CAPITAL ENHANCED EQUILIBRIUM EXCHANGE RATE IN THE CZECH REPUBLIC AND HUNGARY

Emil Adámek¹

¹VŠB – Technical University of Ostrava, Faculty of Economics, Sokolská tř. 33, 70121 Ostrava, Czech Republic
Email: emil.adamek@vsb.cz

Abstract. There exist a lot of approaches to calculate equilibrium exchange rate (EER). This paper deals with so called Capital Enhanced Equilibrium Exchange Rate in the Czech Republic and Hungary. Cointegration analysis is used to verify theoretical approaches to real data. The aim of this article is to construct model of equilibrium exchange rate based on the Purchasing Power Parity theory (PPP) and the Uncovered Interest Parity theory (UIP) in these countries. Significant relationship between selected variables was found in both the Czech Republic and Hungary; and models of EER were made. Periods of undervaluated and overvaluated exchange rate was described as well. It was found that exchange rates were overvaluated in most periods.

Keywords: Equilibrium Exchange Rate, CHEER, the Czech Republic, Hungary, Cointegration

Jel classification: C22, E52, E58

1. Introduction

Komárek and Motl (2012) declare four reasons why central bank should monitor estimates of equilibrium exchange rate. The first one is to gather knowledge for monetary policy implementation. The second motive is that knowledge of EER level helps central banks to set policy instruments. The third reason is that exchange rate is a key factor to evaluation competitiveness of whole economy. The last reason, which is very important especially in the case of the Czech Republic and Hungary, is that information about EER is crucial factor while setting central parity or conversion ratio before joining common monetary union. There exist a lot of approaches to calculate equilibrium exchange rate (EER). For papers summarizing these approaches see e.g. Driver and Westaway (2004), MacDonald (2000) or Égert and Halpern (2006). This paper deals with so called Capital Enhanced Equilibrium Exchange Rate (CHEER as MacDonald (2000) dubbed it). This approach combines two classical economy theories – the Purchasing Power Parity theory (PPP) and Uncovered Interest Parity theory (UIP). Theoretical backgrounds are applied on two Central European countries – the Czech Republic and Hungary.

The aim of this article is to construct a model of equilibrium exchange rate based on both PPP and UIP in these countries. Theories of PPP, UIP and CHEER are summarized in chapter 2. You can find review of empirical literature in Section 3. Data and methods used in the paper are described in Section 4. Output of empirical models is presented in Section 5. Conclusions remain last Section of this paper.

2. Theoretical background

This paper is based on three economic theories - the Purchasing Power Parity theory, the Uncovered Interest Parity theory and its combination - the Capital Enhanced Equilibrium Exchange Rate. Each of them is described in this Section.

2.1 Purchasing Power Parity theory

PPP is one of the oldest theories explaining development of exchange rate (see Cassel, 1922). It is based on the Law of One Price (LOP). LOP says that each commodity should have the same price after conversion by exchange rate($E$):
\begin{equation}
P_D = p_F \cdot E,
\end{equation}

where \( p_D \) is price of a commodity in domestic economy and \( p_F \) is price of a commodity in foreign economy. PPP then declares that if LOP is valid on all markets at the same time, the price can be replaced by price level \((P_D, P_F)\) as Mandel and Tomšík (2008) state:

\begin{equation}
E = f\left( \frac{P_D}{P_F} \right)
\end{equation}

PPP explains the development of exchange rate caused by international movement of goods and services.

\subsection*{2.2 Uncovered Interest Parity theory}

While PPP deals with international with movement of goods, UIP deals with movement of capital flows between two countries. This condition equalizes the ex-ante risk-adjusted nominal rate of return on domestic and foreign currency assets. As such, the expected change in the nominal exchange rate is determined by the interest rate differential and risk premium as Driver and Westaway (2004) claim. Therefore logarithm of nominal exchange rate in time \( t \) (\( e_t \)) should equal:

\begin{equation}
e_t = e_{t+1} + i_t - i^*_t + \sigma_t
\end{equation}

where \( i \) and \( i^* \) represent nominal interest rate in domestic and foreign economy and \( \sigma \) is the foreign currency risk premium, or while providing zero risk premium as:

\begin{equation}
e_t = e_{t+1} + i_t - i^*_t.
\end{equation}

\subsection*{2.3 Capital Enhanced Equilibrium Exchange Rate}

Capital Enhanced Equilibrium Exchange Rate is one of many concepts to calculate equilibrium exchange rate. It was developed by Johansen and Juselius (1991) and it combines PPP and UIP. This approach is based on presumption that while PPP may explain long-run movements in real exchange rates, the real exchange rate may be away from equilibrium as a result of non-zero interest rate differentials. The approach therefore supplements the nominal UIP condition without risk premium, with the assumption that the expected value of the nominal exchange rate can be predicted using relative prices if PPP holds, as Driver and Westaway (2004) claim. A cointegration relationship is then estimated between relative prices, nominal interest rate differentials and the nominal exchange rate.

\section*{3. Review of empirical literature}

Johansen and Juselius (1991) develop some new test for structural hypotheses in the framework of a multivariate error correction model with Gaussian errors. The tests are constructed by an analysis of the likelihood function and motivated by an empirical investigation of the PPP relation and the UIP relation for the United Kingdom. They create five-dimensional system of equations (two prices,
exchange rates, and two interest rates) to find whether the PPP relation is stationary by itself (without the interest rates) and correspondingly whether the nominal interest rate differential is a stationary process. They find negative answer for the PPP relation, but positive for the interest rate differential. Juselius and MacDonald (2004) use similar techniques in case of USA and Japan. They find that interest rates influence development of exchange rate more that trade with goods and services does. Juselius and MacDonald (2003) combine PPP and UIP in case of Germany and USA. They find slow but significant price adjustment towards sustainable level of exchange rate using cointegration analysis.

4. Data and methods

Firstly, the data are described in this section. Secondly, there is also a discussion why particular data was selected. In the next part of this Section, there is explained which econometric techniques were used and why.

4.1 Data

There are serious discussions about which kind of exchange rate should be explained in case of the Equilibrium Exchange Rate concept. As concerns CHEER approach, it is clear that it should be the nominal one (see Johansen and Juselius, 1991 or Driver and Wastaway, 2004). The question here is if it should be bilateral or effective one. In case of bilateral exchange rate, there is no doubt that the one between each country and euro area should be used, because the euro area is the most significant trade partner for both the Czech Republic and Hungary. Based on cointegration analysis the bilateral exchange rate \(X\) provides better results than the effective one so it was used in this model. The data were gathered from the Eurostat database (Eurostat, 2015) and are expressed as CZK/EUR and HUF/EUR respectively. Another serious discussion deals with which price index should be used. In particular, there are two possibilities – a Harmonised Index of Consumer Prices (HICP) and a Producer Price Ondex (PPI). Both indexes were converted to 2005/1 = 100. Then the difference between domestic and foreign value were computed. \(CP\) then represents a differential between domestic and foreign inflation rate as concerns consumers prices:

\[
CP = \text{HICP} - \text{HICP}^*,
\]

whereas \(PP\) represents inflation differential measured by producers prices. Producer prices are defined as follows:

\[
PP = \text{PPI} - \text{PPI}^*.
\]

The higher values of inflation differential should lead to depreciation of nominal exchange rate, so the coefficient (while bilateral exchange rate is expressed as CZK/EUR or HUF/EUR) of variables related to inflation differential should be positive. As concerns interest rates, both sort run and long run interest rates were included. The short run interest rate’s differential \(IS\) were computed as:

\[
IS = i_{3m} - i_{3m}^*.
\]
where \( i_{3m} \) represents 3-month interest rate in domestic country and \( i_{3m}^* \) denotes 3-month interest rate in euro area. Ten-year government obligations \( (i_{10y}) \) were used to approximate long run interest rates. The long run interest rate’s differential \( (IL) \) were computed as:

\[
IL = i_{10y} - i_{10y}^*,
\]

(8)

where * denotes foreign (euro area). The higher values of interest rate differential should lead to appreciation of nominal exchange rate, so coefficients related to these variables should by negative. All variables (exchange rate, inflation and interest rates) are nominal in this approach. Since CHEER is short run concept, monthly data were used. Data covered 2001/1 – 2015/5 periods.

4.2 Methods

The cointegration analysis was used because of two reasons. The first one is that this analysis was used by most of other authors and it was also suggested by author of this concept; see Johansen and Juselius (1991). The second reason is that all variables are not stationary at levels, but they are stationary in first differences. The estimated equation is therefore:

\[
X = f(PP, CP, IS, IL).
\]

(9)

Nevertheless, some coefficients would be non-significant. Also it is possible to use only one time series representing inflation rate, so in the next steps some elimination methods were used to eliminate non-significant or multi-correlated variables. The eliminated variables were chosen considering results of statistical tests and values such as \( R^2 \) or Schwarz criterion. The final results for both countries are presented in next chapter.

5. Results

Since the cointegration analysis is used, the tests for stationarity were made at first. It is important that at least some of variables (see Clark and MacDonald, 1998) are nonstationary at the levels to find long run equilibrium. Augmented Dickey Fuller test (ADF) described by Dickey and Fuller (1979) were chosen as the most common test for stationarity; and its results are presented in the first part of this Section. After considering stationarity of time series the cointegration analysis can be making. Its results are presented in the second part of this Section.

5.1 Testing of stationarity

The null hypothesis of ADF test says that time series has a unit root. It is clear that all variables are stationary in first difference from Table 1 and Table 2. The variable \( PP \) is stationary even in the levels in both the Czech Republic and Hungary.

<table>
<thead>
<tr>
<th>Table 1. ADF test for the Czech Republic</th>
</tr>
</thead>
<tbody>
<tr>
<td>variable</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>( X )</td>
</tr>
<tr>
<td>( PP )</td>
</tr>
<tr>
<td>( CP )</td>
</tr>
<tr>
<td>( IS )</td>
</tr>
<tr>
<td>( IL )</td>
</tr>
</tbody>
</table>

Source: own calculations
Nevertheless, the KPSS test did not confirm its stationarity and Clark and MacDonald (1998) show, that not necessarily all variables have to be integrated at same level. Based on these reasons variable PP was included in the model even though ADF claims that it is I(0).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level Value</th>
<th>Level Prob.</th>
<th>1st Difference Value</th>
<th>1st Difference Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>-1.7719</td>
<td>0.3935</td>
<td>-9.8615</td>
<td>0.0000</td>
</tr>
<tr>
<td>PP</td>
<td>-8.3644</td>
<td>0.0000</td>
<td>-10.0801</td>
<td>0.0000</td>
</tr>
<tr>
<td>CP</td>
<td>-2.1847</td>
<td>0.2127</td>
<td>-11.8690</td>
<td>0.0000</td>
</tr>
<tr>
<td>IS</td>
<td>-2.6240</td>
<td>0.0901</td>
<td>-10.6976</td>
<td>0.0000</td>
</tr>
<tr>
<td>IL</td>
<td>-1.9668</td>
<td>0.3014</td>
<td>-10.3693</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Source: own calculations

### 5.2 Cointegration analysis

As already mentioned above, the best individual models for both countries were estimated separately, based on results of statistical test. In both cases VECM was successfully made with 1 lag included in. The variable CP turned out to be non-significant in both models. Model with short run interest rates provides better results for the Czech Republic, whereas long run interest rates are better approximation of interest differential in case Hungary. As concerns the Czech Republic, the best model would be:

\[
X = 39,454 + 160,233 PP*** - 14,041 IS* \\
(15,2511) \quad (8,108)
\]

where *** represents significance at 1 % level and * means significance at 10 % level. Values of standard deviations are in brackets. Both variables have expected signs. The vector error term is negative (-0.000239) and significant at 10 % level. The weakness of this model is fact that \( R^2 \) is only 8.17 %. In case of Hungary, the best model is:

\[
X = 414,719 + 1190,33 PP*** - 51,608 IL*** \\
(94,411) \quad (22,558)
\]

where *** represents significance at 1 % level. Values of standard deviations are in brackets. Both variables have expected signs. The vector error term is negative (-0.00239) and significant at 1 % level. The value of \( R^2 \) is 19.73 %, which is much better value than in the case of the Czech Republic.
There are development of both bilateral \((X)\) and equilibrium \((CHEER)\) exchange rate of CZK depicted in Fig. 1. It can be seen that exchange rate was over valued in the Czech Republic in most periods. The development of HUF/EUR and Hungarian \(CHEER\) are depicted in Fig. 2. Also HUF seems to be over valued till 2011. There is obvious under valuation of nominal exchange rate in 2013 and 2014.

6. Conclusion

The aim of this article was to construct model of equilibrium exchange rate in two countries – the Czech Republic and Hungary. It was found that in most period exchange rates of both countries were over valued. In both cases, producer price index seems to be a better approximation of price level. It is fact that it measures prices of tradeable goods better than consumer price index does. Short time interest rates are significant in the Czech Republic, whereas long run interest rates are more important
in case of Hungary. The situation in the CR is really interesting. It looks that interventions made by central bank in the autumn of 2013 led to depreciation of CZK to its equilibrium level computed by CHEER approach. Development of HUF/EUR differs from CZK/EUR since 2011. While the Czech currency was undervaluated all time, HUF become overvaluated.

It is also important to say that the CHEER approach is short run model and it is disputable whether it can explain long run equilibrium or not. It neglects some variables which are used in other approaches (such as productivity differential, investment flows or government spending or debt) as well. Another frequently discussed weakness of this approach is that it deals with nominal exchange rate; while possibly a role of real exchange rate is more important.

7. Acknowledgement

This paper was financially supported within the VŠB - Technical University SGS grant project No. SP2015/115 “Institutional and Monetary Context of Economic Integration of European Countries Today“

References