An Empirical Test of Endogenous Growth Model for Egypt

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Abstract

Endogenous growth models attribute long-run growth to the accumulation of capital, enhancing labor force and technological advances. The study applied the Cobb-Douglas production function offered by Romer's endogenous growth model in Egypt using data from the World Bank over the period 1990-2022. A long-term cointegration relation is confirmed between the dependent variable real GDP, which is considered as a proxy for economic growth, and the independent variables, total factor productivity as a proxy for stock of knowledge, Real Gross Capital Formation as a proxy for capital stock and years of schooling as a proxy for labor stock. Altogether, they explain 97% of variations in real GDP. The results reveal that a 1% increase in each of the stock of knowledge and technology, capital and labor leads to a 0.04, 0.44 and 0.80 increase in real GDP, respectively in Egypt over the study period.. Which coincides with the economic theory.

Keywords: endogenous growth, Cobb-Douglas production function, economic growth, knowledge and technology, capital, labor.

1. Introduction :

Theoretically, economic growth models explain the main determinants of economic growth for developing countries. However, empirically, countries can experience varying input productivity and, hence, varying per capita income growth. (Chirwa and Odhiambo, 2018)

The endogenous growth theory emerged during the 1960s, with its first version that couldn't differentiate between capital accumulation and technological progress and is known as AK theory (Howitt, 2018), mainly to criticize the exogenous growth theories by observing the apparent differences in per capita growth rates among countries with similar convergence conditions. Despite the differences between the two models, several common variables are conducive to long-term economic growth, mainly savings and investments in physical and human capital. Both require a stable and efficient macroeconomic performance with minimal policy distortions. (Chirwa and Odhiambo, 2019)

The growth models presented by Frankel (1962), Romer (1986), Lucas (1988), Rebelo (1991), and many others believed that

numerous economic endogenous variables trigger long-run economic growth. Macroeconomic policies, international trade, encouraging competition, education development, and improving the tax system will affect private costs and encourage Profit-seeking firms to undertake R&D. Thus, overall economic efficiency and innovation will be enhanced. (Howitt and Aghion, 1998)

2. Theoretical Background:

Endogenous Growth theory became clear and solid in 1986 when Paul Romer published the first paper on endogenous growth. Unlike the former exogenous models, they explained economic growth as an outcome of the economy's overall performance and not as a result of external forces (Romer, 1994). This theory was initially developed to explain the reasons behind high income per capita and the increasing returns in capital-abundant countries compared to other countries (Chandra, 2022).

Endogenous growth models are subdivided into two branches—the first views economic growth as dependent on accumulating all capital types that increase output with constant returns. Rebelo model is a good representative of this type. The second views economic growth as dependent on the spillover effects of technology and education that can increase aggregate output with increasing returns. Romer-Lucas model is an excellent example of these types of models (Abd El-Fattah, 2011).

2.1AK-technology Model:

In 1962, Marvin Frankel presented his ideas that formed the keystone of the AK endogenous model (Frankel, 1962). According to him, the accumulation of capital –with no explicit extinction between physical, human, and stock of knowledge will achieve long-run economic growth due to technological advances that will offset the diminishing marginal productivity of capital. This forms a constant or even increasing aggregate production growth rate (Howitt, 2018).

Later, in 1986, Sergio Rebelo analyzed this simple original endogenous model and assumed the existence of one capital good and one consumption good. Then, he sophisticated the model by adding more capital and consumption goods and by assuming endogenous labor supply. Besides, Rabelo added two main policy variables, taxation and inflation rates, because of their direct and indirect effects on investment and economic growth. One of his main conclusions was that production factors cannot be accumulated (Rebelo, 1987).

Researchers later extended the model and broadly defined capital to include physical and human capital and knowledge stock. Accordingly, labor is considered a non-reproducible input, unlike human capital, which involves the accumulation of knowledge. (Sena, 2015)

Endogenous growth models, accordingly, assume that the production function is linear and depends on total factor productivity (A), capital (K) and labor (L). Consequently, the saving rate is crucial for long-term growth due to its role in accumulating both human and physical capital (Abd El-Fattah, 2011).

Therefore, policies should encourage the public to substitute current consumption for future consumption and increase savings (Sena, 2015).

2.2 Romer-Lucas model:

Both Nobel laureate Paul Romer (1986) and Robert Lucas (1985, 1988) argued that output growth depends on the private sector's research and development efforts to maximize profits. This technology spillover is considered a pure public good that improves the public stock of knowledge (Romer, 1994).

Romer examined The Cobb-Douglas production function presented by the neoclassical exogenous growth model:

$$\mathbf{Y = A(t)K^{1-\beta} L^{\beta}}$$

Where Y represents net national product, K represents capital stock, L represents labor stock, β is marginal labor productivity and A is the level of technology and is determined outside the model. With the neoclassical assumptions of a constant saving

rate equal to the investment rate within a closed economy, Romer proved the failure of the exogenous theory country's conditional convergence by examining data over the period 1960-1985 of countries with similar technology level: USA, Phillipins, Singapore and Chad. He also destroyed the assumption that technological change is exogenous and that the same technological opportunities are available in all countries.

To prove the spillover effect of knowledge, Romer modified the exogenous growth model in 1987 by assuming that A is determined endogenously and that β should be assigned a lower value because labor is less productive than capital (Romer, 1994).

Besides, this model has been modified by many other researchers who support public funding for research and development in specific fields, as well as enhancing human capital through education and training to complement private research and development and boost economic growth (Abd El-Fattah, 2011).

In 1994, after releasing the assumption of perfect competition, Romer modified his original endogenous growth model (Chandra, 2022) into a model where the technology level A depends on inputs K and L. Technology is assumed to have a spillover effect and thus isn't limited to a specific firm (j) (Romer, 1994).

$$\mathbf{Yj = A(K, L)\ K_j^{1-\alpha}\ L_j^{\alpha}}$$

2.3Extensions of Endogenous Growth Models:

The endogenous Growth models were subject to several extensions, three of which are the most important. The first is concerned with the role of fiscal policy; the second addresses the role of trade openness, whereas the third examines the role of investment in physical and human capital to achieve economic growth.

- In 1990, Robert Barro addressed the role of fiscal policy in achieving economic growth. He found that increasing government expenditures positively affects economic growth, conditional to spending them on services that enhance the private sector's productivity (Easterly and Rebelo, 1993). Likely, the tax policy applied by the government should generate revenues without discouraging capital owners because capital is the driver to growth.
- The second extension was developed by Grossman and Helpman in 1990 when they examined the impact of comparative advantage in international trade and its effect on economic growth. This model assumes that technological spillovers are global and that country's specialization in production relies on its factor endowments (Abd El-Fattah, 2011). However, according to this model, economic growth relies on research and development that enhances the production of intermediate inputs (Fine, 2000).

- In 1992, Greg Mankiw, David Romer, and David Weil conducted a cross-country comparison and concluded that despite the level of technology is the same worldwide, enhancing human capital (measured by the percentage of the working-age population enrolled in secondary school) and physical capital (measured by the percentage of physical capital investment of GDP) are vital for achieving economic growth. (Romer, 1994).

3. Criticism of Endogenous Growth Theory:

Generally, endogenous growth models are inspired by neoclassical theory, whose assumptions are proven to be unrealistic for developing countries suffering from poor infrastructures, institutional inadequacies, and market imperfections. The theory also predicts that technologies and innovations are public goods available worldwide once produced, neglecting that countries strictly protect their innovations (Onyimadu, 2015).

Furthermore, endogenous growth theory assumes steady-state balanced growth. However, economic growth changes throughout all stages of industrialization among different societies, and output is subject to external shocks and political changes that can alter their levels unexpectedly. Besides, these

models neglect the social variables that can affect economic growth (Fine, 2000).

Endogenous growth models view the growth in physical and human capital as minor sources of growth in aggregate output. Rather, they attribute growth mainly to R&D-based innovation. However, this failed to fully explain the worldwide economic slowdown in the early 1970s.

The slower growth in the United States, compared to Japan, for instance, was explained by many variables not addressed by endogenous growth theory. For example, applying modern Management practices such as just-in-time inventory management and quality control systems were considered the main reasons behind Japan's total output increase. At the same time, the worldwide advancements in information and communication technologies over the 1980s couldn't prevent the slow economic growth in OECD economies (Pack, 1994).

4. Empirical Studies:

The endogenous growth models have been tested in several developed and developing countries; for instance, in Egypt, Mohamed Ali Abd El-Fattah in 2011 used the Data Envelopment Analysis Program over the period 1996 - 2008, where the percentage of R&D from GDP is the model input, and GDP growth rate and the percentage of high technology products from manufactured exports

are the outputs. The results revealed that the Egyptian economy can achieve higher outputs by (16.7%) from the same given inputs with an average estimated technical efficiency of 83.3%. This implies that R&D expenditure should be used efficiently to increase exports. This can be realized only by accumulating savings and directing them towards enhancing human capital to achieve long-run economic growth (Abd El-Fattah, 2011).

The study of Stef De Visscher, Markus Eberhardt, and Gerdie Everaert in 2020 estimated Cobb-Douglas production functions over a panel of 31 developed economies, including a group of recently-developed countries such as South Korea and Taiwan over the period 1953–2014, in order to understand the relation between TFP which is mainly affected by the state of global technology (channeled through international trade, FDI and migration) and the absorptive capacities in the sampled countries proxied by R&D investments. The study concluded that successful governments' policies to enhance their countries' absorptive capacities lead to successful economic growth. Besides, the study extended the model and used additional country-specific variables, including financial development, human capital, and competition policy/regulation, to find that financial development is the most influential variable on absorptive capacity; however, it is subject to diminishing returns (Visscher et al., 2020)

Likely, in 2023, Peter K. Kruse-Andersen examined the impact of R&D on US productivity growth through four endogenous model varieties over the period 1953–2018. The results proved that in the fully endogenous variety model, productivity grows at a constant rate relative to constant research intensity, with labor assumed to be constant. This is an empirical test for the models developed by Grossman and Helpman (1991) and Romer (1990). In the semi-endogenous variety, the long-run productivity growth is proportional to the growth of both labor and research intensity, where the latter leads to technological improvements. The semi-endogenous variety is, therefore, the most preferable for the US (Kruse-Andersen, 2023).

The main goal of this paper is to explore the validity of the economic factors addressed by the endogenous growth theory in Egypt by applying the Cobb-Douglas production function presented and modified by Romer using data obtained from the World Bank over the period 1990 -2022.

5. Endogenous Growth Model in Egypt:

The mathematical formula of the "Cobb-Douglas" function is as follows:

$$\mathbf{Y_t = A_t K_t^{\beta} L_t^{1-\beta} e^{\varepsilon t}}$$

Symbol	Variable	Proxy	Code
Y_t	Economic Growth	Real GDP at constant prices for 2015 in US dollars	lnRGDP
A_t	The stock of knowledge and technology.	TFP	lnTEC
K_t	Capital Stock	Real Gross Capital Formation	lnPCS
B	Elasticity of output with respect to capital	Capital income share of GDP - Share of GDP not earned by labor.	Lnlabs
L_t	Labor Stock	Years of schooling	LnYsch
$1-\beta$	Elasticity of output with respect to labor	(1- capital income share of GDP)	Lnnel
$\mathcal{E}_t$	Zero mean error term		

By converting it to linear form, taking the natural logarithm of both sides and then adding the random error, the function can be presented as follows:

$$\ln (Y_t) = \ln (A) + \beta \ln (K_t) + (1-\beta) \ln (L_t) + \varepsilon_t$$

Rewrite the equation in a linear form:

$$\mathbf{lnRGDP_t = \beta_0 + \beta_1 lnTEC_t + \underline{\beta_2} lnPCS_t + \beta_3 lnYsch + \underline{\beta_4} lnlabs + \beta_5 lnNel + \varepsilon_t}$$

a) Stability Test:

To examine the time series stationarity of the logarithm of the model variables over the study period, a Unit Root Dickey - Fuller Test is applied. The results show that the time series data

is non-stationary at the level, whether with intercept or with trend[1]. However, when taking the first difference, the stationarity of all variables is observed; that is, they are all integrated in the same order, which allows for conducting the cointegration test.

b) Johansen Cointegration Test:

The Johansen & Juselius test (1990) for long-term cointegration between economic growth and the independent variables is applied to evaluate the following hypotheses:

- Null hypothesis (H0: r = 0) There is no cointegration
- Alternative hypothesis (H1: r > 0) There is cointegration.

The results[2] confirm a long-term cointegration between economic growth and the independent variables; that is, the development of each is related to the development of the other, where the number of cointegration vectors (R = 3) is a vector because the calculated value of the Trace Test was greater than the critical values of the Johansson test at the level of significance 1% and 5%, as well as the results of the test of the maximum characteristic values Maximum Eigenvalues Test was supported by the impact test with (R=3) vectors for cointegration, where the calculated value exceeded the critical values at a significant level of 1% and 5%. Therefore, the alternative

[1] Please refer to Table (1), page 12
[2] Please refer to Table (2), page 12

hypothesis that states that there is a long-term cointegration between the study variables is accepted.

c) Fully Modified Ordinary Least Square Methodology (FMOLS)

After verifying the existence of long-term cointegration relation between the variables of the study, a comparison is made between three modern cointegration regression methods, namely Dynamic Ordinary Least Square (DOLS), Fully Modified Ordinary Least Square (FMOLS), and Canonical Cointegration Regression (CCR), in order to reach the best standard model. The FMOLS method is adopted to give the optimal estimate of cointegration as this method is characterized by its high ability to fade the false values of the coefficients that are estimated with the ordinary least squares (OLS) method, in addition to solving the problem of autocorrelation, parameter bias, and maintaining the impact of internal variables that have a common integration relationship, and it also gives better results than other methods and the most appropriate for the study data (Phillips and Hansen, 1988).

The results[3] indicate that all coefficients of the independent variables that make up the Cobb-Douglas equation are characterized by high statistical significance at the 5% level. The logarithm of the stock of knowledge and technology (lntec) is

[3] Please refer to Table (3), page 13

found to be positively affecting the logarithm of economic growth. This result was as expected based on the economic theory and the previous studies confirming the positive and significant impact of technology on economic growth. The hypothesis that technology enhances economic growth in Egypt over the study period is supported by the finding that a 1% increase in the stock of knowledge and technology leads to a 0.04 increase in real GDP, holding the remaining independent variables constant.

Likely, the coefficients of Capital Stock (lnpcs) and Labor Stock (lnysch) are both positively related to economic growth. Increasing capital stock or labor stock by 1% leads to an increase in economic growth in Egypt by 0.44 and 0.80, respectively. The relation between labor stock and economic growth is the highest and strongest among other independent variables. This result coincides with economic theory.

The estimated coefficient of the elasticity of output with respect to capital (lnlabs) is 0.43 and positive and is statistically significant, which is consistent with economic theory, confirming the direct relationship between them. The elasticity of real GDP with respect to labor (lnnel) is also positive and has an impact on economic growth by 0.20.

The estimated equation also has high explanatory power, as the value of the coefficient of determination adjusted R^2 reached

about 97% of the change occurring in the dependent variable, while the remaining percentage (3%) is due to factors that were not included in the equation. From the previous analysis, we conclude the following regression equation:

LNRGDP = 0.88 + 0.04*LNTEC + 0.44*LNPCS + 0.80*LNYSCH + 0.43*LNLABS + 0.20*LNNEL

The Wald Test is applied to prove the significance of the explanatory variables, and the results indicate that the equation is highly significant, according to the statistics of the Fisher test (F-Statistic), which is 6.304. This confirms the existence of a significant effect of the stock of knowledge and technology, capital stock, and labor stock combined on real GDP in Egypt over the period 1990-2022. The p-value reached 0.0186, which is less than 5%.

d) **Evaluating the quality of the Cobb-Douglas equation:**

Several additional tests are applied to confirm the quality of the equation and thus guarantee the conclusion of the study regarding testing the endogenous growth model in Egypt. Firstly, the (Jarque-Bera) test[4] gives a value of 0.698, less than its corresponding tabular values, and the probability value of the test also exceeds the significance level of 0.05. This indicates that the

[4] Please refer to Figure (1), Page 14

series of residuals of the estimated equation follows a normal distribution. Secondly, the variance inflation factor (VIF) values[5] for all dependent variables are less than 10, indicating that the estimated equation does not have a multicollinearity problem. Thirdly, a comparison is made between the actual values and the fitted values to enhance the validity and efficiency of the estimated equation[6].

6. Conclusion:

Endogenous growth theories introduced the concept that long-run economic growth is powered mainly by internal factors that are specific to the economy. These factors affect the incentives to innovate and create technologies. Endogenous growth models can be categorized into two types according to their definition of capital and its return to output. Following the Romer-Lucas model, the study used Cobb-Douglas production function to examine the impact of the stock of knowledge and technology, capital and labor on economic growth in Egypt over the period 1990-2022.

Several configuration tests were applied to confirm the validity of the model and guarantee the results. The results confirm a long-term cointegration between economic growth and

[5] Please refer to Table (5), page 13

[6] Please refer to Figure (2), page 14

the independent variables. Coinciding with the economic theory, technology, capital stock and labor stock have positive and significant impacts on economic growth. These factors combined explain around 97% of the real GDP growth in Egypt. However, the effect of technology is the weakest (0.04), whereas labor stock is the highest (0.8).

The weak yet positive impact of technology can be attributed in developing countries, and Egypt is no exception to the associated need to change social behavior and to accept the digital technology that is usually resisted by the labor force. Historically, this has been proven during the great depression in USA, when the economy faced rapid innovation despite the general economic downturn.

Additionally, the elasticity of output with respect to capital and labor is found to be 0.43 and 0.20, respectively. This high elasticity to capital has been attributed in many countries to the increase in intellectual property. Concerning Egypt, this was confirmed and observed during the first half of the 2000s with the initiation of Intellectual Property Law No. 82/2002, followed by the E-Signature Law No. 15/2004, and later the establishment of the Economic Court in 2008, which is concerned with handling the intellectual property cases.

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Appendix

a) Tables

Table (1) Augmented Dickey-Fuller test statistic.

Variable	At level				1st difference				Co.
	Intercept		Trend and intercept		Intercept		Trend and intercept		
	t-statistic	Prob.*	t-statistic	Prob.*	t-statistic	Prob.*	t-statistic	Prob.*	
LNRGDP	-0.509	0.876	-2.955	0.160	-3.355	0.020	-3.309	0.083	I (1)
LNTEC	-0.651	0.844	-2.968	0.160	-5.280	0.000	-5.998	0.000	I (1)
LNPSC	-0.665	0.841	-2.914	0.171	-5.495	0.000	-5.412	0.000	I (1)
LNYSCH	-1.850	0.349	-1.743	0.703	-1.222	0.649	-3.429	0.071	I (1)
LNLABS	-1.360	0.588	-3.369	0.073	-6.707	0.000	-6.627	0.000	I (1)
LNNEL	-1.574	0.483	-3.189	0.104	-6.721	0.000	-6.718	0.000	I (1)

Source: output from E-views v13.

Table (2) Johansen - Juselius test results for long-term cointegration

Hypothesized	Eigenvalue	Trace Statistic	Critical Value	P-value
None*	0.7613	82.0434	50.2489	0.0000
At most 1*	0.5971	42.7236	31.2869	0.0020
At most 2*	0.4316	17.1221	16.2694	0.0396
At most 3	0.0341	1.0039	4.0335	0.3446

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level

Hypothesized	Eigenvalue	Max-Eigen Statistic	Critical Value	P-value
None*	0.7613	39.3198	28.9636	0.7613
At most 1*	0.5971	25.6015	22.1882	0.5971
At most 2*	0.4316	16.1181	14.9778	0.4316
At most 3	0.0341	1.0039	4.0335	0.0341

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level

Source: output from E-views v13.

Table (3) Results of estimating Cobb's long-term equation by (FMOLS)

Dependent Variable: LNRGDP
Method: Fully Modified Least Squares (FMOLS)
Date: 03/08/24 Time: 16:30
Sample (adjusted): 1991 2022
Included observations: 32 after adjustments
Cointegrating equation deterministics: C
Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNTEC	0.043201	0.017205	2.510954	0.0186
LNPCS	0.442902	0.061214	7.235316	0.0000
LNYSCH	0.801015	0.187394	4.274487	0.0002
LNLABS	0.438407	1.146975	3.869656	0.0007
LNNEL	0.205610	0.664105	3.321178	0.0027
C	0.882741	1.647940	5.390209	0.0000

R-squared	0.982333	Mean dependent var	26.16886
Adjusted R-squared	0.978936	S.D. dependent var	0.412835
S.E. of regression	0.059917	Sum squared resid	0.093340
Long-run variance	0.002524		

Source: output from E-views v13.

Table (4) Wald Test Results

Test Statistic	Value	df	Probability
t-statistic	2.510954	26	0.0186
F-statistic	6.304889	(1, 26)	0.0186
Chi-square	6.304889	1	0.0120

Source: output from E-views v13.

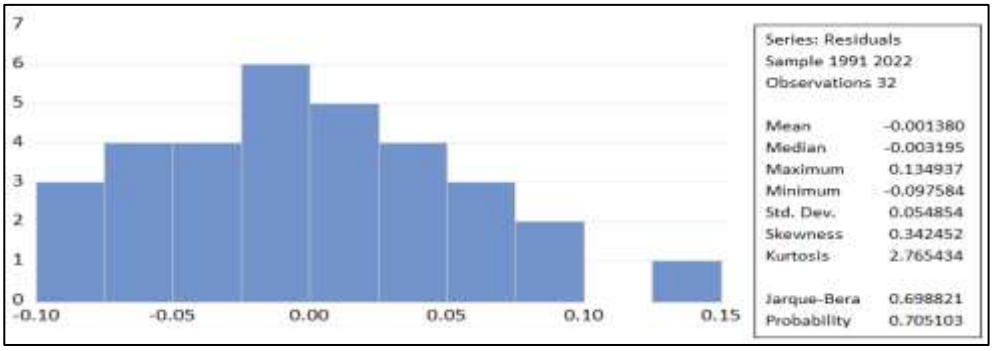
Table (5) Variance Inflation Factor (VIF) Results

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
LNTEC	0.000296	1249.861	2.500500
LNPCS	0.003747	27828.35	11.91380
LNYSCH	0.035117	1566.232	14.17697
LNLABS	1.315551	3511.835	149.2391
LNNEL	0.441035	6213.524	170.5324
C	2.715706	34424.83	NA

Source: output from E-views v13.

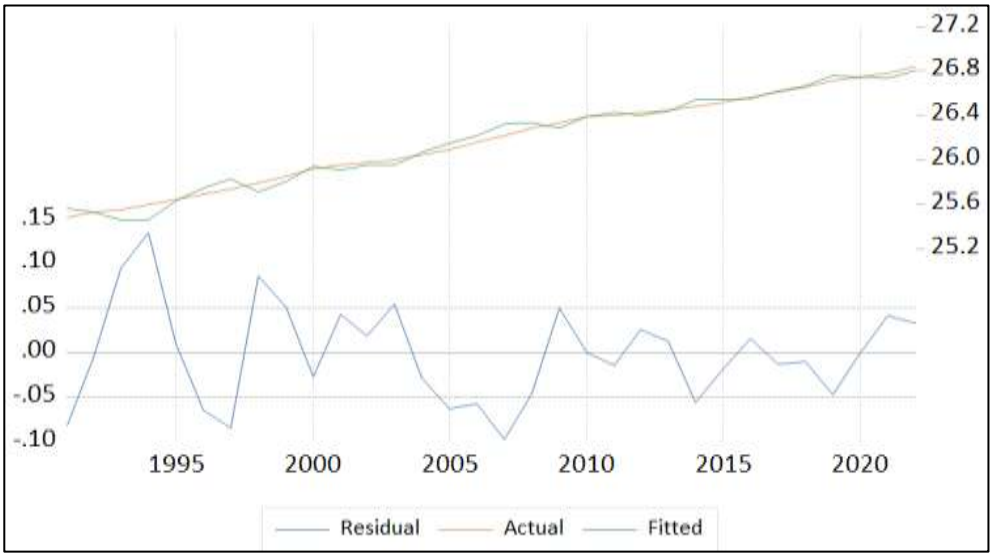
b) Figures

Figure (1) Normal distribution of the residual series



Source: output from E-views v13.

Figure (2) Residual and actual values and remainders.



Source: output from E-views v13.