Estimating the relationship between capital and labor in Algeria for the period 1990-2022

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Abstract

This paper presents a straightforward method for estimating the relationship between labor and capital by estimating the elasticity of substitution, Using a model based on the constant elasticity of substitution (CES) production function, by including the elasticity of substitution. parameter as a first-order parameter, this approach provides a robust framework for empirical analysis. The paper discusses the theoretical foundation of the CES production function and its consequences for estimating the substitution elasticity. The result is that elasticity estimate is greatly influenced by the choice of method. Aggregate elasticity in Algeria is 2.61, this result means that labor and capital can be directly substituted in the production process.

Key words: *labor, capital, CES production function, substitution elasticity.*

Jel Codes Classification : *C22, E23, D24*

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تقدير العلاقة بين رأس المال والعمل في الجزائر خلال الفترة (1990-2022)

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ملخص:

الهدف من المقال هو تقدير العلاقة بين عنصري الإنتاج العمل ورأس المال من خلال تقدير مرونة الإحلال، باستخدام نموذج مشتق من دالة الإنتاج ذات مرونة الإحلال الثابتة (CES)، حيث تم إدراج معامل مرونة الإحلال كمعامل من الدرجة الأولى إذ توفر هذه الطريقة إطارا قويا للتحليل التجريبي.

يناقش المقال الأسس النظرية لدالة الإنتاج CES وتأثيراتها على تقدير مرونة الإحلال بين العمل ورأس المال. تشير النتائج إلى أن قيمة مرونة الإحلال الكلية في الجزائر هي 2.61، مما يعني أن العمل ورأس المال يمكن أن يكونا بديلين لبعضهما في عملية الإنتاج.

الكلمات المفاتيح: دالة الإنتاج ذات مرونة الإحلال الثابتة، مرونة الإحلال، العمل، رأس المال.

تصنيفJEL: *C22، E23، D24.*

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Introduction:

The substitution elasticity between labor and capital (σ) is a fundamental aspect of the supply side of the economy, It holds significant importance across various economic domains, including labor market, the economic growth, and public finance.

Despite extensive research conducted, there is no precise agreement on its value. However, due to its importance, it is necessary to establish a consensus value, or at least a range of values, based on empirical evidence. This will provide guidance for researchers and policymakers. For example, high values of σ, meaning greater than one, can be interpreted as a driver of continuous growth because they suggest that scarce factor can be easily substituted with abundant factor.

The Constant Elasticity of Substitution (CES) production function provides a natural context for studying the parameter σ. The estimation is constrained to only two production factors due to constraints in the availability of data, where factors of production can be classified into broader categories. The interpretation of this flexibility is subject to the feasibility of aggregating different types of labor into one category. Although aggregating skilled labor and capital is more practicable than aggregating various employment categories, this means that the process of substitution between labor and capital entails a partial substitution between different segments of labor and capital. Skilled labor is closely associated with capital, implying that the substitution between capital and labor primarily includes replacing capital for less skilled labor.

The elasticity of substitution between labor and capital stands as one of the fundamental aspects in studying economic dynamics and the impact of developmental policies on the national economy in Algeria. The country is witnessing continuous efforts to enhance economic development and improve the standard of living for citizens. Therefore, measuring the flexibility of substitution between labor and capital has become critically important, it can provide valuable insights into how developmental policies affect income distribution, employment opportunities, and economic growth.

Research Problematic:

This research paper aims to answer the following research question:

What is the nature of the relationship between labor and capital in Algeria for the period 1990-2022?

Research Importance:

The Importance of estimating the elasticity of substitution between labor and capital in Algeria lies in understanding the extent to which labor can be replaced with capital in production processes. Estimating this elasticity helps economists and policymakers understand how each of the production factors - labor and capital - responds to changes in their relative prices, thus identifying the nature of the relationship between labor and capital, if the relationship between them is complementary, meaning that an increase in capital leads to an increase in employment rates by increasing the marginal productivity of labor, it would be preferable to use this policy if the goal is to have a positive impact on employment, however, if the relationship is substitutive, an increase in the use of capital will come at the expense of labor.

Previous studies:

-Study by Samuele Ialenti & Guido Pialli (2022), titled **The increase in the elasticity of substitution between capital and labour.** The objective of the research is to determine the elasticity of substitution between capital and labor within OECD economies. The study's findings suggest that this elasticity is internally determined by both the capital share and capital intensity. Over the period from 1950 to 2017, the elasticity of substitution was found to be variable across nine OECD economies. and that, in fact, During the late 1970s, the elasticity of substitution Amplified , in the presence of labor augmenting technical change.

-Study by Knoblach, Michael and Stockl, Fabian (2019), titled **What determines the elasticity of substitution between capital and labor?.** The study aims To identify the factors influencing the elasticity of substitution between capital and labor in the U.S. The study concluded that that the elasticity of substitution, which is usually estimated in empirical research. Frequently, the immutability of the deep parameter is not guaranteed, as it depends on a diverse range of technological, non-technological, and institutional determinants.

I- The theoretical framework of substitution elasticity:

The study of elasticity delineates the impact of various governmental policies on employment levels. Through its examination, it allows for the identification of appropriate economic policies and their potential utilization across diverse economic sectors, as well as assessing their effectiveness, particularly concerning wage changes and technological advancements and their effects on utilized production methods. This leads us to investigate the elasticity of substitution, which determines the nature of the relationship between labor and capital, consequently enabling the adoption of suitable decisions to increase employment volume and thereby reduce unemployment rates.

I-1- Substitution Elasticity Definition:

Production elements can be used in consecutive merging operations, where they integrate with each other or partially or completely replace each other. Substitutability flexibility allows for determining the possibility of substituting one production element for another in the production process (Cahuc & Zylberberg, 2001, p. 109). The parameter was initially introduced by Hicks in 1932 within a production function featuring two inputs.

I-2- Substitution Elasticity Measurement:

Substitutability between labor and capital measures the impact of changes in the marginal productivity coefficients of labor and capital (or the substitution rate between them) on the quantities used of each, and is given by the following formula: (Gecherta & Havranekb, 2020, p. 06)

$$\sigma = \frac{\text{The relative change in the production factor quantities coefficient. (K)}\mathit{and}\text{(L)}}{\text{"Relative change in marginal productivity coefficient for (L)and(K)}}$$

$$\sigma = \frac{\text{The relative change in the production factor quantities coefficient(K)}\mathit{and}\text{(L)}}{\text{The relative change in the marginal rate of technical substitution between (L)and(K)}}$$

$$\sigma = \frac{\frac{\Delta(\frac{K}{L})}{\frac{K}{L}}}{\frac{\Delta \mathrm{TMS_{LK}}}{\mathrm{TMS_{LK}}}} \qquad (1)$$

If the substitutability equals zero, then labor and capital are absolute complements or perfect complements to each other, and they are used in fixed proportions, this means that there is no possibility for the substitution between labor and capital, with the quantities of both remaining unaffected, regardless of changes in their prices, and there is no substitution at all. The higher the value of elasticity in substituting between labor and capital, the greater the degree of substitution between them as well. If substitutability is infinite, labor and capital form absolute or perfect substitutes (Besanko & Braeutigam, 2010, p. 229), meaning that changes in the relative prices of labor and capital lead to continued substitution indefinitely, in this case, production is carried out using only one element, which is the more abundant one, it is undeniable that these two cases are difficult to find in reality.

According to equation (1), elasticity is positive due to the congruence in the direction of change between the substitution rate and the capital-labor ratio. Capital substitution for labor

in the workplace indicates that any increase in capital (ΔK) will be positive, while the increase in labor (ΔL) will be negative, therefore, the quantity of capital (K) increases and the quantity of labor (L) decreases. Consequently, the substitution rate increases and the capital-labor ratio (K/L) also increases. In equilibrium, the marginal productivity coefficients of both elements equal their relative prices. Thus, the substitution rate equals these prices.

If elasticity is high, meaning (σ) is greater than one, then any slight change in the relative prices of labor and capital leads to a significant change in the quantities used of each. Conversely, if elasticity is low, meaning (σ) is less than one, it means that changes in the quantities used of labor and capital vary only slightly when their relative prices change (Miller, 2008, pp. 5-6)

Classical economic thought assumes the continuous possibility of substitution between labor and capital, if any change occurs in their relative prices or their marginal productivity coefficients, substitution must occur and continue until equilibrium is restored between the two parties. Substitution ceases and the quantities of the elements stabilize once equilibrium is reached. This applies to all units of production without distinction, meaning that substitution is always possible between labor and capital, whether the units are existing or new.

Afterwards, two trends emerged among the supporters of this idea among contemporary economists from the modern classical school: (Stewart & Streeten, 1971, p. 149)

I-2-1- The first trend: Advocates of this trend follow the approach of the old classical thought. If the price of labor decreases or its productivity relatively improves, it can be used as a substitute for the current and newly introduced capital. Additional labor replaces some of the machines and equipment that were used, as well as replacing new machines that could have been operated if the ratio between the prices of the two factors and their productivity had not changed. Similarly, a decrease in the relative price of capital leads to the operation of existing capital and an increase in the use of modern machinery and equipment, and the same happens when the productivity of capital increases relative to labor.

I-2-1- The second trend: This trend restricts the possibility of substitution between the two factors, primarily focusing on new units of capital, this means that a change in the ratio between the prices will lead to an increase or decrease in the use of modern machinery. In the case of a wage increase relative to the interest rate, regulators will tend to purchase more new machines to replace some of the existing labor. Conversely, if the wage decreases relatively, it is in the interest of regulators in this case to employ additional workers in exchange, for reducing the new capital that would have been used if the relative prices of the two factors had remained unchanged. Therefore, according to this trend, the desired levels of employment achieved through labor substitution for capital are lower because the demand for additional labor entirely depends on new investment.

Determining the direction of substitution between labor and capital entails some difficulties, because changes in the wage rate may affect the productivity of labor, causing it to increase. In such a scenario, the regulator faces two options:

- Increased productivity of labor encourages its substitution for capital.
- A wage increase leads to the substitution of capital for labor if the price of capital and its productivity remain unchanged.

Therefore, the substitution process occurs when the existing equilibrium between the marginal productivity factors of production and their relative prices is disrupted, this necessitates government intervention to adjust the prices of production factors through policies such as minimum wage laws, interest rate policies, or tax and customs exemptions on production inputs, this is especially crucial in developing countries characterized by high population rates, where price distortions must be corrected to prevent capital substitution for labor, this means that caution must be exercised when implementing policies that result in

changes in the relative prices of labor and capital factors, taking into account the potential substitution effects that may arise.

I-3- Econometric Specification:

The production function represents the theoretical foundation from which the study of factor substitution elasticity between labor and capital originates. The Cobb-Douglas function is considered one of the most important production functions, but it assumes equal factor substitution elasticity, which does not align with reality. Therefore, research has been conducted to explore alternative forms of production functions where, The studies conducted by Arrow, Chenery, Mihas, and Solow propose a production function with a constant elasticity of substitution (CES) for factors, which takes the following form: (Hansen, 2022, p. 791)

$$y = A(\delta_k K^{-\rho} + \delta_L L^{-\rho})^{\frac{-\mu}{\rho}} \qquad (2)$$

Where:

y : the output;
K ,L :the capital and labor inputs;
A : the coefficient of efficiency (A>0);
(δ_k , δ_L) :The technical intensity of factors;
μ : the return to scale parameter. Its value must be positive;
ρ: the substitution parameter, it is greater than -1.

The elasticity of the substitution between factors can be calculated using the expression σ=1/(1+ρ). It is also important to note that when σ equals one, the CES production function tends toward the Cobb-Douglas function, and when σ equals zero, it becomes a Leontief function with factors of fixed proportions, and transforms into a linear function as σ approaches infinity. In the intermediate scenario, production factors act as either gross complements (substitutes) if σ is less than (greater than) unity (Muck, 2017, p. 8).

Generally, the situation (σ < 1) is observed in advanced economies, where the proportion of skilled workers is higher compared to unskilled workers, making them more integrated with capital. Conversely, the situation (σ > 1) is more prevalent in developing economies, where the proportion of unskilled workers is higher, leading to capital and labor being more substitutable (Sala & Trivin, 2018, p. 7).

The elasticity of substitution is estimated using various models derived from the constant elasticity of substitution production function, this method is straightforward because the elasticity of substitution parameter is included as a first-order parameter, thus providing a much better opportunity for estimation compared to direct estimation from the CES production function where the elasticity is a second-order parameter.

Some estimations for the elasticity of substitution are based on the logarithmic regression of the capital-labor ratio against the wage-rental ratio, this method utilizes the marginal rate of substitution of labor for capital derived from the CES function, all these studies assume broadly constant returns to scale.

duct of capital and labor equals the respective rates of return on capital andThe marginal pro wages (Sampat, 1980, p. 134):

$$\frac{\delta}{A^{\rho}}\left(\frac{V}{K}\right)^{1+\rho} = \mathrm{r} \qquad (3)$$

$$\frac{1-\delta}{A^{\rho}}\left(\frac{V}{L}\right)^{1+\rho} = \mathrm{W} \qquad (4)$$

The marginal rate of substitution of labor for capital is calculated by comparing the ratio of marginal productivities of each factor.

$$MRTS = \frac{\partial K}{\partial L} = \frac{\partial V/\partial L}{\partial V/\partial K} = \frac{1-\delta}{\delta}\left(\frac{K}{L}\right)^{1+\rho} = \frac{W}{r} \qquad (5)$$

The production function may yield the following estimated relationship under the assumption that the marginal rate of technical substitution equals the wage-rental ratio:

$$log\frac{K}{L} = \frac{1}{1+\rho} log\frac{\rho}{1-\rho} + \frac{1}{1+\rho} log\frac{W}{r} \qquad (6)$$

The estimated model takes the following form:

$$log\frac{K}{L} = \frac{1}{1+\rho} log\frac{\rho}{1-\rho} + \frac{1}{1+\rho} log\frac{W}{r} + \varepsilon \qquad (7)$$

In theory, the elasticity value should always be positive, ranging from zero to infinity. However, statistically estimated values of substitution elasticity using the last equation have been found to be negative in various studies.

II- Econometric study:

We will rely on ordinary least squares (OLS) method to estimate the model parameters, due to the necessity of diagnosing the model to ensure obtaining the best unbiased linear estimators with reliable results, the study took into consideration detecting standard problems using the Durbin-Watson test to detect autocorrelation of errors and Lagrange multiplier tests to detect heteroscedasticity and non-normal distribution of the error term.

II-1- Data source:

The study utilizes annual data covering the period from 1990 to 2022 (33 observations). The primary source of this data is the National Statistics Office and the World Bank.

The variables consist of: the number of workers and the real capital stock estimated using the perpetual inventory method, achieved by adding the current year's investment flow to the initial capital stock estimate and subtracting depreciation, then dividing by the investment deflator. The real average wage, calculated by dividing real wage compensation by the number of workers, due to the absence of data on average wages. Additionally, the study employed net exploitation surplus to express the return on capital, this is calculated as the net value added minus workers' wages, divided by the capital stock.

II-2- Estimation Results:

The estimation of the model yielded the following results:

$$\text{Log}\left(\frac{K}{L}\right) = 11.204 + 0.669\ \text{Log}\left(\frac{W}{r}\right) + \varepsilon_t \qquad (8)$$

(20.341) (360.424)

R^2=0.950 $\overline{R^2}$=0.928 F=413.762 n=33

DW=0.553 ARCH(1)=6.627 JB=2.113

It is evident that despite the statistical significance of the model coefficients, error correlation analysis indicates that these results are not acceptable for reliance due to the presence of autocorrelation among errors, as confirmed by the Durbin-Watson test. To address this issue, the model was re-estimated using the Generalized Least Squares (GLS) method. The re-estimation of the model yielded the following results:

$$\text{Log}\left(\frac{K}{L}\right)=3.979+2.609\ \text{Log}\left(\frac{w}{r}\right)+\varepsilon_t \qquad (9)$$

(9.810) (30.081)

R^2=0.756 $\overline{R^2}$=0.748 F=96.232 n=33

DW= 1.244 LM(1)=1.628 ARCH(1)=0.259 JB=2.126

The model is economically acceptable because the signs of the estimated parameters align with economic theory. The elasticity of substitution is greater than one $\sigma = 2.61$, Which means that labor and capital are substitutes (An elasticity of substitution greater than one corresponds to a decrease in the share of labor income (see appendex1).

An increase in wages relative to capital prices will lead to the substitution of capital for labor, economic policies in Algeria, along with a package of legislation related to investment encouragement laws and their amendments, have biased towards capital, causing its substitution for labor in many economic activities, especially in the industrial sector, by influencing the prices of this factor, leading to an increase in its quantity compared to labor. This result can be interpreted as development during the period 1990-2022 focusing on supporting productive and investment projects in various economic sectors, by supporting their imports of raw materials and capital goods such as machinery, equipment, and spare parts, through customs and tax exemptions and providing soft loans, making the cost of capital relatively cheaper than the cost of labor. Additionally, the susceptibility of wages to rise in Algeria despite high unemployment rates in the labor market has led to the substitution of capital for labor in most economic sectors.

It is evident from the value of the determination coefficient that 75% of the variation in the capital-to-labor ratio is explained by its relative prices, with the remainder attributed to other random factors. Additionally, the parameters exhibit statistical significance, as indicated by the student's t-test, where the absolute value of the calculated t-values is greater than the critical value of 1.96 (with degrees of freedom greater than 30, approaching a normal distribution; 1.96 is the critical value for a significance level of 0.05). Moreover, the F-test confirms the presence of a relationship between the dependent and independent variables in the model, as evidenced by the calculated F-value (F= 96.232) being greater than the critical F-value ($F_{0.05}$ (1.31) =4.17). Therefore, the model as a whole is statistically significant.

The Breusch-Godfrey test was employed to detect the presence of autocorrelation in the errors, as the Durbin-Watson test statistic fell within the region of indecision (the computed value of the DW test fell between the critical values of DW at a significance level of 1% (1.17-1.29)). The BG test indicates that the hypothesis of autocorrelation in the errors is rejected in the estimated model, because its calculated value 1.628 is significantly smaller than the critical value for a chi-squared distribution with one degree of freedom and a significance level of 5% **(** $\chi^2_{0.05}(1) = 3.841$**).**

The Arch-LM test indicates that the hypothesis of constant error variance (homoscedasticity) is not rejected in the estimated model because, its calculated value 0.259 is significantly smaller than the critical value for a chi-squared distribution with one degree of freedom and a significance level of 5% **(** $\chi^2_{0.05}(1) = 3.841$**).**

The Jarque-Bera test indicates the acceptance of the hypothesis of normality, meaning that the random errors in the estimated model follow a normal distribution. This is because its calculated value, 2.126 is significantly smaller than the critical value for a chi-squared distribution with two degrees of freedom and a significance level of 5% **(** $\chi^2_{0.05}(2) = 5.991$**).**

Conclusion

This study produced estimates of elasticity of substitution for the overall Algerian economy for the period 1990-2022. Utilizing estimation methods like ordinary least squares and generalized least squares, it was discovered that the elasticity estimates were highly sensitive to the choice of method.

Estimation produced aggregate elasticity estimates in the region of 2.61, it is greater than one This means that labor and capital can be easily substituted, so when the relative price of either changes, the more costly factor (labor) is replaced by the less costly factor (capital), thereby increasing the density of the cheaper factor in production and raising its share of total income.

The conclusion is that there is a bias towards capital utilization, which aligns with the observed decrease in the share of labor income in Algerian data.

Development programs in Algeria, whether related to investment in infrastructure, promoting local industries, or improving social services, are among the factors that may influence the substitutability between labor and capital. Hence, understanding the elasticity of substitution between labor and capital in Algeria in the context of development programs requires a precise analysis of the impact of these programs on productivity and income distribution, as well as studying changes in the labor market and various economic sectors.

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Appendices:

Appendix1: The percentage of labor income and capital income of total income.

t	labor income	capital income
1990	24.71	53.94
1991	22.39	58.57
1992	22.89	58.90
1993	25.49	53.02
1994	22.82	54.83
1995	20.00	58.55
1996	17.74	59.68
1997	17.62	61.24
1998	19.39	59.47
1999	17.51	60.59
2000	13.98	64.83
2001	14.98	64.31
2002	15.35	64.18
2003	14.04	66.54
2004	13.34	66.87
2005	11.34	69.15
2006	10.72	70.50
2007	10.95	70.73
2008	10.52	70.51
2009	13.97	67.49
2010	13.21	68.88
2011	12.44	69.63
2012	12.57	70.16
2013	13.71	68.59
2014	14.04	67.22
2015	15.32	60.66
2016	16.67	64.61
2017	15.77	62.64
2018	15.39	64.40
2019	16.81	63.59
2020	18.54	62.95
2021	15.65	64.64
2022	13.63	68.03

Source: Prepared by the researcher based on data from the National Statistics Office.

Appendix 2: test of autocorrelation in the errors

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 1 lag

F-statistic	1.556939	Prob. F(1,30)	0.2218
Obs*R-squared	1.628136	Prob. Chi-Square(1)	0.2020

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/02/24 Time: 21:04
Sample: 1990 2022
Included observations: 33
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	0.043375	0.265847	0.163157	0.8715
C	-0.001230	0.131116	-0.009380	0.9926
RESID(-1)	0.231249	0.185329	1.247773	0.2218

R-squared	0.049337	Mean dependent var	1.14E-16
Adjusted R-squared	-0.014040	S.D. dependent var	0.695268
S.E. of regression	0.700131	Akaike info criterion	2.211410
Sum squared resid	14.70552	Schwarz criterion	2.347456
Log likelihood	-33.48827	Hannan-Quinn criter.	2.257186
F-statistic	0.778469	Durbin-Watson stat	1.585082
Prob(F-statistic)	0.468162		

Source: Outputs of the eviews 12.

Appendix3: test of Heteroskedasticity of the error term.

Heteroskedasticity Test: ARCH

F-statistic	0.245001	Prob. F(1,30)	0.6242
Obs*R-squared	0.259217	Prob. Chi-Square(1)	0.6107

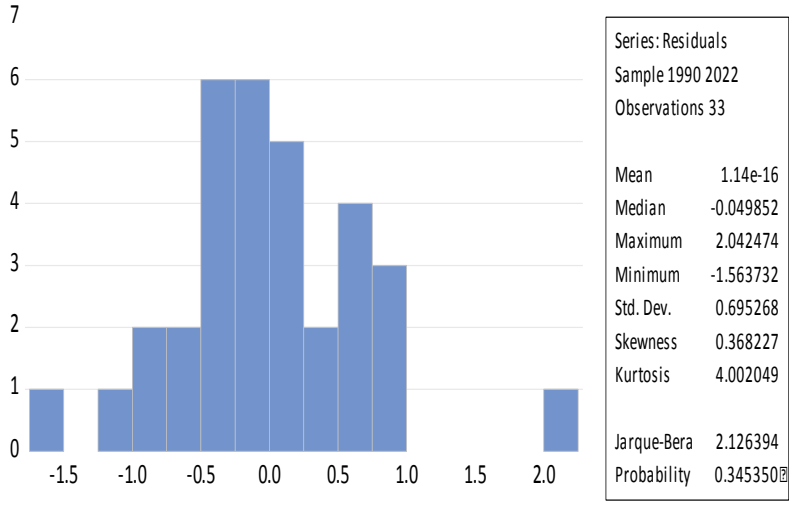
Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/02/24 Time: 21:27
Sample (adjusted): 1991 2022
Included observations: 32 afteradjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.328693	0.101482	3.238928	0.0029
RESID^2(-1)	0.053537	0.108160	0.494975	0.6242

R-squared	0.008101	Meandependent var	0.353031
Adjusted R-squared	-0.024963	S.D. dependent var	0.496027
S.E. of regression	0.502180	Akaike info criterion	1.520744
Sumsquaredresid	7.565532	Schwarz criterion	1.612352
Log likelihood	-22.33190	Hannan-Quinn criter.	1.551109
F-statistic	0.245001	Durbin-Watson stat	1.601787
Prob(F-statistic)	0.624223		

Source: Outputs of the eviews 12.

Appendix4: test of normal distribution of the error term.



source: Outputs of the eviews 12.