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CAN PRODUCTIVITY INCREASES REALLY EXPLAIN THE LIRA APPRECIATION: QUESTIONS FOR THE CENTRAL BANK OF THE REPUBLIC OF TURKEY

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Abstract

This paper studies the Balassa-Samuelson (B-S) hypothesis between Turkey and 27 members of the European Union (EU-27). The Central Bank of the Republic of Turkey (CBRT) in recent years has emphasized the importance of the B-S hypothesis for Turkey. Specifically, the CBRT states that structural reforms, increased confidence, and macroeconomic stability in the post 2001 era have contributed to the strengthening of the national currency through the relative price differentials between tradable versus non-tradable goods (Inflation Report II, 2006, pp: 31-34). Given this emphasis by the CBRT, we test the cointegrating relationship between the real effective exchange rate, relative productivity, real interest rate differentials and the net foreign asset, using recently developed cointegration techniques with multiple structural breaks. The findings reveal that the relative productivities play a limited role in explaining the real effective exchange rate appreciation. In particular, the relationship between the real effective exchange rate and productivity is not supported for the post 2001 era.

Keywords: Balassa-Samuelson Hypothesis, Real Effective Exchange Rate, Relative Productivity, Cointegration, Multiple Structural Breaks

JEL Codes: C22, E31, F31

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Introduction

The Balassa-Samuelson (B-S) hypothesis relies on the productivity differentials between tradable and non-tradable sectors to explain deviations in purchasing power parity. According to the B-S hypothesis, because productivity growth in tradable sectors is higher than in non-tradable sectors, real wages increase in tradable sectors. On the other hand, because the prices of tradable goods are determined in the world market, tradable prices will not increase. With an assumption of perfect labor mobility within a country, increases in wages in tradable sectors will be reflected in non-tradable sectors as well. However, an increase in wages in non-tradable sectors is not accompanied by an increase in productivity. As a result, the prices of non-tradable goods will increase, leading to an increase in the overall price level and the appreciation of the real exchange rate for the domestic economy. Thus, within this framework, the relative productivity differences in tradable vis-à-vis non-tradable sectors between two countries will determine the long-run changes of the real exchange rate.

The Central Bank of the Republic of Turkey (CBRT) in recent years has emphasized the importance of the Balassa-Samuelson hypothesis for Turkey. Specifically, co-observance of the Turkish lira's tendency to appreciate and the price differentials between tradable and non-tradable sectors necessitates a close investigation of the relationship between the real exchange rate and price differentials. In this regard, part of the appreciation of the Turkish lira (TL) can be attributed to the productivity differentials between tradable and non-tradable sectors. In particular, in addition to the direct effects of structural reforms undertaken after the 2001 crisis, increased confidence, optimism, and macroeconomic stability in recent years have contributed to the strengthening of the national currency through the relative price differentials between tradable versus non-tradable goods (Inflation Report II, 2006).

The main purpose of this study then, given the increased consideration of the Balassa-Samuelson effect by the CBRT, is to test whether part of the appreciation of the TL is driven by the relatively rapid productivity increases in the tradable sectors in recent years. Hence, the study examines the validity of the B-S hypothesis between Turkey and 27 member countries of the European Union (EU-27), which includes the majority of Turkey's main trading partners, for the post-financial liberalization era, using recently developed cointegration techniques with multiple structural breaks.

The paper consists of five sections, including the introduction. Section two presents the theoretical framework of the B-S hypothesis and reviews the literature. In section three,

the data and the empirical method used to test the B-S hypothesis are explained. Section four presents the empirical finding, and section five concludes.

Theoretical Framework

There are several possible theoretical explanations in the literature for the real exchange rate movements. One of the most important models of long-run deviations from the purchasing power parity (PPP) was developed by Balassa (1964) and Samuelson (1964). They explained that relative productivity differences across countries cause the real exchange rate to deviate from the PPP in the long run. A rapid productivity increase in the tradable sector vis-à-vis the non-tradable sector in the home country in relation to the rest of the world will cause the aggregate price level to increase faster and consequently cause the home currency to appreciate.

In other words, an increase in productivity in the tradable sector will cause an increase in real wages in that sector. Given the perfect labor mobility within a country, increases in wages in tradable sectors will also increase the wages in non-tradable sectors. However, this increase in wages in non-tradable sectors is not supported by an increase in productivity. Hence, the prices of non-tradable goods will increase, pushing the aggregate price level up, thereby leading to the appreciation of the real exchange rate for the home country.

The basic features of the B-S hypothesis were first described by Samuelson (1964), and empirically tested by Balassa (1964). The functioning of the model relies on some basic assumptions: the PPP holds for tradables; labor productivity determines wages in the tradable sector; labor is not mobile between countries but perfectly mobile within a country, which causes the wages to match between sectors within the home country; and finally, there is perfect capital mobility within and between countries.

Consider a small economy that produces output in tradable and nontradable sectors, using constant returns to scale technology with capital and labor[1]:

$$Y_T = A_T (L_T)^{\gamma} (K_T)^{1-\gamma} \tag{1}$$

$$Y_{NT} = A_{NT} (L_{NT})^{\delta} (K_{NT})^{1-\delta} \tag{2}$$

Where T and NT denote the tradable and non-tradable sectors, Y is output level, and A, L, and K are technology, labor, and capital, respectively. γ and δ denote the share of labor in

[1] Obstfeld and Rogoff, 1996, 204-216

the tradable and non-tradable sectors. Assuming the perfect mobility of factors of production, the profit maximization under the perfect competition yields:

$$W = A_T \gamma (K_T / L_T)^{1-\gamma} \tag{3}$$

$$W = (P_{NT} / P_T) A_{NT} \delta (K_{NT} / L_{NT})^{1-\delta} \tag{4}$$

$$R = A_T (1-\gamma)(K_T / L_T)^{-\gamma} \tag{5}$$

$$R = (P_{NT} / P_T) A_{NT} (1-\delta)(K_{NT} / L_{NT})^{-\delta} \tag{6}$$

Where W and R reflect the wage rate and the interest rate, respectively. The interest rate is determined in the world market. P_{NT} / P_T is the relative price of non-tradables in term of tradables. Taking the logarithms, totally differentiating, and rearranging equations (3-6) yields the domestic version of the B-S hypothesis:

$$d(p_{NT} - p_T) = (\delta / \gamma) da_T - da_{NT} \tag{7}$$

$$(p_{NT} - p_T) = cons + (\delta / \gamma) a_T - a_{NT} \quad . \tag{7a}$$

Where, *cons* stands for constant.

Equation (7) indicates that given the equal factor intensities in the tradable and non-tradable sectors *(δ = γ)*, faster productivity increases in the tradable sector will cause higher prices in the non-tradable sector than those of the tradable sector. The assumption of equal factor intensity is sufficient but not even necessary to reach this conclusion from equation (7). Since the labor intensity is likely to be higher in the non-tradable sector ($\delta > \gamma$), even a mild productivity increase in favor of the tradable sector can generate a higher relative price for the non-tradable sector (Ègert, Halpern and MacDonald, 2006; Kravis and Lispey 1982; Bhagwathi, 1984). Hence, the relative productivity-price relationship in (7) may alternatively be expressed as

$$\left(p_{NT} - p_T\right) = f\left(a_T - a_{NT}\right) \tag{7b}$$

Assuming that the factor intensities are the same for the domestic, and foreign economies *($\delta = \gamma$ and $\delta^* = \gamma^*$)*, then the relationship between the relative price and relative productivity differences between the domestic and foreign economies can be written as follows.

$$\left(p_{NT} - p_T\right) - \left(p_{NT}^{\ *} - p_T^{\ *}\right) = cons + \left(a_T - a_{NT}\right) - \left(a_T^{\ *} - a_{NT}^{\ *}\right) \tag{7c}$$

Equation (7c) reflects the international transmission mechanism of the B-S hypothesis. It explains why the increase in relative productivity of the tradable sector vis-à-vis the non-tradable sector for the domestic economy compared to the foreign economy leads to an appreciation of the domestic currency. An increase in the relative productivity of the tradables

leads to an increase in the prices of non-tradables. This in turn increases the aggregate price level for the domestic economy, causing appreciation of the domestic currency.

The real exchange rate can be expressed as the nominal exchange rate times the domestic price level divided by the foreign price level:

$$Q = EP / P^{*} \tag{8}$$

Where, P^* and P denote foreign and domestic price levels, and Q and E reflect the real and nominal exchange rates. In foreign and domestic economies, the general price level is expressed by the weighted average of tradable and non-tradable goods.

$$P = P_T^{\ \alpha} P_{NT}^{\ 1-\alpha} \tag{9}$$

$$P^{*} = P_T^{*\alpha^{*}} P_{NT}^{*1-\alpha^{*}} \tag{9a}$$

Where, P_T and P_T^* represent the price levels of tradables in home and foreign country; while P_{NT} and P_{NT}^* reflect the price level of non-tradables in the home and foreign country, respectively. α and α^* are shares of the tradable goods in the aggregate price level in home and foreign country.

Assuming that equation (7c) holds and $\alpha=\alpha^*$, taking the natural logarithms of equations (8, 9, 9a), and then substituting (9 and 9a) into equation (8), yields equation (10).

$$q_t = cons + (e_t + p_{Tt} - p_{Tt}^{*}) + (1-\alpha)\left[\left(a_{Tt} - a_{NTt}\right) - \left(a_{Tt}^{*} - a_{NTt}^{*}\right)\right] \tag{10}$$

$$q_t = cons + q_{Tt} + q_{NTt,Tt} \tag{10a}$$

The second term in equation (10), q_{Tt}, is the PPP for tradable goods. It is equal to zero if PPP holds for the tradable sector, so, equation (10) can be rewritten as

$$q_t = cons + (1-\alpha)\left[\left(a_{Tt} - a_{NTt}\right) - \left(a_{Tt}^{*} - a_{NTt}^{*}\right)\right] \tag{10b}$$

Equation (10b) is the standard B-S hypothesis and is purely supply sided and hence fairly restrictive. We relax the assumption of PPP for tradables to be true all the time and focus on balance of payments to explain deviations in it. Given the floating exchange rate regime and assuming no intervention in the exchange rate market, the equilibrium condition for balance of payments would hold (Kanamori and Zhoa, 2006).

$$ca_t + ka_t = 0 \tag{11}$$

ca_t and ka_t in equation (11) are the current account and capital account, respectively. Assuming that the current account in period t is determined by net exports, nx_t and interest earnings (payments) on net foreign assets, nfa_t, we have

$$ca_t = nx_t + \theta_t nfa_t \tag{12}$$

Where θ denotes the real lending (borrowing) rate for the home country while the term, $\theta_t \ nfa_t$ represents the net real interest payments (earnings) for the domestic economy. We are assuming the real lending (borrowing) rate to be constant for the domestic economy and ignoring some other minor components that might influence the current account in equation (12). Next, we turn to the determinants of net exports and assume that changes in the real exchange rate or terms of trade, an indicator of competitiveness, have an effect on net exports and the current account. Open economy macroeconomics also suggests that domestic and foreign incomes also have an impact on net exports. The former worsens net exports by stimulating imports while the latter improves net exports via increasing the demand for domestically produced goods abroad. Hence, the following standard relationship for net exports is proposed.

$$nx_t = \lambda_1(e_t + p_{Tt} - p_{Tt}^*) - \lambda_2 y_t + \lambda_3 y_t^* \tag{13}$$

Where e_t is the nominal exchange rate, p_{Tt} and p_{Tt}^* are the log domestic and foreign price levels, respectively, for tradables, and y_t and y_t^* denote the log of the real domestic and foreign income levels in that order. λ_i, for i=*1*,*2*,3 are the elasticities with respect to the real exchange rate, and real domestic and foreign incomes correspondingly at time *t*.

Turning to the second component of balance of payments, we presume that the capital account is determined by the following relationship.

$$ka_t = \mu\,(i_t - i_t^* - \Delta\, e_{t+1}^e) \tag{14}$$

The term in parenthesis is the uncovered interest rate parity, where i_t and i_t^* represent the domestic and foreign nominal interest rate correspondingly, and Δe_{t+1}^e is the expected change in the nominal exchange rate. Uncovered interest rate parity does not necessarily hold all the time. However, when there are deviations from the parity, appropriate flows of capital will tend to establish the parity again. Specifically, an increase in the home country interest rate will attract international capital and cause the exchange rate to appreciate, while a rise in the foreign interest rate will reduce capital inflow, causing the expected value of domestic currency to depreciate and thus stimulate capital outflow. Hence, assuming the combined impacts of domestic and foreign income levels in equation (13) to be constant (at least fairly stable), the balance of payments nominal exchange rate equation can be written (or approximated) as

$$e_t = cons + (p_{Tt}^* - p_{Tt}) - \frac{\theta}{\lambda_1} nfa_t - \frac{\mu}{\lambda_1}(i_t - i_t^* - \Delta e_{t+1}^e) \tag{15}$$

Equation (15) can be thought of as a general formulation, corresponding to the equilibrium exchange rate. It is compatible with the balance of payments equilibrium under the floating exchange rate regime. Given that the expected change in the exchange rate can be proxied by the home and foreign expected inflation differentials, equation (15) can be rewritten as follows.

$$e_t = cons + (p_{Tt}^* - p_{Tt}) - \frac{\theta}{\lambda_1}(nfa_t) - \frac{\mu}{\lambda_1}(r_t - r_t^*) \tag{15a}$$

For tradable goods the real exchange rate is defined as follows.

$$q_{Tt} = e_t + p_{Tt} - p_{Tt}^* \tag{16}$$

Hence, we can write the real exchange rate for tradables at time *t* as follows.

$$q_{Tt} = cons - \frac{\theta}{\lambda_1} nfa_t - \frac{\mu}{\lambda_1}(r_t - r_t^*) \tag{17}$$

Where r_t and r_t^* reflect real interest rate in home and foreign country at time *t*. Substituting equation (17) in equation (10) we obtain

$$q_t = cons - \frac{\theta}{\lambda_1} nfa_t - \frac{\mu}{\lambda_1}(r_t - r_t^*) + (1-\alpha)\left[\left(a_{T\,t} - a_{NTt}\right) - \left(a_{Tt}^* - a_{NTt}^*\right)\right] \tag{18}$$

or in compact form, we have

$$q_t = f(prod_t, nfa_t, r_t - r_t^*) \tag{18a}$$

Equation (18) is our real exchange rate model, indicating that the real exchange rate is a function of relative productivity differentials, net foreign assets and real interest rate differentials. Equation (18) is completely compatible with equation (5) in Clark and MacDonald (2000).

We study several variations of this model based on the combinations of net foreign assets and real interest rate differentials in addition to relative productivities. In particular, according to the specific to general principle, the following fundamental determinants of the real exchange rate are employed as independent variables in the empirical models analyzed.

Model 1a: $reer_t = cons + \beta_1 prod_t + u_t$

Model 1b: $reer_t = cons + \beta_1 prodtr_t + \beta_2 prodeu_t + u_t$

Model 2a: $reer_t = cons + \beta_1 prod_t + \beta_2 nfa_t + u_t$

Model 2b: $reer_t = cons + \beta_1 prodtr_t + \beta_2 prodeu_t + \beta_3 nfa_t + u_t$

Model 3a: $reer_t = cons + \beta_1 prod_t + \beta_2 rir_t + u_t$

Model 3b: $reer_t = cons + \beta_1 prodtr_t + \beta_2 prodeu_t + \beta_3 rir_t + u_t$

Model 4: $reer_t = cons + \beta_1 prod_t + \beta_2 nfa_t + \beta_3 rir_t + u_t$

Where *prodtr* and *prodeu* stand for relative productivities in the tradable and non-tradable sectors in Turkey and EU27, respectively; *rir* describes real interest rate differentials between Turkey and EU27; *prod* is relative productivity differentials, *prodtr-prodeu* ; and *nfa* is net foreign assets of the home country.

Literature Review

There is a large body of empirical literature dealing with changes in the real exchange rate. Table 1 presents some selected empirical studies with time period, variables used, proxy for productivity, method and the effect of productivity on the real exchange rate.

Alberola et. al (1999) investigated the relationship between the real exchange rate and fundamentals of its external and internal components (stock of the net foreign assets and relative sectoral prices) for the United States (US), Japan Canada, and the EU countries for the 1980:Q1- 1998:Q4 period, using panel cointegration methods. They found the coefficient of relative price differentials (proxy for the B-S effect) to be significant and circa unity as theoretically expected.

MacDonald and Nagayasu (2000) investigated the long-run relationship between the real exchange rate and the real interest rate differential for 14 industrialized countries for the period of 1976-1997. Using panel cointegration tests, they found that the estimated slope coefficients were consistent with the model and that there was a long-run relationship between real exchange rate and real interest rate differentials.

Rahn (2003) estimated the real exchange rate for five EU accession countries by applying the Behavioral Equilibrium Exchange Rate (BEER) and Permanent Equilibrium Exchange Rate (PEER) approach, using quarterly data from 1990:Q1 to 2002:Q1. Both Johansen and panel cointegration techniques revealed that the impacts of productivity differences and net foreign assets on the real exchange rate were positive and significant.

MacDonald and Wojcik (2004) examined the exchange rate behavior of four transitional and EU accession economies, with panel DOLS for the period from 1995 to 2001. They found that the B-S effect led to modest appreciation of the real exchange rate with an elasticity not exceeding 0.51. The results were robust to various changes in the model, such as adding supply and demand effects, and real wages in addition to real interest rate differentials and net foreign assets, and all the macroeconomic variables had correct signs (positive) and

were statistically significant. For related group countries, Alberola and Navia (2008) focused on the role of capital flows and the B-S hypothesis to determine the real exchange rate for new EU members. The authors concluded that the real exchange rate appreciated with productivity growth, and productivity gains improved competitiveness without the need for the exchange rate adjustment.

Table1. Selected Empirical Studies for Testing the B-S Hypothesis

Author(s)	Country	Period	Independent Variables	Productivity Proxy	Method	Sign (B-S)
Balassa (1964)	12	1960	GDP	GDP	OLS	+
Alberola et al. (1999)	11	1980-1998	Prod, nfa	CPI/WPI	Panel	+
Clark and MacDonald (2000)	3	1960-1997	Prod, nfa, rir	CPI/WPI	VECM, Johansen	+,-
Rahn (2003)	5	1990-2002	Prod, nfa	CPI/WPI	Johansen, Pedroni	+
MacDonald and Ricci (2003)	South Africa	1970-2001	Prod, rir, open, nfa, fb,	GDP	Johansen	+
Lommatzsch and Tober (2004)	3	1994-2003	Prod, debt, r,	Y/L	E-G	+, -
Lane and Milesi-Ferretti (2004)	64	1970-1997	Prod, tot, nfa	GDP	DOLS	+
MacDonald and Wojcik (2004)	4	1995-2001	Prod, nfa, rir	Y/L	PDOLS	+
Égert (2005)	6	1985-2004	at-an	Y/L	ARDL, DOLS	+
MacDonald and Ricci (2005)	10	1970-1991	Prod, nfa , at, an, ad, rir	TFP	DOLS	+
Gente (2006)	6	1970-1992	at, an, rir	TFP	Calibration	+
Alberola and Navia (2008)	3	1993-2004	Prod, nfa	Y/L	Johansen	+
Mejean (2008)	16	1981-1999	Prod, nfa, ulc, sa	Y/L	Pedroni	-
Coudert and Couharde (2009)	128	1974-2004	Prod, nfa	GDP	Pedroni	+
Camarero (2008)	12	1970-1998	at, an, ad, nfa, rir, pe.	Y/L	PMGE	+
Bénassy-Quéré et al, (2010)	15	1980-2005	Prod, nfa, tot	CPI/WPI	Panel	-
Alper and Civcir (2012)	Turkey	1987-2010	Y/L, nfa	Y/L	Johansen	+

ARDL: Autoregressive Distributed Lag; **at**: Relative productivity in tradables; **an**: Relative productivity in nontradables; **ad**: Relative productivity in the distribution sector; **CPI:** Consumer price index; **debt**: Total foreign debt; **E-G:** Engle Granger Cointegration Method; **fb**: Ratio of fiscal balance to GDP; **GDP**: Real GDP per capita; **nfa:** Ratio of net foreign assets to GDP; **OLS**: Ordinary Least Squares; **open:** Openness; **pe:** Public expenditure; **PDOLS**: Panel Dynamic Ordinary Least Squares; **PMGE:** Pooled Mean Group Estimation; **p.oil**: Price of oil, **prod:** Relative productivity differentials; **r:** Real interest rate; **rir:** Real interest rate differentials; **sa:** Supplier access; t**ot**: Terms of trade; **ulc** Unit labor cost; **VECM**: Vector Error Correction Model; **Y/L**: Average labor productivity; **WPI**: Producer price index.

Camarero (2008) examined the role of productivity in the behavior of the real exchange rate of the US dollar against the currencies of a group of Organization for Economic

Co-operation and Development (OECD) countries for the 1970-1998 period, employing the pooled mean group estimation (PMGE) method. The study emphasized the relevance of dividing productivity into three sectors: tradable, nontradable and distribution sectors and examined the effects of both productivity and other fundamentals proposed in the real exchange rate literature. The empirical model was constituted from general to specific by dropping variables based on the statistical significance and information criteria. The results suggested that some of the explanatory variables, such as productivity and real interest rate differentials, offer only a limited (partial) explanation for movements of the real exchange rate.

Using yearly data from 1974 to 2004, Coudert and Couharde (2009) employed panel cointegration techniques to investigate the relationship between the real exchange rate and its determinants for 128 countries. They used PPP-adjusted GDP per capita as a proxy for the B-S effect and net foreign assets explanatory variables. The results showed that the real exchange rates appreciated in response to an increase in productivity and net foreign assets. The estimated effect of the B-S magnitudes was fairly modest, between 0 and 0.5.

Bénassy-Quéré et al, (2010) estimated the equilibrium exchange rate by using fundamental and behavioral approaches. The authors investigated 15 advanced and emerging economies, accounting for over 80 percent of the world GDP for the period of 1980-2005, using panel cointegration techniques. To determine the real equilibrium exchange rate, they included net foreign assets, CPI/WPI as proxy for relative productivity differentials, and terms of trade as explanatory variables. The results were all consistent with *a priori* expectations and statistically significant, with an estimated B-S effect of 0.88.

Clark and MacDonald (2000) extended the BEER approach by analyzing permanent and transitory components of the real exchange rate via the Johansen cointegration method. They identified and estimated the equilibrium relationship between the real exchange rate and the B-S effect, net foreign assets and real interest rate differentials for the US and Canadian dollars and the British pound for the period of 1960-1997. They found all variables to be positive and significant for all three currencies except the net foreign assets for the British pound. Net foreign assets for the British pound were found to be positive but statistically insignificant.

MacDonald and Ricci (2003) analyzed the real effective exchange rate for South Africa using the real interest rate differentials, real GDP per capita as a proxy for productivity, terms of trade, openness, fiscal balance, and net foreign assets for the 1970-2001 period. The results obtained via the Johansen cointegration method suggested that one percentage increase

in the interest rate and real GDP per capita relative to the trading partners, appreciated the real exchange rate by 3% and 0.1-0.2%, respectively.

The number of studies dealing with the B-S hypothesis for Turkey is rather few. One noteworthy study by Égert (2005) analyzed the domestic B-S effect (see equation 7 above) for a group of EU-acceding, EU-accession (including Turkey) and the Common Wealth of Independent States (CIS) countries. The study indicated that the relative price–relative productivity relationship was mostly insignificant for Turkey. A recent study for estimating the equilibrium exchange rate for Turkey was conducted by Alper and Civcir (2012) for the 1987:Q1-2010:Q4 period, using the Johansen cointegration method. They employed the BEER approach and included net foreign assets in addition to productivity in the analysis. The authors used the nominal exchange rate expressed in units of dollars per Turkish lira and the GDP deflators of Turkey and the US to construct the real exchange rate. They used the average labor productivity for Turkey as a proxy for productivity due to the lack of availability of sectoral data. They also added three dummy variables (1994, 2001 and 2009) to represent the currency and financial crises in the Turkish economy. The authors concluded that the real exchange rate appreciated with positive productivity shocks while it depreciated in response to the increase in net foreign assets. However, the magnitude of the estimated elasticity for productivity, 5.116, was rather large and well above any reasonable *a priori* expectation and the estimates discussed in the literature above. This result might have been contaminated by the use of a particular proxy for the productivity differential and the way that the real exchange rate series was constructed. In particular, movements of the two series seem to be extremely similar except that the levels are different (see Alper and Civcir, 2012, figure 1).

Data

The data set covers the period from 1990:Q1 to 2011:Q2. We take the EU-27 as the benchmark foreign country. Manufacturing represents the tradable sector, while the non-tradable sector includes construction, wholesale and retail trade, and community, social and personal services. Average labor productivity is used as a proxy for the productivity variable suggested by the theoretical model. Hence, in order to compute productivity in the tradable sector, the total output in manufacturing is divided by the employment level in the manufacturing sector. To calculate productivity for the non-tradable sector as a whole, a weight is needed for each sub-sector productivity. To calculate the weights, we total the output for all non-tradable sub-sectors separately. Then, we calculate the percentage of the

total output attributed to each sub-sector by dividing the total output for each sub-sector into the grand total of output of the broad category of non-tradable sector. All the sectoral output and employment series for EU27 as well as the sectoral output series for Turkey are obtained from the statistical office of the European Union (Eurostat). The employment series for Turkey is from the Turkstat (Turkish Statistical Institute) and the CBRT. The output and employment series for each sub sector are seasonally adjusted using X-12, before the average productivity for each sub-sector is calculated.

Table 2. Variable Definitions

Variables		Explanation	Source
Reer	Real Effective Exchange Rate	Increase in REER of Turkey corresponds to an appreciation of the Turkish Lira	Eurostat
Prodtr	Relative productivity in Turkey	Average labor productivity $prod_T - prod_{NT}$	CBRT, Eurostat, TurkStat
Prodeu	Relative productivity in EU-27	Average labor productivity $prod_T^* - prod_{NT}^*$	Eurostat
Prod	Relative productivity differentials	$prodtr - prodeu$	CBRT, Eurostat, TurkStat
Nfa	Net foreign assets	(Foreign assets - liabilities to non-resident)/GDP	CBRT
Rir	Relative real interest rate differentials	$\left[\left(\frac{1+i}{1+\pi}-1\right)-\left(\frac{1+i^*}{1+\pi^*}-1\right)\right]$	Undersecretariat of Treasury, IFS

i: nominal interest rate; *π:* domestic and foreign inflation rate. * denotes foreign countries.

The dependent variable in our study is the logarithm of the consumer price index (CPI) based real effective exchange rate (*REER*)[2] obtained from Eurostat. An increase in the *REER* of Turkey corresponds to an appreciation of the TL. The net foreign assets series for Turkey is computed by the difference in the total foreign assets minus the liabilities to non-residents divided by the GDP, and from the CBRT. Real interest rate differentials (*RIR*) are proxied by the real interest rate differentials between Turkey and G7. The annual percentage rate (APR) on three month treasury bills (TB) and the CPI based inflation series are used to compute the RIR. Both the TB rates and CPI series for Turkey are from the Undersecretariat of the Treasury, while the TB rates and CPI based inflation series for G7 are from the International

[2] The REER is calculated as the sum of the nominal rate and the trade weighted price or cost deflator. The REER attempts to show movements in prices or the production cost of domestically produced goods relative to prices or the production cost of goods produced by competitor countries when expressed in common currency. Competitors here for Turkey correspond to EU27.

Financial Statistics (IFS). For Turkey the inflation series is calculated by the authors using the Turkish CPI series. The variables used and the data sources are also summarized in Table 2.

Econometric Methodology

As a first step, we start by investigating the order of integration of the real exchange rate and its determinants. Next, the stability of the relationship between the real exchange rate and its determinants are assessed using the tests proposed by Kejriwal and Perron (2010) involving non-stationary but cointegrated variables with multiple structural changes of unknown timing in regression models. The global minimization procedure for the break fractions is the same as in Bai and Perron (1998, 2003). It is obtained via an algorithm, using the principle of dynamic-programming. Nevertheless, the distributions of the break fraction estimates and the sub-Wald test statistics are different from the ones in Bai and Perron (1998, 2003) due to the nonstationarity of the time series. If the empirical application of the Kejriwal-Perron tests corroborates the existence of structural break, then whether the variables are indeed cointegrated needs to be verified, as these tests can reject the null of stability when the regression is a spurious one (Kejriwal, 2008). So, the cointegration tests following Kejriwal (2008), which are based on the extension of the one-break cointegration tests developed by Aria and Kuruzomi (2007) (A-K henceforth) with a null of cointegration, are performed. Because our series seem to exhibit a deterministic time trend (see the figures in the Appendix), we include the trend in the unit root as well as cointegration tests. Finally, we estimate the model with breaks to investigate how the relationship between the real exchange rate and its determinants may have altered over time.

Unit Root Tests

In order to scrutinize the integrating level of variables, the Ng and Perron (2001) tests that have good size and power properties are employed. Ng and Perron (Ng-Perron) provide tests called $MZ_\alpha^{GLS}, MZ_t^{GLS}$, *MSB* and MP_t^{GLS} for investigating the existence of unit roots. $MZ_\alpha^{GLS}, MZ_t^{GLS}$ are obtained by modifying the Phillips (1987) and Phillips and Perron (1988) Z_α and Z_t tests. The *MSB* is derived from the Bhargava (1986) *R* test, and lastly the MP_t^{GLS} test is adopted from the Elliot, Rotherberg and Stock (1996) Point Optimal Test. Letting y_{t-1}^d be the *GLS* de-trended data, The Ng and Perron (2001) test statistics, called *M-GLS* tests, are as follows:

$$MZ_a^d = (T^{-1}(y_T^d)^2 - f_\circ)/(2k)$$

$$MZ_t^d = MZ_a \times MSB$$

$$MSB^d = (k / f_\circ)^{1/2}$$

$$MP_T^d = \begin{cases} \left(\bar{c}^2 k - \bar{c}T^{-1}(y_T^d)\right)^2 / f_0 & if\ x_t = \{1\} \\ \left(\bar{c}^2 k + (1-\bar{c})T^{-1}(y_T^d)^2\right) / f_0 & if\ x_t = \{1, t\}. \end{cases}$$

Where $k = \sum_{t=2}^{T} (y_{t-1}^d)^2 / T^2$,

$\bar{c} = \begin{cases} -7 & if\ x_t = \{1\} \\ -13.5 & if\ x_t = \{1, t\} \end{cases}$, and f_0 is the frequency zero spectrum estimation.

In order to corroborate the results of the Ng-Perron tests, we also employ more conventional unit root tests, namely *ADF* and *KPSS* tests.

Structural Break Tests

Kejriwal and Perron (2010) considered three types of statistics for testing multiple breaks. The first is the sub-Wald test of the null hypothesis of no structural break versus the alternative hypothesis where there is a fixed value of *k* breaks:

$$\sup F_T^*(k) = \sup_{\lambda \in \Lambda_\in} \frac{SSR_0 - SSR_k}{\hat{\sigma}^2} .$$

Where, SSR_0 denotes the sum of squared residuals under the null hypothesis of no breaks; SSR_k denotes the sum of squared residuals under the alternative hypothesis of *k* breaks; $\lambda = \{\lambda_1 \ldots\ldots \lambda_m\}$ is the vector of break fractions defined by $\lambda_i = T_i / T$ for $i = 1, \ldots\ldots m_i$, ; T_i are the break dates; $\hat{\sigma}^2$ is a hybrid estimator of long-run variance involving the residuals computed under both the null and alternative hypothesis; and for some arbitrary small positive number, $\in, \Lambda_\in = \{\lambda : |\lambda_{i+1} - \lambda| \geq \in, \lambda_1 \geq \in, \lambda_k \leq 1 - \in\}$ (Kejriwal and Perron (2010) and Kejriwal (2008)).

The second test, a double maximum test called *UDmax*, checks the null hypothesis of no structural breaks against the alternative of an unknown number of breaks given some upper bound *M* for the number of breaks:

$$UD\max F_T^*(M) = \max_{1 \le k \le m} F_T^*(k)$$

The third test involves a sequential procedure (SEQ) that analyzes the null hypothesis of *k* breaks against the alternative hypothesis of *k+1* breaks:

$$SEQ_T(k+1|k) = \max_{1 \le j \le k+1} \sup_{\tau \in \Lambda_{j,\epsilon}} \left\{ \frac{SSR_T(\hat{T}_1,...., \hat{T}_k) - SSR_T(\hat{T}_1,..., \hat{T}_{j-1}, \tau, \hat{T}_j,..., \hat{T}_k}{\hat{\sigma}^2_{k+1}} \right\}$$

Where $\Lambda_{j,\epsilon} = \left\{ \tau : \hat{T}_{j-1} + (\hat{T}_j - \hat{T}_{j-1})\varepsilon \le \tau \le \hat{T}_j - (\hat{T}_j - \hat{T}_{j-1})\varepsilon \right\}$, and $\hat{\sigma}^2_{k+1}$ is a consistent hybrid estimate of long run variance as in the *SubF* test given above. The model with *k* breaks is obtained by a global minimization of the sum of squared residuals, as in Bai and Perron (2003). The sequential procedure provides a consistent true number of breaks. However, when the parameters change in such a way that the first and third regimes are identical, the sequential procedure may end up selecting no breaks (Bai and Perron, 2006). A useful strategy, then, to determine the number of breaks is to use *SubF* and *UDmax* tests which are significant, and then use the sequential procedure to determine the number of breaks (Kejriwal, 2008). As an alternative, the number of breaks can also be determined by using the Bayesian information criterion (BIC) suggested by Yao (1998) and the modified Schwarz criterion proposed by Liu et al. (1997) (LWZ), defined as;

$$BIC(m) = \ln \hat{\sigma}^2(m) + p^* \ln(T)/T, \text{ and}$$

$$LWZ(m) = \ln(S_T(\hat{T}_1,...,\hat{T}_m)/(T-p^*)) + (p^*/T)c_0(\ln(T))^{2+\delta_0}.$$

Where $p^* = (m+1)q + m + p,\quad and \quad \hat{\sigma}^2(m) = T^{-1} S_T(\hat{T}_1,....,\hat{T}_m)$. $\hat{T}_1,....\hat{T}_m$ denote the estimated break dates and $S_T(\hat{T}_1,....,\hat{T}_m)$ is the sum of squared residuals under *m* breaks. *q* is the number of coefficients which are allowed to change and *p* is the number of coefficients that are held fixed, and finally $\delta_0 = 0.1$ and $c_0 = 0.299$

In this study, stability tests for the relationship between the real effective exchange and a number of regressors are performed, using the sequential procedure as well as the information criteria, following Kejriwal (2008), to investigate the existence of breaks in the real effective exchange rate regressions.

Cointegration Tests with Multiple Structural Breaks

Kejriwal and Perron (2010) show that the structural change tests they suggest have good size and power properties. However, as pointed out in Kejriwal (2008) structural change tests also have power against a purely spurious regression. This means that when the cointegrating relation is unstable, the conventional cointegration tests are biased towards the non-rejection of the null hypothesis of no cointegration Therefore, structural changes in the cointegrating vector may be the reason for the findings of no cointegration in the literature. Hence, cointegration analysis should consider the structural changes. Residual-based tests for one structural change in the cointegration vector at an unknown time under the null of no cointegration against several alternative hypotheses of cointegration are provided by Gregory and Hansen (G-H) (1996). Nonetheless, these tests are developed to have power against the alternative of a single break, and therefore can have a low power when there is more than a single break in parameters Also, the test statistics, which are based on the minimal values of overall possible breakpoints, are not in general consistent estimates of a break date if a change exists (Kejriwal, 2008). Finally, if the primary concern is cointegration with structural breaks, the null of cointegration is a more natural choice from the viewpoint of conventional hypothesis testing.

To avoid these problems, Kejriwal (2008) extends the cointegration test with the known or unknown one structural break tests proposed by A-K to analyze multiple structural breaks under the null hypothesis of cointegration. In current study, following the work of A-K and Kejriwal, we further augment the A-K model with a deterministic trend and allow shifts in the trend as well. The regime and trend shift model used in this study is as follows:

$$y_t = c_i + \delta_i t + z_t^{'}\beta_i + u_t \quad if \;\; T_{i-1} < t \le T_i \quad for\; i = 1,..k+1$$

Where k is the number of breaks, z_t is a vector of I (1) regressors, given by $z_t = z_{t-1} + u_z$, y_t is the dependent I (1) variable, and by convention, $T_0=0$ and $T_{k+1}=T$. Augmenting the above regression model to deal with the simultaneity bias, we use the dynamic *OLS*, adding the leads and lags of the first differences of the regressors.

$$y_t = c_i + \delta_i t + z_t^{'}\beta_i + \sum_{j=-l_T}^{l_T} \Delta z_{t-j}^{'}\Pi_j + u_t^{*} \quad if\; T_{i-1} < t \le T_i \quad for\; i = 1,..,k+1$$

The test statistic for k breaks, then, is given by:

$$\widetilde{V}_k(\hat{\lambda}) = \frac{T^{-2}\sum_{t=1}^{T} S_k(\hat{\lambda})^2}{\Omega_{11}} .$$

Where Ω_{11} is a consistent estimation of the long run variance of u_t^*, $\hat{\lambda} = (\hat{T}_1/T, \ldots\ldots, \hat{T}_k/T)$ *and* $\hat{T}_1, \ldots \hat{T}_k$ are obtained by minimizing the sum of the squared residuals. The above test statistics are compared with the critical values provided by A-K (2007) for one structural break. Critical values for multiple breaks are generated by the authors, modifying the programs developed for Kejriwal (2008)[3].

Empirical Results

Table 3 presents the Ng-Perron unit root tests. Since our series seem to possess a deterministic time trend, unit root tests are conducted with a constant and a deterministic trend in the regression. Table 3 reveals that for all the variables, the null of non-stationary in levels cannot be rejected at any conventional significance level by any of the Ng-Perron tests. *ADF* and *KPSS* tests also corroborate the results in Table 3, while all three tests provide evidence that the first differences of the variables in Table 3 are stationary. Hence, we conclude that the variables used in the study are integrated order of one, I (1).

Table 3. Ng-Perron Unit Root Tests

	Deterministic component: Constant and Trend				
Variables	**lag**	MZ_α	MZ_t	**MSB**	MP_t
Reer	6	-4.43	-1.47	0.33	20.41
Prod	1	-12.52	-2.41	0.19	7.79
Prodtr	1	-10.56	-2.21	0.21	9.02
Prodeu	0	-9.37	-2.15	0.23	9.77
Rir	7	-2.90	-1.18	0.41	30.70
Nfa	2	-12.51	-2.48	0.20	7.39
	1%	-23.80	-3.42	0.143	4.03
Critical Values[a]	5%	-17.30	-2.91	0.168	5.48
	10%	-14.20	-2.62	0.185	6.67

[a]Critical values are from Table 1 of Ng and Perron (2001)

The second step is to assess the stability of the long-run relationship between the real exchange rate and the relative productivity differences and the other variables. We use *Sub-F*, *UDmax* and sequential tests proposed in Kejriwal and Perron (2010) as well as information criteria to determine whether breaks exist in the long-run relationship. Specifically, we first test the null hypothesis of no structural change in the long-run relationship, using *SubF* and *UDmax* tests. The number of breaks is then selected by a sequential procedure and the information criteria following Kejriwal (2008). The results obtained are reported in Table 4. For all the models, overall the tests offer evidence in favor of the presence of break(s). In

[3] The authors would like to thank Mohitosh Kejriwal for making available his Gauss Codes for *SubF-UDmax* tests, sequential procedure, and for generating co-integration critical values.

particular, at least one of the *SubF*, *UDmax* tests and the sequential procedure and both the *BIC* and *LWZ* information criteria select at least one break for all the models studied. It is important to point out that most break dates selected coincide with the period of two crises in Turkey, in the mid-nineties and early 2000s. The mid-nineties and early 2000s were the periods of financial and economic crises in Turkey, in which the Turkish lira lost its value sharply, interest rates sky-rocketed, and inflation began to soar. The Turkish GDP was also reduced significantly in these crises periods. The break fractions and the corresponding break dates are reported in Tables 5 and 6, respectively. Table 6 clearly indicates that most of the break points coincide with these crises periods.

The next step is to confirm the presence of cointegration among the real exchange rate and the other variables to ensure that the rejection of stability is indeed derived from the existence of a cointegration relationship with breaks, and not from a purely spurious regression. In this context, first, both the conventional one break G-H, as well as A-K cointegration tests, and second, cointegration tests with multiple breaks based on the A-K framework, using the break dates selected by the sequential procedure and/or information criteria, are performed.

Table 5 presents the results for G-H (1996) and A-K (2007) one structural break cointegration tests in addition to the multiple structural break cointegration tests. For all the tests, the regression representation is the regime and trend shift model, and the tests with multiple breaks are based on the augmented version of the A-K framework. The results of the G-H tests show we cannot reject the null of no cointegration for Models 1, 2, 3, and 5. For Model 4, the null is rejected only by the ADF_t test, and for Models 6 and 7 both by the Z_t and ADF_t tests. The A-K one break test, on the other hand, rejects the null of cointegration at least at the 5% significance level, except for Models 1 and 3. Putting it differently, A-K tests cannot reject the null of cointegration at the 1% significance level, except for Model 5. In short, G-H and A-K test results for one break are consistent at all conventional significance levels only for Model 5, and certainly contradict each other for Models 1 and 3. The results for the other models are mixed.

Turning to the two-break A-K tests, we cannot reject the null of cointegration for Models 2 and 7 at any conventional significance level. The tests reject the null of cointegration at 5% and 1% significance levels for Models 4, 5 and for Models 1, 3, respectively. Finally, noting that we have evidence of three structural breaks only for Models

1 and 4, the A-K test, $\tilde{V}_3(\hat{\lambda})$, cannot reject the null of cointegration for Model 4, and rejects it only at the 10% level for Model 1.

As the final step, we estimate the models for which there is evidence of cointegration, and compare the coefficients for the sub periods to see how the cointegration relationship may have changed over time. Table 6 shows estimated regressions with the regime and trend shift model. Typically structural breaks are related to Turkey's crises periods, such as 1994 and 2001. The estimated slope coefficients are denoted by $\varphi_1, \varphi_2, \ldots, \varphi_9$ in Table 6. As an example, for Model 5, $z_t=\{prod_t, Nfa_t, Rir_t\}$, φ_1-φ_3, φ_4-φ_6 and φ_7-φ_9 show the estimated impact of *prod*, *Nfa* and *Rir* on *REER* for regimes 1, 2, and 3 respectively. According to Table 6, for Models 1, 2, 3, and 7, relative productivity differentials are significant and have a positive sign, and thereby are consistent with the B-S hypothesis before the structural break in 1994-1995. However, after the 1994-95 structural-break through 2000s, relative productivities, as well as the other explanatory variables, are not generally successful in explaining changes in the *REER*.

The *RIR* either has the wrong sign or is not significant in all the models included. The effect of *NFA*, on the other hand, is always positive and significant until 2001-2002. For Model 2, it is significant until 2006, and for Model 6 for the whole sample period. The effect of a 1% point increase in *NFA* appreciates the *REER* between 0.48% and 1.21%or about 0.8%, averaging over all the sub-periods. Overall, the results offer only very limited support to the B-S hypothesis. In particular, the results do not support the productivity- *REER* relationship for the post 2001 era, contrary to the emphasis placed on the B-S effect by the CBRT. The only exception to this is the positive and significant coefficient for *Prodtr* in Model 6. However, the magnitude of the *Prodtr* coefficient is small (0.17), and all the other coefficients of Model 6 are either insignificant or have the wrong sign.

Conclusions

This paper analyzed the movements of the real effective exchange rate for the Turkish economy for 1990:Q1-2011:Q2 using multiple structural breaks. According to the CBRT Inflation Report II (2006), the experienced appreciation of the Turkish lira in recent years can be attributed to relative productivity differentials. To explain movements of the real effective exchange rate, seven models related to the B-S hypothesis are constituted by adding other variables such as net foreign assets and real interest rate differentials.

According to the estimated cointegration relationships under multiple structural breaks, the findings offer very limited support for the B-S hypothesis. The existence of the B-S effect is generally limited to the pre-2001 period and in some cases even to the pre-1994 period. Given the span of our dataset and the econometric techniques employed, the results do not support the emphasis placed on the B-S hypothesis by the CBRT.

Given the many determinants of the real exchange rate, the above results with a limited number of variables and a relatively short span of data need to be interpreted with caution. In particular, the liquidity surplus in the world in the 2000s combined with the reduced risk premium for Turkey as a result of structural reforms and a relatively more stable macroeconomic environment might have contributed to the wrong signs we obtained for the real interest rate differentials. Furthermore, a change in the expectations about the future value of the real exchange rate might be the driving force for the tendency of the Turkish lira to appreciate in the 2000s. Future research needs to scrutinize these potential explanations as well as the lack of support for the B-S hypothesis for Turkey in the 2000s.

Table 4. Structural Break Tests (Regime and Trend Shift Model)

	y_t={Reer$_t$} Specification	Sub F_T T 1	2	3	4	5	$UD\max$	SEQ$_T$ (k+1|k) k 1	2	3	BIC	LWZ
MODEL 1	z_t ={Prod$_t$} *q=3 m=5, e=0.15, x_t=0, p=3*	**13.03***	8.91	7.44	6.90	**5.71**$^{\#}$	**13.03**$^{\#}$	**14.14**$^{\#}$	**14.88**$^{\#}$	9.29	**3**	**2**
MODEL 2	z_t ={Prod$_t$,Nfa$_t$} *q=4 m=5, e=0.15, x_t=0, p=6*	**14.48***	9.93	8.04	7.29	6.59	**14.48***	**14.26**$^{\#}$	7.82	13.97	**2**	**1**
MODEL 3	z_t ={Prod$_t$,Rir$_t$} *q=4 m=5, e=0.15, x_t=0, p=6*	**16.84***	**11.56***	**9.59**$^{\#}$	6.76	5.94	**16.84***	9.71	13.11	8.46	**2**	**2**
MODEL 4	z_t ={Prodtr$_t$,Prodeu$_t$} *q=4 m=5, e=0.15, x_t=0, p=6*	**17.29***	**15.14****	8.93	**12.33****	**12.35****	**17.29***	**15.93***	**20.88****	**15.62**$^{\#}$	**3**	**1**
MODEL 5	z_t ={Prod$_t$,Nfa$_t$,Rir$_t$} *q=5 m=5, e=0.15, x_t=0, p=6*	**18.12***	10.53	7.86	6.71	6.38	**18.12***	15.51	16.44	13.91	**2**	**1**
MODEL 6	z_t ={Prodtr$_t$,Prodeu$_t$,Nfa$_t$} *q=5 m=5, e=0.15, x_t=0, p=6*	**20.96****	11.10	9.11	8.22	**12.54****	**20.96****	13.15	9.07	14.78	**1**	**1**
MODEL 7	z_t ={Prodtr$_t$,Prodeu$_t$,Rir$_t$} *q=5 m=5, e=0.15, x_t=0, p=6*	**24.24****	**17.08****	**10.92**$^{\#}$	**21.07****	**9.96***	**24.24****	16.33	**22.64***	14.28	**2**	**1**

Critical values are from Tables 1 and 3 of Kejriwal and Perron (2010), **, *, $^{\#}$, denote significance levels at 1%, 5% and 10%, respectively.
q: Number of I (1) regressors; **m**: Number of maximum breaks allowed; **e**: Trimming percentage; **x**: Number of I (0) variables. **p:** Number of leads and lags.

$$y_t = c_i + \delta_i t + z_t^{'} \beta_i + \sum_{j=-l_T}^{l_T} \Delta z_{t-j}^{'} \Pi_j + u_t^{*}$$

Table: 5. Gregory-Hansen and Arai-Kurozumi Cointegration Tests (Regime and Trend Shift Model)

$y_t=\{Reer_t\}$		G-H One Break[b]			A-K One Break[a]		A-K Two Breaks[a]			A-K Three Breaks[a]			
		Z_t^*	Z_α^*	ADF_t^*	$\tilde{V}_1(\hat{\lambda})$	$\hat{\lambda}_1$	$\tilde{V}_2(\hat{\lambda})$	$\hat{\lambda}_1$	$\hat{\lambda}_2$	$\tilde{V}_3(\hat{\lambda})$	$\hat{\lambda}_1$	$\hat{\lambda}_2$	$\hat{\lambda}_3$
$z_t=\{Prod_t\}$	Model 1	-3.83	-26.48	-4.22	**0.060**	0.18	0.069**	0.18	0.52	**0.023#**	0.18	0.52	0.76
	** %1	-6.02	-69.37	-6.02	0.118		0.052			0.031			
	* %5	-5.50	-58.58	-5.50	0.085		0.037			0.024			
	# %10	-5.24	-53.31	-5.24	0.069		0.032			0.021			
$z_t=\{Prod_t, Nfa_t\}$	Model 2	-4.31	-31.97	-4.42	**0.093***	0.18	**0.029**	0.18	0.76	-	-	-	-
	** %1	-6.45	-70.65	-6.45	0.100		0.055						
	* %5	-5.96	-68.43	-5.96	0.068		0.037						
	# %10	-5.72	-63.10	-5.72	0.057		0.031						
$z_t=\{Prod_t, Rir_t\}$	Model 3	-4.38	-32.68	-4.46	**0.040**	0.25	0.046**	0.18	0.52	-	-	-	-
	** %1	-6.45	-70.65	-6.45	0.088		0.044						
	* %5	-5.96	-68.43	-5.96	0.061		0.032						
	# %10	-5.72	-63.10	-5.72	0.049		0.027						
$z_t=\{Prodtr_t, Prodeu_t\}$	Model 4	-5.71	-49.19	**-6.21***	**0.080***	0.18	**0.039***	0.18	0.52	**0.018#**	0.19	0.52	0.70
	** %1	-6.45	-70.65	-6.45	0.100		0.044			0.027			
	* %5	-5.96	-68.43	-5.96	0.068		0.032			0.020			
	# %10	-5.72	-63.10	-5.72	0.057		0.027			0.018			
$z_t=\{Prod_t, Nfa_t, Rir_t\}$	Model 5	-4.45	-33.82	-4.44	0.115**	0.18	**0.035***	0.18	0.55	-	-	-	-
	** %1	-6.89	-90.84	-6.89	0.083		0.035						
	* %5	-6.32	-78.87	-6.32	0.055		0.026						
	# %10	-6.16	-72.75	-6.16	0.045		0.022						
$z_t=\{Prodtr_t, Prodeu_t, Nfa_t\}$	Model 6	**-6.47***	-60.03	**-7.23****	**0.057***	0.24	-	-	-	-	-	-	-
	** %1	-6.89	-90.84	-6.89	0.074								
	* %5	-6.32	-78.87	-6.32	0.052								
	# %10	-6.16	-72.75	-6.16	0.042								
$z_t=\{Prodtr_t, Prodeu_t, Rir_t\}$	Model 7	**-6.45***	-57.63	**-6.37***	**0.055***	0.21	**0.026#**	0.18	0.52	-	-	-	-
	** %1	-6.89	-90.84	-6.89	0.076		0.035						
	* %5	-6.32	-78.87	-6.32	0.051		0.027						
	# %10	-6.16	-72.75	-6.16	0.041		0.023						

[a] Critical values are obtained by simulations using 100 steps and 2500 replications. **, *, #, denote significance levels at 1%, 5% and 10%, respectively.
[b] Critical values are taken from Gregory-Hansen (1996)

$$y_t = c_i + \delta_i t + z_t' \beta_i + \sum_{j=-l_T}^{l_T} \Delta z_{t-j}' \Pi_j + u_t^*$$

Table 6. Estimated Regressions with Multiple Structural Breaks (Regime and Trend Shift Model)

$y_t=\{Reer_t\}$	c_1	c_2	c_3	c_4	δ_1	δ_2	δ_3	δ_4	φ_1	φ_2	φ_3	φ_4	φ_5	φ_6	φ_7	φ_8	φ_9	$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$
$z_t=\{Prod_t\}$																				
BIC	**5.26**	**4.25**	**3.73**	**4.38**	**-0.02**	**0.01**	**0.01**	**0.01**	**0.97**	0.23	-0.55	-0.14	-	-	-	-	-	94:Q2	01:Q2	06:Q2
SEQ	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**	**(0.06)**	**(0.00)**	(0.18)	(0.21)	(0.22)								
	4.77	**4.23**	-	-	-0.00	**0.01**	-	-	0.18	0.06	-	-	-	-	-	-	-	94:Q2	-	-
	(0.00)	**(0.00)**			(0.98)	**(0.00)**			(0.59)	(0.42)										
$z_t=\{Prod_t, Nfa_t\}$																				
BIC	**4.90**	**4.28**	**4.40**	-	-0.00	**0.01**	**0.01**	-	**0.42**	**0.24**	-0.09	**1.15**	**0.77**	-0.17	-	-	-	94:Q2	06:Q2	-
SEQ	**(0.00)**	**(0.00)**	**(0.00)**		(0.55)	**(0.00)**	**(0.02)**		**(0.10)**	**(0.02)**	(0.32)	**(0.01)**	**(0.00)**	(0.66)						
$z_t=\{Prod_t, Rir_t\}$																				
	5.51	**4.39**	-	-	**-0.02**	**0.01**	-	-	**1.40**	-0.00	-0.12	**-0.45**	-	-	-	-	-	95:Q4	-	-
	(0.00)	**(0.00)**			**(0.00)**	**(0.00)**			**(0.00)**	(0.99)	(0.64)	**(0.00)**								
$z_t=\{Prodtr_t, Prodeu_t\}$																				
SEQ	**6.38**	**3.92**	**6.44**	**4.36**	0.01	**0.01**	**0.02**	**0.01**	0.62	0.10	**-0.88**	-0.16	**-2.12**	0.05	-1.94	0.22	-	94:Q2	01:Q2	05:Q1
BIC	**(0.00)**	**(0.00)**	**(0.00)**	**(0.00)**	(0.49)	**(0.03)**	**(0.00)**	**(0.00)**	(0.14)	(0.56)	**(0.05)**	(0.29)	**(0.04)**	(0.94)	(0.16)	(0.47)				
LWZ	**6.27**	**3.63**	-	-	0.01	**0.01**	-	-	0.20	0.11	-1.77	**0.50**	-	-	-	-	-	95:Q4	-	-
	(0.00)	**(0.00)**			(0.44)	**(0.00)**			(0.70)	(0.22)	(0.19)	**(0.07)**								
$z_t=\{Prod_t, Nfa_t, Rir_t\}$																				
BIC	**4.79**	**4.18**	**4.44**	-	-0.00	**0.01**	**0.01**	-	0.30	0.07	-0.08	**1.21**	**0.76**	0.19	-0.37	0.10	**-0.65**	94:Q2	02:Q1	-
	(0.00)	**(0.00)**	**(0.00)**		(0.57)	**(0.00)**	**(0.03)**		(0.17)	(0.60)	(0.34)	**(0.00)**	**(0.00)**	(0.34)	(0.16)	(0.18)	**(0.00)**			
$z_t=\{Prodtr_t, Prodeu_t, Nfa_t\}$																				
BIC	**4.93**	**3.55**	-	-	-0.00	**0.00**	-	-	0.40	**0.17**	-0.50	**0.56**	**1.11**	**0.48**	-	-	-	94:Q2	-	-
LWZ	**(0.00)**	**(0.00)**			(0.87)	**(0.10)**			(0.36)	**(0.02)**	(0.71)	**(0.01)**	**(0.04)**	**(0.00)**						
$z_t=\{Prodtr_t, Prodeu_t, Rir_t\}$																				
LWZ	**8.44**	**4.02**	-	-	0.01	**0.01**	-	-	**1.53**	-0.01	**-4.78**	0.35	**-0.51**	**-0.34**	-	-	-	94:Q2	-	-
	(0.00)	**(0.00)**			(0.33)	**(0.00)**			**(0.00)**	(0.85)	**(0.00)**	(0.12)	**(0.05)**	**(0.00)**						
BIC	**6.56**	**4.12**	**3.77**	-	0.01	**0.02**	**0.01**	-	**0.74**	0.02	0.02	**-2.41**	-0.13	**0.47**	-0.37	-0.05	**-0.45**	94:Q2	01:Q2	-
	(0.00)	**(0.00)**	**(0.00)**		(0.22)	**(0.05)**	**(0.00)**		**(0.06)**	(0.92)	(0.88)	**(0.03)**	(0.88)	**(0.03)**	(0.20)	(0.64)	**(0.00)**			

p-values are in parenthesis. $$y_t = c_i + \delta_i t + z_t' \beta_i + \sum_{j=-l_T}^{l_T} \Delta z_{t-j}' \Pi_j + u_t^*$$

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Appendix

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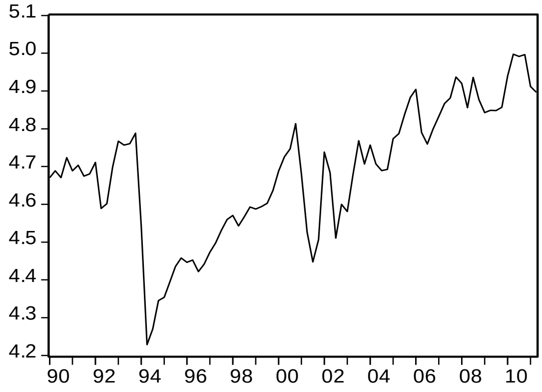

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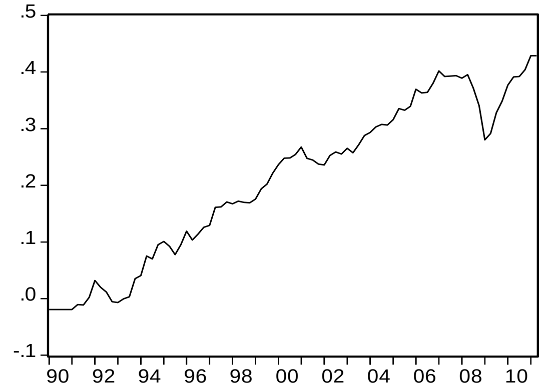

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