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Abstract

This paper examines the major sources of economic growth in Iran using annual time series data (1960 to 2003). The time series properties of the data are analysed by Perron's innovational outlier and additive outlier models. The empirical results based these models show that there is not enough evidence against the null hypothesis of unit root for all of the variables under investigation. Moreover, we found that the most significant structural breaks over the last four decades which have been detected endogenously in fact correspond to the regime change (*e.g* the 1979 Islamic revolution) and the Iraqi war in the 1980s. Finally, an ARDL methodology is employed to obtain the short and long-term determinants of economic growth. The results show that while the effects of gross capital formation and oil exports are highly significant, as expected, non-oil exports and human capital have an even smaller effect than had been anticipated.

JEL classification numbers: C12, C22, C52.

Key words: structural break, unit root tests, ARDL method, Iranian economy.

I. Introduction

Competing viewpoints are held on the possible relationships between trade and economic growth. The lack of consensus on this issue pertains to the fact that expanded trade opportunities can accelerate economic growth through exports but at the same time it may impede the growth of infant industries and impact adversely on the balance of payments. The literature reflects these two divergent perspectives in both conventional 'welfare gain' models and the newer 'endogenous growth' models. The most important distinction is the alternative focus on the effect of trade on economic growth in general and the export sector of the economy and its externality effects in particular. The second approach forms the basis of the present study.

By the late 1980s, 'dynamic endogenous growth' theories had emerged (e.g. Lucas, 1988; Grossman and Helpman, 1990, 1991) and the relationship between trade and growth became a focal point. These theories contend that the importing country gains knowledge, especially through technology embedded in the products traded, which is then adopted by local manufacturers to increase their competitiveness in domestic and global markets. This positive externality continues to emerge as long as there is a local R&D sector capable of exploiting this opportunity. This is an important insight. According to Long and Wong (1997: 45), Lucas (1988) makes use of "learning by doing" as a channel through which human capital and knowledge of an individual or an economy accumulates. Under previous static models, countries tend to specialize in producing specific goods and services according to their comparative advantages; the Lucas dynamic model highlights the increasing role of human capital in the process of economic growth. In a similar vein to Lucas, Van and Wan (cited in Long and Wong, 1997:8) applied the concept of "learning by doing" to the issue of technological transfer through international trade, arguing that technological progress and foreign trade work together to promote economic growth.

Grossman and Helpman (1990) present a dynamic two-country model of trade and growth with endogenous technological progress. They stress the importance of the accumulation of knowledge because it fosters innovative designs for new intermediate products and makes further research less expensive. The authors (1991) go on to suggest that international trade can lead to knowledge transfer in a number of ways: (a) the foreign knowledge embedded in the imported capital and intermediate inputs increases the productivity of domestic resources; (b) the resultant improved communication can lead to the learning new production techniques and product design; and finally,(c) a country's productivity is improved through being exposed to new technologies.

Although earlier 'welfare gain of trade' models discuss the benefits or harmful effects of trade on economic growth, 'endogenous growth' models question the accuracy of the various competing models as the specification. For example, McCombie and Thirlwall (1999) were critical of Grossman and Helpman (1990; 1991) who neglected balance of payments constraints, while Pack (1994) showed that exports must also be incorporated in the model because trade plays an important role in explaining international productivity differences. It is this issue which leads to the theoretical considerations underlying the current analysis. Along with recent empirical findings on trade-GDP nexus, it shows that economic growth is determined by endogenous factors such as physical capital (R&D effects), human capital (representing knowledge spillover effects), export expansion (proxying positive externality effects), and capital and intermediate imports (capturing learning-by-doing effects).

The structure of the paper is as follows: Section II explains the model specification; Section III applies unit root tests based on the Perron (1997) IO and AO models; The results of the ECM version of the ARDL model are presented in Section IV. Finally Section V presents some concluding remarks.

II. Model Specification in the Present Study

It is argued that export expansion might generate positive externality through more efficient allocation of resources, efficient management and improved production techniques, specialization, competition and the economy of scale (Balassa, 1985; Ghatak *et al.* 1997). Hence various development theories have emerged in the literature suggesting that export expansion further accelerates economic growth due to the above-mentioned factors. This is referred to as the export-led growth (ELG) hypothesis.

Drawing upon the existing literature on the trade-growth nexus and following Feder (1983), Ram (1987), Lucas (1988), Salehi-Esfahani (1991), Sengupta (1993), Ghatak *et al.* (1997) and Van Den Berg (1997), we consider the following extended Feder type models in order to identify a long-run relationship between trade and economic growth in an oil-based economy. These models are basically a production function augmented by trade and human capital.

In the specification of the model for Iran, it is assumed that the economy consists of two sectors: production for domestic use Y_D and production for export Y_X, that is:

$$Y = Y_D + Y_X \tag{1}$$

These two sub-sectors have different production functions:

$$Y_D = F[K_D, L_D, M_D, Y_X] \tag{2}$$

$$Y_x = G[K_x, L_x, M_x] \tag{3}$$

As in the Feder model, output in both sectors is produced with the labour (*L*) and capital (*K*) factors allocated to each sector. In addition, adopting an endogenous growth model we include intermediate imports (*M*) as a new factor in equations (2) and (3). As mentioned, imports have been neglected in most studies of the relationship between exports and economic growth. However, endogenous growth models also address the role of imports in the model. Endogenous growth theories emphasize the fact that imports work as a conduit of knowledge spillover from advanced economies. In turn, this knowledge spillover enables the economy to achieve increasing returns (Sengupta, 1993).

Following Feder and others (above mentioned), we also assume that the export sector of the economy generates an externality effect on the production sector for domestic use. According to Feder (1983), Salehi-Esfahani (1991), and Ghatak et al. (1997), the level of products for domestic use depends also on the volume of the exports, due to the positive external effects stemming from the export sector such as: competitive environment; improved production technique; better quality management and workers; and continuous flow of the imported inputs.

The externality effect of the export sector on production for domestic use is approximated by including exports as a factor in equation (2). This equation shows that output for domestic use Y_D is a function of capital K_D, labour forces L_D, intermediate imports M_D (imported inputs allocated into the production of Y_D) and total exports Y_X. Equation (3) also indicates that the export sector Y_X is a function of capital K_X, labour force L_X and intermediate imports M_X, which are necessary for the production in the export sector. A total differentiating of equations (1) to (3) yields:

$$\dot{Y} = \dot{Y}_D + \dot{Y}_X \tag{4}$$

$$\dot{Y}_D = F_K.\dot{K}_D + F_L.\dot{L}_D + F_M \dot{M}_D + F_X.\dot{Y}_X \tag{5}$$

$$\dot{Y}_X = G_K.\dot{K}_X + G_L.\dot{L}_X + G_M.\dot{M}_X \tag{6}$$

where the dot above each variable indicates the corresponding rate of change in that variable. The *Fx* term in equation (5) represents the marginal externality effect of the export sector on Y_D. By substituting (5) and (6) into (4) we obtain:

$$\dot{Y} = F_K.\dot{K}_D + F_L.\dot{L}_D + F_M.\dot{M}_D + F_X.\dot{Y}_X + G_K.\dot{K}_X + G_L.\dot{L}_X + G_M.\dot{M}_X \tag{7}$$

It is also important to note that Feder assumes that the ratio of the marginal factor productivities presented below in equation (8) in the export and non-export sectors differs by the amount δ. This means that the factor productivity in the export sector is higher (by δ fraction) due to the competitive environment, better quality management and more qualified workers in the export sector:

$$\frac{G_K}{F_K} = \frac{G_L}{F_L} = \frac{G_M}{F_M} = 1 + \delta \tag{8}$$

In equation (8) G_L and F_L are the marginal productivities of labour in the two sectors. F_k and G_K are the corresponding marginal productivities of capital in these two sectors. Using equation (8) in equation (7) yields:

$$\dot{Y} = F_K.\dot{K}_D + F_L.\dot{L}_D + F_M.\dot{M}_D + F_X.\dot{Y}_X + (1+\delta)F_K.\dot{K}_X + (1+\delta)F_L.\dot{L}_X + (1+\delta)F_M.\dot{M}_X \tag{9}$$

After rearranging we have:

$$\dot{Y} = F_K[\dot{K}_D + \dot{K}_X] + F_L[\dot{L}_D + \dot{L}_X] + F_M[\dot{M}_D + \dot{M}_X] + F_X.\dot{Y}_X + \delta[F_K.\dot{K}_X + F_L.\dot{L}_X + F_M.\dot{M}_X] \tag{10}$$

One can express equation (8) in terms of *Gs* and substituting them into $[F_K.\dot{K}_X + F_L.\dot{L}_X + F_M.\dot{M}_X]$ The result will be:

$$F_K.\dot{K}_X + F_L.\dot{L}_X + F_M.\dot{M}_X = \frac{G_K}{1+\delta}\dot{K}_X + \frac{G_L}{1+\delta}\dot{L}_X + \frac{G_M}{1+\delta}\dot{M}_X \tag{11}$$

Given $\dot{Y}_X = G_K.\dot{K}_X + G_L.\dot{L}_X + G_M.\dot{M}_X$ [from equation 6], one can write the following equation:

$$F_K.\dot{K}_X + F_L.\dot{L}_X + F_M.\dot{M}_X = \frac{1}{1+\delta}\dot{Y}_X \tag{12}$$

Let us now assume that $\dot{K}_D + \dot{K}_X = \dot{K}$, $\dot{L}_D + \dot{L}_X = \dot{L}$, $\dot{M}_D + \dot{M}_X = \dot{M}$. Then after substituting equation (12) into equation (10) one can obtain:

$$\dot{Y} = F_K.\dot{K} + F_L.\dot{L} + F_M.\dot{M} + [F_X + \frac{\delta}{1+\delta}]\dot{Y}_X \tag{13}$$

In the above equation (13), let the marginal productivity of capital F_K be α; the growth rate of the labour force F_L be β; the growth rate of intermediate imports F_M be γ and the last term of the above equation $[F_X + \frac{\delta}{1+\delta}]$ be θ (representing the productivity differential and the externality effect of the export sector), then we obtain the following:

$$\dot{Y} = \alpha.\dot{K} + \beta\dot{L} + \gamma\dot{M} + \theta\dot{Y}_X \tag{14}$$

This is similar to the neoclassical formulation of the source of economic growth. Equation (14) has often been used to analyse the relationship between the growth of GDP, physical capital, labour, intermediate imports and exports. This same equation is also used in this study but we include oil and non-oil exports instead of the total exports and human capital instead of labour forces as new regressors.

As mentioned above, in Feder model, GDP is considered to be simply a function of ordinary labour force together with the other relevant factors. Due to the low productivity of the labour force and its surplus in the Iranian economy, however, we follow the endogenous growth theory and instead consider, human capital (the number of employed workforce with a university degree) rather than the total labour force in our empirical models. Therefore, we use the following modified Feder model in logarithm form to examine the trade-growth nexus:

$$Ln(y_t) = \beta_0 + \beta_1 Ln(k_t) + \beta_2 Ln(hc_t) + \beta_3 Ln(xo_t) + \beta_4 L(xno_t) + \beta_5 Ln(m_t) + e_t \quad (15)$$

As it can be seen in equation (15) the possible effects of exports on economic growth have been disaggregated into oil (xo) and non-oil. The data are expressed in 1997 constant prices and have been collected from the Central Bank of Iran, and the International Financial Statistics (IFS). In the above equation (15), y denotes real GDP, *k* is gross capital formation, *m* is total real imports and *hc* is human capital, (as represented in this research by the number of employed persons with a tertiary education). In this equation, oil and non-oil exports are shown by *xo* and *xno*, respectively.

In the next sections we will apply unit roots test with the existence of structural breaks based on the Perron (1997) procedure. Then after determining endogenously the times of breaks, we will examine the existence of the long run relationship between GDP and its determinants as formulated in equation (15).

III. Unit Roots Tests with Structural Break

Structural break occurs in many time series for any number of reasons, including economic crises, changes in institutional arrangements, policy changes and regime shifts. An associated problem is testing of the null hypothesis of structural stability against the alternative of a one-time structural break. If such structural changes are present in the data generating process, but not allowed for in the specification of an econometric model, results may be biased towards the erroneous non-rejection of the non-stationarity hypothesis (Perron 1989; Perron 1997; Leybourne and Newbold; 2003). In the following section, the methodologies for testing the unit root hypothesis in the presence of structural break are explained and then these methods are applied for the variables of under investigation in the present study.

Innovational Outlier Models

According to Perron (1997), the innovational outlier (IO) model allow for the gradual changes in the intercept (IO1) and gradual changes in both the intercept and the slope of the trend function (IO2) such that:

$$\text{IO1:}\ x_t = \mu + \theta DU_t + \beta t + \delta D(T_b)_t + \alpha x_{t-1} + \sum_{i=1}^{K} c_i \Delta x_{t-i} + e_t \tag{16}$$

$$\text{IO2:}\ x_t = \mu + \theta DU_t + \beta t + \gamma DT_t + \delta D(T_b)_t + \alpha x_{t-1} + \sum_{i=1}^{K} c_i \Delta x_{t-i} + e_t \tag{17}$$

where T_b denotes the time of break ($1<T_b<T$) which is unknown, DU_t =1 if t > T_b and zero otherwise, DT_t = T_t if t > T_b and zero elsewhere, $D(T_b)_t$ =1 if t=Tb+1 and zero otherwise, x_t is any general ARMA process and e_t is the white noise residual term. The null hypothesis of a unit root is rejected if the absolute value of the t-statistic for testing α=1 is greater than the corresponding critical value. Perron (1997) suggests that T_b (the time of structural break) can be determined by two methods. In the first approach, equations (16) or (17) are sequentially estimated assuming different T_b with T_b chosen to minimize the t-ratio for α =1. In the second approach, T_b is chosen from among all other possible break point values to minimize the t-ratio on the estimated slope coefficient (γ).

The truncation lag parameter or k is determined using the data-dependent method proposed by Perron (1997). In this method the choice of k depends upon whether the t-ratio on the coefficient associated with the last lag in the estimated autoregression is significant. The optimum k (or k^*) is selected such that the coefficient on the last lag in an autoregression of order k* is significant and that the last coefficient in an autoregression of order greater than k* is insignificant, up to a maximum order k (Perron, 1997).

Additive Outlier Model

In contrast to the gradual change in the IO model, the AO model allows the structural changes to take place instantaneously. Testing for a unit root in the AO framework is then given by a two-step procedure (Perron, 1994). To start with, the trend is removed from the series:

$$y_t = \mu + \beta t + \gamma DT_t * + \tilde{y}_t \tag{18}$$

where $\tilde{y}_t$ is the detrended series. Since equation (18) assumes that a structural break only impacts on the slope coefficient, the following is then estimated to test for a change in the slope coefficient:

$$\tilde{y}_t = \alpha \tilde{y}_{t-1} + \sum_{i=1}^{K} c_i \Delta y_{t-i} + e_t \tag{19}$$

Similarly to the IO methodology, these equations are estimated sequentially for all possible values of T_b (T_b = k + 2,..,T-1) where T is the total number of observations so as to minimise the t-statistic for α =1. Similar to the above-mentioned IO model, the lag length here is also data-determined using the general to specific, and the break date is unknown and determined endogenously by the data. The null hypothesis is rejected if the t-statistic for α is larger in absolute value than the corresponding critical value. An alternative method, which is more widely used is to select T_b as the value, over all possible break dates, that minimizes (or maximizes) the value of the t-statistic on γ=0 (Harris and Sollis 2003). This approach has been used in this study.

In order to decide which particular model is most relevant, the following model selection procedure is adopted. First, the least restrictive model (IO2) is estimated and if $t_{\hat{\gamma}}$ is significant at the 5 percent level or better, then the results are reported. If $t_{\hat{\gamma}}$ is not statistically significant, then the results of an IO1 model are presented. Moreover, in order to determine the sudden effect of an unknown structural break, the AO model is also estimated and the results presented in Table 2.

Given the results of the IO and AO models, the unit root null hypothesis is rejected in favor of the alternative hypothesis if the t-statistic for α is significant and greater than the critical values tabulated by Perron (1997). Based on the results reported in Tables 1 and 2, the primary findings of the analysis are as follows. First, the results of both the IO and AO models indicate that all series under investigation are non-stationary. We also applied conventional unit root tests (i.e. ADF and Philips and Perron) and found that all of the variables of under investigation are non-stationary in log level. These results are not reported here but they are available from the authors upon request.

Second, the timing of any structural break (T_b) for each series using both the IO and AO approaches are shown in Tables 1 and 2, respectively. The computed break dates correspond closely with the expected dates associated with the effects of the 1979 revolution and the gradual effect of the Iran-Iraq war beginning in 1980.

[Tables 1 and 2 about here]

IV. The ARDL Cointegration Approach

The autoregressive distributed lag (ARDL) approach is a more statistically significant approach for determining cointegrating relationships in small samples, while the Johansen cointegration techniques require larger samples for the results to be valid (Ghatak and Siddiki, 2001). A further advantage of the ARDL is that while other cointegration techniques require all of the regressors to be integrated of the same order; the ARDL can be applied irrespective of their order of integration. It thus avoids the pre-testing problems associated with standard cointegration tests (Pesaran *et al.*, 2001). The error correction representation of the ARDL model is as follows:

$$\Delta \ln y = \alpha_0 + \sum_{j=1}^{n} b_j \Delta \ln y_{t-j} + \sum_{j=0}^{n} c_j \Delta \ln k_{t-j} + \sum_{j=0}^{n} d_j \Delta \ln lhc_{t-j} + \sum_{j=0}^{n} e_j \Delta \ln xo_{t-j} + \sum_{j=0}^{n} f_j \Delta \ln xno_{t-j}$$
$$+ \sum_{j=0}^{n} g_j \Delta \ln m_{t-j} + \delta_1 \ln y_{t-1} + \delta_2 \ln k_{t-1} + \delta_3 \ln lhc_{t-1} + \delta_4 \ln xo_{t-1} + \delta_5 \ln xno_{t-1} + \delta_6 \ln m_{t-1} + \varepsilon_{1t} \quad (23)$$

The parameter δ_i, where i=1,2,3,4,5,6 is the corresponding long-run multipliers, while the parameters $b_j, c_j, d_j, e_j, f_j, g_j$, are the short-run dynamic coefficients of the underlying ARDL model. The null hypothesis (*i.e.* H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$, implying no cointegration) in the first step is tested by computing a general F-statistic using all the variables appearing in log levels. To begin with, one has to estimate equation (23) excluding the ECM. This term is subsequently incorporated into the ARDL model.

At this stage, the calculated F-statistic is compared with the critical value tabulated by Pesaran *et al.* (2001). The null hypothesis of no cointegration will be rejected if the calculated F-statistic is greater than the upper bound. If the computed F-statistic falls below the lower bound, then the null hypothesis of no cointegration cannot be rejected. Finally, the result is inconclusive if it is between the lower and the upper bound. In such an inconclusives case an efficient way of establishing cointegration is by applying the ECM version of the ARDL model (Bahmani-Oskooee and Nasir, 2004).

Since we use forty-four annual observations, we choose 2 as the maximum lag length in the ARDL model and the calculated F-statistic is equal to 2.96. Given that this falls between the lower bound and the upper bound critical value reported in Pesaran *et al.* (2001) at the 5 percent level, we use the ECM term to determine the long-run relationship among the variables of interest. We have also calculated the F-statistic when each of *Lk, Lhc, Lxo, Lxno,* or *Lm*, appear as a dependent variable separately in the testing procedure. In all of these cases, the F test statistics are less than the corresponding critical values tabulated in Pesaran *et al.* (2001). Therefore, the null hypothesis of no cointegration cannot be rejected and the possibility of a long-term relationship exists if and only if *Ly* appears as a dependent variable followed by its 'forcing variables' (i.e. *Lxo, Lxno, Lm, Lk*, and *Lhc*).

Next we estimate the long-run coefficients of the ARDL model. One of the more important issues in applying ARDL is choosing the order of the distributed lag function. Pesaran and Smith (1998) argue that the SBC should be used in preference to other model specification criteria because it often has more parsimonious specifications: the small data sample in the current study further reinforces this point. The optimal number of lags for each of the variables is shown as ARDL (1,2,0,2,1,1). Table 3 shows the long-run coefficients of the variables under investigation.

(Table 3 about here)

The empirical results reveal that in the long run, even a one percent increase in physical capital leads to a 0.55 percent increase in GDP. While, a one percent increase in human capital leads to a 0.02 percent rise in GDP. This indicates that human capital in Iran does not have a substantial or statistically significant effect on GDP. Similarly, a one percent increase in oil exports leads to a 0.37 percent increase in GDP. Moreover, empirical results in Table 3 show that a one percent increase in non-oil exports leads to 0.036 percent increases in GDP. It is obvious that non-oil exports have an effect on the Iranian economy which, though statistically significant, is less so than expected. It is the oil sector which still generates the bulk of total exports (petrodollars) and acts as the leading sector of the economy. After estimating the long-term coefficients, we obtain the error correction representation of the ARDL model. Table 3 reports also the short-run coefficient estimates obtained from the ECM version of the ARDL model.

The error correction term indicates the speed of the equilibrium restoring adjustment in the dynamic model. The ECM coefficient shows how quickly/slowly variables return to equilibrium and it should have a statistically significant coefficient with a negative sign. Bannerjee *et al.* (1998) holds that a highly significant error correction term is further proof of the existence of a stable long-term relationship. Table 3 shows that the expected negative sign of the ECM is highly significant. The estimated coefficient of the ECM (-1) is equal to -0.60, suggesting that deviation from the long-term GDP path is corrected by 0.60 percent over the following year. This means that the adjustment takes place relatively quickly. Figure 1 represents the forecasting errors and the plots of the actual and forecast values. The graphical evidence presented in Figure 1 indicates the estimated model tracks the historical data very well**. (Figure 1 about here)**

Diagnostic tests for serial correlation, functional form, normality, hetroscedasticity, and structural stability of the model show that there is no evidence of autocorrelation and that the model passes the test for normality. In addition, when analysing the stability of the long-run coefficients together with the short-run dynamics, the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUM) point to the in-sample stability of the model (see CUSUM and CUSUMQ in Figure 2).

V. Conclusion

This paper uses annual time series data from 1960 through 2003 to endogenously determine the most significant and important structural breaks in the major determinants of Iran' economic growth: physical and human capital and trade variables. The empirical results based on the innovational outlier (IO) and the additive outlier (AO) models show that there was not enough evidence against the null hypothesis of unit root for all of the variables under investigation. Moreover, we found that the most significant structural breaks occurring over the last four decades and which were detected endogenously, in fact coincide with the regime change (*e.g* the 1979 Islamic revolution) and the 1980s Iran/Iraq war. This provides complementary evidence to models employing exogenously imposed structural breaks in the Iranian macroeconomy. Next, we employed an ARDL approach to estimate and validate the long- and short-term determinants of economic growth in Iran.

Applying the ECM version of the ARDL model shows that the error correction coefficient, which determines the speed of adjustment, has an expected and highly significant negative sign. The results indicate that deviation from the long-term growth rate in GDP is corrected by approximately

60 percent in the following year. The estimated model passes a battery of diagnostic tests and the graphical evidence (CUSUM and CUSUMQ graphs) indicate that the model is fairly stable during the sample period. Finally, the estimated long-term coefficients show that while the effects of gross capital formation and oil exports are highly significant and impact strongly on GDP, those of the non-oil exports and human capital remain even less substantial than previously expected.

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Table 1. Innovational outlier model for determining the break date in intercept (IO1) or both intercept and slope (IO2)

Variable	Model	*Tb*	*K*	$t_{\hat{\gamma}}$ or $t_{\hat{\theta}}$	$t_{\hat{\alpha}}$	Result
Ly	IO1	1982	2	-3.52	-4.42	Unit root
Lx	IO2	1980	8	4.92	-2.29	Unit root
Lxo	IO2	1980	8	2.59	-2.55	Unit root
Lnxo	IO1	1978	7	-1.76	-4.70	Unit root
Lm	IO1	1982	1	-1.35	-3.78	Unit root
Lk	IO1	1982	4	-3.21	-4.20	Unit root

Note: (1) Critical values for the IO2 models at 1%, 5% and 10% are -5.92, -5.23 and –4.92, respectively. Critical values for IO1 model at 1%, 5% and 10% are -6.07, -5.33 and –4.94, respectively. (2) The innovational outlier model (IO2) allows for breaks in both intercept and slope, whereas the IO1 model allows for break just in intercept. (3) In both models changes are assumed to occur gradually.

Table 2. Additive outlier model (AO) for determining the time of the break

Variable	*Tb*	*K*	$\hat{\gamma}$	$t_{\hat{\gamma}}$	$t_{\hat{\alpha}}$	Result
Ly	1979	1	-0.03	-3.093	-2.5348	Unit root
Lx	1979	0	-0.23	-7.11	-2.9072	Unit root
Lxo	1986	1	0.07	5.62	-3.8450	Unit root
Lnox	1987	7	0.07	5.26	-4.22	Unit root
Lm	1980	1	-0.15	-7.22	-3.6841	Unit root
Lk	1980	1	-0.08	-4.74	-3.6143	Unit root

Note: (1) Critical values for the additive outlier (AO) model at 1%, 5% and 10% are -5.38, -4.67 and –4.36, respectively. (2) The AO model allows for a break in the slope and changes occur instantaneously. (3) *Tb* is selected as the value, which minimizes the absolute value of the t-statistic on the parameter associated with change in slope in (AO) model.

Table 3. Estimated long-run coefficients and short-run error correction model (ECM)

The long-run coefficients results
ARDL (1,2,0,2,1,1)

Regressor	Coefficient	t-Ratio[Prob]
Lk_t	0.5551	16.240[.000]
Lhc_t	0.0205	1.4227[.167]
Lxo_t	0.3725	8.9805[.000]
$Lxno_t$	0.0368	3.0845[.005]
Lm_t	-0.1348	-6.0801[.000]
Intercept	1.2093	12.652[.000]
D79	0.0978	5.0622[.000]
DU80	0.1870	10.6545[.000]

ECM-ARDL: dependent variable: ΔLY

Regressor	Coefficient	Coefficient
ΔLk_t	0.293	8.055[.000]
ΔLk_{t-1}	-0.079	-2.516[.017]
ΔLhc_t	0.012	1.397[.173]
ΔLxo_t	0.245	12.018[.000]
ΔLxo_{t-1}	-0.071	-3.827[.001]
$\Delta Lxno_t$	-0.004	-.4933[.625]
ΔLm_t	-0.018	-0.838[.409]
Intercept	0.727	5.037[.000]
D79	0.058	5.048[.000]
DU80	0.112	6.253[.000]
ECM_{t-1}	-0.601	-6.360[.000]

$\bar{R}^2 = .92822$ F (10, 30) 53.1224[.000]

Note: The SBC is used to select the optimum number of lag in the ARDL model.

Figure 1. Plots of the actual and forecasted values for the level of LY and change in LY

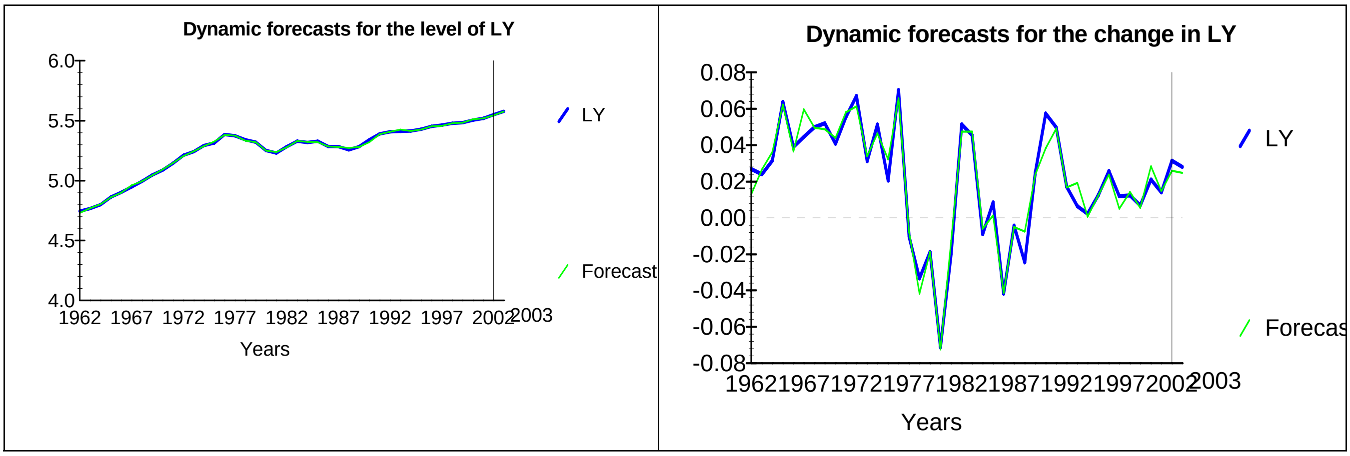

Figure 2. Plots of CUSUM and CUSUMQ statistics for coefficients Stability Tests