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# Economic convergence and the fundamental equilibrium exchange rate in Poland<sup>1</sup>

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## Abstract:

The paper presents an extended version of the fundamental equilibrium exchange rate model (FFER). By introducing potential output into the specification of the foreign trade equations of the partial equilibrium FEER model we show that, under some plausible assumptions, the calculated level of the equilibrium exchange rate is consistent with the estimates of the behavioral equilibrium exchange (BEER). Moreover, we indicate that including the terms of trade as an explanatory variable in a reduced-form BEER equation for the real exchange rate might lead to the indeterminacy of the parameter estimates. The proposed model is applied to analyze fluctuations of the Polish zloty. We show that the real appreciation of the zloty is to a largely an equilibrium phenomenon.

JEL classification: C32, F12, F31

Keywords: Fundamental equilibrium exchange rate, current account, foreign trade.

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## 1. Introduction

The growing literature on equilibrium exchange rates (EER) of central and eastern European countries (CEECs), reviewed e.g. by Égert (2003), has predominantly applied two concepts: behavioral EER and fundamental EER. The BEER, proposed by Clark and MacDonald (1998), is mostly empirical in nature and in most cases not explicitly supported by theoretical considerations. The BEER can be shortly characterized as the theoretical value of an estimated single-equation, cointegration model for the real exchange rate (RER). Among the medium-term determinants of the RER, relative productivity, net foreign assets and the terms of trade are the most frequently used in the empirical applications. The FEER, presented by Williamson (1994), uses a complete macroeconomic model of an economy, or a partial equilibrium model of foreign trade, to find the level of the RER that would be consistent with the simultaneous attainment of internal and external equilibrium. In most studies internal equilibrium is defined as null output gap and external equilibrium as the current account equal to its exogenously set target.

The two EER approaches to modeling CEECs' exchange rates tend to be considered complementary rather than substituting. This might be due to the fact that in the standard specification of the FEER model an increase in domestic output leads to a deterioration in the current account, which requires a depreciation of domestic currency. This was shown by Clark and MacDonald (1998), who solved the FEER model to derive a reduced-form single equation for the RER in which an increase in domestic output is weakening the domestic currency. This is, however, contradicting the empirical findings pointing to a significant and positive relationship between the GDP per capita and the real exchange rate (see. e.g. Balassa, 1964).

The problem with the application of the FEER concept to transition economies was discussed by Maeso-Fernandez et al. (2005). The authors claim that changes in productivity are not accounted for in this approach, whereas the catching-up process is one of the central arguments of the equilibrium exchange rate appreciation in CEECs. In other words, the standard specification of trade equations in the FEER model does not take into account that real exchange rate appreciation related to the process of real convergence should not have negative effects on the current account balance. Two studies tried to address this issue. Égert

and Lahrèche-Révil (2003) proposed a tree-equation vector autoregression model that combines a relationship between relative productivity and the real exchange rate, which is empirically supported by the BEER literature, with external equilibrium concept of the FEER. In the second study, Bulíř and Šmídková (2005) extended the specification of trade equations of the traditional FEER model by including the inward stock of foreign direct investment (FDI). Their model implies that inflows of FDI were the main reason behind the process of real exchange rate appreciation in CEECs.

In this paper we address the above-mentioned discrepancy between the BEER and FEER concepts by introducing potential output into the specification of the foreign trade equations. We show that the BEER equation is, under some plausible assumptions, a reduced form of our FEER model. Moreover, we indicate that if our specification is correct, including the terms of trade as an explanatory variable in a reduced-form BEER equation for the real exchange rate might lead to the indeterminacy of the parameter estimates. The proposed model is applied to analyze fluctuations of the Polish zloty.

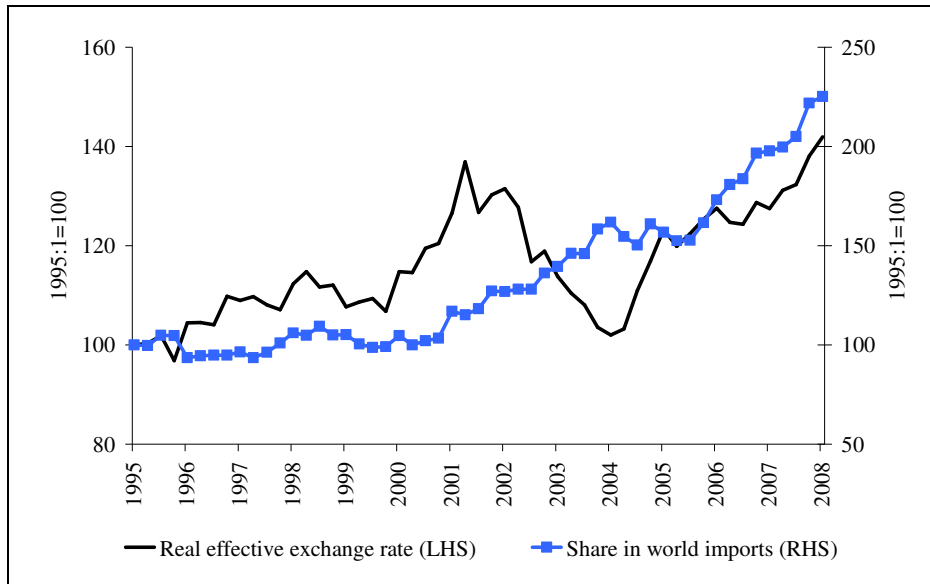
The structure of the article is as follows. Section 2 discusses issues concerning the specification of trade equations in converging economies. Section 3 describes the FEER model. In Section 4 we present the results of FEER estimates for the Polish zloty. Section 5 investigates the sensitivity of equilibrium exchange rate with respect to the normative assumptions of the FEER model. In section 6 we derive the reduced-form equation for the real exchange rate. The last section summarizes the main findings of the paper and concludes.

## **2. Foreign trade and economic transformation in Poland**

Foreign trade equations are the heart of the partial equilibrium FEER model. In most applications of the FEER (e.g. Williamson, 1994, for the G7 economies and Coudert and Couharde, 2003, for CEECs) the specification of the foreign trade equations is of Armington's (1969) type, which assumes that each country produces one variety or the consumer perceives varieties originating from a country as perfect substitutes. This implies that export demand is determined solely by two factors: foreign demand and relative prices. In this model, an increase in the share in foreign markets involves deterioration in the terms of trade and thus real exchange rate depreciation, which is clearly in opposition to the Polish experience. While in the period 1995-2007 the share of Poland in world imports more than doubled, the GDP

deflator based real effective exchange rate of the Polish zloty appreciated by about 50% (see Figure 1).

**Figure 1. The share in world imports and RERs of Poland**



Source: IMF Directions of Trade Statistics, Eurostat, OECD Main Economic Indicators.

The rapid growth of Poland's share in the world trade since the beginning of the transformation was rather due to supply factors, namely profound changes in the sectoral composition of output and ownership structure of firms. These changes, which are not accounted for in the standard specification of the foreign trade equations, have had tremendous effects on patterns of the foreign trade, both in terms of its geographical and sectoral composition. Although the detailed analysis of the foreign trade changes in Poland is not the focus of this paper, we point here to a few of the most important facts that have had impact on Polish trade:

- substantial inflows of foreign direct investment enhanced intra-firm trade between western European and Polish firms (Lane and Gian Maria Milesi-Ferretti, 2007);
- EU integration and reduction in impediments to trade resulted in a rapid growth of intra-industry trade both in horizontally and vertically differentiated goods, which has been reflected, among others, by the increasing share of trade in intermediate goods in total trade;
- gradual change in the export structure from labor-intensive products, for instance textiles, into more capital and skill intensive goods such as motor vehicles and electrical machinery (see Table 1).

**Table 1. The structure of Polish exports**

SITC products	1995	2000	2006
0. Food and live animals	9.1	7.5	8.3
1. Beverages and tobacco	0.7	0.4	0.7
2. Crude materials, except fuels	4.5	2.8	2.2
3. Mineral fuels etc	8.2	5.1	4.5
4. Animal and vegetable oils	0.1	0.1	0.2
5. Chemicals and related products	7.7	6.8	7.1
6. Basic manufactures	27.5	24.8	22.7
7. Machinery, transport equipment	21.1	34.2	40.0
8. Misc. manufactured articles	20.8	18.3	13.0
9. Goods not classified elsewhere	0.2	0.0	1.2

Source: Own calculations based on UN Comtrade.

Although it is very difficult, if possible, to integrate the above factors into a general equilibrium framework<sup>2</sup> that could be used to derive a reduced form equation for aggregate exports, it seems obvious that foreign trade has been strongly affected by structural changes that took place in Poland. In this article we propose to account for this phenomenon by adding potential output into the standard Armington specification of the foreign trade equations. As a result, the aggregate volume of exports is given by the relationship:

$$\frac{X}{YF} = \left( \frac{PX}{PF \times NER} \right)^{-\alpha_1} YPOT^{\alpha_2}, \quad (1)$$

which states that the share of exports ( $X$ ) in foreign output ( $YF$ ) is a negative function of relative prices of exports ( $PX$ ) and foreign output ( $PF$ ) adjusted for nominal effective exchange rate ( $NER$ ), and a positive function of potential output at home ( $YPOT$ ). Parameters  $\alpha_1$  and  $\alpha_2$  stand for price and potential output elasticities of exports, respectively. A similar specification of exports equation was derived e.g. by Gagnon (2007), who used a Krugman (1989) type of differentiated goods model, by taking into account “love for variety” into a micro-founded optimizing framework.

<sup>2</sup> To our best knowledge, the paper by Bruha and Podpiera (2007), which extends heterogenous firms model by Melitz (2003), is the only trial to account for these factors in analyzing CEECs within a general equilibrium framework.

### 3. The FEER model

The empirical application of the partial equilibrium FEER model consists of the three following stages. First, the parameters of the foreign sector model of an economy are estimated. The model is then simulated to find a relationship between the current account and the real exchange rate. Finally, the FEER is computed as the level of the real exchange rate that equalizes the model's implied current account, assuming that output gaps at home and abroad are closed, with its exogenously set target level. This implies that the calculations of the FEER involve (i) estimating or calibrating the foreign trade equations, (ii) computing the level of potential output at home and abroad, and (iii) setting the target for the current account balance.

Taking into account the considerations from the previous section, in this paper the FEER is computed as the solution of the following system of equations:

$$x - yf = \alpha_1 ypot - \alpha_2 (px - pf - ner) \quad (2)$$

$$m - y = \beta_1 yfpot - \beta_2 (pm - p) \quad (3)$$

$$px = \gamma p + (1 - \gamma)(pf + ner) \quad (4)$$

$$pm = \delta p + (1 - \delta)(pf + ner) \quad (5)$$

$$rer = p - pf - ner \quad (6)$$

$$DD + X - M = Y \quad (7)$$

$$PX \times X - PM \times M + CA\_TR + CA\_INC = CA \quad (8)$$

$$Y = YPOT \quad (9)$$

$$YF = YFPOT \quad (10)$$

$$CA = TCA, \quad (11)$$

where lower-case letters define natural logarithms of the corresponding variables. Equations (2) and (3) relates the shares of exports ( $X$ ) in foreign GDP ( $YF$ ) and imports ( $M$ ) in domestic GDP ( $Y$ ) to potential output ( $YPOT$  and  $YFPOT$ ) and relative prices, in line with the specification discussed in the previous section (see eq. 1). Equations (4) and (5) define export ( $PX$ ) and import prices ( $PM$ ) as a weighted average of domestic ( $P$ ) and foreign prices ( $PF$ ) adjusted for the nominal effective exchange rate ( $NER$ ). This “price maker – price taker” specification is very often used to model countries whose trade consist predominantly of

differentiated manufactured products. Given the definition of the real effective exchange rate (eq. 6), exports and imports price competitiveness measures are equal to:

$$(px - pf - ner) = \gamma rer \quad (12)$$

$$(pm - p) = (\delta - 1)rer \quad (13)$$

Relationships (7) and (8) are GDP and current account identities, respectively: GDP is the sum of domestic demand (*DD*) and net trade, whereas the current account is the sum of balances on trade, current transfers (*CA\_TR*) and income (*CA\_INC*). Finally, equations (9)-(11) express the internal and external balance conditions, stating that foreign and domestic output gaps are closed and the current account balance is equal to its target level (*TCA*). Given the exogenously set values of *YPOT*, *YFPOT* and *TCA*,<sup>3</sup> the model can be solved for domestic demand and the real exchange rate ensuring the simultaneous attainment of the internal and external equilibria. The solution for the real exchange rate is called FEER.

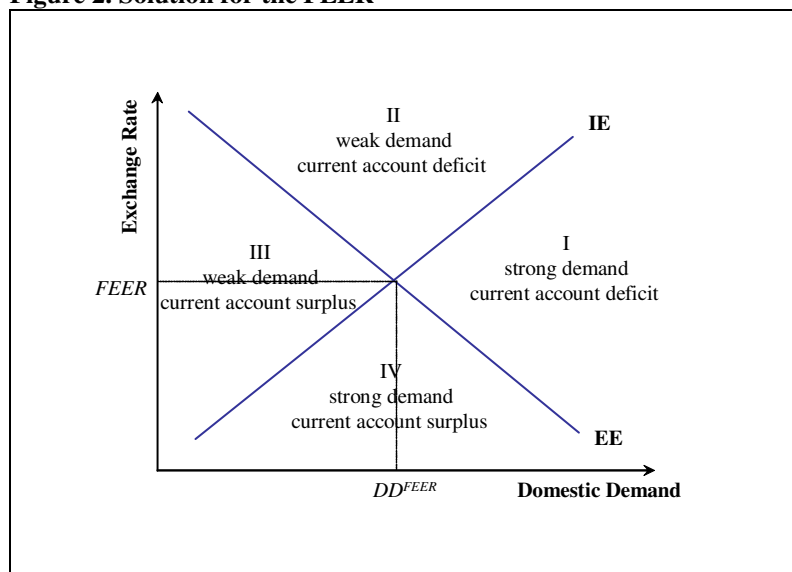
The system given by equations (2)-(11) can be illustrated by a Swan diagram, as presented in Figure 2. The horizontal axis represents domestic demand and the vertical axis represents the real exchange rate, where an upward movement stands for domestic currency appreciation. The internal equilibrium locus (*IE*) is sloped upward as a rise in domestic demand requires a proportional decline in net trade, and thereby real exchange rate appreciation, so that the output gap remained closed. As regards the external equilibrium locus (*EE*), it is sloped downward as current account deterioration entailed by stronger domestic demand has to be counterbalanced by domestic currency depreciation, so that the current account remained at its target level. The intersection of the internal and external loci defines the FEER and the corresponding, equilibrium level of domestic demand.

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<sup>3</sup> And other exogenous variables of the model such as *PF*, *YF*, *P*, *CA\_TR* and *CA\_INC*, which in opposition to *Y\_POT*, *YF\_POT* and *TCA* are observable.



**Figure 2. Solution for the FEER**



Source: Adopted from Rosenberg (1996, p. 32)

The analysis of Figure 2 shows that within this framework there are four cases of economic disequilibrium. The first (third) quadrant represents a country with excessive (subdued) domestic demand, which leads to a current account deficit (surplus)<sup>4</sup> and a positive (negative) output gap. On the other hand, the second (fourth) quadrant is an example of a country with an overvalued (undervalued) real exchange rate. The weak (strong) external price competitiveness, in turn, results in a negative (positive) output gap and a current account deficit (surplus). The policy implications are twofold. First, if a country is running a current account deficit (surplus) and the output gap is negative (positive) then it is a clear signal that the real exchange rate is overvalued (undervalued). Second, if domestic demand is excessive (subdued) then setting the real exchange rate at its fundamental level does not guarantee that the economy will return to its fundamental equilibrium. In most cases reaching the fundamental equilibrium requires both: adjustment in the real exchange rate and domestic demand.

#### **4. Empirical evidence**

In this section we illustrate how the FEER model can be empirically tested by applying the concept to analyze the equilibrium value of the Polish zloty. We start by discussing the data issues. Then, we move to estimates of the foreign trade model given by equations 2-3 and 12-13. The next sub-section discusses the normative assumption concerning the target current

<sup>4</sup> Here a current account deficit should be interpreted as a current account balance that is below the target current account.

account level, which is a very important input in FEER calculations. Finally, we present the results.

#### 4.1. The Data

The foreign sector is defined as a weighted average of the three CEECs, the euro area, Denmark, Japan, Sweden, Switzerland, the United Kingdom, and the United States. The weights, which are shown in Table 2, are taken from the BIS database for effective exchange rate indices calculated on the basis of trade flows in the period 2002-2004 (see Fung and Klau, 2006). As two important trading partners, namely China and Russia, are omitted in the analysis due to data problems, the used weights cover around 81% of the BIS effective exchange rate index.

**Table 2. Weights for foreign sector**

	Weight
Czech Republic	4.0
Hungary	2.3
Slovakia	1.6
Denmark	2.1
Sweden	3.6
United Kingdom	6.8
Euro area	68.1
Japan	3.5
Switzerland	2.1
United States	5.9

Source: Calculations on the basis of Fung and Klau (2006).

The national account data concerning seasonally adjusted nominal and real exports, imports and GDP for the EU countries are taken from Eurostat and for the non-EU countries from the OECD Main Economic Indicators (MEI). Potential output for each economy is computed by applying the Hodrick-Prescott filter with the smoothing factor  $\lambda = 1600$  to real GDP quarterly series. Nominal effective exchange rates are calculated on the basis of the average rate of domestic currencies against the US dollar from the OECD MEI. Finally, the data for the international investment position and the current account are taken from the National Bank of Poland.<sup>5</sup>

<sup>5</sup> The annual data for the international investment position were transformed into quarterly series by applying the “cubic-match last” conversion method.

#### 4.2. Foreign trade model

The foreign trade model, the specification of which is given by equations (2)-(3) and (12)-(13), was estimated using data from the period 1995:1–2008:1, which translates into 53 quarterly observations. We started by analysing the level of integration of the model variables using the Ng-Perron (2001) tests for the null hypothesis of nonstationarity and the Kwiatkowski et al. (1992) test for the null hypothesis of stationarity. As the null hypotheses are different, these tests are complementary. The results, which are presented in Table 3, indicate that all variables are nonstationary, i.e. integrated of the first order.

**Table 3. Stationarity tests**

variable	Level					1 <sup>st</sup> difference					Conclusion
	Ng-Perron tests				KPSS	Ng-Perron tests				KPSS	
	MZA	MZT	MSB	MPT		MZA	MZT	MSB	MPT		
Exports <i>x</i>	-	-	-	-	***	***	***	***	***	-	I(1)
Imports <i>m</i>	-	-	-	-	***	***	***	**	***	-	I(1)
Export prices <i>px</i>	-	-	-	-	***	***	***	***	***	-	I(1)
Import prices <i>pm</i>	-	-	-	-	***	***	***	***	***	-	I(1)
Domestic output <i>y</i>	-	-	-	-	***	***	***	***	***	-	I(1)
Foreign output <i>yf</i>	-	-	-	-	***	***	***	***	***	-	I(1)
Real exchange rate <i>rer</i>	-	-	-	-	**	***	***	***	***	-	I(1)

Notes: Constant is the only deterministic variable included in the test equation. The NG-Perron tests were applied to the GLS detrended data, where the long-run autocovariance matrices were computed using the autoregressive spectral density estimator with the maximum lag length set on the basis of the Schwarz information criterion. In the case of the KPSS test, the long-run autocovariance matrices were estimated using the Bartlett kernel with the bandwidth set according to the Newley-West method. Stars indicate probabilities: \* for  $p < 0.10$ , \*\* for  $p < 0.05$  and \*\*\* for  $p < 0.01$ , whereas hyphens stand for  $p > 0.10$ .

We proceeded by estimating parameters of the foreign trade model using seemingly unrelated regression, which is an appropriate method to analyze a system of multiple equations with cross-equation parameter restrictions and correlated error terms. The parameters of the system were estimated under the restriction of equal potential output elasticities of exports and imports, the restriction that was not rejected by the data. It should be noted that this restriction ensures the stabilization of the trade balance in the case of constant real exchange rate and the same growth pace of the home and foreign economies. The results were as follows:

$$x_t - yf_t = 2.10 \underset{(0.06)}{ypot_t} - 0.67 \underset{(0.11)}{(px_t - pf_t - ner_t)} - 28.85 \underset{(0.76)}{ADF} = -3.43 \text{ (p=0.047)} \quad (14)$$

$$m_t - y_t = \underset{(0.06)}{2.10} yfpot_t - \underset{(0.21)}{0.80}(pm_t - p_t) - \underset{(0.79)}{29.88} \quad ADF=-3.29 \text{ (p=0.064)} \quad (15)$$

$$px_t - pf_t - ner_t = \underset{(0.07)}{0.74} rer_t - \underset{(0.06)}{0.17} \quad ADF=-7.06 \text{ (p=0.000)} \quad (16)$$

$$pm_t - p_t = -\underset{(0.06)}{0.16} rer_t - \underset{(0.05)}{0.13}, \quad ADF=-4.48 \text{ (p=0.000)} \quad (17)$$

where the figures in parentheses stand for the standard deviation of estimates. All estimates are of correct sign and acceptable magnitude. The price elasticity of exports and imports, amounting to 0.67 and 0.80 respectively, is moderate and comparable to the findings of the literature (e.g. Faruqee and Isard, 1998). In the case of the potential output elasticity, the estimate of 2.10 is high and significant, supporting our hypothesis that trade flows are to a large extent driven by supply factors. As for the price equations, the results indicate that Poland is predominantly a price-maker country, which is rather in opposition to our prior expectations. Finally, it should be noticed that according to the ADF test, the residuals of all relationships are stationary at 10% significance level and thereby these relationships might be classified as cointegrating ones.<sup>6</sup>

#### 4.3. Target current account

A large part of international capital flows might be classified as short-term and speculative. These kinds of flows are influenced by the relative monetary policy stance, expectations concerning temporary nominal exchange rate trends or changes in risk premium. Moreover, in the short term, capital flows might also be affected by a one-off adjustment in the portfolio structure of financial institutions or large FDI, the effects of which vanish in the medium run. In the article, we define the “target current account” as a value of the current account that abstracts from the above short-term capital flows.

In the literature there are several methods for calculating the medium-term current account balance. Below, we refer to the two most frequently used in the empirical studies on Poland and other CEECs. The first one, the theoretical foundations of which are based on the intertemporal approach to the current account, considers the medium-term capital flows as a reflection of life-time decisions of economic agents concerning savings and investment. The empirical application involves the estimation of a reduced-form panel equation relating the current account to a set of standard macroeconomic fundamentals, such as relative GDP per

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<sup>6</sup> The *p*-values are calculated using MacKinnon (1996) programs for cointegration tests.

capita, the demographic structure and fiscal policy. The most prominent examples of this analytical approach are the studies by Debelle and Faruquee (1996) or Chinn and Prasad (2003). As regards the results of this kind of estimates for Poland, Doisy and Herve (2003) found that the target level for the current account deficit in 1999 ranged from 3.1% to 4.9% of GDP, Bussière et al. (2004) indicated that in 2002 Poland would run a current account deficit in the range from 2.4% to 5.2% of GDP, whereas Abiad et al. (2006) estimated that in the years 1997-2004 the current account deficit in Poland should have fluctuated between 6% and 10% of GDP.

The second approach, proposed by Milesi-Ferretti and Razin (1996), treats the current account as an increment to the stock of net foreign assets. The current account is considered to be sustainable if it does not endanger the intertemporal solvency of the country, or in other words, does not lead to an excessive build-up of foreign liabilities. As regards the relevant studies for Poland, Zanghieri (2004) calculated that the sustainable current account deficit ranges from 4.3% to 8.3% of GDP, whereas Aristovnik (2006) indicated a range between 1.0% and 5.0% of GDP. The differences in the results can be explained by different assumptions concerning net FDI inflows, potential growth rate or the steady-state level of external debt.

In this article we calculate the level of the target current account using an extended version of the Milesi-Ferretti and Razin framework, which incorporates the convergence of net foreign assets to a steady-state level and valuation effects. We start by describing the law of motion for the stock of net foreign assets ( $B_t$ ):

$$B_t = B_{t-1} + CA_t + VE_t, \quad (18)$$

where  $VE_t$  stands for valuation effects. Dividing the above equation by nominal GDP leads to the following specification:

$$b_t = b_{t-1}(1 - \Delta y_t - \Delta p_t) + ca_t + ve_t \quad (19)$$

where the lower-case letters define the ratios with respect to GDP. Given the convergence of net foreign assets to a steady-state level ( $\bar{b}$ ):

$$\Delta b_t = -\rho(b_{t-1} - \bar{b}), \quad (20)$$

the target level of the current account can be calculated as:

$$tca_t = \rho(\bar{b} - b_{t-1}) + b_{t-1}(\Delta p_t + \Delta y_t) - ve_t. \quad (21)$$

According to the above expression, in the medium term the current account might differ from zero for the three following reasons: (i) to allow the adjustment of net foreign assets to a steady-state, (ii) positive growth of nominal GDP and (iii) the existence of valuation effects.

In the empirical application, the parameterization of equation (21) is as follows. The convergence path  $\rho$  is set to 0.025 so that within a quarter there is a fall of 2.5% in the distance between the actual and steady-state level of net foreign assets. Following Bulř and Šmídková (2005) the steady-state level of net foreign liabilities  $\bar{b}$  is chosen to be 65% of annual GDP. As regards the growth rates of prices  $\Delta p$  and output  $\Delta y$ , we take the inflation target of 2.5% per year and potential output growth. Finally, we assume that valuation effects are equal to some fraction of net foreign assets:

$$ve_t = \kappa b_{t-1}, \quad (22)$$

where we set  $\kappa = 0.01$  to reflect the 2000-2006 historical average for the case of Poland.

The results of calculated current account deficit are presented in Table 4. They show that between 2000 and 2004 the target current deficit improved gradually from 4.0% to 3.5% of GDP, which was associated with a deterioration in the international investment position.

Thereafter, it increased slightly, amounting to 3.8% of GDP in 2008:1 due to an acceleration in potential output growth. It should be noted, that our results are broadly in line with the findings of the studies reviewed above.

**Table 4. Target current account calculations**

	Data (annual average)			$tca_t$	Target current account decomposition		
	$b_t$ (% of GDP)	$\Delta p_t$ (%, QoQ)	$\Delta y_t$ (%, QoQ)		$\rho(b_{t-1} - \bar{b})$ convergence	$b_{t-1}(\Delta p_t + \Delta y_t)$ output growth	$-ve_t$ val. effects
2000	-122	0.6	0.8	-4.0	-3.5	-1.8	1.2
2001	-117	0.6	0.8	-4.0	-3.5	-1.6	1.2
2002	-125	0.6	0.8	-4.0	-3.5	-1.7	1.2
2003	-153	0.6	0.9	-3.6	-2.8	-2.2	1.5
2004	-162	0.6	1.0	-3.5	-2.4	-2.7	1.6
2005	-162	0.6	1.2	-3.7	-2.5	-2.9	1.6
2006	-170	0.6	1.3	-3.8	-2.3	-3.2	1.7
2007	-175	0.6	1.3	-3.8	-2.1	-3.4	1.7
<b>08q1</b>	<b>-177</b>	<b>0.6</b>	<b>1.3</b>	<b>-3.8</b>	<b>-2.1</b>	<b>-3.4</b>	<b>1.8</b>

#### 4.4. Estimates of the FEER

We start the estimation of the FEER by calculating an underlying current account, i.e. the current account that would prevail if:

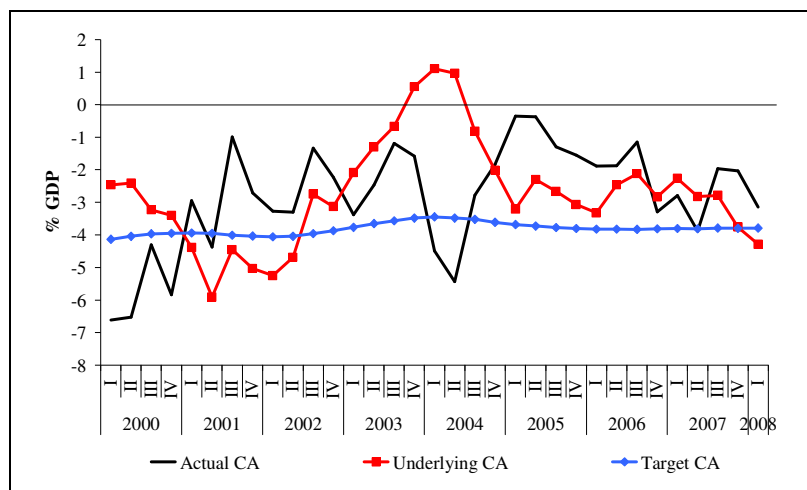
domestic and foreign output gaps were null;

trade volumes and prices were at their medium-term levels;

the transfer and income balances were adjusted for temporary factors.

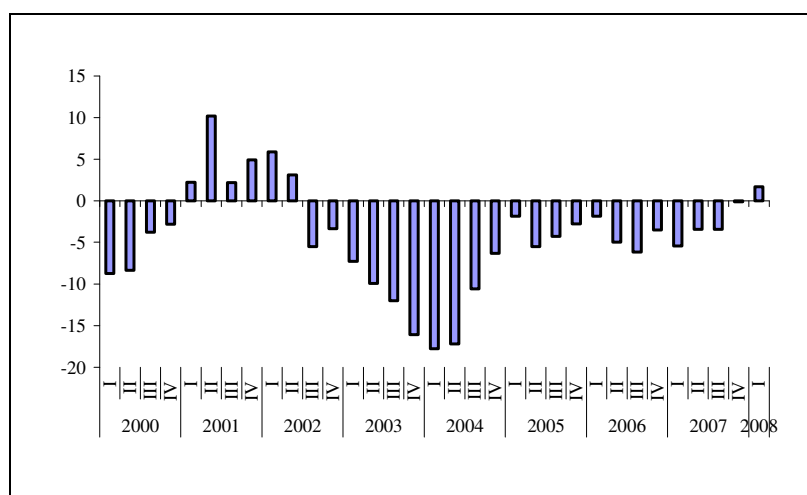
In this regard, we calculate the underlying trade balance by taking the theoretical values for export and import prices and volumes from equations (14)-(17), given that internal balance conditions (9) and (10) are met. The adjustment of income and transfer balances for temporary factors is done by using the Hodrick-Prescott filter. The underlying current account is subsequently calculated according to definition given by equation (8). The results, as presented in Figure 3, show that for most of the period 2000:1-2008:1 the underlying current account fluctuated at levels above the target current account, where the difference was the most evident at the turn of 2004. The only exceptions are the years 2001-2002 and the first quarter of 2008, when the underlying current account stood below its target level. Within the FEER framework, a high (low) level of the underlying current account balance means that the real exchange rate is undervalued (overvalued), where the scale of real exchange rate misalignment is positively related to the difference between the underlying and target current account.

**Figure 3. Actual, underlying and target current account**



We estimate the scale of Polish zloty misalignment by solving the system of equations described in the previous sections, and calculating the real exchange rate equating the underlying and target levels of the current account. According to the results, in the years 2003-2004 the zloty was undervalued by over 10%, whereas in mid-2001 it was overvalued by around 10%. It was also found that the appreciation of the zloty that occurred after EU accession did not result in the overvaluation of the zloty: in 2008:1 the difference between the estimated FEER and the actual real effective exchange rate was almost negligible, amounting to around 2% (see Figure 4).

**Figure 4. Real exchange rate misalignment**



Note: Positive values stand for overvaluation.

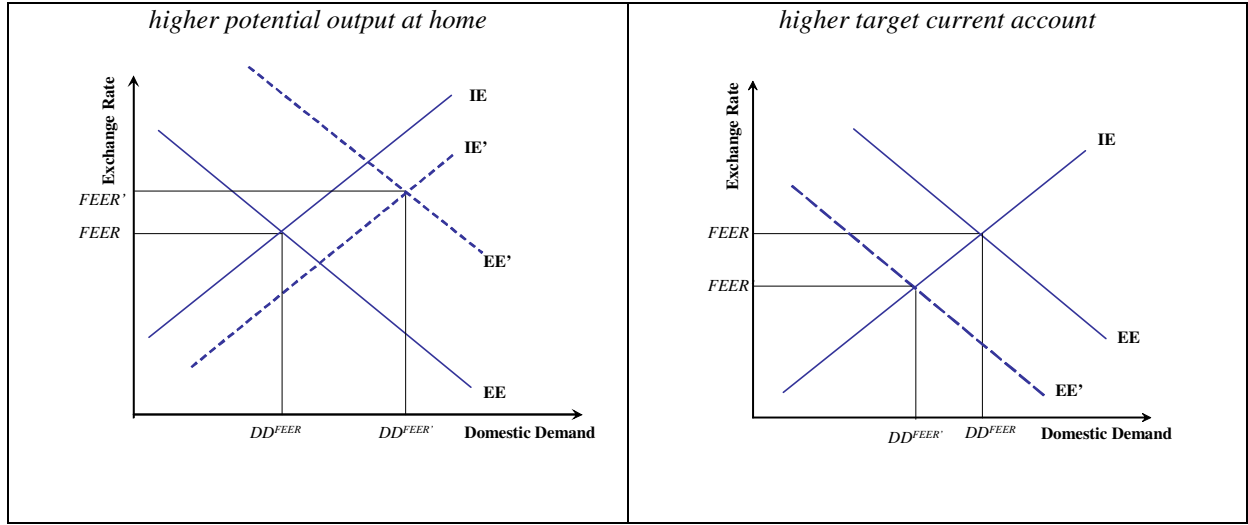


## 5. Sensitivity analysis

The FEER estimates are as plausible as the underlying foreign trade model and the assumptions for potential output and the target current account. These assumptions, however, are based on some normative judgment and calculations and thereby surrounded by a high degree of uncertainty. For that reason, the application of the FEER method in estimating real exchange rate misalignments might be considered incomplete, if it is not accompanied by a sensitivity analysis. As stated by Driver and Wren-Lewis (1999), the assessment of the FEER estimates with respect to the model's assumptions might address two sets of issues: (i) those related to the parameterization and specification of the foreign trade model, and (ii) those related to the exogenous variables of the FEER model. In this paper we focus on the second aspect of the sensitivity analysis, i.e. we answer the question: how FEER estimates are affected by the changes in the assumed levels of potential output and the target current account. We do it using both, graphs and analytical calculations.

As regards the relationship between the assumed level of potential output and the FEER, it is illustrated in the left-hand panel of Figure 4. Higher potential output at home is shifting the internal balance curve  $IE$  to the right, as growth in aggregate supply requires an increase in aggregate demand of the same magnitude, so that internal equilibrium condition is satisfied. Moreover, if the potential output elasticity of exports  $\alpha_1$  is above unity, growth in the supply-side performance of the economy is also improving the underlying current account, and thus shifts the external balance curve  $EE$  to the right. The result for the real exchange rate is appreciation, where the analytical proof of this result is presented in the further part of this section. The effects of changes in the assumed level of the target current account are illustrated in the right-hand panel of Figure 5. A higher target current account balance means a leftward shift of the external equilibrium curve, and thereby requires lower domestic demand and weaker domestic currency.

**Figure 5. Sensitivity analysis**



We proceed by computing the magnitude of the effects of changes in the normative assumptions on the estimates of the FEER. Toward this goal we combine the current account and external balance identities (equations 8 and 11) and calculate the dynamics of the target current account to GDP ratio, given that the economy is in its fundamental equilibrium:

$$\Delta tca_t = \tau_t [(\Delta px_t + \Delta x_t) - (\Delta pm_t + \Delta m_t)] + \Delta ca\_inc_t + \Delta ca\_tr_t. \quad (23)$$

Here  $\tau$  stands for economic openness defined as the share of nominal export in GDP, which for simplicity is assumed to be the same as the relevant imports share. According to the specification of the foreign trade model (eqs 2, 3, 12 and 13), the definition of the internal balance (eqs 9 and 10), and assuming equal potential output elasticities ( $\alpha_1 = \beta_1$ ), the trade balance equals to:

$$(\Delta px_t + \Delta x_t) - (\Delta pm_t + \Delta m_t) = -\lambda \Delta rer_t + (\alpha_1 - 1)(\Delta ypot_t - \Delta yfpot_t), \quad (24)$$

where  $\lambda = \alpha_2 \gamma + \beta_2 - \beta_2 \delta - \gamma + \delta > 0$  if the Marshall-Lerner condition is met. The combination of the above two expressions, (23) and (24), leads to a reduced-form equation for the growth rate of the real exchange rate:

$$\Delta rer_t = \frac{(\alpha_1 - 1)(\Delta ypot_t - \Delta yfpot_t)}{\lambda} + \frac{\Delta ca\_inc_t + \Delta ca\_tr_t - \Delta tca_t}{\lambda \tau_t}. \quad (25)$$

Substituting the parameters of the above relationship by their estimates, and taking into account that in 2008:1 the openness coefficient  $\tau$  was equal to 0.43, we can calculate that:

$$\Delta rer_t = 1.52(\Delta ypot_t - \Delta yfpot_t) + 3.24(\Delta ca\_inc_t + \Delta ca\_tr_t - \Delta tca_t). \quad (26)$$

This means that an increase in the assumed level of domestic (foreign) potential output by 1% appreciates (depreciates) the real exchange rate of the Polish zloty by 1.52%. The results also show that an increase in the assumed level of the target current account, or a decrease in the balance on current transfers, by 1% of GDP required in 2008:1 a real depreciation of the zloty by 3.24%. It should be noticed that the above semi-elasticity is changing over time, depending on the level of trade openness of the Polish economy.

## 6. A comparison of the FEER and the BEER

In this section we argue that by including potential output into the specification of the foreign trade equations of the FEER model we can derive the reduced form-equation for the real exchange rate that encompasses a standard specification of the BEER relationship, as proposed by the Clark and MacDonald (1998). According to their specification, the medium-term value of the real exchange rate is a function of three fundamentals: the terms of trade (*TOT*), net foreign assets to GDP ratio and some measure of the Balassa-Samuelson effect (*BS*):

$$rer_t^{MT} = \vartheta_0 + \vartheta_1 bs_t + \vartheta_2 b_t + \vartheta_3 tot_t, \quad (27)$$

where  $\vartheta_i > 0$  for  $i=1,2,3$ . We also show that if the openness of the country concerned is not constant over time, the relationship between the real exchange rate and net foreign assets to GDP ratio is non-linear. For that reason we argue that the ratio of net foreign assets to trade value should be used as an explanatory variable in single-equation models for the real exchange rate, as in Faruquee (1995). Finally, we demonstrate that if our specification of the foreign trade model is correct, the inclusion of the terms of trade into a set of explanatory variables in the specification of the BEER model might lead to coefficients indeterminacy.

We start the derivation of the reduced form-equation for the real exchange rate by combining equations (21) and (22) and calculating the dynamics of the target current account:

$$\Delta tca_t = (\Delta p + \Delta y - \rho - \kappa) \Delta b_{t-1}. \quad (28)$$

We proceed by assuming that the income balance is equal to interest payments on net foreign assets, and thereby:

$$\Delta ca\_inc_t = i \times \Delta b_{t-1}, \quad (29)$$

where  $i$  stands for nominal interest rate. Finally, on the basis of relationships (12) and (13) we compute that the terms of trade are a linear function of the real exchange rate:

$$tot_t = (\gamma - \delta) rer_t. \quad (30)$$

Substituting the three above expressions to equation (25) yields the following relationship:

$$[1 - \varphi_3(\gamma - \delta)] \Delta rer_t = \varphi_1 (\Delta ypot_t - \Delta yfpot_t) + \frac{\varphi_2}{\tau_t} \Delta b_{t-1} + \varphi_3 \Delta tot_t + \frac{\varphi_4}{\tau_t} \Delta ca\_tr_t, \quad (31)$$

where  $\varphi_1 = (\alpha_1 - 1) / \lambda$ ,  $\varphi_2 = (\rho + \kappa + i - \Delta p - \Delta y) / \lambda$ ,  $\varphi_3$  is undetermined and  $\varphi_4 = 1 / \lambda$ . As a result, the reduced form equation for the real exchange rate is:

$$rer_t = \varphi_0 + \frac{1}{1 - \varphi_3(\gamma - \delta)} \left[ \varphi_1 (ypot_t - yfpot_t) + \varphi_2 \frac{b_{t-1}}{\tau_t} + \varphi_3 tot_t + \varphi_4 \frac{ca\_tr_t}{\tau_t} \right]. \quad (32)$$

Assuming that the relative potential output is a good approximation of the Balassa-Samuelson effect<sup>7</sup>, and that the trade openness and current transfer balance are stable over time, the above expression is the same as the one proposed by Clark and MacDonald (eq. 27). However, as the parameter  $\varphi_3$  is not uniquely determined, any estimates of the coefficient  $\vartheta_3$  different from zero might result in an erroneous interpretation of estimates for  $\vartheta_1$  and  $\vartheta_2$ , the parameters of the BEER model described by relationship (27).

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<sup>7</sup> In his seminar paper Balassa (1964) uses relative output per capita as a good approximation of relative productivity.

## 7. Conclusions

The application of the FEER model in modeling central and eastern European economies has been as far considered subject to many shortcomings, primarily due to the fact that changes in productivity were not accounted for in this approach, whereas the catching-up process is one of the central arguments of the equilibrium exchange rate appreciation in CEECs. We have addressed this issue by including potential output in the specification of the foreign trade equations. As a result, contrary to the standard FEER specification, in our model real convergence is leading to an appreciation of the real exchange rate. This finding is consistent with an extensive literature applying the BEER concept in the analysis of CEECs currencies.

Moreover, in this paper we have shown that by including potential output into the specification of the foreign trade equations of the FEER model one can derive the reduced form-equation for the real exchange rate that is encompassing the standard specification of the BEER relationship, as proposed by the Clark and MacDonald (1998). We claim that if the openness of the country concerned is not constant over time, the single-equation model for the real exchange rate should take the ratio of net foreign assets to trade value as one of the explanatory variables. Finally, we have shown that if foreign trade prices are a weighted average of foreign and domestic prices then the inclusion of the terms of trade into a set of explanatory variables in the specification of the BEER model might lead to coefficients indeterminacy. As a result, we argue that the BEER and our version of the FEER should be considered as substituting approaches to calculate equilibrium exchange rates.

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