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An empirical analysis of simulated model of economic growth for United Kingdom

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Abstract

This study investigates a simulation model of economic growth for United Kingdom for the period 1970-2017. The purpose of this study is to examine the main determinants of economic growth examining a structural system equation model. Two stage least squares method is used in order to examine the direct and indirect relationships between the dependent variables of the model. Finally, a Monte Carlo simulation method is applied in order to define the sensitivity analysis and predictive ability of the estimated system equation model.

JEL Classification Numbers: O11, C22
Keywords: economic growth, system equation model, Monte Carlo simulation

1 Introduction

The theoretical ambiguity on the positive effect of trade openness and investments on economic growth is reflected in the modern empirical literature. Some researchers point out the strongly positive effects of trade openness on economic growth (Chang et al 2009), but others such as Harrison (1996) and Rodríguez and Rodrik (2001) are keenly supporters of the different aspect. According to Adam Smith's analysis of market specialization, trade openness promotes the efficient allocation of resources through comparative advantage, allows the dissemination of knowledge and technological progress, (Chang et al 2009). Furthermore, trade openness encourages competition in domestic and international markets increasing returns to scale (Grossman and Helpman, 1991).

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However, if market or institutional imperfections exist, trade openness can lead to under-utilization of human and capital resources and concentration in extractive economic activities, leading specialization not to technologically advanced and increasing-return sectors (Chang et al 2009). The recent revival of interest in the relationship between trade of openness and economic growth examines the insights and techniques of endogenous growth models. Endogenous growth theory also predicts that trade liberalization promotes economic growth facilitating the transactions of goods and services, the efficiency of investments and causing positive externalities for firms (Rivera-Batiz and Romer, 1991). Many models emphasize that well-functioning financial intermediaries and markets promote economic growth through technological progress and innovation, so increase the demand of financial services and therefore foster efficient resources allocation by facilitating information and transactions costs (Greenwood and Jovanovic, 1990; Bencivenga, Smith, and Starr, 1996).

The main issue is not only concentrated on analysing some theoretical determinants of economic growth, but also is referred to the statistical analysis of a system equation model based on basic econometric methodology. Surely, this paper examines a very powerful economy which is characterized by higher rates of economic growth facilitating the investments growth and trade of openness growth. UK's economy is regarded as one of the most rich and widely developed countries worldly. The model hypothesis predicts that investments, trade of openness and consumption promote economic growth taking into account the negative effect of inflation rate and interest rate.

This empirical study has the following objectives:

- To examine the interrelation among economic growth, trade of openness, investments
- To make simulations by estimating a system equation model with Monte Carlo simulations method.
- To examine the predictive ability of the model by calculating the inequalities ratios indices of Theil.

The remainder of the paper proceeds as follows: Section 2 describes the methodology of empirical study, while section 3 analyses the empirical results. Finally, section 4 provides the conclusions of this paper.

2. Data and Methodology

2.1. Data analysis: In this study the method of ordinary least squared method is adopted to estimate the effect of investments, trade of openness and consumption on economic growth. Initially, ordinary least squares method is applied in order to find out the interrelation between the examined variables based on economic theory. For this reason basic diagnostic econometric tests are examined for their reliability and validity such as autocorrelation and specification tests for each equation relatively. Then a system equation model is estimated by using the two-stage least squares method and a Monte Carlo simulation model is applied for sensitivity analysis.

Suppose that each equation can be estimated separately with ordinary least squares method and then a structural system equation model is estimated by using the two-stage least squares method. All variables are transformed to their logarithmic form in order to obtain better statistical estimations:

$LGDP_t = c_1 + c_2 LI_t, + c_3 LOP_{t-2} + c_4 LCS_t + [ar(1)=c(5)] + u_{1t}$ (1)
$LI_t = c_6 + c_7 LGDP_{t-1} + c_8 LIND_{t-1} + [ar(1)=c(9)] + u_{2t}$ (2)
$LOP_t = c_{10} + c_{11} LGDP_{t-1} + c_{12} LOP_{t-1} + c_{13} LR_{t-3} + u_{3t}$ (3)
$LCS_t = c_{14} + c_{15} LGDP_{t-2}, + c_{16} LOP_{t-1} + c_{17} LCPI_{t-2} + [ar(1)=c(18)] + u_{4t}$ (4)

regarding each variable as a dependent one with other independent variables respectively
where:
GDP = gross domestic product
I = investments
OP = trade of openness
CS = consumption
CPI = inflation rate
R = interest rate
L = logarithmic symbol
t = time trend

Following the empirical studies of Adamopoulos (2010a), Vazakidis and Adamopoulos (2011a), the variable of economic growth (GDP) is measured by the rate of change of real GDP, investments are expressed by gross fixed capital formation, inflation rate is expressed by consumer price index, while trade of openness denotes the sum of imports and exports to gross domestic product.

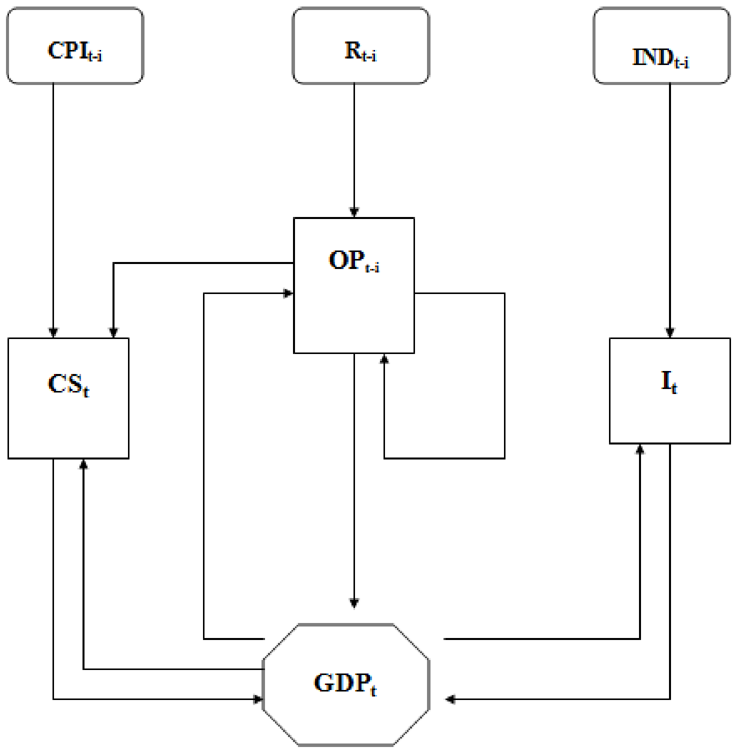
Basic hypotheses of system equation model are presented as follows:

Hypothesis H_1 : $\uparrow I_t \Rightarrow \uparrow GDP_t$ through $\uparrow IND_t$
Hypothesis H_2 : $\uparrow OP_t \Rightarrow \uparrow GDP_t$ through $\downarrow R_t$
Hypothesis H_3 : $\uparrow CS_t \Rightarrow \uparrow GDP_t$ through $\downarrow CPI_t$

Analyzing theoretical hypotheses of the system equation model we can infer that

- an increase of investments causes an increase of economic growth through the relative increase of industrial production
- an increase of trade openness causes an increase of economic growth through the relative decrease of interest rate
- an increase of consumption causes an increase of economic growth through the relative decrease of inflation rate

The system equation model is presented by the following diagram



In this empirical study annual data are used for UK and the time period ranges from 1970 to 2017, regarding 2010 as a base year. The statistical data are transformed in logarithmic valued and are obtained from statistical database of European Committee Economic and Financial Affairs. (AMECO, 2017), The graphs of examined variables are presented as follows (Figure 1).

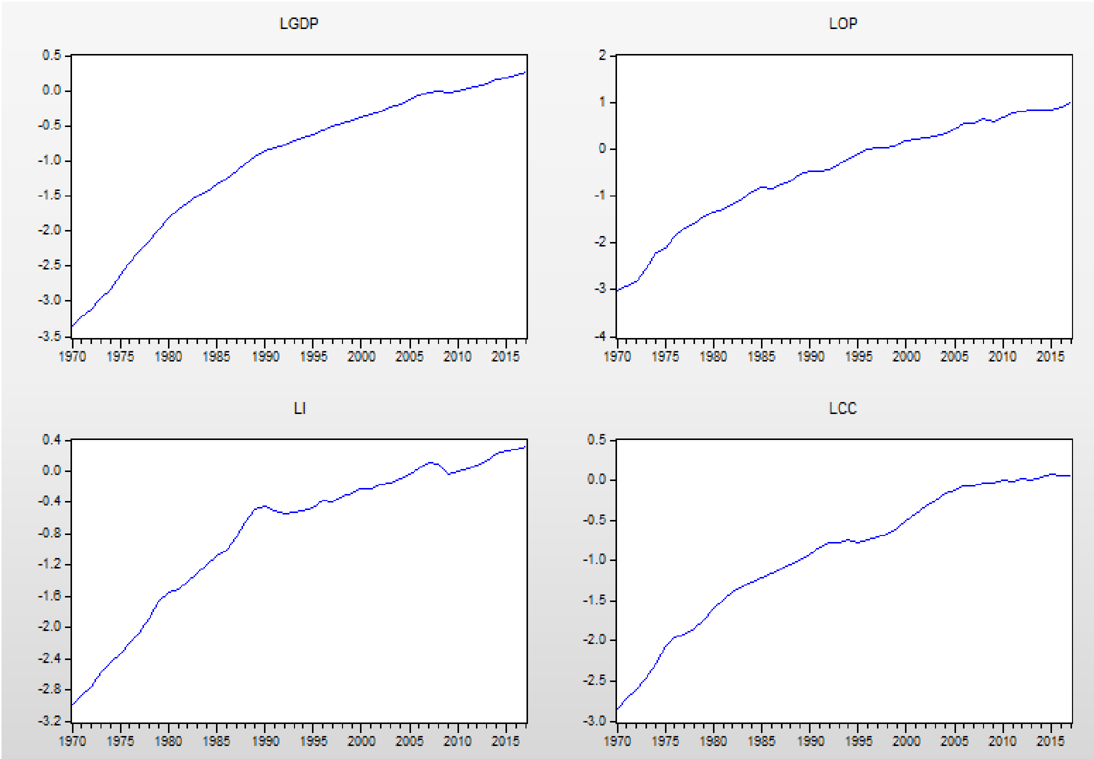


Figure 1: Graphs of dependent variables

2.2.Methodology

The structural system equation model is consisted by four logarithmic equations. The dependent variables are ($LGDP_t$, LI_t, LOP_t, LC_t,) and the independent variables are ($LGDP_{t-1}$, $LGDP_{t-2}$, LOP_{t-1}, LOP_{t-2}, $LIND_{t-1}$, $LCPI_{t-2}$, LR_{t-3}). Each equation is examined for statistical significance based on the statistical diagnostic tests such as possible existence of autocorrelation problem, heteroskedasticity test, normality test and specification test. The Eviews 10.0 (2017) software package is used to conduct these tests.

2.2.1.Ordinary least squares method

Initially, ordinary least squares method is applied to estimate a linear regression model. for statistical significance. This method defines that the regression line is fitted to the estimated values by minimizing the sum of squared residuals which indicates the sum of the vertical distances among each point and the relative point on the regression line. The smallest distances the better regression line is fitted. A regression model has a general form as follows:

$$Y_t = a + bX_t$$

Estimating a regression model with ordinary least squares method, mainly we have to find the estimations of constant term ($\widehat{a}$) and the slope of equation model ($\widehat{b}$), namely to solve the following patterns (Katos, 2004)

$$\hat{b} = \frac{n\sum X_t Y_t - \sum X_t \sum Y_t}{n\sum X_t^2 - (\sum X_t)^2} \text{ and } \hat{a} = \overline{Y}_t - \hat{b}\overline{X}_t,$$

where $\overline{Y}$ is average of values of Y (dependent variable) and $\overline{X}$ average of values of X (independent variable).

The final estimated model has the general form as follows (Katos, 2004)

$$\hat{Y}_t = \hat{a} + \hat{b}X_t$$

2.2.2. Diagnostic tests

The estimation of a regression model is mainly based on some basic specification tests (Vazakidis, 2006). If the assumptions of these specification tests are violated then there are problems of statistical significance. In order to examine whether these diagnostics tests are violated we use some statistical tests as Durbin Watson test statistic for autocorrelation, Breusch-Godfrey-Pagan test statistic for heteroskedasticity, Ramsey Reset test statistic for functional form, Jarque-Bera test statistic for normality test, Engle test statistic for ARCH effect (Ramsey, 1969, Durbin and Watson, 1971, Breusch, 1978, Jarque-Bera, 1980, Engle, 1982). Autocorrelation test refers to the way of residuals are distributed randomly and correlated. Autocorrelation test is violated when the residuals are not distributed correctly around the regression line and are not correlated In order to test autocorrelation we use Breusch-Godfrey (1978) (B-G) test which is regarded more reliable than Durbin and Watson (1971) (D-W) test statistic.

The null hypothesis defines that there is no autocorrelation in residuals, while the alternative defines that there is autocorrelation in residuals. We reject null hypothesis when the value of Breusch-Godfrey (BG) test statistic is larger than the value of chi-squared distribution $x^2(2)$ (Breusch, 1978, Godfrey, 1978, Seddighi et al 2000,)

In order to correct the existence of autocorrelation problem, we can use the first order autoregression model. The autoregressive coefficient defines that each disturbance equals to a portion of a preceding disturbance plus a random effect expressed by v_t namely

$$u_t = \rho u_{t-1} + v_t \quad |\rho| < 1 \text{ where } \rho = \text{autoregressive coefficient}$$

Ramsey (1969) reset test statistic is used for specification test of equation model. The null hypothesis defines that there is correct specification in the equation model, while the alternative defines that there is misspecification. We reject null hypothesis when the value of Ramsey Reset test is larger than the value of chi-squared distribution $x^2(2)$.

Breusch-Godfrey-Pagan test statistic is used for heteroskedasticity test. Under heteroskedasticity, the residuals of the estimated model don' t have constant variance. The null hypothesis defines that there is homoskedasticity in estimated residuals, while the alternative defines that there is heteroskedasticity. We reject null hypothesis when the value of Ramsey (1969) Reset (RR) test is larger than the value of chi-squared distribution $x^2(2)$ (Breusch and Pagan, 1979, Katos, 2004)

$$BGP = n*R^2 = n* \frac{\sum\left(\widehat{Y}_t - \overline{Y}_t\right)^2}{\sum\left(Y_t - \overline{Y}_t\right)^2}$$

Normality test for residuals is examined by Jarque-Bera test statistic. The null hypothesis defines that the residuals are normally distributed in the equation model, while the alternative defines that the residuals are not normally distributed. We reject null hypothesis when the value of Jarque-Bera test statistic is larger than the value of chi-squared distribution $x^2(2)$. Jarque-Bera (1980) (JB) test statistic examines whether the coefficients for skweness and kyrtosis are jointly zero (Seddighi et al 2000, Katos, 2004)

$$JB = n\left[\frac{m_3^2}{6} + \frac{(m_4-3)^2}{24}\right] \text{where } m_3 = \frac{Eu^3}{s^3} \text{ and } m_4 = \frac{Eu^4}{s^4}$$

Finally, the existence of ARCH effect is examined by Engle (1982) test statistic. The null hypothesis defines that there is no ARCH effect in the equation model, while the alternative defines that there is ARCH effect. We reject null hypothesis when the value of Engle test statistic is larger than the value of chi-squared distribution $x^2(2)$

$$EN= (n-p) *R^2$$

where n is a sample size, p expresses the degrees of freedom and R^2 is the coefficient of determination (Seddighi et al 2000, Katos, 2004).

2.2.3. Two stage least squares method

Two stage least squares method is used for estimation of structural system equation model. Simulation defines the simultaneous solution of the system equations model., while a Monte Carlo simulation method is used for making predictions in the estimations of system equation model (Katsouli 2003, Katos et al 2004).

2.2.4.1 Sensitivity analysis

Simulation policies are useful to test for *predictive ability* of the estimated model. The main goal of simulation method is to examine whether a possible exogenous shock in one independent variable effects on the other dependent variables. In order to *make simulation policies* we have to estimate the dynamic multipliers of dependent variables of the system equation model. For this reason we estimate the percentage change of experimental values of dependent variables to simulated values as follows:

$$mpl = \frac{x_t^{\exp} - x_t^{sim}}{x_t^{sim}} *100 \text{ or } mpl = \frac{x_t^{\exp}}{x_t^{sim}} \quad \text{(Katos, 2004).}$$

where x^{exp}=experimental values of x and x^{sim}=simulated values of x

Furthermore, the best predictive ability of the system equation model is achieved by estimating the inequalities ratios indices of Theil, specifically bias ratio, variance ratio and covariance ratio as follows:

$$U = \frac{\sqrt{\frac{1}{T}\sum\left(x_t^{sim} - x_t\right)^2}}{\sqrt{\frac{1}{T}\sum(x_t^{sim})^2} + \sqrt{\frac{1}{T}\sum(x_t)^2}} \quad \text{Theil index} \qquad (1)$$

$$U^M = \frac{(\bar{x}^{sim} - \bar{x})}{\frac{1}{T}\sum(x_t^{sim} - x_t)^2} \quad \text{bias ratio} \qquad (2)$$

$$U^S = \frac{(s_{x^{sim}} - s_x)^2}{\frac{1}{T}\sum(x_t^{sim} - x_t)^2} \quad \text{variance ratio} \qquad (3)$$

$$U^C = 1 - (U^M + U^S) \quad \text{covariance ratio} \qquad (4)$$

The smaller dynamic multipliers and inequalities ratios indices the better predictive ability of the system equation model. Bias ratio(U^M) measures the distance between the average of simulated values of time series and the average of actual values of time series. Variance ratio (U^S) measures the distance between the variance of simulated values of time series and the variance of actual values of time series. Covariance ratio (U^C) is a non-systematic prediction failure. The smaller values of inequalities ratios indices the better fitting of simulated values of time series to actual values of time series. Perfect adjustment exists when Theil index equals to zero (Katos, 2004).

3 Empirical Results

The significance of the empirical results is dependent on the variables under estimation. The number of fitted time lags and the usage of first order autoregressive term was selected for the best estimations results and for existence of statistical significance in each equation model. Based on Levine and Zervos (1998) and Shan (2005) studies the model of economic growth is mainly characterized by the direct effect of investments, trade of openness, and consumption, while there is an indirect effect of inflation rate, interest rate and industrial production

Estimating each equation with ordinary least squares method we can infer that there is statistical significance in coefficients of independent variables based on probabilities and t-student distribution test statistics. Their estimated values have the expected statistical sign based on economic theory. The coefficient of determination in each equa-tion is very high (0,99) and is close to unity, so the model is very well adjusted (Table 1).

The same conclusion is easily confirmed by studying probabilities and F-distribution test statistics. All probabilities values are lower than 5% and t-student and F-student test statistics are greater than critical values obtained by statistical tables of t-student and F-distributions for 5% level of significance. Durbin Watson test statistic indicates that there is a possible problem of autocorrelation, while there is a possible existence of multicollinearity problem due to the highest values of coefficients of determination (Table 1).

Examining the economic interrelation between dependent and independent variables we can infer that investments, trade of openness and consumption have a positive effect on economic growth (equation 1), economic growth and industrial production have a positive effect on investments (equation 2), economic growth has a positive effect on trade of openness, while interest rate has a negative effect on it (equation 3), and finally economic growth and trade of openness have a positive effect on consumption (equation 4), while inflation rate has a negative effect on consumption (equation 4). The results of ordinary least squared method estimations appear in Table 1.

Table 1: Method: Ordinary Least Squares

Equation 1: Dependent Variable: LGDP				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.1286	0.0371	-3.4585	0.0013
LI	0.4380	0.0595	7.3503	0.0000
LOP(-2)	0.2514	0.0470	5.3490	0.0000
LCS	0.3819	0.0734	5.2026	0.0000
AR(1)	0.7972	0.0962	8.2849	0.0000
R-squared	0.9995	Akaike info criterion		-4.6897
Adjusted R-squared	0.9994	Schwarz criterion		-4.4512
F-statistic	17423.59	Durbin-Watson stat		2.1217
Prob(F-statistic)	0.0000			
Equation 2: Dependent Variable: LI				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.3091	1.2184	-1.8951	0.0650
LGDP(-1)	0.8403	0.0375	22.3520	0.0000
LIND(-1)	0.5275	0.2636	2.0007	0.0519
AR(1)	0.7952	0.0872	9.1165	0.0000
R-squared	0.9971	Akaike info criterion		-2.9877
Adjusted R-squared	0.9968	Schwarz criterion		-2.7909
F-statistic	3657.39	Durbin-Watson stat		1.7429
Prob(F-statistic)	0.0000			
Equation 3: Dependent Variable: LOP				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.4410	0.1393	3.1659	0.0029
LGDP(-1)	0.1636	0.0969	1.6884	0.0989
LOP(-1)	0.7646	0.0968	7.8951	0.0000
LR(-3)	-0.0698	0.0256	-2.7176	0.0096
R-squared	0.9971	Akaike info criterion		-2.9663
Adjusted R-squared	0.9969	Schwarz criterion		-2.8057
F-statistic	4825.19	Durbin-Watson stat		2.1346

Prob(F-statistic)	0.0000

Equation 4: Dependent Variable: LCS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.2783	0.0627	-4.4384	0.0001
LGDP(-2)	0.6906	0.1424	4.8470	0.0000
LOP(-1)	0.3762	0.0945	3.9785	0.0003
LCPI(-2)	-0.5086	0.1126	-4.5164	0.0001
R-squared	0.9933	Akaike info criterion		-2.5657
Adjusted R-squared	0.9928	Schwarz criterion		-2.4067
F-statistic	2096.64	Durbin-Watson stat		0.4338
Prob(F-statistic)	0.0000			

The empirical results of ordinary least squared method (based on Table 1) are summarized as follows:

$$LGDP_t = -0.12 + 0.43\,LI_t, + 0.25\,LOP_{t-2} + 0.38\,LCS_t + [ar(1)=0.75] + u_{1t} \quad (1)$$
$$LI_t = -2.30 + 0.84\,LGDP_{t-1} + 0.52\,LIND_{t-1} + [ar(1)=0.79] + u_{2t} \quad (2)$$
$$LOP_t = 0.44 + 0.16\,LGDP_{t-1} + 0.76\,LOP_{t-1} - 0.06LR_{t-3} + u_{3t} \quad (3)$$
$$LCS_t = -0.27 + 0.69\,LGDP_{t-2}, + 0.37\,LOP_{t-1} - 0.50\,LCPI_{t-2} \quad (4)$$

As we can see from the above results an increase of investments per 1% causes a relative increase of gross domestic product per 0.43, an increase of trade of openness per 1% causes a relative increase of domestic product per 0.25, an increase of consumption per 1% causes a relative increase of gross domestic product per 0.38 (Equation 1). Also, an increase of gross domestic product per 1% causes a relative increase of investments per 0.84, an increase of industrial production index per 1% causes a relative increase of investments per 0.52, (Equation 2).

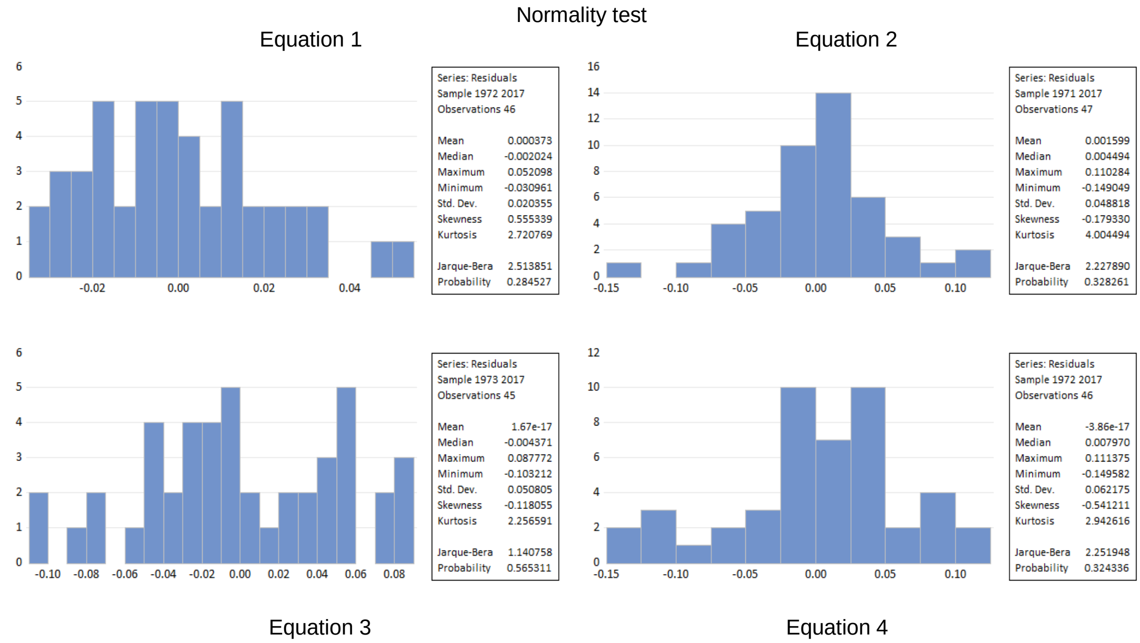
Furthermore, an increase of gross domestic product per 1% causes a relative increase of trade of openness per 0.16, while an increase of interest rate per 1% causes a relative decrease of trade of openness per 0.06 (Equation 3). Finally, an increase of gross domestic product per 1% causes a relative increase of consumption per 0.87, an increase of trade of openness per1% causes a relative increase of consumption per 0.19, while an increase of inflation rate per 1% causes a relative decrease of consumption per 0.47 (Equation 4).

Examining each equation for statistical significance based on the statistical diagnostic tests we can conclude that there are statistical problems in the specification tests in third and fourth equation models, due to the lower probabilities of 5% level of significance. In first and second equations there is statistical significance in all diagnostics tests. Finally, there is no arch effect only in fourth equation model and there is statistical significance in normality tests in all equation models. The results related to diagnostic tests appear in Table 2.

Table 2: Diagnostics tests

Ramsey RESET Specification Test:			
	Equation 1		
F-statistic	1.3750	Prob. F(1,39)	0.2481
Log likelihood ratio	1.7861	Prob. Chi-Square(1)	0.1814
	Equation 2		
F-statistic	1.9603	Prob. F(1,41)	0.1690
Log likelihood ratio	2.4445	Prob. Chi-Square(1)	0.1179
	Equation 3		
F-statistic	7.9805	Prob. F(1,40)	0.0073
Log likelihood ratio	8.1862	Prob. Chi-Square(1)	0.0042
	Equation 4		
F-statistic	5.0369	Prob. F(1,41)	0.0303
Log likelihood ratio	5.3300	Prob. Chi-Square(1)	0.0210
Heteroskedasticity Test: Breusch Godfrey Pagan			
	Equation 1		
F-statistic	0.2677	Prob. F(3,42)	0.8482
Obs*R-squared	0.8633	Prob. Chi-Square(3)	0.8343
	Equation 2		
F-statistic	0.0845	Prob. F(2,44)	0.9190
Obs*R-squared	0.1800	Prob. Chi-Square(2)	0.9139
	Equation 3		
F-statistic	0.3159	Prob. F(3,41)	0.8138
Obs*R-squared	1.0167	Prob. Chi-Square(9)	0.7972
	Equation 4		
F-statistic	0.5021	Prob. F(3,42)	0.6828
Obs*R-squared	1.5929	Prob. Chi-Square(9)	0.6610
ARCH Test:			
	Equation 1		
F-statistic	0.0655	Prob. F(1,43)	0.7992
Obs*R-squared	0.0684	Prob. Chi-Square(1)	0.7936
	Equation 2		
F-statistic	3.2077	Prob. F(1,44)	0.0802
Obs*R-squared	3.1256	Prob. Chi-Square(1)	0.0771
	Equation 3		
F-statistic	0.0472	Prob. F(1,39)	0.8292
Obs*R-squared	0.0493	Prob. Chi-Square(1)	0.8243
	Equation 4		
F-statistic	31.4934	Prob. F(1,43)	0.0000
Obs*R-squared	19.0245	Prob. Chi-Square(1)	0.0000

The results related to normality test of residuals by estimating Jarque-Bera statistic test appear in Table 2.



The graph of estimated residuals shows that there are normally distributed estimated residuals (Figure 2).

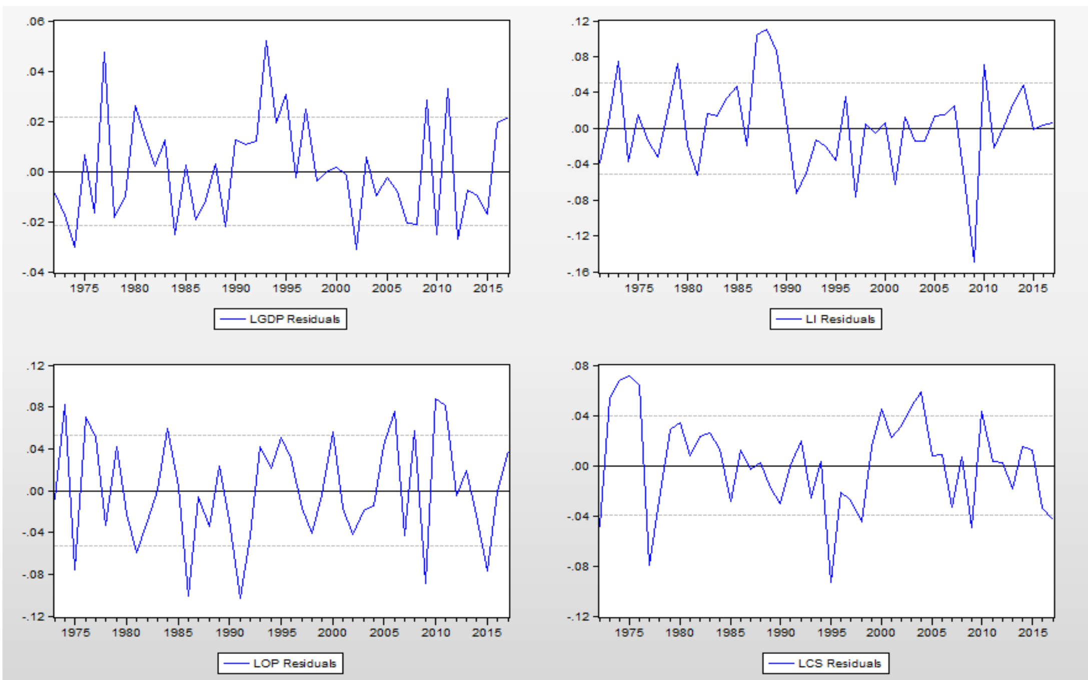


Figure 2: Graph of estimated residuals

Also the correlogram of residuals indicates that there is a problem in autocorrelation test (Figure 3).

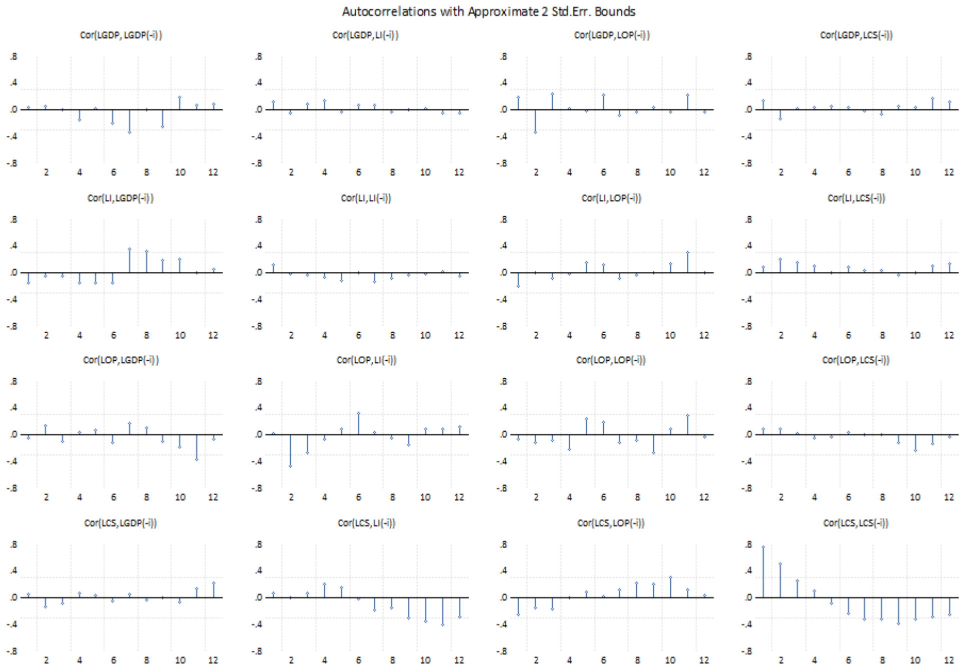


Figure 3: Correlogram of residuals

Finally, the graph of confidence ellipse of coefficients of estimated equations model indicates the existence of statistical significance (Figure 4).

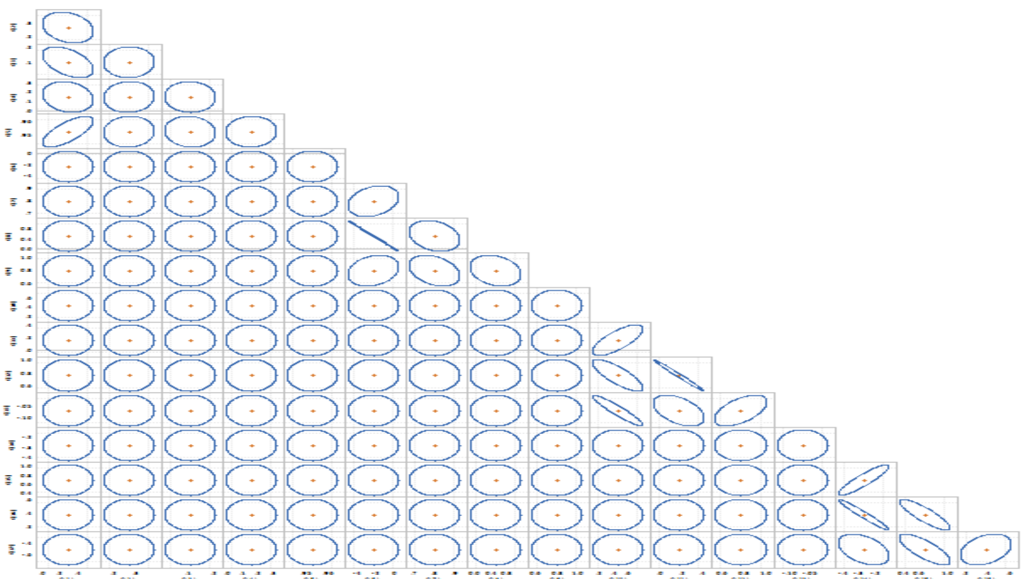


Figure 4: Graph of confidence ellipse of coefficients

Estimating the system equation model with two stage least squared method we can see that that there is statistical significance in coefficients of independent variables based on probabilities and t-student distribution test statistics. Their estimated values have the expected statistical sign based on economic theory. All probabilities values are lower than 5% level of significance. Durbin Watson test statistics indicates that there is a possible problem of autocorrelation (Table 3). Table 3 presents the results from two stage least squared method.

Table 3: Estimation Method: Iterative Two-Stage Least Squares

Sample: 1973 2017 -Observations 45

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.176031	0.037105	-4.744177	0.0000
C(2)	0.575161	0.043447	13.23821	0.0000
C(3)	0.278652	0.058765	4.741797	0.0000
C(4)	0.193018	0.073869	2.612975	0.0098
C(5)	-1.636717	0.921235	-1.776655	0.0775
C(6)	0.829357	0.021280	38.97381	0.0000
C(7)	0.379657	0.197845	1.918964	0.0567
C(8)	0.441096	0.139326	3.165932	0.0018
C(9)	0.163627	0.096912	1.688410	0.0932
C(10)	0.764641	0.096850	7.895131	0.0000
C(11)	-0.069811	0.025688	-2.717636	0.0073
C(12)	-0.232703	0.062803	-3.705285	0.0003
C(13)	0.822086	0.146847	5.598264	0.0000
C(14)	0.304730	0.095072	3.205256	0.0016
C(15)	-0.607072	0.115184	-5.270470	0.0000

Determinant residual covariance	2.34E-11		
Equation: LGDP = C(1) + C(2)*LI + C(3)*LOP(-2) + C(4)*LCS			
R-squared	0.9987	Durbin-Watson stat	0.5925
Jarque-Bera test	0.4596		
Equation: LI = C(5) + C(6)*LGDP(-1) + C(7)*LIND(-1)			
R-squared	0.9905	Durbin-Watson stat	0.4089
Jarque-Bera test	0.9385		
Equation: LOP = C(8) + C(9)*LGDP(-1) + C(10)*LOP(-1) + C(11)*LR(-3)			
R-squared	0.9971	Durbin-Watson stat	2.1346
Jarque-Bera test	0.5706		
Equation: LCS = C(12) + C(13)*LGDP(-2) + C(14)*LOP(-1) + C(15)*LCPI(-2)			
R-squared	0.9933	Durbin-Watson stat	0.9933
Jarque-Bera test	0.7002		

The empirical results of two-stage least squared method (based on Table 3) are summarized as follows:

$$LGDP_t = -0.17 + 0.57\,LI_t, + 0.27\,LOP_{t-2} + 0.19\,LCS_{t-1} + u_{1t} \quad (1)$$
$$LI_t = -1.63 + 0.82\,LGDP_{t-1} + 0.37\,LIND_{t-1} + u_{2t} \quad (2)$$
$$LOP_t = 0.44 + 0.16\,LGDP_{t-1} + 0.76\,LOP_{t-1} - 0.06LR_{t-3} + u_{3t} \quad (3)$$
$$LCS_t = -0.23 + 0.82\,LGDP_{t-2}, + 0.30\,LOP_{t-1} - 0.60\,LCPI_{t-2} + u_{4t} \quad (4)$$

As we can see from the above results an increase of investments per 1% causes a relative increase of gross domestic product per 0.57, an increase of trade of openness per 1% causes a relative increase of gross domestic product per 0.27, an increase of consumption per 1% causes a relative increase of domestic product per 0.19 (Equation 1). Also an increase of gross domestic product per 1% causes a relative increase of investments per 0.82, an increase of industrial production per 1% causes a relative increase of investments per 0.37 (Equation 2).

Furthermore, an increase of gross domestic product per 1% causes a relative increase of trade of openness per 0.16, while an increase of interest rate per 1% causes a decrease of trade of openness per 0.06 (Equation 3). Finally, an increase of gross domestic product per 1% causes a relative increase of consumption per 0.82, an increase of trade of openness per 1% causes a relative increase of consumption per 0.30, and finally an increase of inflation rate per 1% causes a relative decrease of consumption per 0.60 (Equation 4). Testing for autocorrelation we can infer that there is a problem in autocorrelation in all equations except from equation 3, due to lower probabilities values of Durbin-Watson test, however on the other hand, multicollinearity problem is avoided.

Therefore, estimating the system equation model with Monte Carlo simulation method we can infer that the estimated simulated values are very close to actual one, so the model is very well simulated (Figure 5). Examining the changes of a possible increase of industrial production of 10% in 1972 in estimations of the simulation model, we can infer that there is a rapid increase of dynamic multiplier of investments in 2005, but a rapid decrease in 2006, while there is a rapid increase of dynamic multipliers of trade of openness in 1997, but a rapid decrease in 1998. Furthermore, we can infer that there is a rapid increase of dynamic multiplier of consumption in 2010, but a rapid decrease in 2011, while there is a rapid increase of dynamic multipliers of trade of openness in 1997, but a rapid decrease in 1998, while there is a rapid increase of dynamic multipliers of economic growth in 2007, but a rapid decrease in 2008 (Figure 6).

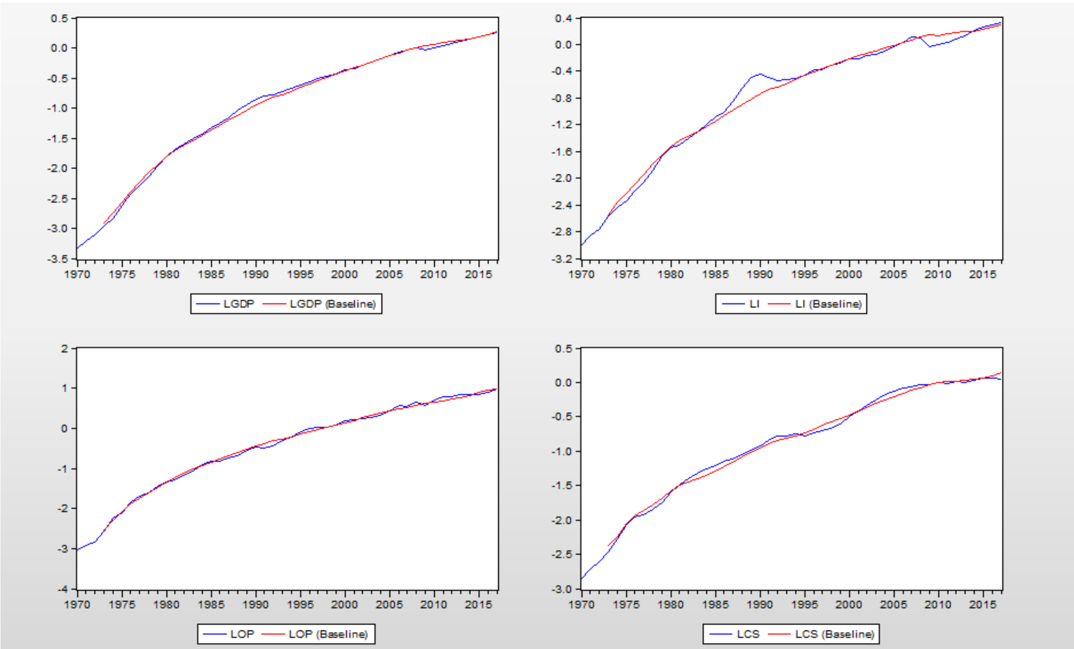


Figure 5: Graph of Monte Carlo simulation model

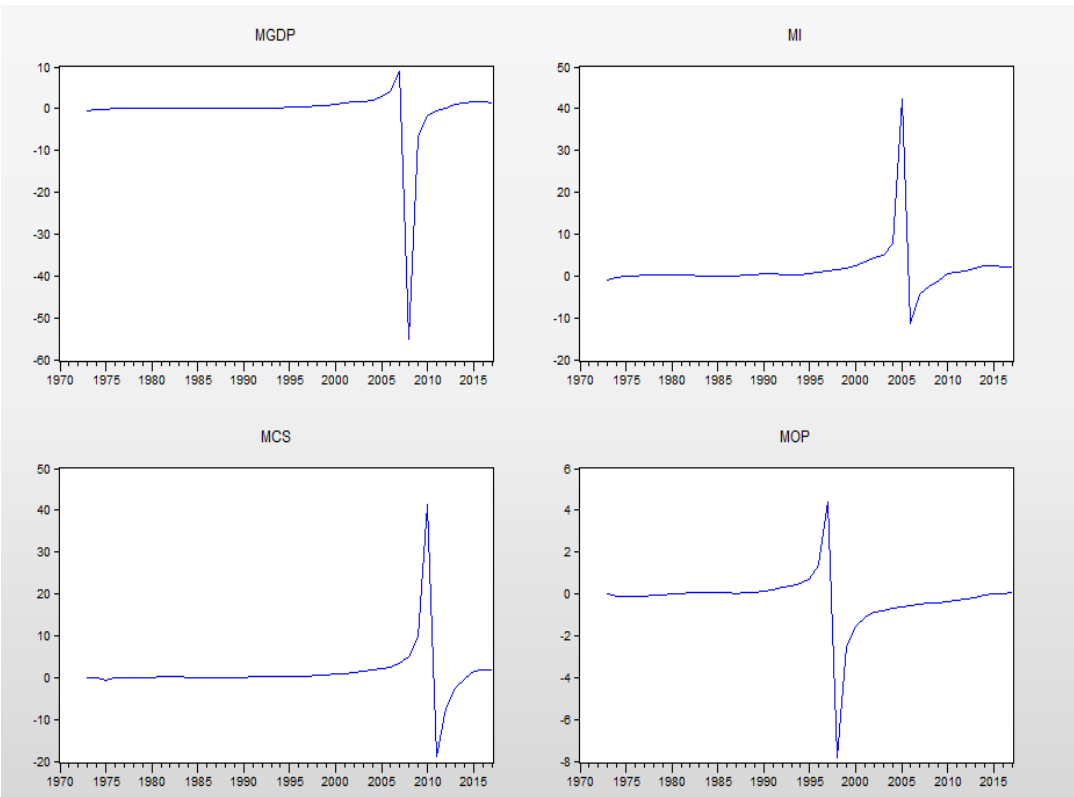


Figure 6: Graphs of dynamic multipliers of estimated simulated model

The results of estimated inequalities ratios indices of Theil, suggested that there is a good predictive ability of simulated system equation model (Table 4).

Table 4: Estimations of inequalities ratios indices

	U **THEIL INDEX**	**U^M** **BIAS RATIO**	**U^S** **VARIANCE RATIO**	**U^C** **COVARIANCE RATIO**
$LGDP_t$	0.0632	0.4586	0.3144	0.227
LI_t	0.1130	0.0309	0.9408	0.0283
LOP_t	0.0298	0.0316	0.4227	0.5457
LCS_t	0.3250	0.5193	0.1551	0.3256

4 Conclusions

This study examines a simulation model of economic growth for United Kingdom for the period 1970-2017. The purpose of this study is to estimate a simulation model of economic growth examining a structural system equation model. Initially, the results of two-stage least squares method suggested that economic growth is mainly characterized by the direct effect of trade of openness, investments and consumption and by indirect effect of industrial production index, inflation rate and interest rate.

Furthermore, the empirical results of Monte Carlo simulation method indicated that the system equation model is very well simulated, since the simulated values are close to actual values of examined variables. A possible change in industrial production index in 1972 causes a rapid increase of dynamic multipliers of economic growth in 2007, but a rapid decrease in 2008. Finally, the results of estimated inequalities ratios indices of Theil suggested that there is a good predictive ability of simulated system equation model.

Many empirical studies examining the main determinants of economic growth differ relatively to the sample period, the examined countries and the estimation methodology. The empirical results of this paper are agreed with the studies of Vazakidis (2006)**,** Vazakidis and Adamopoulos (2011a). However, more interest should be focused on the comparative analysis of empirical results for many other countries in future research.

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