Real exchange rate misalignments in CEECs: Have they hindered growth?

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Abstract:

We study the impact of exchange rate misalignment on economic activity in nine Central and Eastern European (CEE) economies. Exchange rate misalignments are computed from country-specific long-run exchange rate relationships with determinants suggested by open macroeconomic models such as interest rate differentials or the Balassa-Samuelson effect. There was a clear reduction in misalignments, but this has been reversed to some extent after 2008. Exchange rate overvaluation has a negative impact on economic activity. The effect of misalignments on economic activity seems to be nonlinear, as overvaluation has a stronger effect than undervaluation. Other factors of economic activity, including institutions, also show nonlinear effects.

Keywords: real exchange rate misalignments, growth, Central and Eastern European countries, panel smooth transition regression

JEL code: O11, F41, F15

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1. Introduction

This paper studies the relationship between real exchange rate misalignments and economic activity in nine Central and Eastern European (CEE) countries, namely Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. There has been a lot of debate around the use of exchange rates as a policy instrument and the effectiveness of using exchange rate regimes as a development strategy. Movements in exchange rates may have lasting effects on economic activity through the Balassa-Samuelson effect, which links exchange rates and economic activity. In the various successful East Asian economies, the exchange rate has been at the centre of the policy debate. The exchange rate policy of China has, however, been associated with persistent current account surpluses, and debate still surrounds the question of currency undervaluation and competitiveness. Whether other emerging economies can adapt their exchange rate policies to catch up with more developed countries is an issue of some importance.

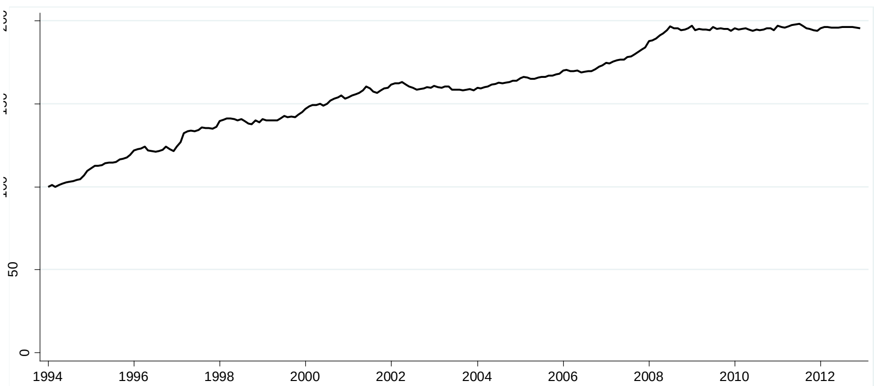
The dynamics of real exchange rates has become a key macroeconomic concern in the European Union. The euro area, which is the ultimate sign symbol of the economic integration of the EU, has always been a central element in maintaining stability in the EU, and most EU members have to join it eventually. Ever since its creation, the euro has been a goal of aspiration in the EU that can only be reached by those who meet the criteria. All EU members except the UK and Denmark must join the euro area but only after they have achieved the Maastricht convergence criteria.[1] One of the four official criteria is that a country aspiring to use the euro must join the Exchange Rate Mechanism II (ERM II) under the European monetary system having not devalued its currency for two years. Countries in the ERM II that are not yet using the euro must keep their exchange rate within +/- 15% of a predetermined central level against the euro.

[1] Sweden has opted to stay out of the euro area by declining to join the ERM II.

Some of the countries in our study have joined the euro area, these being Estonia, Latvia, Lithuania, Slovakia and Slovenia, but the remaining countries, Bulgaria, the Czech Republic, Hungary and Poland, are not in the ERM II. A simple average of the real effective exchange rates of these nine CEE countries is shown in Figure 1, and it represents the dynamics of the real effective exchange rates of these countries against the euro. It shows that the real exchange rate experienced a real appreciation of around 100% on average from the beginning of 1994 to the end of 2012. A growing literature has attributed this vigorous appreciation to the Balassa-Samuelson effect and the productivity gains of the open sector. Some relevant references are Halpern and Wyplosz (2001), Égert et al (2003), and Égert (2005).

The main contribution of this paper is its study of the relationship between economic activity and exchange rate misalignment in some of the newer members of the EU who have joined the euro or are aiming to do so. The exchange rates of these CEE countries showed a pattern of appreciation during the period. How this trend affects economic activity may indicate whether it is justifiable to consider membership of the euro area as a virtue.

Figure 1. Average real effective exchange rate



Notes: Data from Eurostat. Simple average of the real effective exchange rate, monthly observations (base: January 1994).

Most of the empirical literature uses the First Difference GMM and System GMM estimators, which are better suited for panels with large N and short T. This paper mainly focuses on the time series dimension, adding to the growing number of cross-country studies that find time series evidence of a link between economic activity and exchange rates. The cointegration relationship that defines the equilibrium real exchange rate (RER) is country specific and does not impose parameter homogeneity across countries in a long-run exchange rate relationship. We use the Johansen (1988, 1991) cointegration approach in a time series dimension for each of the target countries. Misalignment of the real exchange rate from its equilibrium values has a nonlinear effect on growth. It is reasonable to use panel regression to estimate the relationship between growth and RER misalignment if it is assumed that the countries have the same technology. We also estimate nonlinear models to account for any possible asymmetric effects in the misalignment. The key findings are that currency overvaluation is negatively correlated with economic activity and the effect of overvaluation is much stronger than that of undervaluation.

The remainder of this paper is organised as follows. A review of previous studies can be found in Section 2. Section 3 summarises the theoretical background. Section 4 presents the empirical analysis in two parts, one studying the RER misalignment and the other investigating the use of growth regressions. Section 5 concludes.

2. Literature review

There is a growing literature that studies the relationship between real exchange rate misalignments and economic activity. Most of this literature fundamentally uses growth regressions with a measure of real exchange rate misalignment and a group of control variables from the literature on growth regressions. RER misalignments are defined as deviations of the exchange rate from an equilibrium level. An important distinction between different studies is the measure of RER misalignment. One branch uses purchasing power parity (PPP) exchange rate measures to find the equilibrium level and misalignments (Rodrik, 2008, and Prasad et al, 2007). The equilibrium exchange rate corresponds to the level which is consistent with the PPP definition.

Rodrik (2008) is probably the most influential contribution to this branch of the literature and shows that undervaluation has a positive effect on growth. However, if the PPP hypothesis does not hold in practice, the PPP exchange rate calculation is not a valid proxy for the long-run equilibrium.

A second group of studies define the equilibrium exchange rate as a function of a set of fundamentals. Once the functional form of the relationship between the fundamentals and the RER is defined, the long-run equilibrium level and its misalignment can be found. The long-run relationship is usually obtained using either time series or panel cointegration techniques. Ideally, the selection of these fundamentals should be based on a model for determining exchange rates. Razin and Collins (1999) start from the stochastic Mundell-Fleming model developed by Frenkel and Razin (1996), which is the stochastic version of the Mundell-Fleming model with short-run price rigidities. The equilibrium RER is the rate that would prevail were there full flexibility, while misalignments are deviations that are caused by price rigidity. Their results are consistent with an overvalued currency having a negative effect on economic growth, and also with there being some nonlinearities in the relationship. Aguirre and Calderon (2005) base their equilibrium RER measure on Obstfeld and Rogoff's (1995) model, where the economy has two sectors, the traded goods sector and the non-traded sector, and government spending. The model proposes that the fundamentals of the equilibrium exchange rate are productivity, net foreign assets, the terms of trade and government spending. The relationship between depreciation and growth is positive, which is in line with Rodrik (2008).

Other studies base their selection of which variables to consider as exchange rate fundamentals on the previous literature. This is seen in such studies as Berg and Miao (2010), MacDonald and Vieira (2010), Schröder (2013), Comunale (2017) and Habib et al. (2017), the first two of which find similar results to those of Rodrik (2008), as undervaluation pushes economic growth higher. Comunale (2017) and Habib et al. (2017) find the same result to be robust. In contrast however, Schröder (2013) and

Aguirre and Calderon (2005) find the effect of overvaluation to be stronger than that of undervaluation. Further, they find that undervaluation is not a positive factor for growth.

Across the literature the search for asymmetric effects from overvaluation and undervaluation has gained relevance because of its policy implications. A linear view of how misalignment affects growth usually implies that undervaluation promotes growth while overvaluation is harmful for economic activity. Rodrik (2008), Berg and Miao (2010), MacDonald and Vieira (2010), Comunale (2017) and Habib et al. (2017) find little evidence that the effects of undervaluation and overvaluation are asymmetric. However, there is a second strand of the literature that does find asymmetric effects and suggests both positive and negative misalignments are harmful to the economy. Aguirre and Calderon (2005) find the effects of both overvaluation and undervaluation to be negative for growth, with overvaluation having a stronger effect. Schröder (2013) finds both undervaluation and overvaluation to be negatively correlated with growth. Finally, the results found by Bajo-Rubio and Díaz-Roldán (2009), who following the approach of Thirlwall (1979) and Thirlwall and Hussain (1982), show evidence on how the balance of payments constrain economic growth in the CEEs.

3. Theoretical background

The analysis requires two relationships to be estimated, these being the equations for the exchange rate and economic activity, each of which has its own set of fundamentals. From the first relationship, the fundamentals of the RER (q_t) are per capita income (y_t) and a vector X_t which groups the remaining variables. Per capita income captures the Balassa-Samuelson effect of productivity gains in exchange rate appreciation. The equation for determining the exchange rate is defined as the equilibrium equation

$$q_t^e = f(y_t, X_t) \quad (1)$$

where the vector X contains government consumption, investment, openness, terms of trade and real-interest rate differentials.

The functional form of the relationship is usually linearised to simplify the complexity of the estimation. The most common approach is to select the fundamentals in an ad hoc fashion, implying that they are reduced-form equations for the exchange rate that is to be estimated. A few studies have presented formal models that can obtain structural equations for the exchange rate.

The exchange rate does not adjust instantaneously to its equilibrium level (q_t^e), meaning the exchange rate is also affected by some short-run dynamics. These short-run deviations from the equilibrium are the real exchange rate misalignments, that is,

$$q_t = q_t^e + mis_t \quad (2)$$

When the misalignments (mis) are introduced, the estimation of the exchange rate equation becomes a dynamic model.

The second equation relates economic activity and RER misalignments. This is the hypothesis which is most important for our research question of whether the short-run dynamics of the exchange rate affect output. The general form of the economic activity equation is

$$y_t = g(y_{t-1}, mis_t, W_t) \quad (3)$$

where additional determinants of economic activity are included in W_t. This dynamic equation can be obtained by combining a production function with a partial adjustment equation. Vector W_t includes the determinants from the production function, such as investment, human capital, openness, and government spending, some of which were also fundamentals of the real exchange rate in (1). The lagged dependent variable captures the dynamic path of y_t.

Mankiw et al. (1992) provide an extensively used framework that fits equation (3) and use the Cobb-Douglas production function to linearise equation (3). The log-linearised solution of the dynamic equation in the Solow model combined with the production function gives the growth regression in the form of the partial adjustment model. The lagged dependent variable (y_{t-1}) is the conditional convergence result from the literature on growth regression.

It is common to compute multiple-year averages, like the non-overlapping five year average, in order to eliminate any cyclical component of output and to capture the growth effects of the steady state determinants of the Solow model. However, this disregards the time-series properties of the data in three ways. First, the number of observations is considerably reduced, so a lot of information for the time series dimension is thrown away. Second, no distinction is made about whether the variables are stationary or nonstationary, given that T is small. Third, the endogeneity of y_{t-1} may pose a problem since, as Nickell (1981) showed, the presence of fixed effects requires large T for consistency. This third issue has attracted the most attention, as the dynamic panel GMM estimation techniques (Arellano and Bond, 1991, and extensions) are standard in empirical studies.

This strategy is unavailable to us since our empirical results rely mostly on time series variation, and we make better use of the data so as not to lose too many degrees of freedom in the time dimension. Furthermore, we avoid the risk of y_{t-1} becoming endogenous, because T is the dominant dimension of the panel. When N is relatively small or T relatively large, the dynamic panel GMM estimator may not be the best choice since its asymptotic properties rely on large N and the correlation of the lagged dependent variable with the error term may become insignificant so that endogeneity is not an issue. From their analysis of Monte Carlo simulations, Judson and Owen

(1999) consider that the performance of the System GMM is not superior to that of the OLS with fixed effects in panels when T>30, as it is in our case.

4. Results

4.1. Fundamentals of RER

Since there is ample evidence in the literature that Purchasing Power Parity does not hold[2] even in the long run,[3] the equilibrium exchange rate is defined as country specific. Therefore a country-specific cointegrating relationship is proposed where the real exchange rate depends on productivity, government consumption (gov_t), investment (inv_t), openness ($open_t$), terms of trade (tot_t) and real-interest rate differentials ($i_t - i_t^*$):

$$q_t^e = \alpha_0 + \alpha_1 y_t + \alpha_2\, open_t + \alpha_3 tot_t + \alpha_4 inv_t + \alpha_5 gov_t + \alpha_6 (i_t - i_t^*) \quad (4)$$

where all the variables are expressed in logarithms except for the interest rate. The cointegrated VAR (CVAR) method of Johansen (1988, 1991) is applied to test whether there is a long-run relationship between these variables. See the data appendix for a definition and the data sources of the variables.

We use similar fundamentals to those of Berg and Miao (2010) and MacDonald and Vieira (2010) among previous empirical studies. The empirical specification may also be interpreted as being consistent with the theoretical framework of Aguirre and Calderon (2005), with openness and investment replaced by net foreign assets.[4] This is the Obstfeld and Rogoff (1995) model augmented with a public sector. The exchange rate equation obtained from this model is log-linear.

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[2] For example, see Cuestas (2009) for a PPP study in CEE countries.

[3] Some authors have moved to a framework with a very long span of data where there is some evidence that PPP may hold (e.g. Taylor, 2002); however, this has also been challenged (e.g. Engel, 2000).

[4] As in Comunale (2017) an alternative approach is to include capital inflows. However, in our paper we include a larger numbers of fundamentals that may become collinear with capital inflows.

Our preliminary analysis, the results of which are omitted due to space limitations but are available from the authors upon request, finds all the exchange rate fundamentals for all the countries to be I(1). Likewise, the rank tests obtained as trace and maximum eigenvalue statistics show there to be one cointegrating relationship between these variables for each country. These results support our strategy of estimating a long-run exchange rate using quarterly data running from 1995 to 2012. The cointegrating vectors for each country can be found in Table 1, where the coefficients of the real exchange rate have been normalised to 1. The coefficients of the variables that were not significant at the 10% level have been omitted, with government spending and openness missing in five cases.

Table 1: Equilibrium Real Exchange Rate – cointegration relationship

	(1) Bulgaria	(2) Czech Rep.	(3) Estonia	(4) Hungary	(5) Latvia	(6) Lithuania	(7) Poland	(8) Slovakia	(9) Slovenia
Real exch rate	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Income per cap	-0.812***	-1.078***	-0.359***	-1.143***	-0.587***	-1.308***	-1.375**	-1.430***	-0.274***
	(0.031)	(0.0429)	(0.0225)	(0.106)	(0.182)	(0.214)	(0.657)	(0.146)	(0.0637)
Openness				0.317***	2.939***	1.740***	1.267**	-1.270***	0.138**
				(0.0850)	(0.493)	(0.413)	(0.600)	(0.273)	(0.0653)
Term of Trade	1.258***	-3.081***	-0.768***	-8.980***	-14.01***	23.09***	-5.809***	-15.92***	3.861***
	(0.458)	(0.909)	(0.0353)	(1.255)	(1.169)	(2.046)	(0.874)	(2.031)	(0.332)
Investment	0.212***		0.280***				1.168***		0.174**
	(0.021)		(0.0351)				(0.384)		(0.0760)
Gov Expenditure		0.474**		1.177***	2.438***		7.687***	-2.474***	0.395*
		(0.212)		(0.248)	(0.661)		(1.337)	(0.500)	(0.213)
Interest rate diff	-0.001***	-0.011***	0.0016**	-0.005***	-0.015***	-0.0102**	0.0241***	0.0127***	
	(0.000)	(0.00119)	(0.0006)	(0.001)	(0.0032)	(0.0049)	(0.0053)	(0.0025)	
Constant	-2.907***	6.736***		17.07***	18.56***	-48.36***		39.90***	-9.839***
	(0.940)	(1.991)		(2.525)	(2.869)	(4.216)		(4.428)	(0.732)
Logl	712.6	1262	1138	1221	1014	971.6	1071	1075	1305
Lags	4	3	2	3	2	2	2	3	2
Obs	66	67	68	67	68	68	68	67	68

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The negative sign of per capita income for all countries is consistent with the Balassa-Samuelson effect, whereby more developed countries should have a more highly valued currency because of productivity differentials in the non-tradable sector. The

Balassa-Samuelson effect is the real appreciation generated by the increase in the relative price of non-tradable goods that follows an increase in productivity in the more competitive tradable market. This is driven by the upward pressure on wages in the non-tradable sector that arises because wages in the tradable sector are higher since productivity growth is faster in that sector than in the non-tradable sector. Most of the international literature that looks at the empirical fulfilment of this relationship has shown evidence in support of the Balassa-Samuelson effect.

All the other variables may either show some change in sign, which is not always surprising since different hypotheses predict different signs, or may become non-significant in some specifications. Openness is not significant in five countries but it has a positive sign in the remaining four, which is as expected. Openness is expected to cause the real exchange rate to depreciate since trade liberalisation reduces the domestic prices of tradable goods, shifting demand away from non-tradables. This should make prices in the non-tradable sector fall, producing a real depreciation. The results for the Terms of Trade are mixed since the coefficient is always significant, but it is negative, as expected, in five countries and positive in the other four countries. The expected sign is negative because an improvement in the terms of trade should lead the currency to appreciate.

The interest rate differential to the international interest rate is significant in seven countries and we would expect to find a negative coefficient. If the interest rate of a small economy is higher than the international interest rate, creating the potential for capital inflows, we should observe an upwards trend in the exchange rate. This is the case in four of the countries, but the sign is the opposite in the other three economies. A possible explanation for this may be expectations. Our proxy for the interest rate differential is computed assuming forward-looking expectations for one period ahead, but it may be that it should use expectations for more than a year in some cases. Moreover, if for any reason there are expectations that monetary policy will cause the currency to appreciate or depreciate further than one period into the future, we may find the opposite sign when we consider the exchange rate observed rather than the expected exchange rate.

The expected signs for government consumption and investment are ambiguous, and they depend on the shares of spending on tradable and non-tradable goods. If the government spends relatively more on non-tradable goods, the sign should be negative, and it should be positive if relatively less is spent. Likewise, the sign should be negative if investment depends more on non-tradable goods. Investment spending seems to be more important since it is non-significant in only three countries, while government spending is non-significant in five countries. The dominant sign of both coefficients is positive, with only two exceptions among the nine countries, which implies that both government spending and government investment are relatively higher on tradable goods. It is surprising to find this sign for government spending, though perhaps not so much for investment, as it would imply that the productive sectors in these countries rely on imported goods.

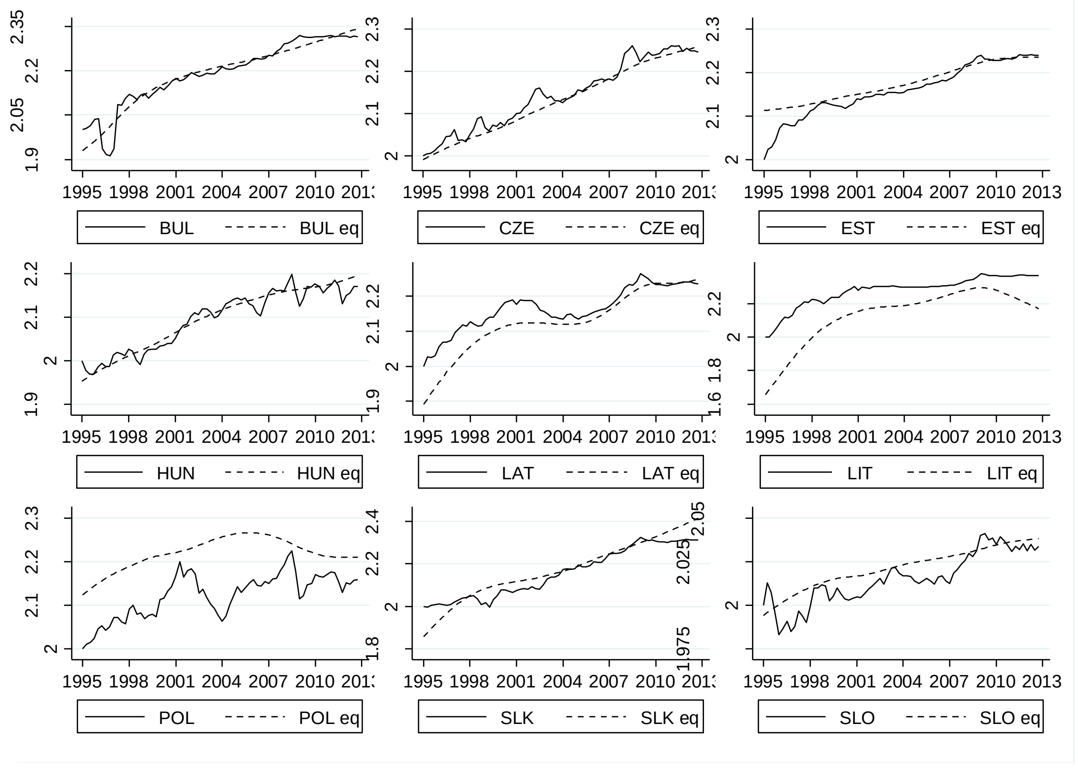
As Arberola (2003) points out, a cointegration relationship between the real exchange rate and its fundamentals would provide an estimate of the equilibrium if the equilibrium level of the determinants were observed, which is not the case. Therefore, for the long-run exchange rate to be calculated, the long-run values of the fundamentals must first be separated from their short-run fluctuations. We use the Hodrick-Prescott filter for this.[5] Since the filtered permanent component may be taken as the sustainable level, this is consistent with the concept of an equilibrium level. The equilibrium exchange rate from (4) is obtained by feeding the estimated model with the permanent components of the fundamentals. Figure 2 displays the original time series and its long run equilibrium counterpart.

Figure 3 shows the evolution of the computed misalignments ($m\hat{\imath}s$) over time by country. The misalignments are expressed in percentage points of q_t^e to give

[5] In short, the time series is viewed as the sum of transitory and permanent, or trend, components, where the filter captures the smooth path of the trend component by minimising the sum of the squares of its second difference. For each RER fundamental, the trend path is interpreted as the equilibrium level.

comparability, as this has the advantage that it is independent of the base year of the exchange rate index. The result is moderation of the misalignment. There is a clear overall pattern of misalignment being reduced until the third quarter of 2008. This pattern is even clearer if Lithuania and Poland are not considered. After 2008 quarter 3, the misalignments increase but they tend to die out in a few quarters, except for those in Lithuania, where there is a clear trend of increasing misalignment towards over-appreciation, while Slovakia and Poland also seem to be experiencing increasing misalignment, though it is not so clear cut. Additionally, it is interesting to see that the misalignments in Lithuania are apparently always overvalued and those in Poland are undervalued.

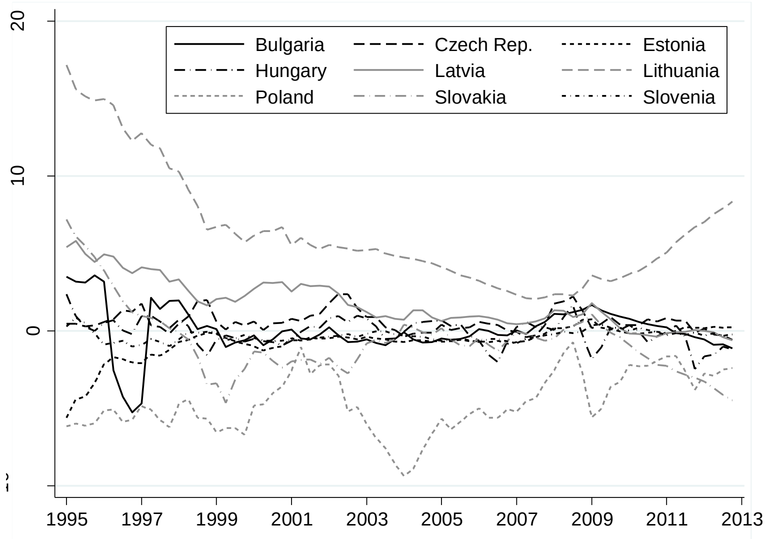
Figure 2: Long-run real exchange rates



Notes: The equilibrium exchange rates are computed using the cointegrating coefficients in Table 1 and the permanent component of the exchange rate fundamentals found with the Hodrick-Prescott filter.

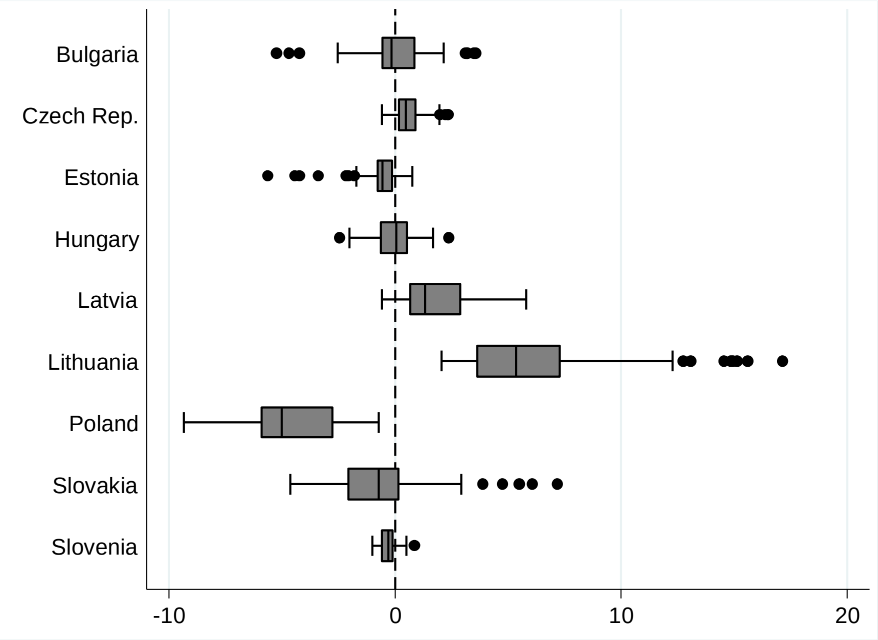
The box plots in Figure 4 show which countries have an overvalued or undervalued currency. It seems countries with overvalued or undervalued exchange rates also face a large amount of variability. Lithuania and Latvia both have overvalued currencies and large variability, while Poland and Slovakia also show large variability though their currencies are mostly undervalued. On the other side, Bulgaria, the Czech Republic, Estonia, Hungary and Slovenia have currencies with low variability that do not appear to be persistently overvalued or undervalued. The magnitude of misalignments is not large for these countries as it is always below 5% in either direction, especially in Slovenia, Hungary and the Czech Republic, where misalignments are below 2%.

Figure 3: Real Exchange Rate misalignments; misalignment over time (%)



Note: the misalignments are computed in percentage points of the equilibrium exchange rate using the cointegrating relationships in Table 1.

Figure 4: Real Exchange Rate misalignments by country (%)



Note: the misalignments are computed in percentage points of the equilibrium exchange rate using the cointegrating relationships in Table 1.

4.2. Economic activity

Once it has been found, the measure of the misalignments is used for looking at the relationship between misalignments and economic activity. The empirical strategy this time pools all the countries together to obtain a panel estimator where all the variables are in first differences:

$$\Delta y_{it} = \beta_0 + \beta_1 \Delta y_{it-1} + \beta_2 \Delta m\hat{i}s_{it} + \Gamma' \Delta X_{it} + \Phi' \Delta Z_{it} + u_{it} \tag{5}$$

Vector X groups openness, investment and the long-run exchange rate (q^e), all variables that were also included in the cointegrating relationship (1), while vector Z contains a new set of variables that may affect economic activity, such as education, financial development measured as domestic credit from the financial sector, and other institutional factors like the perception of corruption, the rule of law and regulatory quality. See the data appendix for the definition and sources of the variables. Since the variables in X were found to be I(1), the model is expressed in first differences, which would additionally account for any country fixed effects.

From the perspective of the production function, the assumption that functional form is homogenous across countries may be consistent with technology transfers between countries, which can reduce technology differences and free the flow of input variables such as capital, which is relatively movable across countries, and labour. This is common practice in cross-country studies such as growth regressions and the catching up hypothesis, which says that poor countries tend to catch up with more developed countries through technology transfers. This, however, is not to imply that these two theories predict that all countries would eventually gain the same level of development, since the neoclassical growth model notes that countries may have different steady states, and the catching up hypothesis allows for cultural differences.

Instead, a low level of initial economic activity is a potential source of faster growth through technology transfer or capital flows. Even theories that use the new endogenous growth models to predict persistent differences in growth and economic activity may also propose that either technology or capital or both may be easily transferred between countries.

Table 2 shows the results of the panel estimations where the dependent variable is our proxy of economic activity, which is per capita output in first differences. This is a common measure of growth in the literature since the variable is measured in logarithms. Column (10) is the estimation of equation (5). Our measure of RER misalignment is included in the regression together with the long-run real exchange rate, and openness and investment, which were among the variables included as fundamentals in equation (1). The coefficient for the misalignment is negative and significant, as is the long-run real exchange rate, which would suggest that it is harmful for economic growth if the exchange rate appreciates.

Next, a nonlinear specification is proposed where the exchange rate may be affected in different ways by overvaluation and undervaluation. The introduction of the dummy variable I_{POS} (1 if $m\hat{i}s > 0$ and 0 otherwise) and the interaction terms $\Delta m\hat{i}s_{it} \times I_{POS}$ and $\Delta m\hat{i}s_{it} \times I_{NEG}$ (where I_{NEG} is the complement of I_{POS}) allows positive and negative misalignments to have different effects:

$$\Delta y_{it} = \beta_0 + \beta_1 \Delta y_{it-1} + \beta_2(\Delta m\hat{i}s_{it} \times I_{NEG}) + \beta_3 I_{POS} + \beta_2(\Delta m\hat{i}s_{it} \times I_{POS}) \\ +\Gamma' \Delta X_{it} + \Phi' \Delta Z_{it} + u_{it} \qquad (6)$$

The estimates of equation (6) can be found in columns (11) to (20) with alternative determinants of economic activity. We find evidence that misalignments affect economic activity in a nonlinear fashion. The interaction terms are both significant at 1% and negative, and the difference between the two coefficients is also statistically significant, with overvaluation of the currency having a larger effect on economic activity.

The negative effect of the lagged values of Δy_t is consistent with our expectations. Within the framework of growth regressions, this result may be interpreted as favouring the conditional convergence. However, this result may be interpreted in different ways, as the negative sign would be consistent with the effect of the business cycle, which would also imply that past values for output should have a negative sign. Periods of fast growth may be followed by a slowing down, while periods of low growth may be followed by speeding up. The positive sign for investment is also in line with the production function approach. Investment is the control variable that is used most commonly in the literature, indicating the positive effect that capital accumulation has on output. This effect is statistically significant with a positive coefficient in all the regressions, and the sign is as expected. Some authors have found a positive correlation between openness and growth (Dollar, 1992, Sachs and Warner, 1995, Frankel and Romer, 1999), but some other studies have questioned the robustness of these results (Levine and Renelt, 1992, Sala-i-Martin, 1997 and Rodriguez and Rodrik, 1999). In this, the negative sign for openness in our results is in line with this second strand of the literature.

A number of variables with annual frequency are considered,[6] including enrolment in secondary school and years of schooling of the labour force as two proxies for human capital, and R&D spending and exports of high technology as proxies for technological development. Human capital is usually regarded as another important control variable in the production function tradition. Exports of high technology is the only one of these which is statistically significant and which has the expected sign, positive in this case.

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[6] These variables have been transformed into quarterly observations.

Table 2: Economic Activity – Growth regressions

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Lagged dependent var.	-0.183***	-0.204***	-0.201***	-0.205***	-0.208***	-0.206***	-0.214***	-0.214***	-0.219***	-0.220***	-0.218***
	(0.032)	(0.026)	(0.027)	(0.027)	(0.028)	(0.029)	(0.027)	(0.027)	(0.028)	(0.028)	(0.028)
Investment	0.129***	0.137***	0.137***	0.136***	0.136***	0.134***	0.138***	0.137***	0.136***	0.136***	0.137***
	(0.021)	(0.018)	(0.018)	(0.018)	(0.016)	(0.017)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)
Openness	-0.437***	-0.436***	-0.435***	-0.445***	-0.421***	-0.445***	-0.437***	-0.432***	-0.445***	-0.445***	-0.444***
	(0.072)	(0.071)	(0.071)	(0.071)	(0.072)	(0.075)	(0.068)	(0.069)	(0.068)	(0.069)	(0.068)
Exch. Rate (long run)	-0.458**	-0.487**	-0.512**	-0.623***	-0.552**	-0.744**	-0.706***	-0.728***	-0.952***	-0.958***	-0.831***
	(0.224)	(0.228)	(0.230)	(0.237)	(0.215)	(0.291)	(0.249)	(0.260)	(0.262)	(0.267)	(0.248)
Misalignment	-1.674***										
	(0.370)										
I_{NEG} × Misalignment		-0.854***	-0.849***	-0.884***	-0.699***	-0.747***	-0.711***	-0.707***	-0.730***	-0.737***	-0.733***
		(0.240)	(0.241)	(0.247)	(0.235)	(0.246)	(0.238)	(0.239)	(0.245)	(0.243)	(0.243)
I_{POS} × Misalignment		-2.772***	-2.767***	-2.777***	-2.871***	-2.846***	-3.191***	-3.075***	-3.172***	-3.175***	-3.173***
		(0.406)	(0.404)	(0.401)	(0.363)	(0.389)	(0.526)	(0.502)	(0.533)	(0.533)	(0.535)
Education (enrolment)			0.002								
			(0.002)								
Schooling years				0.013							
				(0.013)							
High Tech. Exports					0.003**		0.002**	0.003**	0.003**	0.003**	0.003**
					(0.001)		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R&D expenditure						-0.035					
						(0.035)					
Financial development							-0.002**		-0.001**	-0.001**	-0.002**
							(0.001)		(0.001)	(0.001)	(0.001)
M2 (% of GDP)								-0.002*			
								(0.001)			
Corruption									-0.004		
									(0.003)		
Rule of Law										-0.004	
										(0.003)	
Regulatory quality											0.003
											(0.004)
Constant	0.008***	0.010***	0.010***	0.010***	0.010***	0.011***	0.011***	0.011***	0.013***	0.014***	0.008**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)
I_{POS}		-0.004*	-0.004*	-0.004*	-0.004*	-0.004*	-0.003	-0.003	-0.004*	-0.003	-0.003
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	630	630	610	624	620	568	604	604	592	592	592
Adjusted R-squared	0.440	0.458	0.458	0.458	0.471	0.469	0.485	0.482	0.487	0.487	0.486

Notes: The dependent variable is per capita output (logs). Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficients in bold indicate their difference is statistically significant at the 5% level. Regressions (10) and (11) are based on equation (5). Regressions (12) to (19) are based on equation (6). All the variables are in first differences. I_{NEG} and I_{POS} are dummy variables for negative and positive values of the misalignments.

Table 2a: Summary of the results

	Sign
Lagged dependent var.	-
Investment	+
Openness	-
Exch. Rate (long run)	-
Misalignment	-
I_{NEG} × Misalignment	-
I_{POS} × Misalignment	-
Education (enrolment)	0
Schooling years	0
High Tech. Exports	+
R&D expenditure	0
Financial development	-
M2 (% of GDP)	-
Corruption	0
Rule of Law	0
Regulatory quality	0
I_{POS}	0-

Another factor that is usually included in the literature is institutions. Although many proxies have been explored, they are mostly non-significant in our results. Only the two proxies for financial development, M2 and domestic credit provided by the financial sector as a percentage of GDP, are statistically significant. Other institutional factors, such as control of corruption, the rule of law and regulatory quality, were not statistically significant. Given the important changes in the institutions in these transitional economies in the last 25 years, we would have expected to find some type of association with economic activity. It may be that the period analysed is too short at 12 years to allow any effect from these institutions to be observed. Table 2a shows a summary of the results.

5. A nonlinear approach to growth

A common assumption with panel data is that the heterogeneity in the data can be completely captured using either individual or time fixed effects, or both. When this is done, the coefficients of the variables considered in the model do not vary along time or across panel members. This problem can be solved by introducing parameter heterogeneity in the specification, which means the threshold effects in it are considered. In addition, linear models are particular cases of nonlinear ones. In this context nonlinear models provide us with further flexibility in the econometric analysis, which cannot be attained with linear models.

This leads us to the Panel Threshold Regression (PTR) model, developed primarily by Hansen (1999). More precisely, in the present paper we consider an extension of the PTR specification called the Panel Smooth Threshold Regression (PSTR) model. González et al. (2005) and Fok et al. (2005) proposed using smooth transition specifications in the panel data framework, as they have been widely used in the study of time series. The PSTR model can be formulated as:

$$\Delta y_{it} = \mu_i + [\pi_0 \Delta m\hat{i}s_{it} + \Pi' \Delta V_{it}]\big(1 - F(s_{it}; \gamma, c)\big)$$
$$+[\lambda_0 \Delta m\hat{i}s_{it} + \Lambda' \Delta V_{it}] F(s_{it}; \gamma, c) + u_{it} \qquad (7)$$

where $F(.)$ is the transition function. With the new transition function, this is a nonlinear model and it is estimated by nonlinear least squares. Using first differences does not eliminate the fixed effects as it does in the linear model, so they are introduced by μ_i. The vector V gathers all the K control variables, which are the lagged dependent variable and the controls from both vector X and vector Z, while Π and Λ are two $1 \times K$ vectors of coefficients. Although equation (7) only has one transition function between two regimes, the framework can be extended to consider additional regimes that introduce more transition functions.

The transition function is bounded between 0 and 1, so that the PSTR coefficients vary between the two regimes. The coefficient of the misalignments varies between π_0 and λ_0, while the coefficient of any other control variable from vector V (v_k) would vary between π_k and λ_k (with $k = 1,2, \dots K$). As Colletaz and Hurlin (2006), and Kadilli and Markov (2012) point out, the values of the estimated coefficients are not directly interpretable, and only their signs can be interpreted in a direct manner.

The transition function contains the slope parameter γ and the location parameter c. The first of these shows how rapid the transition between the extreme regimes is, while c indicates the threshold between these regimes. As $\gamma \to \infty$, the PSTR in (7) approaches the two-regime panel threshold model described in Hansen (1999); and as $\gamma \to 0$, the model comes closer to being linear. The transition variable and the associated value of $F(s_{it})$ determine the regime for country i at time t.

A common selection for $F(.)$ is the logistic specification (Granger and Teräsvirta, 1993; Teräsvirta, 1994; Jansen and Teräsvirta, 1996):

$$F(s_{it}; \gamma, c) = \left[1 + exp\left(-\gamma(s_{it} - c)\right)\right]^{-1} \quad (8)$$

with $\gamma > 0$. The case of the logistic function implies that $F(-\infty) = 0$ and $F(\infty) = 1$, while $F(c) = 0.5$; this being so, extreme regimes are associated with s_{it} values far above or below the threshold, where their dynamics may be different. With more than two regimes, additional threshold parameters (c_j) are required, introducing additional multiplicative terms inside the exponential function.

If the nonlinear specification is more appropriate than the linear model from section 4, a hypothesis that is yet to be tested, the remaining challenge is to select the appropriate transition variable (s_{it}). As Kadilli and Markov (2012) noted, the selection of the transition variable is one of the most important problems when specifying the PSTR model since the model places no restrictions on it. In the current paper, we consider economic reasons for alternatives to the transition variable;

authors like Fok et al. (2005) also select their transition variable using economic intuition. The obvious candidate is the misalignment itself as a transition variable, which would indicate the importance of the misalignment in capturing the nonlinearities in the dynamics of these economies.

5.1. Empirical results

The empirical analysis is presented in Tables 3 and 4. The transition variable we have considered is the one that is most suitable for the analysis: the RER misalignment itself and its first lag. All the regressors set out in section 3 are initially considered in the specification, including the lagged dependent variable, the misalignment, the equilibrium exchange rate, the five other quarterly variables from X and the annual control variables from Z.

The linearity test, which is the diagnostic test of homogeneity against the PSTR alternative, is important since the Panel STR specification is not identified if the DGP is homogenous. The PSTR model (7) and (8) adopts a homogenous form if we impose either $H_0: \gamma = 0$ or $H_o': \theta_0 = \lambda_0$ and $\theta_k = \lambda_k$. In that case we can use these assumptions to test linearity. One problem that arises is that the corresponding tests are nonstandard because the PSTR model contains unidentified nuisance parameters under the null hypothesis. This issue was already a major concern in the time series context.

To circumvent these problems, González et al. (2005) propose that the transition function $F(s_{it}; \gamma, c)$ be replaced by its first-order Taylor expansion around $\gamma = 0$. A test equivalent to $H_0: \gamma = 0$ can then be performed using the auxiliary regression from the Taylor approximation. As in Colletaz and Hurlin (2006), and Seleteng et al. (2013), three versions for this test are considered, namely the Wald LM, Fisher LM and Likelihood Ratio tests. Table 3 presents the diagnostic statistics from the linearity tests; in all cases, the null of linearity can clearly be rejected in favour of a PSTR specification.

Table 3: Linearity tests results

	Linearity test					
Transition variable	H_0: linearity *vs* H_1: PSTR model with two regimes			H_0: linearity *vs* H_1: PSTR model with three regimes		
	LM_{Wald}	LM_{Fisher}	LR	LM_{Wald}	LM_{Fisher}	LR
rermiss100_hp	32.759	2.222	33.811	45.397	1.533	47.451
	(0.005)	(0.005)	(0.004)	(0.035)	(0.037)	(0.022)
L.rermiss100_hp	39.038	2.682	40.545	58.274	2.021	61.719
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)

Notes. p-values in parentheses. The transition function is the logistic one.

We proceed to estimate a PSTR specification for economic activity in Table 4, together with some diagnostic and validation statistics. For each regression, the parameter estimates are grouped in two columns that are associated with the two extreme cases $F(.) = 0$ and $F(.) = 1$. However, it is important to note that unless the transition function takes an extreme value of zero or one, each observation is a weighted average of the two regimes, with weights given by $F(.)$.

In regression (21), the nonlinearity in the model is concentrated in the effect of the misalignment as we impose $\pi_k = \lambda_k$ while $\pi_0 \neq \lambda_0$. This is the same specification as in regression (16) in Table 2, but augmented with the transition function where the threshold parameter is endogenous rather than zero. The threshold is estimated to be 0.0004, a magnitude which is reasonably close to zero. This is consistent with the assumption in Table 2. After this, two extreme regimes can be defined, with a lower regime associated with undervaluation and dominated by π_k coefficients, and an upper regime that could be associated with undervaluation of the real exchange rate through λ_k coefficients. The number of observations is quite balanced as 46% of them exceed the estimated threshold. The dynamics of economic activity will differ depending on the existing regime.

The sign and magnitude of the coefficients are very similar to what they were in regression (16), except the misalignment, which stops being statistically significant as the currency becomes undervalued. Likewise, the transition between the two regimes is very rapid given the large magnitude of $\hat{\gamma}$. It should be highlighted that this always has a negative effect on the economy; an increase in the currency misalignment harms economic activity, while a decrease in misalignment improves it. Any measure that increases the misalignment in overvaluations would be a bad policy. This is in line with previous results in the literature where overvaluation of the currency is found to have a negative impact on economic growth while undervaluation does not have such an impact. The reason or rationale behind this is that overvaluation tends to damage the competitiveness of exports abroad while making imported products more expensive internally.

From Figure 5 it can be seen that the economy that experienced the most adverse effect from its real exchange rate being overvalued would be Lithuania, followed by Latvia, while Poland has had an undervalued currency, which is also detrimental for economic activity. These results are in contrast with Comunale (2017), who finds that the exchange rates in all the CEECs are mostly overvalued during this period. It may be recalled though that the set of fundamentals used by Comunale (2017) is limited to capital flows and a behavioural real exchange rate.

Regression (22) allows for nonlinearities in the effect of the other determinants of economic activity. We include other variables that become statistically significant in one or both of the regimes. Exports of high technology are significant only at 10% in

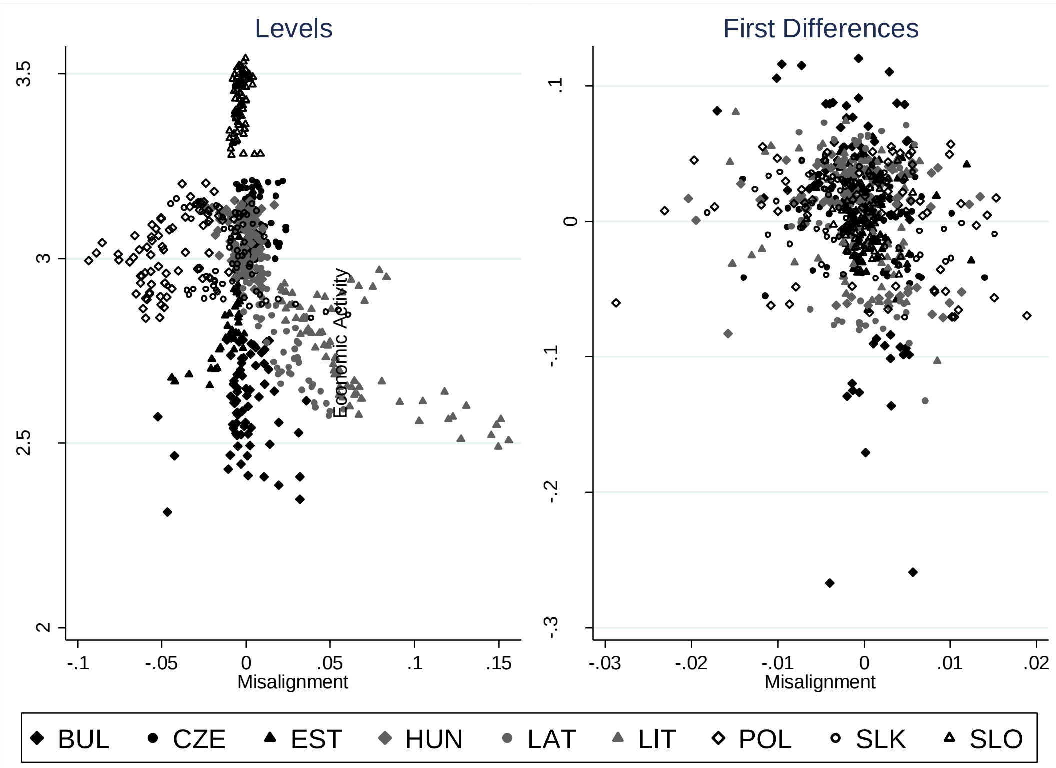
Table 4: Economic Activity - PSTR models

	(21)		(22)		(23)		(24)		(25)	
VARIABLES	$F(.) = 0$	$F(.) = 1$	$F(.) = 0$	$F(.) = 1$	$F(.) = 0$	$F(.) = 1$	$F(.) = 0$	$F(.) = 1$	$F(.) = 0$	$F(.) = 1$
	π_i	θ_i	π_i	θ_i	π_i	θ_i	π_i	θ_i	π_i	θ_i
Misalignment	-0.365	-3.768***	-0.174	-4.387***	-0.388*	-3.961***	-0.805***	-2.112***	-1.522***	-2.018***
	(0.228)	(0.534)	(0.234)	(0.601)	(0.234)	(0.538)	(0.232)	(0.440)	(0.487)	(0.418)
Lagged dependent variable	-0.220***		-0.217***	-0.230***	-0.231***		-0.230***	-0.244***	-0.223***	
	(0.027)		(0.044)	(0.054)	(0.027)		(0.066)	(0.040)	(0.030)	
Investment	0.139***		0.131***	0.155***	0.138***		0.114***	0.181***	0.159***	
	(0.014)		(0.025)	(0.026)	(0.014)		(0.026)	(0.026)	(0.012)	
Openness	-0.444***		-0.307***	-0.569***	-0.445***		-0.142	-0.601***	-0.565***	
	(0.068)		(0.103)	(0.099)	(0.065)		(0.100)	(0.085)		(0.072)
Exchange rate (long run)	-1.025***		2.909***	-1.612***	1.743**	-1.313***	0.840	-0.756***		-0.951***
	(0.260)		(0.939)	(0.365)	(0.728)	(0.287)	(0.742)	(0.272)		(0.299)
High technology exports	0.002*				0.003**					
	(0.001)				(0.001)					
Education (enrolment)					0.003*		-0.001	0.005*		
					(0.002)		(0.003)	(0.003)		
Financial development	-0.002***		0.002*	-0.004***		-0.003***	0.004***	-0.004***		-0.003***
	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)	(0.001)		(0.001)
Rule of Law			-0.033***	-0.008	-0.028**				-0.014**	
			(0.012)	(0.013)	(0.011)				(0.007)	
Regulatory quality			0.034***	0.024*	0.022**				0.023**	
			(0.012)	(0.014)	(0.009)				(0.011)	
gamma	129.7		161.7		163		255.1		8049	
ctr	0.000419		0.00178		0.00354		-0.00484		-0.00546	
Observations	604		596		572		594		596	
Adjusted R-squared	0.490		0.521		0.503		0.523		0.510	
$F(.) \leq 0.05$	0.118		0.154		0.168		0.163		0.300	
$F(.) \geq 0.95$F	0.156		0.164		0.159		0.318		0.658	

Notes: Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors in parentheses, with *** p<0.01, ** p<0.05, * p<0.1. Coefficients in bold are statistically different from each other at the 5% level. All regressions include country fixed effects. The coefficients are grouped in two columns, one for each regime. The transition variable for the first three regressions is the real exchange rate misalignment, while the last two regressions use the first lag of the RER misalignment. The dependent variable is per capita output (logs). All the variables are in first differences.

regression (21) and become nonsignificant as we introduce more nonlinearities in the model. The misalignment shows the same behaviour as in regression (21). Other control variables show similar behaviour, as the coefficients in the two regimes are similar in sign and magnitude, which may be interpreted as a shortage of evidence of nonlinearities in these factors, except for the equilibrium exchange rate, which now has a positive coefficient when the economy is running with an undervalued currency.

Figure 5: Economic activity and RER misalignments



Note: Economic activity refers to per capita income (in logs), while the misalignments are computed in percentage points of the equilibrium exchange rate using the cointegrating relationships in Table 1.

Two other institutional variables, the rule of law and regulation quality, are introduced because their coefficient is statistically significant in at least one of the two regimes. Regression (23) imposes some constraints, reducing the number of parameters that are to be estimated. Coefficients that are not statistically significant are set to zero, so $\pi_k = 0$ or $\lambda_k = 0$, while coefficients that are not statistically different in the two regimes are constrained to be the same, so $\pi_k = \lambda_k$. The previous results are confirmed, though the threshold parameter has increased to 0.00345, with 38% of the observations above it. However, this is still a small threshold and overvaluation still has a negative impact on economic activity. Interestingly, technology and education become statistically significant and have the expected sign.

The relative importance of the institutional variables is shown to depend on the regime. The rule of law and the quality of regulation are more important during periods when the currency is undervalued, while financial development becomes more important in periods of overvaluation. With an overvalued currency, in the second regime, and a well-developed financial market, the economy is more prone to receiving short-term capital inflows, fed by expectations that further appreciation may increase financial instability, which is known to affect economic growth negatively. This may explain the negative sign for financial development in the second regime. However, it is more difficult to find a connection between an undervalued currency and the rule of law or the quality of regulation

The last two regressions repeat the analysis but replace the exchange rate misalignment as the transition variable with its lag. Most of the previous results remain, though some of the nonlinear effects disappear and the rule of law and regulation quality are no longer significant. The coefficients of the misalignments of the two regimes are closer to each other than before.

6. Conclusions

In this paper we have analysed the degree of RER misalignments, and we use these misalignments in a growth regression set up for a group of CEE countries. The empirical strategy was successful in identifying the long-run relationship for individual countries between the exchange rate and a group of fundamentals from open macroeconomic models and from the results of previous empirical studies. Most of the signs for the cointegration relationship are as expected. The misalignment shows a clear pattern of shrinking in magnitude and disappearing until 2008, after which the trend is partially reversed. However, if Lithuania were to be excluded, there would be no clear increase in the dissipation of the misalignment.

The misalignments are negatively associated with growth. It is harmful for economic activity if the exchange rate is overvalued as was found in most of the previous literature such as Berg and Miao (2010), MacDonald and Vieira (2010), Schröder (2013), Comunale (2017) and Habib et al. (2017). However, countering the results in those studies, nonlinearities indicate that the effect of an overvaluation is much stronger than that of an undervaluation. This asymmetric effect is in line with previous results from Aguirrea and Calderón (2005) for a sample of 60 countries. Undervaluation has had a limited effect on economic activity in the experience of CEE countries.

Implementing the threshold regression approach shows the nonlinearity is mostly driven by exchange rate misalignments. The results obtained emphasise that CEE countries, which were transitional economies during most of the period analysed, need a combination of factors if they are to develop further. They must pay particular attention to their foreign exchange relationships and public policies in general, and to how they consolidate their economies; moreover, the degree of financial development means that other institutional variables, such as corruption and the rule of law, have a key role to play.

Acknowledgments.

Juan Carlos Cuestas acknowledges the financial support from the ECO2017-85503-R and ECO2017-83255-C3-3-P projects from `Agencia Estatal de Investigación' (AEI) Spain and `Fondo Europeo de Desarrollo Regional' (FEDER). Comments from two anonymous referees are gratefully acknowledged. The views expressed are those of the author and do not necessarily represent the official views of Eesti Pank, the European Central Bank or the Eurosystem.

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Data appendix

The first set of variables is the real exchange rate and six other variables that represent its fundamentals: per capita output, openness, terms of trade, investment, government spending, and interest rate differentials against Germany. All of them are transformed into logs, except interest rate differentials. Figures for GDP and GDP-related components (government consumption, gross capital formation and exports plus imports) and for population come from Eurostat, as does terms of trade, which is defined as the ratio of price indexes for exports and imports, and the real effective exchange rate. To obtain real interest rates, the harmonised CPI series were taken mainly from Eurostat. The harmonised CPI time series from Eurostat for the period 1996Q1-2012Q4 has been expanded backward using national CPI figures from the IMF statistics. To compute real interest rates, forward looking rational expectations are assumed implicitly since the nominal interest rates, which are annualised, are adjusted by the year to year change in the CPI one period ahead.

The time series for interest rates were mainly taken from the IMF IFS database for deposit rates. It was challenging to obtain comparable interest rates for the full period 1995Q1-2012Q4 for some countries because of changes in the methodology. Countries which join the euro area are required to homogenise their statistics for retail market interest rates within a set timeframe. Euro area members collect their interest rate statistics following the standards of the Monetary Financial Institutions (MFI) statistics. Once a country joins the MFI statistics, it is difficult to compare the new time series with those that came earlier. Germany, our choice for the representative international interest rate for these economies, is the country where this limitation is most severe, as the methodology there changed in 2003. The countries in the sample that changed their methodology are Poland (2006), Slovakia (2008), Slovenia (2009) and Lithuania (2010), while Bulgaria, the Czech Republic, Estonia, Hungary and Latvia used the same methodology throughout the whole period 1994-2012. For the countries where the methodology was changed, the national interest rates (i_N) for the initial part of the sample were complemented, when necessary, with the new IMF series (i_{IMF}) to extend the series out to 2012Q4. If there is a change in the methodology in the period, the old series is extrapolated with the new series: $i_{Nt+1} = i_{Nt}(i_{IMF\ t+1}/i_{IMF\ t})$.

Additional annual variables that were considered, having been transformed into quarterly observations, include school enrolment (secondary school, % gross), domestic credit provided by the financial sector (% of GDP), and money and quasi money (M2, as % of GDP), which were taken from the World Development Indicators (World Bank). Data for the institutional variables of control of corruption, rule of law and regulatory quality come from the World Bank governance dataset (Kaufmann et al., 2008).