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EXCHANGE RATES AND NON-LINEAR DYNAMICS IN OUTPUT: EVIDENCE FROM BULGARIA

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Abstract

This paper assesses the effect of changes in real exchange rates on output growth by applying a smooth transition regression (STR) model in the case of Bulgaria – a European Union accession country. The nonlinear estimation technique employed here offers more flexibility in terms of allowing for possible asymmetric effects of real appreciations on growth, contingent upon the behavior of relevant economic variables. The nonlinear model reveals that real appreciations have helped growth in Bulgaria for most of the period 1994-2004. Real appreciations can turn contractionary only under excessive real money growth, which has occurred only sporadically.

KEYWORDS: Exchange rates, devaluation, output growth, smooth transition regression, transition economies, Bulgaria, EU accession

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Introduction

It is not unusual for devaluations to be at the center of economic adjustment and stabilization programs. They are frequently used to improve a country's balance of payments position, boost domestic employment, and accumulate more international reserves. However, while there is consensus that devaluation is a useful instrument for balance of payments adjustment, substantial controversy persists around the effect devaluations have on real output.

How real output reacts to depreciations or devaluations[2] becomes all the more important for transition economies, and especially for those countries aspiring to join the European Union (EU), such as Bulgaria[3]. One important objective for these EU accession countries, or other candidate countries, is to boost output so as to accelerate the process of economic convergence. In the second half of the 1990s, while transition economies showed a healthy dose of growth performance, real output convergence resurfaced as an important issue in the policy and theoretical literature. Gács (2003) shows that during the period 1988-1999 the relative position of most Central and East European Countries (CEECs) vis-à-vis the EU as a whole worsened, and thus there were no signs of convergence. He points out that the per-capita GDP of 10 CEECs[4] as a percentage of the EU 15 average declined from 53% in 1988 to 38.8% in 1999.

Halpern and Wyplosz (1997) observe that in most transition economies liberalization was followed by sharp real exchange rate depreciation and a subsequent appreciation.

For much of the post 1997 period, when Bulgaria instituted a currency board system, their exchange rate has appreciated in real terms. Has the ensuing loss in international competitiveness, caused by this real appreciation, hurt real economic activity? The goal of this study is to investigate this issue empirically.

Large exchange rate movements in transition economies have prompted several empirical assessments but have not put an end to the controversy surrounding their effect on real output. To mention some of the more recent studies on the topic, Mitchell and Pentecost (2001) find devaluations contractionary in a panel study of Bulgaria, Czech Republic, Poland and Slovenia in the short-run as well as the long run. The long run contractionary effect is somewhat mitigated by a

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[2] The terms depreciation and devaluation are used interchangeably in this paper since the focus is the estimation of the effects of changes in the real exchange rate on output.
[3] The other announced EU accession country is Romania.
[4] This group includes Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia.

rise in output one year after the devaluation. In contrast, Karadeloglou et al. (2001), using a wage-price-GDP model, find devaluations to be slightly expansionary in Slovenia, only initially expansionary in Bulgaria, and contractionary in Poland.

Several authors have pointed out that real output contractions often follow periods of real exchange rate overvaluation, while also noting incidences of expansion episodes and real exchange rate appreciations (see Kiguel and Liviatan, 1992; Razin and Collins, 1997; Papazoglou, 1999; Kamin and Rogers, 2000). A large part of the literature has approached the estimation of these output effects in a panel setting. Edwards (1989b), Chou and Chao[5] (2001) and Ahmed (2003) find that real depreciations hurt output growth. Similar results have been produced by other studies that have resorted to calibration techniques (see Gylfason and Schmid, 1983; Solimano, 1986). The literature on contractionary devaluations is rich and has vastly improved our understanding of how exchange rates influence output, regardless of some inherent problems with imputed parameters, feedback effects, spurious[6] regression (even in a panel setting) or challenges in teasing out specific country effects[7]. Even though there is an abundance of time series studies that focus on the experience of one country, little effort has been made to identify the conditions under which depreciations can turn contractionary. A few notable exceptions are studies by Agenor[8] (1991), Ahmed et al. (2002) and Mejia-Reyes at al (2004).

This paper analyzes the impact of changes in the real exchange rates on output growth for Bulgaria – a EU accession country. The contribution of this study to the literature is primarily to elucidate the conditions under which depreciations are more likely to be contractionary (or expansionary) in this transition economy. More specifically, it investigates the reaction of output to real exchange rate changes by employing a nonlinear smooth transition regression (STR) model. An STR model makes it possible to discern the existence of asymmetric effects. This model especially allows for the identification of the circumstances under which depreciations can be contractionary or

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[5] They employ panel unit root tests in a bivariate framework

[6] Spurious regression results lead to the inference of a worthy relation between two variables, when in fact the relation is fictitious and may arise because of a third unseen factor, often referred to as a "confounding factor".

[7] To assess the effects of devaluation on output, the literature has taken four different approaches: the “before–after” approach; the “control group” approach; the “comparison-of-simulations” approach; and econometric modeling. For a comprehensive review of all four approaches see Bahmani-Oskooee and Miteza (2003).

[8] Agenor (1991) distinctly evaluates the effects of unticipated and unanticipated depreciations. He asserts that unexpected real exchange rate depreciation is expansionary, while anticipated real depreciations have an irreversible contractionary effect.

expansionary, or merely contractionary to different degrees. In STR models, the explanatory variables affect the endogenous variable through two different regimes. Their effects can vary between these two regimes in terms of magnitude as well as sign. In this sense, STR models can be thought of as regime-switching models, where the transition from the “low” to the “high” regime occurs smoothly. Hence, an STR model allows for a continuum of states between the two extreme regimes (Teräsvirta, 1998). This smooth transition between regimes, which is prompted by the behavior of a given variable (referred to as the *transition variable*), is more able to capture the dynamic relationships between aggregate economic series that usually have gradual structural changes. The literature of contractionary devaluations has yet to benefit from nonlinear methods of estimation, such as the smooth transition regression approach. A study by Mejia-Reyes at al (2004) is the only paper using STR to investigate the effects of real exchange rates on growth for six Latin American countries. In general, they found that the economic determination of growth varies depending on whether the real exchange rate is depreciating or appreciating, and that real depreciations may be contractionary. While nonlinear methods of estimation in the general literature on contractionary devaluation are at best scarce, no such studies exist on transition economies.

In this investigation I use a nonlinear STR model and seek a transition variable, or a regime indicator, among the variables of the model (GDP growth, real money growth, government spending growth, the rate of real depreciation/appreciation, and their lags). The rate of real money growth is found to be the most effective transition variable. Therefore the two extreme regimes are distinguished by low and high rates of money growth. The findings show that the effects of the real depreciations on output vary depending on how fast the money supply is growing (or shrinking).

The remainder of the paper is organized as follows. Section 2 summarizes economic developments in Bulgaria. Section 3 outlines the general theoretical framework. The model, methodology and estimation procedure are described in Section 4. Section 5 reports the empirical results followed by conclusions in Section 6.

Macroeconomic Developments in Bulgaria

Focusing on the case of Bulgaria is relevant, timely and interesting for a variety of reasons. First, the country experienced hyperinflation, banking and currency crises in late 1995, which culminated in early 1997, after which it instituted a currency board (Berlemann and Nenovski, 2004). As an unusual arrangement, the currency board attained the desired macroeconomic stabilization goals and helped resume positive output growth over the period 1998-2004. However, output growth has been anemic - by developing country standards - raising concerns over the convergence criteria imposed by Bulgaria's pending EU accession in 2007.

Bulgaria commenced a stabilization program under an IMF stand-by agreement in 1991. The program involved price liberalization, establishing a market-determined exchange rate, deregulating current account transactions, improving fiscal discipline, and restraining credit through tight monetary policy (Wyzan, 1998). In this first attempt to transition to a market based economy, price reform was completed to a good degree, but privatization of state enterprise assets was very sluggish (Berlemann and Nenovski, 2004). Because economic reforms in Bulgaria were slow and largely inconsistent until about 1997, the first four stand-by agreements with the IMF were not successful and the country entered each new agreement in a poorer condition than the one before (Eke and Kutan, 2005).

Failure to pursue reforms in a timely manner only worsened budget deficits and spurred contingent claims on the budget from guarantees on state-firm loans. The government did not have the political will to shut down the loss-making enterprises as it would have caused massive unemployment. Instead, the government pressured state-owned commercial banks into subsidizing state firms with more credit lines. By 1996, most of these ended up as nonperforming loans, accumulating large losses for the banking system. Lack of true independence by the Bulgarian National Bank (BNB) contributed to this unplanned, but systematic, rescuing of state-owned enterprises that nationalized their enormous losses via monetization (Berlemann and Nenovsky, 2004). As a result, confidence in the banking system plummeted and banks started experiencing massive withdrawals of deposits. Because the public accelerated its currency substitution efforts away from the lev, the BNB was forced to intervene in the foreign exchange market to defend the exchange rate. Dwindling international currency reserves afforded the BNB only a few years until 1996. With interest rates as high as 300% in September 1996, the crisis became unmanageable. After depreciating by 590 per cent in 1996, the lev plunged by another 250 per cent in February 1997. The annual inflation for 1997 was 578 per cent (Berlemann and Nenovsky, 2004). Ensuing political unrest in early 1997 resulted in early parliamentary elections and a new government with a clear mandate to expedite economic reforms.

With the support of the IMF a currency board was established in 1997, which helped restore confidence and single digits inflation. Currency board systems had already been embraced with some success by other EU accession countries like Estonia and Lithuania. In the post 1997 period Bulgaria has seen higher growth rates, increasing investment levels, acceptable price stability, accelerated privatization, a deepening of financial markets, and a more open economy. The currency board arrangement contributed to a more responsible fiscal policy as well. Nonetheless, employment and output losses during the 1996-1997 crises had not been recouped by year 2000 (Valev, 2004).

It is interesting and important to note that the currency board in Bulgaria was not modeled after pure currency board systems as in Argentina or Estonia. Miller (2001) details the ways in which BNB did maintain some discretion over monetary policy even after the currency board was established. Indeed the inclusion of atypical items in BNB's balance sheet, as pointed out by Nenovsky, Hristov and Mihaylov (2002), allowed the central bank some "wiggle room" to use several policy instruments. Bulgarian and Lithuanian governments, holding accounts at the central bank, could affect changes in the reserve money, typically following government budget cycles. This scope for discretion was in contrast with the design and operation of orthodox currency boards systems.

Looking forward, besides being an important issue in itself, the relationship between exchange rates and output has the potential to complicate the process of transition for Bulgaria and other countries aspiring to join the EU. Among several Maastricht criteria, to adopt the Euro a country's inflation rate must not exceed 1.5 percentage points above the best three member economies. Moreover, the nominal exchange rate must be contained within "normal fluctuation margins" (+/- 15 percent) for at least two years preceding the official adoption of the Euro. These two criteria may pose serious challenges for economies in transition. As transition economies experience productivity growth in tradables that exceeds that in the EU, their real exchange rate will appreciate[9]. This real appreciation can materialize as a nominal exchange rate appreciation, as a rise in the home price level relative to EU levels, or a combination thereof. Either outcome will violate one of the two criteria mentioned above.

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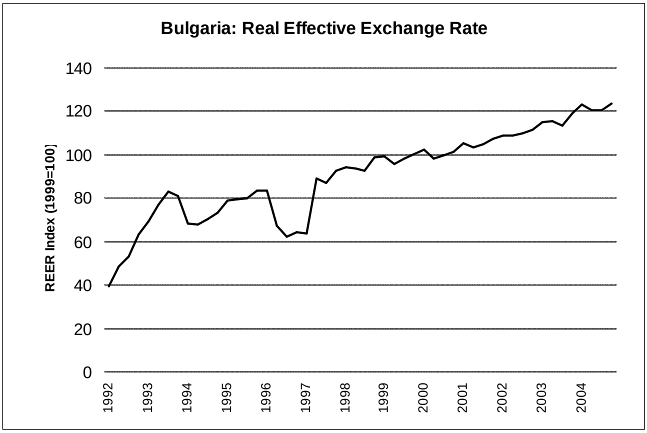
[9] Commonly referred to as the Balassa-Samuelson hypothesis. For a more detailed discussion of other causes of this observed real appreciation in transition economies see Egert and Kutan (2005).

Figure 1: Real Effective Exchange Rate Appreciation in Bulgaria Source: IFS database



In theory, a plausible plan B would be to vent these pressures prior to the critical two-year period by allowing a precipitous appreciation and thus slashing inflation on tradables**.** Dean (2002) provides an example of such pre-accession appreciation: the Czech crown appreciated by 25% vis-à-vis the US Dollar in 2002, while their inflation rate dropped from 5% to 2%. Estimating the effects of such sizeable appreciations on output is critical in view of the considerable differences in per-capita GDP levels between accession and new member countries on one hand and the more established EU economies on the other.

The Theoretical Framework

The *"orthodox"* school advocates the argument that depreciation is expansionary because of its expenditure switching effects and the increased production of tradables that it stimulates. In addition, depreciations can cause output to contract because of other factors.

First, depreciation can cause a contraction in aggregate demand through:

(1) A redistribution of income in favor of those with high marginal propensity to save as profits in export and import-competing industries rise when tradables become relatively more expensive. The ensuing lower real wages are likely to result in a contraction of aggregate spending since the marginal propensity to save from profits exceeds that from wages (Diaz-

Alejandro, 1963; Cooper, 1971a; and Krugman and Taylor, 1978). This channel may prove even more contractionary under foreign ownership of capital (Barbone and Rivera-Batiz, 1987).

(2) A reduction in investment, especially when it consists largely of imported capital goods (Branson, 1986; Buffie, 1986b; and van Wijnbergen, 1986).

(3) Increased debt and debt service burden for countries with sizable external loans denominated in foreign currency, which drains off resources that could be used in spending and production (Cooper, 1971b; Gylfason and Risager, 1984; and van Wijnbergen, 1986).

(4) A reduction in real wealth or real balances that is brought about by the higher price level following devaluation. The restoration of real balances necessitates a fall in expenditure (Bruno, 1979; Gylfason and Schmid, 1983; Hanson, 1983; and Gylfason and Radetzki, 1991).

(5) A low government marginal propensity to spend out of tax revenue. The initial increase in the home currency value of trade following devaluation causes tariff revenue to rise. The subsequent redistribution of income from the private to the public sector can cause aggregate spending to shrink if the government has a low marginal propensity to spend (Krugman and Taylor, 1978).

(6) Real income declines if the trade balance is initially in deficit and foreign currency out-payments outstrip in-payments (Cooper, 1971c; and Krugman and Taylor, 1978).

(7) Increased interest rates resulting from a reduction in the real volume of bank credit and the monetary base, following a devaluation-induced price and wage inflation (Bruno, 1979; and van Wijnbergen, 1986).

Second, devaluations may also reduce aggregate supply via three main channels:

(1) More expensive imported inputs (Gylfason and Schmid, 1983; Hanson, 1983; Gylfason and Risager, 1984; Islam, 1984; Gylfason and Radetzki, 1985; Branson, 1986; Solimano, 1986; and van Wijnbergen, 1986).

(2) Higher wages due to indexation based on price levels (Hanson, 1983; Gylfason and Risager, 1984; Gylfason and Radetzki, 1985; Branson, 1986; Edwards, 1986b. Solimano, 1986; and van Wijnbergen, 1986).

(3) Costlier working capital resulting from increased demand for money and higher interest rates (Bruno, 1979; and Wijnbergen, 1986).

Awareness of the existence of these effects has often caused hesitation among many developing countries contemplating devaluation as a response to grave balance of payments crises. Their resistance may be the result of (i) uncertainty about the exchange rate elasticity of import demand and export supply, (ii) the effect on domestic expenditures; (iii) and the imminent harmful side effects on GDP growth, employment, inflation, real wages and income distribution. It is with regard to this resistance that Cooper (1971c) observes that devaluations often precede changes in finance ministers.

The Model, Methodology, and Estimation Procedure

The model

Edwards (1989b) builds a theoretical model, which reproduces the process of output determination in a small open economy with tradables, non-tradables, and sector-specific capital. World prices of tradable are assumed fixed. Exportable and importable items use domestic labor and capital; non-tradables use imported inputs as well. The country has a stock of foreign debt and a wage indexation system that links wages with a price index. Edwards uses his ten-equation model to derive a testable reduced form, which has since been used unchanged or with minor enhancements by numerous authors in the literature[10]. The reduced form equation takes the following general form:

$$\Delta y = f\,(\Delta g, \Delta m, \Delta e) \qquad (1)$$

Where Δy is real GDP growth, Δg represents the growth in government demand for non-tradables proxied by government expenditures, Δm is a measure of the rate of money growth, and Δe is the rate of real exchange rate[11] depreciation. The main objective is to capture the sign and size of the coefficient of real exchange rate depreciation rate. Since the exchange rate has been defined as units of home currency per unit of foreign currency, a negative coefficient for the exchange rate would imply that devaluations are contractionary.

As indicated in the theoretical framework section above, the sign of the coefficient of the exchange rate term is ambiguous and necessitates an econometric approach to estimate the net effect on output.

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[10] For more details on the theoretical foundations of this reduced form equation, see Edwards (1989b).

[11] The nominal exchange rate measures the price of the home country's currency in terms of another country's currency. The real exchange rate measures a country's trade competitiveness by adjusting the nominal exchange rate with inflation differentials among countries.

With a few exceptions (Mejia-Reyes, 2004), the empirical literature on contractionary devaluation has investigated the issue by using linear regression methods. The assumption of linear regression is convenient but not necessarily the optimal assumption under all circumstances. This paper investigates the exchange rate and output growth relationship using a nonlinear function.

A large section of this literature is built on the use of panel data in the tradition of seminal papers like Edwards (1986a, 1989b). While advantageous in terms of overcoming the problem of short available time series data, panel data studies impose the restrictive assumption that output reacts in the same fashion to devaluations across all panel members. By contrast, this study makes an attempt to add to an already rich literature an approach that is not as restrictive and that allows real depreciations to have varying effects on growth depending on the behavior of other relevant economic variables.

Definition of STR Models

Following Terasvirta (2004), the standard STR model of the following form is employed:

$$y_t = \phi' z_t + \theta' z_t \, G(\gamma, c, s_t) + u_t \qquad (2)$$

where z_t includes a vector of lagged endogenous variables and a vector of exogenous variables. ϕ and θ are (m+1) by 1 parameter vectors and $u_t \sim \text{iid}(0,\sigma^2)$. The transition function $G(\gamma, c, s_t)$ is bounded between zero and unity and a function of the continuous transition variable s_t. The slope of the transition γ indicates the speed with which the transition from regime 1 to regime 2 occurs. The location parameter c determines where the transition takes place along the range of the known transition variable s_t. While function G can take many forms, the logistic function, which increases monotonically in s_t is the usual approach in the STR literature, and it is defined as follows:

$$G(\gamma, c, s_t) = \left(1 + \exp\{-\gamma \prod_{k=1}^{K} (s_t - c_k)\}\right)^{-1}, \gamma > 0 \qquad (3)$$

Depending on the slope parameter γ, for small values of s_t the value of G is close to zero, while for large s_t the value of G is close to one. When s_t reaches the value c (location parameter) G takes a value of 0.5. The two states G=0 and G=1 represent two distinctive regimes that, in turn, define two separate linear relationships between the independent and the explanatory variables. The transition between these two extreme regimes can be very smooth when the slope parameter γ is small or abrupt if γ is large. When γ=0 the logistic STR (LSTR) model nests the linear model, whereas when $\gamma \rightarrow \infty$ the LSTR model becomes a switching 2-regime model. Typically the parameter K in (3) is either equal to 1 or 2. When K=1 (LSTR1) the model captures asymmetric behavior. Such a model can be used for instance to characterize the asymmetric effects of expansionary and contractionary monetary policy. When K=2 (LSTR2) the dynamic behavior is similar for large as well as small values of the transition variable s_t. The transition variable is stochastic and often chosen from among the set of explanatory variables in the model.

The Modeling Procedure

The modeling procedure includes three steps: specification, estimation, and evaluation. For a detailed description of these steps see Terasvirta (2004).

Specification includes three stages. In the first stage of specification *linearity tests* are performed on a starting linear model to ascertain whether a non-linear model is a better choice than a linear one. If that is the case, these tests will also determine whether an LSTR1 or LSTR2 model should be used[12]. The specification and dynamics of the linear system to be used as a starting point are based on a sequential elimination of regressors which leads to the largest reduction of the Akaike Information Criterion (AIC) up to the point where no more improvement is possible[13]. Linearity is tested against an STR model with a predetermined transition variable. The latter can be chosen based on economic theory or the test can be run repetitively with each variable in z_t (including trend if there is one) serving as a transition variable. If the null hypothesis cannot be rejected it implies that a linear model is more suitable. Otherwise, the model with the smallest p-value (strongest rejection) is selected for STR estimation.

Following Terasvirta (2004), linearity tests are based on the following regression:

$$y_t = \beta_o' z_t + \sum_{j=1}^{3} \beta_j' \tilde{z}_t s_t^j + u_t^*, \qquad t = 1, \ldots, \mathrm{T}, \qquad (4)$$

where the transition function is approximated by a Taylor expansion around the null hypothesis γ=0. This null hypothesis is equivalent to H_0: $\beta_1 = \beta_2 = \beta_3 = 0$. The test is run for every transition variable. Terasvirta (1994) recommends choosing the model for which the rejection of the null is strongest, but one can also

[12] The choice may also be an exponential STR model (ESTR), but that possibility is not modeled in this study.

[13] For more details see Brüggemann and Lütkepohl (2001). This procedure is amounts to a sequential elimination of those regressors with the smallest t-ratios up to where all remaining t-ratios exceed some limit value.

compare the fit of potential nonlinear models via a grid search method. When a number of small *p*-values are very close to each other, the decision to select a preferred model can be deferred up to the evaluation phase.

If linearity has been rejected, the *type of model* is selected in the second stage of specification. In this paper the choice is among an LSTR1 and LSTR2 model. Utilizing the auxiliary regression (4), Terasvirta (2004) suggests the following test sequence:

H_{04}: $\beta_3=0$

H_{03}: $\beta_2=0|\beta_3=0$

H_{02}: $\beta_1=0|\ \beta_2=\beta_3=0$

According to this sequence, an LSTR2 should be selected if H_{03} gives the smallest *p*-value. If not, LSTR1 will be the choice. This is the test sequence followed in this paper, however, to conserve space I present only the *p*-values of an alternative test by Escribano and Jorda (1999), which adds $\beta_4' \tilde{z}_t s_t^4$ to regression (4) and tests the general linearity hypothesis $\beta_1= \beta_2= \beta_3= \beta_4=0$. Both tests produce similar results.

The third stage involves *reducing the size of the model*. In the context of the chosen non-linear model it may be useful to eliminate redundant variables or lags. Imposing $\phi_j=0$ implies that z_{jt} does not contribute in the "low" (G=0) regime. Similarly, imposing $\phi_j=-\theta_j$ forces the combined coefficient to zero under the "high" (G=1) regime. Lastly, z_{jt} can be forced to figure in the linear part alone when the restriction $\theta_j=0$ is imposed[14].

The next step is that of parameter estimation, which starts with obtaining good *initial values*. The STR model parameters are estimated by a nonlinear optimization routine that maximizes the log-likelihood. Initial values are found by doing a grid search with a log-linear grid in γ and a linear grid in c. The values of the parameters that yield the minimum residual sum of squares over the grid search are taken as starting values[15].

Evaluating the STR model is the third and final step. Once the parameters have been estimated, it is essential to investigate the validity of the model

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[14] Particularly when the sample size is small, the estimation of the algorithm may not converge. Under these circumstances, Terasvirta (2004) suggests starting to impose zero restrictions on the nonlinear part first.

[15] For a better grid, the slope parameter γ is divided the Kth power sample standard deviation of s_t so as to make it scale-free.

assumptions. It is useful to test the assumption of no error autocorrelation. The test procedure is based on the regression of the estimated residuals from the STR model on lagged residuals and the partial derivatives of the log-likelihood function with respect to the model parameters[16]. Another informative test is that of no remaining non-linearity against the alternative hypothesis that there is additional nonlinearity which can be captured through a second transition function. The F statistics produced by this test are interpreted in much the same way as for the tests on linearity described above. Also, non-constant parameters may be a signal of model misspecification or merely a real change in the relationship between the economic variables over time. The null of parameter constancy is tested against a smooth and monotonic change in parameters over time. The results of the F-tests are given for three alternative transition functions with K=1, 2, 3 respectively in terms of *p*-values. Lastly, we also present the LM-test of no ARCH (Engle, 1982), as well as the Jarque-Bera normality test (Jarque and Bera, 1980).

Empirical Results

The quarterly dataset includes data for Bulgaria spanning the period from the first quarter of 1994 to the fourth quarter of 2004. In all, there are 44 observations on the four variables included in equation (1). For more details on data sources and variable definition see Appendix. In an attempt to capture the dynamics of growth the model allows for four lags in the endogenous variable and two lags in the exogenous variables. Also, because the levels of all variables involved in the estimation of equation (1) are non-stationary[17], they have been transformed into first differences of their natural logarithms. The use of differenced logarithms as opposed to percentage changes is favored particularly where there is substantial volatility as is the case in many CEEC economies during the first half of the 1990's.

Since this paper concentrates on the possibility of a non-linear relationship and hence asymmetric effects of real depreciations on growth, the first step is to perform the linearity tests described in section (3) above. To that effect, it is necessary to obtain the specification and dynamics of the linear system to be used as a starting point for the linear tests. This process is based on the sequential elimination of regressors which leads to the largest reduction of the AIC and it results in the specification and coefficients reported in the first column of Table 2, under the heading "Linear Model". Note that the rate of

[16] For details on the application of this test to STR models see Teräsvirta (1998)
[17] The results of the unit root tests are available upon request.

depreciation appears to have a contractionary impact on output after two quarters. This is to say that, regardless of the circumstances, a real depreciation will hurt output growth on average. It is also worth noting that tests on the linear specification do not raise any red flags and the fit is rather solid, with an R^2 of 0.90.

Table 1 presents the *p*-value results of the linearity tests performed on the linear model just described. The lowest *p*-value, which indicates the strongest rejection of the null of linearity is marked with an asterisk and occurs when the contemporaneous money growth rate (Δm_t) is used as a transition variable. Based on the heuristic procedure of comparing the *p*-values of H_{02}, H_{03}, and H_{04}, an LSTR1 model is selected. Even though the linearity tests evince that for the majority of the transition variables used, the optimal choice would be some type of non-linear model, I choose to proceed with the estimation of an LSTR1 model with Δm_t as transition variable. This choice is intuitive for the additional reason that with the introduction of the currency board, there was a clear-cut regime shift in terms of money supply behavior, which under a currency board arrangement grows only as a function of international reserves at hand. The regime shift brought about by the currency board is expected to change the nature of the relationship between output, money, government spending and the exchange rate. The introduction of the STR model identifies a transition variable that conditions the smooth change of the slope coefficients to capture this new relationship. Such changes in slope coefficients are not possible in a traditional linear model even with the inclusion of dummy variables.

Because the null of linearity has been rejected, one can safely proceed to estimate the chosen STR model. The STR model parameters are estimated using conditional maximum likelihood via a nonlinear optimization routine explained in Section (3) above.

To reduce the size of the non-linear model I impose the restriction θ_j=0 for the intercept, Δm_t and Δm_{t-1}, which forces these terms to appear in the linear part alone. The resulting LSTR1 model and the estimated coefficients for both regimes are reported in the last two columns of Table 2.

Table 2 reports the values of γ and *c*, which yield the minimum residual sum of squares in the grid search process. The slope parameter γ is 7.34, which makes for a relatively smooth transition from a regime of “slow” money growth (*G*=0) to a regime of more rapid money growth (*G*=1) as depicted by Figure 1. It is important to note that the standard deviation of the estimated slope parameter is quite small. According to Terasvirta (2004), a large standard deviation of the slope parameter can pose a numerical challenge in the estimation of an STR for a small sample. Figure 1 makes it obvious that the transition from one extreme regime to the next occurs when the money growth rate is about close to 0% (roughly the value of the location parameter c=-0.009).

It is evident from Table 2 and Figure 1, that particularly under conditions of shrinking money supply (when G=0 and the real money growth rate is less then -10%) real depreciation will be contractionary[18]. An increase in the exchange rate as defined here represents a depreciation, so a negative sign for the real exchange rate term under G=0 implies that the faster the real money balances contract, the more contractionary real depreciations become. The coefficient on the real exchange rate term in the low regime is relatively sizeable and statistically significant.

The coefficient of the higher regime shows that as the pace of real money balances picks up, real depreciations become gradually less contractionary. When the money growth rate accelerates toward 10% real depreciations become increasingly less contractionary until ultimately, under G=1, their total effect on growth becomes positive at 0.22719 (equal to the sum -2.37893+2.60612). What follows is the estimated STR model in equation form:

$$\underset{}{\Delta y}= \underset{(14.23)}{0.166} - \underset{(0.62)}{0.00088\,\Delta y_{t-2}} \underset{(-6.96)}{-0.987\,\Delta y_{t-3}} \underset{(9.05)}{+0.954\,\Delta y_{t-4}} + \underset{(0.86)}{0.087\,\Delta g_{t-2}} \underset{(-2.41}{-0.270\,\Delta m_t} -$$

$$\underset{(-11.31)}{0.908\Delta m_{t-1}} \underset{(-11.86)}{-3.624\,\Delta m_{t-2}}$$

$$\underset{(-6.00)}{-2.38\,\Delta e_{t-2}} + [\underset{(-4.55)}{-0.48\,\Delta y_{t-2}} \underset{(6.84)}{+1.33\,\Delta y_{t-3}} \underset{(-6.66)}{-1.24\,\Delta y_{t-4}} \underset{(-2.83)}{-0.33\,\Delta g_{t-2}} \underset{(10.53)}{+3.00\,\Delta m_{t-2}} \underset{(5.16)}{+2.61\,\Delta e_{t-2}}] \times$$

$$[1+\exp(-7.34 \times \frac{1}{0.142} \times (\Delta m_t +0.0096)]^{-1} \qquad (5)$$

where numbers in parenthesis are t-ratios and 0.142 is the sample standard deviation of the transition variable.

It is interesting at this point to compare the results of these linear and nonlinear models with respect to the effects of real depreciations on growth. The results from the linear estimation in column one give support to the contractionary depreciation hypothesis. However the findings of the STR model are more nuanced in that they confirm the contractionary depreciation hypothesis only in the face of rapidly declining real money balances. By contrast, when money growth accelerates, real depreciations become expansionary.

[18] By the same token, appreciations will be expansionary.

The signs of the coefficient of concurrent and lagged real money growth are all negative in the “lower” regime. This result is intuitive because the low regime is one in which real money balances are declining rapidly (in excess of 10%). Understandably the effect of lagged real money growth becomes positive under the monetary expansion regime *G*=1. The interpretation of the sign of Δg_{t-2} is a challenge under *G*=1 as its combined coefficients suggest a negative effect on growth.

All the diagnostic tests and the goodness of fit measures have been presented at the bottom of Table 2. The explanatory power of the STR model appears vastly superior to that of the linear model. The diagnostic tests do not raise any concerns with respect to the model specification, the assumption of no error autocorrelation, and parameter constancy. In addition the *p*-values of the LM-test of no ARCH of order (8), and the Jarque-Bera normality test do not show any model inadequacies.

Conclusions

This paper adds to the existing empirical literature on the effect of devaluations and depreciation on output growth. The case of Bulgaria is chosen to examine this relationship due to the fact that the nature of the link between exchange rates and output is particularly critical for transition economies, and even more so for countries aspiring to join the European Union.

The empirical literature on contractionary devaluations is rich and illuminating, but has for the most part examined this issue by making use of linear regression methods. While the assumption of a linear relationship is convenient, it may not describe the relationship adequately, particularly when the effects of exchange rates or other relevant variables on output are asymmetric. A considerable number of studies, most particularly panel data studies, impose the restrictive assumption that output reacts in the same fashion to devaluations across all panel members and under all circumstances at home. By contrast, this study contributes to an approach that is not as restrictive and that allows real depreciations to have varying effects on growth depending on the behavior of other relevant economic variables by using a nonlinear function.

This paper estimates a reduced form equation where output growth is a function of changes in the real exchange rates, real money growth, and changes in government expenditure. The estimation of a smooth transition regression model results in more nuanced findings that lend support to the contractionary devaluation hypothesis only in the face of rapidly declining real money balances. By contrast, when money growth accelerates, real depreciations become expansionary. Since Bulgaria has experienced significant real exchange rate appreciation for most of this period, its output growth has benefited. Only when the real money growth rate exceeds 9% (on a quarterly basis) does real appreciation turn contractionary. Fortunately, that has occurred sporadically.

Naturally, any model would have difficulty capturing these effects while an economy undergoes structural changes in transition. It must be said that, likewise, an STR model may be quite adroit at handling regime changes but not necessarily systemic economic changes.

Also, while this real appreciation may have helped real output growth, it might also have contributed to a worsening external sector imbalance by helping create large and growing current account deficits. These deficits remain to date one of the foremost concerns for the Bulgarian economy as it prepares to enter the EU, and naturally, a currency board system is not well-suited for balance of payments adjustment.

The findings of this paper do not support the adoption of an overly expansionary monetary policy aimed at inducing expansionary depreciations. It is now well established that such policies would bring about unhealthy inflationary pressures. Instead, this paper intends to shed light into the exchange rate – output relationship of a transition economy in the process of monetary and economic integration and convergence with the EU. Even though other current EU accession or candidate countries do not have a currency board, as they approach the final stages of entry into the monetary union, a change in monetary policy from a money-based one (under floating or managed floating) into a return-to-peg[19] strategy is a must. In so far as this latter is similar to a currency board, it would be interesting to see if similar results are valid for other European Union potential candidate countries like Albania, Bosnia and Herzegovina, the Former Yugoslav Republic of Macedonia, and Serbia and Montenegro.

[19] Ultimately their currencies will be fixed to the Euro.

References

Agenor, P.-R.(1991), "Output, devaluation, and the real exchange rate in developing countries," *Weltwirtschaftliches Archive*, 127, 18–41.

Ahmed, S., Gust, J., Kamin, S. B. and Huntley, J. (2002). "Are depreciations as contractionary as devaluations? A comparison of selected emerging and industrial economies", Board of Governors of the Federal Reserve System International Finance Division Discussion Paper Number 737.

Ahmed, S., (2003), "Sources of Economic Fluctuations in Latin America and Implications for Choice of Exchange Rate Regimes," *Journal of Development Economics*, 72, 181-202.

Bahmani-Oskooee, M. and Miteza, I. (2003), "Are devaluations expansionary or contractionary: A survey article," *Economic Issues,* forthcoming.

Bahmani-Oskooee, M. and Rhee, H.-J. (1997), "Response of domestic production to depreciation in Korea: An application of Johansen's cointegration methodology," *International Economic Journal*, 11, 103-112.

Bahmani-Oskooee, M.(1998), "Are devaluations contractionary in LDCs?" *Journal of Economic Development*, 23, 131-144.

Bahmani-Oskooee, M.; I. Miteza and ABM Nasir (2002), "The long-run relation between black market and official exchange rates: evidence from panel cointegration," *Economics Letters*, 76, 397-404.

Bahmani-Oskooee, M. and Miteza, I. (2003), "Are devaluations expansionary or contractionary: A survey article," *Economic Issues*, 8, pp. 1-28.

Barbone, L., and Rivera-Batiz F.(1987), "Foreign capital and the contractionary impact of currency devaluation, with an application to Jamaica," *Journal of Development Economics*, 26, 1-15.

Barlow, D., (2004), "Purchasing Power Parity in Three Transition Economies." *Economics of Planning*, 36, 201-221.

Berlemann, M. and Nenovsky, N. (2004), "Lending of First Versus Lending of Last Resort: the Bulgarian Financial Crisis of 1996/1997," *Comparative Economic Studies*, 46(2), 245-271.

Branson, W.H.(1986,) "Stabilization, stagflation, and investment incentives: The case of Kenya, 1979-1980," in *Economic Adjustment and exchange rates in developing countries,* eds by S. Edwards, L. Ahamed, Chicago, 267-293.

Brüggemann, R. and Lütkepohl, H. (2001), "Lag selection in subset VAR models with an application to a U.S. monetary system," in R. Friedmann, L. Knüppel and H. Lütkepohl (eds.), *Econometric Studies: A Festschrift in Honour of Joachim Frohn*, LIT Verlag, Münster, 107-128.

Bruno, M. (1979), "Stabilization and stagflation in a semi-industrialized

economy," in *International Economic Policy. Theory and Evidence*, eds by R. Dornbusch, J.A. Frenkel, Baltimore, 270-289.
Buffie, E.F.(1986a), "Devaluations and imported inputs: The large economy case," *International Economic Review* (Philadelphia), 27 (February), 123-140.
Buffie, E.F.(1986b), "Devaluation, Investment and Growth in LDCs," *Journal of Development Economics* (Amsterdam), 20 (March), 361-379.
Chou, W.L, and Chao, C.-C., (2001), "Are currency devaluations effective? A panel unit root test." *Economics Letters*, 72, 19-25.
Cooper, R.N.(1971a), "Currency devaluation in developing countries," in *Government and Economic Development*, eds by G. Ranis, Yale University Press, New Haven.
Cooper, R.N.(1971b), "Devaluation and aggregate demand in aid receiving countries," in *Trade Balance of Payments and Growth*, eds by J.N. Bhagwati and others, Amsterdam and New York: North-Holland.
Cooper, R.N.(1971c), "An assessment of currency devaluation in developing countries," in *Government and the Economy,* eds by G.Ranis, New Haven: Yale University Press.
Copelman, M and Werner, A.M.(1995), "The Monetary Transmission Mechanism in Mexico", Board of Governors of the Federal Reserve System, *International Finance Discussion Papers,* No. 521, September.
Dean, J. W. (2002), "Exchange Rate Regimes in Central and Eastern European Transition Economies, with Lessons for Ukraine," Simon Fraser University. 20 Feb. 2006 <http://www.sfu.ca/economics/research/discussion/dp02-8.pdf>.
Diaz-Alejandro, C.F.(1963), "A note on the impact of devaluation and the redistributive effects," *Journal of Political Economy* 71, 577–580.
Diaz-Alejandro, C.F.(1965), "Exchange rate devaluation in a semi industrialized country: The experience of Argentina, 1955—1961," (MIT Press, Cambridge, MA).
Edwards, S.(1986a), "Are Devaluations Contractionary?" *The Review of Economics and Statistics*, 68, 501-508.
Edwards, S.(1986b), "Terms of Trade, *Exchange Rates and Labor Markets Adjustment in Developing Countries,"* NBER Working Paper No. 2110. Mass., Cambridge.
Edwards, S.(1989a), "Exchange controls, devaluations, and real exchange rates: The Latin American Experience," *Economic Development and Cultural Change.* 37, 457-494.
Edwards, S.(1989b), Real Exchange Rates, Devaluation, and Adjustment. MIT Press, Cambridge, MA.

Egert, B., and Kutan, A. (2005), “Exchange Rate Economics in Transition Countries,” *Economic Systems*, 29, 123-129.

Eke, B. and Kutan, A. M.(2005), “IMF-supported Programmes in Transition Economies: Are They Effective?” *Comparative Economic Studies*, 47(1), 23-40.

Engle, R. F. (1982), “Autoregressive Conditional Heteroscedasticity, With Estimates Of The Variance Of The United Kingdom Inflation,” *Econometrica*, 50, 987-1007.

Escribano, A., and Jorda,O. (1999). “Improved testing and specification of smooth transition regression models’, in *Nonlinear Time Series Analysis Economic and Financial Data*, Kluwer Academic Publishers, USA.

Gács, J., (2003), “Transition, EU Accession and Structural Convergence,” *Empirica*, 30, 271-303

Gylfason, T., and Radetzki, M.(1991)), “Does devaluation make sense in the least developed countries?” *Economic Development and Cultural Change*, 40, 1-25.

Gylfason, T., and Risager, O.(1984), “Does devaluation improve the current account?” *European Economic Review*, 25, 37-64.

Gylfason, T., and Schmid, M.(1983), “Does devaluation cause stagflation?” *Canadian Journal of Economics*, 16 (4), 641-54.

Halpern, L., and Wyplosz, C., (1997), “Equilibrium exchange rates in transition economies,” *IMF Staff Papers*, 44, December, 430-461.

Hanson, J.A.(1983), “Contractionary devaluation, substitution in production and consumption and the role of the labour market,” *Journal of International Economics*, 14, 179-189.

Hoffmaister, A. W., Végh, C. A.(1996), “Disinflation and the recession-now-versus recession-later hypothesis: evidence from Uruguay,” *IMF Staff Papers*, 43, 355-394.

Islam, S.(1984), “Devaluation, stabilization policies and the developing countries: A macroeconomic analysis,” *Journal of Development Economics*, 14, 37-60.

Jarque, C. M. and Bera, A. K. (1980), “Efficient Tests For Normality, Homoscedasticity, And Serial Independence Of Regression Residuals,” *Economics Letters*, 6, 255-259.

Kamin, S.B.(1988), “Devaluation, external balance, and macroeconomic performance in developing countries: a look at the numbers,” *Princeton Essays in International Finance* No. 62.

Kamin, S. B., Klau, M.(1998), “Some multi-country evidence on the effects of real exchange rates on output,” Board of Governors of the Federal Reserve System International Finance Discussion Papers, Number

611.
Kamin, S. B. and Rogers, J. H. (2000). “Output and real exchange rate in developing countries: an application to Mexico”, *Journal of Development Economics*, 61, 85-109.
Karadeloglou, P., Chobanov, G., Delakorda, A., Milo, W., Wdowinski, P.(2001), “The Exchange Rate, Prices and the Supply Response Under Transition: A Simulation Study,” in *Exchange Rate Policies, Prices and the Supply Response*, eds by C. Papazoglou, E.J. Pentecost, Chapter 6, Palgrave, Basingstoke, 78-88.
Kiguel, M. A. and Liviatan, N. (1992), “The Business Cycle Associated with Exchange Rate-based Stabilizations,” *World Bank Economic Review*, 6, 279-305.
Krugman, P., Taylor, L.(1978), “Contractionary effects of devaluation,” *Journal of International Economics*, 8, 445–456.
Lizondo, S., Montiel, P.J.(1989), “Contractionary devaluation in developing countries: an analytical overview,” *IMF Staff Papers*, 36, 182–227.
Mejia-Reyes, P. Osborn, D. R. and Sensier, M. (July 2004), “Modeling Real Exchange Rate Effects On Growth In Latin America,” Vers. 35. University of Manchester. 25 Feb. 2006 <http://repec.org/res2004/SensierMejia-ReyesOsborn.pdf>.
Miller, J. B.(2001), “The Bulgarian Currency Board,” *Comparative Economic Studies*, 43(1), 53-74.
Mills, T.C., Pentecost, E.J.(2001), “The Real Exchange Rate and the Output Response in Four EU Accession Countries,” *Emerging Markets Review*, 2, 418-430.
Mitchell, A.J., Pentecost, E.J.(2001), “The Real Exchange Rate and the Output Response in Four Transition Economies: A Panel Data Study,” in *Exchange Rate Policies, Prices and the Supply Response,* eds by C. Papazoglou, E.J. Pentecost, Chapter 5. Palgrave, Basingstoke, 68-77.
Morley, S.(1992), “On the Effects of Devaluation During Stabilization Programs in LDCs,” *Review of Economics and Statistics*, LXXIV, 21-27.
Nunnenkamp, P., Schweickert, R.(1990), “Adjustment policies and economic growth in developing countries – Is devaluation contractionary?” *Weltwirtschaftliches Archive*, Vol.126, 474-493.
Nenovsky, N., Hristov, K., Mihaylov, M., (2002), “Comparing institutional and organizational design of Currency Boards in transition countries,” *Eastern European Economics*, 40, 3-36.
Papazoglou, C. (1999). “Exchange rate policy and output growth: The experience of the transition economies of Central and Eastern Europe”, *Post-Communist Economies*, 11, 319-36.

Razin, O. and Collins, S. M., (1997), "Real Exchange Rate Misalignments and Growth," National Bureau of Economic Research (NBER) Working Paper No. 6174.

Rogers, J. H., Wang, P.(1995), "Output, inflation and stabilization in a small open economy: Evidence from Mexico," *Journal of Development Economics*, 46, 271-93.

Santaella, J. A., Vela, A.E.(1996), "The 1987 Mexican disinflation program: An exchange rate-based stabilization?" *IMF Working Paper,* No. 24.

Sheehey, E.J.(1986), "Unanticipated inflation, devaluation and output in Latin America," *World Development,* 14, pp.665-671.

Solimano, A.(1986), "Contractionary Devaluation in the Southern Cone: The Case of Chile," *Journal of Development Economics*, 23, September, 135-151.

Taye, H.K.(1999), "The impact of devaluation on macroeconomic performance: The case of Ethiopia," *Journal of Policy Modeling*, 21(4), 481-496.

Terasvirta, T. (1998), "Modelling Economic Relationships with Smooth Transition Regressions," in A. Ullah and D.E.A. Giles (eds.), *Handbook of Applied Economic Statistics*, Dekker, New York, 507-552.

Terasvirta, T. (2004), "Smooth Transition Regression Modelling," in H. Lütkepohl and M. Krätzig (eds.), *Applied Time Series Econometrics*, Cambridge University Press, Cambridge, 222-242.

Valev, N. (2004), "No pain, no gain: market reform, unemployment, and politics in Bulgaria," *Journal of Comparative Economics*, 32(3), 409-425.

Van Wijnbergen, S.V.(1986), "Exchange Rate Management and Stabilization Policies in Developing Countries," *Journal of Development Economics*, 23, 227-247.

Wyzan M. L.(1998), "The political economy of Bulgaria's peculiar post-Communist business cycle," *Comparative Economic Studies*, 40(1), 5-43.

Apendix: Data Sources and Variable Definition

Data were predominantly extracted from the International Financial Statistics (IFS) of the International Monetary Fund, through the online database Webstract.

The dataset contains quarterly information for Bulgaria from 1994 I to 2004 IV. Data for GDP were obtained from line 99 of the IFS. Nominal Exchange rates are period average market rates obtained from the “rf” item of Exchange Rates and Exchange Rate Arrangements section of the IFS. A broad measure of money comparable to what is commonly referred to as the M2 monetary aggregate has been used, and was extracted from subject codes 35L for Bulgaria. Government Expenditures for Bulgaria were obtained from the government finance section of IFS line 82.

Following Edwards (1989b), we define the real exchange rate as follows:

$$e = NER \frac{P_T}{P_N}$$

Where NER is the nominal exchange rate expressed in units of the home currency per unit of foreign currency, P_T is the foreign currency denominated international price of tradeables and P_N is the domestic price for nontreadables. To compute the real exchange rate, I use period average market rates for the bilateral Leva-US Dollar rate and proxy P_T and P_N with the US wholesale price index and Bulgarian CPI respectively.

All variables in the estimated models have been transformed into first differences of their natural logs to make the stationary.

Figure 2. Logistic Function of the LSTR1 Model versus Δm_t

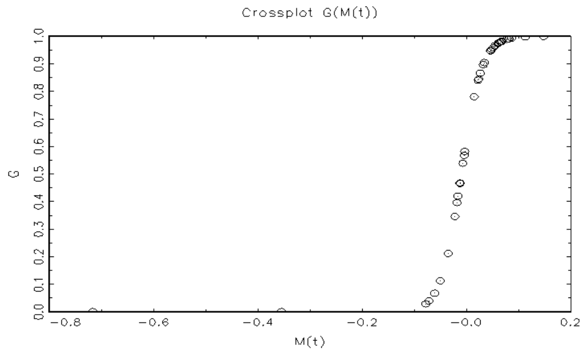

Table 1. Tests of Linearity against an STR Specification

Transition Variable	p-value	Preferred Model
Trend	1.2857e-01	Linear
Δy_{t-1}	1.7692e-02	LSTR2
Δy_{t-2}	2.3669e-03	LSTR1
Δy_{t-3}	7.0355e-04	LSTR2
Δy_{t-4}	3.3617e-04	LSTR1
Δg_{t}	2.4974e-02	LSTR2
Δg_{t-1}	2.6159e-02	LSTR2
Δg_{t-2}	3.5844e-02	LSTR1
Δm_{t}	1.2493e-04*	LSTR1
Δm_{t-1}	6.8666e-02	Linear
Δm_{t-2}	1.7524e-02	LSTR1
Δe_{t}	4.4425e-01	Linear
Δe_{t-1}	2.6598e-02	LSTR1
Δe_{t-2}	7.9526e-02	Linear

Note: Results presented as *p*-values.

Table 2. Estimated Linear and 2-regime LSTR1 Models for GDP Growth

Transition Variable	Linear model	LSTR1 model	
		***G*=0**	***G*=1**
Intercept	0.116	0.16619	
	(7.266)	(14.2301)	
Δy_{t-1}			
Δy_{t-2}	-.337	-0.00088	-0.47508
	(-4.545)	(0.6193)	(-4.5511)
Δy_{t-3}	-0.297	-0.98728	1.32582
	(-2.751)	-6.9556)	(6.8417)
Δy_{t-4}	0.327	0.95416	-1.23501
	(4.505)	9.0457)	(-6.6567)
Δg_t			
Δg_{t-1}			
Δg_{t-2}	0.195	0.08720	-0.33424
	(2.230)	0.8607)	(-2.8272)
Δm_t	-1.011	-0.26973	
	(-8.704)	-2.4085)	
Δm_{t-1}	-0.698	-0.90792	
	(-5.305)	-11.3120)	
Δm_{t-2}	-1.429	-3.62396	3.00108
	(-7.576)	-15.8610)	(10.5267)
Δe_t			
Δe_{t-1}			
Δe_{t-2}	-0.643	-2.37893	2.60612
	(-2.288)	-6.0009)	(5.1588)
Transit. Vb			Δm_t
γ / c		$\gamma =$ 7.33596	$c =$ -0.00956
		[1.7135]	[0.0046]
Goodness-of-fit			
SD of resid		0.0335	
R^2	0.8996	0.9905	
AIC / SC	-4.56/-4.18	-6.49/-5.77	
Diagnostics *(p-values)*			
Autocorr. (8)	0.3426	0.9273	
Normality	0.6295	0.8267	
ARCH (8)	0.9939	0.5947	
Constancy		0.5620	
Nonlinearity		Not computed (inversion problem)	

Notes: t-statistics in parenthesis.