Nonlinear real exchange rate dynamics in Slovenia and Slovakia[1]

Peter Mikek
Wabash College
Indiana, USA
e-mail: mikekp@wabash.edu

Alenka Kavkler
Faculty of Economics and Business
University of Maribor, Slovenia
e-mail: alenka.kavkler@uni-mb.si

Abstract:

We model the dynamics of the real exchange rate in two transition economies: Slovenia and Slovakia in a nonlinear framework with smooth transition regression and a vector of 3 endogenous variables. We allow for different transition function in each of individual equations included in a vector error correction model. After testing for nonlinearities, we choose the transition variables and estimate the smooth transition vector autoregression. We find evidence that the real exchange rate dynamics is nonlinear. Additionally, the real exchange rate varied asymmetrically with respect to two monetary regimes: when the central bank targeted real exchange rate and when it targeted inflation and price stability.

Keywords: nonlinear models**,** smooth transition vector error-correction models, real exchange rate, unemployment, wages.

JEL classification: C30, C32, E24, E31, E41.

[1] This research was supported by a grant from the CERGE-EI Foundation under a program of the Global Development Network. All opinions expressed are those of the authors and have not been endorsed by CERGE-EI or the GDN.

Introduction

Modelling the dynamics of real exchange rates with linear models has rendered rather limited success. Thus we ask whether the modelling of the real exchange rate in a multivariate model with smooth transition autoregression (STVAR) improves the description of its dynamics, accounts for possible asymmetries, and allows for distinguishing between alternative regimes.

In addition to various shocks, real exchange rates respond to different states of the economy. The changes in the transition economies such as Slovenia and Slovakia have been both very rapid and deep. Institutional adjustments in economic environment building the market are surely a prime example of structural breaks. Therefore the traditional modelling techniques are not adequate to describe dynamics of many economic variables in such an environment. However, recently developed models of smooth transition regression (STR) lend themselves naturally to modelling development in variables subject to structural breaks and asymmetric dynamics.

STR models allow for smooth changes from one regime to another rather than abrupt switching between regimes. Methodology found has been successfully used to model a number of economic issues, including Okun's Law (Mayes and Viren, 2002; Kavkler et al., 2007a), Phillips curve (Kavkler and Boehm, 2005), company's investment decision (Gonzalez et al., 2005), business cycles (Fok et al., 2005a, 2005b) and others. However, the most numerous are applications to exchange rates.

There may be many reasons for modelling the exchange rate with nonlinear models, including transport costs, tariffs or non-tariff barriers, official interventions on the foreign exchange market. Sarno and Taylor (2002), Sarno (2003), and Taylor (2006) assess the contribution of nonlinear models to explaining the behaviour of exchange rates. Numerous authors reject linearity in favour of STAR models describing exchange rate dynamics: Liew, Chong and Lim (2003), Rapach and Wohar (2006), Paya, Venetis, and Peel (2003).

A growing number of studies apply nonlinear logistic STAR (LSTAR) or Exponential STAR (ESTAR) models and find (rapid) mean reversion in both real and nominal exchange rates: Taylor, Peel, and Sarno (2001); Sarno and Taylor (2002) for four major dollar real exchange rates; Guerra (2003) for the Swiss frank–German mark; Liew, Bahrumshah and Lim (2004) for the Singapore dollar-US dollar; Paya and Peel (2005) for high inflation countries; Leon and Najarian (2005); and Baum, Barkoulas and Caglayan. (2001) using deviations from PPP obtained by the Johansen cointegration method. Additionally, Sollis (2005), Leon and Najarian (2005) reject unit root for real exchange rates. Asymmetries in adjustment of real exchange rate to equilibrium was studied in Leon and Najarian (2005), and Legrenzi and Milas (2006). Arghyrou, Boinet, and Martin (2005) study PPP deviations in Central Europe and find that the short-run dynamics of the real exchange rates is nonlinear and asymmetric, while the speed of adjustment depends on the size and sign of the deviation. These papers all share a univariate approach to modelling the exchange rate. Kavkler et al. (2007a) is a nice overview of the literature.

Different from previous studies, Legrenzi and Milas (2006) study a VAR that includes exchange rate, unemployment rate and real wages. They find evidence of both nonlinearities and asymmetries in exchange rates. We extend their basic approach to model the real exchange rate for a transition economy within multivariate framework and using monthly data. Additionally, we relax their assumption that the dynamics of the real exchange rate is governed by the same transition variable and the same type of the transition function in all three equations of their STRVEC model. The approach of smooth transition VAR (STVAR)[2] is especially promising for economic environment characterized by a number of deep-reaching changes in economic environment. The approach implies that the regime switching in these economies was not abrupt process with sudden changes and allows for incorporating varying speed of adjustment from almost instantaneous to more protracted. This seems to describe well the changes in

[2] Weise (1999), Van Dijk et al. (2002), and Camacho (2004), and extended the STR modelling developed by Teräsvirta into VAR framework.

transition economies and captures both asymmetries in the behavior of the real exchange rate and its adjustment to structural breaks.

In deriving the linear equation that is used as a basis for the model we follow Legrenzi and Milas (2006). Thus the equation reflects two sector economy: tradables and nontradables. We then employ a multivariate STVAR methodology to model the nonlinear dynamics of the real exchange rate. One prominent source of nonlinearity in these economies were certainly official exchange rate interventions due to both countries attempts to stabilize the economies and meet the Maastricht criteria. The vector of variables includes monthly observations of real exchange rates, real wages and unemployment rates.

1. Multivariate smooth transition models

Weise (1999), van Dijk (2001) and Camacho (2004) extended the STR modeling approach to vector autoregressive models of smooth transition. Their STR specification is limited to the case where the transition between different parameter regimes is governed by the same transition variable and the same type of transition function in every equation of the system. They argue that since the economic practice imposes common nonlinear features, all equations share the same switching regime. But this argument is not convincing, since such a conclusion cannot be derived from economic theory, while applied econometric studies analyzing nonlinear systems are scarce. Kavkler et al. (2007b) propose an augmented specification procedure that allows for different transition variables and different functional forms in different equations of the system. The procedure employs the system linearity test as well as single equation linearity tests (based on system estimates of auxiliary regressions). All linearity tests are derived with the help of a Taylor expansion of the transition function. The system linearity test will be rejected if at least one of the relationships under observation is nonlinear, or more specifically, is characterized by smooth transition between parameter regimes. It is reasonable to believe that situations with only one of the equations being nonlinear can occur in the economic practice. Estimating all equations with the smooth transition specification would be inefficient in this case. This problem may be solved with the help of the single equation linearity tests. Details can be found in Kavkler et al. (2007b).

A Smooth Transition Vector Error Correction Model (STVECM) can be written in the following form (Rothman et al., 2001)

$$\begin{aligned}\Delta y_t &= \left(I - G(s_t)\right)\left(\mu_1 + a_1 z_{t-1} + \sum_{j=1}^{p-1}\Phi_{1,j}\Delta y_{t-j}\right) + \\ &+ \left(G(s_t)\right)\left(\mu_2 + a_2 z_{t-1} + \sum_{j=1}^{p-1}\Phi_{2,j}\Delta y_{t-j}\right) + \varepsilon_t\end{aligned} \quad \textbf{(1)}$$

y_t and μ_i are (kx1) vectors, z = ß'y are error correction terms. a_i, Φ_{1j} and Φ_{2j} are compatible matrices of parameters. Endogenous variables y_t are I(1) and ε_i are iid(0,Σ). $G(s_t)$ is a (kxk) diagonal transition matrix of continuous transition functions in individual equations ($G_i(s_{ti})$, i=1,2,…,k). Note that unlike Rothman et al. (2001) and Legrenzi and Milas (2006) we allow for a possibility of different transition variables and different transition functions in different equations. This incorporates regime switching and allows two different regimes for each of the equations included in the STVECM. The extremes are captured by transition function Gi being either 0 or 1. However, transition from one regime to the other is smooth.

The most popular functional forms of the transition function are as follows:

Logistic STR (LSTR1) Model: $G_1(\gamma, c; s_t) = \dfrac{1}{1 + e^{-\gamma(s_t - c)}}$ **(2)**

G_1 is a monotonously increasing function of the transition variable s_t, bounded between 0 and 1. $G_1(\gamma, c; c) = 0.5$; therefore the location parameter c represents the point of transition between the two extreme regimes with $\lim_{s_t \to -\infty} G_1 = 0$ and $\lim_{s_t \to \infty} G_1 = 1$. The restriction $\gamma > 0$ is an identifying restriction. If $\gamma \to \infty$ in G_1, then model (1) converges to a switching regression model with the extreme regimes $y_t = x_t'\varphi + u_t$ and

$y_t = x_t'(\varphi + \theta) + u_t$. For γ = 0, the function G_1 is constant and equal to 0.5. In this case, model (1) simplifies to a linear regression model.

LSTR2 Model: $$G_2(\gamma, c_1, c_2; s_t) = \frac{1}{1 + e^{-\gamma(s_t - c_1)(s_t - c_2)}} \quad \textbf{(3)}$$

Monotonous transition may not always be satisfactory in applications. The quadratic logistic function in the LSTR2 model is a nonmonotonous transition function that is especially useful in the case of reswitching. G_2 is symmetric about the point $\frac{c_1 + c_2}{2}$ and $\lim_{s_t \to \pm\infty} G_2 = 1$. G_2 is never equal to 0; its minimal value lies between 0 and 0.5

Exponential STR (ESTR) Model: $$G_3(\gamma, c; s_t) = 1 - e^{-\gamma(s_t - c)^2} \quad \textbf{(4)}$$

Sometimes it is desirable that small absolute values of the transition variable are related to small values of the transition function. The ESTR model with an exponential transition function complies with the above condition for c = 0. Both the LSTR2 model and the ESTR model enable reswitching, but they differ in the rapidity of reswitching. For a large value of γ, the transition of s_t from 1 to 0 and back to 1 is much faster for the ESTR model as compared to the LSTR2 model, where the reswitching can be slower when the gap between c_1 and c_2 is large. Some further details can be found for example in Kavkler et al. (2007a).

Testing for linearity in equation (1) above implies testing the null $H_0 : \gamma = 0$ against $H_1 : \gamma > 0$. Luukkonen, Saikkonen and Teräsvirta (1998) suggest replacing the transition function by its Taylor approximation of a suitable order around $\gamma = 0$. The equation is rewritten as a polynomial in the transition variable and the coefficients in the nonlinear part of the equation are then jointly tested to zero. Third order auxiliary regression (i.e. a third order polynomial in s_t) is usually used. The type of transition function is determined with the help of a sequence of nested hypotheses that test for the order of polynomial in s_t (see Teräsvirta (1998) for details).

Because of the short time series available for the transition economies under observation (Slovenia and Slovakia) it is not possible to implement the linearity tests based on third order auxiliary regression. Similar to Legrenzi and Milas (2006) we work with the first order approximation and restrict our attention to the LSTR1 transition function, while allowing for different transition variables in different equations.

For a VEC model, the first order auxiliary regresssion is as follows:

$$\Delta y_t = M + A_0 z_{t-1} + \sum_{j=1}^{p-1} B_{0,j}\Delta y_{t-j} + S_t A_1 z_{t-1} + \sum_{j=1}^{p-1} S_t B_{1,j}\Delta y_{t-j} + e_t \qquad \textbf{(5)}$$

where S_t is a diagonal matrix with transition variables in individual equations as diagonal elements, M is a vector of regression constants, A_i and B_i are compatible matrices of coefficients. Under the null hypothesis of system linearity, H_0: $A_1 = B_{1j} = 0$ against the alternative that at least one is not zero. This can be tested with a straightforward Lagrange multiplier test where the test statistic is asymptotically χ^2-distributed. However, the F-version of the linearity test is usually preferred because of its better small sample properties.[3]

2. Specification of the real exchange rate

Next we apply the general theoretical framework discussed in the preceding section to the real exchange rate. Like Legrenzi and Milas (2006) we assume two sector economy, with tradables and nontradables sectors. While tradables sector is fully exposed to international competition the nontradables sector is not. Thus the production in the latter assumes profit maximizing monopolistic competitive companies. The domestic price (p) is thus a weighted average of tradable (p^T) and nontradable (p^N) prices in logs:

$$p = \gamma p^T + (1-\gamma) p^N \qquad \textbf{(6)}$$

[3] Some further details are in Kavkler et al. (2007a) and comprehensive discussion in Teräsvirta (1998) and in Luukkonen, Saikkonen and Teräsvirta (1998).

where γ represents a share of tradables in home output. In perfectly competitive environment p^T is a given parameter for firms. However, the price of nontradables is chosen to include a mark-up over unit labor costs (Obstfeld and Rogoff, 1996):

$$p^N = w + \mu \qquad \textbf{(7)}$$

where μ represents the mark-up and w is the wage rate that is due to competition for labor the same in both sectors. Additionally, the mark-up depends on the gap between actual (y) and full-employment (y^*) output:

$$\mu = \psi(y - y^*) \qquad \textbf{(8)}$$

Additionally, denoting unemployment by u and assuming Okun's Law to hold:

$$-\lambda u = (y - y^*) \qquad \textbf{(9)}$$

the following can be derived from (6) above:

$$p^T - p = -(1-\gamma)(w - p^T) + (1-\gamma)\psi\lambda\, u \qquad \textbf{(10)}$$

In (10) the real exchange rate is a function of real wages and unemployment. While sign for real wages is negative ($0 < \gamma < 1$) the sign for unemployment could be either positive or negative. This depends on elasticity ψ, which corresponds to procyclical versus counter cyclical behaviour of the mark up. Both are possible: Legrenzi and Milas (2006) cite evidence for its procyclical behavior in the UK, Rotemberg and Woodford (1999) or Gali et al. (2002) find counter cyclical behaviour. An increase in $p^T - p$ represents improvement of international competitiveness of home economy and thus real depreciation. In terms of notation above (10) implies the following vector of k = 3 endogenous variables $y = (p^T - p,\ w - p^T,\ u)'$.

However, focusing on monthly data we could not find monthly data on prices of domestically produced goods (GDP deflator on monthly basis). Therefore we opted to slightly augment the above specification in the following way:

$$y = (p^T – p^N,\ w - p^T,\ u)' \quad \textbf{(11)}$$

This is only a slight modification and the real exchange rate being a ratio of tradable to non tradable prices obtains in a multitude of models (e.g. Obstfeld and Rogoff, 1996). Indeed, it is more common than the ratio proposed by Legrenzi and Milas (2006). For this specification we use monthly seasonally adjusted data from 1993m1 to 2007m3. w is the unit labor cost measured by an index of gross nominal monthly wage (in EUR), u is unemployment rate, p^T is price of tradables measured by the PPI for manufacturing sector. Monthly frequency of data proved to be a real challenge forcing us that we used CPI for services as a measure for p^N. This is justified by the fact that only minute share of services is traded across the borders and therefore price of services can serve as a proxy for price of nontradables. All variables are in logs. The data were obtained from several sources including the Vienna Institute for International Economics Studies (WIIW), the administrator of the Monthly Database on Central and Eastern Europe, Statistical Office of the Republic of Slovenia and OECD.

3. Empirical results

Results for Slovenia are presented first. As is frequently reported in studies of the kind (Kavkler et al., 2007a, or Ahmad and Gloser, 2007) estimation for Slovakian data did not converge and therefore we present only results for linear model.

4.1 Slovenia

In a preliminary specification, the linear vector error-correction model was specified. This simplifies the search for an appropriate nonlinear specification. Table 1 shows the results of ADF unit root tests for the data. The log levels of the all series are I(1), but differences are I(0). As neglected autocorrelation structure may lead to false rejections of the linearity hypothesis (Teräsvirta, 1994), the order of autoregression was chosen on the basis of the serial correlation tests. Thus, a model with a lag order 2 was specified.

Table 1: ADF Unit Root Test Results for Slovenia (p-values)

Variable	$\left(p^T - p^N\right)_t$	$\left(w - p^T\right)_t$	u_t
ADF p-value	0.9605	0.3940	0.0713
Variable	$\Delta\left(p^T - p^N\right)_t$	$\Delta\left(w - p^T\right)_t$	Δu_t
ADF p-value	0.0062	0.0000	0.0000

Both the trace and the max-eigenvalue statistic indicate existence of r = 1 cointegrated vector. Consequently, the long run behavior or the Slovenian real exchange rate is characterized by the following cointegrating equation (with SE in parenthesis):

$$ce_t = 0.4633 + (p^T - p^N)_{t-1} + \underset{(0.2550)}{2.0911} \cdot (w - p^T)_{t-1} - \underset{(0.1101)}{0.1807} \cdot u_{t-1} - \underset{(0.0011)}{0.0046} \cdot trend \tag{12}$$

The equation corresponds to the real exchange rate equation in (10) above with additional trend and constant terms. Additionally, the sign of unemployment points to procyclical mark-up (similar to Legrenzi and Milas, 2006). The coefficient of 2.0911 for (w-p^T) shows the share of tradables to be more than 2/3. This is certainly consistent with the fact that Slovenia is a small and very much open economy.

The system linearity tests and the single equation linearity tests (based on first order auxiliary regression (5)) are performed in the next step. The first and the second lag of the three endogenous variables as well as the contegrating equation ce_t are regarded as candidates for the transition variable. Since in the augmented specification procedure different transition variables are allowed in different equations of the system, there are $7^3 = 343$ possible transition variable triplets. The system linearity test and all of the single equation linearity tests are rejected in only six cases. These are shown in Table 2 below.

Table 2: Linearity Test Results (p-values)

LINEARITY TESTS (p-values)						
Transition variables			Test results			
1st eq.	2nd eq.	3rd eq.	System	1st eq.	2nd eq.	3rd eq.
$\Delta\left(p^T - p^N\right)_{t-1}$	$\Delta\left(w - p^T\right)_{t-1}$	$\Delta\left(w - p^T\right)_{t-2}$	0.0002	0.0039	0.0228	0.0419
$\Delta\left(p^T - p^N\right)_{t-1}$	ce_t	$\Delta\left(w - p^T\right)_{t-2}$	0.0004	0.0036	0.0472	0.0265
Δu_{t-1}	$\Delta\left(w - p^T\right)_{t-1}$	$\Delta\left(w - p^T\right)_{t-2}$	0.0006	0.0146	0.0265	0.0348
Δu_{t-1}	Δu_{t-2}	$\Delta\left(w - p^T\right)_{t-2}$	0.0006	0.0141	0.0253	0.0360
$\Delta\left(p^T - p^N\right)_{t-2}$	$\Delta\left(w - p^T\right)_{t-1}$	$\Delta\left(w - p^T\right)_{t-2}$	0.0011	0.0292	0.0322	0.0444
$\Delta\left(p^T - p^N\right)_{t-2}$	Δu_{t-2}	$\Delta\left(w - p^T\right)_{t-2}$	0.0011	0.0312	0.0330	0.0458

According to the augmented specification procedure proposed by Kavkler et al (2007b), the transition variable triplet with the strongest rejection of system linearity is chosen. Thus, the following transition variables are used: $\Delta(p^T - p^N)_{t-1}$ in the first, $\Delta(w - p^T)_{t-1}$ in the second and $\Delta(w - p^T)_{t-2}$ in the third equation of the system. While the first two will be interpreted in conjunction with the coefficients estimated below, the third one corresponds well to economic theory. It shows tight relationship between real wages and unemployment. In particular, unemployment reacts strongly to real wages with two months lag, consistent with some frictions on the labor markets. It is interesting that the transition variable in any of the equations is not a deviation from the cointegrating vector (ce). Unlike Legrenzi and Milas (2006) we deal with a transition economy where structural changes were large and they distorted a simple exchange rate dynamics.

As already explained, the LSTR1 transition function is specified in all equations, since it is not possible to perform third order auxiliary regression for the linearity tests and carry out the described sequence of nested hypotheses to determine the type of transition function. Following Teräsvirta (1994) all the transition functions are scaled by the standard deviation of the transition variable and in this way γ becomes scale free parameter.

The estimated coefficients of the proposed smooth transition vector error-correction model and the results of the diagnostic tests are given in Table 3 below. The transition function in the i -th equation is denoted by $G_i(s_t)$ with

$$G_1(\gamma,c;s_t)=1\Big/\Big(1+\text{Exp}\Big(\underset{(0.0101)}{-8.6466}\Big(\Delta(p^T-p^N)_{t-1}\underset{(0.0009)}{+0.0077}\Big)/\sigma(\Delta(p^T-p^N)_{t-1})\Big)\Big) \quad \textbf{(13)}$$

$$G_2(\gamma,c;s_t)=1\Big/\Big(1+\text{Exp}\Big(\underset{(1.0977)}{-12.5695}\ \Big(\Delta(w-p^T)_{t-1}\underset{(0.0068)}{-0.0489}\Big)/\sigma(\Delta(w-p^T)_{t-1})\Big)\Big)$$

$$G_3(\gamma,c;s_t)=1\Big/\Big(1+\text{Exp}\Big(\underset{(0.0118)}{-250.4726}\ \Big(\Delta(w-p^T)_{t-2}\underset{(0.0002)}{+0.0106}\Big)/\sigma(\Delta(w-p^T)_{t-2})\Big)\Big)$$

The transition functions with parameter c indicate existence of two different regimes. For all transition functions the speed adjustment parameter γ is rather large and indicates rapid transition from one extreme regime ($Gi(s_t)=0$) to another ($Gi(s_t)=1$). In particular the transition for the third equation is extremely quick, corresponding to large structural shifts, such as changing labor market legislation. All the estimated coefficients in transition functions are highly significant.

Interpretation of different regimes in this framework is difficult since we allow for changes in regimes in all the variables of the system. However, focusing on the exchange rate equation we can interpret the regimes as reverting to the long run relationship or not, and whether the reversion is smooth process or not. In particular, the smooth process would indicate the policy of targeting real exchange rate by the central bank. Alternatively, oscillating reversion to the long run relationship is likely to indicate a different paradigm in monetary policy focusing on inflation and price stability. Results of estimated nonlinear model are given in Table 3 below:

Table 3: Smooth Transition Vector Error-Correction Model

Regressors	Equations		
	$\Delta\left(p^T - p^N\right)_t$	$\Delta\left(w - p^T\right)_t$	Δu_t
Linear part			
$const$		0.0066 (0.0013)	-0.0030 (0.0009)
$\Delta\left(p^T - p^N\right)_{t-1}$	0.3217 (0.0907)		
$\Delta\left(w - p^T\right)_{t-1}$	-0.1316 (0.0266)	-0.5885 (0.0729)	
Δu_{t-1}	-0.2692 (0.0785)		0.8582 (0.1444)
$\Delta\left(p^T - p^N\right)_{t-2}$	0.2095 (0.0434)		-0.7032 (0.0900)
$\Delta\left(w - p^T\right)_{t-2}$		-0.3911 (-0.3911)	
Δu_{t-2}	0.1036 (0.0374)	-0.4123 (0.1069)	0.2479 (0.0652)
ce_t	-0.0551 (0.0442)	-0.1740 (0.0352)	
Nonlinear part			
$const \cdot G(s_t)$	-0.0032 (0.0006)	0.1833 (0.0560)	
$\Delta\left(p^T - p^N\right)_{t-1} \cdot G(s_t)$	-0.5196 (0.1470)		
$\Delta\left(w - p^T\right)_{t-1} \cdot G(s_t)$		-3.9788 (1.0535)	-0.3944 (0.1155)
$\Delta u_{t-1} \cdot G(s_t)$	0.2204 (0.0858)		-0.7755 (0.1527)
$\Delta\left(p^T - p^N\right)_{t-2} \cdot G(s_t)$	-0.4636 (0.0490)	-10.2059 (3.6944)	0.8022 (0.0958)
$\Delta\left(w - p^T\right)_{t-2} \cdot G(s_t)$	-0.0912 (0.0215)	-0.7426 (0.2361)	
$\Delta u_{t-2} \cdot G(s_t)$	-0.0971 (0.0402)		
$ce_t \cdot G(s_t)$	0.1293 (0.0450)		
R^2_{nl}	0.2699	0.6933	0.3471
$S.E._{nl}$	0.0052	0.0140	0.0084
R^2_{lin}	0.1433	0.6471	0.2334
$S.E._{lin}$	0.0055	0.0148	0.0090
$\hat{\sigma}^2_{nl} / \hat{\sigma}^2_{lin}$	0.7461	0.8782	0.8338

Diagnostic tests (p-values)			
AR LM (8)	0.6445	0.2496	0.4230
ARCH LM (8)	0.9992	0.5538	0.1869
Param. const. lin.	0.6508	0.7579	0.2294
Param. const. nl.	0.2550	0.2483	0.3452

Notes: standard errors are given in brackets. AR LM (8) denotes the no remaining error autocorrelation test (with no autocorrelation up to 8 lags under the null hypothesis). The ARCH LM (8) notation is analogous. The param. const. lin. refers to the LM3 test for the constancy of parameters in the linear part of the equation and param. const. nl. in the nonlinear part (see Lin and Teräsvirta (1994) for details).

Focusing on the real exchange rate equation, all the coefficients are highly significant, providing evidence in favor of nonlinear specification. The only exception is the coefficient for the deviations from the cointegrating vector in linear estimation. 0.3217 for $\Delta\left(p^T - p^N\right)_{t-1}$ shows the gradual appreciation of the real exchange rate over time. The appreciation of real exchange rates for transition economies, including Slovenia, is widely documented (e.g. Coricelli and Jazbec, 2001). As productivity in tradable sector in transition economies is growing rapidly due to the process of catching up, the productivity in nontradable sector is growing much slower. However, competing for the same labor imposes same real wage and therefore due to Balassa Samuelson's effect the transition economies experienced appreciation of their real exchange rate. The process was very dynamic during first part of economic transition but has been slowing down (e.g. Mikek, 2007). The positive coefficient smaller than 1 shows this slowing of real appreciation

Additionally, the monetary policy in Slovenia before 2000 was focusing on stabilizing the real exchange rate (Bole, 2003). After 2000, however, it changed its focus and devoted its efforts to disinflation and price stability. Figure 1 in the Appendix shows a change in dynamics of the real exchange rate around 1999/2000 which corresponds to changing focus of Slovenian monetary policy. It is interesting to notice the break around the same time also for real wages and dynamics of unemployment.

Considering nonlinear part, the coefficient for $\Delta\left(p^T - p^N\right)_{t-1}$ is the sum of the linear and nonlinear estimates: -0.1979 = 0.3217-0.5196. This means that the convergence (coefficient less than 1) was characterized by fluctuating towards the long run relationship. This indicates periods when monetary authority was not targeting real exchange rate. Instead it was vigorously pursuing disinflation, as was the case recently.

It would, or course, be simplistic to assume that regimes were not switching also before and after 1999/2000. In particular, the transition function in figure 5 shows switching regime also in early stages of economic transformation and in 2004. The regimes may have been switching due to various reasons. However, monetary authority occasionally caused switching the regimes. One of the reasons for this was that in a very open economy with strong exchange rate pass through effect, it saw stabilization of the exchange rate as a tool for stabilizing the prices (Bole, 2003).

4.2 Slovakia

Authors frequently report problems with converging in STR models (e.g. Kavkler et al., 2007a, or Ahmad and Gloser, 2007). This was the case also when applying the methodology described above to monthly data for Slovakia. The model did not converge. Therefore we have no evidence to reject the linearity in data for real exchange rate in Slovakia. However, the long run dynamics of the Slovakian real exchange rate is governed by the following cointegrating equation:

$$\begin{array}{l} ce_t = -0.8236 + (p^T - p^N)_{t-1} - \underset{(0.5221)}{2.9737} \cdot (w - p^T)_{t-1} + \underset{(0.1748)}{0.6247} \cdot u_{t-1} + \underset{(0.0023)}{0.0188} \cdot trend \end{array} \quad \mathbf{(14)}$$

Similarly as above, the coefficients indicate very open economy with very large share of tradables in their production. The sign for unemployment indicates counter cyclical behaviour of unemployment.

Additionally, the following linear model was obtained:

Table 4: Real exchange rate linear VAR(1) model for Slovakia:

	Equations		
Regressors	$\Delta\left(p^T - p^N\right)_t$	$\Delta\left(w - p^T\right)_t$	Δu_t
const	-0.0062 (0.0013)	0.0050 (0.0028)	-0.0022 (0.0014)
$\Delta\left(p^T - p^N\right)_{t-1}$	-0.1255 (0.0815)	-0.2085 (0.1594)	-0.0647 (0.0854)
$\Delta\left(w - p^T\right)_{t-1}$	-0.0127 (0.0413)	-0.2140 (0.0808)	-0.0634 (0.0433)
Δu_{t-1}	-0.2637 (0.0719)	0.0225 (0.1405)	0.3920 (0.0752)
ce_t	-0.0016 (0.0090)	0.0533 (0.0176)	-0.0350 (0.0094)
R^2	0.1068	0.1542	0.3338
S.E.	0.0147	0.0287	0.0154

Notes: standard errors are given in brackets.

Again focusing on the exchange rate equation, we are surprised by negative signs of coefficient for $\Delta\left(p^T - p^N\right)_{t-1}$ and $\Delta\left(w - p^T\right)_{t-1}$. However, these are not significant. Indeed, the only significant coefficient in this equation is associated with Δu_{t-1}, indicating that an increase in unemployment has negative effect on the relative price of tradables. An increase in unemployment is likely to be associated with lower wages and prices in both sectors. The effect seems to be stronger in tradable sector and consequently decreases real exchange rate and depreciate real exchange rate.

5 Conclusion

The economic transition is characterized by many structural breaks in data due to institutional adjustments and general improvements in productivity. However, not all of the switches in regimes are abrupt. The smooth transition vector error correction model provides a framework that can successfully incorporate both asymmetries and structural breaks in time series.

We generalize the approach and estimate a different transition function in each equation of the vector error correction STR system applying it to monthly data. In a model of the real exchange rate in a two sector economy with tradables and nontradables, the prices of former are determined on competitive markets, the prices of latter based on a mark-up upon the real wage.

We find strong evidence in favor of nonlinear dynamics in the real exchange rate in Slovenia. The estimated cointegrating vector implies a realistically high share of tradables for the small open economy. The coefficients show appreciation of the real exchange rate over the observed period, but it is gradually phasing out. Additionally, the coefficients are consistent with exchange rates reverting to their long-run relationship. The transition functions clearly identify two regimes related to the exchange rate. The results are consistent with the change in monetary policy during the period 1999-2000. During this time, the monetary authority abandoned smoothing of the real exchange rate and started pursuing disinflation or price stability. For Slovakia we we only report the linear model since the nonlinear model does not converge.

6 References

Ahmad, Y., S. Glosser (2007), Searching for Nonlinearities in Real Exchange Rates. Manuscript, University of Wisconsin: Whitewater, WI.

Arghyrou, M. G., V. Boinet, C. Martin (2005), Beyond purchasing power parity: Nominal exchange rates, output shocks and non linear/asymmetric adjustment in Central Europe. Money Macro and Finance Research Group Conference, paper No. 35.

Baum, C. F., J. T. Barkoulas, M. Caglayan (2001), Nonlinear adjustment to purchasing power parity in the post Bretton-Woods era. Journal of International Money and Finance, Vol. 20(3), 379-399.

Bole, V. (2003), Denarna politika v času odštevanja (Monetary policy during the count down). Gospodarska gibanja. Ekonomski institut Pravne fakultete. Ljubljana. No. 346, 23-43.

Camacho, M. (2004), Vector Smooth Transition Regression Models for US GDP and the Composite Index of Leading Indicators. Journal of Forecasting, Vol. 23, 173-196.

Coricelli, F. and Jazbec, B. (2001) Real exchange rate dynamics in transition economies. CEPR Discussion Paper No. 2869, London.

Fok D., D. van Dijk, P. H. Franses (2005a), A multi-level panel STAR model for US manufacturing sectors. Journal of Applied Econometrics, Vol. 20(6), 811-827.

Fok D., D. van Dijk, P. H. Franses (2005b), Forecasting aggregates using panels of nonlinear time series. International Journal of Forecasting, Vol. 21(4), 785-794.

Gali, J., M. Gertler, D. Lopez-Salido (2002), Mark-ups, gaps and the welfare costs of business fluctuations,. NBER Working paper no. 8850, Cambridge, MA.

Gonzalez, A., T. Teräsvirta, D. van Dijk (2005), Panel Smooth Transition Regression Models. Research Paper Series 165, Quantitative Finance Research Centre, University of Technology, Sydney.

Guerra, R. (2003), Nonlinear adjustment towards purchasing power parity: the Swiss Franc-German Mark case. Swiss Journal of Economics and Statistics, Vol. 139(1), 83-100.

Kavkler, A., B. Böhm (2005), Nonlinear Okun's law: a smooth transition regression approach. In: Neichev, S. (ed.). *Economic development and growth: 4th International Symposium Economy & Business Proceedings.* Bourgas: Bulgarian Academy of Science: 12-21.

Kavkler, A., P. Mikek, B. Böhm, D. Borsic (2007a), Nonlinear Econometric Models: The Smooth Transition Regression Approach. Submitted to *Journal of Economics and Statistics.*

Kavkler, A., B. Böhm, D. Borsic (2007b), Smooth transition vector error-correction (STVEC) models: An application to real exchange rates. Submitted to …

Leon, H., S. Najarian (2005), Asymmetric adjustment and nonlinear dynamics of real exchange rates. International Journal of Finance & Economics, Vol. 10(1), 15-39.

Legrenzi, G., C. Milas (2006), Non-linear real exchange rate effects in the UK labour Market, manuscript, Keele University, Great Britain.

Liew, V. K. S., T. T. L. Chong, K. P. Lim (2003), The inadequacy of linear autoregressive model for real exchange rates: empirical evidence from Asian economies. Applied Economics, Vol. 35(12), 1387-1392.

Liew, V. K. S., A. Z. Baharumshah, K. P. Lim (2004), On Singapore dollar-US dollar and purchasing power parity. Singapore Economic Review, Vol. 49(1), 71-84.

Lin, C.F., T. Teräsvirta (1994), Testing the constancy of regression parameters against continuous structural change. Journal of Econometrics, Vol. 6, 211-228.

Luukkonen, R., P. Saikkonen, T. Teräsvirta (1998), Testing linearity against smooth transition autoregressive models. Biometrika, Vol. 75, 491-499.

Mayes, D.G., M. Viren (2002), Asymmetry and the Problem of Aggregation in the Euro Area. Empirica, Vol. 29, 47-73.

Mikek, P. (2007), The Dynamics of Shock Correlations between the Old and New Members of the European Union, manuscript, Wabash College.

Obstfeld, M., K. Rogoff (1996), Foundations of International Macroeconomics. The MIT Press, Cambridge Massachusetts.

Paya, I., I. A. Venetis, D. A. Peel (2003), Further evidence on PPP adjustment speeds: the case of effective real exchange rates and the EMS. Oxford Bulletin of Economics and Statistics, Vol. 65(4), 421-437.

Paya, I., D. A. Peel (2005), The process followed by PPP data. On the properties of linearity tests. Applied Economics, Vol. 37(20), 2515-2522.

Rapach, D. E., M. E. Wohar (2006), The out-of-sample forecasting performance of nonlinear models of real exchange rate behaviour. International Journal of Forecasting, Vol. 22 (2), 341-361.

Rotemberg, J.J., and M. Woodford (1999), The cyclical behavior of prices and costs. In J.B. Taylor and M. Woodford (eds.) Handbook of Macroeconomics, Vol. 1B., Amsterdam, North-Holland, 1051-1135.

Rothman, P., D. van Dijk, P. H. Franses (2001), Multivariate STAR Analysis of Money Output Relationship. Macroeconomic Dynamics, Vol. 5(4), 506-532.

Sarno, L. (2003), Nonlinear exchange rate models. A selective overview. IMF Working Papers 111.

Sarno, L., M. P. Taylor (2002), Purchasing power parity and the real exchange rate. IMF Staff Papers 49: 65-105.

Sollis, R. (2005), Evidence on purchasing power parity from univariate models: the case of smooth transition trend stationarity. Journal of Applied Econometrics, Vol. 20(1), 79-98.

Taylor, M. P. (2006), Real exchange rates and purchasing power parity: mean-reversion in economic thought. Applied Financial Economics, Vol. 16(1/2), 1-17.

Taylor, M. P., D. A. Peel, L. Sarno (2001), Nonlinear mean-reversion in real exchange rates: toward a solution to the purchasing power parity puzzles. International Economic Review, Vol. 42(4), 1015-1042.

Teräsvirta, T. (1994), Specification, estimation, and evaluation of smooth transition autoregressive models. Journal of the American Statistical Association, Vol. 90, 208-218.

Teräsvirta, T. (1998), Modelling economic relationships with smooth transition regression. In: *Handbook of Applied Economic Statistics*. Marcel Dekker: New York. p: 507-522.

van Dijk, D. (2001), *Smooth Transition Models: Extensions and Outlier Robust Inference.* Tinberg Institute: Amsterdam.

Weise, C.L. (1999), The Asymmetric Effects of Monetary Policy: A Nonlinear Vector Autoregression Approach. Money, Credit and Banking, Vol. 31, 85-108.

Appendix

Figure 1: Plots of data series levels for Slovenia

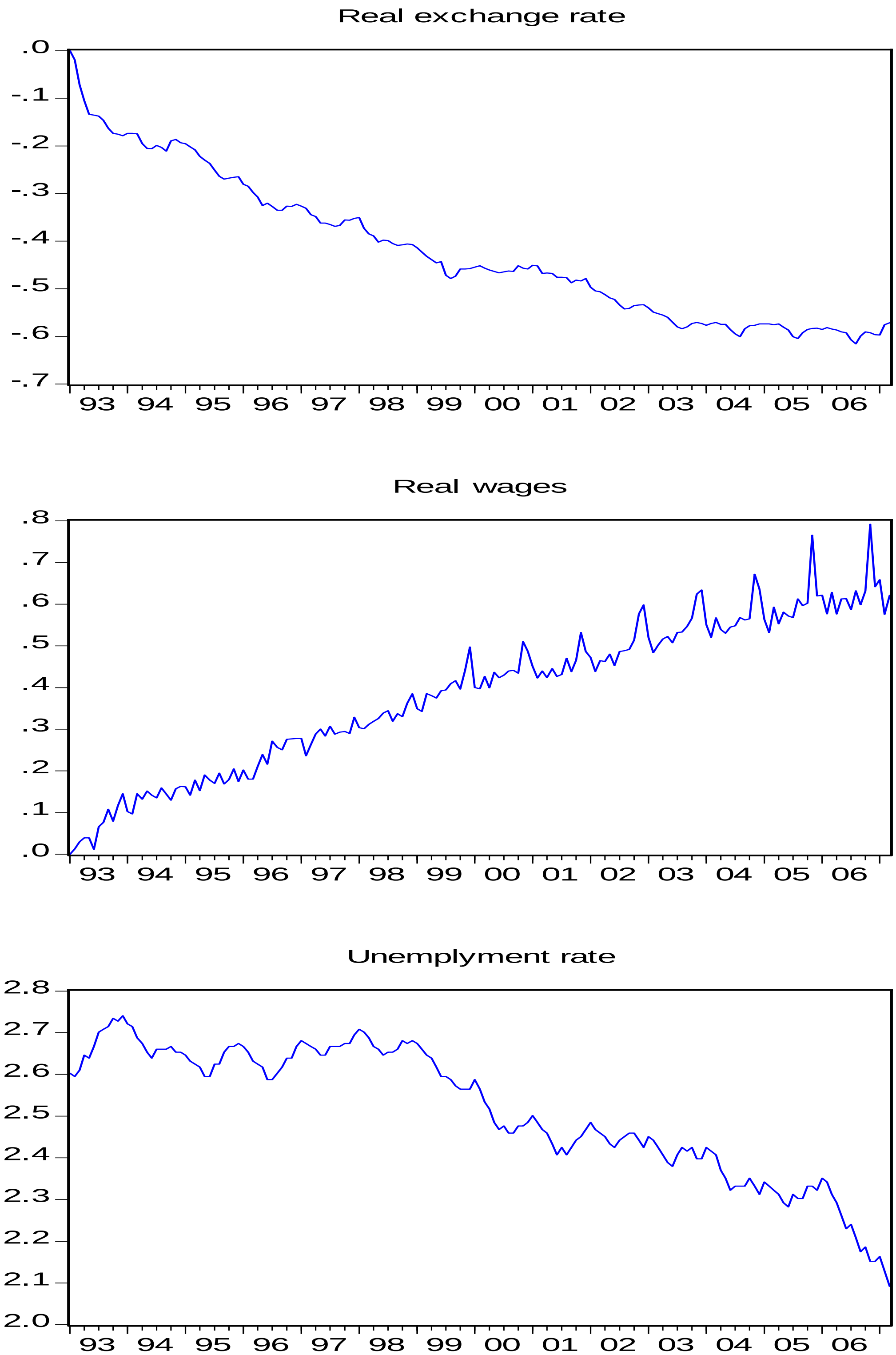


Figure 2: Plots of data series differences for Slovenia

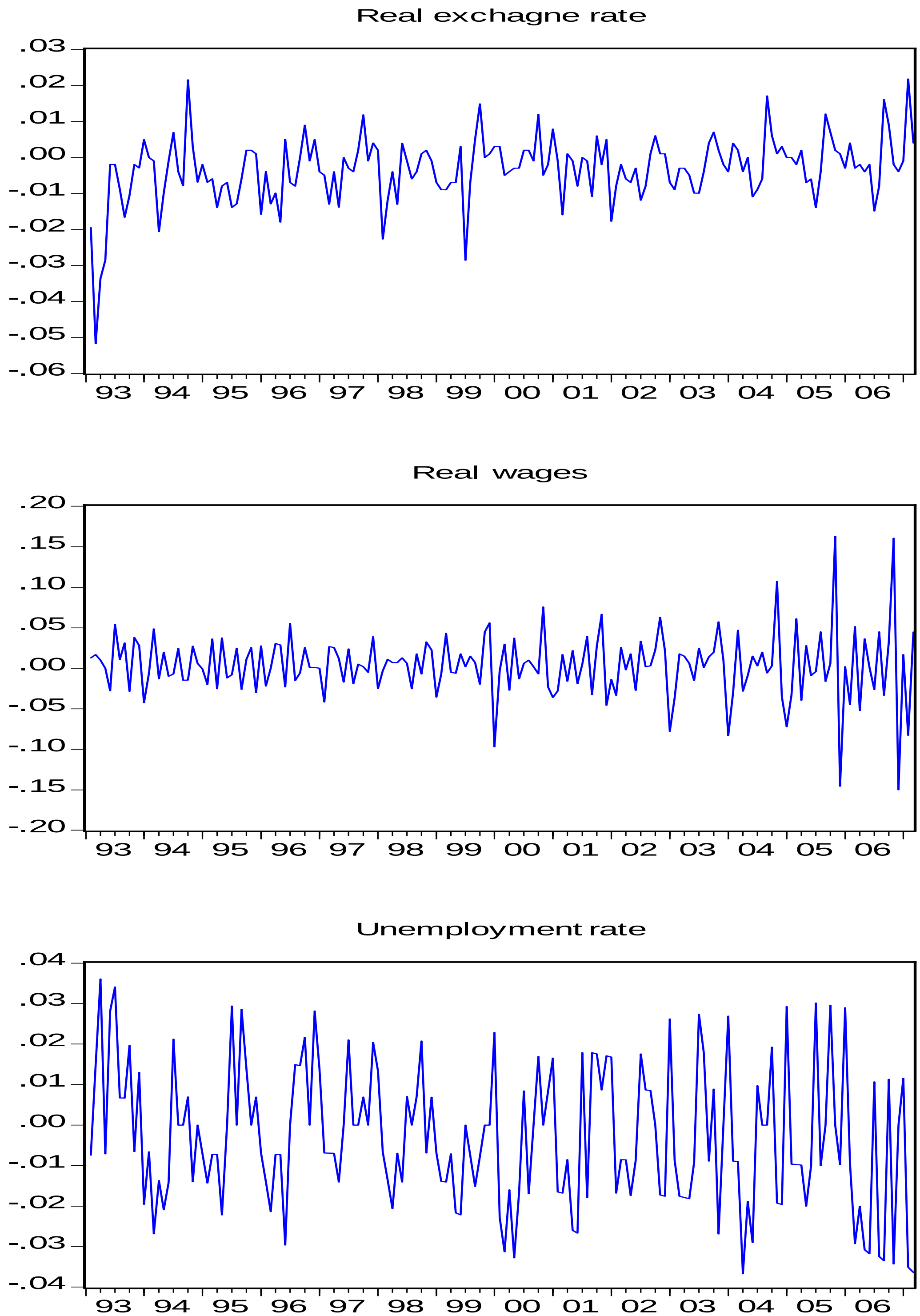
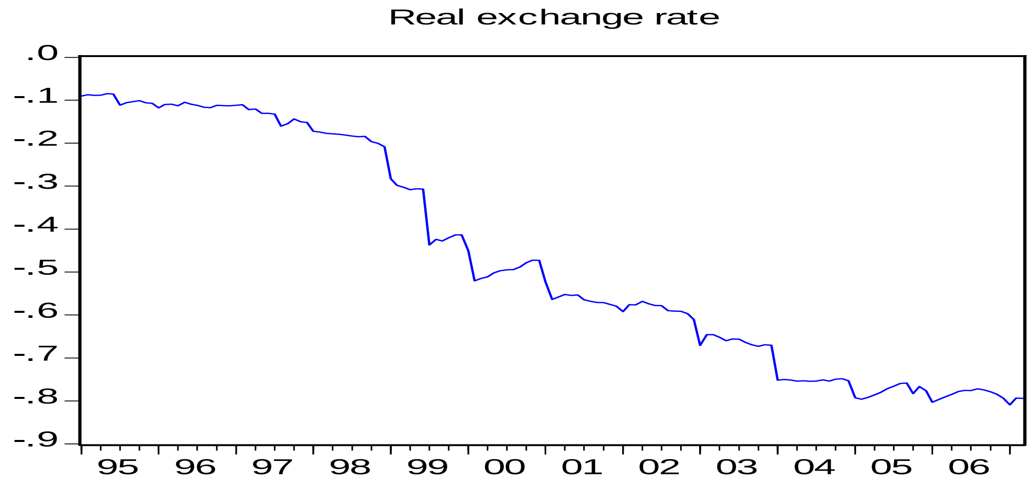


Figure 3: Plots of data series levels, Slovakia



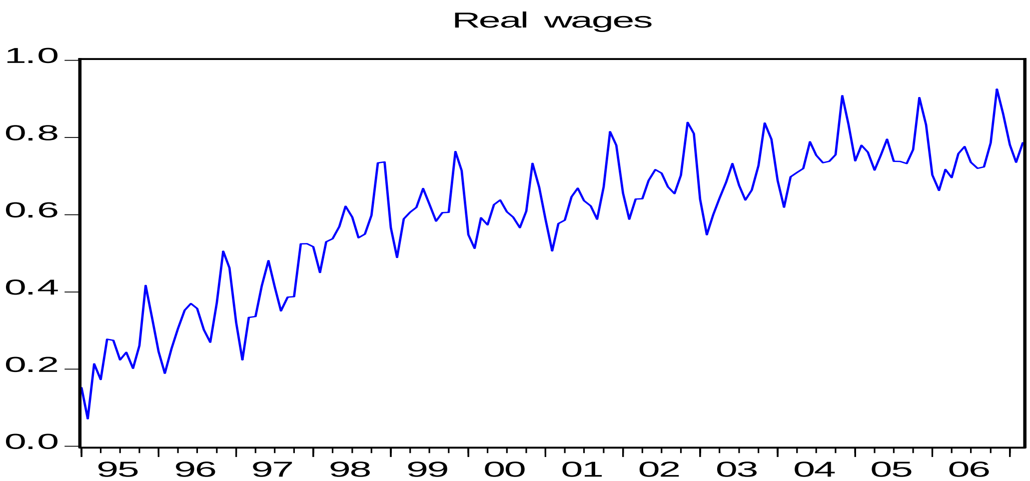


Figure 4: Plots of data series differences, Slovakia

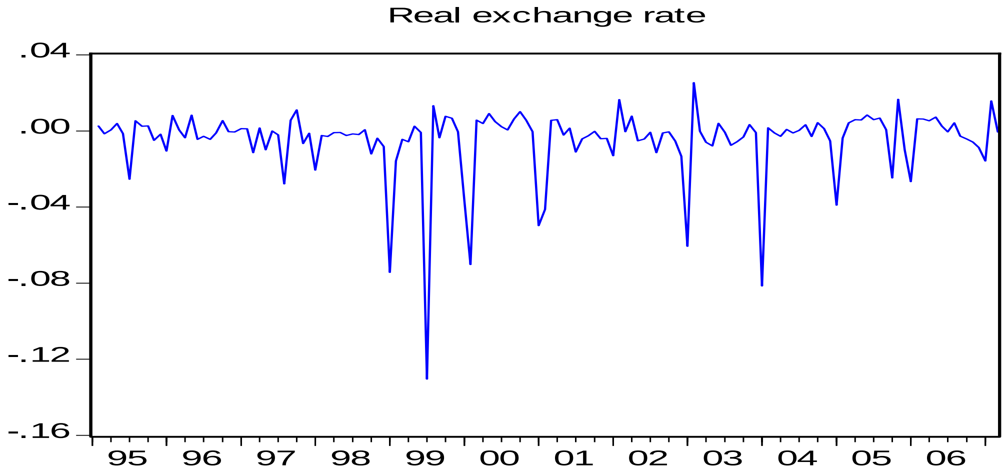
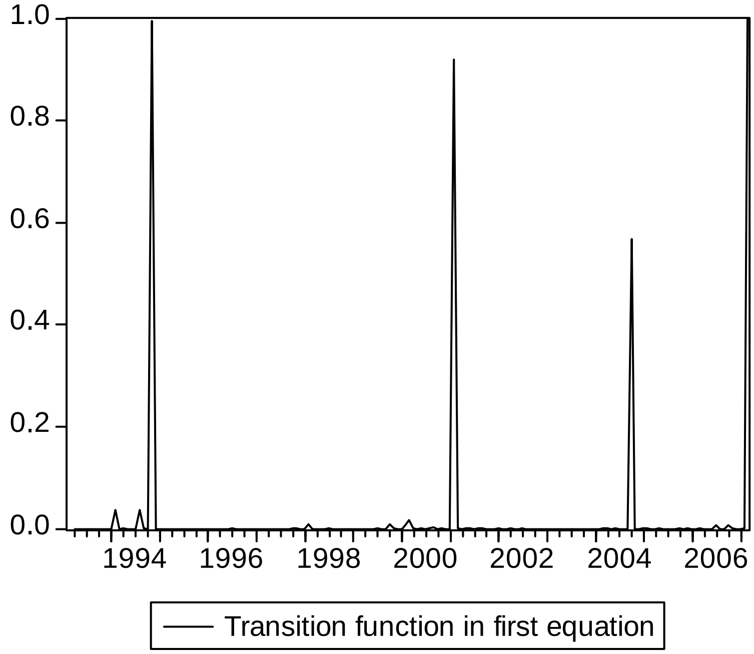
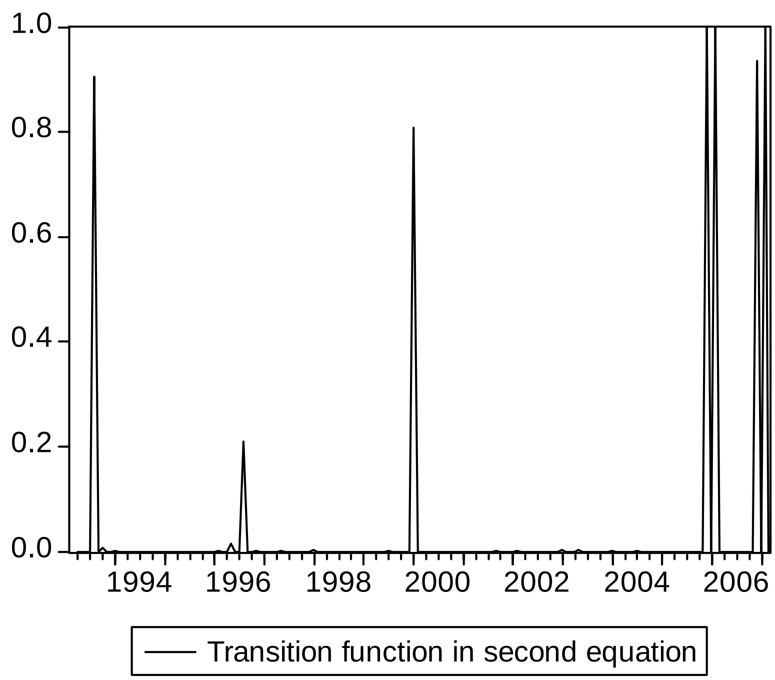
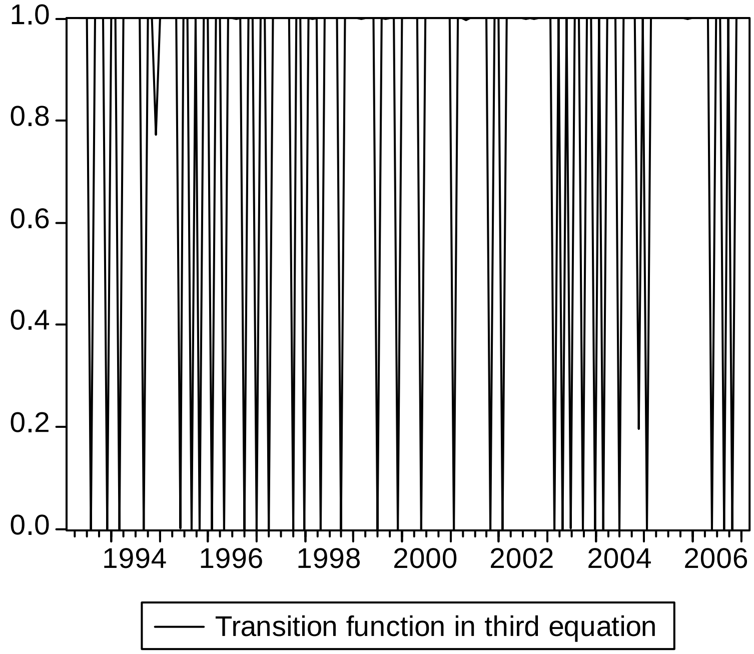


Figure 5: Transition functions in first, second and third equation of the model for Slovenia (as given in (13)), respectively






1.0
0.8
0.6
0.4
0.2
0.0
1994
1996
1998
2000
2002
2004
2006
Transition function in third equation