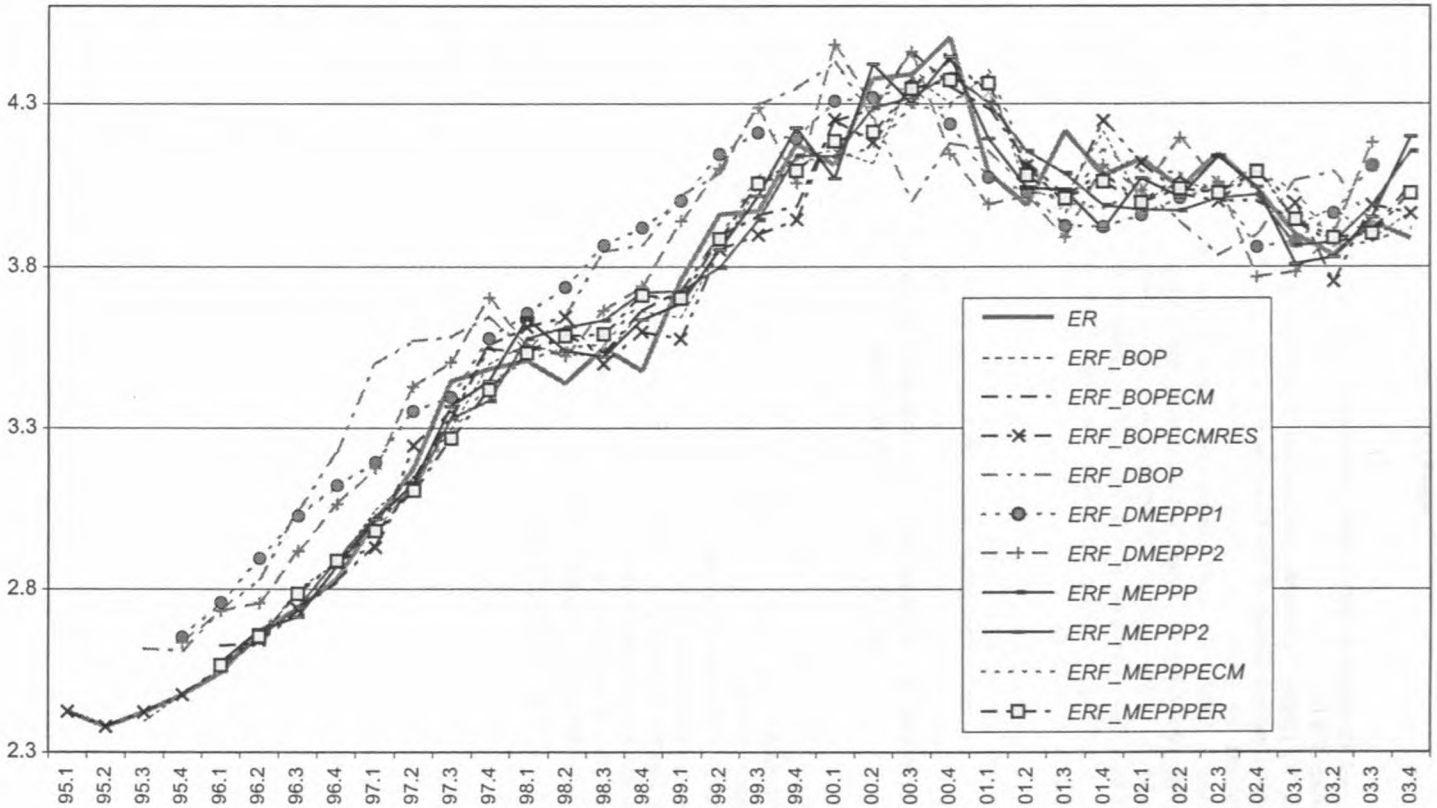

Fig. A1. Forecasts of equilibrium nominal exchange rate and empirical value of nominal exchange rate PLN/USD

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Władysław Milo, Magdalena Rutkowska

UWAGI NA TEMAT PROGNOZOWANIA RÓWNOWAGOWEGO KURSU WALUTOWEGO PLN DO USD

(Streszczenie)

Kurs walutowy jest jedną z ważniejszych cen w otwartej gospodarce. Z praktycznych i teoretycznych powodów bardzo użytecznym jest zbadanie jego poziomu równowagowego. Istnieje bardzo wiele teorii wyjaśniających kształtowanie się kursu walutowego. W artykule przedstawiono determinanty kursu walutowego, wynikające zarówno z teorii monetarystycznej, jak i teorii bilansu płatniczego. Następnie, na ich podstawie oraz przyjmując różne definicje równowagi, zbudowano predyktory nominalnego kursu PLN/USD oraz obliczono jego równowagowe poziomy. Przeprowadzona analiza empiryczna wykazała, że niezależnie od przyjętej definicji stanu równowagi otrzymane trajektorie poziomu kursów równowagi nie różnią się od siebie istotnie oraz są zbliżone do rzeczywistego kształtowania się kursu PLN/USD w okresie 1995–2003.