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Panel Estimations of PPP and Relative Price Models for CEECs: Lessons for Real Exchange Rate Modelling

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Abstract

The paper contributes to the recent empirical literature on real exchange rates in CEECs. Instead of estimating a complete model, the PPP and relative price models (two main components of the real exchange rate) are investigated separately. All empirical tests are conducted in the heterogonous dynamic panel framework. The unbalanced panel includes generally nine CEECs (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic and Slovenia) over 1993-2002. Models are estimated by two econometric methods: FMOLS and PMGE. The trend appreciation of nominal exchange rates deflated with tradables prices is found in most of CEECs. The appreciation was mainly driven by tradables inflation. Formal econometric tests, based on the explicit estimation of constrained coefficients of PPP model, do not support the strong version of relative PPP. This outcome is invariant to the use of bilateral or multilateral exchange rates, different numeraire currency or different specifications of the PPP model with regard to dependent variable. Evidence is provided that the trend appreciation is explained by the non-tradables processing component effect. It is demonstrated that this mechanism plays an important role also in determination of relative prices.

1. Introduction

Determination of exchange rates and defining their equilibrium levels is one of the hotly investigated topics in international macroeconomics. The keen interest in this area is motivated by important policy implications as well as by the fact that some of the issues still remain unresolved. Understanding exchange rate determination, as one of the key macro variables, is essential for analysis and forecasting of any market economy. So far, forecasting of exchange rates has proved a thorny task (Rogoff, 2001) and many controversies over some exchange rate models still prevail (Obstfeld and Rogoff, 2000).

The proliferation of literature on exchange rate economics in the 1990s, as noted by MacDonald (1998), has been largely due to the development and application of more sophisticated econometric and statistical techniques, rather than to any new theoretical advancement. Most of empirical research in this area dealt with developed countries, though very recently empirical papers for transition economies have started to emerge. In particular, exchange rate issues for Central and Eastern European countries (CEECs) have been investigated extensively – for instance: Halpern and Wyplosz (1997) and (2001), De Broeck and Slok (2001), Egert (2002), Fischer (2002), Kim and Korhonen (2002), Drobinsky (2003), Egert (2003), Egert and Lommatzsch (2003), MacDonald and Wojcik (2003), Rahn (2003). The main goal of these papers was to estimate equilibrium exchange rates and measure of the ensuing misalignment – mostly in the context of EMU accession and the choice of euro conversion rates. These studies adopted different approaches in terms of equilibrium exchange rate models as well as econometric techniques, though the dynamic panel estimation methods were prevailing.

The interest in exchange rates topics for transition economies, and for CEECs in particular, has been motivated by several reasons. Given the specific characteristic of the transition period, the exchange rates seem to play a different role than in developed countries (Devereux and Lane, 2001), especially in the context of economic stabilisation (Kowalski *et al.*, 2003). In addition, the transition process makes the definition and measuring of equilibrium exchange rates more complicated as economies are constantly in a state of flux. It also highlights a different importance of some exchange rate effects as opposed to developed countries, for instance due to the scope for productivity catching-up and ensuing

Harrod-Balassa-Samuelson effect. Moreover, data issues seriously constrain estimations possibilities. Transition economies usually suffer more often from macro and microeconomic imbalances and have less developed market mechanisms and institutions. Thus, they are more prone to currency crises and the assessment of exchange rate misalignment and general macroeconomic balance is of key importance for them. In the case of CEECs, additional motivation stems from the need of selecting euro conversion rates upon accession to EMU. In May 2004, ten CEECs are to become members of the European Union (EU) and this will necessitate joining the euro-zone at some point.

Against this background, the paper attempts to contribute to the recent empirical literature on real exchange rates in CEECs. Instead of estimating a complete model, the PPP and relative price models (two main components of the real exchange rate) are investigated separately and related conceptual and data problems are addressed. The paper focuses mainly on testing of the PPP model and providing explanation of the PPP puzzle for CEECs. It also discusses implications of the suggested alternative specification of the PPP model for relative prices model and estimates of equilibrium exchange rates in general. All empirical tests are conducted in the heterogonous dynamic panel framework, estimated with Fully Modified OLS (FMOLS) and Pooled Mean Group Estimator (PMGE) techniques. The panel includes in general nine CEECs (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic and Slovenia) over the period 1993-2002. The exact country and time coverage differs across estimated models and unbalanced panels are most often used. Given the interest in the conversion rates upon EMU accession, estimations are undertaken mostly for exchange rates against the euro. For better understanding of obtained results, panel econometric techniques are briefly described and their interpretation is discussed.

The remainder of this paper is organised as follows. Recent empirical literature on equilibrium exchange rate models for CEECs are briefly presented in Section 2. Then, the basic model of real exchange rate is sketched out in Section 3. Section 4 tests PPP model for CEECs. First, main trends in nominal exchange rates and price indices are described. Then formal econometric testing is pursed followed by investigation of factors causing the deviation from the PPP model. In Section 5, implications of PPP deviations and its alternative model for relative price model are discussed. Section 6 shortly elaborates on econometric panel techniques and interpretation of panel estimates. Finally, Section 7 concludes.

2. Literature review

The issue of exchange rate models and exchange rate misalignments have been investigated extensively and a lot of empirical tests have been performed for advanced countries (see for instance Williamson (1994), Allen and Stein (1995), MacDonald and Stein (1999), MacDonald (2000), and Isard *et al.* (2001)). However, recently more empirical literature for transition economies, and in particular for CEECs, has been emerging. This short literature survey deliberately narrows the number of reviewed papers to those which employed dynamic panel techniques for estimation of equilibrium exchange rates in CEECs.[1] The main focus is on theoretical frameworks of equilibrium exchange rates, exact specification of the models and data problems. The papers described below will be a reference point for further discussion.

Kim and Korhonen (2002) attempted to assess exchange rate misalignments for five CEECs – the Czech Republic, Hungary, Poland, the Slovak Republic, and Slovenia. They adopted the behavioural equilibrium exchange rate (BEER) type of model, where real exchange rate was regressed on GDP *per capita* (proxy for Harrod-Balassa-Samuelson (HBS) effect), gross fixed investment as a share of GDP, government consumption as a share of GDP, and degrees of openness (imports + exports as a share of GDP). As sufficiently long time series for CEECs were not available, the equilibrium exchange rate model was estimated for 29 middle and high-income countries over 1975-1999. Inferences about exchange rate misalignment for CEECs were then based on estimated coefficients. Bilateral exchange rates vs. the US dollar and also real effective exchange rates (but for a smaller sample of countries and shorter period 1980-1999) were used as dependent variables in estimated regressions.[2] Equations were estimated with the PMGE, but as a robustness check the FMOLS was also employed. Both methods rendered the same signs of the coefficients and similar magnitudes. Kim and Korhonen (2002) in their approach avoided explicit estimations of PPP and HBS models, as well as dealing with specific data problems for CEECs. Thus, their measurement of exchange rate misalignment should be treated as very rough approximation that poorly reflects CEECs' characteristics.

[1] For an excellent and extensive survey of equilibrium exchange rate literature for CEECs see Egert (2003).

[2] No information in the paper is provided whether explanatory variables were expressed in relation to foreign country values, and in the case of real effective exchange rates, if they were weighted in addition.

Rahn (2003) also pursued research of equilibrium exchange rates using the BEER framework. He focused on the Czech Republic, Estonia, Hungary, Poland, and Slovenia. Productivity and net foreign asset position were the only two explanatory variables in the real exchange rate model and it was implicitly assumed that PPP held. The relative productivity was proxied by the ratio of CPI to WPI (in relation to a reference country). Such a solution has two main shortcomings. First, it is a very crude classification of tradables and non-tradables as the CPI includes both types of prices. Second, the relative prices could reflect not only the HBS effect but also other mechanisms, like the demand effect (see section 3), and thus is not necessarily a good proxy for relative productivity. Real exchange rates and relative productivity variables were weighted averages of data for main trading partners (the country sample was extended by Lithuania, Latvia, Bulgaria, Romania, the Slovak Republic, twelve members of the euro zone, the United States, the United Kingdom, Japan, and Russia). Rahn (2003) started the analysis with country-specific time-series estimations and then estimated also panel models. The signs of estimated coefficients were the same both for time series and panel models but their magnitude differed with lower levels (in absolute values) for panel estimates. Regressions were run for quarterly data covering in general the period 1990 until first quarter of 2002. For time series estimations the Johannes cointegration method was employed and for panel models FMOLS. In addition to BEER framework, permanent equilibrium exchange rate (PEER) model was estimated. All analysed countries were found to have overvalued real exchange rates, however, with different degree.

MacDonald and Wojcik (2003) investigated equilibrium real exchange rate rates for Estonia, Hungary, Slovak Republic and Slovenia. They used bilateral exchange rates versus the Austrian schilling and quarterly data for a balanced panel covering the period 1Q1995-1Q2001. In their basic BEER model, the real exchange rate was explained by the HBS effect, relative NFA as a percentage of GDP (vs. Austria), and real interest rate differentials. The HBS effect was calculated explicitly, unlike in the two previous papers, as ratio of labour productivity in the tradable and non-tradable sectors, where labour productivity in the corresponding sectors was computed as value added over employment. MacDonald and Wojcik employed panel Dynamic OLS estimation method with one quarter time lag and lead. In addition to basic BEER estimations, MacDonald and Wojcik tested the role of the distribution sector, the demand effect (proxied by private and total consumption as a share of GDP), wages channel in the HBS model as well as the role of regulated prices. The results of the unconstrained

panel estimation of the HBS effect (with productivity in tradables and non-tradables regressed separately) and country-specific for Slovenia and Estonia gives support to the hypothesis about the distribution sector (see Section 4.3). They also found a small but significant demand effect for the model of relative prices, and evidence of importance of a wage channel in the HBS effect.[3] The incorporation of regulated prices variable proved to increase explanatory power of the model and made productivity variables insignificant.

Egert and Lommatzsch (2003) also conducted a diversified investigation of equilibrium exchange rates for CEECs. Their prime objective was to demonstrate variations in equilibrium exchange rate estimates due to different estimations methods and different model specifications. They started with a generic model in the BEER framework, which included the following explanatory variables: labour productivity (different proxies were used), differential in regulated prices (vs. Germany), real interest rate differential, foreign debt as percentage of GDP, openness, terms of trade, government debt to GDP. In addition, Egert and Lommatzsch introduced a new theoretical concept explaining real appreciation of CEECs' currencies (in particular of real exchange rates defeated with tradables prices). According to their model, the real exchange rate appreciates due to the improvement in technology of tradables (proxied with labour productivity in tradables). They pursued both time-series country-specific (Engle-Granger, DOLS, ARDL and Johansen procedure) and panel estimations (pooled and fixed effect OLS, DOLS, PMGE and MGE). Time series estimations were done for the Czech Republic, Hungary, Poland, Slovakia, and Slovenia generally over 1993-2002, whereas the panel models were augmented by data for Croatia, Estonia, Latvia, and Lithuania over 1995-2002. The dependent variable was the bilateral exchange rate vs. the German mark. Their findings demonstrated significant differences in country-specific and panel estimations, not only in terms of the size of the misalignment, but in its direction as well. Egert and Lommatzsch explained this outcome by omitted country-specific factors in panel estimations and sensitivity of results to estimation method as well as sample period.

This very short and selective literature survey demonstrates that empirical estimations of real exchange rates for CEECs were very heterogeneous. This

[3] This is done by augmenting the HBS model with a wage variable and testing significance of productivity variables. If the latter become insignificant, it means that HBS effect in fact works through wage equalisation – see MacDonald and Ricci (2001).

refers not only to the specific forms of underlying exchange rate models, but also to variables definitions as well as country and time coverage. This feature makes comparison of the results difficult. On the other hand, it can be indicative of the scope of possible outcomes. Finally, it should be noted that most of the reviewed papers, but Egert and Lommatzsch (2003), assumed implicitly that the PPP model held.

3. The exchange rate model

Most of empirical models of exchange rates deal with real exchange rates deflated with consumer prices. Given that price levels in a home country and abroad (the latter denoted with *) are defined as a weighted sum of prices of tradables (p_T) and non-tradables (p_{NT}):[4]

$$p = (1-\alpha)\, p_T + \alpha\, p_{NT} \qquad 0< \alpha <1, \qquad (1)$$

$$p^* = (1-\beta)\, p_T^* + \beta\, p_{NT}^* \qquad 0< \beta <1 \qquad (2)$$

(where α and β are the corresponding weights), the standard real exchange rate (q) formula is given by:

$$q = e + p^* - p \qquad (3)$$

where e denotes nominal exchange rate. Rearranging equations (1)-(3) yields:

$$q = q_T + \beta(p_{NT}^* - p_T^*) - \alpha(p_{NT} - p_T) \qquad (4)$$

where q_T is the real exchange rate for tradables only ($q_T = e + p_T^* - p_T$). Equation (4) is a basic real exchange rate definition employed in many theoretical and empirical research papers on exchange rates. This form highlights two main effects that are at work in the determination of real exchange rates. The first refers to the PPP model and the latter to model of relative price determination.[5]

[4] All variables are expressed in logarithms.

[5] For the sake of simplicity in many papers it is assumed that $\alpha = \beta$. This means identical consumption patterns and consequently the same weights in the CPI baskets between tradables and non-tradables.

The PPP model is based on the law of one price which is extended to a basket of tradable goods. According to the absolute PPP paradigm, a nominal exchange rate of any two currencies should reflect closely the relative purchasing powers of the two monetary units represented by national price levels (Isard *et al.*, 2001). The strong version of PPP requires that the nominal exchange rate is exactly equal to the ratio of price levels of tradables in the two countries (i.e. have a unit elasticity – see equation 5). Consequently, the real exchange rate must be stationary and equal to one. The weak version of PPP does not require the unit elasticity and entails only that the real exchange rate reverts to some constant mean (Pedroni, 2001). PPP is a building block of many exchange rates models and is one of the key assumptions of the HBS framework.

The relative prices are usually explained by the Harrod-Balassa-Samuelson (HBS) effect.[6] This model demonstrates how, under the assumption of economy-wide wage equalisation, higher relative labour productivity (tradables vs. non-tradables) leads to higher relative prices (non-tradables vs. tradables). The theoretical elaboration of determination of relative prices was put forward in a general equilibrium framework by Bergstrand (1991). In his model, relative price levels are explained, in addition to HBS model, by Heckscher-Ohlin (HO) relative-factor-endowment effect, and the demand effect. The HO hypothesis in Bergstrand model links factor endowments and relative prices. Given the assumption that production of tradables (non-tradables) is more capital (labour) intensive, the HO model suggests relatively higher prices of non-tradables in countries that are relatively capital abundant (i.e., have comparative advantage in production of capital-intensive goods – under the assumption these are tradables). In addition to the supply-side mechanisms, a demand effect has been put forward. This notion refers to the Linder-type hypothesis (Linder, 1961), which relates the structure of consumption and wealth (proxied by GDP *per capita*). The higher the income, the larger the bias towards consumption of non-tradables (mainly services). These three mechanisms of relative price determination could be applied to the case of price dynamics as well as extended to a two-country framework (or multi-country), where all variables are expressed in relation to the other country(ies) – such as in equation (4).

The empirical investigation of real exchange rates in CEECs will begin with testing of the PPP hypothesis and then the determination of relative prices will be studied.

[6] Harrod (1933), Balassa (1964), and Samuelson (1964).

4. The PPP model for CEECs

4.1. Stylised facts on PPP in CEECs

Prior to formal empirical testing of the relative PPP hypothesis[7] in CEECs, main trends in their real exchange rates deflated with prices of tradables and tradables price indices over 1993-2002 will be analysed (see Appendix A). The prime focus will be on the real exchange rates of domestic currencies against the euro (i.e. the price of one euro expressed in terms of domestic currencies).[8] Because the PPP model should work in principle only for goods that could be traded internationally, the real exchange rate will be deflated with producer prices in manufacturing. This measure is believed to be the best readily available proxy for prices of tradables.[9]

In Bulgaria, apart from two periods of real depreciation of the lev against the euro (in 1994 and 1996-1997) there was a clear appreciation trend. After the financial crisis in 1997 and fixing the lev to the German mark (in 1999 to the euro), the appreciation of the real exchange rate stemmed primarily from higher inflation of Bulgarian tradables prices as compared to the euro zone.

In the Czech Republic, there was also an appreciation trend in the real exchange rate of the koruna against the euro with few exceptions in 1997 and 2002. Between 1993 and 1997 changes in nominal exchange rate of the euro where in check and the positive tradables inflation differential between the Czech Republic and the euro zone was the main cause of the real appreciation. After the financial crisis in 1997, the observed trends reversed: nominal exchange rate of the koruna against the euro was appreciating and the inflation differential approached zero and in 2003 even turned negative.

In Estonia due to early fixing of the kroon to the German mark (in 1999 to the euro), developments in real exchange rate were largely dominated by changes in inflation, though before 1999 some changes in the kroon exchange

[7] Relative PPP refers to price indices as opposed to absolute PPP, where the condition is defined in terms of price levels.

[8] An increase in the exchange rate means a depreciation of domestic currency. The euro exchange rate prior to 1999 refers to the synthetic euro exchange rate as calculated by the ECB.

[9] See Section 4.3. In case of Bulgaria, due to lack of data, the PPI for total industry was used. In all analysed countries, however, these two price indices (the PPI for the industry and for manufacturing only) were very similar.

rate against the synthetic euro played a role as well. Until 1999, prices of tradables in Estonia tended to grow faster than in the euro zone, though the difference was gradually declining. Afterwards, no clear trend in tradables inflation differential was evident. As a result of these developments the real exchange rate stabilised somewhat starting from around 1997-1998.

In Hungary, the real euro exchange rate for tradables followed a clear appreciation trend with the two short periods of relative stabilisation in 1996/1997 and 2001/2002. The real appreciation was mainly attributable to positive tradables inflation (until 2001) as nominal exchange rate of the euro exhibited a sustained depreciation trend with some reversal in 2002. As in the case of Estonia the difference in inflation rates for tradables was on the decline.

In Latvia, the trend appreciation lasted until around 1999. To some extent this stemmed from higher inflation of tradables in comparison to the euro zone (only up to around 1997/1998) and to nominal appreciation of the lat against the euro in 1993, 1997-1998 and 1999/2000. Afterwards, changes in the real exchange rate as well as in inflation differential were two-sided.

In Lithuania, the real exchange of the litas against the euro continued to appreciate until 2000 and only then stabilised due to fixing of the nominal exchange rate to the euro[10] (in February 2002) and equalisation of growth rates in tradables inflation with the euro zone. Until 1998, it was clearly higher inflation (than in the euro zone), which caused this appreciation, but afterwards this was driven mainly by nominal appreciation. At the turn of 1999/2000 there was a period of increases in PPI which could be attributed to the increase in oil prices as oil production and products of thereof constitute a significant part of manufacturing output (and consequently these prices have had substantial weight in the PPI basket).

In Poland until the end of 1999, the real exchange rate did not exhibit any trend and was mean reverting. The nominal depreciation of the zloty against the euro was accompanied by constant though declining positive differential in tradables inflation vs. the euro zone. After 1999 the inflation differential approached zero but nominal exchange rate started to drive the appreciation of the real exchange rate.

In the Slovak Republic, the nominal exchange rate against the euro was largely mean reverting over the whole period under investigation with a depreciation of the mean in 1999. At the same time inflation deferential was positive and fairly constant from 1996 to the end of 2001. Afterwards it

[10] Previously the litas was fixed to the US dollar.

approached zero. Consequently, there was a constant real appreciation in the exchange rate with a break in 1999.

In Slovenia the real exchange of the euro was fluctuating around a constant mean though with long periods of diverting from the mean and with large peaks and troughs. This was accompanied by fairly constant inflation differential for tradables prices and constant depreciation of the nominal exchange rate, which was the deliberate exchange rate policy of Slovenian authorities.

To sum up, for most observations between 1993 and 2002 there was a clear appreciation trend in the real exchange rates of domestic currencies against the euro deflated with tradables prices in CEECs. Poland and Slovenia were the main exceptions. This stemmed (at least in the initial phase) from higher domestic tradables inflation than in the euro zone as nominal currencies were fixed or depreciated at a slower rate. As in most CEECs the convergence of inflation rates for tradables was evident in recent years, in few cases the real appreciation was explained by the appreciation of nominal exchange rates – mostly evident in the Czech Republic, Poland and Hungary. In addition, a close unconditional correlation between CEECs' and euro-zone's tradables inflation was observed.

Although the real appreciation was driven mainly by inflation differential (at least in the initial period), the pattern of changes in the real exchange rate was dominated by volatility of nominal exchange rates – mostly evident for countries with more flexible exchange rate regimes (Poland, the Czech Republic, and the Slovak Republic), but also for Lithuania and Latvia that have been pursuing a fixed exchange rate policy.[11] Thus, the close correlation of nominal and real exchange rates observed in developed economies[12] is also evident in CEECs.

The above observations of a clear appreciation trend of real exchange rates against the euro deflated with tradables prices in CEECs may seem to be at odds with the relative PPP hypothesis.[13] Formal test of the PPP model are discussed in the next section.

[11] For these two countries domestic currencies were not pegged to the euro – in Lithuania litas became pegged to the euro only in February 2002 and before it was pegged to the US dollar; and in Latvia the lat has been pegged to SDR.

[12] Demonstrated among others by Engel (1999).

[13] The recent consensus on PPP theory suggests that this is a very long phenomenon and the speed of convergence is very slow (for developed countries between three and five years – Rogoff, 1996). Thus, it could be claimed that the analysed period is too short to uncover the long-term PPP behaviour or that the observed appreciation trend is in fact a transition towards the PPP equilibrium.

4.2. Econometric tests of PPP in CEECs

The empirical literature on PPP testing is vast and generally two approaches have been distinguished. The first deals with testing stationarity of a real exchange rate. Stationarity means that the real exchange rate reverts to a constant mean. This property is usually analysed using time series or panel unit root tests.[14] There are a lot of controversies over unit root tests and none of them is ideal (see Maddala and Kim, 1998). Recently, panel unit root tests attracted a lot of attention and they have been extensively used in PPP testing.[15] The unit-root approach to PPP testing was applied among others by Parsley and Wei (1995), Frankel and Rose (1996), MacDonald (1996), Bayoumi and MacDonald (1998), and Chortareas and Driver (2001). These tests are appropriate for testing only the weak version of the PPP hypothesis.

Given the visual inspection indicating clear trends in the real euro exchange rates for CEECs and inherent problems with unit root tests as well as their interpretation,[16] no formal testing of stationarity will be conducted. Instead the second method of PPP tests will be pursued. It boils down to a direct estimation of the coefficients for the following equation:

$$e = \alpha_1 p_T - \alpha_2 p_T^* \qquad (5)$$

If the coefficients (α_1 and α_2) in equation (5) – the definition of the nominal exchange rate (e) – are equal to [1,-1], then the real exchange rate (q – as in equation 3) will be constant and equal to one. This is the so called strong version of relative PPP.

In practice, equation (5) can be also estimated with a homogeneity restriction (i.e., restricting the coefficients on prices to be the same). The former approach seems to be more universal as it allows for explicit testing of the homogeneity restriction[17] and could shed more light on the divergence from the

[14] There are numerous tests available, for instance Dickey and Fuller (1979), Phillips and Perron (1998), Elliot *et al.* (1996), Kwiatkowski *et al.* (1992), or Ng and Perron (2001) for times series, and Breitung and Meyer (1994), Levin and Lin (1993), Im *et al.* (1996), or Pedroni (2001) for panel data.

[15] A good survey of unit root tests could be found in Chapter 4 in Maddala and Kim (1999) or Chortareas and Driver (2001). The latter describes their application to PPP investigation and their results.

[16] Especially in the case of panel unit root tests – see Pesaran (2000). The usual null hypothesis of these tests is joint non-stationarity of the real exchange rates. Consequently, rejection of the null hypothesis could mean that only one of the tested series is stationary.

[17] More precisely, the symmetry and proportionality condition.

PPP model, if this is the case. This approach was applied among others by Moon and Perron (2002). They stressed that in this model the PPP hypothesis is the null hypothesis unlike in most unit-root approaches to PPP testing,[18] where if the null hypothesis of real exchange rate nonstationarity (i.e. the condition against the PPP model) cannot be rejected, then it is unclear whether that is because PPP does not hold or because the selected test has low power. On the other hand, testing of the restricted PPP model was pursued among others by Pedroni (2001) and Taylor (1996).

In addition to homogeneity restriction, the specification of equation (5) can be further complicated by the choice of dependent variable. It is often the case, that the PPP framework is interpreted as a model of exchange rate determination – like posed by equation (5). However, in general the PPP framework explains international arbitrage only. Therefore, the PPP could be interpreted also as a model of domestic or foreign price determination (only for tradables). This distinction has important consequences for empirical testing of PPP as it relates to the issue of exogeneity of variables. The very simple theoretical framework of the PPP model does not indicate which variable should be dependent. For time-series estimations, this issue could be addressed in the VAR framework and exogeneity of variables could be tested formally. However, in the case of panel models this cannot be easily done. Therefore, other information on the tested variables should be used in order to determine the most appropriate specification of the PPP model.

The nominal exchange rate for some CEECs was a predetermined or controlled variable – either due to adoption of a *de facto* fixed or crawling peg exchange rate regime.[19] On the one hand, under the fixed exchange rate regime, it does not make sense to use the nominal exchange rate as a dependent variable in time series estimations as it is simply a constant. On the other hand, under more flexible exchange rate regimes, nominal exchange rates tend to be very volatile and difficult to predict.[20] Given both arguments, the nominal exchange rate is not a good candidate for a dependent variable in the PPP model for CEECs.[21] The same should apply to foreign prices of tradables. CEECs are

[18] With some exceptions, like in the case of unit root test due to Kwiatkowski *et al.* (1992).

[19] Changes in exchange rate regimes were quite frequent in some CEECs. See Rawdanowicz (2003) for a brief description of exchange rate regimes in this region.

[20] This relates to the famous finding of Meese and Rogoff (1983) that out-of-sample forecasts based on the actual values of explanatory variables of several exchange rate models were outperformed by random walk forecasts in the short-run (over 1 to 12-month horizon).

[21] Such an approach is justified only if one is convinced that the volatility of nominal exchange rate is not driven by volatility of prices (home or abroad).

small economies and do not have enough market power to influence foreign prices (in this particular application proxied by the euro-zone prices). Given these considerations and the potential problem of exogeneity, the following specification of equation (5) seems most appropriate in the case of CEECs:

$$p_T = \beta_1 e + \beta_2 p_T^* \quad (5a)$$

Estimations of PPP models were conducted for the unbalanced panel of nine CEECs (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic, and Slovenia) covering generally the period 1993-2002. *e* is the nominal euro exchange rate in units of domestic currency (i.e. domestic price of one euro). Prices are proxied by producer prices in manufacturing.[22] For the sake of a robustness check, models will be estimated by two methods for heterogeneous dynamic panels: Fully Modified Ordinary Least Squares (FMOLS) due to Pedroni (2001) and Pooled Mean Group Estimator due to Pesaran *et al.* (1999).[23] In order to secure sufficient number of degrees of freedom the restricted version of model (5a) will be estimated only. The estimates of these two methods should be interpreted as long-run coefficients (cointegration vector).[24] Therefore, they are more appropriate for inferring about the strong version of the PPP hypothesis as coefficient restrictions could be tested formally.

The estimated coefficient of model (5a) turned out to be below one, though in the case of FMOLS estimator the coefficient was not statistically different from one (see Table 1). Thus, the PMGE estimation does not support PPP hypothesis and indicate a depreciation bias, whereas the FMOLS estimation confirms the PPP hypothesis. Both these findings are at odds with the evidence presented in Section 4.1. An analysis of country specific results provides some explanation behind this outcome. Under the FMOLS method, the estimated coefficient for Lithuania was negative and significant (for Latvia only negative). This could be hardly reconciled with the nominal exchange rate model. In the case of Lithuania, this peculiar result could be attributable to the increases in producer prices in manufacturing due to soaring oil prices in 1998-1999.[25] A further

[22] PPP models were also estimated for the PPI for entire industry (i.e. including mining as well as gas, water, and electricity supply sectors). They render similar results and will not be reported here. In the case of Bulgaria, due to lack of the PPI for manufacturing, prices for total industry were used (See Appendix C).

[23] See Section 6 for description of these methods. Also results for the Mean Group Estimator (MGE) are provided in tables as reference values, but are not discussed in the text.

[24] Though no formal testing of cointegration is pursed.

[25] The differences in the goods baskets among countries used for calculations of PPI indices (in this case due to higher share of oil products in Lithuania) could be the reason for this peculiar outcome and in general for the observed deviation from PPP.

analysis of country-specific cases shows that the coefficient for Slovenia is below one, though it is not statistically different from one. In this case we have the confirmation of the PPP model. This could stem from the deliberate exchange rate policy of permanent nominal devaluation of the Slovenian tolar. For other countries, however, the estimated coefficients turned out significantly higher than one, indicating the appreciation bias.[26] FMOLS panel coefficients are mean average of country-specific results and thus are sensitive to outlier estimates (like the mean group estimator discussed in Pesaran *et al.* (1999)). In order to check the scope of bias due to specific outcome for Lithuania, the model (5a) is re-estimated excluding this country.

Table 1. PPP test – model (5a)

	FMOLS estimates	PMGE estimates	MGE estimates
Dependent variable	PPIM	PPIM	PPIM
Explanatory variables			
PPP (eur + ppim_eur)	0.991 (39.487)	0.950 (38.510)	0.800 (5.969)
Error Correction (Phi)		-0.086 (-4.551)	-0.123 (-5.773)
No. of countries	9	9	9
No. of quarters by countries	37 42 39 34 40 40 42 34 39	33 38 35 30 36 36 38 30 35	33 38 35 30 36 36 38 30 35
Lag truncation/maximum lag	4	4	4

Notes: t-ratios in parentheses. Countries included in the panel: BUL, CZE, EST, HUN, LAT, LIT, POL, SLK, and SLO. For definitions and sources of variables see Appendix C.

Table 2. PPP test – model (5a) excluding Lithuania

	FMOLS estimates	PMGE estimates	MGE estimates
Dependent variable	PPIM	PPIM	PPIM
Explanatory variables			
PPP (eur + ppim_eur)	1.269 (42.630)	0.952 (39.037)	0.915 (7.869)
Error Correction (Phi)		-0.088 (-4.107)	-0.126 (-5.274)
No. of countries	8	8	8
No. of quarters by countries	37 42 39 34 40 42 34 39	34 39 36 31 37 39 31 36	34 39 36 31 37 39 31 36
Lag truncation/maximum lag	4	3	3

Notes: t-ratios in parentheses. Countries included in the panel: BUL, CZE, EST, HUN, LAT, LIT, POL, SLK, and SLO. For definitions and sources of variables see Appendix C.

[26] Though for Poland, like in Slovenia, it was not statistically different from one. Thus, the estimates for Slovenia and Poland are consistent with the observed trends in exchange rates and prices (see Section 4.1).

The exclusion of Lithuania proved to have a downward bias on the panel estimates in the case of FMOLS estimations, but changed very little estimates under the PMGE (see Table 2). Summarising, both methods of estimations reject the strong version of PPP, but only under the FMOLS the appreciation bias was confirmed.

To demonstrate sensitivity of the coefficients to the selection of dependent variable in the PPP model, two remaining specifications (with the nominal exchange rate and foreign prices as dependent variables) are presented in Table 3 (only for FMOLS method). They clearly demonstrate that the coefficients are significantly lower than one and lower than the estimates of model (5a). These results would suggest an even further deviation of the PPP and the bias towards real appreciation of the exchange rates against the euro in CEECs. This especially applies to the model, where manufacturing prices in the euro zone are the dependent variable. This result is not surprising as exports from CEECs constitute only a small share of total goods turnover in the euro zone. Hence, it would be strange, if changes in prices in CEECs corrected for changes in nominal exchange rates would have significant impact on prices in the euro zone.[27] The above results prove that the specification of the PPP model does matter for empirical results of PPP tests.[28]

Table 3. PPP test – alternative specification of dependent variable

	FMOLS estimates	FMOLS estimates
Dependent variable	EUR	PPIM_EUR
Explanatory variables		
PPP (ppim – ppim_eur)	0.426 (32.543)	
PPP (ppim – eur)		0.335 (27.099)
No. of countries	9	9
No. of quarters by countries	37 42 39 34 40 40 42 34 39	37 42 39 34 40 40 42 34 39
Lag truncation	4	4

Notes: t-ratios in parentheses. Countries included in the panel: BUL, CZE, EST, HUN, LAT, LIT, POL, SLK, and SLO. For definitions and sources of variables see Appendix C.

[27] This could be reinforced with some theoretical arguments in favour of pricing-to-market practices in the euro-zone market.

[28] It should be noted, however, that the diagnostic tests in PMGE (not reported here) have not proved superior statistical properties of any specification of the PPP model (i.e. in all specifications there were some problems with standard diagnostics).

4.3. Explaining the PPP puzzle

Given clear indications of the appreciation trends in q_T, the failure of finding evidence for the strong version of PPP should not be surprising. Apart from the fact of relatively short period of investigation (in view of long-term deviations from PPP found for developed countries) there are a number of potential factors undermining the strong version of PPP model or causing problems with testing it. The recognition of these issues is essential for understanding of the exchange rate determination in CEECs.

The most commonly quoted problems with testing the PPP hypothesis (see Rogoff (1996) or Cecchetti *et al.* (2000)) relate to transport costs, tariff and non-tariff trade barriers, monopolistic practices for pricing to segmented markets, imperfectly competitive markets where changes in prices are costly, differences in indirect taxes, and the distinction between tradables and non-tradables,.

The usual classification of tradables as goods, and non-tradables as services is too crude, though availability of sufficiently disaggregated data limits the manoeuvre in this area. The distinction between tradables and non-tradables is sometimes controversial, though some operationalisation of this concept could be introduced.[29] When dealing with price indices only, more freedom in the construction of tradable and non-tradable categories exists as quite often detailed data on CPI basket is available. However, when calculations of labour productivity for the corresponding classification must be undertaken, this freedom is fairly limited. In this paper, due to data constraints and needs to estimate models with labour productivity for both sectors, tradables prices were proxied by producer prices in manufacturing, and non-tradables with prices of services (according to the domestic CPI definition) – see Appendix C.

Moreover, the "theoretical" distinction between tradables and non-tradables could be changed in practice due to the occurrence of frictions to arbitrage (mainly transport costs and trade barriers). Under no-arbitrage conditions (i.e. price/exchange rate ranges for which there are no incentives for arbitrage) some tradables may in fact become non-tradables. This could lead to non-linearities in the PPP model (see for instance Parsley and Wei, 1995). In the case of CEECs, one could expect some elimination of obstacles to arbitrage, primarily thanks to the gradual abolition of trade barriers envisaged by association agreements with

[29] For instance, De Gregorio *et al.* (1994) define tradables as those sectors for which the export share in total production is larger than 10 per cent.

the EU and for some CEECs by CEFTA trade agreements. However, due to data and conceptual constraints as well as the limited scope of this paper, no formal investigation of this hypothesis will be performed.

Testing of PPP could be made difficult also due to the occurrence of different exchange rate regimes in CEECs. As PPP is based primarily on international arbitrage, it seems more reasonable to expect to find evidence for PPP under fixed exchange rate regimes, than under free floats. The arbitrage is less likely to occur (or occur in a less smoothly manner) when changes in nominal exchange rates are volatile and unpredictable – the usual feature of floating exchange rate regimes. Under these conditions international comparison of prices is more difficult and the arbitrage is more risky. This could lead, in addition to transport cost and trade barriers, to occurrence of no-arbitrage thresholds as a consequence of sunk costs of international arbitrage and ensuing inclination to wait for sufficiently large arbitrage opportunities to engage in trade (Sarno and Taylor, 2002). For instance, Parsley and Wei (1995) find a positive relation between deviation from PPP and nominal exchange rate volatility. Apparently, the hypothesis of differences between exchange rate regimes requires formal testing. Although heterogeneity of exchange rate regimes in CEECs makes them an interesting group for such a test, frequent changes of exchange rate regimes and short duration of any particular regime in some of CEECs make econometric tests difficult to implement (Rawdanowicz, 2003).[30] This particular feature could result in low stability of estimated coefficients of the PPP model and problems with finding firm evidence in favour or against the PPP hypothesis.

In the next subsections, more formal tests of selected alternative hypotheses for the deviations from the strong version of the PPP model will be attempted.

4.3.1. Multilateral exchange rates

The lack of evidence in favour of the strict version of PPP could be also attributable to using bilateral exchange rates and price ratio for only one pair of countries. This approach would be appropriate for a theoretical two-country

[30] In addition, the CEECs with fixed exchange rate regimes are not good candidates for testing of the PPP model with the euro as a numeraire currency. The euro was not a pegging currency for most of the observations in the panel sample (see Section 4.1 and footnote 11). Testing differences between exchange rate regimes would make sense only, if the numeraire currency would be the pegging currency.

model, but in the real world with more diversified trade links this might be a too restrictive assumption. In the context of international price arbitrage, it is more likely that price and exchange rate developments in more than one country have impact on domestic prices of tradables. If this is the case, PPP testing should be done for nominal effective exchange rates and weighted price indices (Alberola *et al.*, 1999). Although, the euro exchange rate used in the above estimations is in fact a weighted exchange rate for the euro-zone member countries, a broader country converge will be tested additionally. Consequently, weighted nominal effective exchange rates[31] and price indices were constructed for nine CEECs. For the sake of simplicity constant weights were based on exports shares in 2001.[32]

Table 4. PPP test – multilateral exchange rates

	FMOLS estimates	PMGE estimates	MGE estimates
Dependent variable :	PPIM	PPIM	PPIM
Explanatory variables			
PPP (ppim_w – neer)	1.206 (33.560)	1.460 (51.924)	1.031 (2.793)
Error Correction (Phi)		-0.144 (-3.135)	-0.199 (-4.451)
No. of countries	9	9	9
No. of quarters by countries	Balanced: 31	Balanced: 28	Balanced: 28
Lag truncation/maximum lag	4	3	3

Notes: t-ratios in parentheses. Countries included in the panel: BUL, CZE, EST, HUN, LAT, LIT, POL, SLK, and SLO. For definitions and sources of variables see Appendix C.

Regressions in the multi-country setup rendered more uniform results for both methods of estimation (see Table 4). The results reject the PPP hypothesis as coefficients are significantly different from one and indicate the appreciation bias (coefficients are higher than one). Like in previous specifications Lithuania stands as an outlier with the negative sign. Focusing on PMGE results, it should be noted that although diagnostic statistics indicate some problems as in the case of bilateral exchange rate estimations, the speed of convergence to the equilibrium (the Error Correction term) is significantly higher (in absolute terms). This could prove that the analysis in a multi-country framework has impact on PPP testing and in general estimation of exchange rate models and seems to be less prone to outlier estimates of bilateral exchange rates.

[31] In this paper, the nominal effective exchange rates are expressed in terms of a unit of domestic currency, i.e. differently to the bilateral nominal exchanges rates. An increase in the effective exchange rate means appreciation. See Appendix C for more details on variable definition.

[32] This is a very simple approach. More sophisticated methods (for instance that take into account competition in third markets) were not feasible due to data constraints. For description of different weighting schemes see Zanello and Desruelle (1997).

4.3.2. Imperfect substitutability of tradables

In the quest for deviations from PPP one could question whether tradables in CEECs and the euro zone are close substitutes (especially that CEECs are technologically less advanced),[33] and whether international arbitrage should be expected at all. The issue of substitutability was addressed among others in MacDonald and Ricci (2002). Testing of the PPP hypothesis would only make sense for goods that are close substitutes. As the coefficients in the models discussed so far turned out statistically significant, such a strong hypothesis (of perfect non-substitutability) does not find support in the data. However, some arguments in favour of some incomplete substitutability (or the ensuing slack in arbitrage) could be gained from the comparison of price levels collected for calculations of PPP exchange rates. In 1999, the PPP exchange rates calculated in terms of the euro for various groups of tradables prices are lower than market exchange rates (i.e. more appreciated) – see Table B.2 in Appendix B. This means that price levels of tradables in CEECs are lower than in the euro zone when calculated according to market exchange rates. Persistent lower price levels could suggest that analysed goods are not close substitutes and do not compete in the same market. A similar comparison of PPP exchange rates per one unit of the Polish zloty and market exchange rates shows that the differences are significantly smaller, though the former are still below market exchange rates (see Table B.1 in Appendix B). This could suggest that it is more likely to observe international arbitrage among CEECs rather than in trade with the euro zone.

Table 5. PPP test – PLN as a numeraire currency

	FMOLS estimates	PMGE estimates	MGE estimates
Dependent variable :	PPIM	PPIM	PPIM
Explanatory variables			
PPP (pln + ppim_pln)	0.817 (35.303)	0.685 (15.940)	0.333 (1.634)
Error Correction (Phi)		-0.091 (-4.341)	-0.147 (-1.809)
No. of countries	8	8	8
No. of quarters by countries	37 42 39 34 40 40 34 39	34 39 36 31 37 37 31 36	34 39 36 31 37 37 31 36
Lag truncation/maximum lag	4	3	3

Notes: t-ratios in parentheses. Countries included in the panel: BUL, CZE, EST, HUN, LAT, LIT, SLK, and SLO. For definitions and sources of variables see Appendix C.

[33] For instance, as proxied by GDP per capita or labour productivity levels.

To check this possibility PPP models with the Polish zloty as a numeraire currency (excluding the euro) are estimated. The obtained results neither supported the strong PPP hypothesis, nor indicated significantly faster speed of convergence (see Table 5). This time, however, a clear indication of a depreciation bias was evident, which is broadly consistent with the behaviour of exchange rates vs. the Polish zloty. Thus, no clear evidence about imperfect substitutability of goods can be gained from these estimations.

4.3.3. Testing non-tradables processing component hypothesis

One conceptual framework that could potentially explain the persistent deviation from PPP caused primarily by tradables inflation differential is the link between prices of non-tradables and tradables.[34] This concept is based on the view that arbitrage in the goods market does not take place at the consumer level as non-tradables (mainly services) contribute to production and distribution of tradables. Consequently prices of tradables include the non-tradables processing component. MacDonald and Ricci (2001) extended the standard HBS model to incorporate this particular mechanism. In their framework, the distribution sector (non-tradables sector that delivers both intermediate inputs to the firms that use them in the final stage of tradables production and final goods to consumers) is separated from other non-tradables and tradables. According to this theoretical model, the increase in relative productivity of the distribution sector (vs. the foreign country) is expected to appreciate the real exchange rate, if the distribution sector delivers goods to the tradable sector (as intermediate inputs) rather than to consumers. MacDonald and Ricci (2001) found evidence for this type of causality in empirical estimations for selected OECD countries over the period 1970-1992. The productivity of the distribution sector was proxied with different variables (total factor productivity and ratio of employees to total employment). They also demonstrated that homogeneity restriction on the relative productivity in the tradable and non-tradable sectors (in a standard real exchange rate model) is rejected. The estimated elasticity for the non-tradables (in absolute values) proved to be higher.

Also Lee and Tang (2003) investigated the issue of non-tradables processing component for developed countries. They focused primarily on regressing real

[34] Egert and Lommatzsch (2003) followed a different rout by devising a model based on technological improvement of tradables.

exchange rates and its two main components (the PPP and relative prices – as in equation 4) on unrestricted relative productivity for tradables and non-tradables and the wage effect. Unlike MacDonald and Ricci (2001), they did not separate the distribution sector from the non-tradables and analysed the non-tradables aggregate as a whole (though did some tests with the productivity of the retail sector). Lee and Tang (2003) assumed that the improvement in non-tradables productivity could lead to the depreciation of the real exchange rate. These theoretical expectations were derived from models of McDonald and Ricci (2001),[35] Benigno and Thoenissen (2002) and Corsetti and Debola (2002). Estimations covered twelve OECD countries over the period 1970-1997 and rendered support to the hypothesis of non-tradables processing component. They tested the hypothesis indirectly by focusing on significance of non-tradables productivity in the equation for q_T and insignificance of the standard HBS specification for relative prices. They have not tested explicitly the effect on the real exchange rate.

So, under the hypothesis of non-tradable processing component (distribution sector), an additional wedge in price levels as well as in inflation may arise. Consequently, it could be difficult to find support for the PPP hypothesis when using in tests the "observed" prices of tradables (i.e. containing the non-tradables processing component). In this context, higher differences between market exchange rates and PPP exchange rates in terms of the euro than in terms of the Polish zloty (discussed in Section 4.3.2) could be attributable to differences in price levels of services (being a proxy for distribution sector) rather than of low substitutability.[36] The latter are smaller among CEECs than when compared to the euro-zone level (see Appendix B).

Although, it would be reasonable to expect producer prices (used in PPP testing in this paper) to be less prone to the non-tradables processing component effect (as they do not reflect final consumer prices), the formal testing of this hypothesis will be pursed.[37] The form of the test will be similar in concept to Lee and Tang (2003). They estimated the real exchange rate deflated with the tradables prices on the relative (domestic vs. foreign) unit labour costs

[35] The variant of MacDonald and Ricci (2001) model, where the distribution sector is more concentrated on delivering goods to consumer than to producers (as inputs for production of tradables) and works via lowering of non-tradables prices.

[36] For elaboration of this issue see Rawdanowicz (2003).

[37] Nevertheless, producer prices could be subject to non-tradables processing component effect as in the case discussed in MacDonald and Ricci (2001), where the distribution sector provide services mainly for production of tradables and not for delivering final goods.

(nominal average wages over labour productivity – ULC) in the tradable and non-tradable sectors. Here the tested model is modified so as domestic prices of tradables are the dependent variable and to augment explanatory variables with the PPP component (like in the specification of the restricted equation 5a).[38] The ULC should capture the determination of tradables and non-tradables prices in the HBS framework, and under the hypothesis of non-tradables price component the ULC for non-tradables should be significantly different from zero. All variables should be positively correlated with the dependent variable.

The estimations by FMOLS[39] gives support to the non-tradables processing component hypothesis as the ULC variable for non-tradables turned out significant (see Table 6, column 2). At the same time the PPP component is also significant and correctly signed, suggesting that some international arbitrage takes place.[40] It should be noted that the coefficient on the PPP term is significantly lower than in the previous estimations of the "pure" PPP models. This could mean that after taking into account the non-tradables processing component, the frictions to international arbitrage are as a matter of fact even greater. However, this result is driven, to some extent, by the outlier estimate for Lithuania. The same finding is confirmed in estimations for multi-country definition of the PPP component (weighted average nominal effective exchange rates and price indices – see

Table 6, column 4). Finally, for the sake of robustness check, the same estimation was done with the Polish zloty as a numeraire currency instead of the euro. The signs and significance of the coefficients are the same though some differences in the magnitude could be noticed. As in previous estimations, heterogeneity of country-specific results was evident.

Finally, it should be noted that the testing of the non-tradables processing component effect sheds more light on determination of tradables inflation,

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[38] Here unit labour costs are not related to foreign country, unlike in Lee and Tang (2003).

[39] PMGE estimations were also undertaken. However, short time series combined with many explanatory variables resulted in high sensitivity of the estimates with regard to the selection of lag order and initial estimates. This makes the results less reliable. Nonetheless, in all specifications the coefficient on ULC in non-tradables proved to be positively signed and significant. Main differences in obtained results concerned the sign and significance of the tradable sector. Moreover, there was indication of significantly higher speed of convergence.

[40] The test of the non-tradables processing component as specified in Lee and Tang (2003) was also carried out (i.e. q_T was regressed on relative – vs. foreign country – labour productivity of tradables and non-tradables and wages). The results confirmed correctness of the sings and statistical significance of the relative unit labour costs for the non-tradables, though the coefficient on the relative unit labour costs in the tradables turned out negative.

however, it does not tackle the problem of nominal exchange rate determination. The PPP component is here interpreted as a channel of international arbitrage, rather than a nominal exchange rate model. This could be an important omission given the fact that the observed trend appreciation in CEECs was in some cases driven by nominal appreciation (see Section 4.1).

Table 6. Test of non-tradables processing component hypothesis (FMOLS estimates)

	Dependent variable	Dependent variable	Dependent variable
Explanatory variables	PPIM	PPIM	PPIM
PPP (eur+ppim_eur)	0.347 (7.040)		
PPP (ppim_w – neer)		0.378 (7.615)	
PPP_PLN			0.167 (9.807)
ULC_T	0.193 (4.208)	0.135 (3.720)	0.020 (5.732)
ULC_NT	0.189 (10.807)	0.204 (9.582)	0.344 (10.171)
No. of countries	7	7	6
No. of quarters by countries	37 39 33 28 33 31 22	31 31 31 28 31 31 22	37 39 33 28 31 22
Lag truncation	4	4	4

Notes: t-ratios in parentheses. Countries included in the panel: CZE, EST, HUN, LIT, POL, SLK, and SLO. For definitions and sources of variables see Appendix C.

5. Implications for equilibrium exchange rate models

The permanent deviation from the PPP model in CEECs and some evidence in favour of non-tradables processing component have important implications for exchange rate models, and in particular for estimates of equilibrium exchange rates. These implications will be discussed below.

First, the clear appreciation trend in the real exchange rates against the euro deflated with tradables prices in many CEECs proves that approximation of real exchange rates (in terms of overall consumer price index) with the ratio of relative prices (non-tradables vs. tradables) is not appropriate. Such an approach does not reflect properly changes in the real exchange rates. A similar argument, for paying attention to shifts in the real exchange rate deflated with tradables prices, was provided in Engel (1999) and Roger and Jenkins (1995). In these papers it was demonstrated that in developed countries the variability of q_T always dominated the variability of relative prices (mainly due to variability of

nominal exchange rates). Thus, the implicit assumption that PPP holds in Kim and Korhonen (2002), Rahn (2003) or MacDonald and Wojcik (2003) may lead to biased estimates of equilibrium exchange rates.

Table 7. Determination of relative prices (FMOLS estimates)

Dependent variable	RP	RP	RP	RP
Explanatory variables:				
RPRO (pro_t-pro_nt)	1.137 (12.434)		0.779 (6.367)	
PRO_T		0.779 (6.367)		-0.096 (-2.514)
PRO_NT		0.607 (3.421)	1.386 (10.556)	0.110 (0.321)
WAGE				0.559 (17.916)
No. of countries	7	7	7	7
No. of quarters by countries	37 39 33 28 33 32 22	37 39 33 28 33 32 22	37 39 33 28 33 32 22	37 39 33 28 33 32 22
Lag truncation	4	4	4	4

Notes: t-ratios in parentheses. Countries included in the panel: CZE, EST, HUN, LIT, POL, SLK, and SLO. For definitions and sources of variables see Appendix C.

Second, as prices of non-tradables were proved to have significant impact on prices of tradables (via non-tradables processing component), the standard modelling of relative prices in the HBS framework is not appropriate. As the prices of tradables are a function of non-tradables prices (the extent of this dependence remain a matter of empirical testing),[41] determinants of non-tradables prices should have a double entry in the function of relative prices (non-tradables vs. tradables). They would explain not only movements in prices of non-tradables but also indirectly of tradables. Thus, the determinants of relative prices would have some deceleration effect on relative prices dynamics. If one factor would cause prices of non-tradables to increase, it would at the same time add (to some extent) to inflation in tradables. Consequently, the ratio of non-tradables to tradables price would not increase to the same extent.

To test the impact of the non-tradables processing component, four variations of relative prices determination model are estimated by FMOLS and PMGE methods.[42] First, a standard HBS effect is tested. Relative prices (non-tradables

[41] The use of aggregate non-tradables is a bit crude approach. The explicit distinction of distribution sector – such as in MacDonald and Ricci (2001) would be preferred.

[42] The estimations focus on the 'internal' HBS effect, i.e. variables are not related to a foreign country. The term relative refers here only to tradables vs. non-tradables (or vice versa). Estimations with international comparison (related to the euro zone) were also conducted with FMOLS and rendered very similar results (they are not reported here).

Table 8. Determination of relative prices (PMGE estimates)

Dependent variable	RP	RP	RP	RP
Explanatory variables:				
RPRO	1.371 (7.289)		0.208 (1.482)	
PRO_T		0.229 (1.759)		0.067 (0.593)
PRO_NT		1.031 (3.479)	1.165 (6.638)	0.331 (1.593)
WAGE				0.332 (6.355)
Error Correction (Phi)	-0.036 (-1.577)	-0.082 (-3.777)	-0.094 (-4.469)	-0.109 (-2.617)
No. of countries	7	7	7	7
No. of quarters by countries	34 36 30 25 30 29 19	34 36 30 25 30 29 19	34 36 30 25 30 29 19	34 36 30 25 30 29 19
Maximum lag	3	3	3	3

Notes: t-ratios in parentheses. Countries included in the panel: CZE, EST, HUN, LIT, POL, SLK, and SLO. For definitions and sources of variables see Appendix C.

vs. tradables) are regressed on relative productivity (tradables vs. non-tradables) – see Table 7 and Table 8, column 2. In both estimation methods the coefficient turned out significant, positive and higher than one. The magnitude of this coefficient is surprisingly high (much higher than the similar estimate of MacDonald and Wojcik, 2003). This may indicate that some other factors are at work. According to Burstein *et al.* (2001), the higher elasticity than that predicted by standard HBS model[43] could occur, if tradables need to be aggregated with non-tradables so as to be delivered to consumers (MacDonald and Ricci, 2001).

In order to test this hypothesis, the equation for relative prices is regressed on unconstrained labour productivity for tradables and non-tradables (see Table 7 and Table 8, column 3). The coefficient of productivity in the non-tradables sector (which could be treated as the aggregate proxy for non-tradables processing component or distribution sector) is positive and significant (evident for two estimation methods), which is in contrast with the traditional HBS effect.[44] These results suggest that non-tradables sector plays a more important role in production of tradables, than in delivering tradables to consumers – as suggested and proved for developed countries in MacDonald and Ricci (2001). This should not be surprising given the price indices used (i.e. the PPI in manufacturing) in this test. The improvement in non-tradables productivity lowers prices of tradables and leads to an increase in relative wages and relative

[43] Theoretically, it should be equal to the expenditure share on non-tradables.

[44] MacDonald and Wojcik (2003) arrived at different result for similar estimations. Their elasticity is negative, but below (in absolute values) the elasticity of the tradables sector. Thus, also suggesting some non-standard HBS effects.

prices (real appreciation of the exchange rate) – the same effect as in the case of the increase in tradables productivity. Similar inferences can be obtained from the model including both the traditional HBS effect and non-tradable processing component – the former proxied by relative productivity (constrained) and the latter by labour productivity in the non-tradable sector (see Table 7 and Table 8, column 4). The non-tradables productivity is significant and positive, whereas the standard HBS effect positive and lower than one (though in the case of PMGE is not significant at 5 per cent level).

Finally, to test the role of the wage channel in the augmented HBS framework, relative prices are regressed on unconstrained labour productivity in tradables and non-tradables as well as average wages in the total economy. This estimation proves that indeed wage is an important channel – the coefficient is positively signed and significant (see Table 7 and Table 8, column 5). At the same time, under both estimation methods, the productivity of non-tradables becomes insignificant. This is consistent with the hypothesis that gains in non-tradable processing efficiency are transmitted via rising productivity for tradables and in turn average wages. As far as productivity in tradables is concerned, the outcome differs with the estimation method. Under FMOLS it is significantly negative, whereas under PMGE positive and insignificant. The former outcome may suggest some problems with substitutability (see MacDonald and Ricci, 2001).

It should be noted, that although both methods supported the non-tradables processing component hypothesis, the diagnostic tests under PMGE indicated some fundamental problems in estimated equations. In addition, the above estimations could suffer from omitted variable problem – for instance due to a failure of accounting for a demand effect or capital-labour ratio as in the Bergstrand (1991) model or for controlled prices. The latter factor was proved to have impact on estimates of exchange rate models in CEECs (MacDonald and Wojcik (2003) and Egert and Lommatzsch (2003)).

Third, if one accepts the hypothesis of the non-tradables processing component and the fact that very high inflation at the beginning of the 1990s was a transition phenomenon, then the consequences of this effect for estimation of real exchange rates would be less pronounced in the future. In the environment of low and stable inflation (especially of non-tradables) the appreciation of the real exchange rate deflated with tradables prices should be less dependent on the non-tradables processing component. This point leads also to a consideration that the early period of transition in CEECs is not a good sample for estimating equilibrium exchange rate models and drawing inferences about

equilibrium exchange rate levels. Similar reservation may apply to the violation of PPP. Over a longer horizon, there might be more evidence in favour of PPP (or for a faster speed of convergence), especially when CEECs are expected to become increasingly more integrated in the EU markets.

6. Panel estimations and equilibrium exchange rates

At this point it is important to discuss the consequences of using panel estimates for equilibrium exchange rates. The usual reason for using panel models is the possibility of gaining more information by pooling time-series observations across countries. There are various methods of pooling the data. Extracting common information for different countries brings some benefits (in terms of more precise and reliable results), though it may come at the cost of omitting country-specific factors.

The panel estimations in this paper were conducted using the two popular methods for dynamic heterogeneous panels – PMGE and FMOLS.[45] The former allows one to estimate ARDL models as well as their error correction representations with an explicit estimation of long-run relationships. For each group (country) in a panel, an error correction model (ECM) is estimated with a homogeneity restriction imposed on long-run coefficients, whereas short-run coefficients are allowed to vary and are averaged across groups. Thus, a PMGE can be viewed as an intermediate approach between the mean group estimator (the average of separate estimates for each group) and fixed/random effects panel models which allow only an intercept to vary across groups – all other coefficients and error variances are constrained to be homogenous (Pesaran *et al.*, 1999). It should be noted that homogeneity restrictions of long-run coefficients are formally tested. However, it is very often the case that they are rejected (see Pesaran *et al.*, 1998). Indeed, in the numerous estimations in this paper no support for such homogeneity was found.

The group FMOLS by Pedroni (2001) draws on the time-series approach of fully modified OLS. The latter is a non-parametric approach which deals with

[45] Another option would be to employ the panel dynamic ordinary least square method (DOLS) as MacDonald and Wojcik (2003) did. DOLS is a parametric method where endogeneity is dealt with by explicit modelling of leads and lags of explanatory variables. The evidence on superiority of either FMOLS or DOLS is mixed (Harris and Sollis, 2003), but the latter method requires more observations in the time dimension.

endogeneity in single-equation models (in terms of contemporaniety and the failure of weak exogeneity – Patterson, 2000). As the panel estimates are simple means of coefficients from country-specific equations, they are prone to outliers or country-specific factors. This was clearly evident in the case of the PPP model estimated with and without Lithuania (see Section 4.2). The FMOLS does not allow to estimate the speed of convergence – the factor which could be helpful in assessing properties of a given model. On the other hand, the non-parametric approach – such as FMOLS – does not sacrifice a lot of degrees of freedom, which is the case for the PMGE.

Panel estimations for CEECs presented in this paper indicated that this group of countries (despite many common features) exhibit a significant heterogeneity in terms of exchange rate mechanisms. This was mostly evident for FMOLS country-specific results in cases where sings of estimated coefficients were different and for PMGE when homogeneity restrictions were rejected. Similar problems were described in Egert and Lommatzsch (2003). This may be indicative of some important country specific factors that were omitted in panel estimations. The heterogeneity of and frequent shifts in exchange rate regimes might be one of the reasons behind this.

Finally, it should be noted that the time dimension – especially in dynamic panels – is very important for exchange rates modelling. Only a proper accounting for variable dynamics could render robust results. This especially applies to the case of using quarterly data in the time dimension. Testing a proper specification of a model may require inserting as many as four lags. This is usually very costly in terms of the loss of degrees of freedom. Thus, panel models that were employed only because it was not possible to estimate country-specific time-series models are a second-best solution and they might not be able to model properly dynamic relations in exchange rate models. This could be the case of MacDonald and Wojcik (2003), who used only one lag and leads in their panel DOLS estimations.

Given the above considerations, panel estimations for CEECs should be interpreted with caution. They are more suited for proving some general theory, rather than inferring about country–specific information. Therefore, panel estimates, in general, should not be used to provide detailed guidelines for equilibrium exchange rates and the conversion rates upon EMU accession for a given country. Moreover, panel results should be analysed together with country-specific information. As it was demonstrated in testing of PPP models and in Egert and Lommatzsch (2003), such information could help to interpret and understand panel estimates. In addition, point estimates were demonstrated

to be sensitive with regard to the estimation method. Having no prior information on superiority of a given estimation method, the differences in point estimates should be treated as an interval of potential outcomes.

7. Conclusions

The paper contributed to the recent empirical literature on real exchange rates in CEECs. Instead of estimating a complete model, the PPP and relative price models (two main components of the real exchange rate) were investigated separately. All empirical tests were conducted in the heterogonous dynamic panel framework. The panel included generally nine CEECs (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic and Slovenia) over the period 1993-2002. The exact country and time coverage differed across estimated models. For the sake of sensitivity check models were estimated simultaneously with two econometric methods: FMOLS and PMGE. The investigation of PPP began with noting a clear appreciation trend in real exchange rates vs. the euro deflated with prices of tradables in most of CEECs. This fact suggested contradictions with the prediction of the relative PPP model. The appreciation was mainly driven by differential in tradables inflation, but in few cases also by appreciation of nominal exchange rates. The numerous formal tests, based on the explicit estimation of constrained PPP model coefficients, did not support the strong version of the PPP paradigm (and in some cases confirmed the appreciation trend). This outcome was invariant to the use of bilateral or multilateral exchange rates, different numeraire currency or different specifications of the model with regard to the dependent variable. Given the relatively short period of analysis and the list of numerous factors undermining the perfect arbitrage, that were not taken into account, these findings should not be surprising. The conducted estimations proved that using multilateral exchange rates rendered more robust results and point estimates were sensitive to the particular specification of the PPP model with regard to the dependent variable. Some tentative evidence was found for the hypothesis of imperfect substitutability of tradables between CEECs and the euro zone, though estimations did not render any unambiguous proofs.

Given these findings, the hypothesis of non-tradables processing component as an explanation of the PPP puzzle was tested. MacDonald and Ricci (2001) and

Lee and Tang (2003) provided some theoretical and empirical evidence in favour of this hypothesis for developed countries. Also in this paper, such evidence was found. The increase in productivity of non-tradables was demonstrated to cause the appreciation of real exchange rates. This suggests that the non-tradables (a crude proxy for the distribution sector) was mainly orientated towards providing intermediate inputs for the tradable sector rather than to final consumer goods. This should not be surprising given that producer prices were used in these tests. Having found confirmation for the non-tradables processing component in the PPP model, similar investigation was pursued for the model of relative prices. These estimations also rendered affirmative results. In addition, the wage channel was proved to play the key role in determination of relative prices.

Against this background, the paper stressed that the failure to take into account the appreciation of the real exchange rate in terms of tradables prices and the alternative specification of non-tradables processing component in models of exchange rate determination for CEECs could lead to biased results. This should be particularly important for estimates of equilibrium exchange rates. In addition, the heterogeneity of behaviour among CEECs and some sensitivity to outliers was demonstrated. This highlights the necessity to interpret panel estimations cautiously. In this respect, country-specific information helps to interpret and understand panel estimates. Point estimates also turned out to be sensitive to the panel estimation method.

Bibliography:

Alberola, E., S.G. Cervero, H. Lopez, and A. Ubide (1999), 'Global equilibrium exchange rates: euro, dollar, "ins", "outs" and other major currencies in a panel cointegration framework', *IMF Working Paper*, No. WP/175/99, December

Allen, R.P. and J.L. Stein (1995), *Fundamental Determinants of Exchange Rates*, Oxford

Balassa, B. (1964), 'The Purchasing Power Parity Doctrine: A Reaprisal', *Journal of Political Economy*, Vol. 72, pp. 584-596

Bayoumi, T. and R. MacDonald (1998), 'Deviations of Exchange Rates from PPP: A Story Featuring Two Monetary Unions', *IMF Working Paper*, No. WP/98/69, May

Benigno, G. and Ch. Thoenissen (2002), 'Equilibrium Exchange Rates and Supply-Side Performance", *Bank of England Working Paper*, No. 156, June

Bergstrand, J.H. (1991), 'Structural Determinants of Real Exchange Rates and National Price Levels: Some Empirical Evidence', *American Economic Review*, Vol. 1, Issue 1, March, pp. 325-334

Breitung, J. and W. Meyer (1994), 'Testing for Unit Roots in Panel Data: Are Wages on Different Bargaining Levels Cointegrated?', *Applied Economics*, Vol. 26, pp. 353-361

Burstein, A.T., J.C. Neves, and S. Rebelo (2001), 'Distribution costs and real exchange rate dynamics during exchange-rate-based stabilisations', *UCLA Economics Online Papers*, No. 268

Cecchetti, S., N. Mark, and R.J. Sonora (2000), 'Price level convergence among United State cities: Lessons for the European Central Bank', *NBER Working Paper*, No. 7681, May

Chortareas, G.E. and R.L. Driver (2001), 'PPP and the real exchange rate–real interest rate differential puzzle revisited: evidence from non-stationary panel data', *Bank of England Working Paper*, No. 138, June

Corsetti, G. and L. Debola (2002), 'Macroeconomics of International Price Discrimination', *mimeo*, Yale University, http://aida.econ.yale.edu/~corseti/

De Broeck, M. and T. Slok (2001), 'Interpreting Real Exchange Rate Movements in Transition Countries', *IMF Working Paper*, No. WP/01/56, May

De Gregorio, J., A. Giovannini, and H. Wolf (1994), 'International Evidence on Tradables and Nontradables Inflation', *European Economic Review*, Vol. 38, pp. 1225–1244

Devereux, M.B. and P.R. Lane (2001), 'Exchange Rates and Monetary Policy in Emerging Market Economies', *mimeo*, June

Dickey, D.A. and W.A. Fuller (1979), 'Distribution of the Estimators for Autoregressive Time Series with a Unit Root', *Journal of the American Statistical Association*, Vol. 74, pp. 427-431

Drobinsky, R. (2003), 'Convergence in per capita income levels, productivity dynamics and real exchange rates in the EU acceding countries', *Empirica*, Vol. 30(3), pp. 305-334

Egert, B. (2002), 'Equilibrium Real Exchange Rates in Central Europe's Transition Economies: Knocking on Heaven's Door', *William Davidson Working Paper*, No. 480, July

Egert, B. (2003), 'Assessing Equilibrium Exchange Rates in CEE Acceding Countries: Can We Have DEER with BEER without FEER? A Critical Survey of the Literature', *Focus on Transition*, Vol. 2, Oesterreichische Nationalbank, pp. 38-106

Egert, B. and K. Lommatzsch (2003), 'Equilibrium Real Exchange Rates in Acceding Countries: How Large Is Our Confidence (Interval)?', *Focus on Transition*, Vol. 2, Oesterreichische Nationalbank, pp. 38-106

Elliott, G., T.J. Rothenberg, and J.H. Stock (1996), 'Efficient Tests for an Autoregressive Unit Root', *Econometrica*, Vol. 64, pp. 813-836

Engel, C. (1999), 'Accounting for Real Exchange Rate Changes', *Journal of Political Economy*, No. 107, pp. 507-583

Fischer, C. (2002), 'Real Currency Appreciation in Accession Countries: Balassa-Samuelson and Investment Demand', *BOFIT Discussion Paper*, No. 8

Frankel, J. A. and A.K. Rose (1996), 'A panel project on purchasing power parity: mean reversion within and between countries', *Journal of International Economics*, Vol. 40, pp. 209-24

Halpern, L. and C. Wyplosz (1997), 'Equilibrium Exchange Rates in Transition Economies', *IMF Staff Papers*, No. 44(4), pp. 430-61

Halpern, L. and C. Wyplosz (2001), 'Economic Transformation and Real Exchange Rates in the 2000s: The Balassa-Samuelson Connection', *mimeo*, http://heiwww.unige.ch/~wyplosz/recent.htm

Harris, R. and R. Sollis (2003), *Applied Time Series Modelling and Forecasting*, John Wiley & Sons Ltd, Chichester

Harrod, R.J. (1933), *International economics*, James Nisbet and Cambridge University Press, London

Im, K.S., M.H. Pesaran, and Y. Shin (1996), 'Testing for Unit Roots in heterogeneous Panels', *University of Cambridge Discussion Paper*, (Revised March 2002)

Isard, P., H. Faruqee, G.R. Kincaid, and M. Fetherston (2001), 'Methodology for Current Account and Exchange Rate Assessments', *IMF Occasional Paper*, No. 209, December.

Kim, B.Y. and I. Korhonen (2002), 'Equilibrium exchange rates in transition countries: Evidence from dynamic heterogeneous panel models', *BOFIT Discussion Papers*, No. 15

Kowalski, P., W. Paczynski, and L. Rawdanowicz (2003), 'Exchange rate regimes and the real sector: a sectoral analysis of CEE countries', *Post-Communist Economies*, Vol. 15, No. 4, December

Kwiatkowski, D., P.C.B. Phillips, P. Schmidt, and Y. Shin (1992), 'Testing the Null Hypothesis of Stationary against the Alternative of a Unit Root', *Journal of Econometrics*, Vol. 54, pp. 159-178

Lee, J. and M.K. Tang (2003), 'Does Productivity Growth Lead to Appreciation of the Real Exchange Rate?', *IMF Working Paper*, No. WP/03/154, July

Levin, A. and C-F Lin (1993), 'Unit Root Tests in Panel Data: New Results', *University of California Discussion Paper*, No. 93-56

Linder, S.B (1961), *An Essay on Trade and Transformation*, Wiley, New York

MacDonald, R. (1996), 'Panel unit root tests and real exchange rates', *Economic Letters*, Vol. 50, pp. 7-11

MacDonald, R. (1998), 'What Do We Really Know About Real Exchange Rates?', *Oesterreichische Nationalbank Working Paper*, No. 28

MacDonald, R. (2000), 'Concepts to Calculate Equilibrium Exchange Rates: An Overview', *Economic Research Group of the Deutsche Bundesbank Discussion Paper*, No. 3/00, July

MacDonald, R. and J.L. Stein (eds) (1999), *Equilibrium Exchange Rates*, Kluwer Academic Publisher

MacDonald, R. and L. Ricci (2001), 'PPP and the Balassa Samuelson Effect: The Role of the Distribution Sector', *IMF Working Paper*, No. WP/01/38, March

MacDonald, R. and L. Ricci (2002), 'Purchasing Power Parity and New Trade Theory', *IMF Working Paper*, No. WP/02/32, February

MacDonald, R. and C. Wojcik (2003), 'Catching Up: The Role of Demand, Supply and Regulated Price Effects on the Real Exchange Rates of Four Accession Countries', *Strathclyde Discussion Papers in Economic*, No. 03-02

Maddala, G.S. and I.M. Kim (1998), *Unit Roots, Cointegration, and Structural Change*, Cambridge University Press, Cambridge

Meese R. and K. Rogoff (1983), 'Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?', *Journal of International Economics*, Vol. 14, February, pp. 3-24

Moon, H.R. and B. Perron (2002), 'The Seemingly Unrelated Dynamic Cointegration Regression Model and Testing for Purchasing Power Parity', *Cahiers de recherche*, Universite de Montreal, No. 2000-03

Ng, S. and P. Perron (2001), 'Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power', *Econometrica*, Vol. 69(6), pp. 1519-1554

Obstfeld, M. and K. Rogoff (2000), 'The six major puzzles in international macroeconomics: is there a common cause?', *NBER Working Paper*, No. 7777, July

Parsley, D.C. and S.J. Wei (1996), 'Convergence to the Law of One Price without Trade Barriers of Currency Fluctuations', *NBER Working Paper*, No. 5654, July

Patterson, K.D. (2000), *An Introduction to Applied Econometrics: A Time Series Approach*, Palgrave Macmillan

Pedroni, P. (2001), 'Purchasing power parity tests in cointegrated panels', *The Review of Economics and Statistics,* Vol. 83(4), pp. 727–731

Pesaran, M.H. (2000), 'On the interpretation of Panel Unit Root Tests', *mimeo*, October

Pesaran, M.H., R.P. Smith, and T. Akiyama (1998), *Energy Demand in Asian Economies*, Oxford University Press

Pesaran, M.H., Y. Shin, and R.P. Smith (1999), 'Pooled Mean Group Estimation in Dynamic Heterogeneous Panels', *Journal of the American Statistical Association*, Vol. 94, pp. 621-634

Phillips, P.C.B. and P. Perron (1988), 'Testing for a Unit Root in Time Series Regression', *Biometrika*, Vol. 75, pp. 335-346

Rahn, J. (2003), 'Bilateral equilibrium exchange rates of EU accession countries against the euro', *BOFIT Discussion Paper*, No. 11

Rawdanowicz, L. (2003), 'The EMU enlargement and the choice of the euro conversion rates: Theoretical and empirical issues', *CASE Studies & Analyses*, No. 269, December

Roger, J.H. and M. Jenkins (1995), 'Haircuts or Hysteresis? Sources of Movements in Real Exchange Rates', *Journal of International Economics*, Vol. 38, pp. 339-360

Rogoff, K. (1996), 'The Purchasing Power Parity Puzzle', *Journal of Economic Literature*, Vol. 34, No. 2, June, pp. 647-668

Rogoff, K. (2001), 'The failure of empirical exchange rate models: no longer new, but still true', *Economic Policy Web Essay*, http://www.economic-policy.org/commentaries.asp

Samuelson, P. (1964), 'Theoretical Notes on Trade Problems', *Review of Economics and Statistics*, Vol. 46, pp. 145-154

Sarno, L. and M.P. Taylor (2002), *The economics of exchange rates*, Cambridge University Press, Cambridge

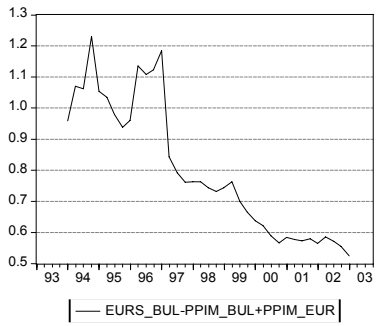
Taylor, A. (1996), 'International Capital Mobility in History: Purchasing Power Parity in the Long-Run', *NBER Working Paper*, No. 5742, September

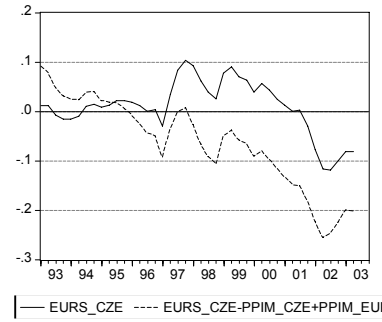
Williamson, J. (ed.) (1994), *Estimating Equilibrium Exchange Rates*, Institute for International Economics, Washington

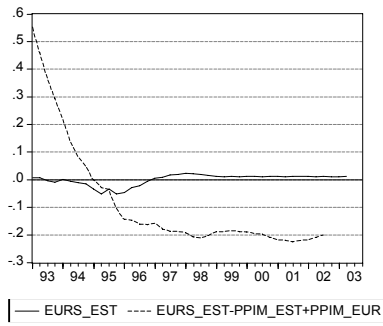
Zanello, A. and D. Desruelle (1997), 'A Primer on the IMF's Information Notice System', *IMF Working Paper*, No. WP/97/71, May

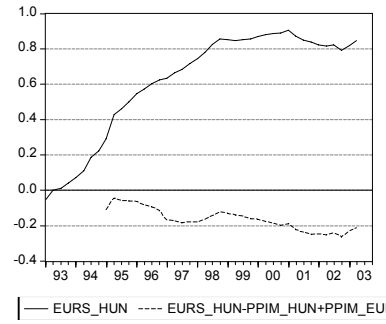
Appendix A. Figures

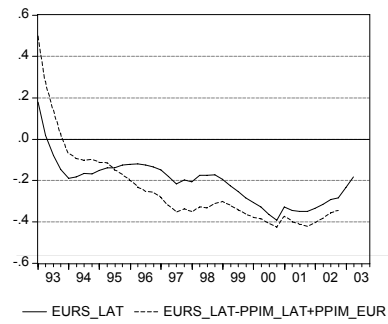
Nominal (standardised) and real exchange rate of the euro deflated with prices of tradables (PPI in manufacturing)

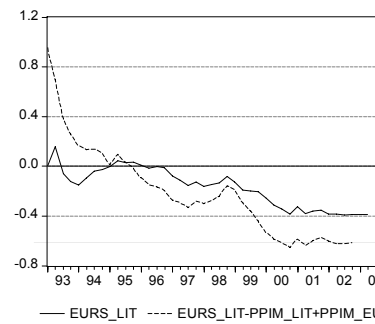


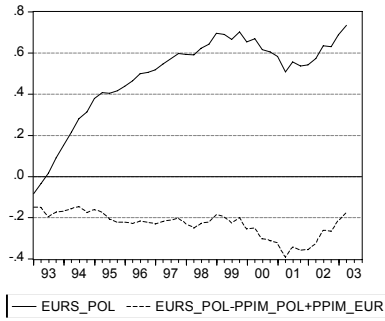








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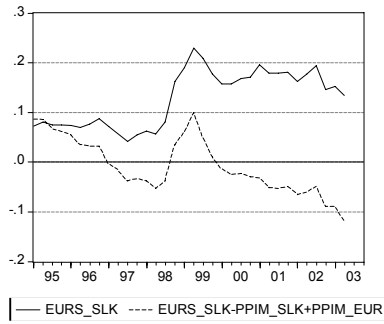
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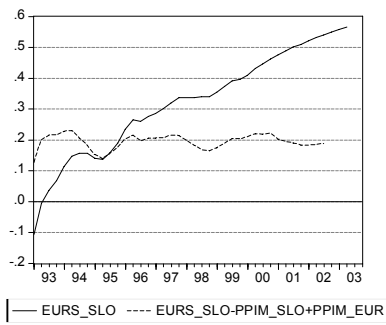
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Appendix B. Statistical data

Table B.1. Comparison of PPP and market exchange rates in terms of PLN in 1999

	CZE	HUN	SLK	BUL	EST	LAT	LIT	SLO
Market exchange rate	8.714	59.78	10.426	0.463	3.700	0.148	1.008	45.82
PPP exchange rates:								
Total goods	8.170	58.71	8.943	0.303	3.842	0.160	1.014	59.23
Consumer goods	8.264	57.43	8.513	0.308	3.565	0.157	0.978	60.85
Non durable goods	8.329	58.55	8.671	0.316	3.623	0.151	0.977	65.96
Semi durable goods	8.346	54.69	8.272	0.292	3.926	0.202	1.093	57.94
Durable goods	7.544	54.10	8.128	0.278	2.929	0.144	0.866	44.90
Capital goods	8.252	61.95	9.765	0.293	4.493	0.171	1.128	57.79
Food and non-alcoholic beverages	7.826	58.62	9.624	0.357	4.141	0.181	1.096	79.83
Alcoholic beverages, tobacco and narcotics	8.081	52.81	7.293	0.248	3.654	0.183	1.065	47.10
Clothing and footwear	8.657	57.96	8.055	0.318	4.103	0.214	1.128	57.90
Furnishing, households equipment, routine household maintenance	8.097	56.54	8.551	0.210	3.580	0.150	0.926	51.43
Transport	7.756	67.15	7.172	0.320	3.317	0.160	0.879	55.09
Machinery and equipment								
Total services	7.029	52.32	6.215	0.239	3.279	0.119	0.719	74.10
Consumer services	6.806	53.69	6.136	0.259	3.383	0.128	0.722	69.63
Government services	7.369	52.07	6.510	0.209	3.158	0.106	0.720	79.23
Collective services	8.198	56.46	6.888	0.178	3.027	0.109	0.736	73.61
Individual services	7.035	49.34	6.492	0.232	3.258	0.105	0.716	84.80
PPP vs. market exchange rate								
Total goods	0.938	0.982	0.858	0.655	1.039	1.088	1.005	1.293
Consumer goods	0.948	0.961	0.816	0.665	0.964	1.062	0.969	1.328
Non durable goods	0.956	0.979	0.832	0.683	0.979	1.026	0.969	1.440
Semi durable goods	0.958	0.915	0.793	0.631	1.061	1.367	1.084	1.264
Durable goods	0.866	0.905	0.780	0.600	0.792	0.978	0.859	0.980
Capital goods	0.947	1.036	0.937	0.633	1.214	1.159	1.118	1.261
Food and non-alcoholic beverages	0.898	0.981	0.923	0.772	1.119	1.229	1.087	1.742
Alcoholic beverages, tobacco and narcotics	0.927	0.883	0.700	0.537	0.988	1.240	1.056	1.028
Clothing and footwear	0.993	0.970	0.773	0.688	1.109	1.450	1.119	1.264
Furnishing, households equipment, routine household maintenance	0.929	0.946	0.820	0.454	0.968	1.020	0.918	1.123
Transport	0.890	1.123	0.688	0.691	0.896	1.085	0.872	1.202
Machinery and equipment	0.966	0.961	0.951	0.742	1.082	1.023	0.994	1.108
Total services	0.807	0.875	0.596	0.516	0.886	0.805	0.713	1.617
Consumer se rvices	0.781	0.898	0.588	0.559	0.914	0.871	0.716	1.520
Government services	0.846	0.871	0.624	0.452	0.854	0.719	0.714	1.729
Collective services	0.941	0.944	0.661	0.384	0.818	0.739	0.730	1.607
Individual services	0.807	0.825	0.623	0.501	0.880	0.710	0.710	1.851

Notes: PPP and market exchange rates in terms of national currencies (per unit of the Polish zloty). PPP exchange rates refer to consumer price levels.

Source: PPP exchange rates – Eurostat and OECD, market exchange rates (annual average) – IFS, IMF.

Table B.2. Comparison of PPP and market exchange rates in terms of euro in 1999

	CZE	HUN	POL	SLK	BUL	EST	LAT	LIT	SLO
Market exchange rate	36.83	252.7	4.226	44.07	1.956	15.637	0.623	4.26	193.7
PPP exchange rates:									
Total goods	21.71	156.0	2.658	23.77	0.806	10.211	0.426	2.69	157.4
Consumer goods	22.20	154.3	2.686	22.87	0.827	9.577	0.421	2.63	163.5
Non durable goods	20.96	147.3	2.516	21.82	0.795	9.116	0.381	2.46	166.0
Semi durable goods	22.64	148.3	2.712	22.44	0.793	10.650	0.547	2.97	157.1
Durable goods	26.84	192.4	3.557	28.91	0.988	10.420	0.513	3.08	159.7
Capital goods	21.69	162.8	2.628	25.66	0.770	11.806	0.449	2.96	151.9
Food and non-alcoholic beverages	18.30	137.1	2.338	22.50	0.835	9.682	0.424	2.56	186.7
Alcoholic beverages, tobacco and narcotics	23.94	156.5	2.963	21.61	0.736	10.828	0.542	3.16	139.6
Clothing and footw ear	21.65	145.0	2.501	20.15	0.796	10.263	0.535	2.82	144.8
Furnishing, households equipment, routine household maintenance	20.71	144.6	2.558	21.87	0.538	9.157	0.385	2.37	131.6
Transport	21.87	189.4	2.820	20.23	0.903	9.353	0.451	2.48	155.4
Machinery and equipment									
Total services	9.82	73.1	1.397	8.68	0.334	4.580	0.166	1.00	103.5
Consumer services	11.03	87.0	1.621	9.95	0.420	5.484	0.208	1.17	112.9
Government services	8.54	60.4	1.159	7.55	0.243	3.660	0.123	0.83	91.8
Collective services	10.78	74.3	1.315	9.06	0.234	3.982	0.143	0.97	96.8
Individual services	7.31	51.3	1.039	6.75	0.241	3.386	0.109	0.74	88.2
PPP vs. market exchange rate									
Total goods	0.590	0.618	0.629	0.539	0.412	0.653	0.684	0.632	0.813
Consumer goods	0.603	0.611	0.636	0.519	0.423	0.612	0.675	0.616	0.844
Non durable goods	0.569	0.583	0.595	0.495	0.407	0.583	0.611	0.577	0.857
Semi durable goods	0.615	0.587	0.642	0.509	0.405	0.681	0.878	0.696	0.811
Durable goods	0.729	0.762	0.842	0.656	0.505	0.666	0.823	0.723	0.825
Capital goods	0.589	0.644	0.622	0.582	0.394	0.755	0.721	0.695	0.784
Food and non-alcoholic beverages	0.497	0.542	0.553	0.511	0.427	0.619	0.680	0.601	0.964
Alcoholic beverages, tobacco and narcotics	0.650	0.619	0.701	0.490	0.376	0.692	0.870	0.741	0.721
Clothing and footwear	0.588	0.574	0.592	0.457	0.407	0.656	0.858	0.662	0.748
Furnishing, households equipment, routine household maintenance	0.562	0.572	0.605	0.496	0.275	0.586	0.617	0.556	0.679
Transport	0.594	0.749	0.667	0.459	0.461	0.598	0.724	0.582	0.802
Machinery and equipment	0.818	0.813	0.847	0.806	0.629	0.916	0.866	0.841	0.938
Total services	0.267	0.289	0.331	0.197	0.171	0.293	0.266	0.236	0.534
Consumer services	0.300	0.345	0.384	0.226	0.214	0.351	0.334	0.275	0.583
Government services	0.232	0.239	0.274	0.171	0.124	0.234	0.197	0.196	0.474
Collective services	0.293	0.294	0.311	0.206	0.120	0.255	0.230	0.227	0.500
Individual services	0.199	0.203	0.246	0.153	0.123	0.217	0.175	0.175	0.455

Notes: PPP and market exchange rates in terms of national currencies (per unit of the euro). PPP exchange rates refer to consumer price levels.

Source: PPP exchange rates – Eurostat and OECD, market exchange rates (annual average) – IFS, IMF.

Appendix C. Data sources and definitions

The following variables are calculated for each country separately.

Name	Definition	Source
EUR	Nominal exchange rate: domestic currency per unit of the euro (increase = depreciation)	IFS-IMF
PLN	Nominal exchange rate: domestic currency per unit of the Polish zloty (increase = depreciation)	IFS-IMF
NEER	Nominal effecti ve exchange rate (increase = appreciation); defined for a narrow basket of 9 currencies – the euro and 8 remaining CEECs' currencies; weights were based on 2001 export shares	Author's calculation based on IFS-IMF and Direction of Trade Statistics – IMF data
PPIM	Producer price index for manufacturing (with exception of BUL)	IFS-IMF and national sources
PPIM_W	Weighted price index for p roducer prices in manufacturing of 9 analysed countries: euro zone and remaining 8 CEECs	Author's calculation based on IFS-IMF and Direction of Trade Statistics – IMF data
CPI_NT	CPI prices of services (definition differs across countries)	MEI-OECD and national sources
RP	$\frac{CPI\_NT}{PPIM}$; relative prices (non-tradables vs. tradables)	
ULC_T	$\frac{WAGE}{PRO\_T}$; unit labour costs for the tradable sector	
ULC_NT	$\frac{WAGE}{PRO\_NT}$; unit labour costs for the non-tradable sector	
WAGE	Nominal average wages in the total economy	IFS-IMF and national sources
PRO_T	$\frac{VA\_T}{EMP\_T}$; producti vity in the tradable sector	
PRO_NT	$\frac{VA\_NT}{EMP\_NT}$; productivity in the non-tradable sector	
RPRO	$\frac{PRO\_T}{PRO\_NT}$; relative productivity (tradables vs. non-tradables)	
VA_T	Value added at constant prices in the tradable sector	National sources
VA_NT	Value added at constant prices in the non-tradable sector	National sources
EMP_T	Employment in the tradable sector	National sources
EMP_NT	Employment in the non-tradable sector	National sources

Notes: PPP and market exchange rates in terms of national currencies (per unit of the euro). PPP exchange rates refer to consumer price levels.

Source: PPP exchange rates – Eurostat and OECD, market exchange rates (annual average) – IFS, IMF.

The euro-zone data is collected from the ECB's monthly bulletin and OECD databases.

For the calculations of labour productivity (value added and employment data) tradables are defined as manufacturing (for EST, HUN, LIT, SLK, and EUR) and as industry (for POL and SLO – no further disaggregation was possible), whereas non-tradables as construction, market and non-market services.

Country abbreviations:

BUL – Bulgaria, CZE – the Czech Republic, EST – Estonia, HUN – Hungry, LAT – Lithuania, LIT – Lithuania, POL – Poland, SLO – Slovenia, SLK – the Slovak Republic, and EUR – the euro zone.